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PLURAL PRONOUNS WITH QUANTIFIED ANTECEDENTS*

Daniel Hardt
Computational Linguistics
Copenhagen Business School
dh@id.cbs.dk

Abstract

It is well known that plural pronouns can have quantified antecedents which do not c-command them. While both Heim's E-type approach and DRT's Abstraction approach can handle some cases of this, there are certain cases neither approach can handle, when the quantified antecedent is embedded with the scope of another quantifier. We show how both approaches can be modified to solve the problem.

1 The Problem

Evans (77,80) points out that a quantifier can be the antecedent for a plural pronoun which is outside the quantifier's scope, as illustrated by the following examples:

(1) John beats most donkeys he owns. They ("the donkeys John owns and beats") complain.

(2) Every farmer beats most donkeys he owns. They ("the donkeys the farmers own and beat") complain.

(3) Every student turned in a paper. They ("the papers the students turned in") were all identical.

(4) Each time every student turned in a paper they ("the papers the students turned in") were all identical.

Evans' solution to this problem is his E-Type approach, according to which the pronoun denotes "the object(s), if any, which verify the antecedent quantifier-containing clause" (Evans 1980)[p. 219]. Thus "they" is interpreted according to the parenthesized paraphrases in (1) - (4). This basic insight has been incorporated in DRT as the Abstraction operation (Kamp and Reyle 1993) and in the LF-based E-Type approach of (Heim 1990). However, neither of these approaches correctly captures all the above readings.

In what follows, I first compare Heim's and Kamp & Reyle's approaches. While Heim's approach succeeds with (1), it fails with (2)-(4), because it produces a pronoun representation with free variables. Kamp & Reyle's Abstraction is a more flexible implementation of Evans' idea than Heim's. Abstraction nonetheless fails on (2), again because of a free variable problem.

I present a solution to this problem in which Abstraction can add discourse referents in higher level boxes. This solution involves a somewhat different representation than that of Kamp and Reyle, which I term ι-Abstractions. The resulting representations provide a general solution to the above problem; the desired truth conditions can be derived by relying on a cumulative

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interpretation with scope over the entire Abstraction box. Next, I show that a similar solution is possible for Heim's E-Type approach. Then I examine a problem with unwanted inferences involving decreasing quantifiers and Abstraction. This problem appears to be avoided with Heim's approach, although the relevant facts are not entirely clear.

1.1 The E-type Approach

On Heim's approach (Heim 1990)[p. 170], "they" is interpreted as a definite description constructed from the S containing the antecedent NP. Heim assumes that the antecedent NP is raised to a position adjoining S, giving the structure [NP S], and the resulting definite description is *[the NP S]*. For (1), we have the following:

(5) [[most x donkey(x), he$_i$ owns x] [John$_i$ beats x]] .
(They) [[[the X donkey(X), he$_i$ owns X] [John$_i$ beats X]] X complain].

The antecedent quantified NP ("most donkeys he owns"), together with the matrix S ("John beats x") is copied to the position of the E-type pronoun, "they". The determiner of the antecedent NP is replaced with "the". (This is the effect of Heim's approach, although it is not described in exactly this way.) In addition, I will permit singular, lowercase variables to be converted to plural, uppercase variables. This is an extension of Heim's account, which does not apply to the case of plurals, although Heim briefly considers the issue of plurals, and considers the possibility "we waive [the] requirement . . . for syntactic number agreement" [p. 172].

I will also follow the standard assumption, discussed in (Evans 1977, Evans 1980) and much subsequent literature, that definite descriptions involve a maximality requirement. Finally, we observe that plural variables permit a variety of readings; in the above example, X is interpreted distributively. In other words, there is an implicit universal quantification over the elements of the set (see discussion in, eg, (Kamp and Reyle 1993)[p. 326]). So the set X described by the constructed definite description is the maximal set X such that:

(6) $\forall x : x \varepsilon X$. donkey(x) AND he$_i$ owns x AND John$_i$ beats x

This is the set of donkeys owned and beaten by John, as desired. We now turn to (2). Heim's approach produces the following representation:

(7) [[every x farmer(x)] [[most y donkey(y) x owns y] [x beats y]]].
[[[the Y donkey(Y), x owns Y] [x beats Y]] Y complain]

The representation for "they" is "the donkeys x owns and x beats". This contains a free variable x, which is not interpretable. (Heim 1990) points out the same problem for (3) and (4).

1.2 Abstraction in DRT

We turn now to DRT's Abstraction, which is defined as follows (Kamp and Reyle 1993)[p. 343]:

Given a *triggering configuration* which is a QNP represented as a duplex condition $K_1 < Qv > K_2$, occurring in DRS K, we

- Form the union $K_0 = K_1 \bigcup K_2$.

- Choose a discourse referent w from the Universe of K_0, and add to K a new discourse referent Y, together with this condition: $Y = \Sigma w : K_0$.

For (1) we produce the following representation:

(8)

X

x
donkey(x), own(John,x)
<most x>
beat(John,x)

X = Σ x
donkey(x), own(John,x), beat(John,x)

complain(X)

So the set X is the maximal sum constructed of elements x such that x is a donkey owned and beaten by John, as desired.

Unlike Heim's approach, Abstraction successfully handles (3) and (4). Consider (3): on Heim's approach, the pronoun representation is "the papers turned in by x", with x unbound. The Abstraction approach avoids this problem, because x is implicitly existentially quantified in the resulting representation.

(9)

Y

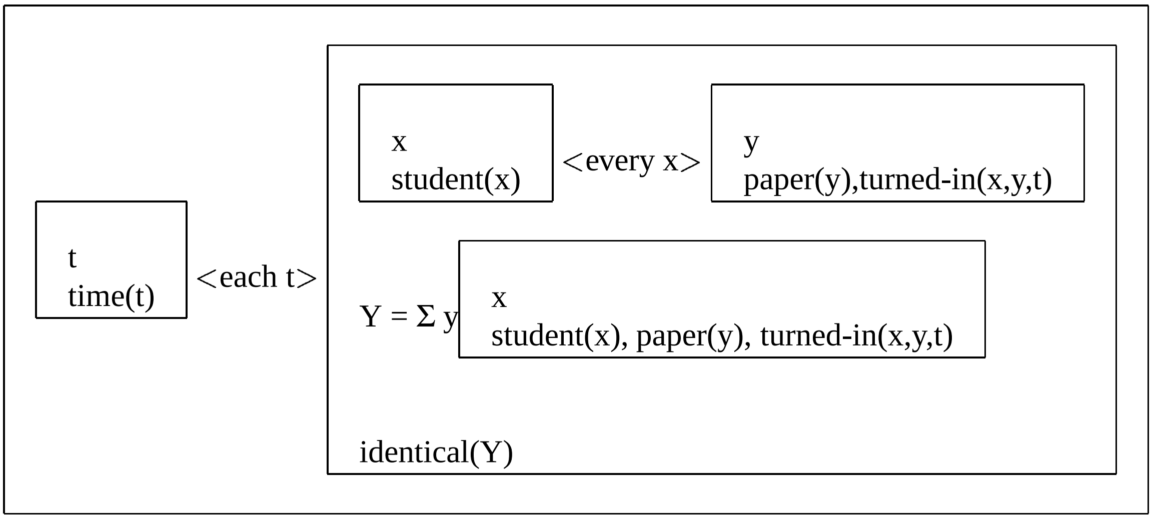
x
student(x)
<every x>
y
paper(y),
turned-in(x,y)

Y = Σ y
x
student(x),
paper(y),
turned-in(x,y)

identical(Y)

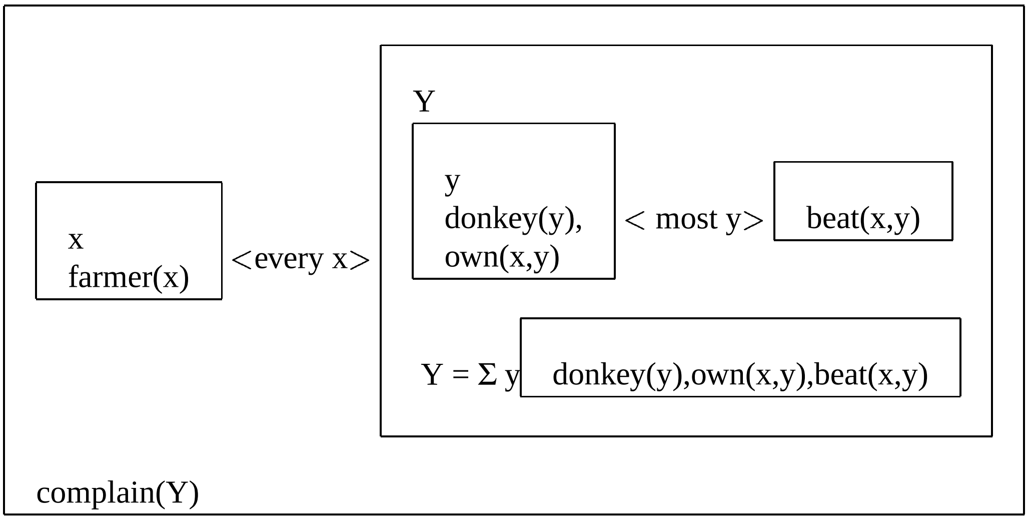
Here, Y is the maximal sum of objects y such that y is a paper turned in by some student x. Abstraction also produces the correct representation for (4).

(10)



Here, for each time t, we construct a sum Y consisting of all papers y turned in by some student x at time t. This is as desired. However, Abstraction fails on (2), producing the following DRS:

(11)



Following the definition of Abstraction, the discourse referent Y is introduced within the box containing the antecedent duplex condition (“most donkeys”) . Since this is an embedded box, Y is not accessible to the pronoun “They”.

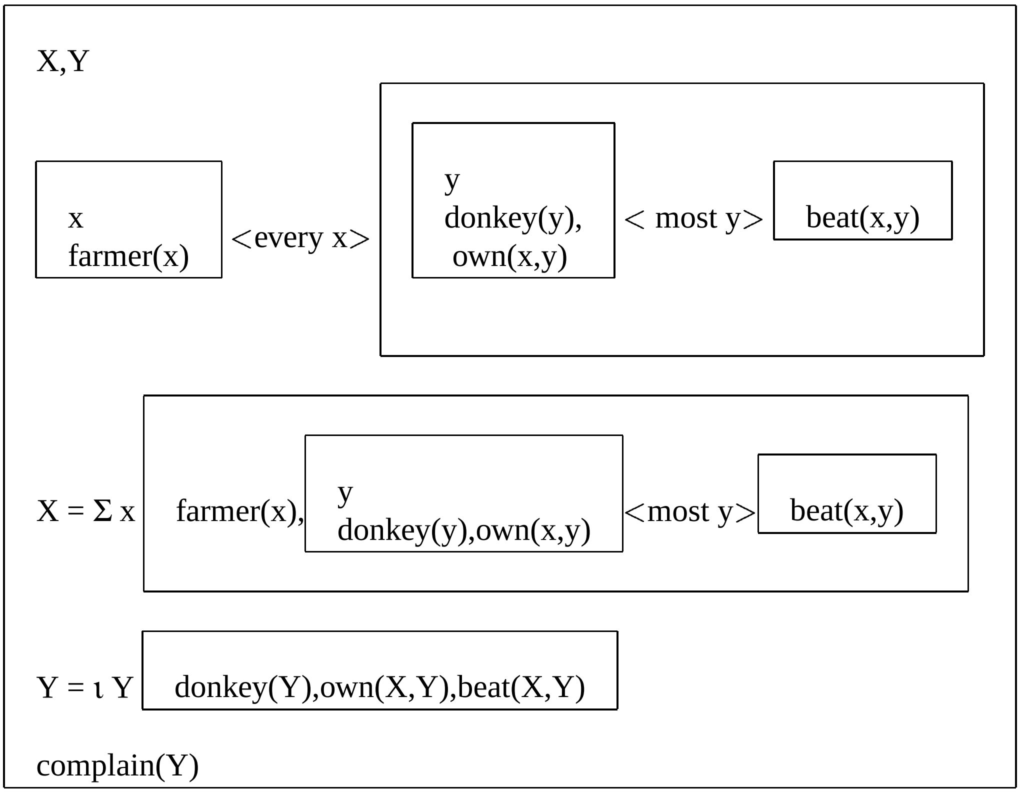
2 The Solution: ι-Abstraction

The problem for Abstraction involves nesting of boxes; if the antecedent duplex condition is nested, the plural discourse marker is introduced in a nested box. But example 2 shows that it must be made accessible in higher level boxes. Our solution is to modify Abstraction, so that it can introduce a plural discourse referent in a higher level box. This will require some modifications in both the construction and the interpretation of Abstractions, and I will define an alternative form of Abstractions, ι(iota)-Abstractions.

2.1 Abstractions at Higher Levels

We allow Abstraction to introduce a plural discourse referent at a higher level than the antecedent duplex condition. The boxes introduced at higher levels will require a somewhat different interpretation than the Σ-boxes of the Kamp and Reyle. So I will write these higher level boxes as ι-boxes. We produce the following representation for (2).

(12)



Now the discourse referent Y is accessible at the top-level DRS, where it is needed. (Here, we have also applied Abstraction on the set X, representing the farmers.) However, our solution requires some changes to Abstraction, both in terms of the Construction Rule and the interpretation of the box produced by Abstraction.

2.2 Construction Rule: ι-Abstractions

The plural discourse referent Y is introduced above using ι rather than Σ. This is meant to indicate that, rather than summing up all the values of a given singular variable, we place conditions which determine a unique maximal set. Thus, the Abstraction construction rule must contain two options, allowing the construction of ι-boxes in addition to Σ-boxes.

- Given a QNP represented as a duplex condition $K_1 < Qv > K_2$, occurring in DRS K
- Form the union $K_0 = K_1 \bigcup K_2$.
  - Choose a discourse referent w from the Universe of K_0, and add to K a new discourse referent Y, together with this condition: $Y = \Sigma w : K_0$.

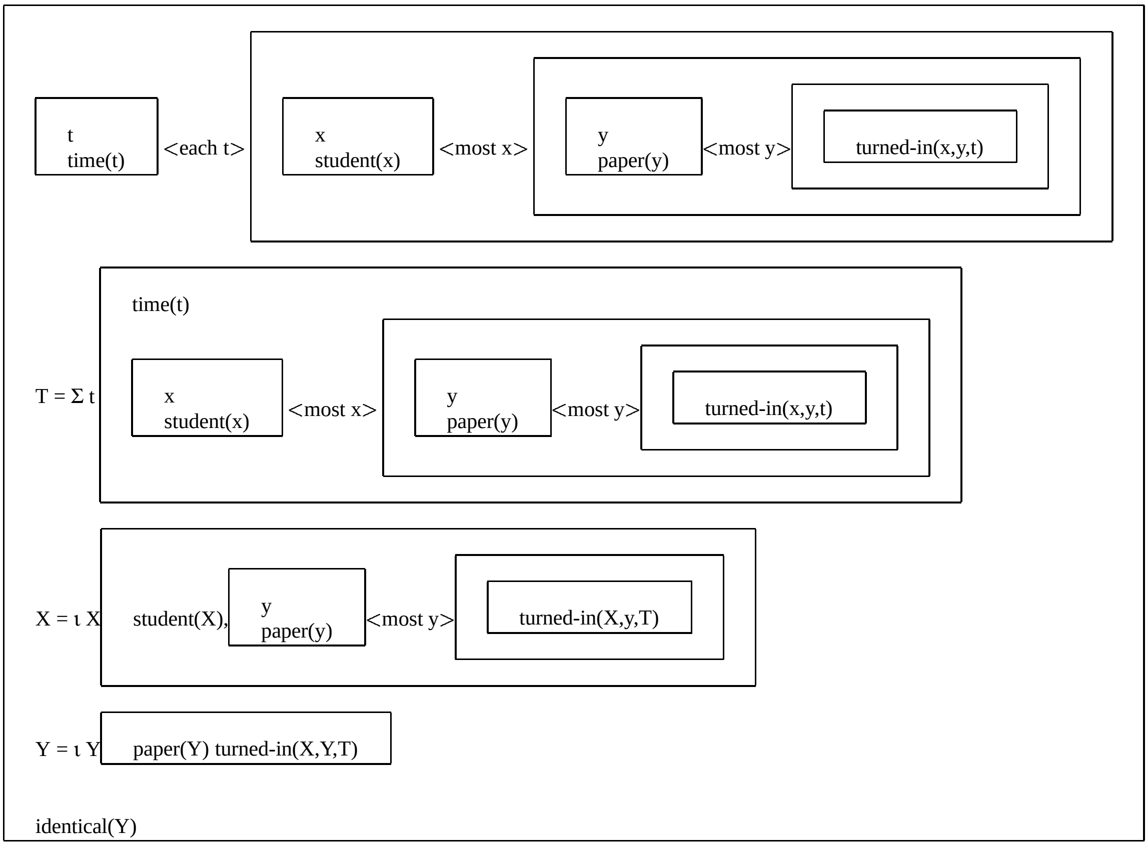
    OR
  - add to K' (where K' contains K), a new discourse referent Y, together with this condition: $Y = \iota Y : K_0$.

The two options are either to add the new discourse referent to the box K which contains the antecedent duplex condition, as in the original rule, or add the new discourse referent to a higher level box, in which case we have an ι-box, with the alternative representation. Since we have now moved the box K_0 to a higher level, variables bound within K_0 may become unbound. Any such variable is converted to a plural discourse referent, and its interpretation is also fixed by Abstraction.

2.3 How Much Higher?

Our construction rule for ι-boxes states that the plural discourse referent be added to a box K' which contains K, the box containing the antecedent duplex condition. This places no limit on how many levels up it is possible to move. We suspect that this is correct; in (13), the set definition for Y is introduced two levels higher than the box containing the antecedent duplex condition "most papers".

(13) Each time, most students turned in most papers. They were all identical.



Here, T is defined by an ordinary, Σ-box: it is the set of all times t such that most students turned in most papers at time t. X and Y are defined by ι-boxes: the intended interpretation for X is the set of students that turned in most papers at one of the times in T, and Y is the set of papers turned in by one of the students x at one of the times t. Below, we describe exactly how these interpretations are achieved.

3 Interpretation of ι-Abstractions

Recall Kamp and Reyle's interpretation rule for Σ-boxes (Kamp and Reyle 1993)[p. 420]:

(14) $X = \Sigma z K$ is verified by a function f in Model M iff
$f(X) = \oplus\{b : b \varepsilon U_M \& M \models_{f \cup \{<z,b>\}} K\}$

This rule states that X is the maximal sum of individuals *b* such that, when *b* is the value for *z*, *K* is true. Our ι-boxes require a somewhat modified version of this rule:

(15) $X = \iota XK$ is verified by a function f in Model M iff
$f(X) = S \& M \models_f K$ AND $\forall$ S$'$, g such that $g = f[X, S'] \& M \models_g K$, S$' \subseteq S$

This rule states that the ι-box is verified by f if f maps X to a set S such that all the conditions in K are true, and furthermore, S is the maximal such set.

We return now to (12), where we constructed the following ι-box:

(16) Y = ι Y $\boxed{\text{donkey(Y),own(X,Y),beat(X,Y)}}$

The set Y is defined as "donkeys owned and beaten by X". Since Y's definition occurs outside the scope of "every x", X is interpreted according to the set definition, "farmers who beat most of the donkeys they own". Intuitively, this should mean: *the maximal set Y such that Y are donkeys, the X own the Y's, and the X beat the Y's.* Or more naturally, *the set of donkeys that are owned and beaten by the farmers (X).*

In fact, this interpretation is available in DRT, making use of what (Kamp and Reyle 1993)[p. 414] term the "cumulative interpretation", citing (Scha 1981). The following definition is adapted from (Kamp and Reyle 1993)[p. 414]:

(17) $R(A,B) \iff \forall a : a \varepsilon A. \exists b : b \varepsilon B.\ R(a,b)$ AND $\forall b : b \varepsilon B. \exists a : a \varepsilon A.\ R(a,b)$

I follow Kamp and Reyle in treating the cumulative interpretation as involving implicit quantification over the two set variables involved. However, with ι-Abstractions, the quantification must have scope over the entire ι-box, rather than the individual conditions within the box. Thus we interpret the box above as follows:

(18) Y = ι Y
$\forall y : y \varepsilon Y. \exists x : x \varepsilon X.(donkey(y), own(x,y), beat(x,y))$ AND
$\forall x : x \varepsilon X. \exists y : y \varepsilon Y.(donkey(y), own(x,y), beat(x,y))$.

This means that Y is the set of all donkeys such that, for every donkey y, there is an x in X such that x owns and beats y, and for every farmer x in X, there is a donkey y, such that x owns and beats y. Note that this gives a different reading than treating the conditions independently as cumulative predications:

(19) $\forall y : y \varepsilon Y. \exists x : x \varepsilon X.own(x,y)$ AND $\forall x : x \varepsilon X. \exists y : y \varepsilon Y.beat(x,y)$

This would allow donkeys as elements of Y as long as they are owned by some farmer and beaten by some different farmer. (18) correctly restricts Y to include only donkeys that are beaten and owned by the same farmer. The reading represented by (19) is weaker than that of (18), and does not appear to be naturally available. It may be that this is merely a preference, and that the weaker reading is also possible under certain circumstances. But I will not attempt to resolve that issue here.

4 A Solution for Heim's E-Type Approach

A similar solution is available for Heim's E-Type Approach. Consider the problematic LF given above in Section (1), for example (2):

(20) [[every x farmer(x)] [[most y donkey(y) x owns y] [x beats y]]].
[[the Y. donkey(Y) x owns Y] [x beats Y]] Y complain.

The apparent problem is that *x* appears free in the definite description that is constructed as the interpretation of "They". However, Heim's approach affords a natural solution to this problem: since *x* appears outside the scope of a coindexed, quantificational antecedent, it can be treated as an E-type pronoun. Thus it should itself be treated as an implicit definite description which is reconstructed in the usual way. This gives rise to the following LF:

(21) [[the Y donkeys(Y) **[the X farmers(X) [[most y donkey(y) x owns y] [x beats y]]]** owns Y] [x beats y]] [Y complain].

Finally the definite description is raised, to produce the final representation.

(22) **[the X farmers(X) [[most y donkeys(y) x owns y] [x beats y]]]** [[the Y donkeys(Y) X owns Y] [X beats Y]] [Y complain].

There is no longer the problem of a free variable *x*. Note again that the singular *x* has been reconstructed as a plural variable X. Does the above LF give the right interpretation? As long as we assume that distributive and cumulative interpretations are generally available, the correct interpretation is available, in much the same way as it was for the ι-Abstractions discussed above.
The set X is defined by the following description:

(23) [the X farmers(X) [[most y donkeys(y) X owns y] [X beats y]]]

Interpreting the predication distributively over X, we get the following:

(24) [the X. $\forall x : x \varepsilon X$. farmer(x) [[most y donkeys(y) x owns y] [x beats y]]]

This is the set of all farmers who beat most of the donkeys that they own, as desired. Next we have the set Y, defined as follows.

(25) [[the Y donkeys(Y) X owns Y] [X beats Y]] [Y complain].

Assuming a cumulative interpretation, we have this:

(26) [[the $Y.\forall y : y\varepsilon Y.\ \exists x : x\varepsilon X$.(donkey(y),own(x,y),beat(x,y)) AND
$\forall x : x\varepsilon X.\exists y : y\varepsilon Y$.(donkey(y),own(x,y),beat(x,y)).]

Thus we can see that in fact no real modification is necessary to Heim's approach, other than observing that the E-type strategy is available to any variable outside the scope of a coindexed quantificational antecedent. The desired interpretation can then be obtained by appealing to generally available distributive and cumulative interpretations.

5 Abstraction and Decreasing Quantifiers

We have seen how the DRT-based Abstraction approach and Heim's E-type approach can be successfully modified to deal with the problematic examples involving free variables in the antecedent to plural pronouns. I would like to examine the following difference between Heim's approach and the DRT approach: on the DRT approach, Abstraction applies freely to any duplex condition. On Heim's approach, it is the occurrence of the E-Type pronoun which first gives rise to the construction of the definite description, which presupposes the existence of the described set. (Nouwen 2002) argues that DRT's Abstraction leads to a problem with decreasing quantifiers, because of the following difference in entailments:

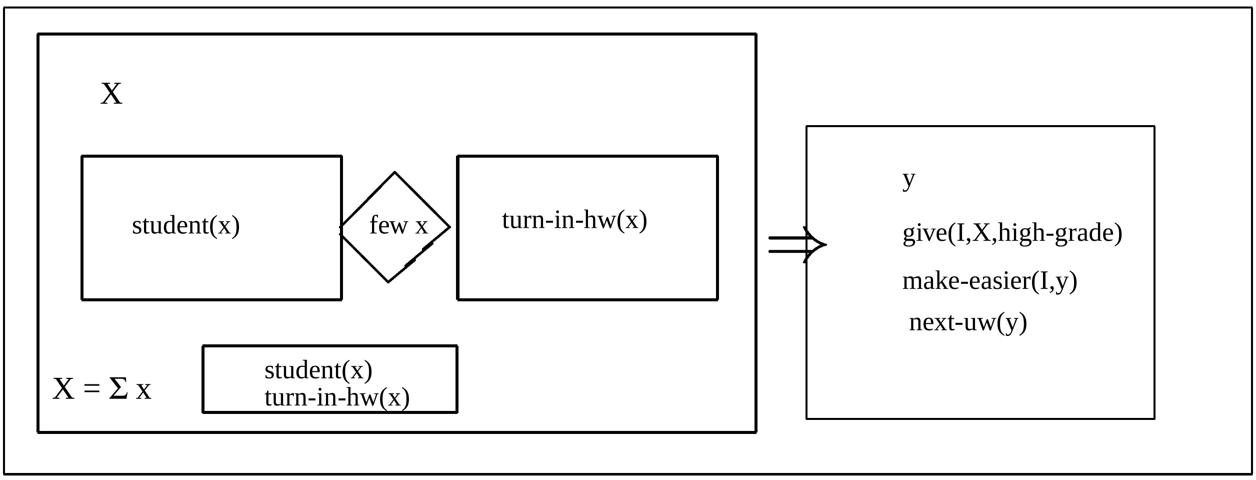
(27) Few congressmen admire Kennedy $\not\Rightarrow$ Some congressmen admire Kennedy.

(28) Few congressmen admire Kennedy, and they are very junior $\Rightarrow$ Some congressmen admire Kennedy.

Nouwen notes that the duplex condition itself ("few congressman") does not entail the existence of the relevant set. Apparently it is the pronoun which is the source of the entailment. This suggests that DRT Abstraction should be modified to follow the Heim account in this regard; Abstraction should not be permitted to apply unless it is needed, to resolve a pronoun occurrence.

The facts are not entirely clear, however. Consider the following example:

(29) If few students turn in the homework, I give them high grades, and make the next homework easier.



Note that Abstraction must apply because of the pronoun "them". This means that the restrictor box means "few (but some) students turn in the homework". This appears to give the wrong truth conditions, by strengthening the antecedent of the conditional. In particular, in the case where *no* students turned in the homework, the antecedent would simply be false, so that it would not entail that I make the next homework easier. This seems to be incorrect. One solution would be to permit Abstraction to construct empty sets as antecedents for pronouns.

6 Conclusion

While DRT and Heim's E-Type approach both incorporate Evans' basic insight concerning plural pronouns beyond the scope of quantified antecedents, both approaches fail in some cases, because of problems with unwanted free variables. I have shown how the DRT Abstraction approach can be modified to solve this problem in a general way, by adding a different form of Abstractions, ι-Abstractions. I showed that the most natural interpretation can be derived by using cumulative interpretations, with scope over the entire ι-box. I show that a similar solution is available for Heim's approach. Finally, I addressed some apparent problems with interpretations involving DRT's Abstraction and decreasing quantifier antecedents. While Heim's approach appears to avoid the problem, I give an example showing that the facts about entailments in such cases are not entirely clear.

References

Evans, G.: 1977, Pronouns, quantifiers, and relative clauses, *Canadian Journal of Philosophy* **7**, 467–536.

Evans, G.: 1980, Pronouns, *Linguistic Inquiry* **11**, 337–362.

Heim, I.: 1990, E-type pronouns and donkey anaphora, *Linguistics and Philosophy*.

Kamp, H. and Reyle, U.: 1993, *From Discourse to Logic*, Kluwer, Dordrecht.

Nouwen, R.: 2002, Context, collectivity and emptiness, *in* K. Alberti G., Balogh and P. Dekker (eds), *The proceedings of the Seventh Symposium on Logic and Language, Pecs, Hungary*.

Scha, R.: 1981, Distributive, collective and cumulative quantification, *in* J. Groenendijk, T. Janssen and M. Stokhof (eds), *Formal Methods in the Study of Language*, Dordrecht, pp. 483–512. Volume 136.