# Man and Woman: the Last Obstacle for Boolean Coordination

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**Abstract**

The word *and* can be used both intersectively and collectively. A major theme in research on coordination has been the quest for a lexical entry that unifies these uses, either based on boolean intersection or based on collective formation. Focusing on English noun-noun coordination, this paper argues for the boolean option. This immediately delivers the intersective behavior of *and*, as in *liar and cheat*; as for its collective behavior, as in *man and woman*, it falls out of the interaction of *and* with a series of independently motivated type shifters, mainly taken from Winter (2001). Such coordinations are interpreted collectively because the two nouns are interpreted in the same way as the DPs in *a man and a woman*.

## 1 Introduction

The word *and* can be used both intersectively, as in the sentences in (1), and collectively, as in the sentences in (2). This paper focuses on noun-noun conjunction in English, which also shows both intersective and collective behavior. For example, sentence (1b) is about a person in the intersection of the sets denoted by the predicates *liar* and *cheat*, while sentence (2b) is about a collective entity formed by a man and a woman.

(1) a. John **lies and cheats**. *(intersective)*
    b. That **liar and cheat** can not be trusted. *(intersective)*

(2) a. **John and Mary** met in the park last night. *(collective)*
    b. A **man and woman** met in the park last night. *(collective)*

A major theme in research on coordination has been the quest for a lexical entry that unifies such uses, either based on boolean intersection, as for example by Gazdar (1980), or based on "non-boolean" set/sum formation, as for example by Heycock and Zamparelli (2005). Many authors also assume that *and* is lexically ambiguous between the two uses (e.g., Link, 1984).

The purpose of this paper is to argue for the boolean option, that is, for the idea that *and* invariably denotes generalized intersection. This immediately delivers the intersective behavior of *and*, as in (1). For example, the coordination in (1b) is predicate intersection:

(3) $[\![\text{liar and cheat}]\!] = \lambda x.\mathbf{liar}(x) \wedge \mathbf{cheat}(x)$

As for the collective behavior of coordination, as in (2), I will show that it emerges as a consequence of the interaction of *and* with a series of independently motivated type shifters. Coordinations like *man and woman* are interpreted collectively because the two nouns are interpreted in the same way as the DPs in *a man and a woman*.

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## 2 Analysis: Boolean *And* plus Type Shifters

I assume that *and* always has the meaning in (4), suggested among others by Gazdar (1980). Following Winter (2001), I will refer to this as the "boolean assumption". Roughly, Gazdar's entry says that a conjunction of sentences $S_1$ *and* $S_2$ is true whenever both of the conjuncts are true, and a conjunction of subsentential constituents $C_1$ *and* $C_2$ denotes their intersection.

(4) $$[\![\text{and}_{bool}]\!] = \sqcap_{\langle \tau, \tau\tau \rangle} =_{def} \begin{cases} \wedge_{\langle t, tt \rangle} & \text{if } \tau = t \\ \lambda X_\tau \lambda Y_\tau \lambda Z_{\sigma_1}. X(Z) \sqcap_{\langle \sigma_2, \sigma_2\sigma_2 \rangle} Y(Z) & \text{if } \tau = \sigma_1\sigma_2 \end{cases}$$

I build on Winter (2001), who does not consider noun-noun conjunction but who shows that the boolean option is viable in related cases, such as the collectivity effect in the VP of (2a). Winter's account relies on the insight that one can use the minimizer in (5) to "distill" any intersection or union of principal ultrafilters into a set of sets of their generators.

(5) **GQ minimizer:** $\min =_{def} \lambda Q_{\tau t} \lambda A_\tau.\ A \in Q \wedge \forall B \in Q[B \subseteq A \rightarrow B = A]$

For example, the intersection of the generalized quantifiers that are obtained by Montague-lifting the two constants corresponding to *John* and *Mary* is $\{P \mid j \in P\} \cap \{P \mid m \in P\}$, the set of all properties that hold both of John and of Mary. The result of applying the minimizer in (5) to this set is $\{\{j, m\}\}$. Following Winter, I represent plural individuals as sets, so this is the property of being the plural individual consisting of John and Mary. This is one of the two properties involved in sentence (2a); the other is denoted by the VP and is a property of sets who met in the park last night. The meaning of (2a) can then be obtained by combining these two properties via the silent existential-closure type-shifter E defined in (6), whose meaning is the same as the meaning of the determiner *a*: it states that the intersection of the two properties it combines with is not empty. As Winter discusses in detail, one can also think of E as a generalization of independently-needed choice-functional operators. The fact that choice-functional operators are generally taken to apply to nouns makes it a natural assumption to apply E to nouns as well, as I will do below.

(6) **Existential-closure type-shifter:** $E =_{def} \lambda P_{\tau t} \lambda Q_{\tau t}.\ P \cap Q \neq \emptyset$

Given these assumptions, Winter analyses the subject of sentence (2a) as in (7), a property which is true of any set that contains the plural individual consisting of John and Mary. This gives the right truth conditions once it combines with the VP, as shown here:

(7) $[\![\text{E}(\min(\lambda P.P(\text{john}) \cap \lambda P.P(\text{mary})))]\!] = \lambda C_{\langle et,t \rangle}.\{j, m\} \in \text{C}$

Turning now to noun-noun coordination, which Winter (2001) does not discuss, I assume that the coordination *man and woman* in (2b) involves the two silent operators just presented, but in a different order. Specifically, I assume that E may apply to nominal predicates without affecting their syntactic category. So it can apply to a nominal like *man* and return another nominal, which I assume it does here (on both sides of the conjunction). The standard assumption is that coordination does not affect syntactic categories, so the result of coordinating E(man) with E(woman) is again a nominal. At this stage, the denotation of *man and woman* is the same as the denotation of the noun phrase *a man and a woman*, although their syntactic categories differ. The denotation results from intersecting the generalized quantifier $\lambda P.\exists x.\text{man}(x) \wedge P(x)$ with the generalized quantifier $\lambda P.\exists x.\text{woman}(x) \wedge P(x)$. The result is the following:

(8) $[\![\text{E(man) and E(woman)}]\!] = \lambda P_{et} \exists x \exists y.\mathbf{man}(x) \wedge \mathbf{woman}(y) \wedge P(x) \wedge P(y)$

With Winter, I assume that a nominal predicate of type $\langle et, t\rangle$ must first be "distilled" before it can be used further, in this case as the restrictor of the (overt) determiner *a*. As in the previous case, this is achieved by the minimization operator. Conceptually, here as before, the input to this operator is a generalized quantifier over ordinary individuals, and its output is a predicate over collective individuals. In this case, assuming (as I will throughout the paper for convenience) that the set of men and the set of women are disjoint, the output is the predicate that holds of any man-woman pair:

(9) $[\![\text{min}(\text{E(man)} \cap \text{E(woman)})]\!] = \lambda P_{et} \exists x \exists y.\mathbf{man}(x) \wedge \mathbf{woman}(y) \wedge P = \{x, y\}$

From here on, I will abbreviate this collective predicate as **mw-pair**.

As mentioned, I model collective predicates as set predicates of type $\langle et, t\rangle$. Ordinary determiners expect their restrictor and their nuclear scope to be of type $\langle et\rangle$. To combine with $\langle et\rangle$-type predicates, I assume following Winter that determiners are adjusted via the determiner fitter *dfit*, defined as follows:

(10) **Determiner fitter:** $\text{dfit} =_{def} \lambda D_{\langle et,\langle et,t\rangle\rangle} \lambda A_{\langle et,t\rangle} \lambda B_{\langle et,t\rangle}.D(\bigcup A)(\bigcup(A \cap B))$

Winter motivates this operator by sentences like (11), in which the collective predicate *met* is an argument of a quantificational determiner.

(11) No students met.

To see how determiner fitting works, note first that the plural morpheme on *students* is modeled by Winter by a "predicate distributivity" (*pdist*) operator, whose function is similar to the well-known * and D operators in the literature on plurals (e.g. Link (1998)) but which also prepares ordinary $\langle et\rangle$-type predicates for determiners that have been adjusted for collective predicates via determiner fitting. The *pdist* operator is defined as follows:

(12) **Predicate distributivity:** $\text{pdist} =_{def} \lambda P_{et} \lambda P'_{et}.P' \neq \emptyset \wedge P' \subseteq P$

Using the operators (10) and (12), Winter analyzes sentence (11) in terms of the meanings of singular *no* and *student*. Its meaning is predicted to be "No student is a member of a set of students that met".

(13)
$$
\begin{aligned}
&[\![\text{dfit(no)(pdist(student))(met)}]\!]\\
&= [\![\text{no}]\!](\bigcup \text{pdist}([\![\text{student}]\!]))(\bigcup (\text{pdist}([\![\text{student}]\!]) \cap [\![\text{met}]\!]))\\
&= [\![\text{no}]\!]([\![\text{student}]\!])(\bigcup \{P \in [\![\text{met}]\!] : P \subseteq [\![\text{student}]\!]\})\\
&= \neg\exists x.\ [\mathbf{student}(x)\ \wedge \exists P.\ x \in P \wedge P \in \mathbf{meet} \wedge \forall y.y \in P \rightarrow \mathbf{student}(y)]
\end{aligned}
$$

Given this, my LF for sentence (2b) is shown in (14). It is true iff its VP, the collective predicate *met in the park*, holds of at least one man-woman pair.

(14)
$$
\begin{aligned}
&[\![\text{dfit(a)(min(E(man) and E(woman))(meet\_in\_the\_park)}]\!]\\
&= \exists(\bigcup \mathbf{mw\text{-}pair})(\bigcup(\mathbf{mw\text{-}pair} \cap \mathbf{meet\_in\_the\_park}))\\
&= \exists x.\exists y.\mathbf{man}(x) \wedge \mathbf{woman}(y) \wedge \mathbf{meet\_in\_the\_park}(\{x, y\})
\end{aligned}
$$

The semantics of *dfit* ensures that this sentence requires the man and the woman in question to have been part of the same meeting, as opposed to having each met separate people. If we had not used *dfit*, we would have predicted weaker truth conditions. The sentence would already be true if a man met some other men in the park, and a woman met some other women in the park in a separate meeting. So the assumption is crucial that determiners expect their arguments to be of type $\langle et \rangle$, and that they adjust via *dfit* when their arguments are of type $\langle et, t \rangle$.

Of course, noun-noun coordination does not require the VP to be collecitve. A sentence like (15a), with a distributive predicate in the VP, is represented as in (15b). Here, *pdist* and *dfit* make sure that the property of smiling is distributed over the two elements of any man-woman pair that makes the sentence true.

(15) a. A man and woman smiled.
b. $[\![\text{dfit(a)(min(E(man) and E(woman))(pdist(smile))}]\!]$
$= \exists x.\exists y.\mathbf{man}(x) \wedge \mathbf{woman}(y) \wedge \{x, y\} \subseteq \mathbf{smile}$

# 3 Comparison to Previous Work

Like any system that adopts a uniform meaning for *and*, this one avoids redundancy, which improves on Link (1984). Since the meaning I adopt is boolean, it generalizes to S, VP, and DP coordinations without problems (Gazdar, 1980). This improves on Heycock and Zamparelli (2005), one of the few journal-length treatments of the semantics of noun-noun coordination. Noun-noun coordination is discussed in Winter (1995) and Winter (1998) though not in Winter (2001). The present system is vastly different from the treatment of noun-noun coordination in Winter (1998). I now discuss Heycock and Zamparelli (2005) and Winter (1998) in more detail.

## 3.1 Heycock and Zamparelli (2005)

Heycock and Zamparelli (2005) adopt a non-boolean entry for *and* that is equivalent to the one in (16). Essentially, this entry combines two sets of sets by computing their cross-product, except that instead of putting any two elements together to form a pair, it forms their union. Heycock and Zamparelli (2005) call this operation *set product* in reminiscence of the notion of cross-product.

(16) $[\![\text{and}_{coll}]\!] = \lambda Q_{\langle \tau t, t \rangle} \lambda Q'_{\langle \tau t, t \rangle} \lambda P_{\tau t} \exists A_{\tau t} \exists B_{\tau t}.\ A \in Q \wedge B \in Q' \wedge P = A \cup B$

Heycock and Zamparelli (2005) assume that nouns and VPs denote sets of singletons. For example, the noun *man* denotes the set of all singletons of men, $\lambda P.|P| = 1 \wedge P \subseteq \mathbf{man}$. When the nouns *man* and *woman* are conjoined, the entry in (16) generates the following denotation:

(17) $[\![\text{man and}_{coll}\text{ woman}]\!]$
$= \lambda P_{et} \exists A_{et} \exists B_{et}.\ |A| = 1 \wedge A \subseteq \mathbf{man} \wedge |B| = 1 \wedge B \subseteq \mathbf{woman} \wedge P = A \cup B$
$= \lambda P_{et} \exists x \exists y.\ \mathbf{man}(x) \wedge \mathbf{woman}(y) \wedge P = \{x, y\}$

This denotation is equivalent to the one my system generates, as seen in (9). In this respect, my system can be seen as a reconstruction of the one in Heycock and Zamparelli (2005) from first principles. But there is an important difference. I assume that all instances of *and* are boolean while Heycock and Zamparelli assume that all instances of *and* have the non-boolean denotation in (16). The latter assumption leads to problems when quantifiers are conjoined that are not upward entailing, as in the following cases:

(18) a. No man and no woman smiled.
b. Mary and nobody else smiled.

Assume first, as Heycock and Zamparelli do, that the simplex DPs are treated as generalized quantifiers, as shown in (19) for *no man* (the unusual types are due to the assumption that nouns denote sets of singletons):

(19) $[\![\text{no man}]\!] = \lambda Q_{\langle et,t\rangle}.\neg\exists X_{\langle et\rangle}.[\![\text{man}]\!](X) \wedge Q(X)$

Heycock and Zamparelli predict that the complex DP in (18a) holds of the union of any set **A** containing no man and any set **B** containing no woman. As **A** may contain women and **B** may contain men, the resulting truth conditions are too weak. For example, (18a) is true in a model that contains a smiling man called John, a smiling woman called Mary, and no other smilers. This is for the following reason. The entry for *no man* in (19) holds of the set containing nothing but the singleton of Mary, since that set contains no man; the corresponding entry for *no woman* holds of the set containing nothing but the singleton of John since that set contains no woman. According to entry (16), the DP in (18a) therefore holds of the union of these two sets, namely, the set containing nothing but the singletons of John and of Mary. But this set is precisely the denotation of *smiled* in this model. For analogous reasons, (18b) is predicted to be true in this model (assuming that *nobody else* in this context means *nobody other than Mary*).

Heycock and Zamparelli are aware of this problem and suggest that scope-splitting analyses of *nobody*, as proposed by Ladusaw (1992) and others for languages with negative concord, might help here. On these analyses, the lexical entry of *no* is separated into one part that contains only $\neg$ and another part that contains everything else including $\exists x$, and the negation part is free to take scope in a higher position than the rest. But adopting such an approach would wrongly predict that (18b) means the same as *It's not the case that Mary and someone else smiled.* That sentence, unlike (18b), is true when Mary didn't smile but someone other than Mary smiled. And of course, standard English does not have negative concord, so adopting a split-scope analysis of *no* is not an available option for standard English.

## 3.2 Winter (1995, 1998)

In contrast to Winter (2001) discussed above, earlier work including Winter (1995) and Winter (1998, ch. 8) discusses noun-noun coordination, which is taken to require a departure from the boolean assumption. In that work, *and* always returns the denotations of its two conjuncts as an ordered pair. For example, *man and woman* is translated as the ordered pair in (20).

(20) $[\![\text{man and woman}]\!] = \langle \lambda x.\mathbf{man}(x), \lambda x.\mathbf{woman}(x)\rangle$

When such a pair combines with other items in the tree, it is first propagated upwards in a style reminiscent of alternative semantics (e.g., Rooth, 1985), in the sense that each of the two computations proceeds in parallel with the other. At any point in the derivation, this ordered pair can be collapsed back into a single denotation by application of $\sqcap$ as defined in (4). When this operation happens immediately, it mimics the behavior of boolean *and*; the reason for introducing it is to give *and* the possibility to take arbitrarily wide scope. As Winter (1998) demonstrates, this leads to the right results in cases like (21), which is ambiguous between readings (21a) and (21b).

(21) Every linguist and philosopher knows the Gödel Theorem.
  a. Everyone who is both a linguist and a philosopher knows the Gödel Theorem.
  b. Every linguist knows the Gödel Theorem, and every philosopher knows the Gödel Theorem.

In Winter (1998)'s analysis of (21), if $\sqcap$ is introduced immediately, this leads to the reading in (21a); if it is introduced after the conjuncts have combined with the determiner and optionally with the VP, the reading in (21b) is generated. On the present account, reading (21a) is obtained by intersection; reading (21b) is obtained by insertion of the type shifters E, *min*, and *dfit* as demonstrated in the discussion of *man and woman* above.

However, the delayed introduction of intersection in Winter (1998) overgenerates. For example, the system does not prevent *No girl sang and danced* from meaning *No girl sang and no girl danced*. To see this, consider the following derivation:

(22) a. $[\![\text{sang and danced}]\!] = \langle \lambda x.\mathbf{sing}(x), \lambda x.\mathbf{dance}(x)\rangle$
b. $[\![\text{no girl}]\!] = \lambda P.\neg\exists x[\mathbf{girl}(x) \wedge P(x)]$
c. $(22b)((22a)) = \langle \neg\exists x[\mathbf{girl}(x) \wedge \mathbf{sing}(x)], \neg\exists x[\mathbf{girl}(x) \wedge \mathbf{dance}(x)]\rangle$
d. Application of $\sqcap$: $\neg\exists x[\mathbf{girl}(x) \wedge \mathbf{sing}(x)] \wedge \neg\exists x[\mathbf{girl}(x) \wedge \mathbf{dance}(x)]$

The problem here is similar to the one facing early accounts of VP coordination in Transformational Grammar via conjunction reduction. By allowing the subject to enter the computation twice and by giving *and* scope over it, such accounts overgenerate in many cases where the subject is a quantifier. The present system avoids this problem since *and* is interpreted as local, not delayed, intersection. A sentence like *No girl sang and danced* is interpreted simply by intersecting *sang* and *danced* locally.

To be sure, intersecting *sang* and *danced* locally is also a possible derivation in Winter (1998). The present account must be prevented from overgenerating by blocking the application of type shifters like E to verbs, like *sang* and *danced*. For this reason, I assume that the distribution of type shifters and other silent operators is not free but is constrained by syntax, just like the distribution of ordinary words. This assumption is discussed and defended at length in Winter (2001). Of course, one could adopt the system of Winter (1998) by constraining the application of $\sqcap$ syntactically as well, for example by requiring pairs to be collapsed at certain nodes including VP. However, one might then as well adopt the present system and avoid the departure from the boolean hypothesis.

# 4 *And* vs. *Or*

Most authors who adopt the boolean analysis of coordination assume that it applies in equal ways to *and* and *or*. I will assume the same here. That is, I adopt the following entry for *or* based on Gazdar (1980), analogous to the boolean entry for *and* shown in (4):

(23) $$[\![\text{or}_{bool}]\!] = \sqcup_{\langle \tau,\tau\tau\rangle} =_{def} \begin{cases} \vee_{\langle t,tt\rangle} & \text{if } \tau = t \\ \lambda X_\tau \lambda Y_\tau \lambda Z_{\sigma_1}.X(Z) \sqcup_{\langle \sigma_2,\sigma_2\sigma_2\rangle} Y(Z) & \text{if } \tau = \sigma_1\sigma_2 \end{cases}$$

Bergmann (1982) challenges the boolean analysis based on examples that involve noun-noun coordination. The puzzle Bergmann raises is the following: Why are the sentences in (24a) equivalent while those in (24b) are not? The purpose of this section is to provide a solution for Bergmann's puzzle.

(24) a. Every cat and dog is licensed. $\Leftrightarrow$ Every cat or dog is licensed.
b. A cat and dog came running in. $\not\Leftrightarrow$ A cat or dog came running in.

For the sentences in (24a), the present system generates (among others) two equivalent LFs, shown in (25) and (26) along with their translations. For convenience, I treat the VPs *came* *running in* and *be licensed* as unanalyzed predicates. They are distributive predicates, or atom predicates in the sense of Winter (2001), which means that they do not by themselves trigger determiner fitting. The application of *dfit* in (25a) is triggered by the type of the collective predicate *cat and dog*, which is treated in the same way as *man and woman* above. In a slight departure from Winter (1998), who assumes that applying *dfit* changes the pronunciation of *every* to "all", I assume that the pronunciation of *every* is not affected when the conjoined DPs are singular.

(25) a. dfit(every)(min(E(cat) and E(dog)))(pdist(be_licensed))
b. $\bigcup\{\{x,y\}|\mathbf{cat}(x) \wedge \mathbf{dog}(y)\} \subseteq \bigcup\{\{x,y\}|\mathbf{cat}(x) \wedge \mathbf{dog}(y) \wedge \{x,y\} \subseteq \mathbf{be\_licensed}\}$

(26) a. every(cat or dog)(be_licensed)
b. $\mathbf{cat} \cup \mathbf{dog} \ \subseteq\ \mathbf{be\_licensed}$

The translations in (25b) and (26b) are equivalent, as the reader may verify. As for the sentences in (24b), there is no way to generate equivalent LFs for them. For example, the LFs in (27a) and (28a) correspond to the most prominent (if not the only) readings of the two sentences in (24b), and they evaluate to the nonequivalent formulae in (27b) and (28b).

(27) a. dfit(a)(min(E(cat) and E(dog)))(pdist(come_running_in))
b. $\exists x \exists y.\mathbf{cat}(x) \wedge \mathbf{dog}(y) \wedge \{x,y\} \subseteq \mathbf{come\_running\_in}$

(28) a. a(cat or dog)(come_running_in)
b. $\exists x.(\mathbf{cat}(x) \vee \mathbf{dog}(x)) \wedge \mathbf{come\_running\_in}(x)$

## 5 The Non-Ambiguity of *Or*

Unlike *and*, which is descriptively ambiguous between intersective and "non-boolean" uses, *or* has no such seeming ambiguity in any known language (Payne, 1985). As Winter (2001) emphasizes, this provides strong motivation against accounts that attribute collective uses of *and* to this word being ambiguous between a boolean and a non-boolean entry, since such accounts provide no explanation of the fact that *or* is not ambiguous in the same way. The type-shifting account of Winter (2001) provides a general answer to this question. Interestingly, this answer also extends to the present system. As discussed above, I have assumed that a surface string of the shape *N1 and N2* can correspond to the two LFs "N1 ⊓ N2" and "min(E(N1) ⊓ E(N2))". These two structures have completely different meanings. This explains why *and* sometimes looks like intersection and sometimes like collective formation. As for noun-noun disjunction, however, the situation is different. I assume that the same structures are generated: "N1 ⊔ N2" and "min(E(N1) ⊔ E(N2))". You might expect that this incorrectly predicts that *or* is ambiguous in an analogous way to *and*. But these two structures evaluate to almost the same thing, and because of determiner fitting, the remaining difference between them disappears in the course of the rest of the derivation. While "N1 ⊔ N2" underlies the derivation in (26), "min(E(N1) ⊔ E(N2))" underlies the following derivation, which is equivalent to (26).

(29) dfit(every)(min(E(cat)) ⊔ min(E(dog)))(pdist(be_licensed))
$= \text{dfit(every)}(\text{min}(\{P|P \cap \mathbf{cat} \neq \emptyset \vee P \cap \mathbf{dog} \neq \emptyset\})(\{P|P \neq \emptyset \wedge P \subseteq \mathbf{be\_licensed}\})$
$= \bigcup\{\{x\}|x \in (\mathbf{cat} \cup \mathbf{dog})\} \subseteq \bigcup(\{\{x\}|x \in (\mathbf{cat} \cup \mathbf{dog})\} \cap \{P|P \neq \emptyset \wedge P \subseteq \mathbf{be\_licensed}\}$
$= (\mathbf{cat} \cup \mathbf{dog}) \subseteq ((\mathbf{cat} \cup \mathbf{dog}) \cap \mathbf{be\_licensed})$
$= (\mathbf{cat} \cup \mathbf{dog}) \subseteq \mathbf{be\_licensed}$

## 6 Summary and Outlook

The boolean option is arguably the only unproblematic one outside the DP; I have shown that it is also preferrable within the DP. The intersective behavior is expected. The collective behavior comes for free in the framework of Winter (2001), where we already have in place the right set of operators to generate collectivity effects. The system sketched here can be easily extended to handle plural nouns, which raise counting-related issues (e.g. *Ten men and women got married today*), and as my anonymous reviewer points out, also to "hydras" such as *every man and woman who met at the concert* (Link, 1984). As I will discuss elsewhere, accounting for related patterns across languages, discussed by Heycock and Zamparelli (2005) and references therein, leads to interesting questions about the semantics and scope of plural and agreement morphemes.

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