The Dynamics of Sophisticated Laziness

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1 Introduction

A semantics for pronouns should give general principles to determine their interpretation. This involves, among other things, to explain which antecedents are accessible for a particular occurrence of a pronoun, and, if any, how they affect its semantic value. But deciding upon an interpretation comes with a choice of semantic category to which the pronouns belong. In the literature, two options have been considered. Sometimes pronouns are taken to be quantifiers (Keenan, Neale), but most often they function as terms (Quine, Geach, Evans, Richards, the current dynamic theories). In this paper, where generalized quantification and anaphora is the main issue, I try to further the E-type analysis, developed out of Evans 1977, 1980, that some pronouns are quantifiers interpreted in context. My aim is to account for a class of anaphor phenomena within an extension of the generalized quantification theory as it developed in the 1980s.[1]

The choice of category assigned to a pronoun has a strong influence on how the problems with pronouns are analyzed. With respect to the familiar donkey sentence, for instance, the view that pronouns are bound variables makes it natural to seek for a solution for the problematic 'it' in terms of a special treatment of the antecedent 'a donkey.'

(1) *a.* Every farmer who owns a donkey beats it.
b. [every x : Fx][every y : Dy $\wedge$ Oxy]Bxy
c. [every x : Fx][an y : Dy $\wedge$ Oxy][every y : Dy $\wedge$ Oxy]Bxy

And, indeed, within the discourse representation theory (DRT) of Kamp 1981 and Heim 1982, which takes pronouns to be bound variables, the indefinite is seen as a restricted free variable. The dynamic predicate logic (DPL) of Groenendijk & Stokhof 1990, 1991, which stands in the same tradition, gives the indefinite its standard semantics as an existential quantifier. But it has the side-effect of passing on objects to be referred to at a later stage. These treatments of the indefinites have a semantical change of other quantifiers and connectives in their wake. By contrast, an E-type analysis tries to find a solution for the donkey sentence in the interpretation of the pronoun. E.g., Richards 1984 treats the 'it' in (1a) as a universal quantifier which is restricted by descriptive material inherited from its antecedent. In this way (1c) results, which is equivalent to (1b). Note that Richards' approach makes it possible to handle all other expressions in a standard manner.

[1] Cf., Barwise & Cooper 1981, Van Benthem 1983, 1984, Keenan & Stavi 1986.

In case of (1) the bound variable approach and the E-type analysis yield equivalent results. But this is not always so. It is a distinguishing feature of DRT that it employs an extended and refined version of Lewis' 1975 unselective quantification, where sequences of individuals are quantified over. This works well for the standard quantifiers 'some,' 'all,' 'no,' and 'not all,' but as Partee 1984 notes in general it may lead to the well-known proportion problem (cf., section 2.1.1). Partee's example concerns the quantifier 'most,' and a first indication of how the proportion problem might be solved in this case is given by Kadmon 1990, sec. 3. Due to Chierchia 1992 and Van Eijck & De Vries 1992, Kadmon's suggestion developed into a form of dynamic generalized quantification. The idea is to embed the standard theory of generalized quantification within a dynamic framework by copying material from its restriction to its scope. Interestingly, the copied material is often quite like the material which is copied to enable the interpretation of E-type pronouns. However, this dynamic generalized quantifier theory faces some restrictions. First, it can only deal with anaphor links within the restriction and scope of a quantifier. Second, it is no straightforward matter to generalize this to extrasentential anaphora. Third, it introduces ambiguities which the corresponding natural language sentences seem to lack. This, combined with the apparent convergence of ideas, strongly suggests that it is worthwhile to start at the other end of the scale. Namely, to use the techniques developed by DRT and DPL in order to formalize an E-type analysis. In this way we might profit from its good reputation concerning generalized quantification.

One such formalization is the dynamic quantifier logic (DQL) presented here. It tries to capture intra- and extrasentential anaphora with respect to arbitrary quantifiers by means of a minimal deviation from their standard semantics. To this end the view is adopted that E-type pronouns are expressions which depend for their interpretation on the context change effected by their antecedents. Note that this description of the matter applies as well to the E-type analyses given recently by Heim 1990 and Neale 1990, as to the dynamic systems of Groenendijk & Stokhof 1990, 1991. Indeed, these are my main points of departure.

DQL can best be viewed as a standard 'static' logic which comes with a separate dynamic module to model the change in context. That is, it uncouples the context change potential of a formula from its standard denotation. Here, contexts are functions from variables to formulas, which are constructed as we go along. A simplified example would be that as soon as a possible antecedent '$[\mathrm{D}x : \phi]\psi$' is encountered, the variable x receives the value $\phi \wedge \psi$. The contexts which result are used in the interpretation of anaphoric elements. More in particular, I will hold that singular pronouns denote choice functions which pick an arbitrary element from the set $\widehat{x}.\phi \wedge \psi$. While plural anaphora are interpreted as numberless descriptions; i.e., universal quantifiers as restricted by $\widehat{x}.\phi \wedge \psi$ but with the extra requirement that the set is non-empty (cf., Neale 1990, 235). Even this sketch indicates that we need not worry too much about the semantics of quantifiers; it will be the standard one supplied with a contextual parameter. It is only the contribution to the context of possible antecedents which has to be spelled out in detail. An attractive side-effect of uncoupling the denotation of an expression from its context change potential is that the interpretation of a text and the way it affects the context can be determined in parallel. As we shall see, this kind of 'parallel processing' allows for a compositional treatment of kataphora and MiG sentences (of course, to the extent that it is possible at all in a system like DQL).

The notion of context used here is different from that of DPL, where they are sets of assignments. This is inessential. With respect to a model, the information given by a formula might as well be represented by some set of assignments which verify it. This would make contexts functions from variables to sets of assignments. But there are certain advantages to the more syntactic format. First, it gives a perspicuous view on scope possibilities and the like, which are less visible when the information is encoded by means of assignments. In this way the syntactic approach figures as a specification stage, whose less attractive features could be eliminated by means of an assignment semantics as soon as is known what is required. Second, syntactic manipulations might be easier to implement, and this, after all, is an important aim of the DYANA project. Third and most important, it uncovers a phenomenon which makes the mechanism to determine the descriptive content of E-types rather intricate and interesting. It is the fact that the copied material often contains free variables which somehow have to get bound to yield the desired meaning.

The semanticists which have been working in the E-type tradition are well aware of this problem, but they mainly paid attention to the intrasentential cases where the variables remain bound by the relevant operators. Little attention has been paid to extrasentential anaphora, which are much more challenging in this respect. These anaphora may involve partial descriptions so that their free variables are not taken care of without further ado. Here is an example.[2]

(2) *a.* Quite a few people gave most of their relatives a^1 kiss.
They$_1$ were tender.
b. [quite a few x : Px][most y : Rxy][an z : Kz]Gxyz. [pro z]Tz.
c. [the z : K$z \wedge$ Gxyz]

Plainly this discourse is intelligible. Yet the numberless description (2c), which gives the interpretation of the quantifier [pro z], contains two free variables. The question arises of how they can be resolved and whether all possible ways to do so are equally useful. The syntactic approach to contexts will give a clear view on the available options. This is important, for modelling these dependencies in a principled way is one of the main obstacles in formalizing a fully general version of an E-type analysis. The present paper aims at giving a detailed proposal to this effect.

Although it will only do justice to some of the niceties of natural discourse, this formalization is rewarding. It shows that the resolution of E-type pronouns follows principles which are at work in other discourse phenomena as well. In order to be resolvable, the interpretation of pronouns has to run parallel to that of their antecedents. The antecedents and the pronouns depending on them must share enough scope structure to be cogent. Such parallelism is also typical of VP anaphora. It is argued in Prüst, Scha, and Van den Berg 1993, 4 that 'the problem of verb phrase anaphora must be viewed from a general discourse perspective.' Although I do not apply one here, I am convinced that my formalism is compatible with such a general framework.

All in all, the treatment of pronouns studied here is one of laziness. But due to the subtle dependencies, the laziness is sophisticated.

Overview

The present paper is organized as follows. Section 2 begins to discuss the main proponents of the bound variable analysis: DRT and DPL. Here the focus is mainly on their problems and prospects concerning generalized quantifiers and anaphora. This is followed by an overview of the different E-type analyses, but now with a special emphasis on its treatment of singular pronouns. Section 3 compares to issues raised in the preceding sections. This leads to the following conclusion. As far as quantifiers and anaphor pronouns are concerned, a wide coverage can be obtained by minimal means if singular E-type pronouns are treated as choice functions and

[2] I use Barwise's 1987 notation of indicating an antecedent by a superscript and an anaphor by a subscript.

plural E-type pronouns as numberless descriptions. These expressions depend for their interpretation on the context, which is here mainly supplied by the text itself. The sentential part of the dynamic quantifier logic which captures these intuitions, is defined in section 4. In section 5 the logic is applied to MiGs and donkeys, and other familiar examples.

Section 6 studies a few problems and options with respect to the interpretation and the scope behaviour of extrasentential anaphora. It is at this point that the analogy with VP anaphora emerges, i.e., that in some cases the scope relation among pronouns should coincide with that of their antecedents. An extension of DQL, presented in section 7, shows how to deal with extrasentential anaphora in a formal way. Interestingly, if parallelism is required between antecedents and anaphora it need not be ensured by copying scope information. That the parallelism obtains in these cases can be proved as soon as texts are built from sentences, not just from formulas. However, due to the fact that some pronouns depend for their interpretation on the linguistic context, some care has to be taken to define the appropriate notion of sentence.

This paper is one in a series concerning quantification and anaphora. As I said, my aim is to develop a semantics which has an immediate connection with generalized quantifier theory. I discern three steps in making some progress on this topic: (i) to show how quantification theory can be extended to cover anaphora in a distributive (i.e., atomic) environment; (ii) to show how quantification theory can be embedded within theories on collective readings; and (iii) to combine the results of (i) and (ii) to shed some light on the intricacies of quantification and plural anaphora in a collective setting. The present paper is on (i), and Van der Does 1992, 1993 has a proposal concerning (ii). I hope to deal with (iii) in a sequel to this paper.

2 Two traditions on interpreting pronouns

The naive view that pronouns are terms referring to individuals is ridiculed at length in Geach 1962. Geach discerns deictic pronouns and pronouns of laziness. But using Frege's insights, he holds that the other pronouns do not refer: they are the bound variables of quantification theory.

This view is long taken to be basically correct but problematic. There are sentences for which any attempt to specify their logical form along these lines failed, as soon as one tried to do justice to syntactic structure. In this respect donkey sentences set two puzzles. First, the indefinite NP, which Russell held to be an existential quantifier, appears to have universal force (cf., 3b). Second, using traditional tools, as in (3c), the variable $\underline{y}$ which corresponds to the pronoun 'it' remains free as soon as one tries to respect the syntactic structure of (3a). This is so independent of the quantifier Q assigned to the indefinite.

(3) *a.* Every farmer who owns a donkey beats it.
b. [every $x : \mathrm{F}x$][every $y : Dy \wedge Oxy$]$\mathrm{B}xy$
c. [every $x : \mathrm{F}x \wedge$ [Q $y : \mathrm{D}y$]$\mathrm{O}xy$]$\mathrm{B}x\underline{y}$

The conclusion is that if pronouns are bound variables the semantics has to be enriched somehow to be able to deal with this problem in a compositional way.

2.1 Pronouns as bound variables

2.1.1 DRT

DRT, which is a breakthrough in logical discourse semantics, respects the idea that pronouns are bound variables and hence seeks its solution in a special treatment of their antecedents. It handles indefinite NPs as non-referential, non-quantificational, restricted free variables, and uses operators to bind them which are much richer than those of predicate logic. More in particular, DRT uses polyadic connectives and quantifiers which may bind several variables simultaneously. For instance, (4a) is represented by (4b), where the universal quantifier binds both variables at once. And (4c) is modelled by (4d) in which all free variables are bound with universal force.

(4) *a.* Every farmer who owns a donkey beats it.
b. [every xy : $\mathrm{F}x \wedge \mathrm{D}y \wedge \mathrm{O}xy$]$\mathrm{B}xy$
c. If a philosopher reads a comic he remains silent.
d. $\mathrm{P}x \wedge \mathrm{C}y \wedge \mathrm{R}xy \Rightarrow \mathrm{S}x$

In general, which variables are to be bound is decided at a representational level where they are introduced as 'discourse referents.' The initial version of DRT has led to several extensions covering such topics as interrogatives, propositional attitudes, tense and aspect, presuppositions, and VP ellipsis.

With respect to quantification, Partee 1984 notes that the sophisticated view of quantifiers as binary relations between relations of indefinite arity may lead to unwelcome results. E.g., the truth conditions of (5a) as given by (5b) are correct if Q is 'all,' 'some,' 'no,' or 'not all.'

(5) *a.* Q men who own a car wash it on Sunday
b. [$\mathrm{Q}xy$: $\mathrm{M}x \wedge \mathrm{C}y \wedge\ \mathrm{O}xy$]$\mathrm{W}xy$

But they are undesirable in quite a few other cases. The familiar counterexample is that of 'most.' For that quantifier, (5b) would be true incorrectly if there are two men, one of which owns two cars that he washes on Sunday while the other owns just one car which he doesn't wash on Sunday. Notice that a quantifier such as 'two' would lead to the same difficulties if treated in this way. This shows that the proportion problem is nothing to do with first-order definability.

Within DRT the proportion problem is discussed by Kadmon 1990, 303–306. And for the case of 'most' she proposes to analyse (6a) as (6b), which is arrived at by copying material from its restriction to its scope.[3]

(6) *a.* Most men who own a car wash it on Sunday.
b. [most x : $\mathrm{M}x \wedge$ [an y : $\mathrm{C}y$]$\mathrm{O}xy$]([an y : $\mathrm{C}y \wedge \mathrm{O}xy$]$\mathrm{W}xy$)

Sentence (6b) gives the weak reading of (6a): The car owners need not wash all of their cars in order to make (6b) true. In the literature, the strong reading, where all cars have to be washed, is also suggested. The problem of weak and strong readings is discussed by Rooth 1987, Chierchia 1992, and Dekker 1993, among others, and studied in depth by Kanazawa 1993. We come back to it in section 3.

For our present purposes it is more urgent to note that Kadmon's suggestion still leaves the problem whether there is a uniform way in which it can be made to work for all quantifiers. As we shall see shortly, for DPL, which is discussed in the next section, such a method exists.

2.1.2 DPL

At first, DRT was presented as a 'major revision of semantic theory' (cf., Kamp 1981, 2). It appeared as if a proper treatment of anaphora required a new methodology, in which the interpretation of a pronoun required a crucial use of an intermediate representational level. For different reasons people have tried to avoid this methodological change.[4] Groenendijk & Stokhof 1991, in particular, have shown:

[3] The example is from Evans 1985, 117.

[4] Cf., Zeevat 1989, available in ms. since 1985, Barwise 1987, Rooth 1987, and Asher & Wada 1988, among others.

1. that a discourse semantics can be compositional;
2. that the Russellian analysis of indefinites as existential quantifiers can be sustained; and
3. that 1 and 2 combine with an nice treatment of adverbs of quantification.[5]

They achieve this remarkable effect by means of an analogy with the logics developed within computer science. In the abstract, a computer program is a device that transforms the contents of a memory to another one. Think of a memory address as a variable and of the content of the cell associated with an address as the value of a variable under an assignment. Then a non-deterministic program becomes a relation between assignments. This procedural view on meaning can be exploited to give a new semantics to the standard syntax of first-order logic. Groenendijk & Stokhof 1991 shows that $\exists$, $\neg$, and $\wedge$ form a basic stock of logical constants, and defines:[6]

1. An atomic sentence α is a test which returns the input assignment iff it satisfies α in the standard sense.
2. A negation $\neg\phi$ is a test which returns the input assignment iff the denotation of ϕ has no output for the given input.
3. A conjunction $\phi \wedge \psi$ is the relational composition of ϕ and ψ. That is, assignments a_1 and a_2 stand in the relation $\phi \wedge \psi$ if there is an assignment a_3 that links a_1 and a_2 via the relations of ϕ and ψ, in that order.
4. An existential quantification $\exists x\phi$ is the relation which results from first choosing an assignment which differs at most at x from a given input and than to proceed via the relation ϕ.

This embedding of first-order logic within a dynamic framework enriches the meaning of the logical constants. They may transmit objects introduced by the indefinites to be picked up by pronouns later on. Pronouns are still bound variables, but the notion of binding is no longer the standard one. Indefinites may bind variables outside their syntactic scope. This is reflected in the following equivalences, which hold unconditionally (cf., Groenendijk & Stokhof 1991, 63, 65):

(7) *a.* $(\exists x\phi) \wedge \psi \quad \doteq \quad \exists x(\phi \wedge \psi)$
b. $(\exists x\phi) \rightarrow \psi \quad \doteq \quad \forall x(\phi \rightarrow \psi)$

Here $\phi \doteq \psi$ means: ϕ denotes the same relation as ψ in all models. Thinking of juxtaposed sentences as conjoined, the equivalence (7a) takes care of the extrasentential anaphor in (8).

(8) A^1 man walks in the park. He_1 whistles.

And (7b) is of course crucial for a proper treatment of donkey sentences.

Up till now the discussion indicates that DRT's successful treatment of singular anaphora and indefinite NPs can also be attained by almost standard means. And this comes with the bonus that DPL's quantificational resources are extended quite easily in a uniform way. Following up on Kadmon's observation, Chierchia 1992 gives two ways in which generalized quantifiers could be added in terms of the

[5] See Dekker 1993, ch. 1 for an excellent overview.
[6] Other connectives and quantifiers are defined in terms of $\exists$, $\neg$, and $\wedge$.

familiar static ones (cf., also Van Eijck & De Vries 1992). Using the dynamic connectives $\wedge$ and $\rightarrow$, he defines:[7]

(9) $[\mathrm{Q}_{weak}\ x : \phi](\psi)$ *iff* $[\mathrm{Q}x : \phi](\phi \wedge \psi)$
$[\mathrm{Q}_{strong}\ x : \phi](\psi)$ *iff* $[\mathrm{Q}x : \phi](\phi \rightarrow \psi)$

The quantifiers are internally dynamic: they only preserve anaphoric links between their arguments. Rather than to give the semantics explicitly (which is not difficult), I recall how they work in case of donkey sentences:

(10) *a.* $[\mathrm{Q}_{weak}\ x : \mathrm{F}x \wedge [\mathrm{an}\ y : \mathrm{D}y \wedge \mathrm{O}xy]](\mathrm{B}xy) \doteq$
$[\mathrm{Q}x : \mathrm{F}x \wedge [\mathrm{an}\ y : \mathrm{D}y \wedge \mathrm{O}xy]]([\mathrm{an}\ y : \mathrm{D}y \wedge \mathrm{O}xy]\mathrm{B}xy)$
b. $[\mathrm{Q}_{strong}\ x : \mathrm{F} \wedge [\mathrm{an}\ y : \mathrm{D}y \wedge \mathrm{O}xy]](\mathrm{B}xy) \doteq$
$[\mathrm{Q}x : \mathrm{F}x \wedge [\mathrm{an}\ y : \mathrm{D}y \wedge \mathrm{O}xy]]([\mathrm{every}\ y : \mathrm{D}y \wedge \mathrm{O}xy]\mathrm{B}xy)$

Since the quantifiers used in (10) are the standard ones, the proportion problem is absent. It is also worth to point out that the definitions use two notions of conservativity. But whereas these two notions are statically equivalent, they are different in a dynamic setting (cf., Kanazawa 1993, 17).[8] One may wonder whether a quantifier should always be ambiguous between a weak and a strong reading. This issue is discussed in section 3.

The logics DRT and DPL push the idea that pronouns are bound variables to its limits by enriching the meaning of connectives and quantifiers in various ways. For the purposes of this paper, which focuses on quantification, it should be stressed that these logics are especially good at explaining the phenomena involving singular anaphora and unselective binding. And we have seen how this success can be retained while extending the formal language with generalized quantifiers. Unfortunately, the quantifiers only handle intrasentential anaphora. They do not cover the plural and the extrasentential anaphora, which are so abundant in everyday speech. In order to cover these as well, it seems as if the semantics has to be made more expressive to be able to encode and pass on the relevant information (cf., Van den Berg 1991, 1992). By contrast, the DRT solution consists of generalizing from a collective semantics for quantifiers, which may have the undesirable side-effect of leaving the verb phrase outside its scope (cf., Van der Does 1993).[9] The question arises to what extent such enrichments are necessary. After all, it would be nice to have a semantics which stays as close as possible to the generalized quantifier theory as we now know it. It seems that in this respect the E-type analysis has something to offer. The ensuing section has an overview of the various ways in which it has been formalized.

2.2 Pronouns as descriptions

Currently, there is a renewed attention for the E-type analysis; cf., Heim 1990, Kadmon 1990, and the admirable defence in Neale 1990, ch. 5 and 6. One of the reasons may be that previous work in this tradition leaves the impression that anaphora could be accounted for by means of a minimal change of the semantics (cf., Evans 1977, 1980, Cooper 1979, Richards 1984, among others). In giving a

[7]The subscripts indicate which reading results. See Kanazawa 1993, 15–16 for some worked out examples. Of course, this solution is available to DRT as well, as soon as its quantificational duplex conditions are restricted to one variable (cf., Kamp & Reyle t.a.).

[8]Normally, a quantifier Q is said to be conservative iff: $QXY \Leftrightarrow QXY \cap X$, for all sets X and Y. Kanazawa observes that this is equivalent to requiring: $QXY \Leftrightarrow QX\overline{Y} \cup X$, for all sets X and Y. Here $\overline{Y}$ is the complement of Y relative to the domain.

[9]In this article I do scant justice to the work of Kamp & Reyle t.a., ch. 4 and Van den Berg 1991, 1992 concerning plural anaphora. As I said in the introduction, I hope to address this issue in a sequel to this paper. And that will be a good occasion to make up for this omission.

fully rigorous formalization, which is still to be done, the main task seems to be to provide a mechanism which determines the descriptive content of a pronoun from an antecedent and makes it available for use further on. Of course, even a crash course in discourse theory will dispel the illusion that such a mechanism is simple. Yet, it should be possible to define it so that the semantics of quantifiers and connectives are left in place. In section 4, I aim to show that this impression is correct. But prior to that I give an overview of the various formalizations of E-type anaphora and the subtle differences which arise here. The singular pronouns receive special attention.

2.2.1 Some options

A famous examples within the E-type analysis is Evans' (11a).

(11) *a.* Few^1 MPs came to the party, but they$_1$ had a marvellous time.
b. $[\text{few } x : \text{MP}x]\text{C}x \wedge \text{H}\mathit{they}_x$.

According to Evans (11a) should be analysed as (11b), in which the reference of the term 'they' is fixed by the description 'the MPs who came to the party.' However, Evans proposal is only one out of several related options.

First, there is the issue of where the content of the descriptions comes from. As Heim 1990, 165 puts it, this could at one extreme 'rely very heavily on extragrammatical (i.e., pragmatic or psychological) factors,' while at the other there are 'tighter and somehow more 'syntactic' limitations on the range of readings that actually emerge.' In this paper, I try to stay as close as possible to the syntactic extreme. That is, I try to keep in line with Evans 1977, 1980, Richards 1984, Neale 1990, and Heim 1990, sec. 5.

Second, there is the question of whether or not E-type pronouns refer. Evans argues that they do. E-type pronouns as terms which have their reference fixed by description are scopeless rigid designators. And Evans 1985, 131–133 has some observations on scope with respect to psychological attitudes, negations, modalities, and time, which seem to indicate that this is indeed required. However, Neale 1990, 185– 189 shows that the data is more complex (cf., also section 6). For this reason I follow Richards 1984 and Neale 1990 and make E-type pronouns sensitive to scope.

This still leaves the option of making them either non-referring terms or quantifiers (Richards 1984 and Neale 1990, respectively). In the next section we shall see that these variants do not differ too much. I choose Neale's approach, since it has the virtue of using the format which has become standard in the treatment of natural language quantifiers. Before comparing Neale and Richards, I recall some of the problems for the E-type analysis with singular pronouns. Here I introduce my own proposal involving choice functions, which is defended in more detail in section 3.

2.2.2 Uniqueness

Evans holds that singular pronouns correspond to singular definite descriptions. But there are well-known cases which indicate that this is problematic. Heim 1982, 28 observes that on this proposal the anaphor sentence of (12a) means (12b).

(12) *a.* A^1 wine glass broke last night. It$_1$ had been very expensive.
b. The wine glass that broke last night had been very expensive.
c. Just one wine glass broke last night.

As a consequence the entire discourse can only be true in those contexts where the antecedent sentence in (12a) is equivalent to (12c). This runs counter to the intuition that as far as this sentence goes, more than one wine glass might have been broken only some of which were expensive (cf. also Kadmon 1990, 278, 282).

Singular descriptions also block the so-called strong reading of a donkey sentence, which is preferred by most semanticists. The E-type treatment of 'it' gives (13a) the meaning that every farmer who owns a donkey beats the unique donkey he owns. However, it has often been argued that the reading (13b) is more prominent.

(13) *a.* Every farmer who owns a donkey beats it.
b. $[\text{every } x : \mathrm{F}x][\text{every } y : \mathrm{D}y \wedge \mathrm{O}xy]\mathrm{B}xy$

More worrying is (14), again from Heim 1982.

(14) Everybody who bought a sage plant here bought eight others along with it.

Sentence (14) would be uninterpretable as soon as it is required that each client bought a unique sage plant.

There are various ways in which one could respond to these observations: (i) one could argue that Evans' proposal is somehow correct after all, or (ii) one could propose a new interpretation of singular E-type pronouns. The second option is taken by Richards 1984 and Neale 1990, among others, and is studied in section 2.2.3. The first option is defended by Evans 1977, 1980, Cooper 1979, and more recently by Kadmon 1990. It will occupy the rest of this section.

Kadmon 1990 has many interesting observations which aim to show that the uniqueness requirement can be defended as soon as one takes 'implicated, accommodated and contextually supplied material' serious. For instance, in case of (12) and (13) she holds that not only the pronoun 'it' but also the antecedents 'a wine glass' and 'a donkey' come with a uniqueness requirement. This is not a semantic but a pragmatic phenomenon which has to be accommodated at the appropriate places within the corresponding DRSs (cf., Kadmon 1990, sec. 3.3). With respect to these examples, Kadmon holds, in line with Kripke 1977 and Lewis 1979, that in using a singular anaphor pronoun an object has to be raised to salience somehow. This object '**does** have to be unique in **some** way' (Kadmon 1990, 282). If it cannot be distinguished from other similar objects, the sentences cannot be used felicitously.

Kadmon's argument might give the special reasons required by Gricean maxims for the use of (13) and (14) rather than the unproblematic (15a,b).[10]

(15) *a.* Every farmer who owns donkeys beats them.
b. Everybody who bought sage plants here bought nine of them.

However, she holds that there is an important difference between (14), and (13) and (14). In case of (14) it is precisely the fact that the plants bought are indistinguishable from each other which would save uniqueness: the 'choice of unique plant (per buyer) can **always** remain undetermined' (Kadmon 1990, 318).

There is an apparent tension between Kadmon's analysis of (12) and (13), and that of (14). It is the fact that in the first case the uniqueness requirement should be accommodated, while in the second case it should not. But there seems to be no principled way in which this distinction could be defended.

In my opinion, Kadmon's view on (14) is more basic than her view on (12) and (13). That is, using Hilbert & Bernays eta-term, I would analyse (12), (13), and (14) as (16a,b,c), respectively.[11]

(16) *a.* $[\text{an } x : \mathrm{W}x]\mathrm{B}x.\ \mathrm{E}\eta x(\mathrm{W}x \wedge \mathrm{B}x).$
b. $[\text{every } x : \mathrm{F}x \wedge [\text{an } y : \mathrm{D}y]\mathrm{O}xy]\mathrm{B}x\eta y(\mathrm{D}y \wedge \mathrm{O}xy).$
c. $[\text{every } x : \mathrm{H}x \wedge [\text{an } y : \mathrm{S}y]\mathrm{B}xy][\mathbf{8}\ z : \mathrm{S}z \wedge z \neq \eta y(\mathrm{S}y \wedge \mathrm{B}xy)]\mathrm{B}xz.$

[10]Kadmon doesn't use the contrast between (13) and (14) on the one hand, and (15a,b) on the other.

[11]The semantics for 'other' in (16c) is from Barwise 1987.

Here $\eta x\phi$ denotes a choice from the set $\widehat{x}.\phi$ if this set is non-empty; otherwise it denotes the null object '•' (cf., Muskens 1989 and the references therein). So, singular pronouns denote choice functions which pick an arbitrary element from a set provided by the antecedent.[12] On this view, it is left to context and to logic to determine whether more information can be extracted from a particular use of these sentences.In some cases the context will make clear that the choice is due to distinguishing features of the given object, whereas in other cases it will be clear that the choice is more or less arbitrary. I will come back to this issue in more detail at the end of section 3 and in section 5.

It is along these lines that I would argue that uniqueness (per choice) is an acceptable facet of singular E-type pronouns. It gives a good semantics for these pronouns, and it keeps the E-type analysis nice and general. By contrast, Richards 1984 and Neale 1990 seek to incorporate the Geachian truth conditions of donkey sentences within this framework. Subtleties aside, they offer the same solution: E-type pronouns are numberless descriptions.[13] Let's see how this proposal fares.

2.2.3 Numberless descriptions

In order to get the universal force of donkey sentences, Richards 1984, 305–307 introduces terms $x[\phi]$. Here ϕ is a formula of a standard first-order language which has x bound. These terms are used to formalize E-type pronouns. To be precise, if the antecedent of such a pronoun corresponds to the quantifier $[\mathrm{Q}x : \phi]\psi$ (with ϕ its restriction and ψ its scope), the pronoun is given by $x[\phi \wedge \psi]$. As is common in this area, the choice of the variables matters: an antecedent and its E-type pronoun should bind the same variable. The reason is that variables not only enable the familiar binding mechanism, they also function as indices to indicate anaphoric links.

Unlike Russell's iota-operator the terms $x[\phi]$ are no abbreviations. But they share with iota-terms that they are ambiguous as to the scope they take. In order to resolve this ambiguity, Richards stipulates that the terms take scope over basic sentences; i.e., atomic sentences or negations thereof. The semantics of a term $x[\phi]$ is now defined in context by requiring that a basic sentence in which it occurs is equivalent to one in which ϕ restricts a universal quantification over x in the basic sentence.[14] In particular, (17a) means (17b):

(17) *a.* $\mathrm{W}xy[\mathrm{C}y \wedge \mathrm{O}xy]$
b. $[\text{every } y : \mathrm{C}y \wedge \mathrm{O}xy]\mathrm{W}xy$

[12]The formalism defined in section 4 uses the choice functions implicitly within the restriction of a quantifier. It enables me to account for the possible dependencies among choices, but this need not concern us here.

My proposal is similar to that of others. Muskens 1989 suggests that choice functions could be used to model indefinite NPs, not singular pronouns. DPL's treatment of the existential quantifier involves an element of choice, which is made explicit using eta-terms by Van Eijck 1993. Meyer Viol 1992 applies indefinite description operators for indefinite NPs and singular pronouns but mainly within a proof theoretic setting. The proposal can also be seen as a variant of Heim 1990, sec. 1, where she argues that such functions should be supplied pragmatically. The functions used here are of a different character, though.

[13]In an unpublished manuscript, which I haven't got hold off, Parsons 1978 is perhaps the first to do this (cf., Neale 1990, xiii).

[14]There is another ambiguity which Richards does not resolve. It makes a difference for (i) which of the terms is eliminated first:

(i) $\mathrm{Hx[Px]y[Rxy]}$

(ii) $[\text{every x : Px}][\text{every y : Rxy}]\ \mathrm{Hxy}$

(iii) $[\text{every y : Rxy}][\text{every x : Px}]\ \mathrm{Hxy}$

The formula (i) means either (ii) or (iii). Indeed, Richards 1984, 306 claim that such terms are independent of each other is incorrect.

As a consequence, Evans' (18a) is represented by (18c), which is its strong reading.

(18) *a.* Most men who own a car wash it on Sunday.
b. [most x : M$x \wedge$ [an y : Cy]Oxy](Wxy[C$y \wedge$ Oxy])
c. [most x : M$x \wedge$ [an y : Cy]Oxy]([every y : C$y \wedge$ Oxy]Wxy)

It should be noted that according to Richards E-types pronouns are numberless: there is no cardinality restriction on the extension of their descriptive content.

Neale's solution is different in a subtle but important way. Instead of as terms, he interprets E-type pronouns as the quantifier 'pro' defined by:[15]

(19) **pro**XY *iff:* $X \subseteq Y$ & $X \neq \emptyset$

A great advantage of this approach is that no stipulations have to be made concerning scope. This is important, for as we shall see in section 6 the scope behaviour of pronouns is less restricted than is suggested by Richards. For this reason, I adopt Neale's format in what follows.

The crucial point of the proposals of Richards and Neale is that the reading (18c) is obtained differently than in DRT or DPL. In (18c) the work is done by the pronoun; the indefinite NP has its standard interpretation as an existential quantifier. The pronoun is not a variable but a context dependent quantifier, which receives its restriction by means of a simple Xeroxing mechanism.

On the E-type analysis the proportion problem does not arise, since it treats all quantifiers in the standard way. And as Neale 1990, ch. 5 and 6 shows, it works well in a remarkable number of cases (donkeys, sage plants, MiGs, among other things). Still, semanticists like Richards and Neale, who aim to incorporate the Geachian truth conditions of (18), encounter what might be called the pronoun problem. As soon as pronouns are quantifiers, one should ask whether the choice of quantifier can be made uniformly over all contexts. The data suggests that this is not so. For instance, (20a) is from Richards 1984, 316, who does not make a secret of the weaker spots in his proposal.

(20) *a.* Some boy built a castle and it fell down.
b. [an x : B$x \wedge$ [an y : Cy]Bxy][every y : C$y \wedge$ Bxy]Fxy

The preferred reading says that one of the castles built by some boy fell down, not that all of them did. But on the numberless description approach, where the pronoun has universal force, this weak reading is unavailable (cf., also Neale 1990, 238). It is worth to point out that if the singular pronoun is interpreted by a choice from the set $\widehat{y}$.C$y \wedge$ Bxy, as proposed in section 2.2.2, the problem does not arise. It is also absent in DRT and DPL.

To summarize, up till now the E-type analysis combines well with quantification theory. But numberless descriptions preclude to discern the weak and strong readings which are said to arise in case of singular pronouns. This is a good occasion to see how the pronoun problem fits within the recent discussion on this topic.

3 Weak and strong readings

A rigorous study of weak and strong readings is in Kanazawa 1992, 1993. He uses interesting logical results to underpin a linguistic claim concerning the question whether the internally dynamic quantifiers should always be ambiguous between a weak and a strong reading.[16]

[15]Neale calls the quantifier 'whe.'

[16]Kanazawa 1992 is under revision, so this discussion has a somewhat tentative character.

3.1 Kanazawa's proposal

Pace the complexity of the data he discusses, Kanazawa 1992 suggests that at least in case of the doubly monotone quantifiers there is a principled way to choose one of the readings. To this end he first observes that the preferred reading of donkey sentences with relative clauses is closely tied up with the monotonicity behaviour of its main determiner (cf., Kanazawa 1993, 3):

(21) *a.* Every student who borrowed a book from Peter returned it.
$\downarrow$MON$\uparrow$, strong reading: all books returned
b. No students who borrowed a book from Peter returned it.
$\downarrow$MON$\downarrow$, weak reading: no book returned
c. Two students who borrowed a book from Peter returned it.
$\uparrow$MON$\uparrow$, weak reading: a book returned
d. Not every student who borrowed a book from Peter returned it.
$\uparrow$MON$\downarrow$, strong reading(?): a book not returned

The examples indicate that in case the main determiner is monotone in both arguments, a donkey sentence has a weak reading if they are monotone in the same direction, and a strong reading otherwise.

Kanazawa goes on to show that this linkage between readings and monotonicity behaviour is confirmed by some of his logical results concerning Chierchia's extension of DPL. The key question is whether the definitions preserve the monotonicity behaviour of the static quantifier, when this notion is suitably generalized to the framework of DPL. It turns out that in case of the doubly monotone quantifiers only one of the readings fully preserves their monotonicity pattern ('DMON' for: dynamic monotonicity; Kanazawa 1993, 21):

Q	Q_{weak}	Q_{strong}
$\uparrow$MON$\uparrow$	$\uparrow$DMON$\uparrow$	$\not\uparrow$DMON$\uparrow$
$\uparrow$MON$\downarrow$	$\not\uparrow$DMON$\downarrow$	$\uparrow$DMON$\downarrow$
$\downarrow$MON$\uparrow$	$\not\downarrow$DMON$\uparrow$	$\downarrow$DMON$\uparrow$
$\downarrow$MON$\downarrow$	$\downarrow$DMON$\downarrow$	$\not\downarrow$DMON$\downarrow$

And the quantifier reading that does preserves monotonicity is precisely the one favoured! It should be noted that in case of the doubly monotone 'all,' 'some,' 'no,' and 'not all,' the polyadic treatment of DRT obtains the same distribution of weak and strong readings.

Kanazawa's observation is not fully general. There are non-monotone quantifiers besides quantifiers which are monotone in only one argument. But he uses this fact to suggest that in case of 'most,' which is $\not\downarrow\not\uparrow$MON$\uparrow$, people allow sentences like (18a) to have a strong and a weak reading (e.g., Heim 1983, 63).

In sum, Kanazawa suggests that in some cases the DPL treatment of dynamic generalized quantifiers allows for a principled choice between the weak and the strong readings of donkey sentences. Before we evaluate this proposal in more detail, I would like to consider how this insight could be made available for pronouns in general.

3.2 The pronoun problem

The pronoun problem can now be rephrased as follows. As soon as one tries to incorporate Geachian truth conditions of donkey sentences within an E-type approach, one seems bound to give them always a strong or always a weak reading. By contrast, the use of dynamic generalized quantifiers circumvents the problem, since the choice of reading is taken care of by the determiner.

It is worthwhile to look in more detail how this result is achieved within DPL. As said, indefinite NPs are treated as existential quantifiers but they have the side-effect of introducing an object which may be the value of a pronoun, i.e., a variable. The rôle of the determiner is now to enforce one of the readings for each pair consisting of an indefinite antecedent in its restriction and an anaphor in its scope. Interestingly, this involves copying material from the restriction to its scope. It happens under the banner of conservativity, but often a sentence results which is equivalent to one in which the same material is copied as on the E-type analysis. This is particularly clear in case of donkey sentences, for then we have (10), which is repeated here for convenience:

(22) *a.* $[\mathrm{Q}_{weak}\ x : \mathrm{F}x \wedge [\mathrm{an}\ y : \mathrm{D}y \wedge \mathrm{O}xy]](\mathrm{B}xy) \Leftrightarrow$
$[\mathrm{Q}x : \mathrm{F}x \wedge [\mathrm{an}\ y : \mathrm{D}y \wedge \mathrm{O}xy]]([\mathrm{an}\ y : \mathrm{D}y \wedge \mathrm{O}xy]\mathrm{B}xy)$
b. $[\mathrm{Q}_{strong}\ x : \mathrm{F} \wedge [\mathrm{an}\ y : \mathrm{D}y \wedge \mathrm{O}xy]](\mathrm{B}xy) \Leftrightarrow$
$[\mathrm{Q}x : \mathrm{F}x \wedge [\mathrm{an}\ y : \mathrm{D}y \wedge \mathrm{O}xy]]([\mathrm{every}\ y : \mathrm{D}y \wedge \mathrm{O}xy]\mathrm{B}xy)$

Of course, an important difference with the E-type analysis remains: it is not the pronoun which induces the readings. Instead, all anaphoric links within a particular linguistic context, delineated by the determiner, are marked for 'strong' or 'weak.' In this way a uniform choice across all contexts is circumvented. It may vary per determiner.

Within an E-type approach one may look for a generalization of the above ideas, which should also work for extrasentential anaphora. This is desirable anyway. One such generalization makes use of the familiar identification of 'monotone decreasing' with 'negative' and 'monotone increasing' with 'positive.' Call an expression *positive* if it occurs in an increasing environment, *negative* if it occurs in a decreasing environment, and *neutral* otherwise. Following up on Kanazawa's observations, it may then be proposed that if an E-type pronoun and its antecedent both occur in a non-neutral environment, it should get a weak reading if the antecedent and the pronoun are of the same polarity but a strong reading otherwise. Whenever the antecedent or the anaphor are in a non-neutral environment, the anaphor may be ambiguous between a weak and a strong reading. However, some observations show that situation is more complex.

3.3 A few precautions

There are four observations which tell against the proposed generalization.

First, the dichotomy weak vs. strong reading seems to be an exceptional phenomenon which only takes place with singular pronouns within particular environments. But there are many linguistic and extralinguistic factors involved here, which make the situation less systematic than it appeared to be in the previous section. For instance, in an appropriate context sentences which are quite like Richards' problematic (20), may have a strong reading after all. For imagine a beach party, where anybody is treated to popcorn as long as she has built a castle. A member of the jury may use (23a) to indicate that a child who actually built two castles is entitled to a treat, although the evidence is no longer at hand.

(23) *a.* This child built a castle. It fell down.
b. This child built at least one castle. ?It fell down.

To the extent that (23b) is felicitous, it shows that the strong reading is emphasized as soon as the existential quantification is made explicit. And in case of the plural anaphora in (24a,b), a strong reading is often if not always the only one available.

(24) *a.* Two boys built some castles. They fell down.
b. A girl who is treated with respect by most boys in her class
tends to ignore them.

Note that in (24b) the main determiner is $\uparrow$MON$\uparrow$, which favours a weak reading in case of singular pronouns.

Second, in Sell's (25) the pronoun and its antecedent both occur positively.

(25) Every chess set comes with a spare pawn^1.
It$_1$ is taped to the top of the box.

The principle would predict a weak reading for the pronoun, but in absence of any further information I rather get a strong one.[17]

Third, the internal dynamic quantifiers incorporate the idea that the anaphoric links within their contexts should be uniformly marked as either 'strong' or 'weak.' But this seems too strict. Consider the 'donkey/dime' sentence (26):

(26) Every farmer who has a horse, and a whip in his barn, uses it
to lash him.

Clear intuitions are absent, but a combined reading in which a whip is used to lash all horses seems available.

Finally, some of the examples discussed in Kanazawa 1992 suggest that the analogy noted in (21) can be inverted. Using my own variants, we have:

(27) *a.* Every father who has an apple in his rucksack gives it
to his daugther. ($\downarrow$MON$\uparrow$, weak reading: an apple given)
b. At most two climbers who had a flare in their rucksack kept it
for emergencies. ($\downarrow$MON$\downarrow$, strong reading(?): all flares kept)
c. A boy who had an apple in his rucksack didn't give it
to his sister. ($\uparrow$MON$\uparrow$, strong reading: no apple given)
d. Not every girl who had an apple in her rucksack gave it
to her brother. ($\uparrow$MON$\downarrow$, weak reading: no apples given)

Generalizing from these data, the principle should be inverted as well. Sentence (27c) with its VP negation is especially interesting. It points to the fact that if the main determiner decides which reading is to result, the implicit quantification as restricted by the copied material will always take wide scope over the entire VP (cf., 22). But it might well be so that the strong reading results from a weak reading of the pronoun within the scope of negation.

The above discussion shows is that the distribution of weak and strong readings is less systematic than it appeared to be at first sight. This means that whatever analysis one adopts there will be an overgeneration of readings. For it seems hard to sustain that each quantified sentence is ambiguous between a weak and a strong reading. On top of this, an E-type analysis has to face the problem of how to account for the semantic variation to begin with. In section 5, I will argue that the E-type analysis which interprets singular pronouns by means of choice functions, offers an attractive alternative to the treatment of weak and strong readings in DPL. This interpretation combines well with the E-type analysis but avoids the familiar problems with sage plant sentences and the like. It offers a viable alternative to other proposals, if it allows for a reasonably simply formal semantics. As far as sentences are concerned, it is the main aim of the subsequent section to define such a semantics.

4 Dynamic quantifier logic: sentences

Now that some of the basic ideas and intuitions are in place, it is time to incorporate them within a formal system. The system, called dynamic quantifier logic or DQL

[17]Kadmon 1990, 292–4 treats (25) using Roberts' mechanism of subordination. This results in a weak reading.

for short, is best thought of as a standard 'static' logic, which comes with a separate dynamic module to handle the context generated by a text. DQL is defined in two stages. In this section I concentrate on the sentential part. After an impression of its workings in section 5 and a discussion of extrasentential anaphora in section 6, section 7 studies texts.

4.1 The language

Let $\mathcal{L}$ be a language which has individual constants c, d,...; identity '=' besides relation signs R^n, S^m,... of the indicated arity; quantifier symbols 'pro$_{sg}$' and 'pro$_{pl}$;' and two place determiner signs 'all,' 'some,' D, D$'$,... . In what follows I assume that there is an infinite supply of variables. The letters ϕ, ψ,... vary over formulas.

Definition 4.1 (formulas) *The set of formulas is the smallest set satisfying:*

(i) *If $x_1 \ldots x_n$ are variables and R is an n-place relation sign, then $Rx_1 \ldots x_n$ is an atomic formula.*

(ii) *If x and y are variables, then $x = y$ is an atomic formula.*

(iii) *If ϕ and ψ are formulas, then so are $\neg\phi$, $\phi \rightarrow_c \psi$, $\phi \rightarrow_a \psi$, and $\phi \rightarrow_k \psi$.*

(iv) *If x is a variable and ϕ is a formula, then $[\text{pro}_{sg}\ x]\phi$ and $[\text{pro}_{pl}\ x]\phi$ is a formula.*

(v) *If x is a variable, c an individual constant, and ϕ a formula, then $[\text{c}\ x]\phi$ is a formula.*

(vi) *If x is a variable and D a determiner sign, and ϕ and ψ are formulas, then $[\text{D}x : \phi]\psi$ is a formula.*

In case the kind of arrow or the number of pronouns is immaterial, we just use $\rightarrow$ or $[\text{pro}\ x]$.

The language is standard except for the arrows in (iii), the pronouns in (iv) and the treatment of referring expressions in (v). DQL allows to discern *c*lassical, *a*naphoric, and *k*ataphoric connectives. And the arrows in (iii) are used for this purpose. Other connectives are introduced in the familiar way:

$$\begin{array}{lll} \phi \vee \psi & \equiv_{df} & \neg\phi \rightarrow \psi \\ \phi \wedge \psi & \equiv_{df} & \neg(\neg\phi \vee \neg\psi) \end{array}$$

A further idea is that the expressions which correspond to noun phrases, in particular: proper names, pronouns and complex NPs, are represented by quantifiers. The reason is that they should have scope syntactically, since this is important to determine how the pronouns are to be interpreted. Pronouns also need special care in that they may function deictically, as bound variables, or as contextually restricted expressions. The details of how these differences come about are left until the semantics is defined.

4.2 Context change potential

As soon as one interprets E-type pronouns as discussed in section 2.2 and 3, it is crucial that the part of the text in which they occur generates a context to supply their restriction. In this paper, contexts are of a syntactical nature: they are partial functions from variables to formulas. In terms of such contexts, I specify the context change potential of a formula. As will become clear in what follows, much of the work is done at this stage.

Definition 4.2 (context change potential) *With each formula ϕ we assign a function $(\!\lbrack\phi\rbrack\!)$ from contexts to contexts. Using postfix notation, we have:*

(i) $\mathbf{c}(\!\lbrack Rx_1 \dots x_n\rbrack\!) \simeq \mathbf{c}$

(ii) $\mathbf{c}(\!\lbrack x = y\rbrack\!) \simeq \mathbf{c}$

(iii) $\mathbf{c}(\!\lbrack \neg\phi\rbrack\!) \simeq \mathbf{c}(\!\lbrack\phi\rbrack\!)$

(iv) $\mathbf{c}(\!\lbrack \phi \to \psi\rbrack\!) \simeq \mathbf{c}(\!\lbrack\phi\rbrack\!)(\!\lbrack\psi\rbrack\!)$.

(v) $\mathbf{c}(\!\lbrack[\mathrm{c}\ x]\phi\rbrack\!) \simeq (\mathbf{c} \cup \{\langle x, x = c\rangle\})(\!\lbrack(\phi)^x\rbrack\!)$

(vi) $\mathbf{c}(\!\lbrack[\mathrm{D}x : \phi]\psi\rbrack\!) \simeq (\mathbf{c} \cup \{\langle x, (\phi)^x \wedge_a (\psi)^x\rangle\})(\!\lbrack(\phi)^x\rbrack\!)(\!\lbrack(\psi)^x\rbrack\!)$

(vii) $\mathbf{c}(\!\lbrack[\mathrm{pro}_{\mathrm{sg}}\ x]\phi\rbrack\!) \simeq \begin{cases} (\mathbf{c}^{-x} \cup \{\langle x, x = \eta x\mathbf{c}(x) \wedge_a (\phi)^x\rangle\})(\!\lbrack(\phi)^x\rbrack\!) & \text{if } \mathbf{c}(x)\Downarrow \\ \mathbf{c}(\!\lbrack(\phi)^x\rbrack\!) & \text{if } \mathbf{c}(x)\Uparrow \end{cases}$

(viii) $\mathbf{c}(\!\lbrack[\mathrm{pro}_{\mathrm{pl}}\ x]\phi\rbrack\!) \simeq \begin{cases} (\mathbf{c}^{-x} \cup \{\langle x, \mathbf{c}(x) \wedge_a (\phi)^x\rangle\})(\!\lbrack(\phi)^x\rbrack\!) & \text{if } \mathbf{c}(x)\Downarrow \\ \mathbf{c}(\!\lbrack(\phi)^x\rbrack\!) & \text{if } \mathbf{c}(x)\Uparrow \end{cases}$

Here $\mathbf{c}(\!\lbrack\phi\rbrack\!) \simeq \mathbf{c}'$ means that $\mathbf{c}(\!\lbrack\phi\rbrack\!) = \mathbf{c}'$ if $\mathbf{c}'$ is a function; otherwise it is $\mathbf{c}$. Also, $\mathbf{c}^{-x}$ is the function $\mathbf{c}$ minus its value for x. Finally, $\mathbf{c}(x)\downarrow$ means that $\mathbf{c}$ is defined for x ($x \in dom(\mathbf{c})$), and $\mathbf{c}(x)\uparrow$ that it is undefined for x ($x \notin dom(\mathbf{c})$).

Definition 4.2 employs what may be loosely called a constructive view on the increase of information. Rather than eliminating possibilities, as is done in DPL and other systems, contexts are 'structured objects' which are created as we go along. More in particular, the definition is based on the idea that in processing a text from left-to-right the context should record the information given by possible antecedents which is relevant to interpret E-type pronouns. For this reason the quantificational expressions are the only ones which affect the context. The examples in section 5.1 show in detail how the contexts work.

Let me comment on definition 4.2. Atomic sentences, negations, and implications do not affect the context at all. They just add and transfer the information provided by their subformulas. This makes the treatment of negation similar to the complement negation in dynamic Montague grammar (DMG, Groenendijk & Stokhof 1990): it does not block any anaphoric links. Dekker 1993, ch. 2 shows that in case of DMG this has to be refined. It is not clear whether his observations apply to the present system as well, but I hope to address the issue by means of an extension of DQL.[18]

[18] The idea is to use a subrecursion in case of (iii) with presumably the following clauses:

(i) $\mathbf{c}(\!\lbrack\neg Rx_1 \dots x_n\rbrack\!) \simeq \mathbf{c}$

(ii) $\mathbf{c}(\!\lbrack\neg x = y\rbrack\!) \simeq \mathbf{c}$

(iii) $\mathbf{c}(\!\lbrack\neg\neg\phi\rbrack\!) \simeq \mathbf{c}(\!\lbrack\phi\rbrack\!)$

(iv) $\mathbf{c}(\!\lbrack\neg(\phi \to \psi)\rbrack\!) \simeq \mathbf{c}(\!\lbrack\phi\rbrack\!)(\!\lbrack\neg\psi\rbrack\!)$.

(v) $\mathbf{c}(\!\lbrack\neg[\mathrm{c}\ x]\phi\rbrack\!) \simeq (\mathbf{c} \cup \{\langle x, x = c\rangle\})(\!\lbrack(\neg\phi)^x\rbrack\!)$

(vi) $\mathbf{c}(\!\lbrack\neg[\mathrm{D}x : \phi]\psi\rbrack\!) \simeq (\mathbf{c} \cup \{\langle x, (\phi)^x \wedge_a (\neg\psi)^x\rangle\})(\!\lbrack(\phi)^x\rbrack\!)(\!\lbrack(\neg\psi)^x\rbrack\!)$

(vii) $\mathbf{c}(\!\lbrack\neg[\mathrm{pro}_{\mathrm{sg}}\ x]\phi\rbrack\!) \simeq \begin{cases} (\mathbf{c}^{-x} \cup \{\langle x, x = \eta x\mathbf{c}(x) \wedge_a (\neg\phi)^x\rangle\})(\!\lbrack(\neg\phi)^x\rbrack\!) & \text{if } \mathbf{c}(x)\downarrow \\ \mathbf{c}(\!\lbrack(\neg\phi)^x\rbrack\!) & \text{if } \mathbf{c}(x)\uparrow \end{cases}$

(viii) $\mathbf{c}(\!\lbrack\neg[\mathrm{pro}_{\mathrm{pl}}\ x]\phi\rbrack\!) \simeq \begin{cases} (\mathbf{c}^{-x} \cup \{\langle x, \mathbf{c}(x) \wedge_a (\neg\phi)^x\rangle\})(\!\lbrack(\neg\phi)^x\rbrack\!) & \text{if } \mathbf{c}(x)\downarrow \\ \mathbf{c}(\!\lbrack(\neg\phi)^x\rbrack\!) & \text{if } \mathbf{c}(x)\uparrow \end{cases}$

This means that negated quantificational expressions pass on the intersection of a noun and the complement of a verb phrase for further use. To make this work, MON↓ determiners should be introduced as, say, the external negation of a MON↑ determiner (as is well-known, they all can be obtained in this way). It is left to the reader to check that this gives a correct semantics for sentences like: 'Either there is no bathroom here, or it is in a funny place.'

The context change potential of an implication is the composition of its antecedent and its consequent. This left-to-right processing is familiar from DPL, and is also used for the arguments of complex NPs.

Sentences with a quantifier as their main operator introduce a formula which may be used to interpret E-type pronouns. The formula consists of the anaphoric conjunction of the restriction and the scope of the quantifier. With a view to the well-known noun anaphora, it might be considered to make a context a function from variables to pairs of formulas. This would enable to choose between a noun anaphor (projection on the first argument) or an E-type anaphor (conjunction of the elements of the pair). In the following I do not consider noun anaphora any further.

One of the reason why proper names are treated as quantifiers is that it gives a uniform way to model the change of context. Although the information induced by pronouns, quantifiers and proper names is different in character, no special care has to be taken in regard to the interpretation of E-type pronouns. There is no distinction between rules for pronouns which have a referential expression as their antecedent, and those which have a quantifier as their antecedent (as in Evans 1977, 1980 and Neale 1990). It should be noticed furthermore that a pronoun affects an update of the information associated with its variable. The identity in clause (vii) makes sure that singular pronouns with the same variable also pick up one and the same individual during a discourse. Section 5 has more details on this issue.

A pronoun [pro x] which occurs within the scope of a quantificational expression binding x should function as a bound variable. To attain this the clauses (v–viii) employ the operation $(-)^x$ which erases all occurrences of [pro x] within its scope. Strictly speaking $(-)^x$ should be defined recursively, but the only place where it does some work is $([\text{pro } y]\phi)^x$. This is $(\phi)^x$ if $x \equiv y$, but $[\text{pro } y](\phi)^x$ otherwise.[19]

Before closing the section, I want to make some general remarks on the partiality of contexts and context change potentials. The partiality of contexts is natural, since they provide the information given by the preceding text to interpret the E-type pronouns. And of course a text has information on finitely many antecedents. That the contexts are functions is perhaps less natural. Roughly speaking, it captures the idea that for each E-type pronoun at most one antecedent is available. As I said before, besides their standard use in the binding mechanism, variables are used as indices which indicate anaphoric links. Due to the latter, a context ceases to be a function if two antecedents carry the same index. Within the present system this is not allowed. But there are cases where one would want to have multiple antecedents (cf., also Kamp and Reyle t.a., ch. 4):

(28) Once there was a woman who walked in the park.
She met a friend. They had a chat and were happy ever after.

I hope to deal with this issue in the sequel to this paper.

A well-known virtue of partial contexts is that their (un)definedness enables one to model the familiarity theory of definiteness as in Heim 1982, 1983. Here all non-anaphoric NPs are 'unfamiliar,' in the sense that they can only contribute to the context if it is undefined for the variable it binds. But in case of definite NPs it might be stipulated that they are uninterpretable unless the context is defined for its variable. The value of the context for this variable will then be used in its restriction. E-type pronouns are an important example of such definites but other definites could be treated in this way, too (cf., section 6.2). This shows that the

[19] It would be more realistic to require that in this case [pro y] actually binds a variable y, but I set this aside.

familiarity theory is compatible with a quantificational treatment of definite and indefinite NPs.

4.3 Interpretation in context

The next step is to interpret the formulas in context. To this end I use fairly standard models. But recall from section 2.2 thatchoice functions are employed to interpret the singular pronouns. Therefore, a stipulation has to be made concerning their value on the empty set. This value is the null object '$\bullet$,' which is disallowed to occur in the extension of relations (cf., Muskens 1989 for an overview of the issues involved here).

Definition 4.3 (choice function) *A choice function* $\mathbf{h}$ *for a set* X *is a function* $\mathbf{h} : \wp(X) \longrightarrow X \cup \{\bullet\}$ *with:*

$$\begin{cases} \mathbf{h}(X) \in X & \text{if } X \neq \emptyset \\ \mathbf{h}(X) = \bullet & \text{otherwise} \end{cases}$$

A model is now a triple $\mathcal{M} = \langle E, D, ^* \rangle$ with $E = D \cup \{\bullet\}$, $\bullet \notin D$, $D \neq \emptyset$, and * an interpretation function. In what follows, we often ignore E. That is, we think of $\mathcal{M}$ as a standard model $\langle D, ^* \rangle$, where * assigns elements of D to individual constants, n-place relations over D to n-place relation signs, and two-place relations between sets of D to determiner signs. The function * assigns the inclusion relation to 'all,' the relation of non-empty overlap to 'some,' and so on. Often I write **pro**, say, instead of $(\text{pro})^*$.[20]

Definition 4.4 (interpretation in context) *Let* $\mathcal{M} = \langle D, ^* \rangle$ *be a model,* $\mathbf{c}$ *a context,* $\mathbf{h}$ *a choice function for D, and* $\mathbf{a}$ *an assignment for* $\mathcal{M}$*. The truth of* χ *in* $\mathcal{M}$ *with respect to* $[\mathbf{a};\mathbf{c};\mathbf{h}]$ *– notation:* $\mathcal{M} \models \chi\ [\mathbf{a};\mathbf{c};\mathbf{h}]$ *– is defined recursively.*

a. $\mathcal{M} \models Rx_1 \ldots x_n\ [\mathbf{a};\mathbf{c};\mathbf{h}]$ *iff:* $\langle a(x_1), \ldots, a(x_n) \rangle \in R^*$.

b. $\mathcal{M} \models x = y\ [\mathbf{a};\mathbf{c};\mathbf{h}]$ *iff:* $\mathbf{a}(x) = \mathbf{a}(y)$.

c. $\mathcal{M} \models \neg\phi\ [\mathbf{a};\mathbf{c};\mathbf{h}]$ *iff:* $\mathcal{M} \not\models \phi\ [\mathbf{a};\mathbf{c};\mathbf{h}]$.

d. $\mathcal{M} \models \phi \rightarrow_c \psi\ [\mathbf{a};\mathbf{c};\mathbf{h}]$ *iff:* $\mathcal{M} \not\models \phi\ [\mathbf{a};\mathbf{c};\mathbf{h}]$ *or* $\mathcal{M} \models \psi\ [\mathbf{a};\mathbf{c};\mathbf{h}]$.

e. $\mathcal{M} \models \phi \rightarrow_a \psi\ [\mathbf{a};\mathbf{c};\mathbf{h}]$ *iff:* $\mathcal{M} \not\models \phi\ [\mathbf{a};\mathbf{c};\mathbf{h}]$ *or* $\mathcal{M} \models \psi\ [\mathbf{a};\mathbf{c}(\!(\phi)\!);\mathbf{h}]$.

f. $\mathcal{M} \models \phi \rightarrow_k \psi\ [\mathbf{a};\mathbf{c};\mathbf{h}]$ *iff:* $\mathcal{M} \not\models \phi\ [\mathbf{a};\mathbf{c}(\!(\psi)\!);\mathbf{h}]$ *or* $\mathcal{M} \models \psi\ [\mathbf{a};\mathbf{c}(\!(\phi)\!);\mathbf{h}]$.

g. $\mathcal{M} \models [\mathrm{c}\ x]\phi\ [\mathbf{a};\mathbf{c};\mathbf{h}]$ *iff:* $\mathrm{c}^* \in \widehat{x}.[\![(\phi)^x]\!]_{\mathbf{a};\mathbf{c};\mathbf{h}}$.

h. $\mathcal{M} \models [\mathrm{D}x : \phi]\psi\ [\mathbf{a};\mathbf{c};\mathbf{h}]$ *iff:* $\mathbf{D}(\widehat{x}.[\![(\phi)^x]\!]_{\mathbf{a};\mathbf{c}(\!((\psi)^x)\!);\mathbf{h}}, \widehat{x}.[\![(\psi)^x]\!]_{\mathbf{a};\mathbf{c}(\!((\phi)^x)\!);\mathbf{h}})$.

i. $\mathcal{M} \models [\mathrm{pro}_{sg}\ x]\phi\ [\mathbf{a};\mathbf{c};\mathbf{h}]$ *iff:* $\mathbf{h}([\![\mathbf{c}(x)]\!]_{\mathbf{a};\mathbf{c};\mathbf{h}}) \in \widehat{x}.[\![(\phi)^x]\!]_{\mathbf{a};\mathbf{c};\mathbf{h}}$ *and* $\mathbf{c}(x){\downarrow}$.

$\mathcal{M} \models [\mathrm{pro}_{pl}\ x]\phi\ [\mathbf{a};\mathbf{c};\mathbf{h}]$ *iff:* $\mathbf{pro}(\widehat{x}.[\![\mathbf{c}(x)]\!]_{\mathbf{a};\mathbf{c};\mathbf{h}}, \widehat{x}.[\![(\phi)^x]\!]_{\mathbf{a};\mathbf{c};\mathbf{h}})$ *and* $\mathbf{c}(x){\downarrow}$.

$\mathcal{M} \models [\mathrm{pro}\ x]\phi\ [\mathbf{a};\mathbf{c};\mathbf{h}]$ *iff:* $\mathcal{M} \models (\phi)^x\ [\mathbf{a};\mathbf{c};\mathbf{h}]$ *and* $\mathbf{c}(x){\uparrow}$.

Here, $\widehat{x}.[\![\phi]\!]_{\mathbf{a};\mathbf{c};\mathbf{h}}$ *is the set* $\{d \in D \mid \mathcal{M} \models \phi\ [\mathbf{a}[^d/x];\mathbf{c};\mathbf{h}]\}$*. The assignment* $\mathbf{a}[^d/x]$ *is identical to* $\mathbf{a}$ *unless* $\mathbf{a}(x) \neq d$*. In the following I sometimes use terms* $\eta x\phi$*, which are interpreted by* $[\![\eta x\phi]\!]_{\mathbf{a};\mathbf{c};\mathbf{h}} = \mathbf{h}(\widehat{x}.[\![\phi]\!]_{\mathbf{a};\mathbf{c};\mathbf{h}})$.

A second look reveals that definition 4.4 is standard except for two things: (i) the variation in the context per clause; and (ii) the interpretation of pronouns. Note in particular that despite the partiality of the contexts the semantics itself is total (clause i. covers all cases).

[20] For a definition of **pro**, recall (19).

The variation in context DQL uncouples the interpretation of a formula from its context change potential. This allows compound formulas to differ with respect to the subformulas they use when interpreted in context. More precisely, it enables us to discern between 'classical,' 'anaphoric' and 'kataphoric' binary logical operators.

As is well-known, there are sentences which indicate that something like an anaphor/kataphor distinction is called for.

(29) *a.* He whistles and a man is happy.
b. If he whistles a man is happy.
c. No pilot who shot at it hit a MiG that chased him.

In natural language, conjunction is a typical anaphoric operator (29a). Here, conjunction is defined in terms of classical implication and has the truth conditions:

$$\mathcal{M} \models \phi \wedge_a \psi\ [\mathbf{a};\mathbf{c};\mathbf{h}] \text{ iff: } \mathcal{M} \models \phi\ [\mathbf{a};\mathbf{c};\mathbf{h}] \text{ and } \mathcal{M} \models \psi\ [\mathbf{a};\mathbf{c}(\![\phi]\!);\mathbf{h}].$$

As in DPL, its first conjunct may only use the given context, but its second conjunct may use that context together with the anaphor information supplied by the first. On the other hand, conditionals and determiners are more kataphoric in nature (29b,c). This means, e.g., that the antecedent of a conditional may use the initial context supplied with the context generated by its consequent, and conversely. Definition 4.4 can treat the conditionals and the determiners in this way, since the interpretation and the context change of a formula are rather independent of each other.

Of course, this small stock of examples is insufficient to decide upon the precise behaviour of the logical operators in this respect. I rather would like to indicate that DQL is rich enough to sustain these distinctions. A semantics in which the interpretation of a sentence is preceded by an 'on-line' left-to-right processing of its context change potential has difficulties with (29b–c). Unless one applies a backpatching technique as in Van Deemter 1991, ch. 2, such a process does not supply the information needed to interpret the pronoun as soon as it is encountered.

In the following I use anaphoric conjunctions and disjunctions but kataphoric conditionals and determiners, except when indicated otherwise.

The interpretation of pronouns DQL discerns bound, deictic, and E-type pronouns. This means that all possibilities along the two features 'to be bound' (BND) and 'to have an antecedent' (ANT) are realized.[21]

	BND	ANT
bound	+	+
deictic	–	–
E-type	–	+
	+	–

Since BND implies ANT the fourth option is impossible. In (30b–d), the character of the pronoun [pro x] is stated in the rightmost column.

(30) *a.* A man walks and he talks.
b. $[\text{an } x : \text{M}x](\text{W}x \wedge [\text{pro } x]\text{T}x)$ *bound*
c. $[\text{an } y : \text{M}y](\text{W}y \wedge [\text{pro } x]\text{T}x)$ *deictic*
d. $[\text{an } x : \text{M}x](\text{W}x) \wedge [\text{pro } x](\text{T}x)$ *E-type*

[21]To be precise, an occurrence of a pronoun [pro x] is bound iff it is within the scope of an operator binding x. Relative to a context $\mathbf{c}$, such an occurrence has an antecedent iff (i) its bound, or (ii) it is unbound and either $\mathbf{c}$ or an extension thereof is defined for x as soon as the formula which has this occurrence of [pro x] as its main operator is evaluated.

Notice, once more, that in systems like DRT, DPL, and DQL variables play a double rôle: they function as indices to indicate anaphoric links, and as 'place holders' to enable binding. An expression which binds the pronouns [pro x] within its scope is also the antecedent of these pronouns, and such an occurrence of the pronoun should therefore function as a bound variable x. To achieve this, I use the operation $(-)^x$ which erases all occurrences of [pro x] within its scope. E.g., (31a) is (31b).

(31) *a.* $([\text{an } x : \mathrm{M}x]\mathrm{W}x \wedge [\text{pro } x]\mathrm{T}x)^x$
b. $[\text{an } x : \mathrm{M}x](\mathrm{W}x \wedge \mathrm{T}x)$

As should be clear from definition 4.4.i, eliminating [pro x] ensures that the context no longer affects these pronouns. The bound pronouns are taken care of by a total assignment in the usual way.

The deictic and the E-type pronouns remain. They are interpreted as referring expressions or as contextually restricted quantifiers. What is the case depends on the number of the pronoun and on whether the context has information on x. An inspection of definition 4.2 of context change potential reveals that starting from the empty one, a context is only defined for a variable x if it has processed a sentence with a proper name or a determiner binding x. Due to the double rôle of variables, this means that a possible antecedent for [pro x] has been encountered. Therefore, if a context $\mathbf{c}$ is defined for x, an unbound [pro x] should be interpreted as an E-type pronoun. And an E-type pronoun is a choice from the set $\widehat{x}.\mathbf{c}(x)$ if [pro x] is singular, but the quantifier 'pro' restricted by this set otherwise. In case $\mathbf{c}(x)$ is undefined, an unbound [pro x] functions deictically. This is exactly what is given by definition 4.4.i. Note that deictic pronouns, like proper names and singular pronouns, only bear scope syntactically, semantically they are scopeless.

4.4 Truth and entailment

Definition 4.4 stipulates what it means for a formula to be true with respect to an assignment, a context, and a choice function. But the sole function of a context is to supply information on possible antecedents encountered in the preceding text. It is therefore natural to start from the empty context $\emptyset$, which is undefined for all variables. Logically there are other options as well, but here I will use this version.

Definition 4.5 (truth in context) *A formula ϕ is true in a model $\mathcal{M}$ relative to an assignment $\mathbf{a}$ and a choice function $\mathbf{h}$, iff: $\mathcal{M} \models \phi\ [\mathbf{a};\emptyset;\mathbf{h}]$.*

In definition 4.4 and 4.5 a choice function is given by the context. One could think of this function as supplying for each non-empty set an object raised to salience. However, in some circumstances a choice is quite arbitrary so that we have:

Definition 4.6 (arbitrary truth) *A formula ϕ is arbitrary in a model $\mathcal{M}$ relative to an assignment $\mathbf{a}$ iff: $\mathcal{M} \models \phi\ [\mathbf{a};\emptyset;\mathbf{h}]$ for all choice functions $\mathbf{h}$.*

Of course we have the familiar notions of validity, too.

Definition 4.7 (validity) *A formula ϕ is valid in $\mathcal{M}$ – $\mathcal{M} \models \phi$ – iff: ϕ is true in $\mathcal{M}$ relative to all assignments $\mathbf{a}$ and all choice function $\mathbf{h}$. A formula ϕ is valid simpliciter – $\models \phi$ – iff: it is valid in all models.*

Starting from the empty context there are three forms of entailment: classical, anaphoric, and kataphoric.

Definition 4.8 (classical entailment) *A formula ϕ classically entails ψ – $\phi \models_c \psi$, – iff for all $\mathcal{M}$ and all assignments and choice functions for $\mathcal{M}$: If $\mathcal{M} \models \phi\ [\mathbf{a};\emptyset;\mathbf{h}]$ then $\mathcal{M} \models \psi\ [\mathbf{a};\emptyset;\mathbf{h}]$*

Anaphoric entailment is the DQL analogue of entailment in dynamic predicate logic.

Definition 4.9 (anaphoric entailment) *A formula ϕ anaphorically entails ψ – $\phi \models_a \psi$, – iff for all $\mathcal{M}$ and all assignments and choice functions for $\mathcal{M}$: If $\mathcal{M} \models \phi\ [\mathbf{a}; \emptyset; \mathbf{h}]$ then $\mathcal{M} \models \psi\ [\mathbf{a}; \emptyset(\llbracket\phi\rrbracket); \mathbf{h}]$*

It can be used to justify the validity of an inference like:

(32) Two[1] semanticists walk in the park and whistle
$\Rightarrow_a$ They$_1$ walk

In DQL, one might also consider yet another form of entailment.

Definition 4.10 (kataphoric entailment) *A formula ϕ entails ψ kataphorically – $\phi \models_k \psi$, – iff for all $\mathcal{M}$ and all assignments and choice functions for $\mathcal{M}$: If $\mathcal{M} \models \phi\ [\mathbf{a}; \emptyset(\llbracket\psi\rrbracket); \mathbf{h}]$ then $\mathcal{M} \models \psi\ [\mathbf{a}; \emptyset(\llbracket\phi\rrbracket); \mathbf{h}]$.*

A valid kataphoric inference would be:

(33) He$_1$ walks in the park.
$\Rightarrow_k$ So, Pedro[1] is in the park.

Validity as given by in definition 4.7, allows a semantical deduction theorem for each form of entailment:

Proposition 4.11 (deduction theorems) *For $s \in \{c,\ a,\ k\}$:*

$$\phi \models_s \psi \Leftrightarrow\ \models \phi \rightarrow_s \psi$$

Moreover, the notions of entailment collapse in some obvious cases:

Proposition 4.12 *If there is no pronoun in ψ with an antecedent in ϕ, then:*

$$\phi \models_c \psi \Leftrightarrow \phi \models_a \psi$$

If there are no anaphoric links between ϕ and ψ, then

$$\phi \models_c \psi \Leftrightarrow \phi \models_a \psi \Leftrightarrow \phi \models_k \psi$$

I have to leave a further study of the logical properties of of entailment for another time.

Now that the semantics is in place, it is put to work by means of some familiar examples. I shall be especially concerned with showing in more detail how the deictic, the bound, and the E-type pronouns are captured.

5 DQL applied

In order to get a feel for how the sentential part of the system works, section 5.1 considers the examples in (34).

(34) *a.* He shaves him.
b. John loves his mother.
c. If John loves music he admires Mozart.
d. If some women loves him Pedro courts them.
e. The pilot who shot at it hit the MiG that chased him.
f. If a cardinal meets another cardinal he blesses him.

The examples (34a–f), which are be repeated below for convenience, are chosen to clarify the use of (i) the deictic pronouns [34a], (ii) the bound pronouns [34b,e], and

(iii) the E-type pronouns [34c–f]. Moreover, they will show the difference between a pronoun antecedent upon a referential [34b–d] and upon a quantifier expression [34d–f]. Finally, the (34f) shows how the dependency among singular pronouns is dealt with. In what follows, I assume that an appropriate model together with an assignment and a choice function are given. Also, in discussing (34a–f) the contribution of pronouns to the context is ignored. It is nice to see that DQL can handle all of these sentences in a compositional way.

Section 5.2 returns to a question raised earlier, namely: what is the relationship between the readings of a donkey sentence and the nature of the choice which interprets its singular pronouns?

5.1 Some examples

Sentence 34a Disregarding gender, (35a) means (35b). And although the pronouns change the context

(35) *a.* He shaves him.
b. $[\mathrm{pro}_{sg}\ x][\mathrm{pro}_{sg}\ y]\mathrm{S}xy$
c. $\mathrm{S}xy$

it is clear from definition 4.4.i that (35b) is equivalent to (35c).

Sentence 34b The sentences (36) and (37) are from Evans 1985, 77, where he discusses Geach. The logical form of (36a) is (36b), which generates the context (36c).

(36) *a.* John loves his mother.
b. $[\mathrm{j}\ x][\mathrm{the}\ y : [\mathrm{pro}_{sg}\ x]\mathrm{M}yx]\mathrm{L}xy$
c. $\{\langle x, x = \mathrm{j}\rangle, \langle y, \mathrm{M}yx \wedge \mathrm{L}xy\rangle\}$
d. $[\mathrm{the}\ y : \mathrm{M}y\mathrm{j}]\mathrm{Lj}y$

Since $[\mathrm{pro}_{sg}\ x]$ is bound by the quantifier $[\mathrm{j}\ x]$, the use of $(-)^x$ in definition 4.2 makes that it does not show up in the context. And in definition 4.4.g the same operation ensures that the pronoun is disregarded during evaluation. Given the way proper names are handled, we arrive at the truth conditions in (36d); the ones we are after.

Sentence 34c In (37) the pronoun 'he' is not within the scope of the proper name, thought of as a quantifier, and is hence put to work.

(37) *a.* If John loves music he admires Mozart.
b. $([\mathrm{j}\ x]\mathrm{L}x) \rightarrow ([\mathrm{pro}_{sg}\ x][\mathrm{m}\ y]\mathrm{A}xy)$
c. $\{\langle x, x = \mathrm{j}\rangle, \langle y, y = \mathrm{m}\rangle\}$
d. $\mathrm{Lj} \rightarrow \mathrm{A}\eta x(x = \mathrm{j})\mathrm{m}$
e. $\mathrm{Lj} \rightarrow \mathrm{Ajm}$

Sentence (37a) is represented by (37b), which yields (37c). This context is defined for x, so definition 4.4.i shows that (37b) is equivalent to (37d). For convenience, this formula uses the eta-term $\eta x(x = \mathrm{j})$ to indicate a choice from the set $\widehat{x}.x = \mathrm{j}$, although officially such terms are no part of the language. Since the set term denotes the singleton $\{\mathrm{j}^*\}$, one has: $\eta x(x = \mathrm{j}) = \mathrm{j}$. Therefore, (37d) is equivalent to (37e). It should be noted that in this way we circumvent a separate treatment of anaphora with a referential antecedent.

Sentence 34d Kamp 1981, 28 uses a variant of (38) to show that proper names should be placed in the top box of a DRS in order to account for the kataphoric link between 'him' and 'Pedro.' In DQL the link is achieved by the kataphoric interpretation of the implication sign.

(38) *a.* If some women love him Pedro courts them.
b. $[\text{some } x : \mathrm{W}x][\text{pro}_{sg}\ y]\mathrm{L}xy \rightarrow [\mathrm{p}\ y][\text{pro}_{pl}\ x]\mathrm{C}yx$
c. $\{\langle x, \mathrm{W}x \wedge [\text{pro}_{sg}\ y]\mathrm{L}xy\rangle, \langle y, y = \mathrm{p}\rangle\}$
d. $[\text{some } x : \mathrm{W}x]\mathrm{L}x\mathrm{p} \rightarrow [\text{pro } x : \mathrm{W}x \wedge \mathrm{L}x\mathrm{p}]\mathrm{Cp}x$

The truth conditions of (38a) are those of (38b), while (38c) is the context obtained. Since in DQL context generation and semantic interpretation are parallel processes, the context generated by the consequent of (38c) can be used to interpret the antecedent of (38b). Therefore $[\text{pro}_{sg}\ y]$ is an E-type pronoun which chooses from the singleton $\{\mathrm{p}^*\}$ so that p can be substituted for y at the appropriate places. The interpretation of proper names makes sure that this is also done in the restriction of $[\text{pro}_{pl}\ x]$, which gives (38d) as a result.

This is perhaps a good place to make a remark on compositionality. I would like to claim that (38d) is arrived at compositionally. To the extent that this is possible in a system like DQL, its truth is determined by interpreting its subexpressions in context. And these contexts are used in much the same way as the indices in Montague grammar. The mere fact that a context is generated in part by the expressions themselves is strictly speaking accidental. More precisely, with respect to DQL it seems hard to defend that for methodological reasons only a particular text segment may be used while interpreting an expression. But compositionality is a methodological principle, so this is what one should defend in order to refute the claim. Of course, there are empirical grounds to put a bound on the part of the text which may be used. E.g., it is reasonable to limit oneself to the text up to and including the sentence one is processing. However, empirical considerations are not an issue if compositionality is at stake.

Sentence 34e If this reasoning is correct, a similar kind of processing gives a compositional interpretation of the MiG sentences. In discussing (39a), I follow up on Neale 1990, 196–197.

(39) *a.* The pilot who shot at it hit the MiG that chased him.
b. $[\text{the } x : \mathrm{P}x \wedge [\text{the } y : \mathrm{M}y \wedge \mathrm{C}yx]\mathrm{S}xy][\text{the } y : \mathrm{M}y \wedge \mathrm{C}yx]\mathrm{H}xy$
b. $[\text{the } y : \mathrm{M}y \wedge [\text{the } x : \mathrm{P}x \wedge \mathrm{S}xy]\mathrm{C}yx][\text{the } x : \mathrm{P}x \wedge \mathrm{S}xy]\mathrm{H}xy$

Karttunen observes that (39a) has the non-equivalent readings (39b,c), depending on the relative scope of the descriptions. In DQL, (39b) can be obtained as follows. On the subject wide scope reading, (39a) means (40a), which induces (40b).

(40) *a.* $[\text{the } x : \mathrm{P}x \wedge [\text{pro}_{sg}\ y]\mathrm{S}xy][\text{the } y : \mathrm{M}y \wedge [\text{pro}_{sg}\ x]\mathrm{C}yx]\mathrm{H}xy$
b. $\{\langle x, \mathrm{P}x \wedge [\text{pro}_{sg}\ y]\mathrm{S}xy \wedge [\text{the } y : \mathrm{M}y \wedge \mathrm{C}yx]\mathrm{H}xy\rangle,$
$\langle y, \mathrm{M}y \wedge \mathrm{C}yx \wedge \mathrm{H}xy\rangle\}$
c. $[\text{the } x : \mathrm{P}x \wedge \mathrm{S}x\eta y(\mathrm{M}y \wedge \mathrm{C}yx \wedge \mathrm{H}xy)][\text{the } y : \mathrm{M}y \wedge \mathrm{C}yx]\mathrm{H}xy$

As in case of (36), the bound pronoun $[\text{pro}_{sg}\ x]$ in (40a) is not copied into the context. Also, Neale stresses that the other pronoun, $[\text{pro}_{sg}\ y]$, is E-type. For this reason the semantics of DQL gives (40c). But if (40c) is true, there is a unique MiG that chased and was hit by the shooting pilot. So (40c) is equivalent to (39b). The object wide scope reading (39c) is obtained along similar lines. Observe that there is no restriction on the determiners involved in handling MiG sentences.

Of course, if an 'anaphoric' interpretation of determiners were used this solution would not be available. Then the first argument of the definite with wide scope should be evaluated relative to the empty context. This would make $[\text{pro}_{sg}\ y]$ a deictic rather than an E-type pronoun.

Sentence 34f The last example shows how dependencies among choices are accounted for.

(41) *a.* If a cardinal meets another cardinal he blesses him
b. $[\text{an } x : \mathrm{C}x][\text{an } y : \mathrm{C}y \wedge x \neq y]\mathrm{M}xy \rightarrow [\text{pro}_{sg}\ x][\text{pro}_{sg}\ y]\mathrm{B}xy$
c. $\{\langle x, \mathrm{C}x \wedge [\text{an } y : \mathrm{C}y \wedge x \neq y]\mathrm{M}xy\rangle,$
$\langle y, \mathrm{C}y \wedge x \neq y \wedge \mathrm{M}xy\rangle\}$
d. $\mathrm{B}\eta x\mathbf{c}(x)\eta y(\mathrm{C}y \wedge \eta x\mathbf{c}(x) \neq y \wedge \mathrm{M}\eta x\mathbf{c}(x)y)$
e. $[\text{every } x : \mathrm{C}x][\text{every } y : \mathrm{C}y \wedge x \neq y \wedge \mathrm{M}xy]\mathrm{B}xy$

The context (41c) results from the logical form (41b) of (41a). Accordingly, the consequence of the conditional is represented by (41d), which leaves the value $\mathbf{c}(x)$ implicit. This means that if a cardinal meets another cardinal, the context will pick a P from the cardinals meeting another cardinal and then a P′ from the cardinals different from but met by P. Cardinal P blesses P′. In this way DQL makes the choice of 'him' dependent upon a choice of 'he.' As we shall see in the next section, this dependency complies with the general phenomena that in these cases the scope relations of the pronouns should coincide with that of their antecedents.

However, there is still something lacking in the truth conditions of (41b). It is the fact that (41a) reports on a disposition of cardinals to bless the colleagues they meet. Therefore, the choices involved should be rather arbitrary. Within an extensional framework the closest one could get to this reading of (41a) is perhaps the use of a conditional like:

$\mathcal{M} \models \phi \Rightarrow_{all} \psi\ [\mathbf{a};\mathbf{c};\mathbf{h}]$ iff:
If $\mathcal{M} \models \phi\ [\mathbf{a};\mathbf{c};\mathbf{h}]$ then for *all* $\mathbf{h}'$: $\mathcal{M} \models \psi\ [\mathbf{a};\mathbf{c}[\![\phi]\!];\mathbf{h}']$.

This conditional gives the consequent of (41a) its strong reading, where it means (41e). Notice that by varying the italicized quantifier in the definition of $\Rightarrow_{all}$, one seems to get a semantics for adverbs of quantification along the lines of Groenendijk & Stokhof 1991, 81–82. But I have to leave the matter for another time. In the next section, a similar technique is used to deal with the weak and strong readings of donkey sentences.

5.2 Donkeys revisited

The notion of truth as it is given by definition 4.5 makes the use of singular pronouns strongly context dependent. E.g., relative to a context (42a) means (42b).

(42) *a.* Two farmers who own a donkey beat it.
b. Two farmers who own a donkey beat their salient donkeys.

Here 'salient' should be understood in the abstract sense of being the value of a choice function. In this sense the truth of (42a) really depends on the given choice. For suppose there are just two farmers who each own exactly two donkeys but beat only one. Then choosing the beaten donkeys will make (42a) true, while all other choices will make it false. This seems in order, for (42a) may well be used to highlight the misbehaviour of the two farmers. However, other sentences resist a such a contexts dependent reading. Take, for instance, the same two farmers but now choose the donkeys which are not beaten. Then (43) is true

(43) No farmer who owns a donkey beats it.

But if at all, this is only acceptable when the perspective from which the choice is made somehow has no access to the beaten donkeys.

Within DQL the problem can be circumvented by introducing analogues of the weak and strong readings of determiners in DPL. These readings are obtained by 'modalizing' the VP argument of a determiner by means of operators P and A, which yield formulas with the following truth conditions:

$$\mathcal{M} \models \mathrm{P}\phi\ [\mathbf{a}; \emptyset; \mathbf{h}] \text{ iff: } \mathcal{M} \models \phi\ [\mathbf{a}; \emptyset; \mathbf{h}'] \text{ for an } \mathbf{h}'$$
$$\mathcal{M} \models \mathrm{A}\phi\ [\mathbf{a}; \emptyset; \mathbf{h}] \text{ iff: } \mathcal{M} \models \phi\ [\mathbf{a}; \emptyset; \mathbf{h}'] \text{ for all } \mathbf{h}'$$

The weak and the strong readings are now defined by:

(44) *a.* $[\mathrm{D}_w\ x : \phi]\psi \quad \equiv_{df} \quad [\mathrm{D}x : \phi]\mathrm{P}(\psi)$
b. $[\mathrm{D}_s\ x : \phi]\psi \quad \equiv_{df} \quad [\mathrm{D}x : \phi]\mathrm{A}(\psi)$

The readings in (44) are similar to those defined for DPL (cf., 9), but there are two important differences. First, the definition does not copy material from the restriction to the scope of the determiner. This is taken care of by the general E-type mechanism. Second, the determiners are externally dynamic: they change the context in the familiar way. In this connection we should ask whether the modal operator used in the above abbreviations should be copied into the context as well. I'm inclined to think not. If so, the operator $(-)^x$ could be extended to remove them.

It is not difficult to show that the weak and the strong readings of donkey sentences as defined by (44) are equivalent to the familiar ones.

Proposition 5.1 *For all* D*:*

$$\models \quad [\mathrm{D}_w\ x : \mathrm{F}x \wedge [\mathrm{an}\ y : \mathrm{D}y]\mathrm{O}xy][\mathrm{pro}_{sg}\ y]\mathrm{B}xy$$
$$\leftrightarrow_c [\mathrm{D}x : \mathrm{F}x \wedge [\mathrm{an}\ y : \mathrm{D}y]\mathrm{O}xy][\mathrm{an}\ y : \mathrm{D}y \wedge \mathrm{O}xy]\mathrm{B}xy$$
$$\models \quad [\mathrm{D}_s\ x : \mathrm{F}x \wedge [\mathrm{an}\ y : \mathrm{D}y]\mathrm{O}xy][\mathrm{pro}_{sg}\ y]\mathrm{B}xy$$
$$\leftrightarrow_c [\mathrm{D}x : \mathrm{F}x \wedge [\mathrm{an}\ y : \mathrm{D}y]\mathrm{O}xy][\mathrm{pro}\ y : \mathrm{D}y \wedge \mathrm{O}xy]\mathrm{B}xy$$

Note that the strong reading is stated in terms of 'pro' instead of 'all.' This is due to the fact that proposition 5.1 is based on the following identities:[22]

$$\{d \mid \mathrm{D} \cap \mathrm{O}_d \cap \mathrm{B}_d \neq \emptyset\} \quad = \quad \{d \mid \exists \mathbf{h} : \mathrm{B}d\mathbf{h}(\mathrm{D} \cap \mathrm{O}_d)\}$$
$$\{d \mid \emptyset \neq \mathrm{D} \cap \mathrm{O}_d \subseteq \mathrm{B}_d\} \quad = \quad \{d \mid \forall \mathbf{h} : \mathrm{B}d\mathbf{h}(\mathrm{D} \cap \mathrm{O}_d)\}$$

It is natural to ask what happens when the recipes in (44) are iterated. The answer is that nothing happens. Since the modalities P and A are of the S5 variety, they satisfy the equivalences:

(45) *a.* $\models \quad \mathrm{AA}\phi \leftrightarrow \mathrm{A}\phi$
b. $\models \quad \mathrm{PP}\phi \leftrightarrow \mathrm{P}\phi$
c. $\models \quad \mathrm{PA}\phi \leftrightarrow \mathrm{A}\phi$
d. $\models \quad \mathrm{AP}\phi \leftrightarrow \mathrm{P}\phi$
e. $\models \quad \mathrm{A}\phi \rightarrow \phi$
f. $\models \quad \phi \rightarrow \mathrm{P}\phi$

Consequently, iterating (44) is not productive. For example, *a.* gives that the strong strong reading of a determiner is just the strong one, which, in turn, is its weak strong reading according to *c.* The 'reflexivity' axioms *e.* and *f.* provide information on the logical relations between the weak and strong readings of right monotonic determiners.

[22]Here and in what follows I tacitly use the extensionality of determiners: If $\mathbf{D}XY$ and $X = X'$ and $Y = Y'$ then $\mathbf{D}X'Y'$.

Proposition 5.2 *For MON↑ determiners D:*

$$\models \quad [\mathrm{D}_s\ x : \phi]\psi \rightarrow_c [\mathrm{D}x : \phi]\psi \rightarrow_c [\mathrm{D}_w\ x : \phi]\psi$$

For MON↓ determiners:

$$\models \quad [\mathrm{D}_w\ x : \phi]\psi \rightarrow_c [\mathrm{D}x : \phi]\psi \rightarrow_c [\mathrm{D}_s\ x : \phi]\psi$$

For those who are familiar with his work: proposition 5.2 is an analogue of Kanazawa's proposition 2, but it does not impose any requirement on the determiner (cf., Kanazawa 1993, 23).[23]

Another property of the modalities implies that weak and strong readings only occur in case the VP contains singular pronouns.

Proposition 5.3 (i) *If ϕ has no singular pronouns, then*

$$\models \mathrm{A}\phi \leftrightarrow_c \phi \leftrightarrow_c \mathrm{P}\phi$$

(ii) *If ψ has no singular pronouns, then*

$$\models [\mathrm{D}_w\ x : \phi]\psi \leftrightarrow_c [\mathrm{D}x : \phi]\psi \leftrightarrow_c [\mathrm{D}_s\ x : \phi]\psi$$

for all D, *ϕ, and ψ.*

There are also some general relations between the weak and strong readings of the dual $\widetilde{\mathbf{D}} \equiv_{df} \neg\mathbf{D}\neg$ of a quantifier $\mathbf{D}$.[24]

$$\models \quad [(\widetilde{\mathrm{D}})_w\ x : \phi]\psi \leftrightarrow_c [\widetilde{(\mathrm{D}_s)}\ x : \phi]\psi$$
$$\models \quad [(\widetilde{\mathrm{D}})_s\ x : \phi]\psi \leftrightarrow_c [\widetilde{(\mathrm{D}_w)}\ x : \phi]\psi$$

Up to this point, I have shown how the weak and strong reading of a quantified sentence can be modelled within an E-type analysis. This analysis discerns a 'saliency' reading besides. Within the present framework it is natural to ask whether the readings correspond the different kinds of choice. E.g., the strong reading of a donkey sentence might be true in a context if it is clear that the choice involved is arbitrary (i.e., if A('donkey') is true). Proposition 5.4 has some information on this issue for a specific case.

Proposition 5.4 *For all determiners D.*

$$\begin{aligned}\models \quad & \mathrm{A}(\mathrm{D}x : \mathrm{F}x \wedge [\mathrm{an}\ y : \mathrm{D}y]\mathrm{O}xy][\mathrm{pro}_{sg}\ y]\mathrm{B}xy) \\ & \rightarrow_c [\mathrm{D}_s\ x : \mathrm{F}x \wedge [\mathrm{an}\ y : \mathrm{D}y]\mathrm{O}xy][\mathrm{pro}_{sg}\ y]\mathrm{B}xy\end{aligned}$$

The converse implication is valid if D is MON↑. For all determiners D.

$$\begin{aligned}\models \quad & [\mathrm{D}_w\ x : \mathrm{F}x \wedge [\mathrm{an}\ y : \mathrm{D}y]\mathrm{O}xy][\mathrm{pro}_{sg}\ y]\mathrm{B}xy \\ & \rightarrow_c \mathrm{P}(\mathrm{D}x : \mathrm{F}x \wedge [\mathrm{an}\ y : \mathrm{D}y]\mathrm{O}xy][\mathrm{pro}_{sg}\ y]\mathrm{B}xy)\end{aligned}$$

The converse implication is valid if D is MON↑.

[23] Kanazawa [op.cit.,23] also has a result for the left monotonic determiners. It says that in case a determiner is ⇑MON both its weak and its strong reading imply its 'normal' reading, and conversely for a ⇓MON determiner. Combined with his analogue of proposition 5.2 this means that the doubly monotone determiners implicitly define a weak or a strong reading. Thus one can eliminate ambiguity, for if a determiner has the requisite properties it will generate the reading all by itself. Unfortunately, natural language does not fully comply with this nice result (cf., section 3).

[24] The internal negation of a determiner is its complement: $(\neg\mathbf{D})XY \Leftrightarrow \neg\mathbf{D}XY$, for all X, Y. Its internal negation is defined by: $\mathbf{D}\neg XY \Leftrightarrow \mathbf{D}X\overline{Y}$, for all X, Y.

Proof To show that the implication is valid, suppose that relative to a model

$$[\mathrm{D}x : \mathrm{F}x \wedge [\text{an } y : \mathrm{D}y]\mathrm{O}xy][\text{pro } y : \mathrm{D}y \wedge \mathrm{O}xy]\mathrm{B}xy$$

is false. Then we have:

$$\neg\mathbf{D}\mathrm{F} \cap \{d \mid \mathrm{D} \cap \mathrm{O}_d \neq \emptyset\}\{d \mid \emptyset \neq \mathrm{D} \cap \mathrm{O}_d \subseteq \mathrm{B}_d\}$$

with in general $\mathrm{R}_d = \{d' \mid \mathrm{R}dd'\}$. So:

$$\widetilde{\mathbf{D}}\mathrm{F} \cap \{d \mid \mathrm{D} \cap \mathrm{O}_d \neq \emptyset\}\{d \mid \mathrm{D} \cap \mathrm{O}_d = \emptyset \text{ or } \mathrm{D} \cap \mathrm{O}_d \cap \overline{\mathrm{B}_d} \neq \emptyset\}$$

Define $\mathbf{h}$ by: $\mathbf{h}(\mathrm{D} \cap \mathrm{O}_d) \in \overline{\mathrm{B}_d}$ if $\mathrm{D} \cap \mathrm{O}_d \cap \overline{\mathrm{B}_d} \neq \emptyset$, but arbitrary for non-empty $\mathrm{D} \cap \mathrm{O}_d$ otherwise. Then:

$$\{d \mid \mathrm{D} \cap \mathrm{O}_d = \emptyset \text{ or } \mathrm{D} \cap \mathrm{O}_d \cap \overline{\mathrm{B}_d} \neq \emptyset\} = \{d \mid \neg\mathrm{B}d\mathbf{h}(\mathrm{D} \cap \mathrm{O}_d)\}$$

for $\bullet$ is excluded from the extension of B. Extensionality yields:

$$\widetilde{\mathbf{D}}\mathrm{F} \cap \{d \mid \mathrm{D} \cap \mathrm{O}_d \neq \emptyset\}\{d \mid \neg\mathrm{B}d\mathbf{h}(\mathrm{D} \cap \mathrm{O}_d)\}$$

But then also:

$$\neg\mathbf{D}\mathrm{F} \cap \{d \mid \mathrm{D} \cap \mathrm{O}_d \neq \emptyset\}\{d \mid \mathrm{B}d\mathbf{h}(\mathrm{D} \cap \mathrm{O}_d)\}$$

which shows that

$$\mathrm{A}(\mathrm{D}x : \mathrm{F}x \wedge [\text{an } y : \mathrm{D}y]\mathrm{O}xy][\text{pro}_{sg}\ y]\mathrm{B}xy)$$

is false in this model too.

That the converse implication is valid for MON↑ D follows from:

$$\{d \mid \mathrm{B}d\mathbf{h}(\mathrm{D} \cap \mathrm{O}_d)\} \subseteq \{d \mid \mathrm{D} \cap \mathrm{O}_d = \emptyset \text{ or } \mathrm{D} \cap \mathrm{O}_d \cap \overline{\mathrm{B}_d} \neq \emptyset\}$$

for all $\mathbf{h}$. The other validities are proved by a similar reasoning. □

Kanazawa 1992, 1993 shows that the weak and strong readings of a determiner can be used to analyze the following puzzle concerning inference and anaphora posed by Van Benthem. The determiner 'no' is ↓MON↓, yet only (46) is a valid inference. How come?[25]

(46) Every man who owns a garden owns a house
No man who owns a house sprinkles it
$\not\Rightarrow$ No man who owns a garden sprinkles it

(47) Every farmer who owns a female donkey owns a donkey
No farmer who owns a donkey beats it
$\Rightarrow$ No farmer who owns a female donkey beats it

Inference 47 is also valid if a more restrictive verb is chosen such as 'to own and feed.' The solution of Kanazawa 1993, 3 consists of defining 'an appropriate dynamic sense of monotonicity.' which is 'more restrictive than the usual one.' Here a similar solution is possible. Since there are no anaphoric links between the premisses of (46) and (47), it suffices to consider classical entailment.

Now, it is not difficult to give a counter model for (46). Take a model in which just one man owns just one house with just one garden. The man sprinkles the garden but not the house. Then any choice function will make the premisses true but the conclusion false. However, a similar kind of reasoning shows that (47) is

[25]Here and elsewhere '$\not\Rightarrow$' denotes an invalid inference.

invalid as well. The reason is that the notions of entailment defined in section 4.4 keep the choice function fixed. Therefore, the inference reads:

(48) Every farmer who owns a female donkey owns a donkey
No farmer who owns a donkey beats his salient donkey
$\Rightarrow$ No farmer who owns a female donkey beats his salient female donkey

As a matter of fact (48) should be invalid. For a salient female donkey may be different from a salient donkey. But it is hard to read the inference (47) in this contextualized way.

The differences in validity of (46) and (47) do show up as soon as we consider the weak and strong readings of the determiner 'no.' More in particular, it follows from proposition 5.1 that the correct distribution of (in)validity is obtained only in case 'no' has its weak reading.

Lets take stock. Proposition 5.2 shows that if a donkey sentence is true in a context it has a weak reading if its main determiner is MON$\uparrow$, and a strong reading if its determiner is MON$\downarrow$. Proposition 5.4 shows that if in a context the choice is arbitrary, 'simple' donkey sentences have a strong reading. Whether this is so in general is still open. All in all, this means that for simple donkey sentences interpretation in context removes most of the ambiguities. The doubly downward monotone determiners are exceptional in this respect for they seem to favour a weak reading. But perhaps they have no other reading than this one.

It is shown that an E-type analysis handles weak and strong readings as well as a bound variable approach. In fact, the readings given here have the advantage of being externally dynamic. Yet, logically there is still a lot of work to be done. The next step is to consider extrasentential anaphora. In section 6, I shall first pay attention to some problems concerning their interpretation and scope behaviour in an informal way. These observations are formalized in section 7.

6 Parallelism, dependencies, and scope

The extensive research on discourse has uncovered its rich and intricate structure. This structure constraints the interpretation of pronouns and other anaphoric elements. One such constraint, which is called parallelism in Prüst, Scha, and Van den Berg 1993, is that in certain respects anaphora have to share 'enough' structure with their antecedents. It is displayed in a rather strict form in case of VP anaphora. For instance, (49a) could mean that Maaike likes to visit relatives, or that she likes relatives which visit.[26]

(49) *a.* Maaike likes visiting relatives.
b. Brigitte does too.

However, as soon as a reading for (49a) is chosen it automatically carries over to (49b). The VP anaphor in (49b) is not one of simple laziness. In that case each sentence would be twice ambiguous, so that the short discourse might have four readings. But it only has two.

The anaphora studied here exhibit structure sharing which is as strict as that of VP anaphora. This is mainly due to the fact that extrasentential anaphora, which are all of the E-type, could involve partial descriptions. A description is partial iff its (implicit) restriction contains free variables not bound by the pronoun itself. Such variables have to be resolved in terms of the context generated by the preceding

[26]This example is adapted from the overview in Prüst, Scha, and Van den Berg 1993, sec.$\tilde{1}$; see the references therein.

text. But as the examples studied shortly indicate, this requires that in cases like this the scope relations of pronouns should be parallel to that of their antecedents.

That E-type pronouns as 'pronouns of laziness' resemble VP anaphora is already noted by Evans 1985, 131–132. More in particular, Heim's observation that this yields 'a treatment of E-type pronominalization that is much like the Sag-Williams-approach to VP Deletion and other ellipsis constructions' is substantiated by the present system (Heim 1990, 171).

6.1 Resolving dependencies

To show that extrasentential anaphora might require parallelism for their interpretation, I discuss some short discourses. But first I give an example of how extrasentential anaphora are handled to begin with.

6.1.1 Intransitive sentences

A simple case of an extrasentential anaphor is in (50) from Groenendijk and Stokhof 1991, 41.

(50) *a.* Just one[1] man walks in the park. He_1 whistles.
b. [just one x : Mx]Wx. [$\text{pro}_{sg}\ x$]WHx.
c. [just one x : Mx]Wx. WH$\eta x(\text{M}x \wedge \text{W}x)$.

The logical form of (50a) is (50b), whose antecedent sentence induces the context defined by:

(51) $\mathbf{c}(x) \quad \mapsto \quad \text{M}x \wedge \text{W}x$

Since on an E-type analysis the notions of scope and binding are the standard ones, all extrasentential pronouns must be E-type. This is particularly so for the pronoun 'he' which has 'just one' as its antecedent. 'He' is therefore interpreted as a choice from the set $\widehat{x}.\mathbf{c}(x)$; i.e., $\widehat{x}.\text{M}x \wedge \text{W}x$. The antecedent sentence implies that the set is a singleton. So according to the anaphor sentence the unique walking man whistles.

As before, the formula $\text{M}x \wedge \text{W}x$ is just the conjunction of the restriction and scope of the antecedent. It might be thought that this choice of formula is correct because the quantifier 'just one' is conservative. However, (52) shows that this is not so.

(52) Only[1] men walk in the park. They_1 whistle.

Whatever its syntactic status, in case of the non-conservative 'only' the 'intersective' approach works just as well.

Definition 4.2 of context change potential stipulates that pronouns update the formula associated with their variable. Here is an example of why this is so.

(53) Just one[1] man walks in the park. He_1^2 whistles. He_2 airs his dog.

As we have seen, the first pronoun is interpreted as a choice from the men who walk. However, this pronoun changes the value of $\mathbf{c}(x)$ from $\text{M}x \wedge \text{W}x$ to $x = \eta x(\text{M}x \wedge \text{W}x) \wedge \text{WH}x$. Consequently, the second pronoun is interpreted as the previously chosen walking man, who is now also required to whistle. It is instructive to compare this treatment with that of DPL. In DPL the choice associated with the existential quantifier. This quantifier is used to define 'just one' in the familiar way. So it chooses an arbitrary object from the domain, which is then tested for three properties: being the unique man in the park, whistling, and airing of his dog. If it satisfies them all, it is excepted as an output of (53), otherwise it is rejected.

DQL is similar in this respect. But in this logic the elimination is implied by the context set passed on by the pronoun, which may become smaller as we go along. As soon as it becomes empty, singular pronouns denote the null object: the present analogue of DQL's rejection.

6.1.2 Transitive sentences

A more complex situation arises if the anaphor sentence has two pronouns which are linked with NPs in the antecedent sentence:

(54) *a.* Most[1] men own two[2] shavers. They$_1$ keep them$_2$ in good order.
b. [most x : Mx][two y : Sy]Oxy. [pro$_{pl}$ x][pro$_{pl}$ y]Kxy.
c. [pro x : M$x \wedge$ [two y : Sy]Oxy][pro y : S$y \wedge$ Oxy]Kxy.
d. [pro y : S$y \wedge$ Oxy][pro x : M$x \wedge$ [two y : Sy]Oxy]Kxy.

In (54a), the anaphor sentence says that each man who has two shavers keeps *his* shavers in good order. This is precisely what (54c) states.[27] Note the parallelism. In (54b) the scope relation of the pronouns must coincide with that of their antecedents. It is only in this order that we obtain the appropriate meaning.

If in (54b) [pro$_{pl}$ y] were to have scope over [pro$_{pl}$ x], its restriction would have a free variable x; cf., (54d). Yet, the fact that a semantic representation has free variables is no sufficient ground for the corresponding sentence to be meaningless. Quite to the contrary, such variables occur often. I would rather hold that it is one of the main tasks of a formal E-type analysis to give principles that enable a cogent interpretation in these cases.[28] To uncover such principles let's see how we could arrive at an interpretation of the anaphor sentence in (55a). Here the extrasentential anaphor 'they' has an object NP as its antecedent which lies within the scope of the subject NP.

(55) *a.* Most people bought a[1] diamond. They$_1$ were rather expensive.
b. [most x : Px][an y : Dy]Bxy. [pro$_{pl}$ y]Ey
c. [pro y : D$y \wedge$ Bxy]Ey

The context **c** created by the antecedent sentence of (55a) is defined by:

(56) $$\begin{array}{lll} \mathbf{c}(x) & \mapsto & \mathrm{P}x \wedge [\mathrm{an}\ y : \mathrm{D}y]\mathrm{B}xy \\ \mathbf{c}_x(y) & \mapsto & \mathrm{D}y \wedge \mathrm{B}xy \end{array}$$

Here and elsewhere, I indicate the free variables in $\mathbf{c}(y)$ other than y as subscripts. A straightforward application of definition 4.4.i interprets the pronoun [pro$_{pl}$ y] as the partial description [pro y : D$y \wedge$ Bxy]. This is wrong, since the free x is then interpreted via the assignment. And this does not restrict its value to the people who bought a diamond, as it should.

[27] Cf. also Neale 1990, 260. In his dynamic logic for plurals, which generalizes DPL, Van den Berg 1991, 232–240 uses an ingenious distribution operator to achieve the effect.

[28] The problem is noted by Neale 1990 in chapter 6 footnote 41. He gives a rough sketch of two solutions, which are not unlike the one developed here, but concludes that his 'own inclination is to steer well clear of either of these ideas' (op.cit., 261). Heim 1990 only considers cases in which the problem is absent. Richards 1984, 315, on the other hand, observes that his algorithm might produce a reading for the sentence 'Every child built a castle and it fell down' in which the term associated with the pronoun has a 'dangling' occurrence of the variable bound by 'every castle.' According to him this would explain why the sentence feels anomalous. But there are many instances of 'incomplete' pronouns which are yet perfectly in order. The anomaly noted by Richards is perhaps better explained by pointing to the fact that we tend to interpret a singular pronoun as involving a unique object, which is impossible here because of its dependency on 'every castle.' Such tensions are likely to arise in a language which does not wear the dependencies on its sleeve.

The solution I opt for is to complete the description before interpreting it. For the case at hand it is quite clear that the completion should be (57a); or formally (57b) which is (57c) in full.

(57) *a.* The diamonds bought by the people who bought a diamond
b. $[\text{pro } x : \mathbf{c}(x)][\text{pro } y : \mathbf{c}_x(y)]$
c. $[\text{pro } x : \text{P}x \wedge [\text{an } y : \text{D}y]\text{B}xy][\text{pro } y : \text{D}y \wedge \text{B}xy]$
d. $[\text{pro}_{pl}\ x][\text{pro}_{pl}\ y]\text{E}y$

From this we see that although the logical form of the anaphor sentence in (55a,b) appears to be a sentence, its actual semantical representation is (57d).

In general the problem is now to indicate which completion should be chosen and to show how it comes about. As we shall see, the use of explicit completions has the virtue of giving a clear view on the possibilities here.

In this connection it should be observed that (58a) gives another way to complete the anaphor sentence in (55b).

(58) *a.* $[\text{pro } y : [\text{pro } x : \mathbf{c}(x)]\mathbf{c}_x(y)]$
b. $[\text{pro } y : [\text{pro } x : \text{P}x \wedge [\text{an } y : \text{D}y]\text{B}xy](\text{D}y \wedge \text{B}xy)]$

In (58a), or more explicitly in (58b) the restriction is to the diamonds bought by everyone who bought a diamond, disregarding the diamonds bought by only some such person. This is plainly too strong; the reading doesn't even exist. Instead, one should consider for each of the people who bought a diamond all the diamonds he bought, as in (57b,c). Notice, once more, that parallelism is required. The scope relation of the pronouns in (57b) coincides with that of their antecedents.

6.1.3 Ditransitive sentences

Before studying the scope interactions of pronouns and other operators, we consider a ditransitive sentence.

(59) These women gave two men some presents. It pleased them.

The meaning of the anaphor sentence in (59) is rather underdetermined. It could mean that the act of giving presents (to men) pleased the women. Or it could mean that it pleased the men to receive presents from women (although they abhorred the choice of Nietzsche's biography and other such books). Disregarding further alternatives, the reading which has my concern is the one with the anaphoric links as in (60a).

(60) *a.* These women gave two^1 men some^2 presents. It$_2$ pleased them$_1$.
b. $[\text{these } x : \text{W}x][\text{two } y : \text{M}y][\text{an } z : \text{P}y]\text{G}xyz.\ [\text{pro}_{pl}\ y][\text{pro}_{sg}\ z]\text{P}zy.$

An interesting feature of (60a) is that the scope relation suggested by the surface structure of the anaphor sentence is reverse to that required by the antecedent sentence (on its preferred reading). Still this does not enforce the antecedent sentence to keep 'two men' within the scope of 'a present.' Although this is one of its readings, the reading where the men each got a present is just as natural. However, in either case it is clear that the scope relation of the pronouns should parallel that of their antecedents.

I consider the case where 'two men' has scope over 'a present.' Then the context generated by the antecedent sentence is:

(61)
$$\begin{array}{lll} \mathbf{c}(x) & \mapsto & \text{W}x \wedge [\text{two } y : \text{M}y][\text{an } z : \text{P}y]\text{G}xyz \\ \mathbf{c}_x(y) & \mapsto & \text{M}y \wedge [\text{an } z : \text{P}y]\text{G}xyz \\ \mathbf{c}_{xy}(z) & \mapsto & \text{P}z \wedge \text{G}xyz \end{array}$$

Now, if the scope relation of the pronouns had been different from their antecedent, $[\text{pro}_{sg}\ z]$, which is $[\text{pro}\ z : z = \eta z(\text{P}z \wedge \text{G}xyz)]$, would have both x and y free. Perhaps such variables are resolvable so that z is a satisfactory choice of the presents given by x to y. But if done along the lines suggested above, it would not result in the required meaning of the anaphor sentence. This meaning is paraphrased by: each man who got a present from a woman who gave two men a present, was pleased with the presents he got from her. That is, the free x in (62a) should vary over the woman which gave two men a present.

(62) *a.* $[\text{pro}\ y : \text{M}y \wedge [\text{an}\ z : \text{P}y]\text{G}xyz][\text{pro}\ z : \text{P}z \wedge \text{G}xyz]$
b. $[\text{pro}\ x : \text{W}x \wedge [\text{two}\ y : \text{M}y][\text{an}\ z : \text{P}y]\text{G}xyz]$
c. $[\text{pro}\ x : \mathbf{c}(x)][\text{pro}\ y : \mathbf{c}_x(y)][\text{pro}\ z : \mathbf{c}_{xy}(z)]$
d. $[\text{pro}\ y : [\text{pro}\ x : \mathbf{c}(x)]\mathbf{c}_x(y)][\text{pro}\ z : [\text{pro}\ x : \mathbf{c}(x)]\mathbf{c}_{xy}(z)]$

This is achieved by giving (62b) scope over (62a), as in the abbreviated (62c). Again, the 'narrow scope' option of resolving the free x in (62d) is incorrect. Then the anaphoric sentence would mean:

> Each man to whom each woman who gave two men a present, gave a present, is pleased with each present that each woman who gave two men a present, gave to him.

But the men will be pleased with a present that some of these women gave, not just with the presents that all of them gave.

We have seen that the anaphor sentences receive their appropriate meaning if (i) the scope structure of the pronouns is that of their antecedents, and (ii) the free variables are resolved be prefixing 'covert' pronouns which are anaphoric to the NPs which have the antecedents of the overt pronouns within their scope. The question of how this is attained formally is addressed in section 7. There it is argued that it is enough to require that texts consist of sentences as soon the relevant contextual information is assimilated. But before we turn to formalizing these observations, we ask to what extent the (c)overt anaphora may interact with the scope of other operators.

6.2 Scope

Neale 1990, 185–189 argues convincingly that E-type pronouns evoke scope ambiguities. The present proposal predicts that such ambiguities only arise for the plural E-types. Singular pronouns involve a choice of a particular individual, so that (per choice) they are scopeless. I will argue that this is as it should be. Moreover, for the examples considered up till now the overt pronouns in the anaphor sentence remained inside the immediate scope of the covert descriptions which resolved their free variables. But as soon as other operators come into play, one should ask whether or not the 'resolving' descriptions always take the widest scope possible. To study this question, I look at sentences in which pronouns occur within the scope of a negation and of a quantifier.[29]

6.2.1 Negation

Evans 1985, 132 uses (63a) in his argument against E-type pronouns as 'pronouns of laziness.' Instead, I will use it as an argument in favour of my treatment of singular pronouns.

(63) *a.* John owns a^1 donkey but it is not the case that it_1 is male.
b. John owns a donkey but it is not the case that the donkey John owns is male.

[29]For an extensive study of negation within dynamic Montague grammar, see Dekker 1993.

Evans holds that (63b), unlike (63a), is ambiguous, for it 'might be asserted on the ground that there is no such thing as *the* donkey John owns.' This is correct, but it need not lead to Evans' conclusion that E-type pronouns are terms whose reference is fixed by description. For one, the description of a singular E-type pronoun could invariably have the widest possible scope.[30] Also, the singular E-type pronoun could be a term which uses the descriptive content of its antecedent in a different way, as proposed here.

The proposal which gives the description of a singular E-type wide scope is countered by some of Neale's examples, which involve temporal and modal contexts. However, his own theory, where singular pronouns are quantifiers, faces the difficulty that (63a) is unambiguous. If singular pronouns are universal quantifiers, the second conjunct has two readings. But the reading in which the pronoun has wide scope does not occur (cf., example (20) in section 2.2.3). Then all of John's donkeys are not male, but this conjunct seems to lack such universal force. Its narrow scope reading is acceptable, which makes (63b) state that one of John's donkeys is not male. Still the correct reading is obtained by accident. For it is surely untrue that E-type pronouns should always have narrow scope. (Note in passing that this also tells against giving singular pronouns a weak reading, in which case its narrow scope reading should have to be ruled out.)

If singular pronouns go proxy for a choice from the set supplied by its antecedent, as suggested in section 2.2, they are scopeless (per choice) with respect to the Boolean connectives. This complies with the fact that the anaphor sentences in (64a,b) are as unambiguous as (63a) is.

(64) *a.* John owns a^1 donkey. It_1 is mouse-grey and male.
b. John owns a^1 donkey. It_1 is strong or male.

By contrast, plural pronouns do interact with negation, as is witnessed by (65a).

(65) John owns $some^1$ donkeys.
a. But it is not the case that $they_1$ are male.
b. $They_1$ are mouse-grey and male.
c. $They_1$ are strong or male.

The anaphor sentence (65a) is ambiguous between a wide and a narrow scope reading of the pronoun. The wide scope reading – where all John's donkeys are not male, – is preferred. But the narrow scope reading is available as well. It is made more prominent by the continuation:

His youngest donkey, in particular, is female.

As to conjunction, (65b) is unambiguous. This accords with the fact that plural pronouns are universal quantifiers, which are scopeless with respect to this connective. For disjunction the situation is different: (65c) is ambiguous between a reading where all John's donkeys are strong or all male, and a reading where John's donkeys are all either strong or male.

The above examples did not involve any partial description. But it would be interesting to know whether the completion of such descriptions also partake in scope ambiguities. To detect such a variation, consider (66).

(66) Most students interviewed two^1 politicians.
But it was not so that $they_1$ were cooperative.

Concerning the resolution of the pronouns in the anaphor sentence, we detect the same pattern as before: the scope relation of the anaphora, overt and covert alike,

[30] The observation is made by Soames and quoted by Neale 1990, 186.

is that that of their antecedents. But it is interesting to see that negation may take all possible positions in this quantificational structure.

The truth conditions of the antecedent sentence in (66) are those of (67).

(67) $[\text{most } x : \mathrm{S}x][\text{two } y : \mathrm{P}y]\mathrm{I}xy$

And (67) defines the context:

(68) $\mathbf{c}(x) \mapsto \mathrm{S}x \wedge [\text{two } y : \mathrm{P}y]\mathrm{I}xy$
$\mathbf{c}_y(x) \mapsto \mathrm{P}y \wedge \mathrm{I}xy$

In the abstract the possibilities for the anaphor sentence in (66) are therefore:

(69) *a.* $\neg[\text{pro } x : \mathbf{c}(x)][\text{pro } y : \mathbf{c}_x(y)]\mathrm{C}y$
b. $[\text{pro } x : \mathbf{c}(x)]\neg[\text{pro } y : \mathbf{c}_x(y)]\mathrm{C}y$
c. $[\text{pro } x : \mathbf{c}(x)][\text{pro } y : \mathbf{c}_x(y)]\neg\mathrm{C}y$

The contents of these abstract specifications should be clear from the following paraphrases:

69a One of the students interviewed a professor who was not cooperative.

69b Each of the students interviewed a professor who was not cooperative.

69c For each of the students it was so that each of the professors she interviewed was not cooperative.

In my opinion, each paraphrases gives an acceptable interpretation of the antecedent sentence in (66).

This ends my discussion of negation. We pass on to consider the scope behaviour of pronouns and other quantifiers.

6.2.2 Quantification

In regard to scope, the quantifiers behave no different from negation. To see this, singular pronouns are considered first.

The semantic and contextual information that goes with the antecedent sentence of (70a) is in (70b).

(70) *a.* John's daughters bought a^1 comic. Two friends read it$_1$.
b. $[\text{john's } x : \mathrm{D}x][\text{an } y : \mathrm{C}y]\mathrm{B}xy$.
$\mathbf{c}(x) \mapsto \mathrm{D}x \wedge [\text{an } y : \mathrm{C}y]\mathrm{B}xy$
$\mathbf{c}_x(y) \mapsto \mathrm{C}y \wedge \mathrm{B}xy$

I think that the anaphor sentence has two readings:

(71) *a.* $[2\ z : \mathrm{F}z][\text{pro } x : \mathbf{c}(x)]\mathrm{R}z\eta y\mathbf{c}_x(y)$
b. $[\text{pro } x : \mathbf{c}(x)][2\ z : \mathrm{F}z]\mathrm{R}z\eta y\mathbf{c}_x(y)$

That is, one has either *a.*: two friends read for each of John's children a book that it bought, or *b.*: for each of John's children there are two friend who read a book that it bought.

As to plural pronouns, the context generated by the antecedent sentence in (72) is the same as that of (70).

(72) John's daughters bought some^1 comics. Two friends read them$_1$.

But apart from the readings corresponding to (71a,b), the anaphor sentence has the reading (73c).

(73) *a.* $[2\ z : \mathrm{F}z][\text{pro } x : \mathbf{c}(x)][\text{pro } y : \mathbf{c}_x(y)]\mathrm{R}zy$
b. $[\text{pro } x : \mathbf{c}(x)][2\ z : \mathrm{F}z][\text{pro } y : \mathbf{c}_x(y)]\mathrm{R}zy$
c. $[\text{pro } x : \mathbf{c}(x)][\text{pro } y : \mathbf{c}_x(y)][2\ z : \mathrm{F}z]\mathrm{R}zy$

The new reading may be paraphrased by: for each of John's children that bought some comics and all the comics that it bought there are two friends who read them.

The above examples strongly suggest that the scope parallelism between antecedents and anaphora is an all pervading phenomenon. But this is not so. For if a pronoun has a referential expression as its antecedent, it inherits its scopelessness. E.g., there is no difference in meaning between (74c1,c2)

(74) *a.* Mary^1 loves John^2. He_1 adores her_2
b. $[\text{m } x][\text{j } y]\text{L}xy$
c. 1 $[\text{pro}_{sg}\ x][\text{pro}_{sg}\ y]\text{A}xy$
2 $[\text{pro}_{sg}\ y][\text{pro}_{sg}\ x]\text{A}xy$
d. Lmj. Ajm

In both cases the short discourse (74a) comes to mean (74d). This makes clear that the parallelism constraint is only at work in case there is a dependency between the antecedents themselves.

Apart from parallelism in case of dependent antecedents, there is a further constraint: non-anaphoric quantifiers should not be allowed to complete an anaphor sentence. To continue example (73), if we had formalized its anaphor sentence by

(75) $[2\ x : \text{F}x][\text{pro } y : \mathbf{c}_x(y)]\text{R}zy$

we would also have obtained a sentence. But then the anaphor sentence wrongly comes to mean that two friends read all the comics *they* bought. Completion by means of quantifiers is only possible in case of definite NPs which, like E-type pronouns, depend for their interpretation on the context. For instance, the anaphor sentence in (76a) is modelled by (76b).[31]

(76) *a.* A few^x children bought some^y sweets.
The_x boys ate them_y immediately.
b. $[\text{the } x : \text{B}x \wedge \mathbf{c}(x)][\text{pro } y : \mathbf{c}_x(y)]\text{E}xy$
c. $\mathbf{c}(x) \quad \mapsto \quad \text{C}x \wedge [\text{an } y : \text{S}y]\text{B}xy$
$\mathbf{c}_x(y) \quad \mapsto \quad \text{S}y \wedge \text{B}xy$

Spelled out in detail the anaphor sentence means: each boy among the children who bought some sweets ate the sweets that he bought immediately. Since (76b) uses the context (76c) given by the antecedent sentence in (76a), this is precisely what the anaphor sentence states.

The picture emerged that natural language employs extrasentential anaphora to exchange prolixity for economy of speech. As ever so often, it achieves this by means of implicit contextual restriction. We have seen that extrasentential E-type pronouns, like the intrasentential ones, are interpreted by means of descriptive material inherited from the preceding text. This section has ample evidence that the scope relations of pronouns should parallel those of their antecedents if there is a dependency between them. A further constraint is that non-anaphoric quantifiers may not bind free variables in the inherited material. This binding is reserved for the definite NPs which depend for their interpretation on this material (among other things). Prime examples are the (c)overt E-type pronouns, but other overt definites may be used, too. Except for the standard ones, there are no restrictions on the ways in which (c)overt pronouns interact with the scope of other operators. The ensuing section shows how these observations could be formalized.

[31]Van Deemter 1991, ch. 1 discusses examples of this kind within the framework of DRT.

7 Dynamic quantifier logic: texts

The previous section unearthed two constraints on the resolution of anaphora:

a. The scope structure of anaphora is strictly parallel to that of their antecedents in case there is a dependency among the antecedents.

b. Free variables in the inherited material are resolved by covert E-type pronouns which are anaphoric to the NPs which have the antecedents of the overt definite anaphora within their scope.

The question is now how DQL ensures that these constraints are satisfied. I will show that in the relevant instances the scope relation of anaphora and their antecedents are as they should be as soon as a text is a sequence of sentences. And in order to preclude non-anaphoric quantifiers to bind variables in the inherited material their variables should be 'fresh.' Texts which comply with these requirements are called *admissible*. The admissible texts are arrived at in two steps. First, section 7.1 defines the notion of a sentence in context. This is necessary, for due to the contextual dependence of pronouns this notion is somewhat different from the usual one. Section 7.2 proves that admissible texts satisfy the constraints a and b.

7.1 Admissible texts

Definition 4.1 of formulas gives *a* notion of sentence. Since proper names, pronouns and quantifiers are variable binding expressions, one might call the formulas with no free variables pre-sentences. However, the discussion in the previous section has made clear that a fully-fledged notion of sentence can only be arrived at in context. Example (77) recalls why this is so.

(77) *a.* Two girls love their marbles. They are colourful.
b. $[\text{two } x : \mathrm{G}x][\text{the } y : \mathrm{M}y \wedge \mathrm{of}xy]\mathrm{L}xy.\ [\text{pro}_{pl}\ y]\mathrm{C}y$
c. $\mathbf{c}(x) \quad \mapsto \quad \mathrm{G}x \wedge [\text{the } y : \mathrm{M}y \wedge \mathrm{of}xy]\mathrm{L}xy$
$\quad\ \mathbf{c}_x(y) \quad \mapsto \quad \mathrm{M}y \wedge \mathrm{of}xy \wedge \mathrm{L}xy$
d. $[\text{pro } y : \mathrm{M}y \wedge \mathrm{of}xy \wedge \mathrm{L}xy]\mathrm{C}y$
e. $[\text{pro } x][\text{pro } y : \mathrm{M}y \wedge \mathrm{of}xy \wedge \mathrm{L}xy]\mathrm{C}y$

A straightforward representation of discourse (77a) is the pair of pre-sentences in (77b). Although (77b) does not appear to have any free variables it should still not be considered a text. The reason is that the antecedent sentence in (77b) yields the context (77c). As a consequence, the truth conditions of the anaphor sentence are those of (77d), which has a free occurrence of x. This is incorrect. Indeed, the meaning of the anaphor sentence is rather given by (77e). Not just because '[pro x]' binds the free x in (77d). But also because its restriction in (77c) does not introduce any new free variables: (77e) remains a sentence even if the context is taken into account.

So a first condition on a text to be admissible is that it consists of sentences, not just of pre-sentences. And what is to be counted as a sentence is determined in part by the context. We shall now formalize this notion of sentence in a sequence of steps. The strategy is to reduce the notion of sentence in context to the standard notion of sentence by explicitly assimilating the context generated by a text into a formula. Therefore I start with introducing texts and the way in which they affect the context.

Definition 7.1 (pre-texts) *A pre-text is a sequence of pre-sentences:*

(i) *The empty text ε. is a pre-text.*

(ii) *If τ is a pre-text and σ is a pre-sentence, then $\tau\sigma.$ is a pre-text.*

Definition 7.2 (context change potential) *The context change potential of a pre-text is defined by:*

(i) $\mathbf{c}[\![\varepsilon.]\!] \simeq \mathbf{c}$

(ii) $\mathbf{c}[\![\tau\sigma.]\!] \simeq \mathbf{c}[\![\tau]\!][\![\sigma]\!]$

Here, $\simeq$ is as in definition 4.2.

Pre-texts are treated as if they are anaphoric conjunctions of pre-sentences. The context they evoke determines whether a particular occurrence of a formula is a sentence. A formula absorbs such contextual information in the following way.

Definition 7.3 (formula in context) *The translation $(\phi)^{\mathbf{c}}$, $\mathbf{c}$ a context, is defined by:*

(i) $(Rx_1 \ldots x_n)^{\mathbf{c}} \equiv Rx_1 \ldots x_n$

(ii) $(\neg\phi)^{\mathbf{c}} \equiv \neg(\phi)^{\mathbf{c}}$

(iii) $(\phi \rightarrow_c \psi)^{\mathbf{c}} \equiv (\phi)^{\mathbf{c}} \rightarrow (\psi)^{\mathbf{c}}$

(iv) $(\phi \rightarrow_a \psi)^{\mathbf{c}} \equiv (\phi)^{\mathbf{c}} \rightarrow (\psi)^{\mathbf{c}[\![\phi]\!]}$

(v) $(\phi \rightarrow_k \psi)^{\mathbf{c}} \equiv (\phi)^{\mathbf{c}[\![\psi]\!]} \rightarrow (\psi)^{\mathbf{c}[\![\phi]\!]}$

(vi) $([\mathrm{c}\ x]\phi)^{\mathbf{c}} \equiv [\mathrm{c}\ x]((\phi)^x)^{\mathbf{c}}$

(vii) $([\mathrm{D}x : \phi]\psi)^{\mathbf{c}} \equiv [\mathrm{D}x : ((\phi)^x)^{\mathbf{c}[\![(\psi)^x]\!]}]((\psi)^x)^{\mathbf{c}[\![(\phi)^x]\!]}$

(viii)
$$\begin{array}{lcll} ([\mathrm{pro}_{sg}\ x]\phi)^{\mathbf{c}} & \equiv & [\mathrm{pro}\ x : x = \eta x\mathbf{c}(x)]((\phi)^x)^{\mathbf{c}} & \textit{if } \mathbf{c}(x)\!\downarrow \\ ([\mathrm{pro}_{pl}\ x]\phi)^{\mathbf{c}} & \equiv & [\mathrm{pro}\ x : \mathbf{c}(x)]((\phi)^x)^{\mathbf{c}} & \textit{if } \mathbf{c}(x)\!\downarrow \\ ([\mathrm{pro}\ x]\phi)^{\mathbf{c}} & \equiv & ((\phi)^x)^{\mathbf{c}} & \textit{if } \mathbf{c}(x)\!\uparrow \end{array}$$

A formula ϕ is a sentence in context $\mathbf{c}$, iff $(\phi)^{\mathbf{c}}$ is a sentence in the standard sense; i.e., $\mathrm{FV}((\phi)^{\mathbf{c}}) = \emptyset$.

Definition 7.4 extends the above translation to texts.

Definition 7.4 (texts in context) *Let $\mathbf{c}$ be a context. The translation $(\tau)^{\mathbf{c}}$ is defined by:*

(i) $(\varepsilon.)^{\mathbf{c}} = \varepsilon.$

(ii) $(\tau\phi.)^{\mathbf{c}} = (\tau)^{\mathbf{c}}(\sigma.)^{\mathbf{c}[\![\tau]\!]}$

Now we are in a position to define the notions we are after.

Definition 7.5 (sentence in context) *Let τ be a text, and σ an occurrence of a pre-sentence in τ (i.e., $\tau \equiv \tau'\sigma\tau''$). This occurrence of σ is a sentence iff $(\sigma)^{\emptyset[\![\tau']\!]}$ is a sentence in the standard sense.*

Definition 7.6 (admissible texts) *A text τ is admissible iff:*

(i) *$(\tau)^{\emptyset}$ is a sequence of sentences;*

(ii) *the non-anaphoric quantifiers in τ – i.e., the proper names and the non-definite determiners, bind a variable which only occurs within their own restriction and scope or in that of E-type pronouns and definites anaphorically linked to them.*

Notice that clause (i) ensures that each anaphor has a unique antecedent.

7.2 Parallelism

Now we set out to prove that admissible texts satisfy the constraints a and b stated at the beginning of this section. For a start, I introduce a dependency relation on the domain of the context generated by a text. As we shall see, this relation corresponds to the scope relation of possible antecedents. It can hence be used to show that the scope of anaphora and their antecedents are parallel.

Definition 7.7 (dependency relation) *Let* $\mathbf{c}$ *be a partial function from variable to formulas. The dependency relation* $<_{\mathbf{c}}$ *on the domain of* $\mathbf{c}$ *is defined by:* $x <_{\mathbf{c}} y$ iff: $x \in \mathrm{FV}(\mathbf{c}(y))$ and $x \not\equiv y$, *for all* $x, y \in \mathrm{dom}(\mathbf{c})$. *One reads* $x <_{\mathbf{c}} y$ *as* y *depends on* x (*in* $\mathbf{c}$).

If it is clear which $\mathbf{c}$ is intended it is dropped as a subscript. The examples in section 6 show that the contexts induced by a formula are all of special kind.

Definition 7.8 (context) *A context* $\mathbf{c}$ *is a finite partial function from variables to formulas with: if* $x <_{\mathbf{c}} y$, *then* $\mathrm{FV}(\mathbf{c}(x)) \subset \mathrm{FV}(\mathbf{c}(y))$, *for all variables* x, y.

Here, $X \subset Y$ means that X is strictly included in Y: $X \subseteq Y$ *and* $X \neq Y$. Also, the set $\mathrm{FV}(\phi)$ of free variables in ϕ is defined in a somewhat stricter way than is usual: $\mathrm{FV}(\phi) := \{x \in \mathrm{VAR} \mid x \text{ has a free occurrence in } \phi\}$.[32]

Proposition 7.9 *For each context* $\mathbf{c}$, $<_{\mathbf{c}}$ *is a strict partial order* (*irreflexive, transitive*).

PROOF Irreflexivity is immediate. As to transitivity, assume $x <_{\mathbf{c}} y$ and $y <_{\mathbf{c}} z$. From $x <_{\mathbf{c}} y$ one has: $x \in FV(\mathbf{c}(y))$, and from $y <_{\mathbf{c}} z$ one has: $\mathrm{FV}(\mathbf{c}(y)) \subset \mathrm{FV}(\mathbf{c}(z))$. So $x \in FV(\mathbf{c}(z))$, that is $x <_{\mathbf{c}} z$. □[33]

The idea is that if in a context $\mathbf{c}$ x is dependent on y (i.e., $y <_{\mathbf{c}} x$), one is only interested in those values of x where y receives an appropriate value. This is exactly the issue in section 6 which led to considering the completion of anaphor sentences.

Proposition 7.10 *Let* σ *be an occurrence of a pre-sentence in a text* τ: $\tau \equiv \tau'\sigma\tau''$. *And let* $\mathbf{c} = \emptyset(\![\tau'\sigma]\!)$.

If $x <_{\mathbf{c}} y$ *then there is an* [op x], *and a* [D y: ϕ] *or a* [pro y] *in* $\tau'\sigma$ *such that* [D y: ϕ] *or* [pro y] *is within the scope of* [op x].

PROOF The proof is with induction on τ'. First suppose that $\tau' \equiv \varepsilon$. Now we reason with induction on σ. Since σ is a pre-sentence, the atomic case does not apply. And in case σ is a negation the conclusion is immediate from the induction hypothesis for σ. So assume that $\sigma \equiv \phi \to \psi$. Then $\mathbf{c} = \emptyset(\![\phi]\!)(\![\psi]\!)$. Since $x <_{\mathbf{c}} y$,

[32] A slightly more general notion of context is:

Definition (context*) *A context** $\mathbf{c}$ *is a partial function from variables to formulas with:*

(i) *For all variables* x, y, *if* $x <_{\mathbf{c}} y$, *then* $\mathrm{FV}(\mathbf{c}(x)) \subset \mathrm{FV}(\mathbf{c}(y))$.

(ii) *The set* $\bigcup\{FV(\mathbf{c}(x)) \mid \mathbf{c}(x)$ *is defined*$\}$ *is finite.*

In principle a context* may be infinite (take e.g. $x_n \mapsto x_2 > x_1$), as long as to stock of variables occurring in its image is finite. Each finite context* is a context, and conversely.

[33] For context* one has:

Proposition *For each context** $\mathbf{c}$, $<_{\mathbf{c}}$ *is a strict partial order* (*irreflexive, transitive*) *which is converse well-founded* (*there are no chains* $\ldots <_{\mathbf{c}} x_n <_{\mathbf{c}} \ldots < x_1$).

PROOF Irreflexivity and transitivity are as before. As to is converse well-foundedness: if $\ldots <_{\mathbf{c}} x_n <_{\mathbf{c}} \ldots < x_1$, then $\ldots \subset FV(\mathbf{c}(x_n)) \subset \ldots \subset FV(\mathbf{c}(x_1))$. But this is impossible due to (ii). □

For contexts converse well-foundedness need not be proved, for on a finite domain each strict partial order has this property.

by definition $x \in \mathrm{FV}(\mathbf{c}(y))$ and $x \not\equiv y$. This means (i) that $\mathbf{c}(y)$ is introduced by a subformula [D $y : \chi]\chi'$ or (ii) that it is updated by a subformula [pro $y]\chi$. In the case of (i) $\mathbf{c}(y) \equiv (\chi)^y \wedge (\chi')^y$. Plainly, $x \in \mathrm{FV}([\mathrm{D}\ y : \chi]\chi')$ for $x \not\equiv y$. But σ is a pre-sentence. So there must be an [op x] in σ which binds x. In the case of (ii) for a singular pronoun [pro$_{sg}$ y], $\mathbf{c}(y) \equiv y = \eta y \mathbf{c}'(y) \wedge (\chi)^y$ with $\mathbf{c}'$ a context. Either $x \in \mathrm{FV}((\chi)^y)$ so that the induction hypothesis applies, or $x \in \mathbf{c}'(y)$. The context $\mathbf{c}'$ reintroduces the same two options: its value for y comes from a quantificational formula or it is updated by a pronoun. But since texts are finite there must be a point where only the first possibility arises. And then we reason as under (i). Case (ii) for plural pronouns is analogous. Whenever $\sigma \equiv [\mathrm{c}\ z]\phi$ and $x <_{\emptyset(\![\sigma]\!)} y$, $x \not\equiv z$. For $\mathbf{c}(z)$ contains no free variables other than z. So $x <_{\emptyset(\![(\phi)^z]\!)} y$ and the induction hypothesis does the rest. In case $\sigma \equiv [\mathrm{D}\ z : \chi]\chi'$, $x <_{\emptyset(\![\sigma]\!)} y$ and $x \equiv z$, then [D $z : \chi$] is the [op x] looked for (σ is a pre-sentence). And if $x \not\equiv z$ the induction hypothesis applies.

This completes the subinduction of σ for τ' the empty text. Due to the conjunctive character of texts, the situation where τ' is non-empty is similar. □

We call the E-type pronouns [pro x] and [pro y] dependent in a text τ, if either $x <_{\mathbf{c}} y$ or the converse obtains. Here $\mathbf{c}$ is the context $\emptyset(\![\tau]\!)$. According to parallelism, [pro y] should lie within the scope of [pro x].

Corollary 7.11 *Admissible texts satisfy the parallelism constraint.*

Proof Let τ be an admissible text of the form $\tau'\sigma\tau''$, and let [pro x] and [pro y] be two E-type pronouns in σ which are dependent on each other, say $x <_{\mathbf{c}} y$ with $\mathbf{c} = \emptyset(\![\tau'\sigma]\!)$. In an admissible text anaphora have a unique antecedent. Thus according to proposition 7.10, the antecedent of [pro y] occurs within the scope of the antecedent of [pro x]. But the same scope relation must obtain between [pro x] and [pro y]. For τ is an admissible text, so $(\sigma)^{\emptyset(\![\tau']\!)}$ is a sentence. Also, $x \in \mathrm{FV}(y)$ since $x <_{\mathbf{c}} y$. Therefore, if [pro y] takes scope over [pro x], its restriction contains a free x. Due to the fact that σ is a sentence, there must be an [op x] which binds x. But this would make the occurrence of [pro x] a bound, not an E-type pronoun. □

This ends my discussion of texts and parallelism.

Bibliography

Asher. N & H. Wada: 1988, 'A Computational Account of Syntactic, Semantic, and Discourse Principles for Anaphora Resolution,' *Journal of Semantics* **6**, 309–344.

Barwise, J. : 1987, 'Noun Phrases, Generalized Quantifiers, and Anaphora,' in: Gärdenfors (ed.) 1987, 1–29.

Barwise, J. and R. Cooper: 1981, 'Generalized Quantifiers and Natural Language,' *Linguistics and Philosophy* **4**, 159–219.

Benthem, J. van: 1983, 'Determiners and Logic,' *Linguistics and Philosophy* **6**, 447–478.

Benthem, J. van: 1984, 'Questions about Quantifiers,' *Journal of Symbolic Logic* **49**, 443–466.

Benthem, J. van: 1986, *Essays in Logical Semantics.* Reidel, Dordrecht.

Berg, M. van den: 1991, 'Dynamic Generalized Quantifiers,' in: Van der Does and Van Eijck (eds.) 1991.

Berg, M. van den: 1992, 'Full Dynamic Plural Logic,' manuscript, Department of Computational Linguistics, University of Amsterdam, Amsterdam.

Bäuerle, R., C. Schwarze and A. von Stechow (eds.): 1983, *Meaning, Use, and Interpretation of Language.* De Gruyter, Berlin.

Chierchia, G.: 1992, 'Anaphora and Dynamic Binding,' *Linguistics and Philosophy* **15**, 111–183.

Cooper, R.: 1979, 'The Interpretation of Pronouns,' in Heny & Schnelle (eds.) 1979, 61–92.

Deemter, K. van: 1991, *On the Composition of Meaning.* PH.D. dissertation, University of Amsterdam, Amsterdam.

Dekker, P.: 1993, *Transsentential Meditations. Ups and Downs in Dynamic Semantics.* PH.D. dissertation, University of Amsterdam, Amsterdam.

Does, J. M. van der, & J. van Eijck (eds.): 1991, *Generalized Quantifier Theory and Applications.* Dutch Network for Language, Logic and Information Prepublication, Amsterdam. Revised version to appear with CSLI Lecture Notes.

Does, J.M. van der: 1992, *Applied Quantifier Logics. Collectives and Naked Infinitives.* PH.D. dissertation, University of Amsterdam, Amsterdam.

Does, J.M. van der: 1993, 'Sums and Quantifiers,' *ILLC Prepublication Series* LP–93–05. To appear in *Linguistics and Philosophy.*

Eijck, J. van: 1993, 'The Dynamics of Description,' *Journal of Semantics* **10**, to appear.

Eijck, J. van & F.J. de Vries: 1992, 'Dynamic Interpretation and Hoare Deduction,' *Journal of Logic, Language, and Information* **1**, 1–44.

Evans, G.: 1977, 'Pronouns, Quantifiers, and Relative Clauses (I & II),' *The Canadian Journal of Philosophy* **7**, 467–536 and 777–797. Also in: Phillips (ed.) 1985, ch. 4 and 5.

Evans, G.: 1980, 'Pronouns,' *Linguistic Inquiry* **11**, 337–362. Also in: Phillips (ed.) 1985, ch. 8.

Fine, K. : 1985, 'Natural Deduction and Arbitrary Objects,' *Journal of Philosophical Logic* **14**, 57–107.

French, P.A., T.E. Uehling jr., & H.K. Wettstein: 1977, *Contemporary Perspectives in the Philosophy of Language* University of Minnesota, Minneapolis.

Gärdenfors, P. (ed.): 1987, *Generalized Quantifiers: Linguistic and Logical approaches.* Reidel, Dordrecht.

Geach, P. T.: 1962, *Reference and Generality.* Cornell University Press, Ithaca (NY).

Groenendijk, J. and M. Stokhof: 1990, 'Dynamic Montague Grammar,' in: Kálmán & Pólos (eds.) 1990, 3–48.

Groenendijk, J. and M. Stokhof: 1991, 'Dynamic Predicate Logic,' *Linguistics and Philosophy* **14**, 39–100.

Groenendijk, J., T. Janssen and M. Stokhof (eds.): 1984, *Truth, Interpretation, and Information.* Foris, Dordrecht.

Heim, I.: 1982, *The Semantics of Definite and Indefinite Noun Phrases.* Ph.D. dissertation, University of Massachusetts, Amherst.

Heim, I.: 1983, 'File Change Semantics and the Familiarity Theory of Definites,' in: Bäuerle *et al.* (eds.) 1983, 164–178.

Heim, I.: 1990, 'E-type Pronouns and Donkey Anaphora,' *Linguistics and Philosophy* **13**, 137–177.

Heny, F. & H. Schnelle (eds.) : 1979, *Syntax and Semantics, vol. 10: Selections from the Third Groningen Round Table.* Academic Press, New York.

Kadmon, N. : 1990, 'Uniqueness,' *Linguistics and Philosophy* **13**, 273–324.

Kálmán, L., & L. Pólos (eds.) : 1990, *Papers from the Second Symposium on Logic and Language.* Akadémia Kiadó, Budapest.

Kanazawa, M.: 1992, 'Weak vs. Strong Readings of Donkey Sentences and Monotonicity Inference in a Dynamic Setting,' manuscript, Stanford University. Revised version to appear in *Linguistics and Philosophy.*

Kanazawa, M.: 1993, 'Dynamic Generalized Quantifiers and Monotonicity,' *ILLC Prepublication Series* LP–93–02.

Kamp, H,: 1981, 'A Theory of Truth and Semantic Representation,' reprinted in: Groenendijk et al. (eds.) 1984, 1–43.

Kamp, H. & U. Reyle : to appear, *From Discourse to Logic, ch. 4.* Second European Summerschool in Logic, Language, and Information. Katholieke Universiteit Leuven. Book to appear with: Reidel, Dordrecht.

Keenan, E. (ed.): 1975, *Formal Semantics of Natural Language.* Cambridge University Press, Cambridge.

Keenan, E.: 1987, 'Unreducible n-ary Quantifiers in Natural Language,' in Gärdenfors (ed.) 1987, 109–150.

Keenan, E. and J. Stavi: 1986, 'A Semantic Characterization of Natural Language Determiners,' *Linguistics and Philosophy* **9**, 253–326.

Kripke, S.A.: 1977, 'Speaker Reference and Semantic Reference,' in: French et al. (eds.) 1977, 6–27.

Lewis, D.: 1975, 'Adverbs of Quantification,' in: Keenan (ed.) 1975, 3-15.

Lewis, D. : 1979, 'Scorekeeping in a Language Game,' *Journal of Philosophical Logic* **8**, 339–359.

Ludlow, P. and S. Neale: 1990, 'Indefinite Descriptions: In Defence of Russell,' *Linguistics and Philosophy* **13**, ??–??.

Meyer Viol, W.P.M.: 1992, 'Syntactic Discourse Representation Theory,' manuscript, Centrum voor Wiskunde en Informatica, Amsterdam.

Muskens, R. : 1989, 'A Relational Formulation of the Theory of Types,' *Linguistics and Philosophy* **12**, 325–346.

Neale, S.: 1990, *Descriptions.* The MIT Press, Cambridge (Mass.).

Parsons, T.: 1978, 'Pronouns as Paraphrases,' manuscript, University of Massachusetts at Amherst.

Partee, B.H,: 1984, 'Nominal and Temporal Anaphora,' *Linguistics and Philosophy* **7**, 243–286.

Phillips, A. (ed.): 1985, *The Collected Papers of Gareth Evans.* Clarendon Press, Oxford.

Prüst, H., R. Scha, and M. van den Berg: 1993, 'A Formal Discourse Grammar and Verb Phrase Anaphora,' technical report (version 531B), Department of Computational Linguistics, University of Amsterdam. To appear in *Linguistics and Philosophy.*

Richards, B.: 1984, 'On Interpreting Pronouns,' *Linguistics and Philosophy* **7**, 287–324.

Rooth, M.: 1987, 'Noun Phrase Interpretation in Montague Grammar, File Change Semantics, and Situation Semantics,' in: Gärdenfors (ed.) 1987, 237–268.

Sánchez Valencia, V.: 1990, *Studies on Categorial Grammar and Natural Logic.* PH.D. dissertation, University of Amsterdam, Amsterdam.

Zeevat, H.: 1989, 'A Compositional Approach to Discourse Representation Theory,' *Linguistics and Philosophy* **12**, 95–131.