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A Formal Psycholinguistic Model of SENTENCE COMPREHENSION

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SUMMARY

This paper outlines a psychologically constrained theory of sentence comprehension The most prominent features of the theory are that: (1) syntactic structure is discarded clause by clause (where the traditional notion of clause is modified in certain respects so as to conform to short term memory requirements); (2) the syntactic and semantic processor work in parallel.

The semantic analysis proceeds from the preliminary semantic representation (PSR) via the intermediate SR (ISR) to the final SR (FSR), making crucial use of an encyclopedia which codes semantic knowledge.

The three stages of the semantic analysis are discussed. Concatenation Rules establish the PSR, Meaning Rules and Encyclopedic Rules the ISR, and Semantic Linking Strategies the FSR. At every stage, the semantic representations are in terms of a modified predicate calculus notation.

Syntax-free as well as syntax-sensitive Linking Strategies are presented for clause-internal linking. Finally, syntax-free linking of constituent clauses of complex sentences is described.

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I. SOME PSYCHOLOGICAL CONSTRAINTS ON SENTENCE COMPREHENSION MODELS

In this paper I consider the question of how an automatic sentence recognizer would have to look in order to be compatible with present psycholinguistic knowledge about speech comprehension. The basic premise is that psycholinguistic considerations are of potential interest to computational theories (see, e.g., Schank(1972)).

Let me begin by summarizing some characteristics of speech processing which we know either from experiments, or which are intuitively clear.

First, there is some evidence that the _clause_ is a unit of processing. For instance, Caplan(1972) showed that after a clause boundary is passed, the constituent words of the completed clause are relatively inaccessible, as measured by word recognition latency. The effect was independent of the serial position of the word for which recognition time was tested. This suggests that sentences are processed clause by clause, with only the semantic content regularly retained after the clause boundary is passed. The surface words (and _a fortiori_ the syntactic structure) of the clause would tend to be erased after each clause boundary. [1]

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*This paper is based on chapter VII of my doctoral dissertation (Reimold(forthcoming)). I wish to thank Thomas G. Bever, James Higginbotham, and D.Terence Langendoen for helpful suggestions.

[1]The _a fortiori_ refers to the fact that the syntactic structure

Another study supporting the clause as unit of processing is Abrams & Bever(1969). These authors found that reaction time to short bursts of noise "clicks") superimposed on sentences was longer for clause-final clicks than for clause-initial ones. This would point to the clause as unit of perception, under the assumption that processing is more intensive towards the end of a perceptual unit, and that reaction time to external stimuli is a valid indicator of the intensity of internal processing. (For a review of other studies in support of the clausal processing theory, the reader is referred to Fodor, Bever & Garrett(1974), where arguments are also given for the clause as a decision point across which ambiguities are, normally at least, not carried.)

Secondly, it seems that as we listen to speech, we simultaneously have access to both the syntactic and semantic properties of what we hear. That is, there appears to be _parallel processing_ of the syntax and the semantics of a clause. One finding explained by this assumption is that so-called "irreversible" passive sentences like (1) are perceptually no more complex than their active counterparts (_the girl picked the flower_, in this case). By contrast, 'reversible" passives like (2) take longer to verify vis-a-vis pictures than the corresponding active sentences (Slobin(1966)).

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presumably contains surface words as terminal nodes. Hence if the syntax were regularly preserved the surface words should remain easily accessible, too.

(1) The flower was picked by the girl. (irreversible)

(2) The boy was kicked by the girl. (reversible)

It appears that the syntactic complexity introduced by the passive construction is somehow circumvented by a predominantly <u>semantic</u> method of analysis in the case of irreversible passives.[2] We thus get a picture of speech processing as in Fig.1.[3]

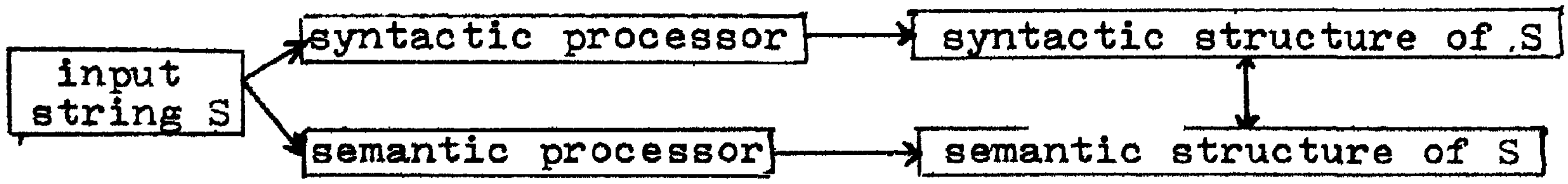

Fig.1: Parallel Processing Model

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[2] Another experimental study supporting the Parallel Processing theory is Marslen-Wilson(1973).

[3] My view of the role of syntax is related to that expressed in Schank(1972), who believes that the function of syntax is "as a pointer to semantic information rather than as a first step to semantic analysis."(p.555) Similarly, Winograd(1971) allows parallel operation of syntactic and semantic analysis. However, the syntactic and semantic processor in Winograd's system have full power, in principle, to question each other about their respective success before proceeding with their part of the analysis. This powerful device has been severely restricted in the theory described here (for details, see Reimold(forthcoming)). The main reasons for this are the greater reliance, in my theory, on "syntax-free" semantic interpretation, and the generally shorter life-span of syntactic structure (see the discussion of "peripheral clauses" below). Woods (1973) also discusses a system with certain facilities for parallel processing, for instance, the "Selective Modifier Placement" facility (SMP). The function of SMP is to select from the list of syntactically admissible alternatives the one which is semantically most appropriate, and return only that alternative to the parser before going on to analyze the rest of the sentence. The most important difference between Woods' proposal and the one presented here is that his semantic processor only chooses among <u>syntactically structured</u> alternatives (and, in that sense, is a fully syntax-sensitve method), whereas my theory postulates no <u>syntactic link</u> between such modifiers and their heads.

Let me return now to the principle of clause-by-clause processing. If we assume that "immediate processing" takes place in short term memory, then we must automatically require that the unit of processing must not exceed the known limits of short term memory. Now since that limit is generally taken to be about 5 words, the clause-by-clause principle cannot be literally true. For instance, (3) lists some "clauses" longer than 5 words. It seems to me, therefore, that we have to revise the traditional concept of clause.

(3)a) John <u>and Bill</u> <u>and Otto</u> stroked <u>and hugged</u> the goat <u>and the goose</u>.

b) The man <u>with the dog</u> <u>with the collar</u> <u>with the bell</u> ... laughed.

c) John met his friends <u>yesterday</u> <u>morning</u> <u>around ten o'clock</u> <u>in a little cafe</u> <u>near Broadway</u>.

I propose to take the underlined phrases in (3) out of the sentence proper and process them as if they were separate clauses. That is, I draw a distinction between the "nuclear" clause and "peripheral" clauses. The non-underlined portions in (3) are nuclear clauses. Peripheral clauses include: Prep-clauses ("with the collar"), Comparison-clauses ("than the old colonel"), Post-clauses ("yesterday," "around ten o'clock, 'in a little cafe"), and Coordinate-clauses ("and Bill," "and hugged").

This treatment of certain phrases as peripheral clauses seems plausible too, if we consider that "adnominal" Prep-phrases, for instance, are semantically like relative clauses, as shown in (4), and that adverbs are parallel to certain "adverbial" clauses, as indicated in (5).

(4) A girl $\left\{ \begin{array}{l} \text{with a green hat} \\ \text{who wore a green hat} \end{array} \right\}$ greeted John.

5) John ate the cake $\left\{ \begin{array}{l} \text{afterwards.} \\ \text{after the guests left.} \end{array} \right\}$

Evidently, <u>with a green hat</u> in (4) is related to <u>who wore a green hat</u>, and the adverb <u>afterwards</u> in (5) can be replaced by full adverbial clauses like <u>after the guests left</u>.

We are presently testing the validity of this notion of peripheral clause. We use sentence pairs like (6a-b):

(6a) The officer threatened to give the woman * a ticket.(clause-internal position of click "*")

(6b) The officer threatened to fine the woman * without a license.(clause-final position of click "*")

Our goal is to determine, using a "click detection" paradigm, whether or not there is a "clause boundary effect" before the final peripheral clause <u>without a license</u> in (6b). Notice that according to my hypothesis, there is a clause boundary after <u>woman</u> in (6b), but not in (6a). It has been shown in a number of studies that clause boundaries (but not phrase boundaries, in general) have certain measurable behavioral effects (cf. the review in Fodor, Bever & Garrett(1974)); so this should apply here too, if peripheral clauses are indeed psychologically real clauses.

Now, the last principle I want to discuss is that in understanding an utterance, people make creative use of their knowledge about the world.[4] For instance, if I only hear you say:

(7) The cat just caught a --

I can immediately guess that the last word was something like <u>bird</u> or <u>mouse</u>. Similarly, if you say:

(8) Put the freezer in the turkey.

I know that you really meant "put the turkey in the freezer,"

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[4]This general point has been made, in one form or another, by many authors. For instance, Winograd(1971) notes that correct understanding of <u>they</u> in "The city councilmen refused to give the women a permit for a demonstration because <u>they</u> feared violence" and "The city coundilmen refused to give the women a permit for a demonstration because <u>they</u> advocated revolution" needs the "information and reasoning power to realize that city councilmen are usually staunch advocates of law and order, but are hardly likely to be revolutionaries."(p.11) Similarly, Schank(1972) envisages a theory of natural language understanding which "has a conceptual base that consists of a formal structure" and "can make predictions on the basis of this conceptual structure"(p.556) The principal differences between these approaches and mine have to do with (1) the <u>form</u> of the stored semantic information (PLANNER and "conceptual case network" representations vs. predicate calculus representations) and (2) the proposed <u>access mechanism</u> to this information. Schank's theory relies on lexical decomposition, while I use the "meaning postulates" method. Winograd opts for a broad procedural approach, representing "knowledge in the form of procedures rather than tables of rules or lists of patterns."(p.21) By contrast, my proposal remains closer to the traditional "declarative" approach, as will become clear

because I know something about turkeys and freezers. No model excluding the possibility of matching speech against stored knowledge of the world can explain such facts. In this connection, consider also the sentences in (9):

(9a) I'm leaving the door open so I won't forget to wind it. (it= the clock-- there was no previous mention of a clock in the dialogue, but the speaker was looking at a Grandfather clock with open door)

(9b) They published Wodehouse immediately he came over. (= published books written by Wodehouse)

(9c) Italy was sitting in the first row, and France in the second. (= people from Italy and France)

(9d) We'd better put in 20 minutes. (= money for 20 minutes -- speaking about a parking meter)

(9e) He's sitting by his plate that isn't there.(= by where he wishes his plate were, by his plate in his wish-world - speaking of a cat)

These sentences can all be understood without difficulty, and the way we understand them is by using our general semantic knowledge.

What this means, then, is that the comprehension model needs to incorporate an encyclopedia which somehow codes semantic knowledge.

In sum, to be compatible with the psychological model, the automatic sentence recognizer should have the following properties:

(1) it should be a clause-by-clause processor, where my notion of "clause" includes some things traditionally regarded as phrases; as soon as the interpretation of a clause is completed, its syntactic structure is erased;

(2) there should be parallel syntactic and semantic processing of each clause;

(3) the recognizer must make systematic use of an encyclopedia which codes knowledge about the world.

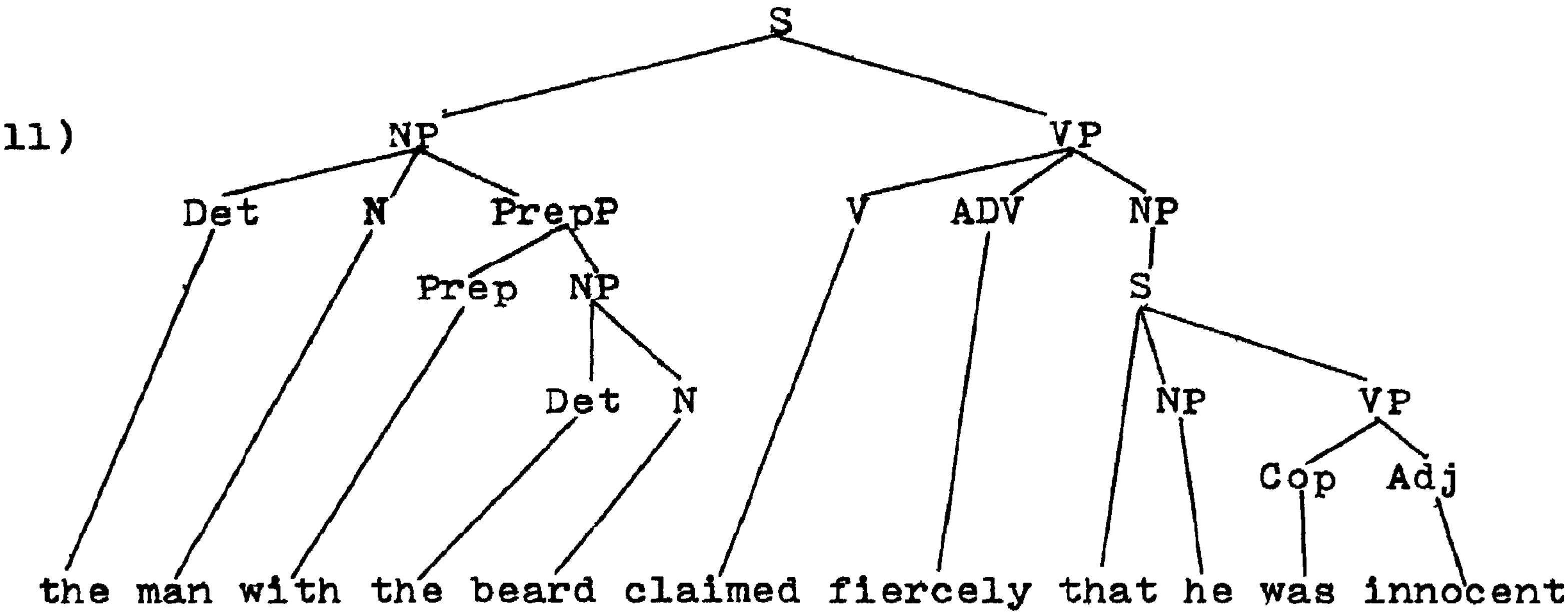
II: TRADITIONAL LINGUISTIC APPROACHES

Putting together the above observations, one can already see that current linguistic theories are not very helpful for the solution of our problem. For instance, linguistic theory would claim that sentence (10) has the syntactic structure in (11), which then undergoes various syntactic transformations until it is finally mapped onto its appropriate semantic structure.

The sentence recognizers most directly meeting this description are probably those developed by Stanley Petrick (see Petrick (1966, 1973)). With some modifications, however, this description also fits the theories presented in Winograd(1971) and Woods(1973). While these systems are feature-manipulating rather than transformational, they nonetheless assume that the life-span of syntax extends over an entire sentence, and they make crucial use of integrated syntactic structures for complex sentences. (For instance, Winograd(1971) presents an integrated syntactic structure for the sentence "Pick up anything green, at least three of the blocks, and either a box or a sphere which is bigger than any brick on the table. Recognizers using an inverse "Generative Semantics" grammar would also fall under this description.

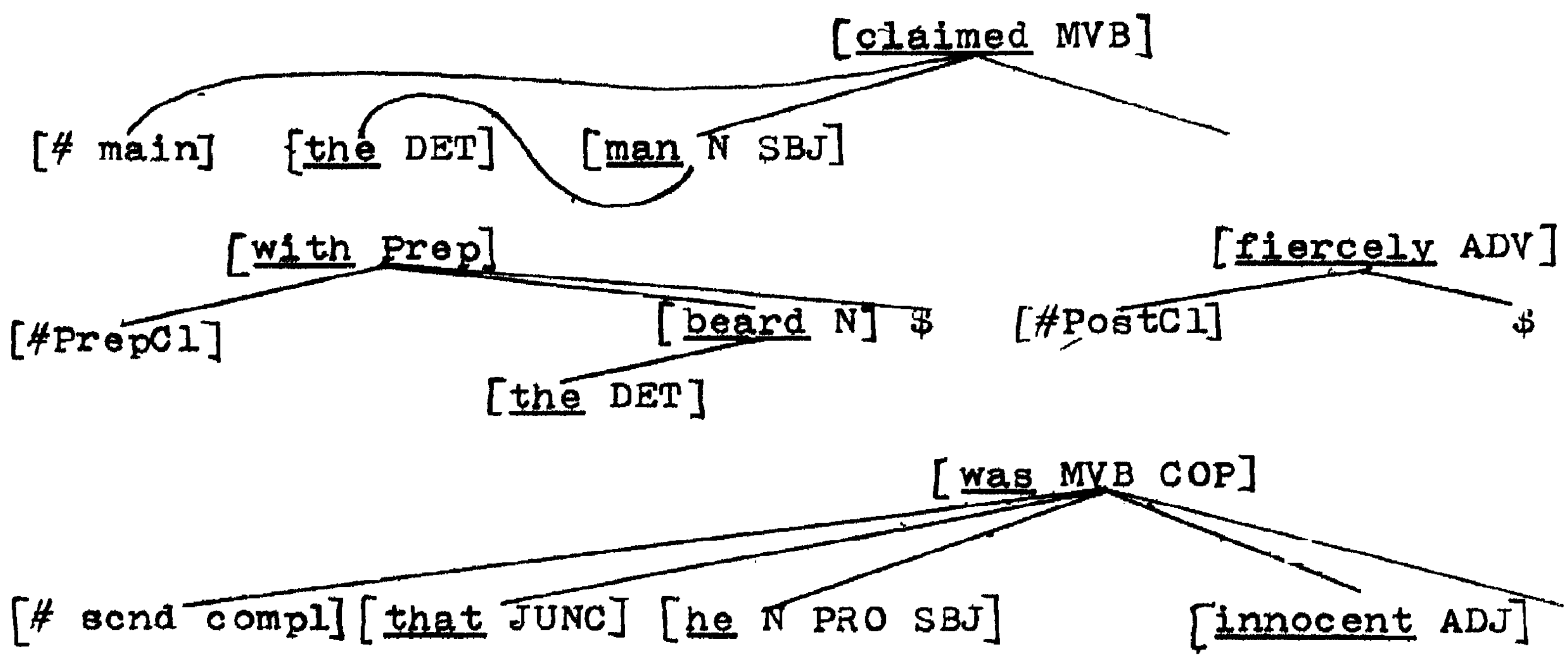
(10) The man with the beard claimed fiercely that he was innocent.

(11)



But in the view I have just sketched, sentence (10) never has any integrated syntactic structure like (11). Instead, as shown in (12), the string <u>with the beard</u>, for instance, is processed as a separate clause, and as soon as its meaning has been extracted and added as qualifier to the preceding noun phrase <u>the man</u>, its syntactic structure is erased.

(12) 4 successive "perceptual clauses" for sentence (10):



Similarly, the "Post-clause" fiercely and the entire complement clause that he was innocent must be linked to the main clause without referring to the syntactic structure of the latter, which is assumed to be erased as soon as the word claimed has been semantically integrated. This would seem to be a more economical procedure, because it minimizes the size of the syntactic ballast that has to be carried along. Compare, for instance, the size of the chunk in (11) to the size of the little chunks in (12).

Secondly, transformational grammar is hardly compatible with the principle of Parallel Processing of the syntax and semantics of a clause. The reason is that according to transformational grammar, the syntactic analysis precedes and determines the semantic analysis. By contrast, Parallel Processing means that at least some of the semantic interpretation rules must be syntax-free.

III: A THREE-STAGE THEORY OF SEMANTIC ANALYSIS

Let us return for a moment to Fig.1. That figure contained a box labelled syntactic processor, and another box labelled semantic processor. As I have stated, these components cannot be identified with the syntactic and semantic components of current transformational grammar. The syntactic processor will not be discussed in detail here (see Reimold(forthcoming) for a fuller discussion). It is a predictive parser using dependency notation. There are no syntactic transformations at all, but the output is a simple surface tree for each clause, with certain nodes marked by functional features like SuBJect, OBJ1, OBJ2, or MainVerB. The trees in (12) above are examples.

For the remainder, let me concentrate on the semantic box. I suggest that there are three stages in the semantic analysis. as shown in Fig.2, namely a preliminary, intermediate, and final semantic representation (PSR, ISR, and FSR).

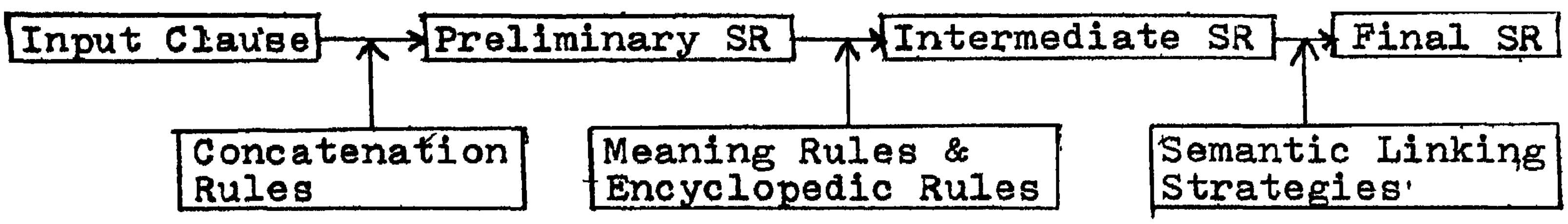


Fig.2: 3-Stage Model of Semantic Analysis

The PSR corresponds to a simple combination of the lexical meanings of the words. Clearly, as we hear the words in a sentence, we immediately grasp their individual meaning, even though we may not be sure yet how they fit together. This then is the preliminary SR.

But we also immediately have access to some of the implications of the words and phrases. For instance, if I hear "cat" I immediately also know "animal." Adding such implications derives the intermediate SR from the PSR.

The final SR is like the preliminary one, except that the appropriate semantic roles have been assigned to all the constituents. An example for the three stages is given in (13).

(13) The boy laughed.

PSR: (THEx:BOYx)(Ey)(E t:PAST t) [LAUGHyt]

ISR: (THEx:BOYx & HUMANx & -ADULTx ...)(Ey)(E t: PAST t & -FUTURE t ...)[LAUGHyt & HUMANy & ANIMATEy & ALIVEyt ...]

FSR: (THEx:BOYx)(Ey)(E t:PAST t) [LAUGHyt & x=y]

(*simplified* to: (THEx:BOYx)(E t:PAST t) [LAUGHxt])

Before translating the structures in (13) into English let me remark on the form of semantic representations.

IV: A MODIFIED PREDICATE CALCULUS NOTATION FOR SEMANTIC REPRESENTATIONS

Each semantic representation consists of a number of *prefixes* and a *matrix*, where the prefixes correspond roughly to the noun phrases of the sentence, and the matrix to the main predicate. For easier reference, I have marked this distinction in the text by always enclosing the matrix in square brackets "[ ]".[6]

For instance, in (13) there are three prefixes, and the matrix is *LAUGHyt*.

Each prefix consists of a quantifier (e.g., *THE*, *E* --which reads "there is at least one"-- or *ALL*), followed by a variable (e.g., *x*,*y*,*z*,*t*,*e* --represented by lower case letters

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[6] The linear notation used throughout here is an abbreviation defined over dependency structures. For details, see Reimold(forthcoming), where definitions are also given for translating these structures into standard predicate calculus.

in the examples), and optionally followed by a backgrounded proposition. Backgrounded propositions are the expressions to the right of the colon within the prefixes. For instance, the first prefix in (13) contains the quantifier THE, the variable x, and a backgrounded proposition BOYx, and the entire prefix is read: "The entity x such that x is a boy."

We can now translate the structures in (13) into English. The first, i.e., the preliminary SR, says:

> "The x such that x is a boy is involved in some vent such that there is some y and some time which is PAST, and y is laughing at time t."

Notice that this only asserts that the boy is somehow involved in this, but it does not specify just how. But in order to describe what the listener actually understands when hearing the boy laughed, we must of course specify which role the boy plays in this event.

Now, looking at the final SR in (13), it can be seen that it is like the PSR, except that it also contains a role assignment (or link, as I will call it), namely x=y. That is, x, the boy, plays the role of y, who was the one who did the laughing. By executing this equation x=y, we can of course simplify the representation, which gives us the last line in (13).

The intermediate SR in (13), furthermore, is like the preliminary SR, but in addition contains certain implications of the words. Thus we have: "the x such that x is a boy and (by implication) human and not adult, etc." And in the matrix of the ISR we get "y laughs at time t and, by implication, y is human and animate and alive-at-time-t." In other words, one cannot laugh unless one is human and alive.

V: THE PSR: CONCATENATION RULES

Let us return again to Fig.2. It shows three different blocks of rules which are responsible for deriving the three stages of the semantic analysis, namely: Concatenation Rules, Meaning Rules and Encyclopedic Rules (collectively referred to as Semantic Knowledge Rules), and finally Semantic Linking Strategies. They will occupy us in this order.

The Concatenation Rules take the semantic definition of the most recent input word and add it to the current preliminary semantic structure. For instance, (14) lists the semantic definitions (namely for <u>the</u>, <u>boy</u>, and <u>laughed</u>) which are relevant for the example in (13) above.

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[7] I have made the simplifying assumption that there are lower-level components providing the syntactic and semantic components with a lexically analyzed input string. This, of course, is almost certainly incorrect, and should be refined by making the matching process partly top-down. (In the case of the syntax this has been done to a certain extent, since it is based on a predictive analyzer. It has not yet been done for the semantics; but it seems that it can be built into the present system relatively easily.) See Nash-Webber (1974) for further discussion, especially his description of the SPEECHLIS system.

(14) (a) [the DET] : (THEv: --) [--]

(b) [boy N] : (E x) [BOYx]

(c) [laughed MVB PAST]: (E y)(E t:PAST t) [LAUGHyt]

Notice that each of the definitions consists again of a prefix and a matrix. There are two Concatenation Rules, namely Joining and Backgrounding. They are stated in abbreviated form in (15) and (16), and are illustrated in (17).

(15) Joining:

Let (X) [M_1] be the current preliminary SR, and (Y) [M_2] the semantic definition of the last input word (which may not be part of an NP), where (X) and (Y) are the prefixes, and [M_1] and [M_2] the matrixes. Then form (X)(Y) [M_1 & M_2].

(16) Backgrounding:

Let {QTFv:(X)(M_1)} be the partial SR for the current NP. Then join the semantic definition (Y) [M_2] of the last input word (if it is part of this NP) as in {QTFv:(X)(Y)(M_1 & M_2)}.

(17) Joining and Backgrounding applied to (13-14):

Start: (THEv:--) [--]

Backgrounding: (THEv:(E x) [BOYx]) [--]

Joining: (THEv:(E x) [BOYx])(E y)(E t:PAST t)[LAUGHyt]

I will not discuss this aspect of the theory in great detail here. Note only that the only syntactic information needed for

Concatenation is whether or not the input is part of an NP. Otherwise the semantic definitions of the words are added from left to right, prefixes behind prefixes, and matrix behind matrix.[8]

VI: THE ISR: SEMANTIC KNOWLEDGE RULES

Going back to Fig.2, the next step was the intermediate SR, which is derived from the preliminary SR by applying Semantic Knowledge Rules, namely Meaning Rules and Encyclopedic Rules. Meaning Rules deal with strict implication, while Encyclopedic Rules are typically probabilistic. For instance, Meaning Rules tell us that if somebody is a baker he must also be human and hence animate and hence concrete, etc.; while Encyclopedic Rules tell us that he _tends_ to wear white clothes, _tends_ to sell bread to people, and similar facts.[9]

I had stated earlier that speech involves using one's knowledge about the world. There are two separate problems with this kind of semantic knowledge: (1) how to code it; (2) how to retrieve it.

Concerning the first problem, I assume encyclopedic

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[8] In the present version of the theory, the semantic processor accepts the semantic definition of a word only if that word has matched the syntactic predictions. It is probably desirable to liberalize this procedure so as to handle ungrammatical sequences.

[9] The distinction between M-rules and E-rules is akin to Katz& Fodor's(1963) distinction between semantic _markers_ and _distinguishers_, the main difference being that Katz & Fodor

information to be coded essentially in the same form as the semantic representations themselves. This makes it easy to transfer to the encyclopedia informatior received in the current dialogue. Such "active" information would be added continuously to the "situational chapter" of the encyclopedia, where this chapter is thought of as containing the linguistic and non-linguistic context of the current utterance.

Concerning the retrieval problem, it is clear that the information in the encyclopedia must be extracted selectively. The solution chosen here is the one characteristic of networks Each Knowledge Rule is given an address, and each lexical entry, as well as each Knowledge Rule, includes pointers to the address of some other relevant Knowledge Rules: Only tnose rules are called up which are associated with the sentence constituents through some pointer.

In the case of Meaning Rules this restriction seems sufficient, because there are only few for each lexical entry. Not so in the case of Encyclopedic Rules. For instance, there are all kinds of things I know about bakers --say, that they tend to wear white clothes for work--, but most of which are irrelevant for understanding and verifying the sentence:

(18) The boy was sold a nice cake by the baker.

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used features whereas I use meaning postulates. For practical purposes, the most important aspect of the distinction is that M-rules are applied obligatorily, while E-rules are applied selectively, according to the intersection technique. (See the discussion below.) For a discussion and critique of the "featural" approach, see Weinreich(1966).

For instance, the sentence is perfectly true even if the baker happened to be wearing a fireman's uniform while selling the cake to the boy.

A good way of restricting the number of Knowledge Rules called up for a given sentence seems the Intersection Strategy (cf. Quillian(1969)) in (19).

(19) <u>Intersection Strategy</u>:

If a clause contains two different constituents A and B <u>both</u> pointing to the same encyclopedic rule E, then call E.

This rule says to call up only those Encyclopedic Rules which are associated with at least two constituents of the sentence. For instance, in (20):

(20) This bread was sold to John by the Italian baker.

<u>baker</u>, <u>sell</u>, and <u>bread</u> all point to the same encyclopedic "pattern" (21), which states that bakers typically sell baked goods to people.

(21) (TYPx:BAKERx)(TYPy:HUMANy)(TYPz:BAKEDGOODz)[SELLxyz]

Hence, the Intersection Strategy would call up this pattern, which could then be used to help interpret the sentence. But the rule specifying that bakers typically wear white clothes for work would not be called up for sentence (20), because only the constituent <u>baker</u> in the sentence would point to this particular pattern.

VII: THE FSR: SEMANTIC LINKING STRATEGIES

Let me return once more to Fig.2. The last rule-block in this figure was labelled Semantic Linking Strategies. They are responsible for deriving the <u>final</u> SR, by assigning the appropriate semantic roles to various parts of the clause. There are two aspects to this: clause-internal linking, and clause-to-clause linking. I would like to discuss clause-internal linking first.

It seems to me that when we listen to speech, we have a choice of how much attention we pay to syntactic details. This is what Parallel Processing is all about, and it means that there are syntax-free linking strategies besides syntax-sensitive ones. (22) gives a synopsis of the linking strategies.

(22) <u>Semantic Linking Strategies</u>:

1. Linking by Variable Type
2. Pattern Matching
3. Contradiction Elimination
4. Canonical Order Strategy
5. Syntax-sensitive Rule
6. "Alternative Linking"

Types 1, 2, and 3 are syntax-free. Type 4, the "Canonical Order" strategy (cf. Bever(1970)) relies on the shallowest aspect of syntax, namely simple linear order of the major clause consituents. Type 5 is sensitive to "functional" features occurring in the syntactic surface tree. The 6th type, "Alternative Linking Strategies," will be explained later on; they, too, are purely semantic, though they apply only after the syntax-sensitive rules have applied (and failed).

Now, within this system of linking strategies, there seem to be different levels of detail. At the shallowest level we have Linking by Variable Type. Pattern Matching requires more semantic detail; and Contradiction Elimination is still more thorough. Furthermore, the syntax-free strategies may be assumed to be simpler than the syntax-sensitive ones, because the latter must keep track of two separate structures namely the semantic and the syntactic structure. I assume that the strategies are ordered according to their relative simplicity, which would give us the order as listed in (22)

Furthermore, I assume that once an acceptable reading has been derived for a clause, application of further strategies in the hierarchy becomes optional. This of course is subject to empirical tests. For instance, Pattern Matching would interpret the sentence:

(23) The baker was sold some stale bread by the butcher.

incorrectly as "the baker sold the butcher some stale bread." If application of further strategies is indeed optional, such sentences should sometimes be misinterpreted.

There is in fact some intuitive support for such a position I think most of ~~us~~ have experienced situations where a slip of the tongue like put the freezer in the turkey passed unnoticed at first. This is most naturally explained by assuming that the syntax never got a chance to apply to the sentence, due to the fact that Pattern Matching resulted in an acceptable reading.

Let me now discuss these Linking Strategies in more detail. The first type was Linking by Variable Type, which is stated in (24).

(24) Linking by Variable Type:

(1) Link the head-variable *v* of each SR-prefix to the MVB-argument of the appropriate type, provided there is only one such appropriate MVB-argument, and *v* is not already linked to some other variable in the SR-matrix;

(2) if *v* is an event-variable *e* then add *e=X*, where X is MVB plus its modifiers and arguments;

(3) if *v* is a predicate variable *F* then substitute for *F* MVB and its arguments.

This rule says to link the "head-variable" (i.e., the left-most variable) of each prefix to the MVB argument which matches its type. Option (2) specifies that event-variables are linked to the event described by the main predicate; and option (3) deals with certain adverbs like *slowly* or *softly*. The rule will be explained using the example (25).

(25) (a) #Yesterday the father of the boy sang $ #horribly # in the bath $.

(b) PSR: $(\mathrm{THE}t_1 : \mathrm{YESTER}t_1)[\mathrm{THE}x : (\mathrm{THE}y : \mathrm{BOY}y)(\mathrm{FATHER}xy)]$
$(\mathrm{E}\ t_2 : \mathrm{PAST}\ t_2)(\mathrm{E}\ x_2)(\mathrm{E}\ F)(\mathrm{E}\ e)(\mathrm{THE}z : \mathrm{BATH}z)$
$[\mathrm{SING}_{MVB}x_2t_2\ \&\ \mathrm{HORRIBLY}(F)\ \&\ \mathrm{IN}ez\ ]$

Looking at (25b), the PSR for sentence (25a), it can be seen that the variables in the prefixes are of several different <u>types</u>: there are the time-variables $\underline{t_1}$ and t_2, individual-variables $\underline{x}$, $\underline{y}$, $\underline{z}$, etc., a predicate-variable $\underline{F}$, and an event-variable $\underline{e}$. The main verb (MVB) is SING, and its arguments are $\underline{x_2}$ and $\underline{t_2}$. Now, time-variables can only be linked to other time-variables, and these links have the specific form $\underline{t_{MVB} \subset t_{PREFIX}}$ ("time-of-the-MVB is included in time-of-the-prefix"), in our case $\underline{t_2 \subset t_1}$. Next there is an individual-variable $\underline{x}$, which matches only the MVB-argument $\underline{x_2}$; hence the link is $\underline{x=x_2}$. Then there is the predicate-variable $\underline{F}$ which, according to option (3) of the strategy, is replaced by MVB plus its arguments, yielding the combined reading $\underline{\mathrm{HORRIBLY(SING}x_2t_2)}$. Finally, the event-variable $\underline{e}$ is linked to the entire event described by the main predicate, namely that x_2 sang horribly at time t_2: $\underline{e=\mathrm{HORRIBLY(SING}x_2t_2)}$. This expands the matrix of (25b) into (26), giving us, after simplification, the final SR (27) for (25a).

(26) $[\mathrm{HORRIBLY(SING}x_2t_2)$ & $\mathrm{IN}ez$ & $t_2 \subset t_1$ & $x=x_2$ & $e=\mathrm{HORR(SING}x_2t_2$

(27) $(\mathrm{THE}t_1{:}\mathrm{YESTER}t_1)(\mathrm{THE}x{:}(\mathrm{THE}y{:}\mathrm{BOY}y)(\mathrm{FATHER}xy))(\mathrm{E}\ t_2{:}\mathrm{PAST}\ t_2)$
$(\mathrm{THE}z{:}\mathrm{BATH}z)\ [\ \mathrm{IN}\ \{\mathrm{HORRIBLY(SING}xt_2),\ z\}$ & $t_2 \quad t_1\ ]$

The entire procedure is syntax-free, with one qualification: the constituent corresponding to the <u>main</u> <u>verb</u> is marked in the semantic representation by a corresponding feature. That is, SING in (25b) is marked as <u>MVB</u>. This syntactic feature is immediately copied from the syntactic structure into the semantic one, where it is preserved until the entire sentence has been processed.

For many constituent types, Linking by Variable Type is the only Linking Strategy that is needed. This is true particularly for adverbs, temporal phrases like <u>last October</u>, PrepP like <u>into the garden</u>, and auxiliary verbs like <u>will</u>. In addition, if a clause has only one nuclear noun phrase, as is the case in sentence (25a), then the entire interpretation is normally taken care of by this strategy.

The next strategy was Pattern Matching, which is stated in (28). It says that if certain clause constituents match a pattern, then they are linked as in the pattern.

(28) <u>Pattern Matching</u>:

(1) Let $(TYPv_1^{!}:A_1v_1)\ldots(TYPv_m^{!}:A_mv_m^{!})\ [\ Bv_1^{!}\ldots v_m^{!}\ ]$ be a pattern called up by a PSR whose MVB is $B_{MVB}(v_1\ldots v_n)$;

(2) then for each SR-prefix head-variable u_i matching exactly one description $A_jv_j^{!}$ in the pattern, add a link $u_i{=}v_j$ (where v_j occupies the same argument-place in B_{MVB} as does $v_j^{!}$ in the predicate B of the pattern); for u_i to <u>match</u> a description A_jv_j, there must be an expression A_ju_i in the ISR.

For instance, our earlier example (20):

(20) This bread was sold to John by the Italian baker.

contains the constituents BREAD, JOHN, BAKER, and SELL. They are linked in accordance with the pattern (21), which stated that bakers typically sell baked goods to people. Here BREAD in (20) matches (by implication) BAKEDGOOD in (21), BAKER in (20) matches BAKER in (21), JOHN matches HUMAN, and SELL matches SELL. Recall that the Intersection Strategy in (19) determines just which patterns are called up for a given sentence. There will usually only be a limited number of activated patterns.

Next consider the Contradiction Elimination Strategy. An abbreviated version of it is given in (29). Roughly, the rule tests which roles each NP _could_ play without leading to a contradiction. Then it checks whether this would lead to a unique combined role assignment for all noun phrases, and if so, it accepts this combination as the interpretation.

(29) _Contradiction Elimination Strategy_:

(1) Let $v_1 \ldots v_m$ be prefix head-variables of a single type T, and $u_1 \ldots u_n$ MVB-arguments of the same type T;

(2) add each combinatorily possible _non-contradictory_ link $v_i = u_j$ to a list; if there is a _unique_ combined m-tuple of links $v_1 = u_j$ & ... & $v_m = u_k$ (where no u_i or v_i occurs more than once), then add this m-tuple of links to the SR.

An example is shown in (30):

(30) The cheese had been seen by the mouse.

PSR: (THEx:CHEESEx)(THEy:MOUSEy)(Ez_1,z_2)[$SEE_{MVB}z_1z_2$]

Non-contradictory links: $x=z_2$, $y=z_1$, $y=z_2$ (z_1 must be ANIMATE, x is INANIMATE!)

Combined 2-tuple of links: $x=z_2$ & $y=z_1$

FSR: (THEx:CHEESEx)(THEy:MOUSEy)[SEEyx]

Notice that even though _mouse_, taken by itself, could be either logical subject _or_ object of _see_, the _combination mouse/cheese_ has a unique semantic relation to _see_, because _cheese_ can of course only be logical object of _see_.

The _Canonical Order Strategy_ is shown in (31). Roughly, the strategy attempts to equate the surface order of the major clause constituents with their "deep order."

(31) _Canonical Order Strategy_:

(1) Let $v_1,\ldots,v_m$ ($m>1$) be prefix head-variables of a single type T (where v_i precedes v_j for $i<j\leq m$), and let $u_1,\ldots,u_n$ be type T argument places of MVB (where u_i precedes u_j for $i<j\leq n$);

(2) then each v_i not yet linked to any matrix-constituent is linked to the MVB-argument u_i, unless MVB has the feature PASV in the syntactic structure.

For example, let (33) be the preliminary SR of (32):

(32) John gave the cat some milk.

(33) (THEx:JOHNx)(THEy:CATy)(Ez:MILKz)$(Ew_1w_2w_3t)$[$GIVEw_1w_2w_3t$]

Here the first three prefixes are not yet linked to any matrix-constituent, and their head-variables x, y, z, are of the same type. Hence they are linked as in (34), yielding, after simplification, the final SR (35).

(34) Links: $x=w_1$ & $y=w_2$ & $z=w_3$

(35) FSR: (THEx:JOHNx)(THEy:CATy)(Ez:MILKz)(E t)[GIVExyzt]

Finally, (36) describes the syntax-sensitive rule. It is sensitive to the feature PASV of the verb and links the constituents marked SBJ, OBJ1, OBJ2, and AGenT to the main verb, insofar as this has not been done by earlier strategies.

(36) <u>Syntax-sensitive MVB-Rule</u>:

(1) The <u>first</u> MVB-argument is linked to the prefix head-variable pointing to:

(a) the SBJ-phrase if MVB is <u>not</u> marked PASV;

(b) the AGT-phrase if there is such a phrase;

(2) link the prefix head-variable pointing to:

(a) an OBJ1-phrase to the <u>second</u> MVB-argument;

(b) an OBJ2-phrase to the <u>third</u> MVB-argument;

(3) if MVB is PASV link the prefix head-variable pointing to the SBJ-phrase to the <u>remaining free</u> (but not the first) MVB-argument.

An example is given in (37).(Here as elswhere in this paper, "#" stands for initial and "$" for final clause boundary.)

(37) # The church$_{SBJ}$ had been given$_{PASV}$ the money$_{OBJ2}$ $
[#PostCl] by the baker$_{AGT}$ $.

PSR: first clause: (THEy:CHURCHy)(THEx:MONEYx)($Ez_1z_2z_3$)
[GIVE$z_1z_2z_3$]

Links: x points to OBJ2, hence $x=z_3$;
y points to SBJ of a PASV verb, hence
$y=z_2$ by option (3) of rule (36);

FSR for first clause: (THEy:CHURCHy)(THEx:MONEYx)(Ez_1)
[GIVE$z_1$yx]

PSR for by-clause: (THEz:BAKERz)

Link: z points to AGT-phrase, hence $z=z_1$ by option (1b);

FSR: (THEy:CHURCHy)(THEx:MONEYx)(THEz:BAKERz) [GIVEzyx]

VIII: DIFFERENT MODES OF PROCESSING

Let me interrupt here to consider the practical problem of constructing an automatic sentence recognizer. Some aspects of the theory I have just sketched may not be optimal for a computational model, even though they seem appropriate for a psychological model. For instance, to a person engaged in normal conversation accuracy of understanding is not very crucial most of the time. Often, the goal may only be to "get the essentials," and if some mistake is made, it is simply corrected later on.

This "normal mode of processing" is what the psychological model sets out to describe. Now, in the case of an artificial intelligence system, one would probably demand higher accuracy, so as to minimize the need for corrections. This is, in some ways, similar to the situation where you put subjects in a psycholinguistic experiment. They usually abandon the "normal mode of processing" very soon and instead employ the strategies that guarantee best performance for the specific experimental task they are faced with. To give an example, consider the common type of experiment where a subject has to verify sentences like those in (38).

(38a) 5 precedes 13.
(38b) 5 is preceded by 13.
(38c) 13 is preceded by 5.

In order to interpret such sentences correctly, his knowledge that 5 in fact precedes 13 is of no help whatsoever to the listener, because true sentences occur together with false ones in this game. Therefore, he will soon drop all semantic short cuts --which he normally employs-- and interpret the sentences purely on the basis of their syntax. In a way, therefore, such experiments do not really tell us anything about normal speech processing.

Still, such conditions of heightened accuracy may be just the ones we want to apply to the artificial intelligence system. Let us therefore consider how such a non-normal mode of processing could be simulated in our theory.

Now, looking back at the Linking Strategies in (22) above (Linking by Variable Type, Pattern Matching, Contradiction-

Elimination, Canonical Order, and Syntax-sensitive MVB-Rule), there is indeed an obvious way of simulating the "high accuracy procedure," namely by dropping type 2, 3, and 4 strategies. These constitute the "short cuts" which work 90% of the time, but sometimes lead to misinterpretations. Notice that the result is still not a syntax-governed model, because most of the linking would still be handled by the syntax-free method of Linking by Variable Type, and syntactic structure would still be erased in clause-intervals. As a matter of fact, in this last respect I think it is possible to go even further than I have done here, and erase syntactic structure after each major clause constituent (i.e., after each NP, adverb, or main verb), retaining only its functional feature, which is then simply integrated into the semantic representation. I have already done this here for the constituent MainVerb, so in a way this would only be a logical extension of my proposal. Looking at the syntax-sensitive MVB-Rule (36), it is evident that it refers exactly to those functional features, namely SBJ, OBJ1, OBJ2, MVB, and AGT.

It would seem, then, that even for purposes of artificial intelligence, it may be preferable to operate with a parallel processing model, thereby minimizing the size of the syntactic structure and the amount of syntactic operations.

Apart from this, I would like to argue that the essential ingredients of Pattern Matching and Contradiction-Elimination are still required for any adequate theory. This brings ~~me~~

back to the sixth type of Semantic Linking Strategies, namely Alternative Linking Strategies.

IX: "ALTERNATIVE LINKING STRATEGIES"

Alternative Linking Strategies apply if the normal strategies (types 1-5) have failed to produce a semantically acceptable reading. These strategies rely heavily on the Semantic Knowledge Rules.

The most important and most general (and the only one to be discussed in the present paper) is the Obvious Connection Strategy in (39). It says, roughly, that if a variable u cannot be linked to the MVB then if the encyclopedia contains a rule connecting u to some other entity u' then try and link this new entity u' to the MVB.

(39) Obvious Connection Strategy:

If the head-variable u of a prefix (QTF_iu:Au) cannot be linked to its appropriate MVB-argument v, and both u and v point to a rule in the encyclopedia such that a connection (QTF_ju':Bu') [Cuu'] between u and u' is derivable, then:

(a) change (QTF_iu:Au) to {QTF_ju':(QTF_iu:Au)(Bu' & Cuu')};

(b) link u' to v.

For instance, consider again sentence (9b):

(9b) They published Wodehouse immediately he came over.

s indicated in (40), the object of PUBLISH must be some ritten work, and Wodehouse of course does not qualify as uch. Therefore, the link between x (Wodehouse) and the ogical object y' of PUBLISH is rejected. Notice that this s just the kind of "semantic anomaly test" which was central o the Contradiction-Elimination Strategy. Its intuitive asis is obvious: the listener normally assumes that the peaker is trying to make sense, and therefore, he will eject all non-sensical interpretations.

40) They published Wodehouse.

PSR: $(\mathrm{THE}_{pl}z{:}\mathrm{THEY}z)(\mathrm{THE}x{:}\mathrm{WODEHOUSE}x)(\mathrm{E}y')\,[\mathrm{PUBLISH}zy']$

ISR: ... WRITERx & HUMANx & ANIMATEx ... WRITTNWRKy' & -ANIMATEy' ...

Encyclopedic Pattern: (TYPx:WRITERx)(TYPy:WRITTNWRKy)[CREATExy]

Rule (39) changes (THEx:WODEHOUSEx) in the PSR to:

{Ey: (THEx:WODEHOUSEx)(WRITTNWRKy & CREATExy)}

Link added by Rule (39): y=y', yielding the FSR:

$(\mathrm{THE}_{pl}z{:}\mathrm{THEY}z)\{\mathrm{E}y{:}\,(\mathrm{THE}x{:}\mathrm{WODEHOUSE}x)(\mathrm{WRITTNWRK}y\,\&\,\mathrm{CREATE}xy)\}$
$[\mathrm{PUBLISH}zy]$

Now, staying with our sentence (40)(They published Wodehouse), if you know that Wodehouse was a writer you also know that he created written works; and the new entity introduced by this encyclopedic rule, namely "written works created by Wodehouse," is the one which is interpreted as logical object of the predicate PUBLISH. This then is the kind of"semantic detour" described by the Obvious Connection Strategy, and this strategy is applicable to the other sentences in (9) too [10]

Now, I think the sentences in (9) exemplify something that happens all the time in speech: namely omission of the obvious. I also think it would be extremely inconvenient if we had to ask people to use only their best Sunday Grammar when conversing with an English-speaking robot. We might as well ask them not to use pronouns, or to speak at a constant pitch of 400 Hertz. To be competitive, the robot should understand Monday Grammar as well, and that means, sentences like those in (9).

X: CLAUSE-TO-CLAUSE LINKING

For the remainder, I would like to discuss clause-to-clause linking. The distinguishing feature of my proposal, as will

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[10] See Schank(1972) for a different approach to the problem of recovering implicit information. He outlines, for instance, a method by which "I like books" would be expanded into the conceptual equivalent of "I like to _read_ books." Schank's theory is based on "conceptual cases" and lexical decomposition rather than meaning postulates. For instance, he claims that "John would be pleased by Mary's going" is a proper part of the meaning of _John wants Mary to come home_, while in my terms "John would be pleased by Mary's going" is merely an allowable inference which may or may not be drawn. _Failure_ to draw an allowable inference explains the possibility of holding _contradictory beliefs_. For instance, somebody might judge _John's uncle left_ to be true, while at the same time believing that _the brother of John's mother or father left_ was false, because he failed to apply the meaning rule relating _uncle_ and _brother of mother or father_. It is difficult to see how a theory based on lexical decomposition would explain such facts. Certainly, it would be unreasonable to claim that a person has not _understood_ the sentence _John's uncle left_ _unless_ he also is aware of the synonymy relation between this sentence and the brother _of John's mother or father left_.

be recalled, is that syntactic structure is <u>erased</u> clause-by-clause. The problem, therefore, is to show that sentences containing more than one clause can in fact be interpreted correctly without referring to the full syntactic structure of any (completed) earlier clause.

Consider first "Post-clauses" --i.e., clause-final adverbs, temporal nouns, and preposition-phrases. They are already covered by the strategy of Linking by Variable Type discussed earlier. For instance, consider again sentence (25a). (Yesterday the father of the boy sang horribly in the bath.) It contains the two Post-clauses <u>horribly</u> and <u>in the bath</u>; and it was shown earlier how they are linked to the main clause by Variable Type. The only <u>syntactic</u> information required for this operation was the marking of the MVB in the semantic representation.

(41) indicates roughly how <u>relative clauses</u> are integrated. (Actually, there are some complications here, but they are irrelevant to the present discussion; the main point here is that again no reference need be made to the syntactic structure of the first clause. For details, see Reimold(forthcoming), where coordinate clauses, comparison-clauses, and various subjectless complement-clauses are treated as well.)

(41) # The girl (# who was tired $) giggled $.

(THEx:GIRLx)[--] and (Ey)[TIREDy] ; link: y=x;

integrated structure: (THEx:GIRLx & TIREDx)[--]

Next consider circumstantial clauses like because the kangaroo jumped in (43). The strategy for these clauses, stated in (42), does again not refer to the syntactic structure of the first clause.

(42) Circumstantial Clause Rule:

Substitute the matrix of the main clause for the free s-argument of the JUNCtor of the circumstantial clause, and join the prefix of the main clause before the prefix of the circumstantial clause.

(43) # The boy was happy $(# [because JUNC] the kangaroo jumped$)

(THEx:BOYx)[HAPPYx] and (THEy:KANGAy)[BECAUSE(s ,JUMPy)]

FSR: (THEx:BOYx)(THEy:KANGAy)[BECAUSE(HAPPYx, JUMPy)]

The same holds true for complement-clauses like that the cake was poisoned in (45). The corresponding strategy is given in (44).

(44) Complement Clause Rule:

Substitute the SR of the complement-clause for the free s-argument of the MVB of the main clause.

(45) # John believed $ ([#compl] that the cake was poisoned $)

(THEx:JOHNx)[BELIEVE$_{MVB}$x s_1] and (THEy:CAKEy)[POISONEDy]

FSR: (THEx:JOHNx)[BELIEVE{ x, (THEy:CAKEy)(POISONEDy) }]

In sum, the principle of clause-by-clause erasure of syntactic structure seems indeed compatible with the requirements of clause-to-clause linking. The exception is the feature MVB, and it was suggested earlier that this syntactic feature is integrated into the semantic representation Notice also that certain aspects of syntactic structure are recoverable from our semantic representations. For instance, the order of the prefixes in the SR reflects the surface order of the NP's of a clause. Hence, if certain constructions require access to such syntactic aspects, this is still not incompatible with erasure of syntactic structure in clause intervals. (For instance, coordinate clauses and certain subjectless complement clauses do often require identification of the surface subject. For detailed discussion, see Reimold(forthcoming).)

XI: THE "TEMPORAL SEQUENCE STRATEGY"

The last strategy discussed here concerns the tense of consecutive clauses. When we interpret sentences S1, S2 in a text or sentence conjunct, where S1 and S2 have the _same tense_, we often assign a relative chronology to the events described by these sentences. I will refer to the principle assigning such a chronology as the Temporal Sequence Strategy. For example, consider (46) (Agatha Christie, _They came to Baghdad_, p.100):

(46) Then his head jerked$_{t_1}$ back a little and he lay$_{t_2}$ still.

Assigning PAST(t_1) to the first clause and PAST(t_2) to the conjoined clause in (46) does not account for actual comprehension: the listener knows that t_2 is later than t_1, even though there is no overt sequence marker (e.g., before, after, then).

As a first approximation, the strategy might be stated as follows:

(47) Temporal Sequence Strategy(preliminary):
Given two main or conjoined clauses C_1, C_2 such that C_1 precedes C_2 and the time t_1 of C_1 has the same "tense predicate" (e.g., PAST, FUTURE) as the time t_2 of C_2, then assume that t_1 DIRPREC t_2.

(47) will require several modifications. First, the rule holds for certain non-tensed clauses as well, as illustrated by (48)(They came to Baghdad, p.44):

(48) Then he was out, across the Khan, back into the Suq...

The full interpretation of (48) must specify that the time of out precedes that of across, which in turn precedes that of back. Since across and back had no overt tense predicate in (48), the strategy must somehow be liberalized to include such cases.

In this connection, consider also (49)(They came to Baghdad, p.71):

(49) Never, I thought, would the plane land. It went$_{t_1}$ round and round$_{t_2}$ and round$_{t_3}$.

If we assumed that $t_1=t_2=t_3$ in (49), then the two conjoined phrases and round and round should be redundant in the same sense in which Fido is a dog and is a dog and is a dog is. However, (49) can quite naturally be interpreted as "the plane went round and then round and then round" (i.e., as t_1 DIRPREC t_2 & t_2 DIRPREC t_3).

Next, the Temporal Sequence Strategy seems blocked if some general semantic principles (in particular, Pattern Matching) suggest a chronology conflicting with that imposed by the Temporal Sequence Strategy. For instance, consider a dialogue like (50):

(50a) What's the matter with John?
(50b) Oh, he broke$_{t_1}$ his arm. He fell$_{t_2}$ off his bike.

Here the second sentence in (50b) is interpreted as preceding the first sentence in (50b) temporally, counter to what the Temporal Sequence Strategy would predict. The reason is obvious: there is a perceived causal connection between the sentences, such that the second sentence describes the cause of the first. Since a cause must precede its effect, t_2 must precede t_1 in (50b).

To formalize this, we can make use of Pattern Matching. For instance, the encyclopedia would contain a pattern like (51), and there would furthermore be a meaning rule like (52).

(51) $(TYPx:HUMANx)(TYPy:LIMBy\&PARTOFyx)[CAUSE(FALLxt_1,BREAKyt_2)]$

(52) $(ALLt_1,t_2)[CAUSE\{A(..t_1..),B(..t_2..)\}$ IMPL t_1 DIRPREC $t_2]$

We need only make sure that the pattern (51) is activated by the two sentences <u>he broke his arm</u> and <u>he fell off his bike</u> in (50b), which can be done by calling up all patterns which are in the intersection of the main verbs of the two sentences. (For instance, <u>break</u> and <u>fell</u> both point to (51).) In effect, we have to add the following principle to the Temporal Sequence Strategy:

(53) <u>Causal Connection Constraint</u>:

If C_1, C_2 are <u>not</u> conjoined by <u>and</u>, call up all Encyclopedic Rules in the intersection of the MVB's of C_1 and C_2. If <u>t_2 DIRPREC t_1</u> is heuristically derivable from a pattern, then add this link to C_2 and do not apply the Temporal Sequence Strategy.[11]

Another restriction seems to be that the Temporal Sequence Strategy is inapplicable to <u>progressive tense</u>. For instance, while t_1 must precede t_2 in (54), they seem to be roughly simultaneous in (55), even though <u>lighting a cigarette</u> and <u>leaving a room</u> normally count as "instantaneous" events (see

[11] The condition against conjunction by <u>and</u> is necessary since <u>and</u> can never mean "and before that..." For instance, a sentence like <u>He broke his arm and fell off his bike</u>. cannot be interpreted as "he broke his arm because he fell off his bike."

the "Short Events Principle" discussed below).

(54) She lit$_{t_1}$ a cigarette and left$_{t_2}$ the room.

(55) She was lighting$_{t_1}$ a cigarette and leaving$_{t_2}$ the room.

Progressive tense turns events into non-instantaneous events.

Finally, I come to the most general and important restriction on the Temporal Sequence Strategy. This restriction is of a subtle semantic nature: it states that the strategy is applicable to clauses C_1, C_2 only if the events described by C_1 and C_2 are unlikely to be simultaneous. Consider, for instance, the following sentence:

(56) She just stood there and looked at him.

It is perfectly possible for someone to stand somewhere and at the same time to look at somebody. Hence no temporal sequence is imposed on stood and looked. By contrast, in (57) (They came to Baghdad, p.76) went and stood must be interpreted as sequenced, since one cannot at the same time go somewhere and stand somewhere else:

(57) She went$_{t_1}$ out from the bar onto the terrace outside and stood$_{t_2}$ by the railing...

Note that it will not do to define the condition of "possible simultaneity" directly for verbs. We cannot say, e.g., that clauses containing stand and go must be"sequenced."

For instance, in (58) and (59), <u>stood</u> and <u>went</u> would be interpreted as simultaneous, the reason being, of course, that different agents are involved, which makes simultaneity conceivable.

(58) Jack stood by the window. Jane went to the door.

(59) Jane went to the door. Jack stood by the window.

It is clear, then, that a detailed semantic analysis is needed to determine "possible simultaneity of two events. The principle can be stated as follows:

(60) <u>Possible Simultaneity Constraint</u>:
Call up all Encyclopedic Rules in the intersection of the MVB's of C_1 and C_2. Unless t_1 t_2 is derivable (strictly or heuristically) the Temporal Sequence Strategy is inapplicable.

There are some cases, however, where two events are normally interpreted as sequenced, even though they could, strictly speaking, be simultaneous. For instance, it is theoretically possible to light a cigarette while getting up, and one certainly would not want to add a rule to the encyclopedia stating that two such events are unlikely to be simultaneous. Nonetheless, (61) is normally interpreted as sequenced:

(61) John got up and lit a cigarette.

Rather than adding some <u>ad hoc</u> principle which somehow codes the intuition that it is awkward to strike a match and hold it to the cigarette while getting up, we can explain this as a consequence of a much more general heuristic principle. Notice that both clauses of (61) describe <u>instantaneous events</u>. Now, the shorter two events, the lower the probability that they coincide. For instance, the probability that the radio plays at the same time when there is a shot is much higher than the probability of there being a shot at the same time with a hiccough. As another illustration, consider (62)(<u>They came to Baghdad</u>, p. 72):

(62) With a fatherly smile he withdrew$_{e_1}$, Victoria sat down$_{e_2}$ on the bed and passed$_{e_3}$ an experimental hand over her hair.

Although it is logically conceivable that all three events e_1-e_3 happened simultaneously, the normal interpretation of these sentences takes them to be sequenced, because they are short and hence unlikely to coincide.

This means, then, that we must add the following heuristic principle:

(63) <u>Short Events Principle</u>:

If C_1, C_2 denote <u>instantaneous events</u> (i.e., <u>INSTANT t_1</u> and <u>INSTANT t_2</u> are derivable from M-rules and E-rules) assume that $t_1 \neq t_2$.

In summary, the Temporal Sequence Strategy takes on the following form:

(64) Temporal Sequence Strategy (revised):

(1) Let C_1, C_2 be two main or conjoined clauses such that C_1 is to the left of C_2 and the time t_1 of the MVB of C_1 has the same tense predicate as the time t_2 of the MVB of C_2, or t_2 or both t_1 and t_2 have no tense predicate; and neither t_1 nor t_2 has the tense predicate PROGRESSIVE;

(2) call up all Encyclopedia Rules in the intersection of the MVB of C_1 and the MVB of C_2;

(a) if C_2 is not introduced by and, and t_2 DIRPREC t_1 is heuristically derivable from the active E-rules and M-rules, then add t_2 DIRPREC t_1 and break off the application of this strategy;

(b) if either $t_1 \neq t_2$ or INSTANT t_1 & INSTANT t_2 is derivable (strictly or heuristically) from the active E-rules and M-rules, then add the link t_1 DIRPREC t_2.

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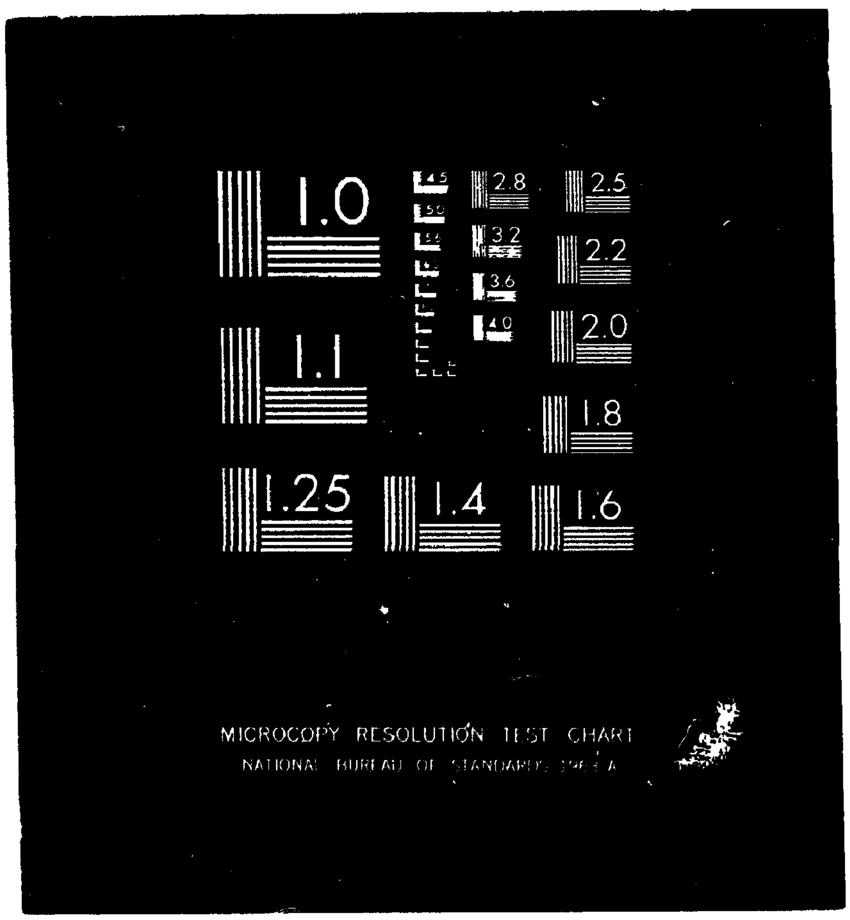
END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