

## Information Dependency in Quantificational Subordination

The purpose of this paper is to show that the received view of the problem of quantificational subordination is incorrect, and that, consequently, existing solutions do not succeed in explaining the facts. On the received view within dynamic semantic frameworks, the determiners treated as universal quantifiers such as *all*, *every*, and *each* behave as barriers to intersentential anaphora, yet allow anaphoric accessibility in a number of situations. We will term such determiners ‘universal determiners’ in what follows. Two basic approaches to these situations can be found in the literature. The first accepts that these logical operators are intrinsically barriers to anaphora, adding extra machinery (e.g. antecedent accommodation in Roberts 1989, 1996) to extract information from under the operators in cases in which anaphora is possible. The second denies that these operators are in fact anaphora barriers, and reconstructs their semantics so that information in their scope can be released, as in Kibble 1996. In this paper, we consider quantificational subordination as a test case. We adopt the second approach outlined above and propose a formalism for determiners that can account for the release of information necessary for anaphora (section 2). We further argue that subordination is not a unified phenomenon, and that in order to make distinctions between different types of quantificational subordination, a mechanism for *information attachment* is required; in our theory, this mechanism is based on accounts of rhetorical relations in SDRT (Segmented Discourse Representation Theory; cf. Asher 1993 and Asher & Lascarides 2003); the account is presented in section 3. Finally, in section 4, we discuss some implications of this approach for subordination involving modals.

### 1. Quantificational Subordination De-Generalized

The following discourses exemplify the phenomenon of quantificational subordination. In discourses like these, pronouns can access information introduced under the scope of determiners like *every* and *each*, contrary to the predictions of (classical) dynamic theories like DRT.

- (1) a. Every hunter that saw *a deer* shot *it*.  
b. *It* died immediately.  
c. \* *It* was a female.  
d. \* *He* intended to kill *it*.
- (2) a. *Each man* loves a woman.  
b. { *They* send / *He* sends } her flowers.
- (3) a. *Every chess* set comes with a spare pawn. (B. Partee, in Roberts 1987)  
b. *It* is taped to the top of the box.

On approaches of the first type (e.g. Roberts 1989, 1996; Frank 1997; Geurts 1999; Poesio & Zucchi 1992), the felicity of discourse subordination between two informational constituents is tied to the availability of a mechanism which extracts information from the first constituent and interprets the second with respect to that information. Such a mechanism is assumed to operate in cases like those above, so that anaphora becomes possible despite assumptions about the anaphora-blocking nature of the first quantifier; it is further assumed that this mechanism is fully general and applies equally to instances of quantificational, modal, and conditional subordination.

However, such accounts encounter several difficulties. In general, they are too liberal in their predictions. For example, according to Roberts (1989) and (1996), (1a,b) receives an interpretation consistent with the conditional rephrasing *if a hunter shot a deer then it died immediately*. The mechanism inducing this interpretation, however, also allows the following reading of (1a,d): *if a hunter shot a deer then he intended to kill it*. The possibility of this interpretation incorrectly predicts discourse (1a,d) to be felicitous. The Roberts-style theories, then, overgenerate in cases like these. In an attempt to deal with this problem, most researchers working with this sort of

account assume the existence of constraints on the extraction mechanism; however, spelling out such constraints has proved to be a non-trivial task.

A more detailed diagnosis of the problem is the following. Proponents of the Roberts-style approach make one crucial assumption that turns out to be at the root of many of the observed problems, including that discussed above: that discourse subordination is a unified phenomenon. In fact, as we show below, this assumption is not correct. Examining why this is so gives substantial insight into the nature of discourse subordination and is the first step on the road to a true solution.

Let us begin by considering a case of conditional subordination:

- (4) If a person goes to school, he will learn some new things. # He's a pretty smart guy.

We are interested in the reading of the conditional in (4) on which the pronoun *he* does not refer to a particular individual, but rather to the nonspecific object introduced in the antecedent. We use the term *proxy information* for information subsumed within the scope of a semantic operator in this manner, to bring out the idea that such information is restricted to the operator domain. As shown by the infelicity of continuing the discourse in (4), the standard dynamic formulation of conditionals as inducing this proxy quality on their content seems to be correct.

Now, however, let us reconsider the quantificational subordination cases. In both DPL and DRT, the interpretation of universal determiners exploit the semantics of conditionals; thus, information introduced under universal determiners turns out to be proxy information which cannot escape the universal domain. As a result, universal determiners serve as anaphora barriers in DRT and DPL. Because of this analysis, the problem of quantification subordination seems to be the same as the problem of making use of proxy information. However, the examination of natural language data makes the idea that sentences like *every student goes to school* provide only proxy information appear to be false. Anaphoric dependence is available relatively unrestrictedly to objects introduced by universal determiners, as in the following examples:

- (5) a. All men love a woman. They send her flowers.  
b. Every man loves a woman. They send her flowers.

We argue that the cases of quantificational subordination involving *each*, such as (2), function in a similar manner. And obviously, the first approach does not have an easy way to explain the straightforward cases in (5).

For similar reasons, the example (6) does not depend on the manner in which the pronouns in (6b) are able to access the 'proxy' information in (6a), but rather on how the information introduced by (6a) can be updated by continuing the discourse with (6b).

- (6) a. *Each degree* candidate walked to the stage. (Sells 1985)  
b. *He* took his diploma from the dean and returned to his seat.

On this account, the problem does not lie in the nature of the mechanism that accounts for anaphora out of quantificational contexts, but in the kind of semantic objects that are introduced by such contexts, and in the kinds of objects can then depend on them for their meaning.

However, the problem of proxy information seems to reappear in certain situations, for instance in the discourses in (1). Here, the information introduced by *a deer* in (1a) truly seems to be temporary; it has no specific reading. Nonetheless, this information is available to the pronoun in (1b) despite its proxy status; but such is not the case for (1c). The notion of proxy information seems to be needed here, as well as some way of restricting access to it. We will argue that these needs are satisfied by the mechanisms of discourse subordination through rhetorical relations implemented in SDRT. Before doing so, however, we introduce our formalism for inducing release of the correct information from universal determiners.

## 2. Formalism



### 3. Information and Coherence in Quantificational Subordination

Our analysis of quantificational subordination is based on two factors, as discussed above: compatibility conditions between the output of various universal determiners and pronouns, and the inference of rhetorical relations between discourse segments. The first part of the analysis corresponds to the formalism presented in section 2; the second part will be introduced shortly.

The first part of the analysis can be summarized as follows. The universal determiners *all*, *every*, and *each* are not intrinsically barriers to anaphora; however, the (dynamic) procedure by which they are processed outputs objects that are intrinsically singular or plural, meaning that only pronouns of the correct type are able to pick them up as antecedents. For instance, in (7), shown paired with their corresponding logical forms, both *all* and *each* output plural objects from the restrictor position, which plural pronouns may pick up; however, the singular nature of the nuclear position in (7a) and the presence of the ‘jump’ operator  $j^{Dep}$  in (7b) makes the object information accessible to a singular pronoun.

- (7) a. All men love a woman. They send her (\*them) flowers.  
 $\exists x; all_x(man(x)); \exists y; a_y(woman(y)); love(x, y); plural(x); singular(y); send(x, y)$   
 $\exists x; all_x(man(x)); \exists y; a_y(woman(y)); love(x, y); plural(x); *plural(y); send(x, y)$
- b. Each man loves a woman. They send her flowers.  
 $\exists x; all_x(man(x)); j^{Dep}(x, y); \exists y; a_y(woman(y)); love(x, y); plural(x); singular(y); send(x, y)$

Thus, from the perspective of transitional information processing, the universal determiners *every* and *each* are ambiguous, and create different situations for anaphoric dependence on each reading.

Similar facts hold for the basic cases of telescoping subordination (8). Here, again, the possibility of anaphoric dependence falls directly out from our formalism; the object output by the universal determiner in the first sentence is of the right sort for the pronoun to pick up, and anaphora is possible without stipulating any additional machinery.<sup>1</sup>

- (8) a. *Each student* in the syntax class was accused of cheating on the exam.  
 $\exists x; all_x(student\_in\_the\_syntax\_class(x)); j^{S-Dep}(x, x); was\_accused\_of\_cheating(x)$ .
- b. *He* was reprimanded by the dean. (Fodor & Sag 1982)  
 $singular(x); was\_reprimanded\_by\_the\_dean(x)$ .

Similarly, the infelicitous instances in (9) fall out of the inability of *every* to provide a object of the right sort to serve as antecedent to a singular pronoun.

- (9) a. ?? *Every dog* came in. *It* lay down under the sofa. (Poesio & Zucchi 1992)  
 b. \*If *every cat* purrs, *it* is happy. (Poesio & Zucchi 1992)  
 c. \*John likes *every dog* and Sam feeds *it*. (Hornstein 1984)

The infelicity of (1a,d) can easily be explained by similar reasoning.

However, this cannot be the full story, for, as is well known, infelicitous examples exist that exhibit precisely the same structure as (8) in terms of determiner-pronoun matching, as in (10):

- (10) a. *Each student* in the syntax class was accused of cheating on the exam.  
 b. \**He* has a Ph.D. in astrophysics.

On our account, the infelicity of (10) is not directly related to the problem of anaphoric accessibility. Rather, the difficulty is simply that the discourse is incoherent, i.e. there seems to be no

<sup>1</sup>From this perspective, the notorious variation in acceptability from speaker to speaker in examples like these is attributable to the nature of the conditions that allow anaphora. On our account, the ‘jump’ operators are used in the processing of sentences, but are not semantic *rules* in that they are not strictly obligatory. Because they are optional, and learned independently of the grammar, speakers may vary in their application of operators of this sort.

meaningful way to connect the two sentences. In SDRT terms, this translates as an inability to infer any discourse relation between the two segments. We spell this idea out formally for the similar case (1), the various segments of which are translated as follows in the formalism presented in section 2:

- (1') a.  $\exists x; all_x(hunter(x)); j^{Dep}(x, y); D(((\exists y; deer(y); saw(x, y)) \rightarrow shot(x, y)))$   
 b.  $singular(y); died\_immediately(y)$   
 c.  $singular(y); a_y(female(x))$

The theory of SDRT update (which includes a theory of discourse attachment, of which space considerations preclude a detailed discussion) gives the following meaning to (1a,b). Here *Result* is a rhetorical relation which requires a causal relation between two bits of information:

- (11)  $\exists x; all_x(hunter(x)); j^{Dep}(x, y); D(((\exists y; deer(y); saw(x, y)) \rightarrow Result(shot(x, y), singular(y); died\_immediately(y)))$

The above may be interpreted roughly as *For every hunter<sup>1</sup>, in case that that hunter<sub>1</sub> saw a deer<sup>2</sup>, he<sub>1</sub> shot it<sub>2</sub> and then caused it<sub>2</sub> to die immediately*, which is intuitively correct. For (1a,c), however, no rhetorical relation can be inferred since the necessary background for this inference is lacking (with additional context, however, such an inference may be forthcoming, improving the discourse). Thus, the following coherent logical form cannot be constructed for any relation *R* for (1a,c):

- (12)  $*\exists x; all_x(hunter(x)); j^{Dep}(x, y); D(((\exists y; deer(y); saw(x, y)) \rightarrow R(shot(x, y), singular(y); a_y(female(y))))$

Similar facts hold for (10), explaining its infelicity.

Thus, on our account, the infelicity of the impossible cases of telescoping follow directly from independently necessary constraints on the coherence of discourse, not from any *ad hoc* constraints that must be defined on the availability of special update mechanisms. This account is related to, but not identical with, the script-based account of Poesio & Zucchi (1992); unlike them, however, our analysis is not specific to quantificational subordination, but falls out of general pragmatic constraints on possible discourses. Our analysis also incorporates a distinction between the information released by various universal quantifiers, which is overlooked in their analysis.

#### 4. Discourse Subordination Re-Generalized

The account presented here can be generalized to other kinds of discourse subordination. In quantificational subordination, licensing depends on compatibility between the object introduced by a universal quantifier and the pronoun which depends on it. Abstracting away from the quantificational case, subordination comes with a compatibility requirement between a dependent object and its antecedent. In the modal domain, this requirement corresponds to a need for the domains of modal operators to ‘fit’ one another. In the literature, it has been noted that certain types of modality work together, and others do not:

- (13) a. A wolf might come in. It would eat you first. (epistemic; subjunctive)  
 b. John should buy a car. He would drive it (deontic; subjunctive)  
 (14) a. A wolf will come in. # It would eat you first. (indicative; subjunctive)  
 b. John might buy a bottle of wine. # He should drink it. (epistemic; deontic)

In our terms, the felicity/infelicity of the above examples corresponds to the compatibility of the modal operators involved.

This observation itself is not new; scholars of modal subordination (Roberts, Frank, Geurts) have all noted it in one form or another. However, we think that our theory provides a new perspective on the facts by claiming that this need for compatibility is not limited to the modal case, but rather holds for all sorts of subordinating contexts. We also take the perspective that, parallel to the quantificational cases which are our main focus here, (a) modal operators are not anaphora barriers, and (b) anaphoric accessibility is also controlled by whether a discourse is coherent.