



DOCUMENT RESUME

ED 150 552

CS 003 917

AUTHOR Nash-Webber, Bonnie Lynn  
 TITLE Inference in an Approach to Discourse Anaphora. Technical Report No. 77.  
 INSTITUTION Bolt, Beranek and Newman, Inc., Cambridge, Mass.; Illinois Univ., Urbana. Center for the Study of Reading.  
 SPONS AGENCY National Inst. of Education (DHEW), Washington, D.C.  
 PUB DATE Jan 78  
 CONTRACT 400-76-0116  
 NOTE 30p.

EDRS PRICE MF-\$0.83-HC-\$2.06 Plus Postage.  
 DESCRIPTORS \*Cognitive Processes; \*Comprehension; Discourse Analysis; Language Research; \*Psycholinguistics; Reading Comprehension; \*Reading Research  
 IDENTIFIERS. \*Anaphora; \*Center for the Study of Reading (Illinois); Inference

ABSTRACT

Inference is discussed as a factor in the derivation of non-explicit antecedents and referents for three types of discourse anaphora: definite pronouns, "one"-anaphora, and verb phrase ellipsis. This derivation process is seen as being part of the normal process of text-understanding. It is claimed that the use of non-explicit antecedents and referents for anaphora depends on a contract between speaker and listener. This contract requires that if the speaker uses an anaphoric expression whose antecedent or referent was inferentially derived, the listener both can and will make the same inference. Insofar as it is shown that many of these inferences rely on one of the few things explicitly available to both speaker and listener alike--i.e., the form of the utterance--the identification of a sentence's formal properties become a matter of cognitive concern. (Author)

\*\*\*\*\*  
 \* Reproductions supplied by EDRS are the best that can be made \*  
 \* from the original document. \*  
 \*\*\*\*\*



ED150552

CENTER FOR THE STUDY OF READING

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY.

Technical Report No. 77

INFERENCE IN AN APPROACH TO  
DISCOURSE ANAPHORA

Bonnie Lynn Nash-Webber

Bolt Beranek and Newman Inc.

January 1978

University of Illinois  
at Urbana-Champaign  
51 Gerty Drive  
Champaign, Illinois 61820

BBN Report No. 3734

Bolt Beranek and Newman Inc.  
50 Moulton Street  
Cambridge, Massachusetts 02138

The research reported herein was supported by the National Institute of Education under Contract No. US-NIE-C-400-76-0116. The author wishes to thank Dr. Carlotta Smith and Dr. Bertram Bruce for reading and suggesting improvements to earlier drafts of this paper.

The National Institute of Education  
U.S. Department of Health, Education and Welfare  
Washington, D.C. 20208

Table of Contents

	<u>page</u>
Abstract	
1. Introduction . . . . .	1
2. Inference and Deep Anaphora . . . . .	3
2.1 Discourse Models . . . . .	3
2.2 Sources of Antecedents and Referents . . . . .	7
2.3 Examples of Productive Inferences . . . . .	11
3. Inference and Surface Anaphora . . . . .	14
4. Conclusion . . . . .	20
References . . . . .	21

## 1. Introduction

If one considers the question of what is accessible to anaphoric reference in English, one soon finds that none of the simple answers - text strings, pieces of syntactic structure, constituents of logical form - is adequate. The following examples should provide sufficient grounds for this claim. For each underlined anaphoric expression, the intuitively correct antecedent is just as intuitively neither a substring nor a constituent of a syntactic or "logical form" representation of the sentence.

- (1) Wendy is going to Spain and Bruce is going to Crete, but in neither case do I know why Ø.  
 $\emptyset$  = that person is going where s/he is going.
- (2) Irv and Martha wanted to dance together, but Martha's mother said that she couldn't Ø.  
 $\emptyset$  = dance with Irv
- (3) Each 3rd-grade girl brought Wendy a brick. On a dare, she stacked them into a 10-foot high wall.  
them = the set of bricks, each of which some 3rd-grade girl brought to Wendy
- (4) Blend a cup of flour with some butter. Moisten it with some milk, then knead it into a ball.  
it = the flour-butter mixture.
- (5) Whether Bruce buys a used car or a moped, his brother will want to borrow it.  
it = the used car Bruce will have brought if Bruce buys a used car or the moped Bruce will have bought otherwise
- (6) I have a '71 Ch. Figeac, a '76 Fleurie, a '71 Ockfener Bockstein and a '75 Durkheimer Feuerberg in the cellar. Shall we have the German ones for dinner tonight?  
ones = wines

(Notice that these examples span a variety of anaphoric processes: sluicing (example 1), verb phrase ellipsis (example 2), definite pronoun anaphora (examples 3-5) and "one"-anaphora (example 6). Thus it should be clear that the existence of non-explicit antecedents is not an isolated phenomenon.)

Now one way of accounting for the existence of non-explicit antecedents in discourse is to say that "inference" is responsible. However as it is obvious that the discourse does not tell the listener explicitly what inferences to make, then one must still explain the fact that to a remarkable degree, both speaker and listener are reasoning in similar ways. This raises the following two questions:

1. What is it that guarantees similar reasoning on the part of both discourse participants?
2. Is there a limit to the kind of reasoning that the discourse participants might be willing to perform in order to derive antecedents?

My primary objective in this paper is to respond to the first question. In doing so, I shall characterize some very productive inferences which can account for many of the non-explicit antecedents of anaphoric expressions. While I shall not respond directly to the second question, my hope is that by identifying such inferences, it may become answerable as well.

In the first part of this paper I shall be discussing two types of "deep anaphora" (cf. Hankamer & Sag (1976)) - definite pronouns and "one"-anaphora - and in the second, a single type of "surface anaphora" - verb phrase ellipsis. I have made this division so as to provoke thinking about other types of "deep" anaphora - e.g., "do it" anaphora, "sentential it" anaphora - along the lines presented in the first part of the paper, and about other types of "surface" anaphora - e.g., sluicing, stripping, etc. - along the lines presented in the second. <\*1>

## 2. Inference and Deep Anaphora

### 2.1 Discourse Models

One possible response to the question of what would guarantee similar reasoning on the part of both discourse participants is to invoke the notion of a discourse model - a concept frequently encountered in Artificial Intelligence literature on natural language understanding. This notion permits a clean account to be given of both the role of inference in text-understanding (Collins, Brown & Larkin, 1977) and of the items accessible to "deep"-anaphora.

Informally, a discourse model may be described as the set of entities "naturally evoked" by a discourse and linked together, by

---

<\*1>. This paper is culled from the author's doctoral dissertation (Nash-Webber, 1978) to which interested readers are referred for further discussion.

the relations they participate in. These I will call discourse entities. (I can see no basic difference between what I am calling "discourse entities" and what Karttunen (1976) has called "discourse referents". My alternate terminology rests on wanting to keep "referent" a separate technical term.) The entities "naturally evoked" by the discourse may have the properties of individuals, sets, stuff, events, activities, etc.

In order to become familiar with the notion of entities "naturally evoked" by a discourse, consider the following sentence.

(7) Each 3rd-grade girl brought a brick to Wendy's house. Then consider each continuation in (8a-e). In each case, I would label the referent of the definite pronoun (i.e., "she", "it" or "they") an entity "naturally evoked" by sentence (7).

(8)a. She certainly was surprised.  
she = Wendy

b. They knew she would be surprised.  
they = the set of 3rd-grade girls

c. She piled them on the front lawn.  
them = the set of bricks, each of which some 3rd-grade girl brought to Wendy's house

d. She was surprised that they knew where it was.  
it = Wendy's house

e. Needless to say, it surprised her.  
it = the brick-presenting event

It is my assumption that one objective of discourse is to communicate a model: the speaker has a model of some situation which, for one reason or another, s/he wishes to communicate to a



listener. Thus the ensuing discourse is an attempt by the speaker to direct the listener in synthesizing a similar model.

Formally, a discourse model is a collection of entities, their properties and the relations they participate in. At any point in the discourse moreover, the discourse model validates the sequence of propositions embodied in the discourse up to that point. Now a speaker is usually not able to communicate at once all the relevant properties and relations associated with one of these discourse entities. That task requires multiple acts of reference. When the speaker wants to refer to an entity in his or her discourse model, s/he may do so with a definite pronoun. In so doing, the speaker assumes (1) that on the basis of the discourse thus far, a similar entity will be in the listener's (partially formed) model and (2) that the listener will be able to access and identify that entity via the minimal cues of pronominal reference. A definite pronoun then has a referent, which is an entity in the speaker's discourse model which s/he presumes to have a counterpart in the listener's discourse model.

Alternatively, the speaker may refer to a discourse entity by constructing a description of it in terms of some or all of its known properties and/or relations (e.g., "a red balloon", "Mary's mother", etc.). This may result in an entity being evoked into the listener's discourse model having at least the properties (or participating in the relations) mentioned in the given description. So while a discourse entity may be the referent of a

definite pronoun, the pronoun's antecedent will be that description conveyed by the immediately preceding text. The relationship between the discourse or the spatio-temporal context on the one hand, and the referents of definite pronouns on the other is thus an indirect one, mediated by the discourse participants' models. The discourse, in communicating property and relation information, serves as one possible source of antecedent descriptions and thus, indirectly, as one possible source of referents.

As for the role of "one"-anaphora (example (6)) in this scheme of things, I am assuming that a "one"-anaphor substitutes for a description. This description is in turn its antecedent. There are at least two possible reasons a speaker may have for using a "one"-anaphor in discourse: brevity and contrast. When a speaker builds a noun phrase around a "one"-anaphor, any additional modifiers in the noun phrase can serve to differentiate and contrast the current description with some set of alternatives which the speaker perceives or believes the listener to be aware of. Where the anaphor-containing noun phrase is being used referentially (i.e., to evoke or pick out a particular entity in the listener's discourse model), those modifiers serve to distinguish the noun phrase's intended referent from other entities in the model. (This last idea derives from Olson (1970).)

## 2.2 Sources of Antecedents and Referents

The role of inference in the scheme becomes clear as one considers how discourse entities can be evoked into the listener's discourse model. There are three such ways in which discourse entities can be evoked: (1) linguistically, from the explicit discourse; (2) perceptually, from the immediate spatio-temporal environment; and (3) inferentially, reasoning from the existence of particular other discourse entities. (Perceptual evocation of discourse entities is another way of looking at the "pragmatically controlled" definite pronouns discussed in Hankamer & Sag (1976).)

Inference also has a role in the formation of descriptions, in that the same three sources as above provide their raw material. The first source of descriptions is the discourse itself, with the language inducing particular ways of viewing and describing things. These things may or may not correspond then to entities in the listener's discourse model. Notice, for example, that after sentence (9) one would not presume any tie-dyed T-shirts to be in that model, since the original sentence is a negative assertion.

(9) Wendy didn't give either boy a tie-dyed T-shirt.  
However, the existence of any referent is irrelevant to the description, "tie-dyed T-shirt" being a possible antecedent for "one" in sentence (10).

(10) However, she did give Janet a red one.

The second source of descriptions is the external environment. As mentioned above, an entity may be evoked into the speaker or listener's discourse model as a result of what s/he perceives. How it is described will depend upon how s/he classifies that perception linguistically. As well as it can be presented on paper, the following is an example of a "one"-anaphor substituting for the speaker's description of some sense perception.

- (11) [Bonnie goes up to a balloon man at the circus and says]  
 "Do you have a blue one with green stripes."  
 one = balloon

Again as with discourse entities, the third source of descriptions is inference. The speaker assumes the listener can and will follow the speaker's unspoken lead to infer:

1. from description  $d_1$  of some entity in his or her discourse model; another description  $d_2$  of that same entity;
2. from entities  $e_1, \dots, e_j$  with descriptions  $d_1, \dots, d_j$  respectively, a new discourse entity  $e_k$  with description  $d_k$ .

For instance, in sentence 6 of the introductory set of examples, the speaker assumes that the listener both can and will infer from the description "Ch. Figeac '71" another description for that same entity - namely "wine". Similarly for the descriptions "176 Fleurie", "Ockfener Bockstein '75" and "Durkheimer Feuerberg '75".

The "one"-anaphor then substitutes for the non-explicit shared description "wine".

In summary, inference can be a source of both non-explicit discourse entities and non-explicit descriptions, provided that the following contract between speaker and listener is maintained: if the speaker uses an anaphoric expression whose antecedent or referent was inferentially derived, s/he must have reason to believe that the listener both can and will make the same inference (even if only to resolve the anaphoric term). The problem now becomes one of either characterizing or enumerating such inferences.

The first thing to observe is that not all chains of reasoning will produce as side effects either new discourse entities or new descriptions. For example, consider the following as the first sentence of a discourse.

(12) You won't believe this, but I saw Wendy's mother at the Led Zeppelin movie last night, and he wasn't with her.

Who does the speaker presume the listener will identify as the referent of "he" in this example? It is clear that the text itself is no help. <\*2>

<\*2>. I unsuccessfully intended the pronoun to refer to Wendy's father. The point is that merely an "if mother, then father" axiom

$$\begin{aligned} & (\forall x) [(E y) . y = \text{mother-of}(x)] \\ & \implies [(E z) . z = \text{father-of}(x)] \end{aligned}$$

i.e., "for any x, if there exists an individual who is x's mother, then there exists an individual who is x's father", true as it may be in the current world, is still not sufficient to yield a referent for "he" in sentence (12). That is, "he" cannot refer to Wendy's father solely by virtue of mentioning her mother.

The second thing to observe is that the range of inferences capable of providing referents for each type of deep anaphora will vary. For example, compare the following two examples: the first contains a definite pronoun, the second, an anaphoric definite description:

- (13) Wendy ran into the kitchen and opened it. (14) Wendy ran into the kitchen and opened the refrigerator:

Here "the refrigerator" refers to the discourse entity describable as "the refrigerator in the just-mentioned kitchen that Wendy ran into". This entity, inferable by a highly salient and rarely false "if kitchen then refrigerator" axiom, is not accessible via the minimal cues of pronominal reference. (In Artificial Intelligence terms, the saliency of a collection of inferences is ensured by their being packaged together into a data-structure called a **frame, schema or script**. In this paper I shall only be concerned with inferences capable of providing antecedents and/or referents for pronominal or elliptic anaphora. For interesting discussions of anaphoric definite descriptions, see Bullwinkle (1977), Charniak (1973), Grosz (1977), Hobbs (1976) and Rieger (1974).)

Now unfortunately, there are no hard and fast rules which delimit the class of inferences which can evoke acceptable antecedents or referents for definite pronoun or "one"-anaphora. In general, the success of a particular inference in evoking a discourse entity or a description will depend on (1) its saliency in the particular context; (2) its contingency (i.e., how likely

it is to be valid in that context); and (3) the pressure of simultaneous demands on the listener's limited processing resources.

However, while I cannot characterize in terms of its defining properties the class of relevant inferences, I can list explicitly some very productive inferences which would have to be included in any account of non-explicit antecedents. While space limits me to presenting only three such inferences here, others can be found in Nash-Webber (1978). (In the following, I will present the axiom schemata used in "inferring antecedents and referents" in terms of a modified predicate calculus whose augmentations include the abstraction (or "lambda") operator ( $\lambda$ ), the iota operator ( $\iota$ ) for forming definite descriptions, equality, restricted quantification and the set operator ( $\{\dots\}$ ). To understand the factors motivating this choice of representation, see Nash-Webber (1978).)

### 2.3 Examples of Productive Inferences

Of the three inference schemata I shall discuss here, the first two can provide non-explicit antecedents and referents for definite pronouns, while the third provides antecedents for "one"-anaphora. The first inference schema (presented in a somewhat simplified form here) applies to existentially quantified propositions in cases where the existential quantifier has widest scope.

$$(Ex:A) . Px \Rightarrow (Ey) . y = \{z: Az \& Pz \& \text{evoke } S_j, z\}$$

i.e., informally, if a proposition  $S_j$  states that there is a member of class **A** for which **P** is true, then there exists an individual describable as "the **A** which **P**'s which was mentioned (or evoked) by  $S_j$ ". Since a unique description can be ascribed to this individual, it can be referred to anaphorically with a definite pronoun. For example,

- (15) a. Wendy ate an apple.
- b. It had a worm inside.

Sentence 15a. can be represented simply as

$$(Ex:Apple) . Ate Wendy, x$$

Since this matches the left hand side of the above axiom schema, it follows that

$$(Ey) . y = \{z: Apple z \& Ate Wendy, z \& \text{evoke } S_{15a}, z\}$$

i.e., there exists an individual describable as "the apple which Wendy ate which was mentioned in sentence 15a". The individual is the discourse entity referred to by "it" in sentence 15b. and the above definite description is its antecedent.

The second inference schema for definite pronouns applies whenever a non-negative sentence contains an existentially quantified noun phrase within the scope of a universal

$$(\forall x:A) (Ey:B) . P x, y \Rightarrow (Ez) . z = \{w|Bw \& (Ex:A) . P x, w\}$$

i.e., informally, if for every **A** there exists a **B** such that **P** is true of the pair, then there exists an individual describable as "the set of **B**'s for which there is some **A** that stands in relation



P to it". Since a unique description is ascribable to this individual, it can be referred to with a definite pronoun. For example,

- (16) a. Each boy gave Wendy a shirt.  
 b. None of them fit.

Sentence 16a. can be represented simply as

$(\forall x:\text{Boy})(\exists y:\text{Shirt}) \text{ Gave } x, \text{Wendy}, y$

Since this matches the left-hand side of the second axiom schema, it follows that

$(\exists z) . z = \{w | \text{Shirt } w \ \& \ (\exists x:\text{Boy}) \text{ Gave } x, \text{Wendy}, w\}$

i.e., there exists an individual describable as "the set of shirts, each of which some boy gave to Wendy". This is the discourse entity referred to as "they" in example 16b.

The third inference schema I will discuss produces non-explicit antecedents for "one"-anaphora. Consider example (6), repeated here:

- (6) I have a '71 Ch. Figeac, a '76 Fleurie, a '71 Ockfener Bockstein and a '75 Durkheimer Feuerberg in the cellar. Shall we have the German ones for dinner?

In this example, the speaker has turned an explicit set description (i.e., the presented list) into an implicit set description (i.e., one based on a defining property) and then used the latter description as an antecedent for "one"-anaphora. In doing so, the speaker presumes the listener is both able and willing to do the same. (That is, the speaker appeals to the "inference contract" mentioned in the previous section.) The unanswered question is why such an inference from explicit to

implicit set description should occur and moreover be predictable.

<\*3>

### 3. Inference and Surface Anaphora

"Surface anaphors" are so called because they are seen to be purely surface phenomena. The primary condition for a successful surface anaphor-antecedent pair (cf. Hankamer & Sag (1976) and Sag (1976)) is that the antecedent forms a coherent structural unit at the level of surface syntax or the level of logical form (subject to some type of Backward Anaphor Constraint). However, that condition is not fulfilled in the following examples which illustrate different types of surface anaphora.

#### Sluicing

- (18) Wendy is going to Spain and Bruce is going to Crete, but in neither case do I know why  $\emptyset$ .  
 $\emptyset$  = that person is going where s/he is going

#### "Do so" Anaphora

- (19) Wendy's car was repaired today by the same guy who had done so last week. (after Kaplan (1976))  
 do so = repair Wendy's car

#### Verb Phrase Ellipsis

- (20) I can walk and I can chew gum. Ford can  $\emptyset$  too, but not at the same time.  
 $\emptyset$  = walk and chew gum

<\*3>. One might note in passing that the first two inference schemata depend solely on the **form** of an utterance, while this third one depends on its content as well. Thus world knowledge can be seen to play a part (although, I would argue, a small one) in **deriving** possible antecedents as well as in **choosing** between them.

- (21) China is a country that Nixon wants to visit, and he will  
 Ø too, if he gets an invitation soon.  
 Ø = visit China

The problem is that of accounting for such exceptions to the above constraint on surface anaphor-antecedent pairs. One way to do so is to again invoke inference. In the remainder of this section, I shall first sketch, albeit briefly, an approach to verb phrase ellipsis based on identity of predication at the level of logical form. I shall then argue that inference can play a part in deriving additional logical forms whose predicates can serve as antecedents for ellipsed verb phrases. I shall illustrate this claim with two examples. Others can be found in Nash-Webber (1978)..

Now if examples such as those above are ignored, the approach to verb phrase ellipsis (or "verb phrase deletion" - VPD) presented in Sag (1976a&b) provides an adequate account. Sag's thesis is that verb phrase ellipsis is conditioned by identical predicates (rather than by identical VPs or identical substrings) in a logical form representation of the two clauses involved. (Identity here is determined modulo differences in the names of bound variables, i.e., "alphabetic variance".) This logical form representation makes essential use of the lambda operator both to bind variables and to form complex predicates which may themselves contain quantifiers and logical connectives. For example, Sag (1976a) assigns the sentence "John scratched his arm" the two logical form representations

- a. John<sub>i</sub>,  $\lambda(x)(x \text{ scratched his}_i \text{ arm})$   
 b. John<sub>i</sub>,  $\lambda(x)(x \text{ scratched } x\text{'s arm})$

That there are two possible logical forms for this sentence explains the ambiguity to be found in a subsequent ellipsed verb phrase sentence like

Fred did  $\emptyset$  too.

(Did what? Scratched his own arm or scratched John's?) Sag claims that

With respect to a sentence S, VPD can delete any VP in S whose representation at the level of logical form is a lambda-expression that is an alphabetic variant of another lambda-expression present in the logical form of S or in the logical form of some other sentence S' which precedes S in the discourse. (Sag 1976a)

In short, Sag shows that by looking at sentences in terms of the predicate-argument relations they express, a clean account can be given of verb phrase ellipsis (barring for now the initial set of examples). This in turn gives credence to the psychological reality of some type of "logical representation" within the dual processes of text generation and comprehension.

But if the process of forming a logical representation is part of the normal process of understanding discourse, then it is possible that alternative ways of understanding a sentence or sequence of sentences, or even valid, salient implications of sentences may also provide lambda-predicates for verb phrase ellipsis. And this is the point I want to stress: whereas Hankamer & Sag's condition implies a very static view of verb phrase ellipsis and other surface anaphora, the above

process-oriented view suggests that a more plastic approach is justified. The proviso seems to be that the form of expression of the derived proposition does not differ radically from the form of those explicitly given.

Now "alternative ways of understanding" and "valid implications" are both notions which involve inference. But not every valid inference provides lambda-predicates accessible to verb phrase ellipsis. For example, the following axiom relates the notions of "selling" and "being bought".

$$(\forall x)(\forall y)(\forall z) . x, \lambda(r)[r \text{ sold } y \text{ to } z] \Rightarrow y, \lambda(s)[s \text{ was bought by } z]$$

i.e., if any x sold any y to any z, then y was bought by z". <\*4>

Notice that this axiom is not sufficient to produce a predicate "was bought by z", given an explicit predicate "sold y to z" --

(22) Bruce sold a waffle iron to Wendy, and an electric wok was  $\emptyset$  too.  
 $\emptyset$  bought by Wendy

Unfortunately, aside from the caveat that the logical forms of both the overt sentence(s) and the derived one be "similar" in some undefined sense, there are no hard and fast rules delimiting the class of productive inferences relative to verb phrase ellipsis. What I shall do in the space remaining then is to set down two inference schemata which account for the two problematic

---

<\*4>. For the remainder of this paper, I will be following Sag's intuitively clear conventions (Sag 1976a&b) for writing logical forms. However, for computational purposes, at least, a more rigorous formalism is called for (cf. Nash-Webber (1978)).

examples of verb phrase ellipsis presented above (examples 20) and 21).

The first inference schema is applicable to a sequence of propositions with identical subjects and auxiliaries: its effect is to abstract a new predicate off of the common argument:

$$y, \text{AUX}(\lambda(r)[P r]) \ \& \ y, \text{AUX}(\lambda(s)[Q s]) \ ==> \\ y, \text{AUX}(\lambda(t)[P t \ \& \ Q t])$$

AUX, the sentence auxiliary, is interpreted as an operator on predicates, although up to now it has been omitted for simplicity. Informally, this schema says that if y P's and y Q's, then y P's and Q's. The propositions on either side of the implication, while structurally different, are semantically equivalent (at least with respect to an extensional semantics).

To illustrate the application of this inference schema, reconsider example (20), repeated below.

- (20) a. I can walk and I can chew gum.  
 b. Jerry can  $\emptyset$  too, but not at the same time.

Sentence (20a) can be represented as <\*5>

$$I, \text{CAN}(\lambda(r)[r \text{ walk}]) \ \& \ I, \text{CAN}(\lambda(s)[s \text{ chew gum}])$$

Since this matches the left-hand side of the above rule schema, it follows that

$$I, \text{CAN}(\lambda(t)[t \text{ walk} \ \& \ t \text{ chew gum}])$$

This has as a constituent the lambda predicate

---

<\*5>. This is actually a simplification of the procedure I follow throughout Nash-Webber (1978), but the essential ideas are the same.

$\lambda(t)$  [t walk & t chew-gum].

i.e., "walk and chew gum", which is intuitively the correct antecedent for the ellipsed verb phrase in sentence (20b). <\*6>

The second rule schema I will discuss here applies to statements of restricted class membership. Its effect is to derive a new proposition expressing the restriction alone, whose lambda predicate is accessible to verb phrase ellipsis. Since I do not have the space here to motivate the notation I need to express this rule schema formally, I will express it informally as

$\langle x \rangle$  is a  $\langle B \rangle$  which  $\langle y \rangle$   $\langle C \rangle$ s  $\Rightarrow$   $\langle y \rangle$   $\langle C \rangle$ s  $\langle x \rangle$

where  $\langle B \rangle$  is a class description (e.g., elephant, snowmobile, etc.) and  $\langle C \rangle$  is a verb phrase whose subject is  $\langle y \rangle$ . To illustrate the application of this rule schema, reconsider example (21), repeated below.

(21) China is a country that Nixon wants to visit, and he will  $\emptyset$  too, if he gets an invitation soon.

Proceeding informally, the first clause of (21) matches the left-hand side of the above rule schema. It therefore follows that

---

<\*6>. The reason for requiring the conjuncts to have identical auxiliaries is the strangeness of those examples in which they do not. For example,

Bruce attended Harvard, and now he is going to MIT.  
Fred {did, does, will, is}  $\emptyset$  too.

"Fred did  $\emptyset$  too" seems to imply only that he attended Harvard. "Fred is  $\emptyset$  too" seems to imply only that he is now going to MIT. The other auxiliaries just seem bizarre. The sense that Fred also attended Harvard and is now going to MIT does not seem to be conveyable using an ellipsed verb phrase.

Nixon wants to visit China.

i.e., using Sag's notation for lambda predicates,

Nixon,  $\lambda(r)[r \text{ wants } \{r, \lambda(s)[s \text{ visit China}]\}]$

This has as a constituent the lambda predicate

$\lambda(s)[s \text{ visit China}]$

which intuitively is the intended antecedent of the ellipsed verb phrase in the second clause of (21).

#### 4. Conclusion

In this paper, I have discussed the concept of inference as a factor in the derivation of non-explicit antecedents and referents for discourse anaphora of both deep and surface varieties. I have shown how inference schemata can be applied to a formal representation of the discourse to produce additional formulae which suggest, through their structure, possible antecedents and referents. I have tried to motivate this as part of the normal process of text-understanding. I have claimed the use of non-explicit antecedents and referents for anaphoric terms depends on a contract between speaker and listener. This contract stipulates that if the former uses an anaphoric expression whose antecedent or referent was inferentially derived, the latter both can and will make the same inference. Insofar as many of these inferences rely on one of the few things **explicitly** available to both speaker and listener - i.e., the form of the utterance - the search for productive inferences vis a vis discourse anaphora is a matter of linguistic concern.



## References

- Bullwinkle, C. Levels of Complexity for Anaphora Disambiguation and Speech Act Interpretation. *Proceedings of 5-IJCAI*, 22-25 August 1977, 43-49.
- Charniak, E. Context and the Reference Problem. In R. Rustin (Ed.), *Natural Language Processing*. New York: Algorithmics Press, 1973.
- Collins, A., Brown, J.S. and Larkin, K. Inference in Text Understanding. In R. Spiro, B. Bruce and W. Brewer (Eds.), *Theoretical Issues in Reading Comprehension*. New Jersey: Lawrence Erlbaum Associates, 1978.
- Grosz, B. The Representation and Use of Focus in Dialog Understanding. Technical Note 151, SRI International, Menlo Park, CA, July 1977.
- Hankamer, J. & Sag, I. Deep and Surface Anaphora. *Linguistic Inquiry*, 1976, 7(3), 391-428.
- Hobbs, J. A Computational Approach to Discourse Analysis (Research Report 76-2). New York: Department of Computer Science, City College, City University of New York, 1976.
- Kaplan, J. The Variability of Phrasal Anaphoric Islands. In S. Mufwene et al. (Eds.), *Papers from the 12th Regional Meeting of the Chicago Linguistics Society*, University of Chicago, Chicago IL.
- Karttunen, L. Discourse Referents. In J. McCawley (Ed.), *Syntax and Semantics* (Vol. 7). New York: Academic Press, 1976.
- Nash-Webber, B.L. A Formal Approach to Discourse Anaphora. Forthcoming doctoral dissertation, Harvard University, 1978.
- Olson, D.R. Language and Thought: Aspects of a Cognitive Theory of Semantics. *Psychological Review*, 1970, 4, 257-273.
- Rieger, C.J. *Conceptual Memory*. Unpublished doctoral dissertation, Stanford University, Department of Computer Science, 1974.
- Sag, I.A. A Logical Theory of Verb Phrase Deletion. In S. Mufwene et al. (Eds), *Papers from the 12th Regional Meeting of the Chicago Linguistics Society*, University of Chicago, Chicago IL, 1976a.
- Sag, I.A. *Deletion and Logical Form*. Unpublished doctoral dissertation, MIT Department of Foreign Literatures and Linguistics, 1976b.

CENTER FOR THE STUDY OF READING

READING EDUCATION REPORTS

- No. 1: Durkin, D. Comprehension Instruction--Where Are You?, October 1977.
- No. 2: Asher, S. R. Sex Differences in Reading Achievement, October 1977.
- No. 3: Adams, M., Anderson, R. C., & Durkin, D. Beginning Reading: Theory and Practice, October 1977.
- No. 4: Jenkins, J. R., & Pany, D. Teaching Reading Comprehension in the Middle Grades, January 1978.

CENTER FOR THE STUDY OF READING  
TECHNICAL REPORTS

\* Available only through ERIC

- \*No. 1: Halff, H. M. Graphical Evaluation of Hierarchical Clustering Schemes, October 1975. (ERIC Document Reproduction Service No. ED 134 926, 11p., HC-\$1.67, MF-\$ .83)
- \*No. 2: Spiro, R. J. Inferential Reconstruction in Memory for Connected Discourse, October 1975. (ERIC Document Reproduction Service No. ED 136 187, 81p., HC-\$4.67, MF-\$ .83)
- \*No. 3: Goetz, E. T. Sentences in Lists and in Connected Discourse, November 1975. (ERIC Document Reproduction Service No. ED 134 927, 75p., HC-\$3.50, MF-\$ .83)
- \*No. 4: Alessi, S. M., Anderson, T. H., & Biddle, W. B. Hardware and Software Considerations in Computer Based Course Management, November 1975. (ERIC Document Reproduction Service No. ED 134 928, 21p., HC-\$1.67, MF-\$ .83)
- \*No. 5: Schallert, D. L. Improving Memory for Prose: The Relationship Between Depth of Processing and Context, November 1975. (ERIC Document Reproduction Service No. ED 134 929, 37p., HC-\$2.06, MF-\$ .83)
- \*No. 6: Anderson, R. C., Goetz, E. T., Pichert, J. W., & Halff, H. M. Two Faces of the Conceptual Peg Hypothesis, January 1976. (ERIC Document Reproduction Service No. ED 134 930, 29p., HC-\$2.06, MF-\$ .83)
- \*No. 7: Ortony, A. Names, Descriptions, and Pragmatics, February 1976. (ERIC Document Reproduction Service No. ED 134 931, 25p., HC-\$1.67, MF-\$ .83)
- \*No. 8: Mason, J. M. Questioning the Notion of Independent Processing Stages in Reading, February 1976. (Journal of Educational Psychology, 1977, 69, 288-297)
- \*No. 9: Siegel, M. A. Teacher Behaviors and Curriculum Packages: Implications for Research and Teacher Education, April 1976. (ERIC Document Reproduction Service No. ED 134 932, 42p., HC-\$2.06, MF-\$ .83)
- \*No. 10: Anderson, R. C., Pichert, J. W., Goetz, E. T., Schallert, D. L., Stevens, K. V., & Trollip, S. R. Instantiation of General Terms, March 1976. (ERIC Document Reproduction Service No. ED 134 933, 30p., HC-\$2.06, MF-\$ .83)
- \*No. 11: Armbruster, B. B. Learning Principles from Prose: A Cognitive Approach Based on Schema Theory, July 1976. (ERIC Document Reproduction Service No. ED 134 934, 48p., HC-\$2.06, MF-\$ .83)
- \*No. 12: Anderson, R. C., Reynolds, R. E., Schallert, D. L., & Goetz, E. T. Frameworks for Comprehending Discourse, July 1976. (ERIC Document Reproduction Service No. ED 134 935, 33p., HC-\$2.06, MF-\$ .83)

- No. 13: Rubin, A. D., Bruce, B. C., & Brown, J. S. A Process-oriented Language for Describing Aspects of Reading Comprehension, November 1976. (ERIC Document Reproduction Service No. ED 136 188, 41p., HC-\$2.06, MF-\$ .83)
- No. 14: Pichert, J. W., & Anderson, R. C. Taking Different Perspectives on a Story, November 1976. (ERIC Document Reproduction Service No. ED 134 936, 30p., HC-\$2.06, MF-\$ .83)
- No. 15: Schwartz, R. M. Strategic Processes in Beginning Reading, November 1976. (ERIC Document Reproduction Service No. ED 134 937, 19p., HC-\$1.67, MF-\$ .83)
- No. 16: Jenkins, J. R., & Pany, D. Curriculum Biases in Reading Achievement Tests, November 1976. (ERIC Document Reproduction Service No. ED 134 938, 24p., HC-\$1.67; MF-\$ .83)
- No. 17: Asher, S. R., Hymel, S., & Higfield, A. Children's Comprehension of High- and Low-Interest Material and a Comparison of Two Cloze Scoring Methods, November 1976. (ERIC Document Reproduction Service No. ED 134 939, 32p., HC-\$2.06, MF-\$ .83)
- No. 18: Brown, A. L., Smiley, S. S., Day, J. D., Townsend, M. A. R., & Lawton, S. C. Intrusion of a Thematic Idea in Children's Comprehension and Retention of Stories, December 1976. (ERIC Document Reproduction Service No. ED 136 189, 39p., HC-\$2.06, MF-\$ .83)
- No. 19: Kleiman, G. M. The Prelinguistic Cognitive Basis of Children's Communicative Intentions, February 1977. (ERIC Document Reproduction Service No. ED 134 940, 51p., HC-\$3.50; MF-\$ .83)
- No. 20: Kleiman, G. M. The Effect of Previous Context on Reading Individual Words, February 1977. (ERIC Document Reproduction Service No. ED 134 941, 76p., HC-\$4.67, MF-\$ .83)
- No. 21: Kane, J. H., & Anderson, R. C. Depth of Processing and Interference Effects in the Learning and Remembering of Sentences, February 1977. (ERIC Document Reproduction Service No. ED 134 942, 29p., HC-\$2.06; MF-\$ .83)
- No. 22: Brown, A. L., & Campione, J. C. Memory Strategies in Learning: Training Children to Study Strategically, March 1977. (ERIC Document Reproduction Service No. ED 136 234, 54p., HC-\$3.50, MF-\$ .83)
- No. 23: Smiley, S. S., Oakley, D. D., Worthen, D., Campione, J. C., & Brown, A. L. Recall of Thematically Relevant Material by Adolescent Good and Poor Readers as a Function of Written Versus Oral Presentation, March 1977. (ERIC Document Reproduction Service No. ED 136 235, 23p., HC-\$1.67, MF-\$ .83)
- No. 24: Anderson, R. C., Spiro, R. J., & Anderson, M. C. Schemata as Scaffolding for the Representation of Information in Connected Discourse, March 1977. (ERIC Document Reproduction Service No. ED 136 236, 18p., HC-\$1.67, MF-\$ .83)

- No. 25: Pany, D., & Jenkins, J. R. Learning Word Meanings: A Comparison of Instructional Procedures and Effects on Measures of Reading Comprehension with Learning Disabled Students, March 1977. (ERIC Document Reproduction Service No. ED 136 237, 34 p., HC-\$2.06, MF-\$.83)
- No. 26: Armbruster, B. B., Stevens, R. J., & Rosenshine, B. Analyzing Content, Coverage and Emphasis: A Study of Three Curricula and Two Tests, March 1977. (ERIC Document Reproduction Service No. ED 136 238, 22 p., HC-\$1.67, MF-\$.83)
- No. 27: Ortony, A., Reynolds, R. E., & Arter, J. A. Metaphor: Theoretical and Empirical Research, March 1977. (ERIC Document Reproduction Service No. ED 137 752, 63 p., HC-\$3.50, MF-\$.83)
- No. 28: Ortony, A. Remembering and Understanding Jabberwocky and Small-Talk, March 1977. (ERIC Document Reproduction Service No. ED 137 753, 36 p., HC-\$.206, MF-\$.83)
- No. 29: Schallert, D. L., Kleiman, G. M., & Rubin, A. D. Analysis of Differences Between Oral and Written Language, April 1977.
- No. 31: Nash-Webber, B. Anaphora: A Cross-Disciplinary Survey, April 1977.
- No. 32: Adams, M. J., & Collins, A. A Schema-Theoretic View of Reading Comprehension, April 1977. (ERIC Document Reproduction Service No. ED 142 971, 49 p., HC-\$2.06, MF-\$.83)
- No. 33: Huggins, A. W. F. Syntactic Aspects of Reading Comprehension, April 1977. (ERIC Document Reproduction Service No. ED 142 972, 68 p., HC-\$3.50, MF-\$.83)
- No. 34: Bruce, B. C. Plans and Social Actions, April 1977.
- No. 35: Rubin, A. D. A Theoretical Taxonomy of the Differences Between Oral and Written Language, January 1978.
- No. 36: Nash-Webber, B., & Reiter, R. Anaphora and Logical Form: On Formal Meaning Representations for Natural Language, April 1977. (ERIC Document Reproduction Service No. ED 142 973, 42 p., HC-\$2.06, MF-\$.83)
- No. 37: Adams, M. J. Failures to Comprehend and Levels of Processing in Reading, April 1977.
- No. 38: Woods, W. A. Multiple Theory Formation in High-Level Perception, April 1977.
- No. 40: Collins, A., Brown, J. S., & Larkin, K. M. Inference in Text Understanding, December 1977.
- No. 41: Anderson, R. C., & Pichert, J. W. Recall of Previously Unrecallable Information Following a Shift in Perspective, April 1977. (ERIC Document Reproduction Service No. ED 142 974, 37 p., HC-\$2.06, MF-\$.83)

- No. 42: Mason, J. M., Osborn, J. H., & Rosenshine, B. V. A Consideration of Skill Hierarchy Approaches to the Teaching of Reading, December 1977.
- No. 43: Collins, A., Brown, A. L., Morgan, J. L., & Brewer, W. F. The Analysis of Reading Tasks and Texts, April 1977.
- No. 44: McClure, E. Aspects of Code-Switching in the Discourse of Bilingual Mexican-American Children, April 1977. (ERIC Document Reproduction Service No. ED 142 975, 38 p., HC-\$2.06, MF-\$0.83)
- No. 45: Schwartz, R. M. Relation of Context Utilization and Orthographic Automaticity in Word Identification, May 1977.
- No. 46: Anderson, R. C., Stevens, K. C., Shiffrin, Z., & Osborn, J. Instantiation of Word Meanings in Children, May 1977. (ERIC Document Reproduction Service No. ED 142 976, 22 p., HC-\$1.67, MF-\$0.83)
- No. 47: Brown, A. L. Knowing When, Where, and How to Remember: A Problem of Metacognition, June 1977.
- No. 48: Brown, A. L., & DeLoache, J. S. Skills, Plans, and Self-Regulation. July 1977.
- No. 50: Anderson, R. C. Schema-Directed Processes in Language Comprehension, July 1977. (ERIC Document Reproduction Service No. ED 142 977, 33 p., HC-\$2.06, MF-\$0.83)
- No. 51: Brown, A. L. Theories of Memory and the Problems of Development: Activity, Growth, and Knowledge, July 1977.
- No. 52: Morgan, J. L. Two Types of Convention in Indirect Speech Acts, July 1977.
- No. 53: Brown, A. L., Smiley, S. S., & Lawton, S. C. The Effects of Experience on the Selection of Suitable Retrieval Cues for Studying from Prose Passages, July 1977.
- No. 54: Fleisher, L. S., & Jenkins, J. R. Effects of Contextualized and De-contextualized Practice Conditions on Word Recognition, July 1977.
- No. 56: Anderson, T. H., Standiford, S. N., & Alessi, S. M. Computer Assisted Problem Solving in an Introductory Statistics Course, August 1977.
- No. 57: Barnitz, J. G. Interrelationship of Orthography and Phonological Structure in Learning to Read, January 1978.
- No. 58: Mason, J. M. The Role of Strategy in Reading in the Mentally Retarded, September 1977.
- No. 59: Mason, J. M. Reading Readiness: A Definition and Skills Hierarchy from Preschoolers' Developing Conceptions of Print, September 1977.
- No. 60: Spiro, R. J., & Esposito, J. Superficial Processing of Explicit Inferences in Text, December 1977.
- No. 65: Brewer, W. F. Memory for the Pragmatic Implications of Sentences, October 1977.

- No. 66: Brown, A. L., & Smiley, S. S. The Development of Strategies for Studying Prose Passages, October 1977.
- No. 68: Stein, N. L., & Nezworski, T. The Effects of Organization and Instructional Set on Story Memory, January 1978.
- No. 77: Nash-Webber, B. L. Inference in an Approach to Discourse Anaphora, January 1978.
- No. 78: Gentner, D. On Relational Meaning: The Acquisition of Verb Meaning, December 1977.
- No. 79: Royer, J. M. Theories of Learning Transfer, January 1978.
- No. 80: Arter, J. A., & Jenkins, J. R. Differential Diagnosis-Prescriptive Teaching: A Critical Appraisal, January 1978.