Resolution of the Antecedent of a Plural Pronoun: Ontological Categories and Predicate

Symmetry

Sungryong Koh

and

Charles Clifton, Jr.

University of Massachusetts Amherst

Correspondence:
Charles Clifton
Department of Psychology
University of Massachusetts
Amhest, MA 01003
cec@psych.umass.edu

Abstract

Two questionnaire studies and two reading time experiments explored how readers determine the reference of the plural pronoun they. The questionnaire studies showed that readers were more willing to take an ontologically homogeneous (all humans) collection of entities as the antecedent of they than an ontologically heterogeneous collection, and that they were more willing to take the entities that fill the thematic roles of a "symmetric" verb like sing with as the antecedent of they than the entities that fill the role of a "nonsymmetric" verb like hit. The questionnaire studies also showed a preference for taking the maximally inclusive group as the referent of they. The reading time experiments showed that these effects occur on-line so that reading is slowed when a temporary ambiguity is resolved in a way that conflicts with the preferences as described. A theoretical framework was described in which two stages of processing, described by an "equivalence" and a "closure" principle respectively, take place.

Keywords: Anaphora, plural anaphors, pronouns, discourse model

Many studies have examined how readers and listeners resolve the reference of singular pronouns and definite descriptions in discourse comprehension (e.g., Chang, 1980; Dell, McKoon & Ratcliff, 1983; Gernsbacher, 1989; Sanford & Garrod, 1981). These studies have typically examined the factors that make a particular phrase an attractive antecedent for a pronoun, including such variables as topichood, centering, distance, gender, and so on (Clifton & Ferreira, 1987; Ehrlich & Rayner, 1983; Garnham, 1999; Gordon & Chan, 1995). We will concentrate instead on some factors that influence the choice of an antecedent for the plural pronoun they, as in (1a) and (1b):

1.   a. Tom, Dick and Harry went to a restaurant last night. They ate a pizza.

          b. Tom and Dick went to a restaurant with Harry last night. They ate a pizza.

It is an interesting fact about they that it is often ambiguous. It need not refer to a group introduced as a plural noun phrase (NP). In the simple case (e.g., 1a) it does. But in other cases a plural referent may be formed that does not correspond to a phrase in the sentence. Although (1b) is ambiguous, they might well refer to all three people. On the other hand, they is not completely free in what it can take as an antecedent. In neither (1a) nor (1b) is the group of Dick and Harry a permissible antecedent.

We will briefly review the rather small literature on the processing of plural pronouns before we advance some proposals about how they are processed. A few studies have examined how readers can treat they as referring to a group that was not introduced as a plural NP. Sanford and Lockhart (1990) experimentally demonstrated the intuition appealed to in our discussion of (1b). They examined subject's continuations of sentences like Mary and John went to the shops and Mary went to the shops with John. Their subjects continued the latter sentence with a plural

reference to the two participants over 20% of the time (over 40% of the time for the sentence that contained a conjoined NP). Carreiras (1997) used a speeded continuation task to show that readers were faster at continuing a (Spanish) sentence of the form <u>Thomas accepted the move to a branch office in Madrid and Sophie got a job in Madrid with a software company. They...</u> when the two referents, Thomas and Sophie, were in the same general location (or scenario) than when they were in different locations or scenarios (e.g., Sophie was in Barcelona). Carreiras also found faster continuations when the antecedent of <u>they</u> had been introduced as a single NP, <u>Thomas and Sophie</u>, than when the individuals mentioned had been introduced separately. Clifton and Ferreira (1987) presented contrasting self-paced reading data suggesting that a "split antecedent" (the group Mary and John in a sentence like <u>Mary went to the shops with John</u>) might be a perfectly acceptable and easily processed antecedent of a plural pronoun. They measured self-paced reading times for a phrase like <u>they bought...</u> following sentences conceptually like those used by Sanford and Lockhart (1990). Reading time was not affected by whether the antecedent of the pronoun had been introduced as an NP or not. Carreiras's (1997) finding of a difference between the two ways of introducing an antecedent does imply that there is some representational effect of how a plural antecedent is introduced. Clifton and Ferreira's (1987) null result (see also Huitema, 1989, for a similar result using eyetracking) suggests that the representational difference may not affect normal reading.

A few studies have examined what might be seen as the opposite process, finding an antecedent for a singular pronoun inside a plural NP. Sanford and Garrod (1981) reported that readers showed comprehension difficulty when one conjunct of a conjoined NP in object position was the antecedent of a singular pronoun, and Albrecht and Clifton (1998) extended this result to

NPs in subject position. It appears that splitting of a group introduced by an NP causes

processing difficulty (at least in some cases; cf. Koh, Sanford & Clifton, submitted) .

Finally, a few studies have examined other uses of plural pronouns. Gernsbacher (1991)

and Oakhill, Garnham, Gernsbacher, and Cain (1992) examined uses of they to designate either a

category or a collection of entities inferred from a singular NP as in I need a plate; where do you

keep them? and I was really frightened by a Doberman; they are dangerous beasts. They found

that such uses were acceptable and discussed them in terms of "conceptual anaphora."

We will extend some observations made by Sanford and Lockhart (1990) and attempt to

formulate some general claims about how the processor copes with the ambiguity of they. The

extent of the ambiguity of they is usefully illustrated in Link's (1983) formal analysis of the

competence that a speaker of English has in using the plural, which amounts to a principled

enumeration of the possible antecedents of a plural pronoun or NP. We note that this analysis is

specific to English and related languages, and that a child acquiring a different language may

well have to acquire a different competence system. Link proposes that English plurals denote

sums of individuals. Suppose that a predicate book denotes three objects (a, b, c). The plural

predicate books can refer to (ab), (ac), (bc), or (abc) (where (ab) represents (in Link's

terminology) the "sum" of (a) and (b)). These collections or sums are partially ordered by a "part-

of" relation. In the example, (ab) is a part of (abc). Link represents the relation between groups as

a join semilattice structure (see Landman, 1991; Partee, Ter Melen, & Wall, 1993), which can be

represented as the structure in Figure 1. This figure is designed to show graphically the

distinction between individuals and the various sums that can be created by the join operation. It

should be viewed as a competence model that illustrates the knowledge a language-user has

about the meaning (or at least, one common meaning) of they. Using the distinction introduced

by Frege (see Brown, 1976; Johnson-Laird, 1983; Winograd, 1972), the reference of a plural

pronoun is a group, and the sense of a plural pronoun is the totality of possible groups in the

semilattice structure. This competence model must be augmented by claims about processing to

be a useful psychological performance model. Koh (2001) discusses several aspects of these

claims. For instance, he notes that the semilattice analysis of the unrestricted competence model

could support the creation of an uncountable infinity of groups, clearly an undesirable property of

a performance model. Koh avoids this problem by restricting the analysis to a finite domain of

entities in the semilattice, a restriction which leads him to term is model the restricted semilattice

model. In the following section, we will present those aspects of Koh's analysis that are directly

relevant to the experiments described in this paper.

<div align="center">*** FIGURE 1 ABOUT HERE***</div>

A performance model for resolving the ambiguity of a plural pronoun

Characterizing the competence of using a plural pronoun in this way encourages viewing

performance as the process of selecting the contextually-appropriate reference of a plural

pronoun, given its sense. It is useful to begin analyzing this process by considering the need for a

representation of discourse as a part of language comprehension (Garnham, 1999). We assume

that a discourse representation is in fact needed, and that a situation model (Sanford & Garrod,

1981), a mental model (Johnson-Laird, 1983), a file card semantics (Heim, 1982), or a discourse

model (Kamp & Reyle, 1992) all suit the purpose adequately. One simple way to represent what

a discourse is about is to maintain a database that contains an entity representing each individual

introduced in the discourse and records the properties or conditions of that individual.

Information about these individuals can be updated as the discourse unfolds. Anaphoric phrases, such as pronouns, can refer to these entities and permit adding new information about the individual designated by the entity. Kamp and Reyle (1992) accepted Link's (1983) idea as part of their analysis of discourse. They called a group of individuals a "non-atomic discourse entity" and permitted such an entity to be entered into the discourse database together with "atomic discourse entities," each representing an individual. A non-atomic discourse entity can be the antecedent of a plural pronoun.

It is necessary to specify the mapping between a syntactic representation and a discourse model. Heim (1982) proposed that whether expressions are definite descriptions, indefinite descriptions, or proper names, they lead a reader or listener to postulate discourse entities. The difference between definite and indefinite NPs comes from familiarity. Indefinite NPs introduce new discourse entities; definite NPs refer to old discourse entities. The general mapping between a syntactic representation and a discourse entity expressed in (2) can be taken as the first step in a performance model of the interpretation of plural pronouns (cf. Sanford & Lockhart, 1990).

2.   NP rule: Every referential NP must correspond to a discourse entity. A referential NP with a plural feature corresponds to a non-atomic discourse entity.

Consider the implication of the NP rule with respect to the construction of a non-atomic discourse entity. According to the NP rule, each NP in (3) must correspond to a discourse entity; it must find an entity in the discourse model or create one. (3) contains two NPs corresponding to atomic discourse entities (John, Mary) and two NPs (the kids, Mary and the kids) corresponding to non-atomic discourse entities.

3.   John hugged Mary and the kids.

The initial stage in the model of comprehending a plural pronoun that we will refer to as the "restricted semilattice model" includes the construction of non-atomic discourse entities following the NP rule. This rule is not sufficient, however. Consider (4):

4.   In the laboratory, John was measuring the water temperature every minute and Mary wrote down the measurements. They had been doing so for one hour.

The plural pronoun in the second sentence presumably refers to John and Mary. This non-atomic entity is not based on the NP rule. It must be constructed. We propose a very general and very powerful principle for constructing non-atomic discourse entities, described in (5):

5.   The equivalence hypothesis: If a discourse entity is equivalent to another discourse entity with respect to some property, these two discourse entities can be grouped as a non-atomic discourse entity.

Intuitively, a group is a collection of entities (atomic or non-atomic) which share some property. The entities are equivalent with respect to this shared property, e.g., in (4), John and Mary share the property of working in the laboratory (cf. Carreiras's, 1997, finding that a plural pronoun seemed to find an antecedent more easily when the two individuals constituting the potential group were in the same scenario than when they were in different scenarios). Now, any two entities presumably share some properties, but the equivalence hypothesis has to be taken to assume that properties adequate to support equivalence must be contextually salient. This makes the equivalence hypothesis very flexible and powerful, which is both a strength and a weakness. It is a weakness because the hypothesis is very difficult to falsify, if any aspect of context can be appealed to as possibly determining the salience of some property on which equivalence is putatively based. But we argue that the very generality of the hypothesis is a strength in that it

leads us to consider a wide variety of factors affecting the interpretation of a plural pronoun and treat them as reflections of a single principle.

Consider the general and abstract characterization of an equivalence relation as a symmetric, transitive, and reflexive relation. "Same age as" is an equivalence relation. Suppose Tom is the same age as Jerry and Jerry is the same age as Tony. It follows that Tom is the same age as himself (reflexivity), that Jerry is the same age as Tom (symmetry), and that Tom is the same age as Tony (transitivity). Any way of establishing that distinct discourse entities are members of the same conceptual category induces an equivalence relation among them, supporting the construction of a non-atomic discourse entity for each possible group of such entities. However, there are other, less obvious predicates that satisfy the criterion for an equivalence relation. Consider (6):

6.   (a)   John sang with Mary and Susan. They ...

        (b)   John recognized Mary and Susan. They ...

Given what we believe is the most common interpretation of <u>sing with</u> (ruling out statements like <u>John sang with the Boston Symphony Orchestra</u>) the statement (6a) entails (or at least implicates) that Mary and Susan sang with John, but (6b) does not entail or even implicate that Mary and Susan recognized John. Similar intuitions hold for reflexivity (under a liberal reading of <u>sing with</u>) and transitivity. Thus, <u>sing with</u> establishes an equivalence relation among its arguments, while <u>recognize</u> does not. We will refer to predicates like <u>sing with</u> as "symmetric" and predicates like <u>recognize</u> as "nonsymmetric." One could follow a suggestion of Sanford and Garrod (1981) and Sanford and Lockhart (1990) and suggest that the arguments of a symmetric predicate are equivalent in terms of the thematic roles they play in the event denoted by the

sentence. One could also follow the analysis of Gleitman, Gleitman, Miller and Ostrin (1996) and

suggest that predicates like sing with are marked with a special lexical feature of "symmetry,"

which makes reciprocal linguistic expressions such as John and Mary sang with each other

essentially equivalent semantically to their corresponding non-reciprocal expressions (we note,

though, that Gleitman et al. did not explicitly consider verb-preposition predicates like sing

with). We propose that this equivalence relation asserted in (6a), whatever its basis, supports the

construction of a non-atomic discourse entity, the collection of the atomic entity John and the

non-atomic entity Mary and Susan, but that a nonsymmetric predicate like that of (6b) does not

support such an act of construction.

The first stage in the restricted semilattice model is thus to construct all the non-atomic

discourse entities that are supported by the NP rule and the equivalence hypothesis. The second

stage is to select one of these as the preferred antecedent of a pronoun. A wide variety of factors

may prove to influence selection, but we propose just one here, the "closure" strategy described

in (7):

7.   The closure strategy: If all the individuals in an interpretation domain belong to one

        group, select this group as the antecedent of a plural pronoun.

The interpretation domain of a plural pronoun is the set of atomic and nonatomic entities that are

explicitly introduced or implicitly justified by the local text. All the individuals belonging to one

group if the interpretation domain is closed under the join (least upper bound formation)

operation, that is, if output of the join of any two members is also a member of the interpretive

domain (hence the term "closure"). In (6a), the join of John plus Mary and Susan is a group that

belongs to the domain, following the equivalence hypothesis. The closure strategy thus predicts

that in (6a) the group consisting of all individuals, the group (John, Mary, and Susan), rather than

the group (Mary and Susan) will be selected as the antecedent of the plural pronoun that begins

the second sentence. On the other hand, considering only equivalence based on verb symmetry,

there is no basis for constructing the group of all individuals in (6b), so the closure strategy

predicts that the smaller group (Mary and Susan) will be selected as antecedent of the pronoun.

This two stage restricted semilattice model could be further specified in several ways.

Following Frazier's (1978) analysis of sentence parsing strategies, it could be viewed as a fully

parallel model, in which non-atomic discourse entities corresponding to all possible groups are

created and maintained in working memory until disambiguating information eliminates

inappropriate antecedents (or in the case of permanent ambiguity, until competition among

factors including the closure strategy and the relative salience of various possible entities is

resolved). It could be viewed as a delay model, in which no groups are created until adequate

information to adequately disambiguate the antecedent of a plural pronoun is received. Or it

could be viewed as a serial model, in which the processor follows the equivalence hypothesis and

the closure strategy to initially select one preferred antecedent, a choice which must be cancelled

if later information proves it wrong. We assume such a serial model in developing the

implications of the restricted semilattice model, but believe that the validity of the equivalence

hypothesis and the closure strategy does not depend on this assumption.

Experimental tests of the Restricted Semilattice model

The questionnaires and experiments to be reported test the restricted semilattice model in

two ways. The first questionnaire and experiment tested whether entities that are members of the

same ontological category (human vs non-human in the present case) are treated as equivalent to

a greater degree than entities that are members of distinct ontological categories, and whether this

equivalence encourages grouping them as a non-atomic discourse entity that can serve as the

antecedent of a plural pronoun (see Sanford & Lockhart, 1990, for discussion of this possibility).

The first questionnaire additionally tested the closure strategy, determining whether a group of all

individuals in a domain would be preferred as the antecedent of they over a smaller group

introduced by an NP. The second questionnaire and experiment tested whether symmetric

predicates (such as sing with) confer equivalence on their arguments, together with testing the

equivalence hypothesis and the closure strategy.

Questionnaire 1

A sentence-continuation task was used to assess the extent to which readers prefer the

antecedent of a plural pronoun to be homogeneous in terms of ontological category. Participants

completed sentences beginning with a plural pronoun and then later indicated what they had

intended the antecedent to be. Their options were either two or three human referents or two

human referents plus a non-human (generally inanimate) referent. The restricted semilattice

model predicts that the frequency of choosing three human referents would be greater than the

frequency of choosing a collection of three entities, two humans plus one non-human, because

the equivalence among members of the same ontological category permits them to be grouped as

a non-atomic discourse entity.

Method

Participants and procedures. Thirty-two University of Massachusetts students participated

for course credit. Eight were assigned to each form of the questionnaire to be described below, in

which the participant was asked to complete each of twelve passages ending with a they (plus

some passages to be described as Questionnaire 2). When they had completed all passages, they

were asked one question about each of their completions, which they could answer by circling

the words that <u>they</u> referred to in their completion of the passage,

     <u>Materials.</u> Twelve passages containing four sentences plus a sentence fragment beginning

with the plural pronoun <u>they</u> were constructed. Each passage had two versions, as indicated in

(8). One (homogeneous) version mentioned three human entities (8a), and the other

(heterogeneous) mentioned two human and one non-human entities (8b). In nine of the 12 cases,

the non-human entity was inanimate. The materials are derived from those used in Experiment 1,

which appear in Appendix 1, with a third human entity substituted for the nonhuman entity in the

homogeneous versions.

8.   (a) A hurricane hit the city.

     A famous musician was missing.

     A distinguished novelist disappeared.

     A doctor also vanished.

     They _____

     (b) A hurricane hit the city.

     A historic painting vanished.

     A famous musician was missing.

     A distinguished novelist disappeared.

     They _____

     Four forms of a questionnaire were created. Each form contained six homogeneous

passages and six heterogeneous passages; each passage occurred as each version in two forms.

The nonhuman referent in the heterogeneous passages occurred as the last sentence in six

passages and as the first sentence in six passages. The twelve passages were combined with 16

passages to be described as Questionnaire 2 and separately randomized for each questionnaire

form.

After the 28 completion passages, the questionnaire continued with 28 interpretation

questions, each corresponding to one completion passage. Each interpretation question contained

the initial four sentences of the corresponding completion passage followed by a list of the three

entities mentioned, in parentheses. Participants were to circle the words in this list that they had

intended they to refer to.

Results and discussion

Participants circled all three entities as the intended antecedent of they more frequently

for homogeneous than for heterogeneous passages, 91 vs 75% of the time, $t1(31) = 2.95$, $p < .01$

and $t2(11) = 2.49$, $p < .05$ (all analyses were conducted permitting separate generalization to

subjects and to items; the results of the former will be referred to by t1 and F1, and the latter, by

t2 and F2). Of the 40 occasions when only two antecedents were circled in the heterogeneous

passage condition, 37 indicated a choice of the two human entities. The three occasions on which

one human and inanimate entity were chosen all came from the same participant. Twelve percent

of all responses had indicated that their intended referent of they was not presented as an option.

In 65% of these cases, the participants so indicating noted that their intended referent was an

entity that could be inferred from the context as a plausible agent of the sentence fragment, e.g.,

"city residents" in example (8). These responses were eliminated from the tabulation.

The data indicate that the preferred antecedent for a plural pronoun was the set of all three

mentioned entities, regardless of their ontological homogeneity. As indicated in the Introduction,

there is a potentially unlimited number of bases for equivalence and thus the formation of a

nonatomic discourse entity that could serve as the antecedent of a plural pronoun. We suspect

that the present passages each made one such basis salient, namely, the fact that all three

individual entities shared participation in the event being described (e.g., the hurricane hitting the

city). This, together with the closure strategy, would promote selection of the collection of all

three atomic entities as the antecedent of the plural pronoun (cf. Barsalou's, 1983, discussion of

ad hoc categories)..

To our minds, however, the most informative result of Questionnaire 1 is that, while

readers are willing to take an ontologically heterogeneous collection of individuals as the

antecedent of a plural pronoun, they are even more willing to accept an ontologically

homogeneous collection. This result is consistent with the equivalence hypothesis and the closure

strategy. Ontological homogeneity is a salient basis of equivalence, and the fact that 91% of the

occurrences of they following homogeneous passages were interpreted as referring to the

complete collection of entities supports the closure strategy.

Experiment 1

The data of Questionnaire 1 are off-line, even retrospective reconstructions of intended

meanings. Experiment 1 used a self-paced reading task to explore the on-line nature of the

preference for ontologically homogeneous antecedents that was apparent in Questionnaire 1. An

initial set of four sentences like the ontologically-heterogeneous sentences of Questionnaire 1

was followed by a single sentence that used the phrase both of them or two of them in an initial

clause. This sentence continued with a second clause that disambiguated the reference of the

anaphoric phrase to either the ontologically-homogeneous pair of humans or the ontologically-heterogeneous pair of human plus nonhuman that had been introduced in the first four sentences.

If readers initially construct groups of ontologically-homogeneous entities as possible antecedents of the anaphoric phrase, as predicted by the equivalence hypothesis, they will preferably take the anaphoric phrase to refer to the pair of human entities. If such an on-line interpretation is made, then when the second clause of the final sentence disambiguates the anaphoric reference to be the pair of nonhumans, the interpretation must be revised. Such revision will, following standard garden-path logic (Frazier, 1978, 1987; Frazier & Rayner, 1982), result in slower reading than when the second clause permits the initial interpretation to be retained. It is possible, but not necessarily the case, that the phrase <u>two of them</u> will be less likely to require an ontologically-homogeneous antecedent than the phrase <u>both of them</u>, since the term <u>them</u> in the former could be interpreted to refer to the set of all three entities and the term <u>two</u> to pick out an arbitrary two. If this is so, then less disruption of reading should be observed when the final sentence contains <u>two of them</u> than when it contains <u>both of them</u>.

Method

    <u>Materials</u>. Sixteen passages like those indicated in (9) were constructed. Twelve had the same initial four sentences as the ontologically-heterogeneous passages of Questionnaire 1, and four similar passages were constructed in addition. All materials appear in Appendix 1. Each passage had four versions, differing in their last sentence as indicated in (9 a-d). The four versions were defined by the factorial combination of <u>both of them</u> vs <u>two of them</u> as the anaphoric phrase and disambiguation to the ontologically-homogeneous vs. ontologically-heterogeneous antecedent. The former disambiguation was effected (in 9a and c) by mentioning

the nonhuman term as a contrast to the referents of the anaphor; the latter (9b and d) by

mentioning the human term as the contrast.

9.   A hurricane hit the city.

          A famous musician was missing.

          A distinguished novelist disappeared.

          A historic painting also vanished.

          (a) We found both of them quickly but are still looking for the historic painting.

          (b) We found both of them quickly but are still looking for the distinguished novelist.

          (c) We found two of them quickly but are still looking for the historic painting.

          (d) We found two of them quickly but are still looking for the distinguished novelist.

          These 16 passages were embedded in a list of 64 passages, including 16 filler passages

and 32 passages from unrelated experiments, varying in length from two to five sentences. The

nonhuman entity was introduced in the fourth sentence of half the experimental passages, and

earlier in the other half. The 16 filler passages, which were intended to disguise the structure of

the experimental passages, introduced multiple discourse entities and contained a singular

pronoun or a quantifier phrase such as many people. Half of all the passages were followed by a

wh- or yes-no question presented together with two possible answers for the reader to choose,

simply to ensure that readers were attending to the material.

          Participants and procedures. Sixty University of Massachusetts undergraduates

participated in individual half-hour sessions for course credit. They first read a six-passage

practice list to become familiar with the procedures and then read an individually-randomized

version of the 64-passage experimental list. A trial began with the presentation of the word

"ready" on the center of a video monitor controlled by a PC-compatible computer. When the

participant pulled the right-hand trigger on a response console, the first sentence appeared. Each

successive pull of the response trigger caused the sentence to be replaced by the next sentence.

Participants were told to pull the trigger as soon as they had understood a sentence, and

understood that their reading time was being measured. On half the trials, the final sentence was

followed by a simple question with two response alternatives below it. The participant was to

pull a response trigger under the correct alternative.

Results and discussion

The mean reading times for the final sentence in each passage are presented in Table 1,

together with percentage of correct responses. The only significant main effect in the analysis of

reading times indicated faster reading when disambiguation forced an ontologically-

homogeneous antecedent of the plural pronoun (9a, c) than when it forced an ontologically-

heterogeneous antecedent (9b, d), 2768 vs 3008 ms, $F_1(1,59) = 15.92$, $p < .001$, $F_2(1,15) = 6.52$,

$p < .05$. There was no hint that anaphor type affected reading time.

Questions may have been answered more accurately in the homogeneous than the

heterogeneous conditions, although since questions were asked of only half the items the by-

items analysis did not have sufficient power to be significant (92 vs 83%; $F_1(1,59) = 9.50$, $p <$

$.001$; $F_2(1,7) = 3.33$, $p = .11$). If this difference in accuracy is real, it may simply reflect the

reading difficulty subjects experienced in the heterogeneous conditions, which may have

disrupted their comprehension or memory.

The data from Experiment 1 are consistent with the results of Questionnaire 1. Both

indicate that readers prefer an ontologically-homogeneous antecedent for a plural pronoun more

than they favor an ontologically-heterogeneous one. Experiment 1 goes further to suggest that the

homogeneous antecedent is chosen before the end of the sentence containing it. Such an initial

commitment followed by a required revision provides a straightforward account of the reading

disruption observed in the heterogeneous conditions. It is logically possible that interpretation of

the anaphor is delayed until the second clause and that a preference for a homogeneous

antecedent conflicts with the mention of a contrasting human in the heterogeneous conditions.

The present experiment was not designed to distinguish such an alternative from our favored

garden-path account, but we do note that both accounts appeal to interpretation of a plural

pronoun during the reading of the sentence that contains it.

Experiment 1 failed to show a contrast between the two types of anaphors. Such a

contrast would have been consistent with the restricted semilattice model; the word <u>them</u> in <u>two</u>

<u>of them</u> could have been taken to refer to the set of three atomic entities, and <u>two</u> could have

chosen any two of them. Apparently, our readers took <u>two of them</u> instead to refer as a unit to a

pair of entities, just as they did <u>both of them</u>, in which case we would expect the preferred

antecedent to be the ontologically-homogeneous pair, as was observed.

Questionnaire 2

The second questionnaire and experiment extended the concept of equivalence beyond

shared membership in an ontological category to equivalent participation in an event. As

discussed in the Introduction, the most available meaning of a symmetric predicate such as <u>sing</u>

<u>with</u> confers equivalence on its participants. A nonsymmetric predicate such as <u>recognize</u> does

not. Under this analysis, a set of three or more participants in an action described by a symmetric

predicate should be more likely to be identified as a group, a non-atomic discourse entity, than a

set of three or more participants in a nonsymmetric activity. Therefore, according to the

equivalence hypothesis and the closure strategy, a plural pronoun should be more likely to take

the full set of entities to be its antecedent when the entities are introduced as the arguments of a

symmetric predicate than when they are introduced as the arguments of a nonsymmetric

predicate.

Questionnaire 2 determined whether this was the case using the sentence-completion task

described in Questionnaire 1.

Method

Sixteen items like those in (10) were constructed. There were two versions of each,

differing in whether the predicate was symmetric (10a) or nonsymmetric (10b). The materials are

the same as the first sentence of the items used in Experiment 2, which appear in Appendix 2.

10.   (a) Tom sang with Jim and Tony at the school. They _____

        (b) Tom recognized Jim and Tony at the school. They _____

These 16 items were combined with the 12 items described in Questionnaire 1 and randomized

as four forms. Each form contained eight symmetric and eight nonsymmetric items,

counterbalanced across forms. As in Questionnaire 1, an interpretation question was constructed

for each completion item. The interpretation question contained the first sentence of the

completion item plus a parenthesized list of the names that it contained.

Questionnaire 2 was run concurrently with Questionnaire 1, so the same participants and

procedures were used. After completing each item, a participant was asked to read each

interpretation question and circle the two or three names that constituted the intended antecedent

of the plural pronoun <u>they</u> in his or her continuation.

Results and discussion

Participants circled all three entities as the intended antecedent of they more frequently

for items with symmetric predicates than with nonsymmetric predicates, 88 vs 61%, t1(31) =

5.93, t2(15) = 3.63, p < .01. Of the 118 responses that indicated the choice of two entities as the

antecedent of they, 114 chose the two people introduced by the conjoined NP (17/19 in the

symmetric predicate condition, 97/99 in the nonsymmetric predicate condition).

As in Questionnaire 1, there was a substantial frequency of three-item choices in the

nonsymmetric predicate items. From our viewpoint, this simply means that there were other

contextually-salient sources of equivalence among all three entities apart from the equivalence

conferred by the symmetric predicate (e.g., they are all humans referred to by proper names). The

informative result is that predicate symmetry increased the frequency of choice significantly,

supporting our claim about the implications of predicate symmetry as well as the equivalence

hypothesis and the closure strategy.

Experiment 2

Experiment 2 was, like Experiment 1, designed to explore the on-line nature of the

apparent preferences for interpreting a plural pronoun. It was designed to test for a semantic

garden path effect, as we claim was observed in Experiment 1. Two-sentence passages with

initial sentences containing either a symmetric or a nonsymmetric predicate and three entities as

arguments (the same materials used in Questionnaire 2). Each passage then continued with a

temporarily ambiguous occurrence of the pronoun they followed in the next clause by an

occurrence of they all or they both. An example appears in (11).

11.   (a)   Tom sang with Jim and Tony at the school. They were happy because they all did

their best. (symmetric predicate, group of three as antecedent)

(b)   Tom sang with Jim and Tony at the school. They were happy because they both

did their best. (symmetric predicate, group of two as antecedent)

(c)   Tom recognized Jim and Tony at the school. They were happy because they all

did their best. (nonsymmetric predicate, group of three as antecedent)

(d)   Tom recognized Jim and Tony at the school. They were happy because they both

did their best. (nonsymmetric predicate, group of two as antecedent)

According to the restricted semilattice model, the initial they should be preferably

interpreted as having the group of all three entities as an antecedent in the symmetric predicate

condition (11a, b). No clear preference would be predicted in the nonsymmetric predicate case,

since factors not manipulated in the experiment would determine whether all three entities would

constitute an equivalence group and thus be available as an antecedent (the pair of entities

introduced as a NP will always constitute a non-atomic group).

In the second clause, they all, presumably taken to be coreferential with the initial they,

disambiguates the antecedent to be a group of all three entities; they both, on the other hand,

disambiguates it to be a group of two, namely, the group introduced by the NP. In (11a and b),

the group of three people is presumably selected as the antecedent of the initial they, following

the equivalence hypothesis and the closure strategy. The second clause confirms this selection in

(11a). However, in (11b), the selection is disconfirmed. The phrase they both must be taken to

refer to the pair introduced as an NP, forcing a revision of the initial interpretation of they.

Presumably, this revision will appear as a disruption of reading.

In (11c and d), no explicit basis of equivalence is provided, so it is unclear whether the

initial interpretation of <u>they</u> will favor the group of three entities or the group of two. The results

of Questionnaire 1 suggest a very modest preference for the former; however, delayed

interpretation is possible. In any event, there is no reason to expect consistent substantial

disruption in either (11c) or (11d).

Method

Materials. Four versions of each of 16 passages were constructed, illustrated in (11). The

first sentence of each item was the same as used in Questionnaire 2, one version (11a, b) with a

symmetric predicate and the other (11c, d) with a nonsymmetric predicate. The second sentence

came in two versions, one (11a, c) disambiguating the plural pronoun to all three entities as

antecedent and the other (11b, d) disambiguating it to the pair of entities introduced by the NP.

All items appear in Appendix 2. These 16 experimental items were embedded in a list containing

16 filler items designed to make the experimental items less distinctive (containing a quantifier

phrase or a singular pronoun) and 32 items from unrelated experiments. A simple wh- or yes-no

question was made up for half of the items. Four of the eight questions about the experimental

passages questioned the identity of the plural pronoun.

Participants and procedures. Forty-eight University of Massachusetts students

participated in individual half-hour sessions for course credit. After reading a six-item practice

list, each participant received the 64-item list in an individually-randomized order. The

procedures used were the same as those described in Experiment 1.

Results and discussion

The mean reading times for the target (second) sentence of each item, and the accuracy of response to comprehension questions, appear in Table 2.[1] The reading times for sentences that disambiguated the plural pronoun to a group of three (11a, c) were faster than for sentences that disambiguated it to the group of two (11 b, d), 2714 vs. 3129 ms, $F1(1, 44) = 6.10$, $p < .05$; $F2(1, 12) = 9.91$, $p < .01$ (in analyses following recommendations of Pollatsek & Well, 1995, to treat counterbalancing groups as a between-subjects factor). Of greater interest, the interaction between predicate type and pronoun resolution was also significant, $F1(1, 44) = 4.98$, $p < .05$; $F2(1, 12) = 8.08$, $p < .05$. The reading times for the they all group-of-three antecedent condition were faster than those in the they both group-of-two condition when a symmetric predicate was used (11a and b), but the difference between the group-of-three and the group-of-two conditions was nonsignificant when a nonsymmetric predicate was used.

Analyses of the error rates did not yield statistically significant results, perhaps because of the small N involved. There was a tendency toward higher accuracy when the pronoun was disambiguated toward a group-of-three antecedent, 81 vs 72%, $F1(1, 44) = 3.47$, $p < .07$, but $F2(1, 4) = 1.97$, $p > .20$. The four questions that involved the referent of they yielded apparently-lower accuracy (means of 71 and 56% for the group-of-three vs. group-of-two antecedent conditions) than other questions (which averaged 89% correct). If this difference is real, it may simply reflect difficulties in remembering the names of the antecedent entities.

The pattern of the interaction is consistent with the garden-path prediction based on the equivalence hypothesis and the closure principle. It suggests that readers of a symmetric predicate did form an equivalence group of all three entities and chose it initially as the

antecedent of the initial temporarily-ambiguous pronoun. This presumed assignment would have

to be revised in sentences that continued with they both, resulting in the slow reading time of

3390 ms. If no assignment was made in the nonsymmetric predicate case, no slowing would be

expected in either nonsymmetric case. The obtained pattern of results suggests that the plural

pronoun was initially interpreted as taking the group-of-three as antecedent in the symmetric

predicate items but may not have initially been assigned in the nonsymmetric predicate case.

Other interpretations of the data are possible, e.g., consistently delayed interpretation of the

initial pronoun together with conflicting information about interpretation in the symmetric

predicate they both case, but all interpretations do support the predictions of the equivalence

hypothesis and the closure strategy.

General Discussion

The present results establish some conditions on the reference of an ambiguous plural

pronoun (see Sanford & Lockhart, 1990, for earlier discussion of related conditions).

Questionnaire 1 and Experiment 1 demonstrated that a group of atomic discourse entities is more

suitable as the referent of a plural pronoun if the group is ontologically homogeneous than if it is

ontologically heterogeneous. Questionnaire 2 and Experiment 2 demonstrated that a group of

atomic discourse entities is more suitable as the referent of a plural pronoun if the entities had

served as the arguments of a symmetric predicate than a nonsymmetric predicate. These effects

were attributed to a very general principle of equivalence, according to which entities can be

summed into groups that serve as referents of a plural pronoun if they are equivalent with respect

to some salient property. An additional principle, the closure principle, appeared to operate in

Questionnaires 1 and 2 and Experiment 2. Readers seemed to prefer to take a maximal group as

the referent of a plural pronoun in preference to a smaller group that had been introduced as an

NP.

We would like to suggest that these principles operate in two stages. In the first stage,

non-atomic discourse entities (groups) are formed on the basis of the NP rule and the equivalence

principle. The competence that permits the formation of groups is described by Link (1983); the

equivalence principle governs which of the groups that are licensed by a reader's grammatical

competence are formed in the course of understanding a sentence. In the second stage, the reader

selects one group as the preferred referent of a plural pronoun. The closure principle affects this

selection. This two-stage process could begin as soon as multiple entities are introduced into the

discourse, or it could be compressed into the time after the pronoun is read. Considerations of

incremental interpretation suggest that the occurrence of a plural NP will immediately trigger the

creation of a discourse entity to which it could refer, if one does not already exist. Whether the

groups that could be created using the join operation discussed earlier are created before explicit

reference is made to them is an open question. Even though Experiments 1 and 2 recorded

reading time, they were not designed to probe into the initial stages of selecting a referent for a

plural pronoun. They simply determined the initial interpretations of phrases like both of them or

they that readers make during normal reading. Additional experiments will be needed to probe

into the details of when non-atomic discourse entities are created.

The equivalence principle is best viewed as a very general principle whose appeal to

"salience" must be fleshed out on empirical grounds. The present research can be seen showing

that ontological category and predicate symmetry are powerful bases of such salience. We

suspect that the factors that determine salience are unlimited in number. Anything that can be

construed as properties of individuals that are relevant in some situation (which probably is

literally anything; cf. Barsalou, 1983) is probably a potential basis of equivalence. It is therefore

unwise to deny that any collection of entities could possibly serve as the antecedent of a plural

pronoun (a sentence like <u>John hoped to impress Mary with his flashy car, but she thought that</u>

<u>they were both too crude</u> is probably acceptable in certain circumstances). But it is possible,

guided by the equivalence principle, to develop ways of predicting that some property of a

discourse will increase or decrease the likelihood of forming a particular set of entities into a

group that can serve as the referent of a plural pronoun.

The equivalence principle (even supplemented by a complete theory of what makes

properties salient) and the closure principle are surely not the whole story of comprehending

plural pronouns. A complete model of the selection of an referent of a plural pronoun would have

to specify how the processor honors the "binding constraints" (e.g., in <u>John and Joe scratched</u>

<u>them</u>, <u>them</u> cannot refer to <u>John and Joe</u>; the sentence would require <u>themselves</u>). It would

specify how bound anaphors are understood (e.g., <u>All the cats flicked their tails</u>, the pronoun

<u>their</u> picks out the tail of each individual cat, not the group of cat-tails; cf Frazier & Clifton,

2000). It would specify how pronouns interact in determining reference (e.g., in <u>Although John</u>

<u>sang with Jim and Mary, he did not think highly of them</u> the <u>he</u> prevents <u>them</u> from referring to

the maximal group)[2]. It would introduce the topic of generic uses of pronouns (raised by

reviewers of the present paper). Consider <u>The terminal cancer patient was told by his family</u>

<u>physician and his oncologist that there was no way of knowing how much longer he would live.</u>

<u>But they always tell cancer patients that.</u> We conjecture that these uses depend on the use of the

generic present tense, perhaps even quantified over time (in the example, by <u>always tell</u>; if the

example had read <u>They always told cancer patients that</u> we suspect <u>they</u> would be taken to refer

to the family physician and the oncologist). We conjecture further that interpreting <u>they</u> as

generic requires inferring a set of individuals to quantify over (a "restrictor" in Heim's, 1982,

sense, which specifies that the individuals of whom something is "always" predicated constitute

the set of physicians who deal with cancer) (see Frazier, 1999, for further discussion). This

inference might take extra reading time compared to the case in which <u>they</u> can refer to an

already-constructed group or support the construction of such a group.

A complete theory of plural pronoun comprehension would also specify whether

centering phenomena that seem to be so important in the comprehension of singular pronouns

(Gordon & Chan, 1995) play a role in plural pronoun processing and whether they interact with

the principles we have discussed here. It seems likely that they do. Consider (12):

(12)   a. Jim was singing with Tom and Tony. They ____

         b. Tom and Tony were singing with Jim. They ____

The plural pronoun may be more likely to take the maximal antecedent (the group of Jim, Tom,

and Tony) in (12a) than in (12b) because the occurrence of the NP <u>Tom and Tony</u> in subject/topic

position in (12b) makes it an attractive antecedent, possibly overriding the closure principle. A

complete theory of plural pronoun comprehension would specify how discourse properties such

as perspective affect interpretation. Koh (2001) found some suggestive but not statistically

significant evidence that embedding a sentence like (13c) in a context like (13a) rather than (13b)

made it relatively more difficult to force the plural pronoun <u>they</u> to refer to the non-maximal

group <u>Ben and Frank</u>. The external perspective represented by (13a) may provide a salient basis

for equivalence among all the entities it encompasses. A complete theory would take a position

on how the content of a pronoun (e.g. gender marking, in a language that marks plural gender or

in plural definite NPs such as the boys) and its phonological markedness (e.g., whether it was

accented) affect plural pronoun interpretation, as Bosch (1988) has done for singular pronouns.

(13)   a. Here is what I observed.

        b. Here is what happened.

        c. Anthony met Ben and Frank in the park.

        We have presented far less than a complete theory of plural pronoun comprehension.

However, we believe we have demonstrated phenomena that require principles like equivalence

and closure to understand, and we propose that these principles will prove to form the core of an

adequate theory of how a reader or listener determines the reference of a plural pronoun.

Appendices

Appendix 1. Materials used in Experiment 1. Alternative forms of anaphor separated by /; homogeneous vs. heterogeneous resolution also separated by /. The items used in Questionnaire 1 had identical content as the first four sentences of each item, apart from the substitution of a human term for the nonhuman term in the homogeneous condition.

1. When the house was burning down, John entered it. He called his son. He called his daughter. He also searched for his briefcase. He saved both/two of them but lost his briefcase/his son.

2. Bill was ready to leave. Finally he wanted to kiss his son. He wanted to see his wife. He also wanted to see his dog. He saw both/two of them but he couldn't see his dog/son.

3. A violent earthquake suddenly hit the town. A promising young researcher was missing. A college student disappeared. A horse was also gone. We found that both/two of them were alive but the horse/researcher was dead.

4. A bomb exploded near the town hall. A young politician got some splinters of the bomb in the brain. A beautiful actress had her backbone broken. A dog also got a lot of splinters in its body. Both/Two of them died in an hour but the dog/politician survived.

5. Tom headed toward his car.He intended to take his young child. He intended to take his pretty niece. He also intended to take his identification. He took both/two of them but left his identification/young child.

6. A reporter saw a small house collapse. The fireman tried to rescue a child. He tried to rescue an old man. He also tried to rescue a cat. Both/Two of them were rescued quickly and the cat/old man was rescued in two hours.

7. The dam downtown burst. A young promising actor disappeared. A minister disappeared. A

box of jewels was also swept away. We found both/two of them in a day but couldn't find the box

of jewels/minister.

8. An airplane slid off the runaway after landing. An airport employee was burnt severely. A

passenger had his neck broken. A dog also got burnt severely. Both/Two of them recovered but

the dog/employee died.

9. A terrible truck accident occurred. A famous bookstore was damaged. The truck driver died on

the spot. An old passerby was also hit. The insurance company paid for both/two of them but

didn't pay for the bookstore/truck driver.

10. An explosion occurred at a construction site last week. One generator broke down. The

foreman died. The director was also severely hurt. The company replaced both/two of them

quickly and replaced the generator/director in a week.

11. A hurricane hit the city. A historic painting vanished. A famous musician was missing. A

distinguished novelist also disappeared. We found both/two of them quickly but are still looking

for the historic painting/distinguished novelist.

12. An avalanche came down from the mountain. A stallion was buried in snow. An old doctor

disappeared. A young fireman was also missing. Both/Two of them were rescued but the

stallion/doctor is still missing.

13. A military boat overturned. A secret weapon disappeared. A general was missing. A

commander was also missing. The military pulled up both/two of them but couldn't find the

secret weapon/commander.

14. A train derailed in the Midwest. A local restaurant was damaged. A pretty girl had her head

damaged. An old passenger also had his legs broken. The train company compensated both/two

of them for loss but didn't pay the local restaurant/pretty girl.

15. A tornado passed through a small village. A famous old tower disappeared. A famous doctor

was missing. A well-known actor also vanished. We located both/two of them in two days but

couldn't locate the tower/doctor.

16. A landslide hit a rural village. An important document was buried. A young child was buried.

   An old man was also buried. Both/Two of them were dug up soon but the document/young

child was not found.

Appendix 2. Materials used in Experiment 2. Symmetric and nonsymmetric verbs are separated

by /, as are all/both. Items used in Questionnaire 2 were identical to the first sentence of these

items.

1. Tom sang with/recognized Jim and Tony at the school. They were happy because they all/both

did their best.

2. Jerry sailed with/guided Mike and George to New Zealand. They were excited that they were

all/both together.

3. Charlie went shopping with/picked up Dan and Marvin yesterday. They were upset because

they were all/both made fun of by a passerby.

4. Brett discussed the decrease in sales with Sandy and Steve/talked to Sandy and Steve about

the decrease in sales. They were worried because they might all/both be demoted by their boss.

5.   Neil went to a flea market with Brian and Arnie/spotted Brian and Arnie at the flea market.

They were annoyed because they were all/both ignored by a merchant.

6.   Ervin had dinner with Terry and Jeffrey last night/treated Terry and Jeffrey to dinner last

night. They became serious because they were all/both shocked by the news about Bosnia.

7. Keith worked with Eric and Gasper/found a job for Eric and Gasper. They were paid well because they were all/both excellent salesmen.

8. Bob played with/spoke to Chuck and Daniel out in the playground. They were unhappy because they were all/both kicked out of the gym by the teacher.

9. Alissa went to the party with Carol and Erica last night/invited Carol and Erica to the party last night. They were tired because they were all/both questioned by a group of reporters.

10. Betty jogged with/followed Joan and Karen around the campus. They were upset because they had all/both been stopped by a policeman.

11. Laura took a train with Ann and Barbara yesterday/saw Ann and Barbara in a train yesterday. They were excited because they were all/both going to the Grand Canyon.

12. Lisa swam with Lynne and Melissa last week/invited Lynne and Melissa to the pool last week. They were upset because they were all/both laughed at by a lifeguard.

13. Nancy chatted with/telephoned Stacey and Rachel last night. They were very talkative because they were all/both happy about their success.

14. Martha walked with Linda and Claire in the park/accompanied Linda and Claire to the park. They were silent because they were all/both very bored.

15. Jen traveled to Paris with Kathleen and Emma/took Kathleen and Emma to Paris. They were happy because they were all/both very satisfied with the trip.

16. Melanie met with/greeted Lydia and Maureen at the town meeting last week. They were pleased because they were all/both elected as committee members.

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Author Note

Footnotes

1. After the first eight participants were tested, an error was discovered in the segmentation of two items. The reading times for these items were excluded when computing mean reading times for these subjects. Since the two items were in different counterbalancing groups, half of the mean reading times for these first eight subjects were based on three, not four, items.

2. We thank Simon Garrod for pointing out examples like this.

Table 1: Reading time (ms) for target sentence and percentage of correct responses to questions,

Experiment 1

Anaphor form	Disambiguation (type of antecedent)	
	Homogeneous	Heterogeneous
both of them	2791 (93%)	3042 (83%)
two of them	2745 (90%)	2973 (83%)

Table 2: Reading time (ms) for target sentence and percentage of correct responses to questions,

Experiment 2

Predicate Type	Antecedent of Pronoun	
	Three entities (all)	Two entities (both)
Symmetric	2677 (81%)	3390 (70%)
Nonsymmetric	2750 (90%)	2869 (74%)

Figure Caption

Figure 1. An illustrative semilattice, showing the atomic discourse entities a, b, and c, together

with the possible non-atomic discourse entities.