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THE FOURTEEN PRIMITIVE ACTIONS AND THEIR INFERENCES

BY

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ABSTRACT: In order to represent the conceptual information underlying a natural language sentence, a conceptual structure has been established that uses the basic actor-action-object framework. It was the intent that these structures have only one representation for one meaning, regardless of the semantic form of the sentence being represented. Actions were reduced to their basic parts so as to effect this. It was found that only fourteen basic actions were needed as building blocks by which all verbs can be represented. Each of these actions has a set of actions or states which can be inferred when they are present.

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1. Introduction

For the past four years there has been an effort undertaken at Stanford to enable computers to understand natural language sufficiently well so as to be able to perform in a dialogue situation. We have attempted to analyze natural language into meaning structures that are unambiguous representations of the meaning of an input utterance. We have required of those representations that they be unique. That is, the meaning representations of any two utterances which can be said to convey the same meaning should be identical.

Thus, we have concerned ourselves with the creation of conceptual structures, and the predictions and inferences that are possible given a formally defined conceptual structure.

The initial form of a conceptual dependency structure was intended to be a language-free unambiguous representation of the meaning of an utterance. In fact, the conceptual structures that were initially used bore a great deal more similarity to the surface properties of English than we now believe should exist in such structures. Subsequently, we began looking for common concepts that could be used for representing the meaning of English sentences, that would facilitate paraphrase by the conceptual structures without losing information. The concept 'trans' was introduced (Schank, Tesler and Weber (1970)) as a generic concept into which words such as 'give' and 'take' could be mapped, such that by specifying attributes of the cases of 'trans' no information would be lost. (For example, 'trans' where the actor and recipient are the same is realized as the verb 'take', whereas, where the actor and donor part of the recipeint case are the same, the verb is 'give'). Such

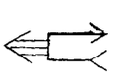
generic concepts simplified the conceptual networks, making them more useful. Furthermore, it became apparent that the linguists' problem of the representation of such concepts as 'buy' and 'sell' became solvable. Semanticists such as Katz (1967) have argued that while these concepts seem close enought it would be arbitrary to choose one as the basic form of the other, so the correct thing to do must be to write formal rules translating structures using 'buy' into structures using 'sell' when this is deemed necessary, Instead of doing this, we made the suggestion (Schank (in press)) that using 'trans' one could map 'buy' into 'trans money causes trans object' and 'sell' into 'trans object causes trans money'. Such a representation eliminates the 'which is more primitive than the other' problem and instead relates the two events that actually occurred.

The naturalness of the concept 'trans' led us to consider whether there might be more of these generic concepts around. Thus we began a search for primitive concepts that can be used as the basis of conceptual structures. This paper discusses the results that we have arrived at. In order to appreciate them however, it will be necessary to set out the rudiments of the conceptual dependency framework first. We shall present in the next section the basics of conceptual dependency.

2. Conceptual Dependency

2.1 Conceptualizations

We are using what is basically an actor-action-object framework that includes cases of the actions. That is, 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. The only actors that are allowed in this schema are animate. That is, an action is something that is done by an actor to an object. (The exception to this rule regards natural forces which shall not be discussed here.)

Actors, actions and objects in our conceptual schema must correspond to real world actors, actions and objects. To illustrate what is meant by this consider the verb 'hurt' as used in 'John hurt Mary'. To treat this sentence conceptually as (actor: John; action: hurt; object: Mary) violates the rule that conceptual actions must correspond to real world actions. 'Hurt' here is a resultant state of Mary. It does not refer to any action that actually occurred, but rather to the result of the action that actually occurred. Furthermore, the action that can be said to have caused this 'hurt' is unknown. In order to represent, in our conceptual structure, an accurate picture of what is going on here the following conceptual relationships must be accounted for: John did something; Mary was hurt; the action caused the resultant state. In conceptual dependency representation, actor-action complexes are indicated by <=>, denoting a mutual dependency between actor and action; object-state complexes are indicated by <≡> denoting a predication of an attribute of an object or by  denoting a change of state

in the object: Causal relationships are indicated by between the causer action and the caused action, denoting a temporal dependency. Causal arrows (⇑) may only exist between two-way dependencies (<=>, <≡> or <≡⊐). That is to say, only events or states can cause events or states.

Thus our representation for this sentence is:

John <=> do
⇑
Mary <≡> hurt

The dummy 'do' represents an unknown action. ('Hurt' is ambiguous between mental hurt ($hurt_{MENT}$) and physical hurt ($hurt_{PHYS}$).)

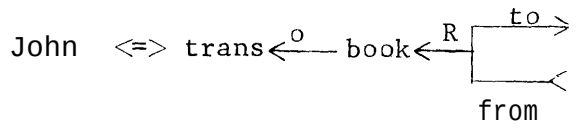
Conceptual dependency representation then, seeks to depict the actual conceptual relationships that are implicit within a natural language utterance.

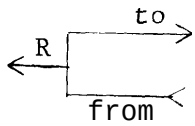
Actions, in conceptual depencency, are things that are done to objects. Actions sometimes have directions (either through space or between humans), and always have means (instruments). These things are called the conceptual cases of an action. Unlike syntactic cases, (as posited by Fillmore (1968) for example) conceptual cases are part of a given action and therefore are always present whenever that action is present. Thus, if an action takes an object, whether or not that object was mentioned it is considered to be present conceptually. If the particular instance of that object was not stated and is not inferable then an empty object slot is retained.

The conceptual cases are: OBJECTIVE; RECIPIENT; DIRECTIVE; and INSTRUMENTAL. Using the notion of 'trans' mentioned above we can deal with the sentence:

John gave Mary a book.

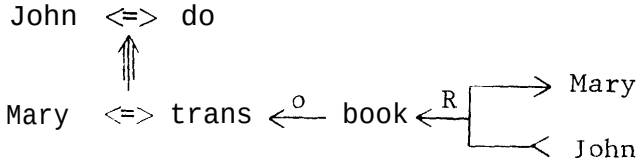
as follows:



The symbol&- denotes 'object cf the ACT' and the symbol 

denotes 'recipient of the object', with the recipient of the object in the 'to' part, and 'donor of the object' in the 'from' part.

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:



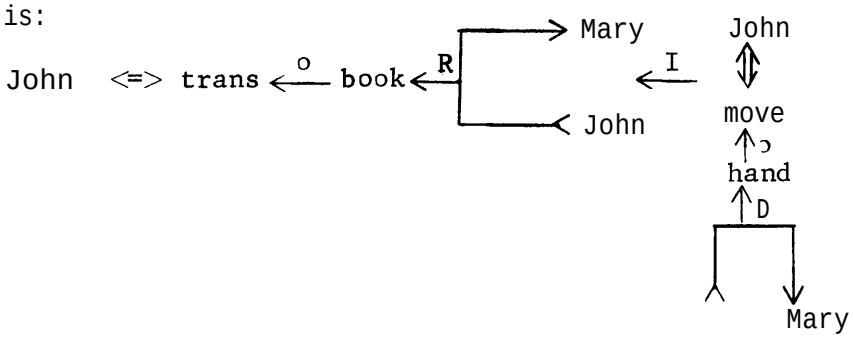
Either of these two structures may have been the intended one, but we assume unless given information to the contrary that the first is correct.

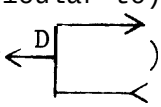
Suppose the sentence had been:

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 actor-action-object complex (called a conceptualization). When the action in the main conceptualization is known, it is possible to delimit the set of possible

instrumental actions. For 'trans' the ACT that is most often the instrument is '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. The conceptual analysis of (3) then is:



The instrumental case is indicated by $\overset{I}{\leftarrow}$ 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 indicate here that the hand is holding the book also, but we shall not enter into that here.)

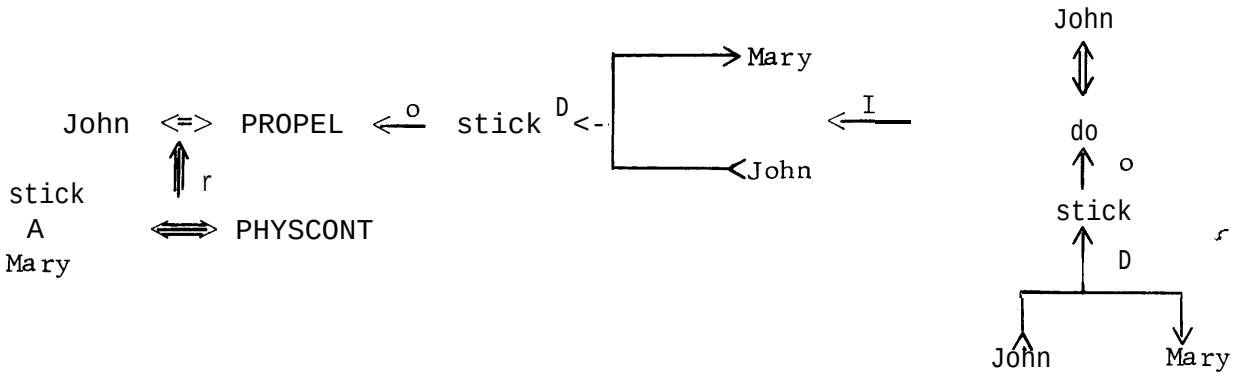
Since every ACT has an instrumental conceptualization that can be said to be part of that ACT, we can see that it should therefore be impossible to ever actually finish conceptually diagramming a given sentence. That is, every ACT has an instrument which has an ACT which has an instrument and so on. In this sentence we might have conceptually something like: "John transed 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 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 point we are making. It is, however, 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 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 of a given sentence corresponds conceptually 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 that causes the conceptualization most directly related to the verb of which it is an instrument syntactically. Conceptually an instrument can never be only a physical object. Thus as an illustration of the first instance we have:

John hit Mary with a stick.

We represent the conceptual action underlying 'hit' by PROPEL which means to apply a force to an object plus the resultant state PHYSCONT. Thus we have conceptually:



The 'do' in the instrumental conceptualization indicates that the action by which the PROPEL-ing was done is unknown. This corresponds to the fact that this sentence is actually ambiguous. The two most common interpretations being that 'he swung the stick' or that 'he threw the stick'. Representing such a sentence in this manner allows for the discovery of this ambiguity. (In an actual computer analysis schema the blank 'do's' can be realized as predictions about missing information which must be discovered either by inquiry or memory search.)

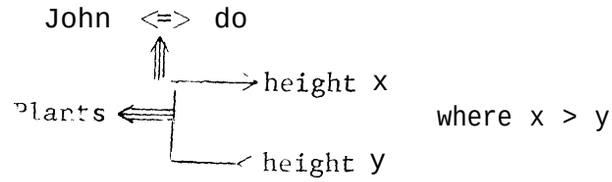
Predictions about what ACT's fit into this instrumental slot are made from the ACT in the main conceptualization. PROPEL requires either 'move' or 'move'+ 'ungrasp' as actions for its first instrument. 'Swing' and 'throw' are mapped conceptually into 'move' and 'move' + 'ungrasp' respectively (with additional information as to manner).

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

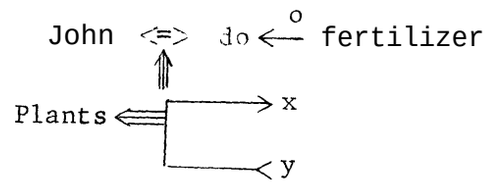
state change. Thus we have as the basis of the underlying conceptualization:



The 'do' in this conceptualization represents the extremely important fact that something was done by John. Thus the plants were not 'growed', they grew. (represented by I " for state change). What John did was not 'causing'; rattler 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 any processor that uses the results of a conceptual analysis.

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 going into how to figure out such a thing.

2.2 Paraphrase Recognition

Before going on into the substance of this paper, it might be interesting to consider how such a deep conceptual analysis of natural language utterances can help us in parsing and understanding those utterances:

Consider:

John prevented Bill from eating the apple.

The verb 'prevent' is conceptually a statement about the relationship of two events, namely that one event causes the inability of the occurrence of a second event. Unless we treat 'prevent' in this manner, important paraphrase recognition ability will be lost, and in addition even the ability to intelligently parse sentence derivative from this will be hindered.

Conceptually then, 'prevent' is not something that anyone can do, rather it expresses the following relationship between two events.

$$\begin{array}{ccc} one_1 & \Leftrightarrow & do_1 \\ & \Uparrow & \\ one_2 & \underset{\not c}{\Leftrightarrow} & do_2 \end{array}$$

That is, $person_1$ doing something caused $person_2$ to not be able to ($\not c$) do something else. Thus we have:

$$\begin{array}{ccc} \text{John} & \overset{p}{\Leftrightarrow} & \text{do} \\ & \Uparrow & \\ \text{Bill} & \underset{p\not c}{\Leftrightarrow} & \text{ingest<\&- apple} \end{array}$$

(p indicates past tense)

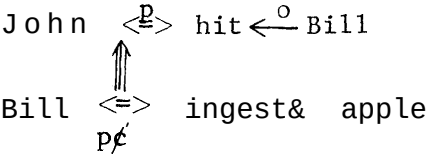
If we had an intelligent understanding system, we might want to know what John 'did' and this representation allows us to realize that we could ask that.

Now consider:

John prevented Bill's eating the apple by hitting him.

Along with the information that 'prevent' represents the conceptual structure shown above is a clue as to how to go about finding what might fill in the first 'do'. This clue is that if the ACT that replaces the 'do' is present it is most probably in the syntactic instrument of 'prevent', that is, in a by-clause.

Thus, that clue is used to give us:



It is important to notice that it is quite possible to realize the above structure as the following sentences as well.

Bill couldn't eat the apple because John hit him.

When John hit Bill it caused Bill to be unable to eat the apple.

When John hit Bill, it meant that Bill had to stay hungry.

The above sentences do not use 'prevent' in words but they do use the concept underlying 'prevent'. It is extremely important that any theory of understanding analyze these sentences or any of the myriad other paraphrases into only one conceptual structure in a natural way. This requires establishing the relationships between actual events rather than between the words that may have been used to describe those events. In order to do this, it is necessary to break words down into the primitive actions and events that they describe.

2.3 Summary

In summary then, conceptual dependency is a representation for expressing the conceptual relationships that underlie linguistic expressions. The basic structure of this conceptual level is the conceptualization. A conceptualization consists of either an actor-action-object construction or an object-state construction. If an action is present then the cases of that action are always present. One case of an action is instrumental which is itself a conceptualization.

Conceptualizations may be related to other conceptualizations causally . Just as it is impossible to have an action without an actor so it is impossible to have the cause of a conceptualization be anything other than another conceptualization. (This means that 'John moved the table' must be conceptually, 'John did something which caused the table to be in a different position'. This doing is not 'move' but rather something that was unstated. The doing can be inferred and is most probably 'apply a force to'.)

Some additional notation which will be used in this paper is:

Existence conceptualizations denoted by <≡>

Locations denoted by <≡> LOC

e.g. X <≡> LOC (Y) means X is located at Y

Locations possessed by Z is denoted by

X <≡> LOC (Y(X))

Tenses are marked over the <=> as:

p = past

f = future

c = conditional

t_F = end of ACT

/ = not

k = continuous

Causes are marked as:

⇑ r = result ⇑ E = enabling condition

⇑ R = reason

⇑ = physical cause

Other requirements on conceptual relations are not stated here because they would only complicate matters. Schank (1972) is a good source for those. __

3. The Primitive Actions

3.1 Introduction

The basic point that this paper shall present is that using the framework for language analysis that was just explained the total number of ACT's that are needed to account for any natural language sentence is fourteen, In stating this, we are not claiming that this number is totally accurate. Rather, the claim is that the order of magnitude is correct and that these fourteen ACT's or some set of ACT's not significantly different than those presented here are all that is necessary to represent the act-ions underlying natural language.

This result is caused partially by our rewriting a great many verbs into caused states conceptually. Nevertheless it is significant that so few ACTs are actually necessary to account for the basis of human activity.

3.2 ACT Types

These are four categories of ACTs that the fourteen ACTs are broken down into: Instrumental (4), Physical (5), Mental (3), and Global (2).

3.3 Physical ACTs

The Physical ACTs are:

PROPEL

MOVE

INGEST

EXPEL

GRASP

It is our claim that these are the only ACTs that one can perform on a physical object. Furthermore, there are restrictions on what kinds

of objects any given ACT will accept.

The meaning of the ACT and the objects are as follows:

PROPEL: means 'apply a force to'; its object must be under a certain size and weight, but for our purposes we will say that any object is acceptable

MOVE: means 'move a bodypart'; the only objects that are MOVE-d (in our sense of MOVE) are bodyparts.

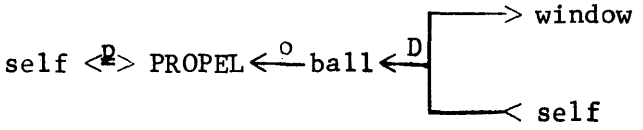
INGEST: means 'take something inside you'; INGEST's object must be smaller than the mouth of the actor or must be divided into pieces smaller than the mouth opening; object should be food.

EXPEL: means- 'take something from inside you and force it out'; its object must have previously been INGEST-ed.

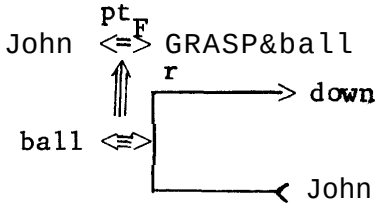
GRASP: means 'to grasp'; object must be within a size limit.

Some example sentences and their analyses are:

I threw the ball at the window.

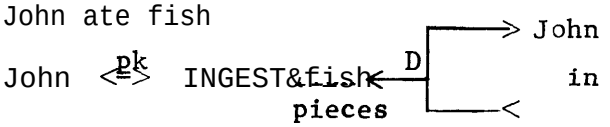


John dropped the ball.

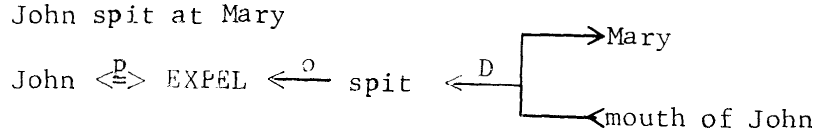


(where t_F means 'the end of' an action)

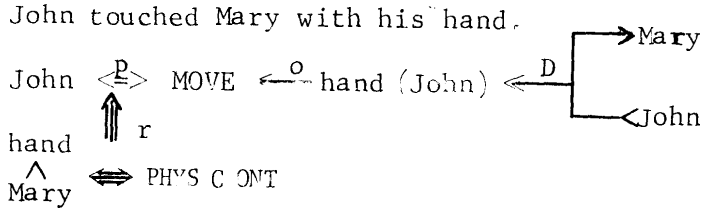
John ate fish



John spit at Mary



John touched Mary with his hand.

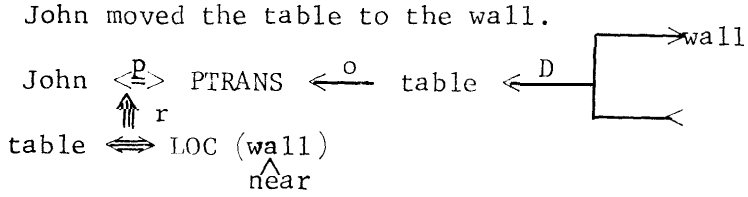


3.4 Global Acts

As can be seen by the nature of the physical ACTs, very often an ACT is somehow more than the sum of its parts. That is, often the result of an ACT is focused on more directly than the ACT itself. Since the representations presented here are intended to represent human thought it is necessary to do the same focussing that humans do. We thus use the notion of Global ACTs which express the change of state consequences and intentions of a variable physical ACT.

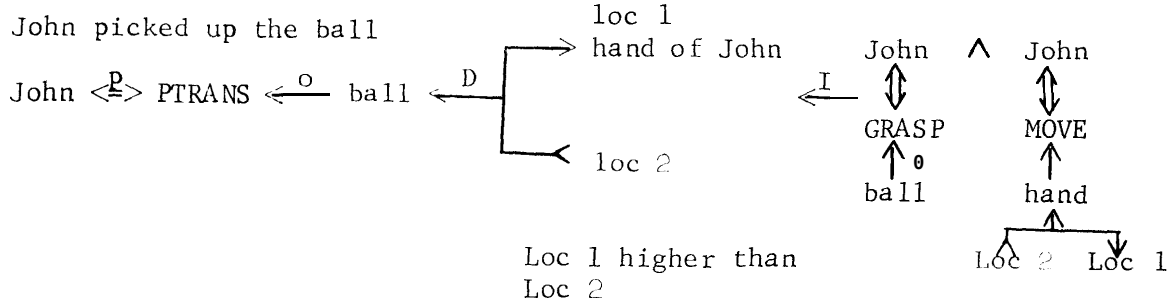
The most important Global ACT is PTRANS. PTRANS expresses the change in physical location of an object. In order to change the physical location of an object it is necessary to perform one of the physical ACTs upon that object first. That is we can have:

John moved the table to the wall.



and

John picked up the ball



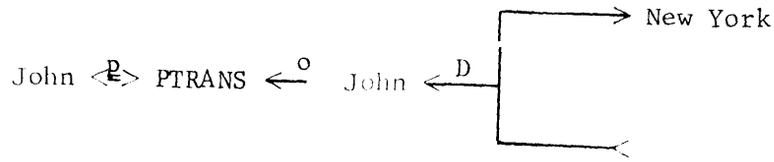
Since PTRANS is of such importance in Conceptual Dependency analysis it is worthwhile to spend some time discussing it. While the use of PTRANS for change of location verbs such as move and pick up is fairly straightforward, we also use PTRANS to represent the ACT underlying the verb 'go'. This is a difficult point for speakers of English to accept and thus requires some explanation.

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'. What is important to realize is that 'John' serves a dual role conceptually here. 'John' is also the object of the sentence 'John went'. In saying this we pay careful attention to the problem of inference from a conceptual analysis.

Since the conceptual represention that we are proposing here are used by a computer that is attempting to understand, it is important that the representations be consistent so the programs that operate on them can be general. One generality that we use (which will be discussed in detail in section 4) is that whenever PTRANS is present, it can be inferred that the object of PTRANS is now located at the location present 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 additionally the case that the location of John has been changed and that, just as for 'move' and 'pickup', John is now probably located at the directive case location.

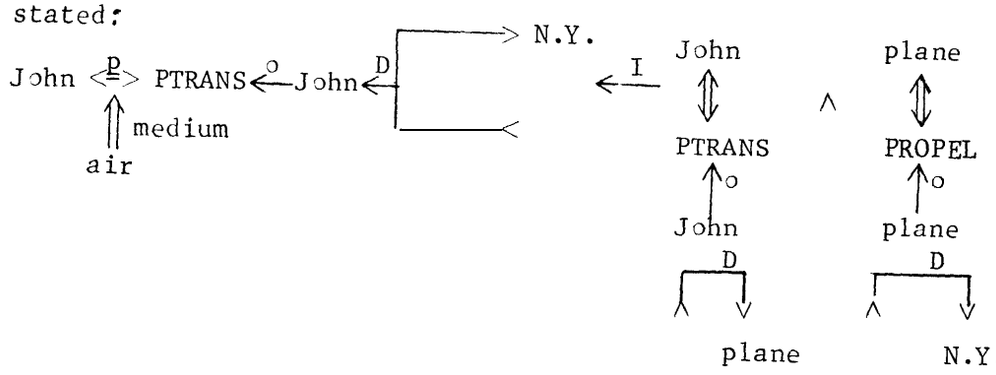
Thus the sentence: John went to New York. is conceptually analyzed as:



Actually, this indicates that the direction is towards N.Y. The completed act requires a generated state result ($\Uparrow$ r). Here we would have:

(That is, John is in New York.)

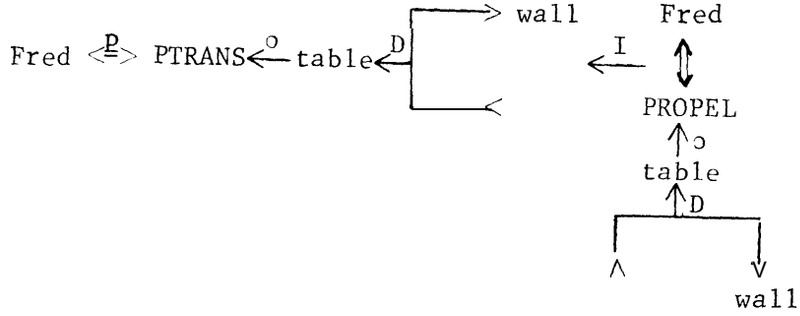
'Flying' to New York is also PTRANS, but here the instruments have been stated:



That is, 'John PTRANS-ed John to New York by means of PTRANS-ing himself to a plane and the plane propelled itself to New York.

It can be seen that whenever PROPEL is present PTRANS can be inferred. Thus for:

Fred pushed the table to the wall we have:

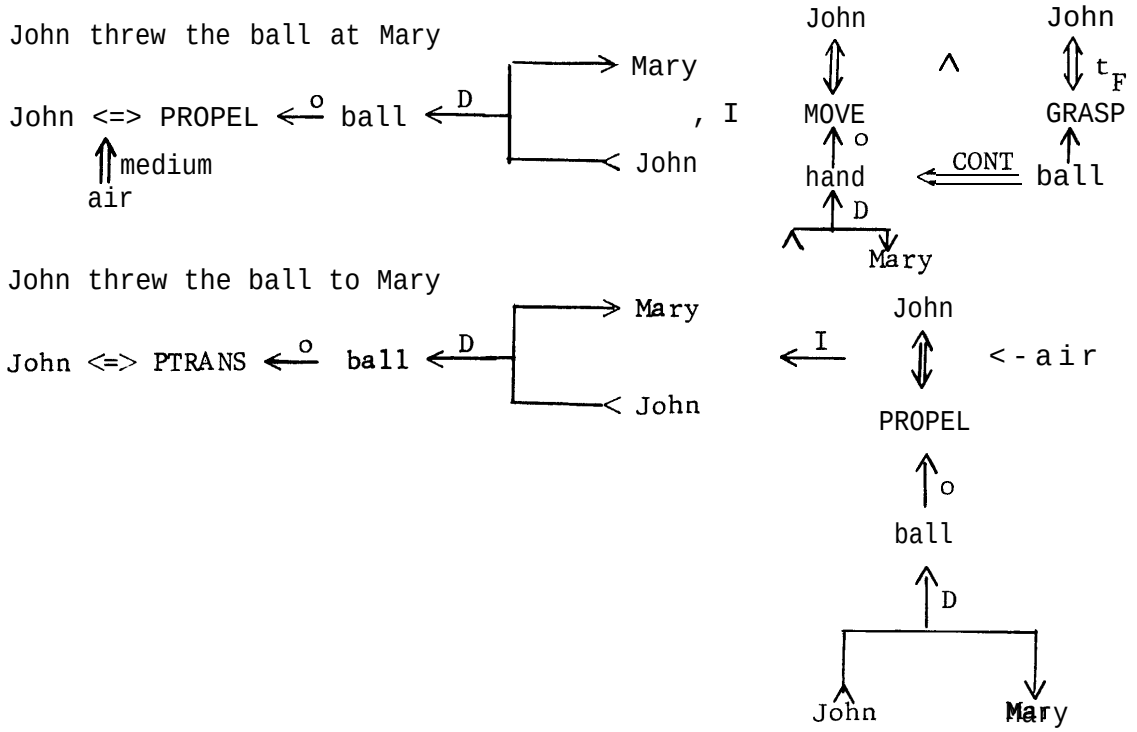


That is, 'push' is PTRANS BY PROPEL. Likewise, 'throw' is also PTRANS by PROPEL, except that medium of propulsion is the air as opposed to the ground, and an ending (t_F) of GRASP is also an instrument.

Using the notions of PTRANS and PROPEL, some interesting distinctions can be drawn that are not otherwise obvious. Consider the distinction between 'throw to' and 'throw at'. While these are the same action from the point of view of an uninvolved observer, they are considerably different in intent. Conceptual Dependency is supposed to capture both intent and observed action, so there should be similar and different parts here.

Both verbs involve the ACT, PROPEL. But 'throw to' has PROPEL as being the means by which the intended ACT of PTRANS was accomplished. So we have:

John threw the ball at Mary

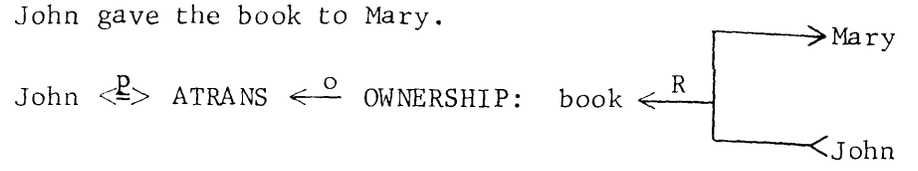


John threw the ball to Mary

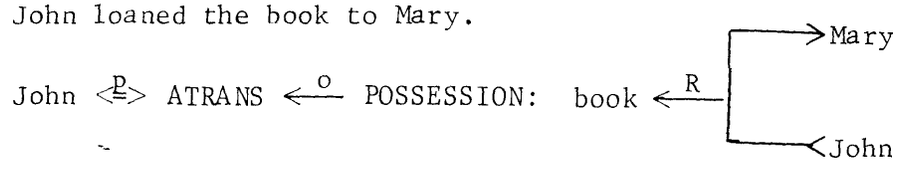
The most abstract of the global ACTs is ATRANS. The objects that ATRANS operates upon are abstract relationships and the physical

instruments of ATRANS are rarely specified. The 'trans' that was referred to in the beginning of this paper is what we call ATRANS. ATRANS takes as object the abstract relationship that holds between two real world objects. We have have :

John gave the book to Mary.



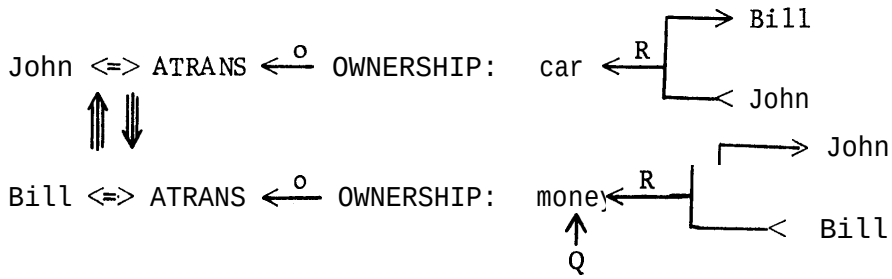
John loaned the book to Mary.



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. The most common instrument for ATRANS is 'MOVE $\xleftarrow{O}$ 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 to an untrained observer. 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 has no notion of possession and therefore has no ATRANS.

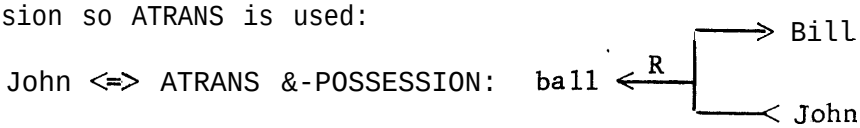
ATRANS operates with a small set of abstract objects. We treat 'sell' as a change in the ownership relations:

John sold his car to Bill.



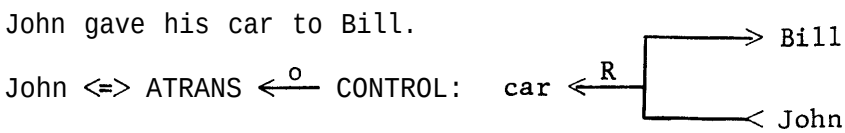
Thus we are saying that two abstract relationships changed because of some mutual causality. Any physical ACTs that took place (i.e. signing a check and handing it to John) are the instruments of the abstract action ATRANS.

We use the verb 'give' in English to denote the change of these abstract relationships. 'John gave the ball to Bill' is a change of possession so ATRANS is used:



Another abstract relationship that can be ATRANS-ed is 'control'. Thus when we say 'John gave his car to Bill', the most likely interpretation is that this is an ATRANS of control rather than ownership. 'ATRANS $\overset{o}{\leftarrow}$ CONTROL' then, is to 'give the use of'.

John gave his car to Bill.

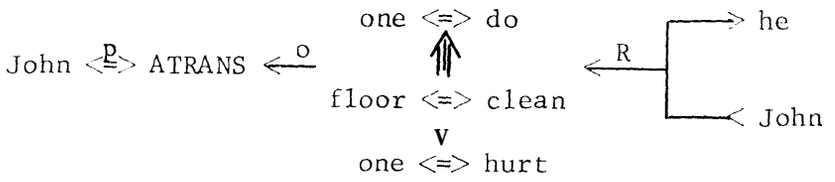


The problem here is that the use of the above primitives makes clear an ambiguity that exists in English that is not otherwise always accounted for in semantic representations. Namely, 'give' can mean a change in possession that required no physical change as in 'John gave Mary the Empire State Building'. 'Give' can also refer to a change in control without a change in possession. Additionally, 'give' can refer

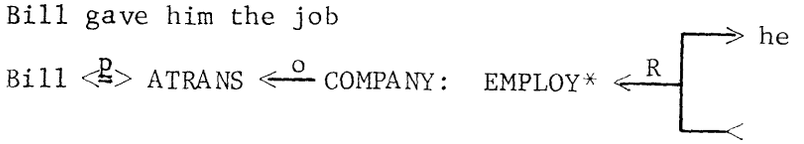
to a change in physical location without a change in the abstract notion of possession, as in 'I gave him my handkerchief'. Basically then whether 'give' means ATRANS or PTRANS or both is dependent on the nature of the object and is often simply ambiguous. This conforms with the notion, expressed in section 4, that a great deal of the information needed to process language is based on the thing involved rather than the action.

Things other than physical objects can be ATRANS-ed. Thus we have:

John gave him the responsibiltty of cleaning the floor.



Bill gave him the job



*The relationship EMPLOY can be reduced in the same way as the verb 'employ' (see section 5).

3.5 Instrumental ACTs

There are four instrumental ACTs:

SMELL

SPEAK

LOOK-AT

LISTEN-TO

These ACTs are not very interesting in that they are used almost totally as the instruments of some other ACT.

SPEAK is the ACT which actually produces sounds and its objects therefore are always 'sounds'. LOOK-AT takes physical objects as object therefore are always 'sounds'.

LOOK-AT takes physical objects as objects and is nearly always the instrument of seeing (the verbs 'see' will be treated in the next section.

LISTEN-TO takes only 'sounds' as objects and is nearly always the instrument of hearing (the verb 'hear' will be treated in the next section).

SMELL is the act of directing ones nose towards and sniffing (sort of). It takes only smells as objects (not the physical objects that produce the smell). SMELL is nearly always the instrument of the verb 'smell' (which will be treated in the next section).

3.6 Mental ACTs

The three mental ACTs are: CONC

MTRANS

MBUILD

Since these ACTs are by no means straightforward, we shall spend some time discussing them.

We postulate the existence of a primitive ACT, CONC, which refers to the act of conceptualization. The object of CONC is always a conceptualization.

The ACT CONC is that which in English is referred to as 'to think-about' in a very broad sense. By CONC we mean:

i) to focus attention on, as well as

ii) to perform mental processing on, where mental processing may

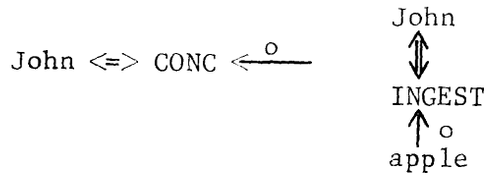
include finding associations, and may, through another mental ACT called MBUILD, result in implications, inferences, etc.

It is true that whenever a person speaks he has CONC-ed the conceptualization which represents the meaning of his utterance. We do not, however, wish to represent this CONC-ing act as a part of the meaning of that utterance. CONC will be used only when the utterance itself refers to certain mental activities, which may have been performed by the speaker or another person. (A similar verbal action, 'entertain' is posited by Price (1969)).

Following is a representative sample of English 'mental activity' verbs and senses in which they can be described conceptually by CONC:

THINK - ABOUT

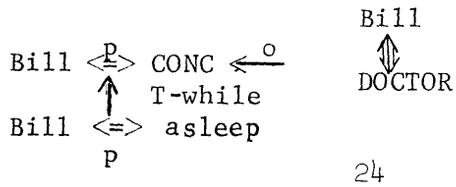
"John is thinking about eating an apple."



We are maintaining the requirement of the conceptual syntax that the object of CONC be a conceptualization, not a concept. Although the syntactic object of the verb 'think-about' may be a noun, we claim it is impossible to conceptualize the isolated meaning of that noun. One may only conceptualize a conceptualization in which that noun fills some role. If we do not know what that conceptualization is, we must represent it with a dummy of some sort.

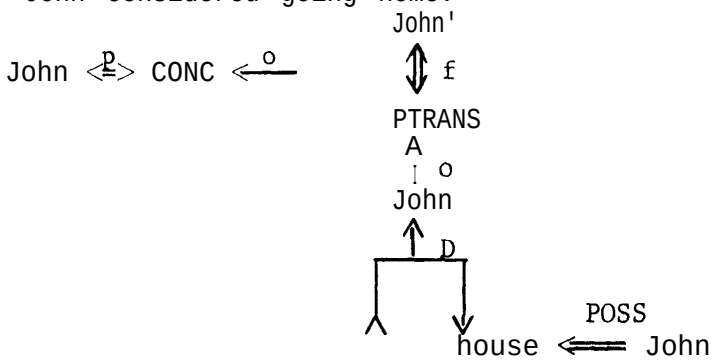
DREAM

"Bill dreamed he was a doctor."



CONSIDER (one sense)

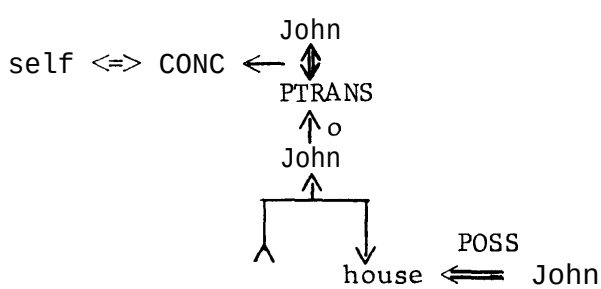
"John considered going home."



Here no distinction has been made between 'consider' and 'think - about'. The difference seems to be that when we hear 'consider' we expect the act to result in the ACTOR's making a decision. But another way of viewing this is to say that English speakers choose 'consider' in those cases in which the object of the conceptualizing is a future action or state over which the 'conceptualizer' has some control. Thus, while it is perfectly understandable, most English speakers would not say: "I considered having wasted two hours yesterday", but rather "I thought about having wasted two hours yesterday".

WONDER

"I wonder if John is going home."

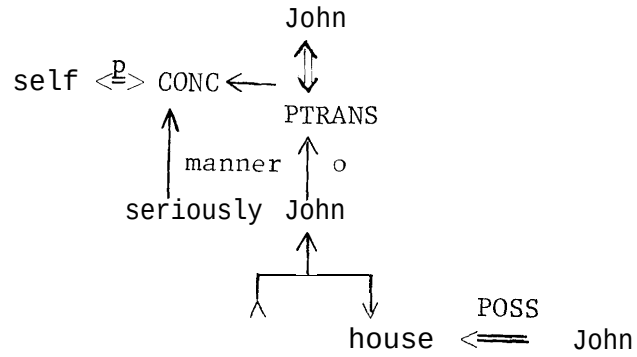


The point here is that the verb 'wonder' indicates CONC with an object conceptualization having the question (?) aspect indicating that the

relationship between 'John' and 'PTRANS' may not have occurred.

PONDER

"I pondered John's going home."



Actions have duration and this needs to be represented conceptually. CONC-ing manner adverbials can be handled by duration modifications. 'To ponder' or 'concentrate on' means to conceptualize something for a period considerably longer than the norm, while to 'give passing thought to' requires the opposite sort of modification.

MTRANS

Once we have the action 'conceptualize', we must consider that it is necessary to do certain actions in order to conceptualize and furthermore that people talk about such actions. That is, given that there is a representation for something being in memory, the problem of how to handle the simple and basic actions of bringing something from and putting something into that memory comes next. The act MTRANS described below is meant to handle this basic flow of information to and from the conscious mind. It, plus various mental building acts, should serve to represent all the ways in which we bring thoughts into our heads.

MTRANS:

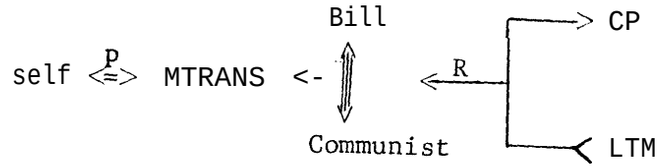
MTRANS represents a change in the mental control of a conceptuali-

zation (or conceptualizations) and underlies verbs like recall, commit to memory, perceive, sense, and communicate. It has several features different from the physical TRANS. For one, the object that is TRANSed does not leave control of the donor, but is copied into the control of the recipeint. Further, the donor and recipeint are not two different people but two different mental processors (or locations: the distinction in the mind is as fuzzy as the distinction between program and data in the computer), which are frequently within the same person. Five such processors will be used here:

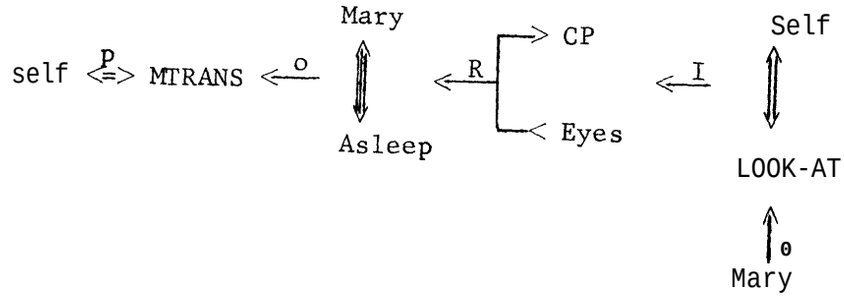
1. Conscious Processor (CP) - this operates on concepts that one has become aware of, performing deductions, making choices, forming associations, and other such actions.
2. Long term Memory (LTM) - this is primarily the store of beliefs one has about the world. It is a processor too, where such actions as forgetting and subconscious association occur, but the level of activity is both low and hard to characterize, so it shall be treated as a passive element here.
3. Immediate Memory (IM) - this is like the LTM and is meant to represent the short term event memory humans use to keep track of propositions relevant to the current situational context.
4. Sense-Organs (Eye, Ear, Nose, Tongue, and Skin) - these are all pre-processors, converting raw sense data into conceptualizations describing that data.
5. Body - this covers whatever processors handle internal sensations such as poin, unease, excitement, etc.

With these items, we can handle many mental verbs, such as

I remembered Bill was a communist:



I saw Mary sleeping:

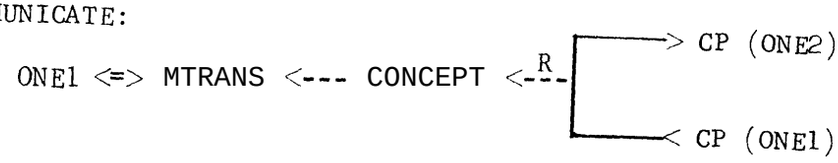


I feel pain:

This use of MTRANS covers mental actions where the concept brought into awareness has been internally arrived at, rather than externally generated.

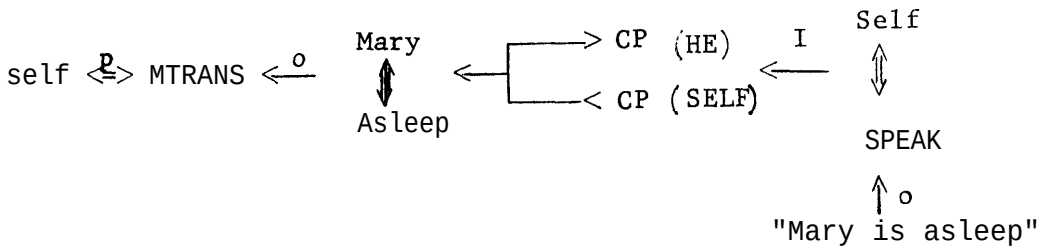
Verbs that refer to externally generated conceptualizations include

COMMUNICATE:

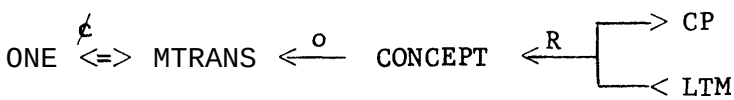


This is pure communication, mind to mind, i.e., telepathy. With the instrumental cast to modify the means of communication we can represent more mundane, indirect verbs like*

I told him Mary was asleep:

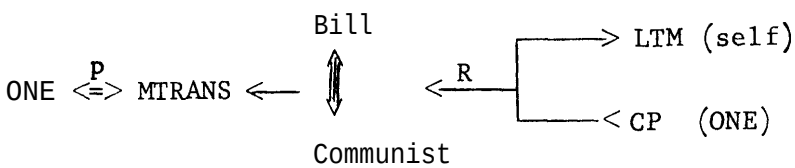


Forgetting is simply the inability to bring something from LTM:



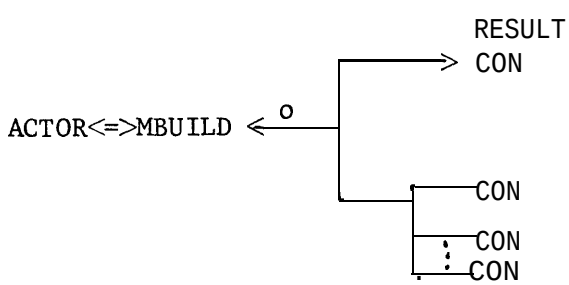
Verbs such as 'learn' and 'teach' also involve MTRANS to LTM from CP. Thus:

I was taught that Bill was a communist.



That is, 'teach'is really like communicate. The actual difference lies in the fact that the communicated information is said to be new in the case of 'teach'. Thus, we also have the information that this information was not in the LTM of self before.

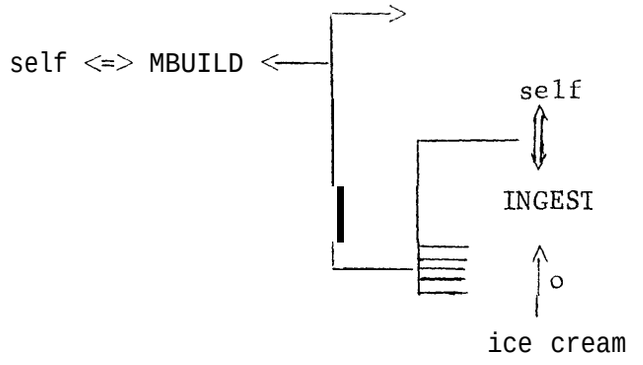
The ACT MBUILD accounts for thought combination. MBUILD is written as:



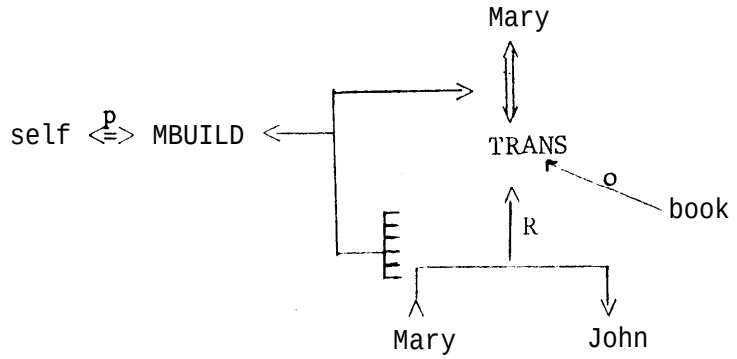
MBUILD takes as object a many-to-one 'functional' arrow that denotes the combination and transformation of several units into one resultant unit. MBUILD plays the role of the action which is antecedent to some more "final" act of accepting the result as knowledge or as a belief. Examples of this type are "conclude", "resolve", "prove to oneself", "solve" and so on. In these cases, an end result is actually produced and its CONC-ing is therefore implicit. In others of these, MBUILD is the only ACT underlying the verb, and there is no result conceptualization yet produced (such as "think over", "consider", "reason out", "relate", etc.) This distinction between the process and the result of the process (and what becomes of the result afterward) is crucial to the unravelling of mental verbs. MBUILD refers only to the process of combination, or attempted combination, and includes no information about the success or failure of the operation. Success can be denoted by the presence of a result in the object slot, and failure by its absence.

EXAMPLES:

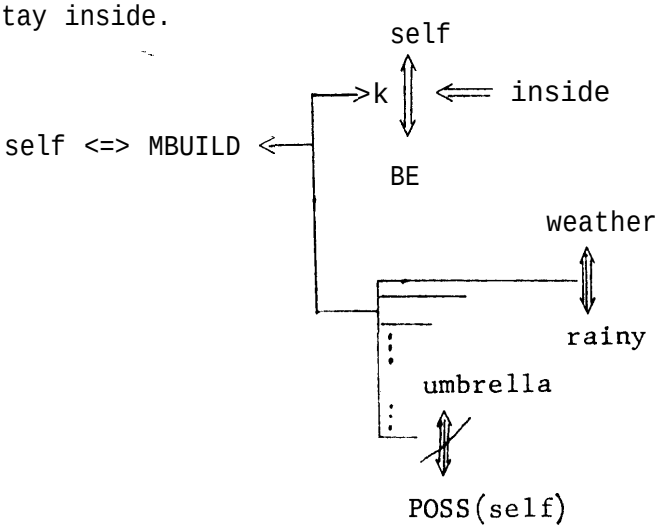
I'm considering the ramifications of eating that ice cream:



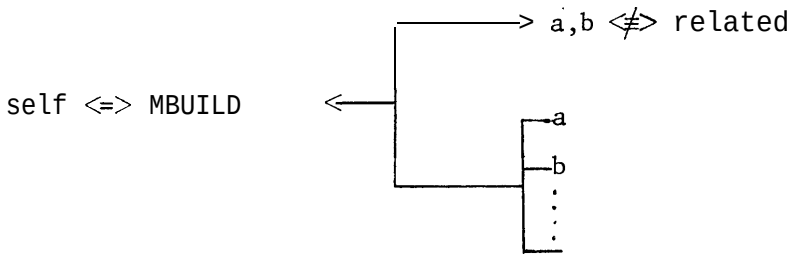
I concluded that Mary gave John the book.



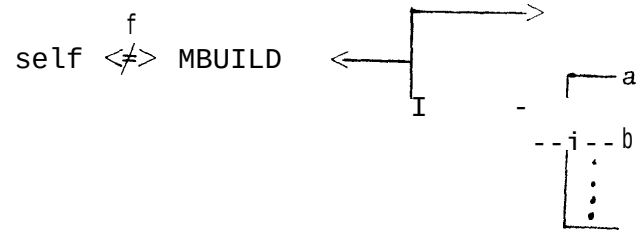
Since it was rainy and I had no umbrella, I figured that I ought to stay inside.



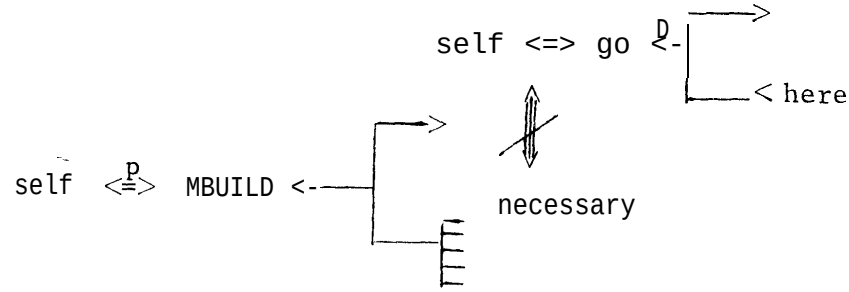
I realize that these facts a and b are unrelated.



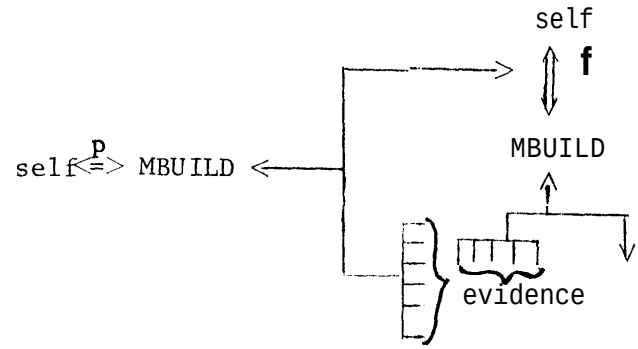
I won't even consider these facts a and b.



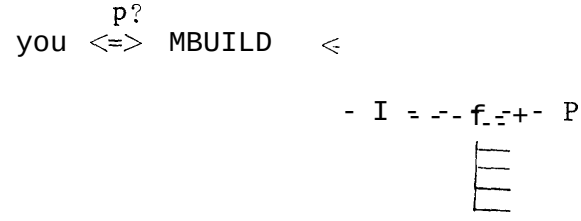
I convinced myself that it was unnecessary to go.



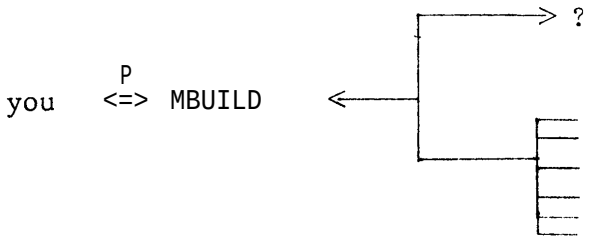
I have weighed the evidence and decided to reconsider.



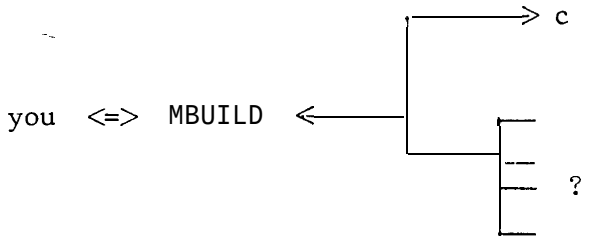
Have you thought about the problem (P) yet?



What did you conclude?



Why did you conclude c?



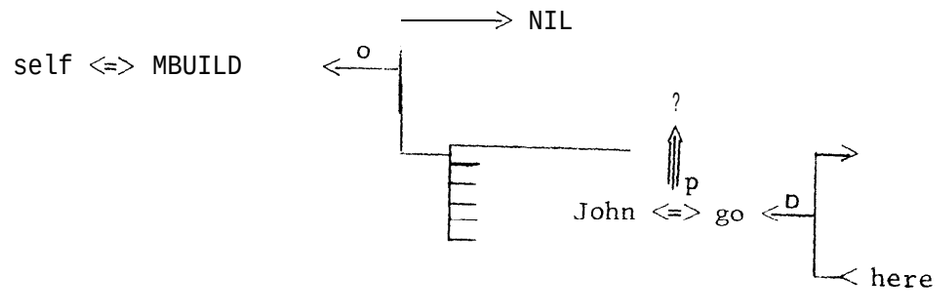
There is one further clarification to be made regarding the relationship of the arguments of MBUILD to the MBUILDing process. There are two cases which we have lumped together in the examples: a) the MBUILDing occurs in "free-form" (is non-directed), and b) the MBUILDing is "directed" by one of its arguments. The first case is characterized by the paradigm: "Here are some things to think about. What can you conclude from them?" In this case, there is no particular problem in mind to direct or constrain the MBUILD to one domain. The second case is that of finding the solution to a particular problem, the answer to a particular question. In this case not only is the MBUILD process "directed" by the problem, but the kinds of other arguments MBUILD will use are implicitly "related" to the problem.

Perhaps these two cases actually represent quite different mental and logical processes. Yet MBUILD seems to be central to both, and their differences involve "micro-processes" which we do not need for the purposes of CD.

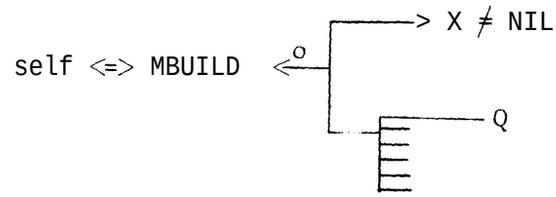
How do we notate directed MBUILD? During the course of answering a question, we are aware of the question itself. To this extent, the question itself is not only directing the MBUILD, but is also one of the arguments of the process. Our notation for directed MBUILDing obeys the convention that the question or problem be written as the first argument of MBUILD, and if a result is present, it is the "answer" to the question relative to that MBUILD.

We conclude this section with a few final examples:

I can't figure out what caused John to leave.

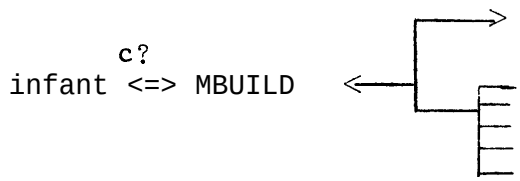


I can answer the question.

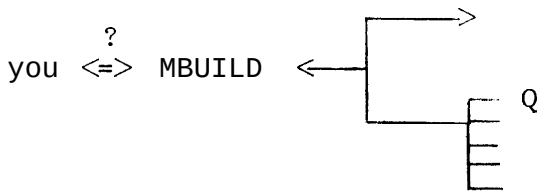


Notice here that we do not write p $\overset{c}{<=>}$ MBUILD. Written this way, we arc asserting that p has the ability or mechanism of thought, not that this mechanism can produce any results. Every normal human being can MBUILD. "Can answer" is therefore signified by the presence of the result.

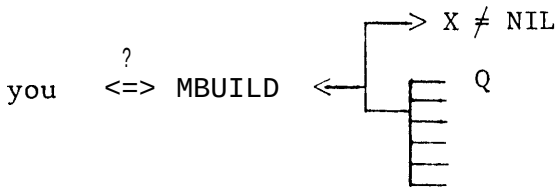
Can a newborn infant think?



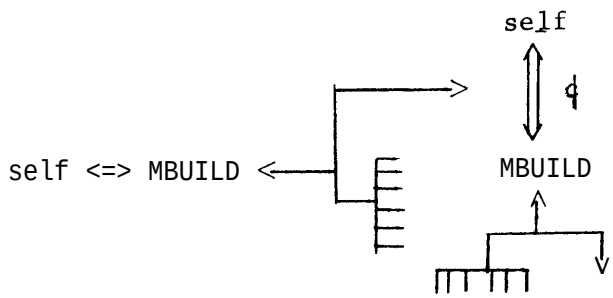
Are you thinking about the question?



Can you answer the question?



I've concluded that I just can't think anymore!



4. Inferences

4.1 The Acts

It should be clear that any attempt of this kind to put sentences into underlying representations that use only a few primitive ACTs must have as its intent the use of these ACTs in some prescribed fashion. Each ACT is basically a memory affector in that whenever that ACT is present certain facts can be inferred from it.

This establishes an "equivalence class of semantics" for any particular graph that comes in, and this insures that semantically different expressions of the same information are recognized as part of this equivalence class. The notion of "information" is therefore this equivalence class established by inferences. Notice that these equivalence classes are not very interesting, since all are certainly true if any one of them is.

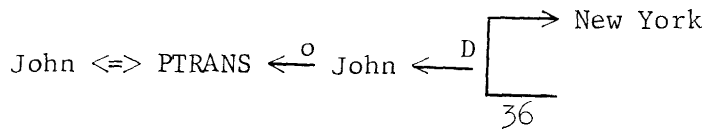
That is, in considering the problem of how to know when something would qualify as a new ACT, the pertinent question to ask is whether the inferences that would be drawn from that ACT are the same as the act of inferences that are drawn from some already existing ACT.

Here it is important to make clear what exactly we mean by an inference. For our purposes, an inference is a conceptualization that is true to some degree of probability whenever some other conceptualization or set of conceptualizations are true. For example, in the sentence

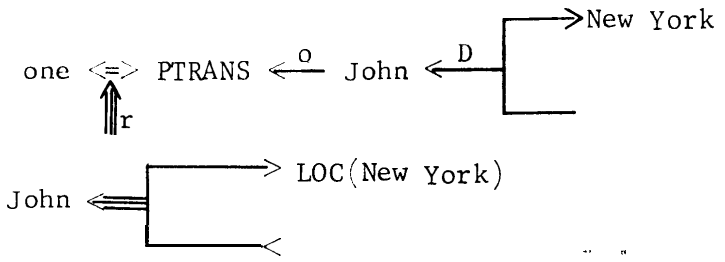
John went to New York.

it is not explicitly stated that John in fact arrived in New York.

'John went to New York' is graphed as:



while 'John arrived in New York' is:



that is, we don't know if he actually got to New York. We know only that he went in that direction. We infer that if we are told something and not explicitly told that the expected inference is invalid, then it is reasonable to draw that inference. In this case PTRANS causes the location inference to be generated in absence of information to the contrary.

(It might be useful to note here that the validity of inferences can be informally checked by use of what we call 'the BUT test'. If it sounds ridiculous to say 'X but not Y'then y is part of the semantic equivalence class of X. For example:

John told Mary that Sam was tall but John never considered if Sam was tall.

Here we treat tell as MTRANS form CP, which means that an idea has to be in one's head before one can communicate it.

On the other hand, if 'X but not Y' is reasonable but alters one's expectations, then Y is a valid inference:

John told Mary that Sam was tall but he didn't believe it.

Here, the inference that MTRANS implies existence in LTM first is being 'butted'.

The third case is when we have 'X but not Y' where the statement is plausible but unrelated.

John told Mary that Same was tall but John didn't eat his sandwich.

A statement of this kind is simply odd. Notice though that if we heard:

John told Mary that Sam was tall but he didn't like flowers.

we would have an implicit predication about tallness implying a liking of flowers that was being 'butted'.)

We shall now sketch the information that is stored about each ACT with reference to inferences and some other matters.

I: INGEST

Let us consider first the ACT INGEST as found in a conceptualization (C1):

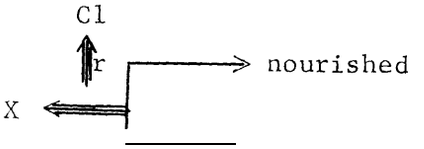
C1: X <=> INGEST $\xleftarrow{o}$ Y $\xleftarrow{D}$ Z, W

The main inferences are:

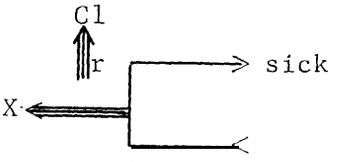
1) PTRANS is implied by INGEST. Therefore all inferences that apply when PTRANS is present apply when INGEST is present (see PTRANS for those inferences).

2) Y ceases to exist in its usual form: Y $\overset{t_F}{\Longleftrightarrow}$ BE

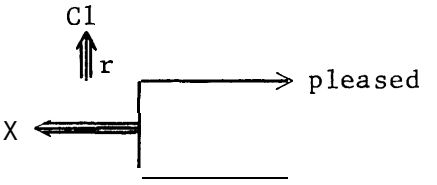
3) if Y is edible then X becomes more nourished:



4) if Y is inedible then X becomes sick:



5) if X thinks that Y tastes good then X is pleased



There are supplementary inferences that depend on the nature of the object (Y) in question. For example if

1) Y is liquor then X might become inebriated.

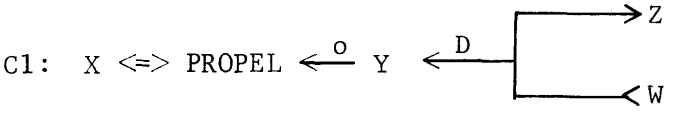
2) Y is candy then X might get bad teeth.

3) Y is medicine then X might get healthier in the case that X was sick and Y is the correct medicine for helping this sickness.

As can be imagined these supplementary inferences are very long and in fact represent information about the object and not the ACT. Such information is stored under the object therefore and we shall not discuss it further. The main point here is to mention the limited set of inferences which can be drawn from the ACT. What is most interesting of course, is that since ACTs establish an equivalence class, the inference information about them need only be explicitly stated once, although it is used for a large number of verbs.

II: PROPEL

The next ACT we shall consider is PROPEL in the conceptualization (C1):

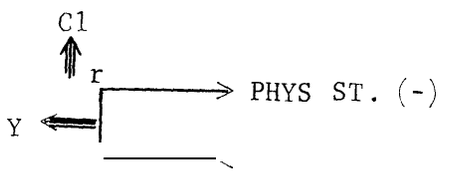


The main inferences are:

1) PTRANS is implied if Y is not a fixed object (i.e. if

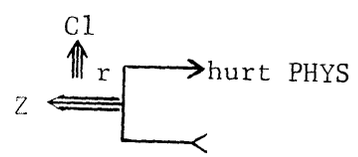
PROPEL-ing it ordinarily would change its location)

2) if Y is rigid and brittle and nonfixed and the speed of instrumental ACT used with PROPEL is great, then Y will become in a negative physical state:

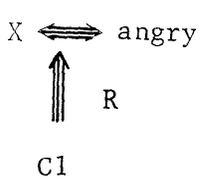


3) it is possible that Z was physically negatively affected by if the state Y ∧ Z ⟺ PHYSCONT is true

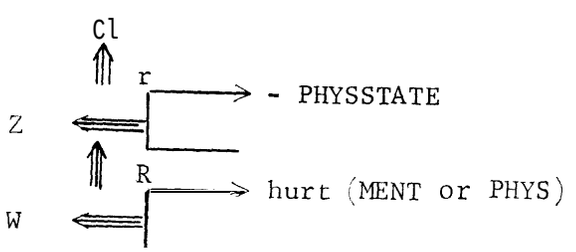
(This state is present when the English verb 'hit' is present for example.



4) if Z is human then it is possible that X was angry at Z:

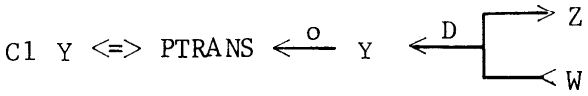


5) if X is inaccurate then it is possible that X was either frustrated or intended to hurt someone (W) by huring Z:



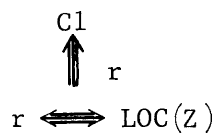
III: PTRANS

The next ACT is PTRANS as in C1:

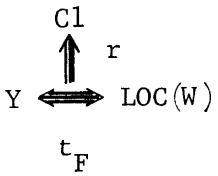


The main inferences are:

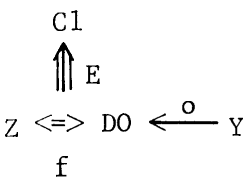
1) Y is now located at Z:



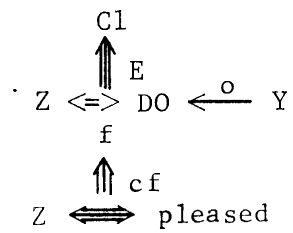
2) Y is no longer at location W:



3) if Z is human and if Z requested C1, or if Z is the actor of PTRANS then Z will probably do whatever is ordinarily done with Y:

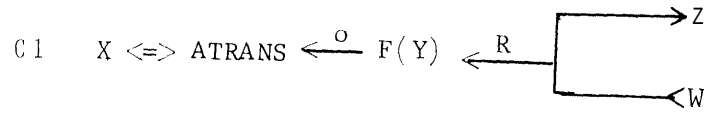


4) We also want to infer that doing (3) will cause him to be pleased: i.e. that he wants to do whatever is ordinarily done with Y:



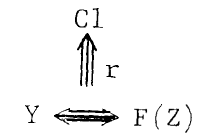
IV: ATRANS

Next we consider ATRANS as in C1:

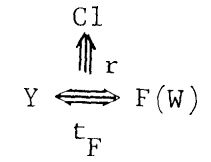


The main inferences are:

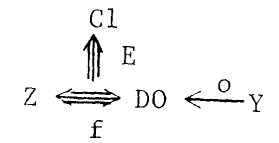
1) Z is now in the abstract relationship F to Y:



2) W is no longer in the abstract relationship F to Y:

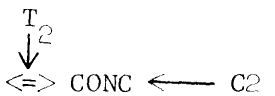


3) If Z requested C1 then Z will probably do the thing that one usually does with Y:



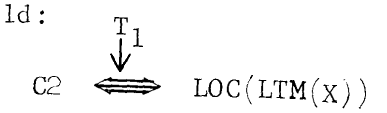
v: CONC

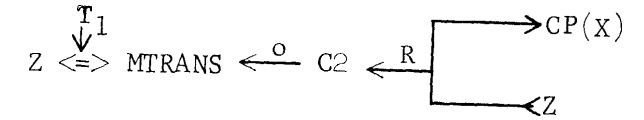
We next consider CONC as in C1:



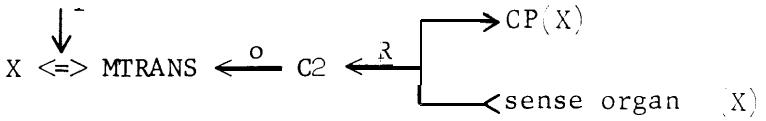
The main inferences are:

1) C2 was brought into the thinking area from either the memory or the outside world:

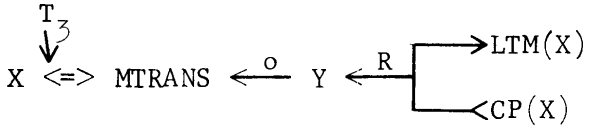
either 

or 

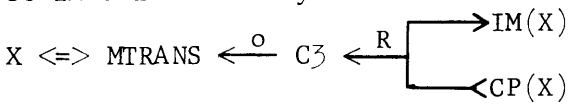
or



2) X will remember for some period of time the conceptualization C2:

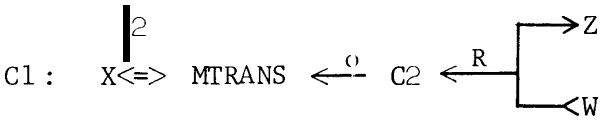


3) Anything that was being thought of before C2 has now been moved to immediate memory.

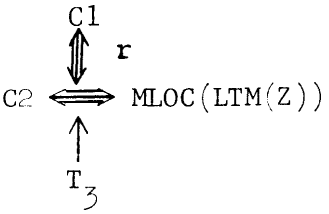


VI: MTRANS

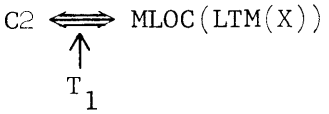
We next have MTRANS in C1:



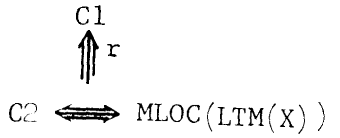
1) When something is MTRANS-ed to Z, if Z is a human and X = W then Z now, "knows" C2:



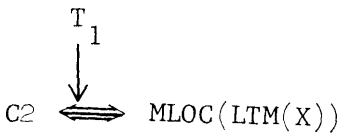
2) When X = W, X can be said to already have "known" C2:



3) If Z and W are parts of X's memory then if Z is LTM or IM then X has just learned (or come to know) C2:

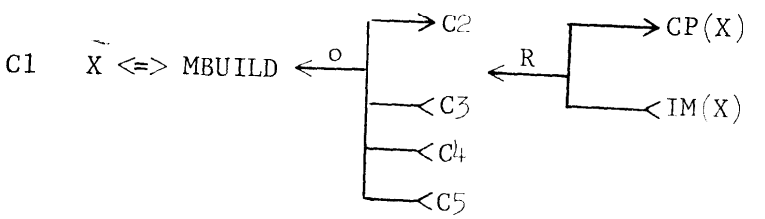


4) If Z and W are parts of X's memory and if W is LTM or IM then X previously "knew" C2:



VII: MBUILD

We next consider MBUILD as in C1:



The main inferences are:

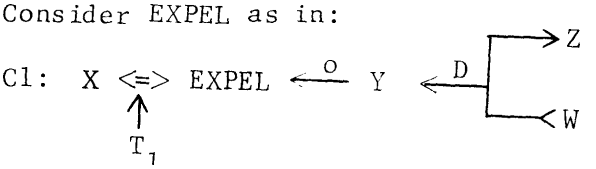
1) X is now thinking about C2:

2) X knows the facts necessary to think up C2:

C3
C4 ⟺ MLOC(LTM(X))
C5

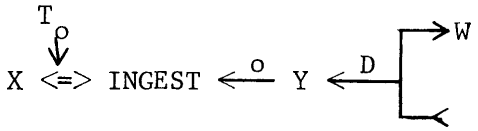
VIII: EXPEL

Consider EXPEL as in:



The main inferences are:

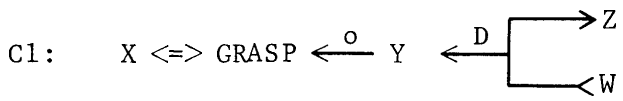
1) Y was previously INGEST-ed:



2) PTRANS can be inferred.

IX: GRASP

Consider GRASP as in C1:



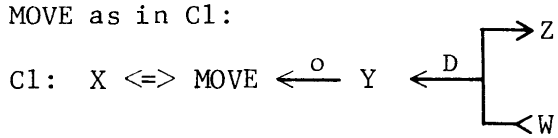
The main inferences are:

1) PTRANS can be inferred.

2) Y is smaller than X and is probably smaller than the object of the instrument of C1.

X: MOVE

MOVE as in C1:



1) X intends to do something with Y, that is, C1 will probably enable some other conceptualization to take place that involves Y.

XI: SPEAK

XII: LISTEN-TO

XIII: LOOK-AT

XIV: SMELL

These ACTs have no inferences other than the fact that an MTRANS about their existence has probably taken place whenever they have been used. This information is not particularly useful since the MTRANS was probably already communicated (with one of the above ACTs as Instrument).

4.2 Instruments

Whenever a given ACT is present, the instrument of that ACT can be inferred from a specific group of ACTs that can be specified for each ACT. For our purposes, an instrumental ACT is defined as an action that takes place as a part of the main ACT, i.e. at virtually the same time as the main ACT. If the instrumental ACT takes place at a time greater than E away from the main ACT, its relationship to the main ACT is not instrumental but causative. We use, in this case, the notion of enable causation (E). Thus, the distinction between causation and instrumentality is, for us, one of time, that is if an ACT is in a continuous flow with another ACT, then it can be instrumental otherwise it is not. However, in either case, the ACT that can be inferred as an instrument or enabling causer is drawn from the set that shall be drawn here:

I. INGEST: The instrument of INGEST is PTRANS.

II. PROPEL: The instrument of PROPEL is MOVE or GRASP (t_F) or PROPEL.

III. PTRANS: The instrument of PTRANS is MOVE or PROPEL.

IV. ATRANS: The instrument of PTRANS is either PTRANS, MTRANS, or MOVE.

V. CONC: The instrument of CONC is MTRANS.

VI. MTRANS: The instrument of MTRANS is either MBUILD, SPEAK, SMELL, LISTEN-TO, LOOK-AT, MOVE or nothing.

VII. MBUILD: The instrument of MBUILD is MTRANS.

VIII. EXPEL: The instrument of EXPEL is MOVE or PROPEL

IX. GRASP: The instrument of GRASP is MOVE.

XI. SPEAK: The instrument of SPEAK is MOVE.

XII. LISTEN-TO: The instrument of LISTEN-TO is nothing.

XIII. LOOK-AT: The instrument of LOOK-AT is nothing.

XIV. SMELL: The instrument of SMELL IS nothing.

N O T E S

General: 1) Often instruments are a specified sequence of actions. For example, 'Throw' is 'PROPEL' by MOVE and then GRASP-ing.

2) Some Actions may occur more than once as the instrument of an ACT. For example, 'take' could be 'PTRANS by MOVE hand towards by MOVE fingers around by MOVE hand from'.

3) We arbitrarily must end our analyses someplace. It seems rather pointless to worry about how people actually move a body part or transfer information in their heads so for MOVE and MTRANS we allow the possibility of no instrumental conceptualization.

I. INGEST: INGEST always has PTRANS as instrument, but the object of the PTRANS is not always known. That is, in order to eat you must either move the food to you or you to the food.

II. PROPEL: In order to PROPEL something which one is holding, it is often necessary to let go. That is the reason that GRASP (t_F) (let go) is listed here.

XI. SPEAK: The instrument MOVE for SPEAK has as object 'tongue'.

XIV - XVI: The three senses LISTEN-TO, LOOK-AT, SMELL are considered to be ultimately primitive (i.e. containing no instrumental elements)

for our purposes.

Whenever an ACT is stated therefore, if only one ACT is known to be a possible instrument then the inference is made. If there is more than one possibility the motivation of the particular program which is using the analysis decides whether to find out about it. That is, if we have, 'John gave Mary a ball', it may or may not be interesting to know if he did it by PROPEL-ing it at her or by MOVE-ing his body part which contained the ball towards her. It is interesting to know that these are the only choices however.

4.3 Backwards Inference

So far the two types of inference that we have given can be made in a forward manner. That is, we learn that a given ACT has taken place and we attempt to decide what things must result when that ACT occurs and also what other ACTs would have had to occur as a necessary part of that ACT.

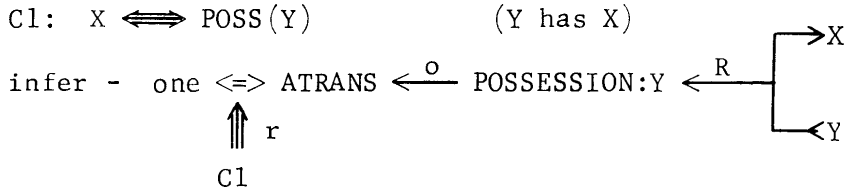
Sometimes it is the case that a conceptualization is communicated that is the result of another unstated conceptualization or the instrument of another unstated conceptualization.

As an example of the former we have resultant states. If we are told 'John has a book', then we know that something must have caused this state to exist. Thus we can infer that 'someone PTRANS-ed the book to John'. Similarly when we are told that 'Mary knows what Fred did' we must be able to infer that this information was MTRANS-ed to Mary. This enables questions of the order of 'Who told her?' to be generated.

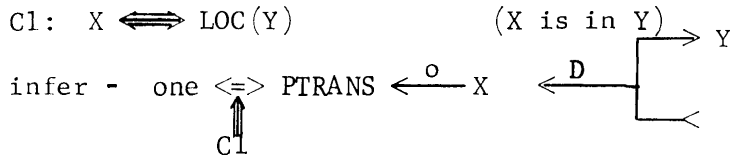
So we add an inference rule which is, whenever certain state

relationships exist, a TRANS ACT can be inferred. Thus:

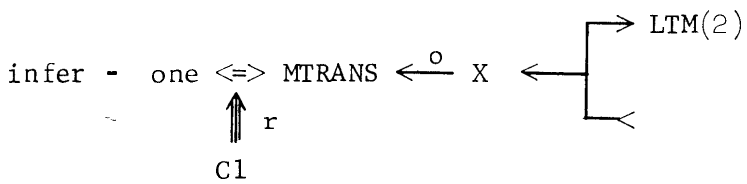
1) Cl: X ⟺ POSS(Y) (Y has X)



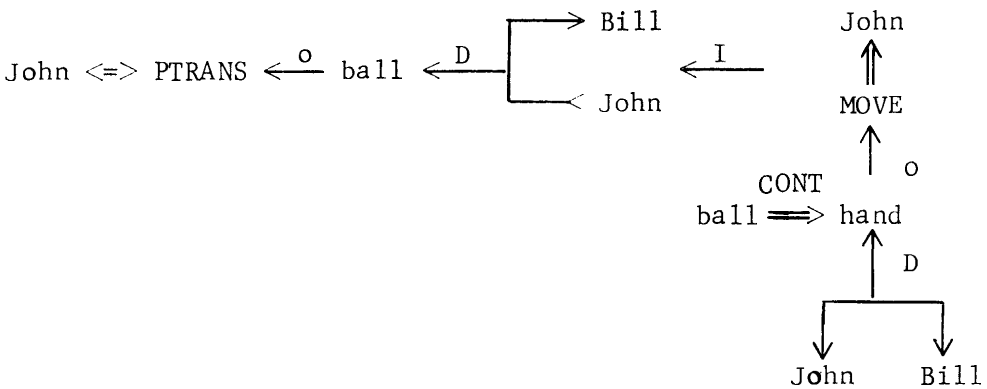
2) Cl: X ⟺ LOC(Y) (X is in Y)



3) Cl: X ⟺ MLOC (LTM(Z)) (Z knows X)



The second kind of 'backwards' inference is when the instrument is mentioned without the main ACT. The main problem here is that one can never really be certain when this is the case. For example, if we have 'John handed the ball to Bill', we have an instance of 'PTRANS by MOVE hand':



The question is, do we have an instance of ATRANS? That is, was only the location of the ball changed or was the possession also changed?

In order to account for this problem it is necessary to work

backwards through the list of instrumental inferences supplied in Section 4.2. That is, anytime that we are presented with an ACT that occurs in the table in 4.2 as an instrumental ACT, we must generate the possibility that the communicated ACT was possibly the instrument of another ACT. Or, we must generate the possibility that this ACT was done with the intention of enabling another ACT to take place. Here again the potential ACTs that might occur can be found in Section 4.2, where the instrumental ACT might possibly have been done in order to enable the ACT of which it is the instrument to occur.

It turns out that for the above example, because ATRANS and PTRANS are so intimately related, whenever PTRANS to a person occurs, it is necessary to generate the possibility that the PTRANS was actually the instrument of ATRANS.

Whenever the semantic restrictions on the stated ACT will meet the requirements of an ACT for which it can serve as instrument, we infer (except in the case of PTRANS/ATRANS) that this ACT was done with the intent of enabling the second ACT to occur.

As an example, suppose we were told that 'John gave Bill an apple'. Since PTRANS can serve as instrument to INGEST, and since the object of PTRANS may serve as the object of INGEST, then this was done to enable that 'Bill ingest the apple'.

Similarly, if we have 'John threw the ball' we would have PROPEL being the potential instrument of PTRANS and therefore would generate the possibility that PTRANS took place (and that this was the intent of the PROPEL-ing). We would also know that there is the possibility that this inference is not correct and that we simply have PROPEL and nothing more.

We have made here, a distinction between instrument and enable causation. We have stated above that the difference between is based on whether the time difference between the two ACTs involved is greater than ϵ . With reference to the problem that we have here labeled backward inference, we have the possibility of an instrumental ACT (and therefore an unstated main ACT) for Group A and an enabling ACT (and therefore an inferred later possibility) for Group B.

GROUP A	GROUP B
PROPEL	PROPEL
SPEAK	PTRANS
SMELL	ATRANS
LISTEN-TO	MTRANS
LOOK-AT	MBUILD
MOVE	CONC
GRASP	INGEST
	EXPEL

These groups are not invariable and only indicate where the first place to look is. Thus, when we see SPEAK, for example, we assume that SPEAK was the instrument of an MTRANS. When we see PTRANS, we consider the possibility that this ACT was done with some desired ACT or state in mind as a causal result. Since some ACTs never cause anything but states (INGEST for example) we don't usually consider them as potential enabling causations.

4.4 Conclusion

The main point that needs to be emphasized here is that once natural language sentences can be reduced to the conceptualizations underlying them with the use of primitive actions the inference process is simplified. We are guaranteed to have activated all parts of the semantic equivalance class if any of its members is activated. The problem of inference is by no means completed by the use of these primitives. What we have done is to reduce the number of inferences that need be stored by rewriting, so to speak, the verb into an ACT from which we can draw inferences. Certain inferences are simply not taken care of by this. For example, if we have 'John kissed Mary', our mapping of kiss into 'MOVE lips towards' will not simplify the problem one bit (Most inferences fall into this category, in fact). One must be careful, not to lose information in doing a conceptual analysis. (That is, 'kiss' is really more than just 'MOVE lips towards'.) However, the mapping of the various verbs into ATRANS, for example, eliminates the problem of having to make the same inference over and over again.

The value of these primitive ACT's is that certain things are true whenever a given ACT is present and thus large amounts of information that is true for a given verb can be written only once for that underlying ACT. These equivalence classes then, are probably much more like what people learn then would be an exhaustive list of what is true for every verb.

In addition, the verb paraphrasing is explained by the use of these primitives. At Stanford, we now have running a program that parses sentences into these primitives and conceptual relations and then finds

paraphrases using entirely different verbs and syntactic constructions. The core of this program is, of course, the notion of primitive ACTs.

In addition, we also have a program that makes inferences ased on the information presented here. The paraphrasing program is described in Goldman and Riesbeck (1973) and the memory and inference program is described in Rieger (1973).

We are not claiming here that we have solved all the problems with respect to a primitive set of ACTs. For example, we are still not satisfied with our representation of certain emotions ('love' for example) and are considering creating another mental ACT of MFEEL to account for it. This brings up the problem of how one decides when a new ACT is warranted or whether the current set is correct or arbitrary. Since our approach has been basically intuitive we really cannot provide a rigorous decision procedure for primitive ACTs. We feel that inferences are an important part of the decision criteria and we have found the ACT set (presented here) to be useful and interesting.

5. Mini-dictionary

The purpose of this dictionary is to illustrate the possibilities of the sixteen primitive ACTs with respect to their power for representation of similarities of meaning. None of the particular analyses presented is correct in any absolute sense. Many of the analyses given here are still under debate even within our own research group. The intent of this dictionary is only to demonstrate the basic method for analyzing verbs in terms of primitives. If any particular analysis is wrong, we would not be surprised. But we claim that no analysis is so far wrong as to require the creation of more conceptual ACTs.

In addition, it is the case that the conceptual dictionary given here does not make a difference between verbs that differ mainly in connotation. For example, 'beg' and 'ask' are treated identically here, yet they have quite different connotations. The purpose of this dictionary is to stress similarities of meaning not the differences. In actual use, we would add an attribute predication to the conceptual structure underlying 'beg' that indicates that the actor is socially demeaned by this ACT. This conforms to our ideas about objective viewing of real world actions. It is quite possible that the actual act of begging might look no different than the act of asking for something. It is only the fact that certain social taboos are violated that makes it 'begging'.

The notation used here makes use of the symbols discussed elsewhere in the paper plus the following:

A and B = actions

Q = mental object

X, Y, T = humans

W, Z = physical objects or locations

P = proposition

nf is a natural force

one is an unstated human actor

* is an unstated actor

(X) indicates possession by X

in X indicates 'in the interior of X'

We have represented here only a small set of the most common senses of the most common verbs in English. Most every verb given here has other senses that occur in other semantic and syntactic environments that have not been mentioned here. How to choose among differing senses of a verb is discussed in Schank (1972).

Instruments have been put in the analyses when they are implicitly part of the verb. If the instrument is ambiguous or unknown it was left out. In addition, the object of ATRANS is written as a single physical object when the abstract relationship being operated upon is unknown.

X advise Y to A = X <=>MTRANS $\overset{o}{\leftarrow}$ Y <=>A ⇑ cf Y <≡> pleased

R → Y, X

X aggravate Y = X <=> Do ⇑ R Y <≡> upset

A aggravate Y = Y <=>A ⇑ R Y <≡> upset

X arrives at Z = X <=> PTRANS $\xleftarrow{O}$ X $\xleftarrow{D}$ Z

⇑ r

<≡> LOC (Z)

X ask Y to A = X <=> MTRANS $\xleftarrow{O}$ Y <=>A ⇑ cf R X <≡> pleased $\xleftarrow{R}$ Y, X

X ask Y about Z = X <=> MTRANS $\xleftarrow{O}$ Z? $\xleftarrow{R}$ Y, X

X attempts to A = X <=> CON&- X <=> Do ⇑ r A

⇑ R

X <=> Do

X beg Y to A = X <=> MTRANS $\xleftarrow{O}$ Y <=>A ⇑ r X <≡> pleased $\xleftarrow{R}$ Y, X

X buy Z from Y = X <=> ATRANS $\xleftarrow{O}$ money $\xleftarrow{R}$ Y, X

⇑ R

Y <=> ATRANS'OZ X

@--T---Y

X believe A = A <≡> LOC (LTM (X))

X believe Y = Y <=> MTRANS $\xleftarrow{O}$ P $\xleftarrow{R}$ X, Y

∧

P <≡> LOC (LTM(X))

X break Z = X <=> Do

⇑ r

2 <≡> broken

X bring z to Y = 'X <=> PTRANS $\xleftarrow{O}$ Z $\xleftarrow{D}$ Y, X

⇑ r

z <≡> LOC (Y)

A bring B = A ⇑ B

A cause B = A ⇑ B

X comes to Z = X <=> PTRANS ←o X ←D → Z
⇑ r
X <≡> LOC (Z)

X comfort Y = X <=> Do
⇑ R
Y ← → comfortable
→ uncomfortable

X communicates with Y = X <=> MTRANS ←o P ←R → Y
→ X

X confuse Y = X <=> Do
⇑ R
Y <≡> confused

X cry = X <=> EXPEL&- tears ←D + - T - - X (fear of X)

x cut z = X <=> PTRANS ←o "cutter" ←D → Z
⇑ r
Z <≡> cut

X decide to A = X <=> MBUILD ←o → X <=> A (f)

X describe Z to Y = X <=> MTRANS ←o Z ⇕ P ←R → Y
→ X

X desire to A = X <=> A
R ⇑ cf <≡> LTM (x)
X <≡> pleased

X die = X $\overset{t_F}{<=>}$ BE

X disturb Y = X <=> Do
R ⇑
Y <≡> disturbed

X doubt Y = Y <=> MTRANS $\overset{o}{\leftarrow}$ P $\overset{R}{\leftarrow}$ (X, Y)
∧
P <≡> LOC (LTM(X))

X drop Z = X $\overset{t_F}{<=>}$ GRASP" Z
nf ⇑ PROPEL/&- Z $\overset{D}{\leftarrow}$ ground

Z fall = nf <=> PROPEL $\overset{o}{\leftarrow}$ Z $\overset{D}{\leftarrow}$ ground

X dream P = X <=> CONC' P
while ⇑
X <≡> asleep

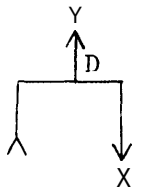
X drink Z = X <=> INGEST-&- Z_{+} $\overset{D}{-}$ I (in X)

X employ Y = X <=> ATRANS $\overset{o}{\leftarrow}$ money $\overset{R}{\leftarrow}$ (Y, X)
R ⇑
Y <≡> Do
R ⇑
X <≡> pleased

X eat Z = X <=> INGEST $\overset{o}{\leftarrow}$ Z $\overset{D}{\leftarrow}$ in X

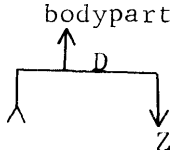
X expect A = A ⇕ f <≡> LOC(LTM(X)) TRUE

X expect Y = Y ⇕ f PTRANS <≡> LOC(LTM(X)) ↑ o



X fear Y = Y <=> DO (f) ⇑ f <≡> LOC(LTM(X)) X <≡> hurt

X feel Z = X <=> MTRANS' Z ⇕ P ← P → CP(X) / body (X) ← I X ⇕ MOVE ↑ o bodypart

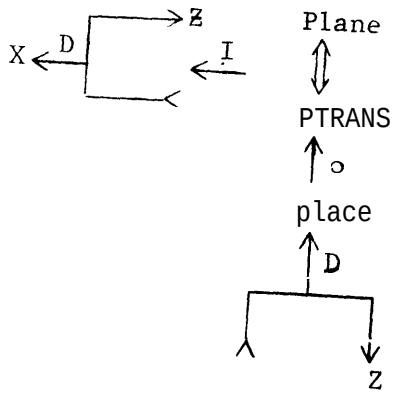


X fight Y = X <=> DO ⇑ r <≡ R ≡> Y <=> DO ⇑ r Y <≡> hurt X <≡> hurt

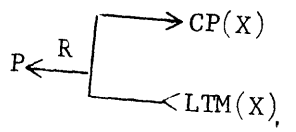
X fix Z = X <=> DO ⇑ r Z ⇐ unbroken / broken

x fly Z <=> X <=> DO ⇑ r Z <=> PTRANS ← o Z ← D → ____ ⇑ in , air

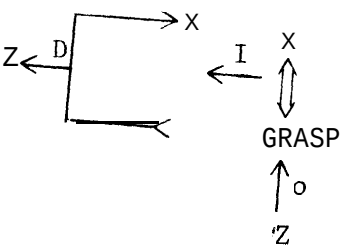
X fly to Z <=> X <=> PTRANS'



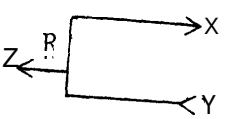
X forget P <=> X <=> MTRANS



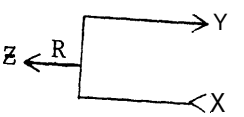
X grab Z = X <=> PTRANS



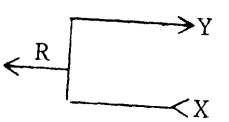
X get Z from Y = Y <=> ATRANS



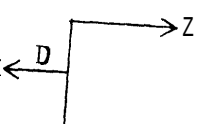
X give Z to Y = X <=> ATRANS



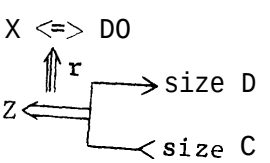
X give Q to Y = X <=> MTRANS



X go to Z = X <=> PTRANS

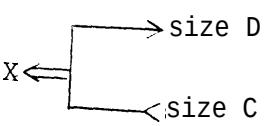


X grow Z = X <=> DO



where D > C

X grow =



X have Z = one $\overset{p}{\Leftrightarrow}$ ATRANS $\xleftarrow{o}$ Z $\xleftarrow{R}$ (X, one)

X hand Z to Y = X $\Leftrightarrow$ PTRANS $\xleftarrow{D}$ (Y, X) $\xleftarrow{I}$ X $\Updownarrow$ MOVE $\xleftarrow{o}$ hand $\xleftarrow{D}$ (X, Y)

X hate Y = X $\Leftrightarrow$ CONC $\xleftarrow{o}$ Y
$\Uparrow$ R
X $\Leftrightarrow$ hateful

X help Y to A = X $\Leftrightarrow$ DO
$\Uparrow$ E
Y $\Leftrightarrow$ A

X hit Y = Z $\wedge$ Y
c
X $\Leftrightarrow$ PROPEL $\xleftarrow{o}$ Z $\xleftarrow{D}$ (Y, X)
$\Uparrow$ r
$\Leftrightarrow$ PHYSCONT

X hurt Y = X $\Leftrightarrow$ DO
$\Uparrow$ r
Y $\Leftrightarrow$ hurt

X imagine P = X $\Leftrightarrow$ CONC $\xleftarrow{P}$ $\Updownarrow$ TRUE

X insult Y = X $\Leftrightarrow$ MTRANS $\xleftarrow{o}$ P $\xleftarrow{R}$ (Y, X)
$\Uparrow$ R
Y $\Leftrightarrow$ $\text{hurt}_{\text{MENT}}$

X interest Y = Y $\Leftrightarrow$ CONC $\xleftarrow{o}$ X
$\Uparrow$ R
Y $\Leftrightarrow$ interested

X keep Z = X <≠> ATRANS $\xleftarrow{o}$ Z $\xleftarrow{R}$ (→ one, < X)

X kick Y = X <=> PROPEL $\xleftarrow{o}$ foot(X) $\xleftarrow{D}$ (→ Y, < X) $\xleftarrow{I}$ X ⇕ MOVE $\xleftarrow{o}$ foot(X) $\xleftarrow{D}$ (X, Y)

X ∧ Y ⇑ r ⟺ PHYSCONT

X kill Y = X <=> DO ⇑ Y ⟺ BE (t_F)

X kiss Y = X <=> MOVE $\xleftarrow{o}$ lips $\xleftarrow{D}$ (→ lips of Y)

X know Y do A = Y ⇕ A <≡> LOC(LTM(X))

X know P = P <≡> LOC(LTM(X))

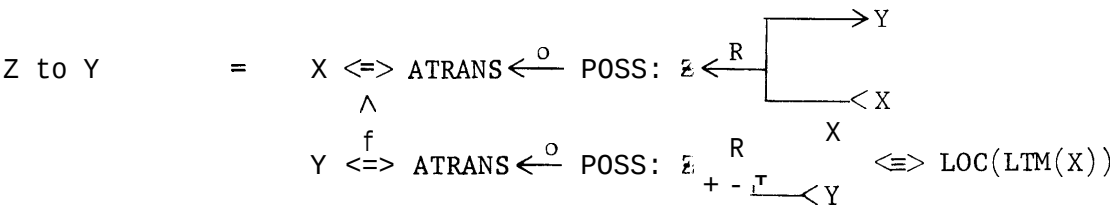
P <≡> LTM (others) (A)

X let Y do A = X <≠> DO ⇑ E Y <=> A (¢)

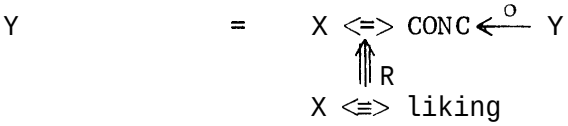
X learn P = X <=> MTRANS $\xleftarrow{o}$ P $\xleftarrow{R}$ (→ LTM(X), < CP(X))

X leave Z = X <=> PTRANS $\xleftarrow{o}$ X $\xleftarrow{D}$ (→ , < Z)

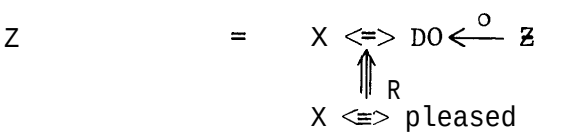
X lend Z to Y =



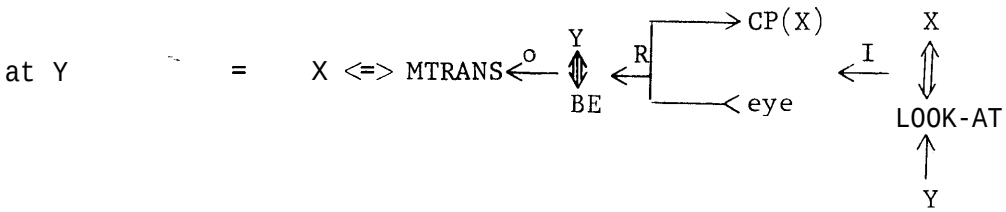
X like Y =



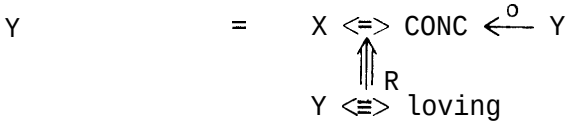
X like Z =



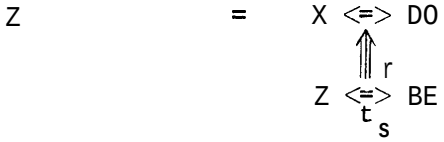
X look at Y =



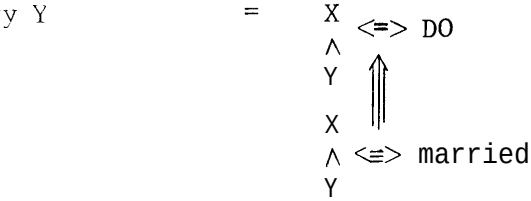
X love Y =



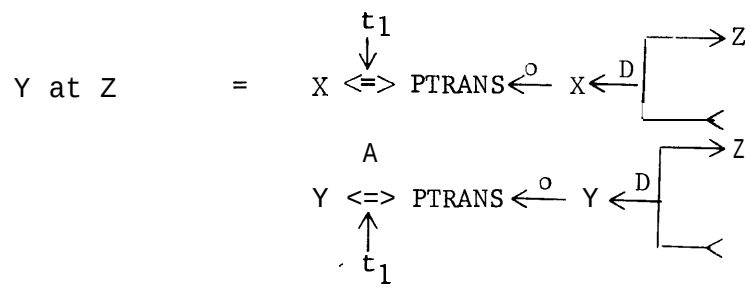
X make Z =



X marry Y =



X meet Y at Z =



X move to Z = X <=> ATRANS $\xleftarrow{o}$ RESIDENCE: X $\xleftarrow{R}$ Z

X move Z to W = X <=> PTRANS $\xleftarrow{o}$ Z $\xleftarrow{D}$ W

$\Uparrow$ r

Z <=> LOC (W)

X object to P = X <=> MTRANS $\xleftarrow{o}$ P

$\Uparrow$ cf

$X \overset{R}{\Leftarrow}$ displeased

$\xleftarrow{R}$ X

X offer Z to Y = X <=> MTRANS' X

$\Updownarrow$ F $\xleftarrow{R}$ Y

ATRANS X

$\uparrow$ o

Z

$\uparrow$ R

X Y

X order Y to A = X <=> MTRANS $\xleftarrow{o}$ Y <=> A

$\Uparrow$ F $\xleftarrow{R}$ Y

Y <=> hurt X

X please Y = X <=> DO

$\Uparrow$ R

Y <=> pleased

X predict P = X <=> MTRANS $\xleftarrow{o}$ P $\overset{f}{\Leftarrow}$ TRUE $\xleftarrow{R}$ X

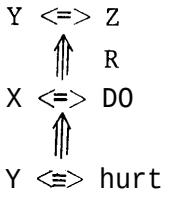
X prevent Y from do A = X <=> DO

$\Uparrow$ R

Y $\overset{c}{\Leftarrow}$ A

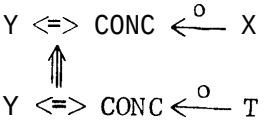
X put Z in W = X <=> PTRANS $\xleftarrow{o}$ Z $\xleftarrow{D}$ in W

X punish Y for doing A =

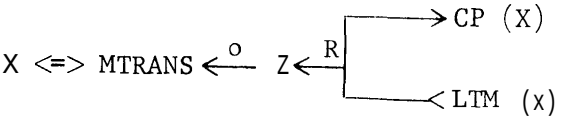


X quit A = $X \overset{t_F}{<=>} A$

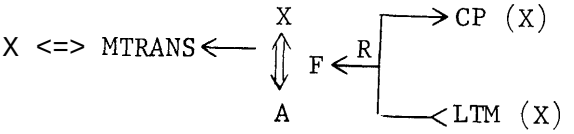
X remind Y of T =



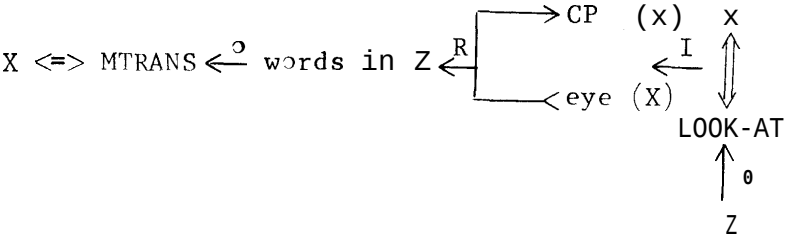
X remember Z =



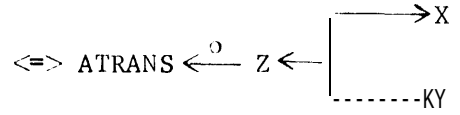
X remember to A =



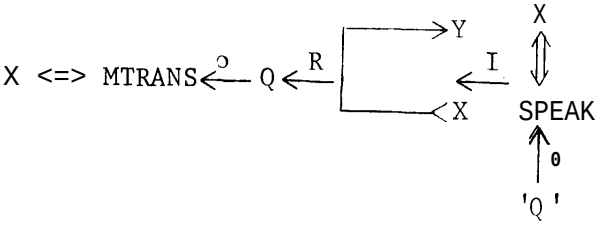
Y read Z =



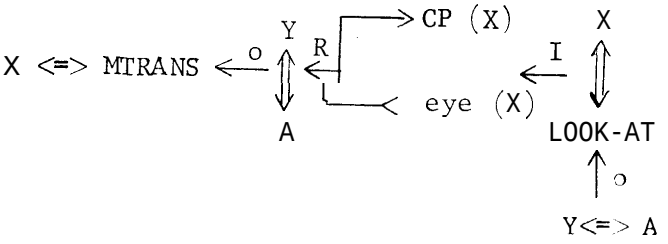
X receive Z from Y =



X say Z to Y =



X see Y do A =



X shoot at Y = X <=> PROPEL $\xleftarrow{o}$ bullet $\xleftarrow{D}$ Y, r ⟵ gun

X shoot Y = X <=> PROPEL $\xleftarrow{o}$ bullet $\xleftarrow{D}$ Y, gun

⇑ r

Y <≡> hurt

X sit on Z = X <=> Do

⇑ r

X <≡> sitting

⇑ on

Z

X Stop Y from A = X <=> Do

⇑ E

Y <=> A

t_F

X swim to Z = X <=> PTRANS $\xleftarrow{o}$ X $\xleftarrow{D}$ Z

⇑ in

water

X suspect Y of A = X <=> CONC $\xleftarrow{o}$ Y ⇕ A

X surprise Y by A = X <=> A

⇑ R

Y <≡> surprised

X take Z from Y = X <=> ATRANS $\xleftarrow{o}$ POSS: Z $\xleftarrow{R}$ X, Y

X take Z (where Z = medicine) = X <=> INGEST $\xleftarrow{o}$ Z $\xleftarrow{D}$ in X

X talk about P to Y = X <=> MTRANS $\xleftarrow{o}$ P, R → Y, X ← I, X ⇕ SPEAK ↑ 'words'

X taste Z = X <=> PTRANS $\xleftarrow{o}$ Z $\xleftarrow{D}$ → mouth of X, <

⇑ R

X <≡> CONC $\xleftarrow{o}$ Z ⇕ 'some taste'

X tell P to Y = X <=> MTRANS $\xleftarrow{o}$ P $\xleftarrow{R}$ → Y, < X

X think about P = X <=> CONC $\xleftarrow{o}$ P

x throw z to Y = X <=> PTRANS $\xleftarrow{o}$ Z $\xleftarrow{D}$ → Y, < X ← I, X ⇕ PROPEL ↑ o, Z ↑ D, X, Y

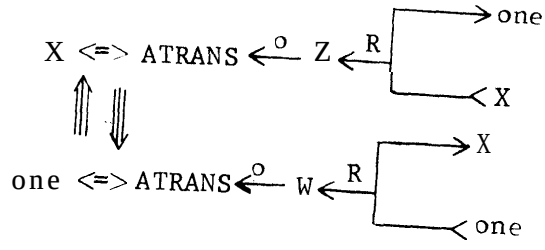
X throw Z at Y = X <=> PROPEL $\xleftarrow{o}$ Z $\xleftarrow{D}$ → Y, < X

X tolerate Y do A = Y <=> A ⇑ R X <≡> displeased ∧ X <≠> Do ⇑ Y <≠> A

X touch Z = X <=> MOVE $\xleftarrow{o}$ Y $\xleftarrow{D}$ → Z, < X

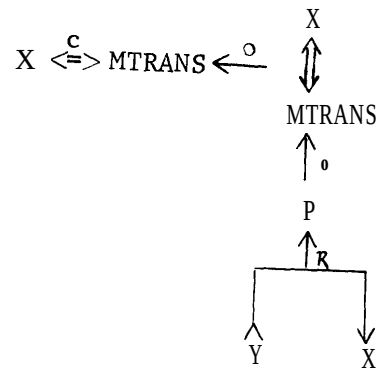
X ⇔ r PHYSCONT Z

X trade Z for W =

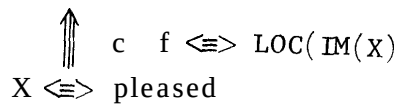


X use Z = X <=> DO o Z

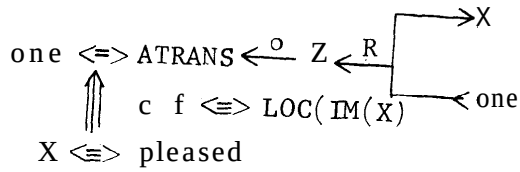
X understand Y =



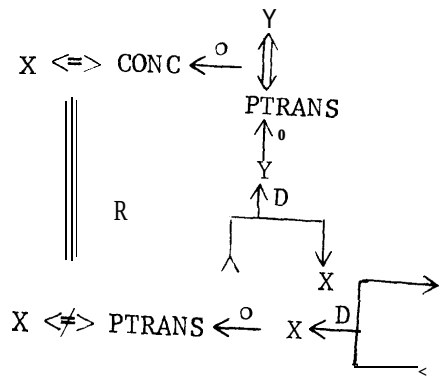
X want Y to A =

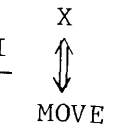


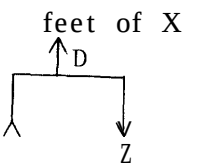
X want Z =

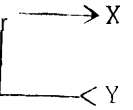


X wait for Y =



X walk to Z = X <=> PTRANS <-o- X <-D-  <-I-



X work For Y = Y <=> ATRANS <-o- money <-R- 

Y <=> ATRANS

R

X <=> DO

R

Y <=> pleased

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