

BOUND VARIABLES AND
OTHER ANAPHORS

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When a noun phrase or a pronoun occurs in a sentence, it is frequently appropriate to ask what entity it refers to, but it is well known that not all uses of noun phrases and pronouns are referential in this simple sense. In computational approaches to language processing, I believe the main thrust in this area has been toward understanding those referential uses of NP's and pronouns which require the use of both linguistic and non-linguistic inferences to determine the most plausible referent for the expression. My emphasis in this paper will be somewhat different. I believe that recent work by linguists, logicians, and philosophers is leading to convergence on the view that there are two fundamentally distinct uses of pronouns which have to be treated quite separately: (i) a use that corresponds to the logician's use of bound variables, and (ii) a use which I will call, for want of a better name, a pragmatic use. It can be argued that bound variable pronouns are restricted to occurrences in syntactic construction with their antecedents, and are fully interpreted at the level of semantics, while pragmatic pronouns need not have linguistic antecedents at all, and require pragmatics as well as semantics for their interpretation.

1. The basic distinction.

The clearest cases of bound variable anaphora involve antecedents like every man and no man which are singular in form but do not refer to individuals, as in (1) and (2).

- (1) Every man put a screen in front of him.
- (2) No child will admit that he is sleepy.

When the he of (2) is understood as anaphorically related to the noun phrase no child, the he clearly does not refer to a particular individual. Rather, the sentence can be understood as the result of binding an open sentence, (3), with a quantifier phrase, no child.

- (3) He_0 will admit that he_0 is sleepy.

(It is immaterial for the purposes of this paper whether we view the process in question as a generative one, as in Montague (1973) or Lakoff (1971), or as an interpretive one, as in Jackendoff (1972) or the I-grammar Montague variant of Cooper and Parsons (1976). The use of subscripted pronouns

rather than x's and y's follows Montague's practice, but that distinction is also immaterial here.)

The semantics of variable binding is well studied in logic; a particularly clear and brief account can be found in Quine (1970). The crucial point here is that the semantics involves consideration of a whole range of possible values for the variables, not the determination of any single value or referent. Equally crucial is that the interpretation of (2) involves an open sentence with two occurrences of the free variable he, one in the position of the antecedent noun phrase, the other corresponding to the surface pronoun.

Using these clear cases, we can discover strong syntactic constraints on the occurrence of bound variable pronouns. With few exceptions, it appears that bound variables must be in construction with their antecedents (the observation is made by Evans (1977); the notion "in construction with" comes from Klima (1964): a constituent A is in construction with a constituent B if and only if A is dominated by the first branching node which dominates B. The term c-command is a more recent alternative name for the same notion.) Thus the following do not permit a bound variable reading:

- (4) (a) Every man walked out. He slammed the door.
- (b) John loves every woman, and he hopes to date her soon.
- (c) If no student cheats on the exam, he will pass the course.

By contrast, the bound variable reading is permitted in cases like (1) and (2) above, in which the pronoun is in construction with its antecedent.

The clearest cases of what I am calling pragmatic uses of pronouns are cases where a pronoun is used with no linguistic antecedent at all, as in (5), or where the antecedent occurs in an earlier sentence of a discourse, as in (6).

- (5) (On walking into a room) Why is he [pointing] here?
- (6) I couldn't reach Elliot last night. He is probably in Boston.

These are cases where the pronoun is being used to refer to a particular individual, and the determination of which individual the intended referent is requires making use of the linguistic and non-linguistic context. Ignoring some complicated cases that I will discuss later, we may say that at the level of purely linguistic description, such pronouns function like free variables which are not bound at all at the semantic level. A sentence containing one expresses a determinate proposition only relative to a particular choice of value for the variable, much as a sentence containing the word now expresses a determinate proposition only relative to a particular time of evaluation. Such choices depend on the context of use of the sentence, which is why I call this a pragmatic use of pronouns.

I believe that there are no absolute rules governing the choice of referent for pragmatic uses of pronouns, but that there are discoverable strategies and principles governing the relative likelihood or

or preference among choices. The other participants in this panel know much more than I do about what those principles and strategies are; I hope they would agree that the output of such principles is a probable or expected referent rather than an absolute referent for the pronoun. For example, in most contexts, the probable referent of the he in (6) is Elliot; but one can easily enough imagine a context where speaker and hearer are most interested in figuring out where Max is, and being unable to reach Elliot is a good clue to Max's being in Boston; then he may be intended and understood as referring to Max. What matters most seems to be the salience and relevance of a particular individual, and I see no reason to draw any theoretical line between cases where that salience comes from the linguistic context as opposed to the non-linguistic context.

Where I do want to draw a sharp line is between the bound variable use and the pragmatic use of pronouns. The bound variable use is best described at the level of syntactic form and semantic interpretation of single sentences, and the relevant question is not what the pronoun refers to, but what quantifier phrase is binding it. The pragmatic use is best described at the pragmatic level, where the full context of the sentence in use is considered; on the syntactic level, these pronouns are really no different from proper names, and at the semantic level, they can be viewed as free variables or as dummy names.

2. Structurally ambiguous pronouns.

I have begun with the clearest examples of the distinction; if all uses of pronouns fell unambiguously into these two categories, I could stop here. All the rest would be a matter of improving the description of the syntactic constraints on bound variable anaphora and unravelling the processing mechanisms that we use to determine the referents of the pragmatic uses of pronouns. But the clear cases do not provide a set of necessary and sufficient conditions for telling the two kinds of pronouns apart. All we can conclude so far by way of conditions is the following:

- (i) A pronoun can function as a bound variable only if it is in the same sentence as its antecedent.¹
- (ii) Any pronoun can be used pragmatically.²

If these are the only conditions, we would expect many occurrences of pronouns to be ambiguous as to which use they have, and indeed many are. The pronouns in (1) and (2) are ambiguous in this way, and the sentences have sharply different interpretations in the two cases. But now consider a sentence like (7):

- (7) The prosecutor believed that he would win the case.

This example can be analyzed either way; if the pronoun is analyzed as a bound variable, the sentence is interpreted as in (7a), and if the pronoun is treated pragmatically, we can represent it as in (7b).

- (7a) (The prosecutor: he₀) [He₀ believed that he₀ would win the case.]
 (7b) The prosecutor believed that he₅ would win the case.

On the pragmatic pronoun reading, the free variable he₅ will be interpreted as some salient individual determined by the context; and one likely choice will be the prosecutor. This looks at first as if we are predicting an ambiguity where there is none. And this is not just an isolated example, since the same situation will arise whenever we have an antecedent noun phrase that picks out a particular individual. But it turns out that there is striking evidence that this is a real structural ambiguity, and not just an artifact of the analysis. I believe that Keenan (1971) was the first to point this out; Sag (1976) and Williams (1977) discuss such cases extensively. The evidence comes from verb phrase deletion, and involves examples like the following:

- (8) The prosecutor believed that he would win the case, and so did the defense attorney.

The missing verb phrase can be understood in just two ways, corresponding to the two structures we have posited for the first clause. On each reading, sentence (8) predicates the same property of the defense attorney as it predicates of the prosecutor: either the property of being an x such that x believed that x would win the case (the bound variable reading), or the property of being an x such that x believes that he₅ (the prosecutor) would win the case (the pragmatic pronoun reading).^{3/} Thus the examples of so-called "sloppy identity" (Ross 1967) of pronouns are really examples of strict semantic identity of predicates. This important generalization can be captured only by recognizing that apparently unambiguous sentences like (7) are in fact structurally ambiguous.

Cases with proper names as antecedents to pronouns work just like (7) and (8); the unified treatment of all noun phrases, including proper names, as quantifier phrases proposed by Montague (1973) is an important aid in permitting the treatment of pronouns advocated here.

Another major source of pronoun ambiguity is the systematic ambiguity of most plural noun phrases as between a "group" reading and an "individual" reading, as in (9).

- (9) Three men lifted the piano.

When the plural pronoun they is used as a pragmatic pronoun, it always refers to a group; but when it is used as a bound variable, it may be either a variable over individuals or a variable over groups. Thus we get two bound variable readings plus a pragmatic pronoun reading for (10).

- (10) The Democrats voted for their wives.

On the group-level bound variable reading, the Democrats as a group voted for their wives as a group. On the individual-level bound variable reading, each of the Democrats voted for his own wife. On the pragmatic pronoun reading, the

Democrats^{4/} voted for some group's wives; that group might be the Democrats themselves, but might be some other group determined by the context. Again the three readings lead to corresponding readings in sentences with verb-phrase deletion:

- (11) The Democrats voted for their wives before the Republicans did.

I will not enumerate the readings, but it can be seen that the positing of the three structures for the first clause plus the requirement that verb phrase deletion be interpreted as semantic identity of predication makes the correct predictions about the possible interpretations of the full sentence.

Yet another source of structural ambiguity is the fact that noun phrases may have other noun phrases embedded within them, and a pronoun may have either the whole noun phrase or a subpart as antecedent. Sentences (12a) and (12b) do not have this particular ambiguity because of the number difference, but (13) is ambiguous as between (13a) and (13b).

- (12) (a) One of the prisoners believed that she could escape.
 (b) One of the prisoners believed that they could escape.^{5/}
 (13) Two of the prisoners believed that they could escape.
 (a) Two of the prisoners believed that they could escape.
 (b) Two of the prisoners believed that they could escape.

Each of these sentences is ambiguous between a bound variable use and a pragmatic use of the pronoun; and sentence (13a) permits either the individual-level bound variable reading (each of the two believed she could escape) or the group-level reading (both believed that both could escape). However, (13b) on the bound variable reading must be a group-level pronoun, because the antecedent is in a partitive construction, which requires a group-denoting noun phrase. A fuller discussion of plural noun phrases and bound variable pronouns can be found in Bennett (1974), although Bennett does not specifically discuss the pragmatic uses of pronouns. No new principles of pronoun interpretation are needed for these cases beyond the important observation that they can function semantically as an individual-level pronoun, that is, just like a singular pronoun. The complexities of these examples result simply from the joint interaction of several individually simple phenomena: bound variable vs. pragmatic uses of pronouns, individual vs. group readings of plurals, and the possibility of either a whole noun phrase or a subpart of it serving as antecedent for a pronoun.

The examples discussed so far are summarized and extended in Table I below. The column headed "Pragmatic Pronoun" should be understood as follows: the given pronoun can be interpreted as referring to an individual or group determinable on the basis of the interpretation of the given "antecedent" as the relevant linguistic context. Thus, for example, while every man does not refer to the group of all men, it can promote that group into salience, as can no man and no men.

- (14) No students came to the party. They thought they weren't invited._{6/}

TABLE I

Antecedent	Bound Variable Pronoun	Pragmatic Pronoun
every man	he	*he, OK they (group)
no man	he	*he, OK they (group)
the man	he	he
John	he	he
one man	he	he
more than one man	he	*he, OK they (group)
at most one man	he	*
three men	they (ind), they (group)	they (group)
one of the men	he	he
{one} of {the men}	they (group)	they (group)
{two}		
two of the men	they (ind), they (group)	they (group)
no men	they (ind)	they (group)
John and Bill	they (ind), they (group)	they (group)
John or Bill	he	they (group) _{7/}

3. Are there "pronouns of laziness"?

Both traditional grammar books and early transformational accounts such as Lees and Klima (1963) suggest a treatment of pronouns different from either of the two I have described. This is the view that a pronoun is a substitute for a linguistically identical noun phrase; (15b) would on this view be derived from (15a).

- (15) (a) John spoke to Mary when John walked in. ⇒
 (b) John spoke to Mary when he walked in.

But such a view requires that semantic interpretation operate on surface structure, since the application of the rule changes the meaning whenever the repeated noun phrase is anything other than a proper noun or a definite description.

- (16) (a) John lost a watch and Bill found a watch ⇒
 (b) John lost a watch and Bill found it.

Given that pragmatic pronouns must be generated directly anyway because of cases where there is no linguistic antecedent, there is then no work left for such a transformation to do; it simplifies neither the syntax nor the semantics. Hence it has been abandoned by linguists of just about every theoretical persuasion.

But there are some cases that look as though they might be better handled via a syntactic substitution rule than by either the bound variable or the pragmatic treatment. One class was introduced by Geach (1962), who provides examples like (17):

- (17) Every man who owns a donkey beats it.

On the defensible assumption that a donkey should be analyzed here as an existential quantifier phrase having narrower scope than the every, this it cannot be analyzed as a bound variable (see Partee 1975a). But it also does not refer to any specific donkey, and so does not appear to be functioning as a pragmatic pronoun. Geach suggests that a sentence like (17) be analyzed in terms of (18):

- (18) Every man who owns a donkey beats the donkey he owns.

Thus the it is viewed as standing for a description recoverable in a complex way from the initial part of the sentence. Geach may or may not have called this an example of a "pronoun of laziness"; the term is his, but it has been used by him and others in a variety of ways. What all uses of the term have in common is the idea that some pronouns should be analyzed neither as bound variables nor as directly referential, but in terms of some syntactically definable relation to an antecedent noun phrase.

Another example for which a "pronoun of laziness" treatment has plausibility is (19), from Karttunen (1969):

- (19) The man who gives his paycheck to his wife is wiser than the man who gives it to his mistress.

This it is also not a bound variable nor directly referential; it seems to be a substitute for the expression his paycheck. In both Partee (1970) and Partee (1975b) I argued for the existence of a syntactic pronoun-of-laziness rule, intended to cover both these examples and those cases of what I am now calling pragmatic pronouns in which the antecedent is itself a directly referring expression such as a proper noun or a definite description. However, neither I nor anyone else that I know of ever succeeded in stating a version of the rule which covered all of these cases without generating clearly unacceptable results as well. Recent arguments by Terry Parsons (personal communication), Robin Cooper (forthcoming), Gareth Evans (1977), Emmon Bach (personal communication), and others have convinced me that there is no way to make the notion of "pronoun of laziness" coherent without reducing it to one which covers only a small subclass of the pragmatic pronouns and hence does no useful work.

What then can we say about the paycheck sentences and the donkey sentences? Many lines of attack are being explored currently; one that I find particularly promising is proposed by Cooper (forthcoming), who suggests a rather natural extension of the notion of pragmatic pronoun to handle them. Before describing his proposal, I need to fill in some background.

Russell's analysis of singular definite descriptions (Russell 1905) requires that there be a unique object satisfying the description in order for the expression to denote anything, and hence notoriously fails to account for the successful reference of a noun phrase like the clock in (20).

- (20) Did you wind the clock?

That the missing ingredient is pragmatic has long been recognized; Cooper (forthcoming) proposes a mechanism that brings in pragmatics in a simple way that parallels the account of pragmatic pronouns given above (which is also basically Cooper's). He proposes for definite descriptions a semantic interpretation like Russell's but with the addition of a free property variable P: the clock then denotes (the property set of) the unique individual x such that clock(x) and P(x). At the

semantic level, P is just a free variable; it is left to the pragmatic interpretation of the sentence in context to determine an appropriate choice for P. In a context where there is no salient distinguishing property, the singular definite description would indeed be inappropriate or uninterpretable. Cooper's treatment can be seen as a formalization of the informal gloss of the (by Katz and others) as "contextually definite".

As a second background step toward Cooper's proposal, consider the interpretation of genitive phrases like that in (21).

(21) John's team lost again.

As is well known, John's team may be the team John owns, or plays for, or roots for, or collects trading cards of, or writes news stories about; there are virtually no limits on the relevant relation. I propose that such constructions be analyzed at the semantic level as definite descriptions containing a free relation variable R, whose value is to be determined at the pragmatic level, by looking for an appropriately salient and relevant relation in the linguistic or non-linguistic context. Thus John's team would be interpreted as (22):

(22) the x such that team (x) and R (John, x).

What is common to these analyses of pragmatic pronouns, definite descriptions, and genitive constructions is the use of semantic free variables that are pragmatically assigned particular values. Introducing the free variables allows a complete specification of the form of the interpretation to be given for each sentence at the semantic level, while providing an appropriate division of labor between semantics and pragmatics in the determination of the content.

Cooper's proposal for the donkey and paycheck sentences is that pronouns can be analyzed not only as free variables, but alternatively as expressions composed of more than one free variable, utilizing free property or relation variables much as in the examples just discussed. The logical formalism is complex, but I will give it for completeness and then try to paraphrase it less formally. A singular pronoun (he, she, or it) may have any translation of the following form:

(23) $\lambda K \exists x \forall y [[\forall \pi] (y \equiv y = x) \wedge K(x)]$,
 where π is a property-denoting expression containing only free variables and parentheses.

What this says is that e.g. it may be interpreted as (the property set of) the unique individual x which has property π . For the paycheck example, an appropriate π will be R (u), where R is a free relation variable and u is a free individual variable that will be bound by the second occurrence of the man. The second clause of (19) will then say "the man u such that u gives the x such that R (x,u) to u's mistress." The pragmatically appropriate R will be "being the paycheck of". The computational complexity of the analysis is justified, I believe, by the fact that only

very salient relations permit the kind of pronoun use evidenced by the paycheck example.

Cooper's analysis of the donkey sentences uses the identical device; for details see Cooper (forthcoming).

The conclusion of this section is that there are no pronouns of laziness; the cases which seemed to require them can be handled by an extension of the notion of pragmatic pronouns. The extension is somewhat complex, but (a) it makes use of the same kind of property and relation variables that are needed for an account of definite noun phrases and genitive constructions, and (b) the examples it is needed for are intuitively complex and infrequent in occurrence.

4. Conclusion.

There are many problems of pronouns and reference that I have not touched on. I have not discussed reflexive pronouns, first and second person pronouns, pronouns in modal contexts, the pro-common noun one, anaphoric determiners like same, different, or other, or any of a host of other topics crucial to a fuller account of the role of pronouns in reference. In some cases the problem is just lack of space and time, but in other cases there are still difficult open problems. I hope that some of what I have included is relatively unfamiliar and potentially useful for computational language processing endeavors, and I count on my fellow panelists to fill in some of the holes I have left.

Footnotes

1. There are apparent exceptions to even this weak a statement, but I believe they are best understood as involving elliptical sentences. Consider the following example (from David Kaplan, personal communication):

A: Could a woman become chairman of the Philosophy Department?

B: Yes, if she's qualified.

The she in the second sentence is not a pragmatic pronoun; but I think it is best treated as bound by an unexpressed antecedent within the second sentence, which is not as it stands a complete sentence, rather than as bound by an antecedent in the previous sentence.

2. There are exceptions to this statement, too, but they all involve idiomatic pronoun-containing expressions like "shrugged his shoulders" or "lost his cool". Reflexive pronouns are not included in this generalization; they are almost invariably bound variable pronouns, except for certain cases that seem to result from instability in the choice of nominative or accusative form. I will not go into any details about reflexive pronouns here.

3. On the pragmatic pronoun reading, the pronoun he can of course refer to someone other than the prosecutor; in that case the missing verb phrase will always be understood as involving reference to the same third person.

4. There is still an individual/group ambiguity for the subject in this case, but it does not affect the interpretation of the pronoun, so I will ignore it.

5. For simplicity I am ignoring the dialect that allows they with a singular antecedent; in that dialect (12b) is as ambiguous as (13).

6. Not every occurrence of a quantifier phrase with no has this effect, as the following example from Evans (1977) shows:

(i) *John owns no sheep and Harry vaccinates them.

The role of non-linguistic inference in interpreting pragmatic pronouns can be seen from the following linguistically similar examples.

(ii) John owns no sheep because Amherst taxes them.

(iii) John now owns no sheep because Harry poisoned them.

In (ii), them seems to be generic sheep rather than any group of sheep; in (iii) the most plausible interpretation seems to be the sheep that John once owned. Perhaps it would be more accurate to say that no man and no men never serve directly as antecedent to a pragmatic they, but sentences in which they occur do sometimes permit the inference of a suitable referent for a pragmatic they.

7. The group in this case is the group of John and Bill. That group can be put into contextual salience by any mention of John and Bill separately, as in the examples below.

(i) John saw Bill yesterday. They decided to go fishing.

(ii) I invited John, but not Bill. They both

came anyway.

(iii) Ask John or Bill. They know where the keys are kept.

8. Montague (1973) treats all noun phrases as devoting property sets, and Cooper follows this practice. While that treatment seems essential for a unified account of noun phrases, I have omitted discussion of it here for simplicity.

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