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Dynamic binding of split antecedents

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ABSTRACT OF THE THESIS

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This paper proposes a dynamic approach to the problem of split antecedents, in which a pronominal element refers back to a disjunctive clause. First, I discuss the ambiguities disjunction gives rise to in intensional contexts, in particular their consequences for anaphoric possibilities. I pay special attention to the interaction of future tense and disjunction, showing the role of temporal structure in the availability of anaphora to a split antecedent.

Second, I propose a dynamic binding account for split antecedents introducing the concept of 'variable complexes'. These are syntactic constructs consisting of two variables that can be bound by two corresponding quantifiers. I implement variable complexes formally as an extension of Dynamic Predicate Logic (DPL; Groenendijk and Stokhof 1991). This provides better empirical coverage and also simplifies the status of disjunction in DPL by giving us an enriched view on the dynamic behavior of connectives.

The thesis of Jos Leonard Tellings is approved.

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Contents

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1 Introduction

The problem of *split antecedents* (henceforth SA) occurs when a pronominal element refers back to a disjunctive clause, either involving DP-disjunction ('DP *or* DP') or a clausal disjunction. I shall take the term 'pronominal element' to include singular (simple) pronouns (*he*, *she*, *it*, etc.), plural pronouns (*they*, *them*, etc.) and what I shall call *disjunctive pronouns* (*he or she*, *him or her*, etc.). The following examples illustrate these, with the disjunctive clause underlined and the pronominal element in boldface:[1]

(1) a. If Mary sees John or Bill, she waves to **him**.

b. Sue or Linda will open the conference. **She** will thank the sponsors first.

c. The department is looking for a phonologist or a phonetician. **He or she** must have an excellent record.

d. The general will send out Frank or Harry to Afghanistan. **They** will join the troops in the Kandahar region.

e. Either a squirrel has got into the attic or a bird is building a nest up there. We have to get **it** out. (Simons 2000:190)

The reference of these pronouns depends on the alternative situations introduced by the disjunctive clause, and is therefore not simply anaphoric to a single quantifier or proper name. Nor can the reference of the pronoun be described by assigning it the descriptive content of the disjunctive clause: for (1a), the following interpretation incorrectly admits

[1] One source, Simons (2000:184), claims that such anaphora is unavailable when the disjuncts are proper names. However, an example such as (1a) is the prototypical example cited in the literature (e.g. Stone 1992). Also the experiment I conducted, described below, contained several examples containing proper names that were accepted by all participants.

the case that Mary sees John, but waves to Bill:

(2) If Mary sees John or Bill, she waves to [John or Bill].

In this paper I will be mainly concerned with two questions. First, it is an old observation (Rooth and Partee 1982) that disjunction gives rise to scopal ambiguities in intensional contexts. In section 2, I will start from Rooth and Partee's (1982) observations, arguing that their discussion conflates a number of ambiguity inducing elements, namely intensional contexts and indefinite descriptions. I adduce additional data that will clarify the situation. This discussion bears on the problem of SA we are interested in, since these ambiguities have direct consequences for anaphoric continuations. I will pay special attention to the interaction of disjunction and future tense, reviewing some relevant literature on tense, modality and their interaction to anaphora along the way.

The second question is how to formally account for the pronominal binding of a split antecedent. Section 3 discusses a number of earlier solutions given in the literature in different semantic frameworks. In section 4.2, I present my own proposal of the dynamic binding of split antecedents involving an innovation of what I call 'variable complexes'. Section 4.3 formally implements variable complexes as an extension of Dynamic Predicate Logic (DPL; Groenendijk and Stokhof 1991).

In the remainder of this introductory section, in order to demarcate the position were we stand, I describe briefly some data and theoretical issues that are related to the two main questions just described, but that I consider to represent issues that are sufficiently independent that for reasons of space a cursory discussion will suffice.

Plural and disjunctive pronouns Although existing literature has almost exclusively focused on singular pronouns, a small experiment I conducted with native English speakers (Tellings 2010a,b) showed that speakers prefer plural pronouns in many cases (e.g. (1d)), and use disjunctive pronouns as well. In the experiment twenty students from the University of Cambridge, all native speakers of English that were not studying linguistics, were presented with a set of sentences containing split antecedents. All sentences contained some surrounding context designed in such a way that either a singular reading for the disjunction was natural (though not absolutely required), or a plural reading was more natural, or both readings were natural. Examples of sentences used in the experiment falling in these three categories are given below:

(3) a. Professor Richard Smith from London or Dr. Paul Brown from New York will be elected as Master of the college. He / they will take residence in the Master's lodge. [singular reading preferred]

b. The department's £5000 study grant will go to Anne or Mary. She has / they have applied well before the deadline. [plural reading preferred]

c. I have decided to employ Brian or Steven as a teacher. I will show him / them the school next week. [both readings natural]

The participants' task was to indicate for each given sentence whether they thought the singular pronoun was more adequate, the plural pronoun was more adequate, both were equally adequate, or neither was adequate. To investigate the use of disjunctive pronouns, each sentence was asked twice, but the second time with the disjuncts differing in gender. In total, twenty-one sentences were given (excluding fillers). The results summarized in Table

1 indicate that speakers tend to use plural pronouns, even in contexts that were designed to make a singular reading more natural.

	Prefer singular pronoun	Prefer plural pronoun	Like both pronouns	Like neither pronoun
Singular reading intended	39%	30%	14%	17%
Plural reading intended	4%	84%	1%	3%
Both readings natural	19%	49%	16%	16%
Total	21%	54%	13%	12%

Table 1. Combined results for same-gender and mixed-gender antecedents. Here 'singular pronoun' stands for singular pronoun (e.g. *she*) or disjunctive pronoun (e.g. *he or she*), depending on the sentence asked.

As for the disjunctive pronouns, I found that in 45 cases (25%) a disjunctive pronoun was preferred in the mixed-gender sentences, as opposed to 31 (17%) for the singular pronoun in the corresponding same-gender sentences. In order to further quantify the use of disjunctive pronouns, I compared the responses on pairs of sentences that were identical except for the gender of the disjuncts. In less than 60% the same answer was given, including 15 cases in which a participant did not like the same-gender sentence at all ('prefer neither pronoun'), but preferred the disjunctive pronoun in the corresponding mixed-gender sentence. Some participants commented that they associate disjunctive antecedents with a more formal register, others indicated that disjunctive pronouns sound 'artificial' to them, and some avoided them in general. For full results and more discussion, I refer the reader to Tellings (2010a).

This was only a small and informal experiment with a number of confounding experimental and conceptual issues. For instance, both disjunctive and plural pronouns can be

used as a gender-neutral pronoun, for example in combination with gender-neutral proper names (Robin, Leslie) and quantifiers (both examples below from the BNC[2]):

(4) a. The commission suggests that anyone over 18 who has contributed to the cost of the property **he or she** occupies should have to agree to its sale.

(BNC, AAC.434)

b. The object is to catch all the other players by hitting them with the ball. Once someone has been caught, **they** help to catch. (BNC, C8P.988)

Hence, unless we have a precise theory of gender-neutral pronouns, we do not know for sure if the plural and disjunctive pronouns were used to refer to both disjuncts, or rather as a gender-neutral pronoun in the mixed-gender sentences.

Furthermore, disjunctive pronouns do not always behave like their singular counterparts, as this example (Edward Keenan, p.c.) shows:

(5) *Either John or Mary considered himself or herself to be a genius.

Given these additional problems with plural and disjunctive pronouns, which are not directly related to the issues I want to discuss in this paper, I will mainly focus on singular pronouns from now on.

'Bathroom sentences' and free choice disjunction A class of sentences that has become known in the literature as 'bathroom sentences' also involve disjunction and anaphora, but in a slightly different way than the SA sentences in (1). The classic example (originally due to Partee) is given in (6) below:

[2]British National Corpus (BNC), accessible on-line at `http://www.natcorp.ox.ac.uk/`.

(6) Either there is no bathroom here, or it is in a funny place. In any case, it is not on the first floor.

In bathroom sentences the first disjunct contains a negation, and the second disjunct contains a pronoun that refers back to the first. There is a large body of literature on bathroom sentences, that I will not review here for reasons of space (Roberts 1989, Krahmer and Muskens 1995, Geurts 1999, Simons 2000 and references therein).

A second well-described aspect of disjunction is its relation with conjunction. From De Morgan's laws it follows how disjunction-conjunction conversion occurs for instance in the antecedent of an implication, but a similar phenomenon occurs in the scope of certain modal contexts – the so-called "free choice problem":

(7) If Mary sees John or Bill, she waves to him.

$(a \vee b) \rightarrow c \Leftrightarrow (a \rightarrow c) \wedge (b \rightarrow c)$

= If Mary sees John, she waves to John, and if she sees Bill, she waves to Bill.

(8) You may have coffee or tea.

= You may have coffee, and you may have tea.

Again, for reasons of space I can only refer the reader to the large literature on this topic, see e.g Zimmermann 2000, Simons 2005, Aloni 2007 and references therein; such data also formed the basis of development of the framework of Inquisitive Semantics, see e.g. Groenendijk and Roelofsen 2009, Aher 2012).

2 Ambiguities

SA sentences allow for various readings. Rooth and Partee (1982) and Partee and Rooth (1983) mention three readings for the sentences in (9):

(9) a. Mary is looking for a maid or a cook. (1982)

b. The department is looking for a phonologist or a phonetician. (1983)

Taking sentence (9b), they distinguish between a 'de re' reading ("the department is looking for a specific person, and that person is a phonologist or a phonetician", p. 21), a 'first de dicto' reading ("the department would be satisfied if they found a phonologist, and they would also be satisfied if they found a phonetician", ibid.) and, finally, a 'second de dicto' reading ("the department has a particular kind of person in mind, but the speaker doesn't know which kind of person this is", ibid.). This ambiguity is also discussed in Larson (1985), who claims that the English *whether* acts as a syntactic indicator of the scopal ambiguity, as well as in the "free choice" literature (Zimmermann 2000:258 and Simons 2005).

2.1 Intensionality and indefinites

The difficulty with sentences of the type given in (9) is that several ambiguity introducing elements combine: an intensional transitive verb (ITV) 'look for' that yields a specific/unspecific ambiguity, a disjunction that yields a scopal ambiguity and indefinite descriptions that allow different uses (quantificational, specific, referential and definite in the terminology of Ludlow and Neale 1991). Let's therefore try to separate these elements and see what ambiguities arise:

(10) a. Mary is looking for a cook. [ITV + indefinite]

b. Mary is looking for John or Bill. [ITV + disjunction]

c. Mary is kissing John or Bill. [disjunction]

d. Mary is kissing a boy or a girl. [disjunction + indefinites]

e. Mary is looking for a maid or a cook. (=(9a)) [disjunction + ITV + indefinites]

Sentence (10a) entertains the familiar specific/unspecific ambiguity that ITV's give rise to (Quine's 1956 'relational/notional' is a less overburdened but maybe less intuitive terminology; see also Forbes 2010 for an overview): on the specific reading, Mary is looking for some specific person, say John, who happens to be a cook, but Mary may not know he is a cook. On the unspecific reading, Mary is looking for some cook or other, but no particular one. This ambiguity does not occur in (10b), because proper names, as rigid designators, do not allow for an unspecific interpretation.[3,4]

Sentence (10b), however, gives rise to a different ambiguity, caused by the disjunction. On one reading, both finding John and finding Bill would satisfy Mary. On the second reading, Mary is looking for one specific person, but the speaker does not know whether this person is John or Bill. Sentences (10c) and (10d), on the other hand, which contain a disjunction

[3]That rigid designators may nevertheless give rise to a meaningful de re / de dicto ambiguity (in the sense that if Mary is looking for the boss or his spokesman, unaware that they are John and Bill, I may report this situation with (10b)) is discussed in Fitch (1981).

[4]Of course, it shows two other properties of ITVs, namely that the truth-value may change under substitution of a coreferential expression, and the lack of an existential requirement for their argument. We observe that this holds for disjunctive phrases equally well as for simple names:

(i) a. Mary is looking for Tully or Clark, but she is not looking for Cicero or Superman.

b. Mary is looking for Zeus or Apollo.

Hence the ambiguity in question occurs under the combination of ITVs and (in)definite descriptions.

and the extensional verb 'kiss', are not ambiguous in this sense. The only available reading is the one in which the speaker does not know which person Mary is kissing. In summary, the ambiguity that Partee and Rooth point to (the difference between the first and second de dicto reading) occurs when the disjunction combines with an intensional transitive verb, as in (10b), but not with an extensional verb like 'kiss'. The reader may wonder why Partee and Rooth regard this ambiguity as a *scopal* one; I will postpone this issue for now, and first discuss indefinites.

Before I return to (10e), I should briefly discuss the confusing fact that indefinite descriptions themselves can be used in different ways. In uttering a simple extensional context, such as (11), I may use the indefinite 'a girl' in a purely quantificational manner, or in a referential manner, in which case I have a certain girl in mind (say, Linda).

(11) John kissed a girl

The large body of literature on this topic may be roughly divided according to two views: the view that the difference is semantic and should be accounted for as such (e.g. Fodor and Sag 1982 distinguish between $(\exists x : \mathsf{girl}(x))$ and $(\mathbf{a_r} x : \mathsf{girl}(x))$, the latter intended for specific indefinites) or the view that the difference is pragmatic (e.g. Ludlow and Neale 1991). The subtle differences between de re / de dicto, wide / narrow scope indefinites and the uses of indefinites, are explained by Ludlow and Neale (1991, §3.1) who take Kripke's (1977) arguments, but apply them to indefinites. Whereas de re / de dicto is a binary distinction, scopal ambiguities can have any number depending on how many scope taking elements are present in the sentence. Furthermore, although the indefinite *a girl* in (11) is 'specific' (relational) in the sense discussed above for intensional contexts (the continuation 'but no

particular one' is unavailable), this is unrelated to whether the *speaker* has a specific girl 'in mind' or not, i.e. has general or a singular belief for the basis of his utterance. So, although de re / de dicto ambiguity is often taken as an instance of scope (by what is sometimes called the Quine-Montague hypothesis), it cannot replace it.

2.2 Generalized disjunction

Returning to our original examples in (9), we observe that both combinations (ITV + disjunction, and ITV + indefinite) occur in the sentence, hence both ambiguities ensue. Their de re and standard (first) de dicto readings correspond to the notional/relational ambiguity discussed above[5] Their first and second de dicto readings correspond to the ambiguity that is particular to disjunction, which we have seen occurs in combination with intensional operators. It is now clear that there should be a fourth reading, namely a 'second de re' reading, which runs something like "the department is looking for a specific person, but the speaker does not know whether that person is a phonetician or a phonologist". The disjunctive ambiguity is treated as a scopal ambiguity by Partee and Rooth; their 1982 paper in particular deals with 'wide scope disjunction'. According to their analysis, the second de dicto (wide scope disjunction) reading of (9b), repeated below, can be paraphrased as (12), both disjuncts being read de dicto.

(9b) The department is looking for a phonologist or a phonetician.

[5]For discussion about the differences between de re/de dicto and relational/notional distinctions, see Recanati (1999), and McKay and Nelson (2010) for semantic and syntactic conceptions of the de re/de dicto distinction.

(12) The department is looking for a phonologist or looking for a phonetician. (Partee and Rooth 1983:22)

More precisely, the 1982 and 1983 papers develop a theory of a generalized (cross-categorial) disjunction (and conjunction) for a Montagovian type-theoretic semantics (see also Simons 2000:191ff. for a more modern exposition). The basic idea is that generalized disjunction is the normal truth-conditional disjunction for truth values, and is defined recursively for higher types:

(13) *Recursive definition of* conjoinable type:

i. t is a conjoinable type;

ii. if b is a conjoinable type, then for any type a, $\langle a, b\rangle$ is a conjoinable type.

(14) *Recursive definition of* generalized disjunction ($\sqcup$):

i. In D_t, $\sqcup$ is equivalent to $\vee$.

ii. Let b be a conjoinable type, and f, g functions in $D_{\langle a,b\rangle}$. Then $f \sqcup g := \lambda x(f(x) \sqcup g(x))$.

Leaving out some calculation steps, the disjunctive phrase 'a maid or a cook' now receives the following translation:

$$\begin{aligned} \textbf{a maid} \sqcup \textbf{a cook} &= \lambda P \exists x(\textbf{maid}'(x) \wedge P\{x\}) \sqcup \lambda P \exists x(\textbf{cook}'(x) \wedge P\{x\}) \\ &= \lambda P \exists x((\textbf{maid}'(x) \vee \textbf{cook}'(x)) \wedge P\{x\}). \end{aligned}$$

In this manner, analogous to normal indefinites, it can be 'quantified in' in order to obtain

the de standard de re and de dicto readings (Rooth and Partee 1982:3):

(15) a. $\exists x((\mathbf{maid}'(x) \vee \mathbf{cook}'(x)) \wedge \mathbf{look\text{-}for}'(\hat{}\lambda P P\{x\})(m))$ (de re)

b. $\mathbf{look\text{-}for}'(\hat{}\lambda P \exists x((\mathbf{maid}'(x) \vee \mathbf{cook}'(x)) \wedge P\{x\}))(m)$ (de dicto)

In order to get the wide scope interpretation (i.e. the translation of the paraphrase in (12)), some more work is needed. By means of type raising, Partee and Rooth obtain the following translation, in somewhat simplified notation:

(16) $\mathbf{look\text{-}for}'(\hat{}\mathbf{a\ maid}')(m) \vee \mathbf{look\text{-}for}'(\hat{}\mathbf{a\ cook}')(m)$ (wide scope de dicto)

Rooth and Partee furthermore make the observation that disjunction behaves like a scopal operator in the sense that it generates multiple ambiguities in case of multiple embedded sentences. The following example (Rooth and Partee 1982:4) has a reading in which the disjunction takes scope between 'believe' and 'say'. This reading expresses that the uncertainty is with John, and not with the speaker (I added some context in parentheses for ease of interpretation):

(17) (John is really hard of hearing. In fact, ...)
John believes that Bill said that Mary was drinking or playing video games.
(But I am sure Bill didn't say that!)

Nevertheless, Rooth and Partee dismiss their type-theoretic approach in favor of a DRT-style solution. Because the paper dates from the time of the very early stages of DRT-style theories, I shall postpone the discussion to section 3.4 where I discuss what Kamp and Reyle (1993) have to say about SA sentences.

2.3 Other contexts

We have seen that the scopal ambiguity of disjunction arises in environments created by intensional transitive verbs. This raises the question if the same ambiguity can be observed in other opaque contexts, such as those created by modal verbs, propositional attitude verbs and the future tense operator. The following examples illustrate this is indeed the case:

(18) a. It is necessary that 5 is odd or even.

1. It is necessary that it is either.

2. It is either necessary that 5 is odd, or that 5 is even, but the speaker doesn't know which.

b. John wants to marry a professor or meet a filmstar.

1. John is satisfied by both.

2. John is satisfied by only one, but the speaker doesn't know which.

c. The department will hire Peter or Amanda.

1. The department is considering two people for the job.

2. The department has decided to hire either one, but the speaker doesn't know who.

There is discussion in the literature on whether future tense really creates an opaque context, although this discussion sometimes seems to be more oriented towards the definition of 'opacity' and 'intensionality'. For instance, Wuttich (1995) argues against future tense creating an opaque context, focusing on the substitution test as a criterion for opacity. Similarly, there is a large body of literature on the relation between future tense and modality (e.g. Enç 1996, Sarkar 1998, Kissine 2008, Del Prete 2012, see also Portner 2009, section 5.1

for an overview). Although (18c) is intended to be read in a 'purely future' reading, it is clear that *will* can express several modal readings. This has lead to different views:

- *will* is purely modal (arguments include *will*'s resemblance with other English modal auxiliaries in several respects, the fundamental uncertainty of the future being embodied by its modal nature, and the future time-shifting that has been argued to be part of other modal verbs as well; see e.g. Enç 1996);
- *will* is ambiguous between modal and purely temporal readings;
- *will* is purely temporal and its modal readings arise as a result of other mechanisms, such as pragmatics (Kissine 2008).

Reviewing the literature defending these positions falls outside the scope of this paper, but more relevant is the observation that the ambiguity in (18c) can be found in other contexts that allow a future time reading, viz. cases in which the present tense is ambiguous between a present and future interpretation (cf. Sarkar 1998:97).

(19) a. [Right now, ...] John or Mary is giving a lecture on modal logic.
(only speaker uncertainty)

b. [At next week's conference, ...] John or Mary is giving a lecture on modal logic.
(speaker uncertainty, or conference's uncertainty)

Because we find that the ambiguity arises in (19b) in which the present tense has a future time interpretation, but not in (19a) with a speech time interpretation, we conclude that the ambiguity in (18c) is not particular to *will* (or any of its potential modal character), but rather to a future time interpretation.

In older literature it was assumed that tense (past, present, future) was semantically represented by sentential tense operators such as $\mathbf{F}\phi$ and $\mathbf{P}\phi$, expressing that ϕ is true at some later, respectively earlier time. This view is expressed in Montague's classic paper (1973) (explained in more detail in Dowty et al. 1981, ch. 5), and adopted for instance in Fodor and Sag (1982:388-9). Returning to (18c), in view of this theory, one may want to represent the ambiguity – in strongly simplified notation – along the lines of (20):

(20) a. $\mathbf{F}\ \exists x.((x = p \vee x = a) \wedge \mathbf{hire}(dept, x))$

b. $\exists x.((x = p \vee x = a) \wedge \mathbf{F}\ \mathbf{hire}(dept, x))$

However, in a seminal paper, Enç (1986) has shown that this classical approach fails to account for several other cases (cf. Kamp and Reyle 1993, section 5.1.2). To mention just one of her examples, under the classical analysis, (21) has two readings ('current sophomores cried in the past', or 'past sophomores cried when they were sophomores'), missing the reading in which past sophomores cried at a past time distinct from when they were sophomores:

(21) Every sophomore cried. (Enç 1986:414)

$\mathbf{P}\,\forall x(\mathsf{sophomore}(x) \longrightarrow \mathsf{cried}(x))$

$\forall x(\mathsf{sophomore}(x) \longrightarrow \mathbf{P}\,\mathsf{cried}(x))$

Instead, Enç (1986) argues for implementing strictly local tense operators that apply to verbs and nouns only. This allows for having two past tense operators, as is required to represent the missing third reading of (21) (one operator for each predicate).

(22) $\forall x(\mathbf{P}(\mathsf{sophomore}(x)) \longrightarrow \mathbf{P}(\mathsf{cried}(x)))$

An important observation, that is not clear from Enç's (1986) paper, concerns the 'tenseless' interpretation of quantification. Sentence (23) shows the familiar ambiguity (current/future astronaut):

(23) a. An astronaut will walk on Mars.

b. $\exists x(\mathbf{F}(\mathsf{astronaut}(x)) \wedge \mathbf{F}(\mathsf{walk\text{-}on\text{-}Mars}(x)))$

When tense operators are strictly local and only applied to verbal or nominal predicates, sequences such as '$\mathbf{F}\,\exists$', asserting future existence, are no longer allowed. Yet, the future-astronaut reading of (23a) can be represented (in simplified form) as in (23b), as long as the tenseless interpretation of the quantifier is ensured. That is, (23b) should not be read as 'there is an x NOW such that ...' (excluding the possibility that the astronaut is yet to be born), but rather as 'there is an x (at some time or timelessly) such that ...' (this is an old observation, cf. Rescher (1966:89)).[6]

Since under this approach of strictly local operators the notions of 'operator' and 'scope' are rather vacuous, so Enç argues, it is better to say that nominal and verbal predicates have a temporal argument (e.g. $\mathsf{sophomore}(x, t)$ for 'x is a sophomore at time t'), where different temporal arguments may or may not be co-referential in analogy with pronominal indices. Although Enç (1986) does not provide a concrete proposal of how this is to be formally implemented, the semantics discussed in the introduction of Musan (1997) is an example of a theory that uses temporal arguments and contextually provided points of evaluation. The third reading of (21) would be represented as follows in her notation:[7]

[6]Recall that quantification in mathematical statements is considered to be timeless as well, i.e. $\exists x.\mathsf{prime}(x)$ does not assert that there is some x that is a prime number NOW.

[7]I leave aside here the question of how this LF is arrived at from the syntactic structure of (21).

(24) $\lambda t(\exists[\lambda t'(C(t')\&\textsc{past}(t)(t'))][\lambda t''(\exists[\lambda u(C(u)\&\textsc{past}(t)(u))]$

$[\lambda v(\forall x(\mathsf{sophomore}(x,v) \longrightarrow \mathsf{cried}(x,t'')))])])$

Here, t, t', t'', u and v are all temporal variables (the entire expression is again a predicate with a temporal variable, hence the λt). The predicate $C(t)$ means that the time t is what the speaker refers to in the present context, and $\textsc{past}(t)(t')$ asserts that t' is prior to t. In summary, (24) is true when there are contextually provided past times t' and u such that all individuals who were sophomores at u, cried at t'. For the details of the semantic computation I refer the reader to the original Musan (1997). It should be clear that the richer theory of Enç (1986), explicated as in Musan (1997), is able to capture the ambiguity in (18c) as well as more complicated cases of disjunction (consider a case such as *A hostage or a political prisoner will speak at the president's party*, which has a reading in which it refers to *former* hostages or political prisoners).

2.4 Anaphoric continuations

The ambiguities that disjunction gives rise to in intensional contexts are relevant to anaphoric possibilities in subsequent discourse. As an example, consider the sentences in (25) below.

(25) a. John or Bill will open the conference. He will thank the sponsors first.

b. John or Bill will open the conference. He is an excellent speaker.

c. John or Bill will open the conference. They are (both) excellent speakers.

d. A professor or an assistant professor will open the conference. He will thank the sponsors first.

e. A professor or an assistant professor will open the conference. He is an excellent speaker.

The first sentence of each example in (25) is ambiguous when considered in isolation between a wide scope (speaker uncertainty) and narrow scope disjunctive reading (future uncertainty). This ambiguity persists in (25a), where *he* may either refer to the individiual who will open the conference of which the speaker is not certain whether it is John or Bill, or to whoever will be chosen to open the conference, John or Bill. In (25b) however, only a wide scope interpretation is possible.

If *will* has modal force, a theory of modal subordination can be applied (Roberts 1989, see Del Prete 2012 for particular focus on *will*). Modal subordination refers to the phenomenon that the truth of an assertion (sentence or part of sentence) is checked relative to another sentence that has modal force. In Roberts's example (1989:683), cited here as (26), the consequent of the conditional is modally subordinate to its antecedent. In particular, the truth of the conditional is determined by temporally adding to the common ground the set to those possible worlds in which John bought a book, and by checking if in all those worlds John is reading that book at home by now.

(26) a. If John bought a book$_i$, he'll be home reading it$_i$ by now. #It$_i$'s a murder mystery.

b. If John bought a book$_i$, he'll be home reading it$_i$ by now. It$_i$'ll be a murder mystery.

The general idea is that subsequent anaphoric reference requires a modal context in order to ensure that the temporarily added set of possible worlds is still available. In particular, in

(26), in order to interpret the second sentence, we need access to the set of possible worlds that was used for interpreting the conditional (i.e. the worlds in which John bought a book), and check if in all those worlds the book in question is a murder mystery. In (26a), this is not possible since the second sentence is in a non-modal present tense, but (26b) contains the modal *will*, thus allowing further reference.

If *will* is considered to be purely temporal, an appeal can be made to rhetorical relations. As an example of related issues that are not cases of modal subordination, Roberts (1989) mentions the following examples:

(27) a. Each student in the syntax class$_i$ was accused of cheating on the exam, and he$_i$ was reprimanded by the dean. (Roberts 1989, ex. (36))

b. #Each student in the syntax class$_i$ was accused of cheating on the exam, and he$_i$ has/had a Ph.D. in astrophysics. (Roberts 1989, ex. (37))

He suggests that the contrast in the availability of further anaphoric reference is because "the second sentence [of (27b)] does not comfortably continue the narrative" (p. 718). The role of rhetorical relations in several linguistic phenomena including anaphora has been appreciated in later literature, for instance in the case of so-called 'evolutive anaphora' (Asher 2000). Evolutive anaphora refers to the case in which an anaphor refers back to an argument of a destruction verb, i.e. of which it is asserted that it no longer exists. The following examples are from Asher (2000:136):

(28) a. The bomb destroyed a VW$_i$. It$_i$ disappeared in a flash.

b. #The bomb vaporized a VW$_i$. The police then inspected it$_i$ closely.

The sentences in (28b) are connected by the rhetorical relation of narrative continuation (as indicated by the word *then*). This relation brings along certain restrictions on the temporal interpretation of the sentences in question, namely that the event described in the second sentence occurred after the event described in the first sentence. Due to the special nature of the destruction verb *vaporize*, the anaphoric reference is not possible. In (28a), however, the sentences are related by another discourse relation (Explanation), and the second event is not thought to have occurred after the first.

The role of rhetorical structure has been explicated further in the semantic theory of Segmented Discourse Representation Theory (SDRT; Asher and Lascarides 2003), in which a hierarchical structure of discourse is proposed (see Spejewski 1996 for similar remarks) in order to account for cases such as the following (Asher and Lascarides 2003:60):

(29) a. Max had a great evening last night.

b. He had a great meal.

c. He ate salmon$_i$.

d. He then won a dancing competition.

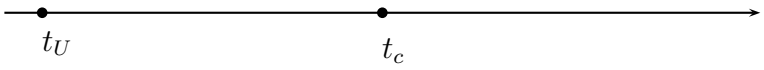
e. #It$_i$ was a beautiful pink.

Standard DRT would not predict the infelicity of (29e), but in SDRT it is argued that because (29d) picks up the narrative sequence started in (29b), subsequent anaphora to *salmon* introduced in (29c) (which is subordinate to (29b) by the *Elaboration* relation) is unavailable by virtue of the so-called 'right-frontier constraint' (see Asher and Lascarides 2003, chapter 1 for details).

In the case of the sentences in (25), we can see the role of time. For instance, (25e) only admits a wide scope reading. Under a narrow scope reading, there is no unique person at the time of utterance (as far as the speaker knows) who will open the conference. Hence, it cannot be asserted of this person that he is an excellent speaker. On the other hand, a continuation with modal force is possible (where *must* is read deontic):

(30) A professor or an assistant professor will open the conference. He must be an excellent speaker.

The time-line of sentences like the ones in (25) may be schematically represented as in (31):

(31) 

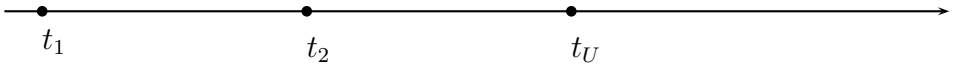
Here t_U is the time of utterance, and t_c ('choice') is a future time at which the speaker comes to know the unique individual that will open the conference.

A slightly more complicated case is illustrated by the data in (32):

(32) a. When it became clear that Romney or Santorum would become the Republican nominee, {they / *he} received a lot of attention.

b. When it became clear in 2008 that Obama or Clinton would become the Democratic nominee, {they / *he or she} received a lot of attention.

In these cases there are three relevant moments in time: t_1 at which it became clear that either of two persons would become the presidential nominee for their party, t_2 at which the nominee was chosen, and the time of utterance t_U, in this case coming after both t_1 and t_2:

(33) 

At the time the *when* clause refers to (i.e. t_1), there is no unique person available for reference by a singular pronoun. However, it may be asserted that both candidates received a lot of attention.

One further set of examples (34–35) illustrates the difference in proper names and (non-specific) indefinites:

(34) [Context: a journalist has found out that this year's Nobel Prize for Literature will be awarded to Smith or Brown. The winner will be officially announced next week.]

a. Smith or Brown will win this year's Nobel Prize for Literature. #She will give an interview tomorrow.

b. Smith or Brown will win this year's Nobel Prize for Literature. They will give interviews tomorrow.

c. Smith or Brown will win this year's Nobel Prize for Literature. She will give an interview immediately after the announcement.

(35) [Context: a journalist has found out that this year's Nobel Prize for Literature will be awarded to a woman author from either Germany or Poland, but hasn't got names. The winner will be officially announced next week.]

a. A German or a Polish author will win this year's Nobel Prize for Literature. #She will give an interview tomorrow.

b. A German or a Polish author will win this year's Nobel Prize for Literature. #They will give interviews tomorrow.

c. A German or a Polish author will win this year's Nobel Prize for Literature. She

will give an interview immediately after the announcement.

In both cases the (a) continuations are infelicitous because by tomorrow the winner is not yet known (cf. a continuation such as *She must have published at least 30 books* for (35a)). Anaphoric reference with *they* is possible only in (34), in which two specific individuals are available for summation.

In summary, I hope I succeeded in clarifying the ambiguity originally described by Rooth and Partee (1982) by separating the contributions of indefinite descriptions and intensional transitive verbs (ITVs) to this ambiguity, and explaining why this ambiguity has been referred to as a *scopal* ambiguity. It turns out that the relevant ambiguity introduced by disjunction appears in several intensional contexts, including in future tense contexts. Although the modal, temporal and intensional nature of *will* are all controversial issues in the literature, future tense contexts play an important role in the availability of certain readings as well as the possibility of anaphoric reference. Because the disjunctive ambiguity is related to uncertainty existing either at the level of the speaker, or at the level of the world, the temporal relation between the time of utterance and the knowledge of the speaker regarding the event in question plays an important role. Depending on one's analysis of the future auxiliary *will*, these can be explained by theories of modal subordination (Roberts 1989) or theories of anaphora that incorporate rhetorical structure (Asher and Lascarides 2003).

3 Earlier solutions

I now turn to the question how to account for the binding relation between a split antecedent and a pronoun within existing formal theories of semantics. Subsequently I will discuss a pragmatic E-type account (Stone 1992; section 3.1), a compositional E-type account (Simons 2000; section 3.2), a D-type account (Elbourne 2005; section 3.3), and Discourse Representation Theory (DRT; Kamp and Reyle 1993; section 3.4). My own proposal will be presented in section 4.

3.1 Pragmatic E-type approach (Stone 1992)

Stone (1992) describes a solution for PSA with singular pronouns in the framework of E-Type pronouns, as developed by Heim (1990). E-Type approaches to pronominal anaphora (ETA) hold the view that pronouns are rigidly referring expressions whose reference is determined by descriptions obtained from the linguistic context (see Elbourne 2005, section 1.3 for a brief introduction in both E-type and D-type description-theoretic approaches). I shall discuss two E-type approaches, Stone (1992) and Simons (2000) (see section 3.2). Stone's theory may be called pragmatic because the descriptive content of the pronoun is obtained via contextually salient functions.

Stone's (1992) solution is formulated in the framework of *situation semantics*. A situation is a partial specification of a possible world, i.e. containing individuals and relations between individuals but not necessarily all individuals or all relations. A proposition may be true, false, or unspecified with respect to a situation. The latter is the case when the situation does not include all information that is necessary to verify the truth-conditions of the proposition.

The partial nature of a situation implies a natural ordering on them: a situation s can be extended into a situation s' such that s' contains all information of s plus some additional information. We can thus speak about a *minimal situation*, i.e. a situation that is minimal with respect to the ordering just described. Each proposition has a unique set of minimal propositions that verify it. For example, the sentence 'A man walks in the park' has a set of minimal situations in which each situation contains a man that walks in the park, and nothing else.

Stone (1992) subscribes to the standard view in dynamic semantics that sentences are entities that update the context, where the context is considered to be a set of propositions. Since each proposition corresponds to a set of minimal situations, one can also talk about the set of minimal situations of a context. In Stone's semantics, a pronoun is a function that assigns an individual to each minimal situation of the context. In a typical example of cross-sentential anaphora, such as (36), after the first sentence has been processed, the context consists of the set of minimal situations that verify that sentence (assuming that the context was hitherto empty):

(36) A man walks in the park. He whistles.

These minimal situations give rise to a contextually salient function f that assigns to each situation s the man that walks in the park in s (uniqueness is assured by minimality). The processing of the second sentence of (36) takes the existing context as input, and the translation of the pronoun is the function f. Hence, if this context contains the minimal situation s', the sentence 'He whistles' is represented as $\mathsf{whistle}(f(s'))$, i.e. 'the man that walks in the park whistles'.

Let me now proceed to Stone's (1992) solution for PSA. Stone adopts Rooth and Partee's (1982) definition of generalized disjunction, as discussed in section 2.2. Stone proposes that a sentence with split antecedents has two minimal situations in each world that make it true. The example used by Stone is (37):

(37) If Mary sees John or Bill, she waves to him. (Stone 1992:367)

In ETA, an implication is true if every minimal situation in which the antecedent is true, extends to a situation in which the consequent is true. The minimal situations that make the antecedent of (37) true are:

(38) the situation in which Mary sees John, and nothing else; and
the situation in which Mary sees Bill, and nothing else.

The pronoun 'him' in the consequent corresponds with the function that picks out the unique person she sees, i.e. John or Bill, depending on the situation. This gives the correct interpretation of (37):

(39) Every minimal situation in which Mary sees John or Bill, extends to a situation in which Mary waves at the man she sees. (Stone 1992:375)

Stone's approach also works for more complex cases, including clausal disjunction, as in example (40):

(40) If Mary hasn't seen John lately, or Ann misses Bill, she calls him. (Stone 1992:378)

The minimal situations for (40) contain either only Mary and John, or only Ann and Bill. The pronouns 'she' and 'him' then pick out their unique referents.

Although the examples discussed above may be small enough to ensure a salient function exists for the interpretation of a pronoun, problems may arise when the context is larger. Stone suggests that 'salience' need not be defined in terms of a formal syntactic link between pronoun and antecedent (as Heim 1990 does), but that a characterization depending on "two intuitively plausible manifestations of respect for context" (p. 370) suffices. The first requirement is that "a salient function must always pick out an individual in a situation that the situation gives information about" (p. 370), which means that a salient function should always assign to a situation s some individual contained in s. The second requirement is that "a salient function [must] take corresponding arguments to corresponding results" (p. 371). The latter requirement is supposed to exclude functions that satisfy the first requirement, but are 'inconsistent' with respect to each situation: for instance, in example (37) (with minimal situations (38)), a function that assigns Mary to some situations, but John to other situations (in which John is available), is not a salient function for the pronoun 'she'.

Now consider a sentence such as (41):

(41) Mary$_i$'s husband saw a girl at the party. *She$_i$ liked her.

Each minimal situation verifying (41) will have to include Mary (in order to define Mary's husband). Yet a function that satisfies both salience requirements by consistently selecting Mary from each minimal situation verifying (41) is not a suitable interpretation for the pronoun 'she'. This problem is similar to the so-called *formal link* problem, discussed in Elbourne (2005, section 2.4), exemplified in (42) where 'her' is supposed to refer back to the

man's wife:

(42) *Every married man is sitting next to her. (Elbourne 2005:64)

Because the translation of 'married man' presumably involves the binary predicate is-married-to(x, y), the man's wife is in principle available as descriptive content for the pronoun 'her'. Some syntactic principle is required in order to restrict the range of suitable interpretation functions (p. 65), casting doubt on Stone's idea of a purely pragmatic notion of salience. Elbourne presents a different description-theoretic framework that provides a very simple solution to the formal link problem (Elbourne 2005:68; see also my discussion of (54) in section 3.3 below).

Finally, recall that we have seen cases in which the two disjuncts can be input for summation and plural anaphora, as in (32a), reproduced below:

(43) When it became clear that Romney or Santorum would become the Republican nominee, they received a lot of attention.

The situations that verify a disjunctive sentence, by virtue of their minimality, never include both discourse referents introduced in the disjuncts, always exactly one. Hence a plural pronoun in a subsequent sentence cannot refer to the summation of both.

3.2 Compositional E-type account (Simons 2000)

Simons (2000) also provides an E-type account for SA data, but one that differs from Stone's (1992) solution in that the descriptive content of a pronoun is obtained from the LF of the antecedent sentence in a compositional manner. For instance, the translation of the pronoun

is governed by the following Pronoun Rule (the *antecedent clause* of a pronoun is defined as the minimal IP dominating the pronoun's antecedent):

(PR) *Pronoun rule* (Simons 2000:188)

If α is an E-type pronoun with antecedent clause ϕ whose logical form is $\mathrm{Det}(F)(G)$, then $\alpha' = \mathsf{the}(\lambda x.F'(x) \wedge G'(x))$.

In a simple cross-sentential case such as (44) (Simons 2000:197), after the LF of the first sentence has been constructed, the Pronoun Rule extracts the property $\lambda x.\mathsf{soprano}(x) \wedge \mathsf{sang}(x)$, so that the pronoun *they* is translated as $\mathsf{the}(\lambda x.\mathsf{soprano}(x) \wedge \mathsf{sang}(x))$. This informally translates to the definite description "the sopranos that sang".[8]

(44) Many sopranos sang. They were wonderful.

In order to apply this idea to SA sentences, first the Logical Form of disjunctive sentences must be specified. Because Simons is concerned with both DP disjunction (45a) and IP disjunction (45b), she adopts the cross-categorial generalized disjunction from Rooth and Partee (1982) as discussed in section 2.2.

[8] Edward Keenan (p.c.) asked how Simons would account for (i):

(i) *No sopranos sang. They were wonderful.

This seems to be a valid question. The crucial rule for finding the recoverable predicate is as follows:

(ii) $[_{\mathrm{NP}}\ \mathrm{Det}\ \overline{\mathrm{N}}]^{\mathrm{P}} = \overline{\mathrm{N}}^{\mathrm{P}}$ ((RP:2) on p. 195)

Simons herself says about this rule that "the determiner itself plays no role in fixing the recoverable predicate" (p. 195). Indeed, it seems that Simons makes bathroom sentences work just because from "no bathroom in the house", one can reconstruct "the bathroom in the house" (p. 156). Note that Simons does discuss related sentences like (iii):

(iii) #No student attended a seminar$_i$. It$_i$ was very dull. (Simons 2000:159)

She says "[a]naphora between a narrow scope indefinite and a pronoun in a conjoined or concatenated sentence is [...] impossible" (p. 159). This is explained by assuming that the interpretation of a free variable that is left over because a second scope-taking element moved to a position higher than the antecedent ('no' scoped over 'a' in (iii)) is unavailable. Since there is only one quantifier in (i) above, this line of reasoning does not offer an explanation for such cases.

(45) a. A squirrel or a bird has got into the attic. We have to get it out.

(Simons 2000:190)

b. Either a squirrel has got into the attic or a bird is building a nest up there. We have to get it out. (Simons 2000:190)

The Pronoun Rule is abandoned as too construction-specific, in favor of the notion of *recoverable predicate*, which is the "relevant property ...of an expression" (p. 195). The recoverable predicate α^{P} is computed compositionally from an LF-subtree α. The relevant rule for disjunction is given in (46):

(46) $[_{\mathrm{XP}}\ \mathrm{XP}_1$ or ... or $\mathrm{XP}_n]^{\mathrm{P}} = \mathrm{XP}_1^{\mathrm{P}} \sqcup \ldots \sqcup \mathrm{XP}_n^{\mathrm{P}}$ (Simons 2000:195)

The new Pronoun Rule is defined as follows:

(PR′) *Pronoun Rule* (revised) (Simons 2000:197)

If α is an E-type pronoun with antecedent clause ϕ, then $\alpha' = \mathsf{the}(\phi^{\mathrm{P}})$.

This yields the following results for the pronouns in (45), with their metalanguage translations:

(47) a. $\mathsf{the}(\lambda x.[\mathsf{squirrel}(x) \vee \mathsf{bird}(x)] \wedge \mathsf{has\text{-}got\text{-}into\text{-}the\text{-}attic}(x))$

"the squirrel or bird that has got into the attic"

b. $\mathsf{the}(\lambda x.[\mathsf{squirrel}(x) \wedge \mathsf{has\text{-}got\text{-}into\text{-}the\text{-}attic}(x)] \vee$

$[\lambda z.[\mathsf{bird}(z) \wedge \mathsf{is\text{-}building\text{-}a\text{-}nest\text{-}up\text{-}there}(z)])$

"the squirrel that has got into the attic or bird that is building a nest up there"

One problem for description-based theories in general are sentences such as (32a), reproduced below:

(48) When it became clear that Romney or Santorum would become the Republican nominee, {they / *he} received a lot of attention.

Consider what descriptive content might be ascribed to the pronouns:

(49) a. ... [the individual that would become the Republican nominee] received a lot of attention

b. ... [the individuals that would become the Republican nominee] received a lot of attention

The descriptive content of the singular pronoun in (49a) is interpretable and might be true with current knowledge (if Romney did indeed get a lot of attention). Yet such an anaphoric relation is unavailable. In the plural case, the descriptive content for *they* in (49b) is non-interpretable (or false) because only one person became the Republican nominee, not two. Yet such an anaphoric relation is available. It seems that some modal changes are required, but this is not straightforward: changing *would* to *might* might work in (49b), but not for (49a).

Peculiarly, Simons (2000) claims that "[in] cases in which one or both indefinites are replaced by proper names [...] the pronoun cannot be given a disjunctive E-type interpretation" (p. 184), citing the following example:

(50) Either Jane or Maud will sing. #She'll perform Mozart. (Simons 2000:184)

Simons also claims that her theory is superior over others (such as DRT and Stone 1992) because they fail to distinguish between proper names and indefinites (see her section 5.7). However, although it seems true that there is a difference between proper names and indefi-

nites in modal contexts, as in (51), it does not hold as a general statement (cf. my footnote 1 on page 1).

(51) a. The department is looking for a phonologist or a phonetician. He must have an excellent academic record.

b. The department is looking for John or Bill. #He must have an excellent record.

3.3 D-type approach (Elbourne 2005)

Elbourne (2005) develops a description-theoretic approach for donkey pronouns. In his theory, the connection between (donkey) pronouns and descriptions is more explicit than in ETA, in that the connection is in fact syntactically represented.

Consider the classic donkey sentence (52):

(52) Every farmer who owns a donkey, beats it.

The basic idea of Elbourne's theory is that a pronoun like 'it' in (52) has the same semantics as the definite determiner 'the'. Furthermore, 'it' has an NP-argument (as determiners do) that has been phonologically deleted (NP-deletion). The LF of (52) is thus as in (53), where [it ~~donkey~~] has the same semantics as 'the donkey':

(53) Every farmer who owns a donkey, beats [it donkey].

There is a requirement that the NP-deletion need a linguistic antecedent, i.e. the NP should be present in the linguistic context. This correctly excludes sentences like (54), where 'it' is supposed to refer to the guitar:

(54) *?Some guitarist should bring it. (from Elbourne 2005:64)

In (54) the NP-deletion [it ~~guitar~~] is not possible, because 'guitar' is not explicitly present in the sentence.

Elbourne (2005, section 2.7.2) admits that SA-sentences are, at first sight, problematic for his theory of NP-deletion. For example, consider the example discussed by Elbourne, (55), cited below:

(55) If Mary sees a donkey or a horse, she waves to it.

We would like 'it' to correspond with the description 'the donkey or horse', but the phrase 'donkey or horse' is not explicitly present in the sentence, hence the NP-deletion [it ~~donkey or horse~~] unavailable.

SA-sentences which contain proper names pose an additional problem. Elbourne uses Stone's example (37), repeated below as (56), as an example:

(56) If Mary sees John or Bill, she waves to him.

In (56) the NP-deletion [him ~~John or Bill~~] is not possible because, first, in English proper names do not take determiners. Second, even if one would ignore the determiner, as in (57), it would not capture the correct meaning of (56).

(57) If Mary sees John or Bill, she waves to John or Bill.

Sentence (57) admits the reading in which Mary sees John, but waves to Bill.

For the first problem, in (55), Elbourne proposes to extend the notion of NP-deletion somewhat. Considering similar VP-ellipsis data, he assumes that an NP-disjunction 'donkey or horse' is reconstruced in stages: each of the parts – the two disjuncts and the the

disjunction operator – is available and they are copied separately. Elbourne does not have an explanation for how this reconstruction process may proceed, but includes it nevertheless as a case of NP-deletion. My objection to Elbourne's program is that syntactic differences (both intra-linguistic and cross-linguistic) require ad-hoc adaptations to the theory, which is undesirable for a theory for *semantics*. Let us consider the Dutch equivalent of (55):

(58) Als Marie een ezel of een paard ziet, zwaait ze ernaar.
if Mary a donkey or a horse sees, waves she to.it
'If Mary finds sees a donkey or a horse, she waves to it.'

The problem is that the pronoun here cannot simply be a description of the form 'determiner + NP-disjunction', but takes the form of a DP-disjunction:

(59) a. *...zwaait ze naar [de / het ezel of paard].
...waves she to the.M / the.NEUT donkey or horse

b. ...zwaait ze naar [**de** ezel of **het** paard].
...waves she to the.M donkey or the.NEUT horse

Dutch differs in two respects from English here: first, *ezel* 'donkey' and *paard* 'horse' have different grammatical genders, and require different determiners; and, second, Dutch in general prefers full DP-disjunction (with two determiners, as in (59b)) above determiner + NP-disjunction (as in (59a)). A full DP-disjunction is not of the form [Det ~~NP~~], and hence does not fit in Elbourne's theory of NP-deletion.

As regards their semantics, sentences (55) and (58) seem to be fully parallel. Therefore one would want a theory of semantics to account for both of them in the same way.

However, Elbourne's (2005) theory is sensitive to syntactic differences between English and Dutch, even though they seem irrelevant to the semantics of the sentences in question. Presumably, a case like (59) can be solved by further expanding the notion of NP-deletion, or by positing some syntactic rule that distributes the determiner over the disjunction; but the problem is that this approach quickly disturbs, as Elbourne himself puts it, the "very fine balance" that is required to solve the "problem of how to constrain the descriptive content of D-type pronouns" (p. 85).

Finally, let me summarize Elbourne's view on the second, more difficult problem in (56). To explain why an NP-deletion [him ~~John or Bill~~] is possible, despite English morphology, Elbourne adduces independent evidence that proper names in English act as predicates, thus taking determiners (covertly). Other languages, like German and Greek, are known to do this overtly (e.g. *der Hans*, 'the Hans'). Elbourne now claims that (55) and (56) are similar cases in that "in one case we have 'waves to the donkey or horse,' [and] in the other case we have 'waves to the (person) identical with John or (person) identical with Bill.' " (2005:88). However this independent evidence may be assessed, there is an additional problem for cases which combine indefinites and proper names, for example (60):[9]

(60) If Mary sees John or a celebrity, she waves to him.

Clearly, the description 'waves to the (person) identical with John or celebrity' is not possible. Again, a DP-disjunction seems to work better, in this case something like 'waves to John or

[9]The following example from an Internet forum shows the actual occurrence of such mixed sentences:

(i) I would not make a big deal out of seeing the President or a celebrity and would not confront/talk to him/her.

Shortened URL `http://goo.gl/4E7i5`. Accessed Nov 18, 2012.

the celebrity'.

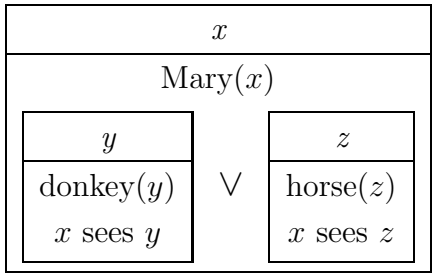
3.4 Discourse Representation Theory (Kamp and Reyle 1993)

Kamp and Reyle (1993) only mention SA briefly (pp. 204-6). Let me use (55) as an example, repeated below.

(55) If Mary sees a donkey or a horse, she waves to it.

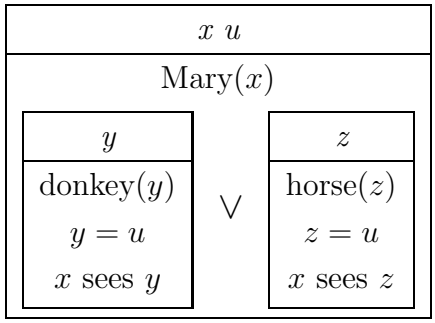
According to Kamp and Reyle (1993:204), the DRS of the antecedent of the conditional in (55) would look like (61):

(61)



It is clear that subsequent anaphora to the split antecedent is not possible, because the donkey and the horse correspond to different discourse referents. An additional discourse referent is needed, which is equated to the donkey or the horse. Kamp and Reyle suggest that the desired DRS looks like (62):

(62)



Then the antecedent of the pronoun can be identified with u. Kamp and Reyle (1993) leave the problem of a translation rule capable of turning (61) into (62) as "a topic of further investigation" (p. 206).

Kamp and Reyle do not discuss anaphora to split antecedents when occurring in the subject position of a clause. On the other hand, they do have different representations for split antecedents in subject and object positions (cf. their example (2.135)). Let me take (63) as an example:

(63) A professor or an assistant professor will open the conference.

According to Kamp and Reyle's (1993) rules, its DRS would look like (64):

(64)

$x\ y\ z$
conference(x)
professor(y)
assistant-professor(z)
y opens x $\bigvee$ z opens x

Here the disjuncts are in the main DRS, not in the disjunctive condition. For subsequent anaphora, a similar strategy could be employed as the one used in (62):

(65)

$x\ y\ z\ w$
conference(x)
professor(y)
assistant-professor(z)
y opens x, $y = w$ $\bigvee$ z opens x, $z = w$

That means, however, that a second, different rule would be required to deal with split antecedents in subject positions, which seems undesirable.

An option that is not discussed in Kamp and Reyle (1993) is proffered by Rooth and Partee (1982), who suggest a DRT-style solution in favor of their generalized disjunction account discussed in section 2.2. The basic idea is that a disjunctive clause introduces a single discourse referent, that is provided with a disjunctive condition. The DRS in (61) would then alternatively be represented along the lines of (66):

(66)

$x\ y$
$\text{Mary}(x)$
$[\lambda z.\ \text{donkey}(z) \vee \text{horse}(z)](y)$
x sees y

Although a construction rule for DP disjunction can be straightforwardly formulated to incorporate this proposal, the problem is that the two indefinites in the disjuncts no longer have their own discourse referent. In her discussion of Rooth and Partee's proposal, Simons (2000) says that this "violation of the standard rule in DRT [...] is to be licensed by the rule for the translation of the disjunction itself" (p. 225). I would like to add, however, that the already discussed case in which the sum of two disjuncts is referred to by a plural pronoun (see (43)=(32a)) requires the availability of both discourse referents for summation. Hence, the "violation" that Simons speaks about is still problematic. The second problem that Simons (2000) mentions is that Rooth and Partee's proposal does not work for clausal disjunction, as in (45b), repeated below:

(67) Either a squirrel has got into the attic or a bird is building a nest up there. We have to get it out.

Indeed, it is difficult to see how a construction rule would work for such a case.

4 Dynamic Predicate Logic and variable complexes

In this section I will discuss the framework of Dynamic Predicate Logic and argue that the account for anaphora to split antecedents Groenendijk and Stokhof (1991) propose for this framework is technically flawed. I will propose an alternative account by the introduction of *variable complexes*, which will be described in section 4.2, together with some required technical background on DPL. Finally, the proposal will be worked out formally in section 4.3.

4.1 Background

Dynamic Predicate Logic (DPL), developed in Groenendijk and Stokhof (1991) (henceforth G&S), was designed as a compositional theory of discourse semantics. Compositionality issues arise in both cross-sentential anaphora and donkey anaphora:

(68) a. A man walks in the park. He whistles. (G&S, p. 41)

$\exists x.(\mathsf{man}(x) \wedge \mathsf{walk}(x) \wedge \mathsf{whistle}(x))$

b. Every farmer who owns a donkey, beats it.

$\forall xy.\big((\mathsf{farmer}(x) \wedge \mathsf{donkey}(y) \wedge \mathsf{own}(x,y)) \rightarrow \mathsf{beat}(x,y)\big)$

The translation of (68a) is problematic with respect to compositionality, because the LF of the first sentence of (68a) does not occur as a subformula in the entire expression. The translation of (68b) breaches the principle of compositionality by representing the indefinite description *a donkey* with a universal quantifier (instead of the usual existential quantifier), which furthermore has wide scope over the relative clause.

Instead, in order to retain compositionality, we would like to translate (68a) and (68b) in the following way:

(69) a. $\exists x.(\mathsf{man}(x) \wedge \mathsf{walk}(x)) \wedge \mathsf{whistle}(x)$

b. $\forall x.\big((\mathsf{farmer}(x) \wedge \exists y.(\mathsf{donkey}(y) \wedge \mathsf{own}(x,y))) \rightarrow \mathsf{beat}(x,y)\big)$

Of course, in standard predicate logic, variables x in the second conjunct of (69a) and y in the consequent of the implication in (69b) are free, and cannot be bound by their respective quantifiers. Groenendijk and Stokhof set out to develop a variant of predicate logic – *dynamic* predicate logic – which allows variable bindings of the type desired in (69).

As its name suggests, DPL is a theory of dynamic semantics, which means that the meaning of a sentence is not determined by its truth conditions, but rather by the way it changes the information that the interpreter has while hearing the sentence. This information is contained in *information states* and a dynamic theory of meaning models the way sentences yield transitions from one information state to another. As it seems, 'information state' is a rather vague term, and it is difficult to model all (relevant) information an interpreter has. Therefore, the dynamic aspect of DPL (as it is for DRT) is limited to the behavior of anaphora as in the sentences given above. Formally, information states are modelled as *assignment functions*, assigning individuals to variables.

Dynamic connectives An important notion in the theory of DPL is that of *dynamic* connectives; connectives may be externally or internally dynamic depending on their ability to allow binding relations between their conjuncts, farther than in normal predicate logic is allowed (such as for conjunction in (69)). Informally, a binary connective is *internally*

dynamic if it can bind variables from one conjunct to another. It is *externally dynamic* if it can bind variables in conjuncts yet to come. To see how this dynamic binding works technically, and how dynamic connectives are represented in the DPL formalism, I will briefly review the most important aspects of DPL semantics.

In standard predicate logic (PL), the semantic value of a formula ϕ, written $[\![\phi]\!]$ is a set of assignment functions: the set of assignments that make ϕ true. In DPL, $[\![\phi]\!]^{DPL}$ denotes a set of *pairs* of assignment function, which captures the essential idea that formulas take an input information state and can output a different information state. This can be written using set notation (70a), or with infix notation (70b):

(70) a. '$[\![\phi]\!]^{DPL} = \{\langle g, h\rangle \mid \ldots\}$'

b. '$g[\![\phi]\!]^{DPL}h$ is true iff ...'

I will use set notation, following the original G&S paper, but the reader might find it insightful to translate to the infix notation, as this intuitively captures better the idea of formulas taking an input and an output.

When g, k are assignment functions and x a variable, the notation $g[x]k$ indicates that g and k are equal except possibly what they assign to x. Now, external staticity is being modeled as being a *test*. A formula is a test when its input and output assignment are always identical, and it only 'tests' if the assignment verifies ϕ. For example $\forall$ is externally static, which can be seen in the formula directly from the '$g = h$' condition:

$$[\![\forall x.\phi]\!]^{DPL} = \{\langle g, h\rangle \mid g = h \,\&\, \forall k : k[x]h \Longrightarrow \exists j : \langle k, j\rangle \in [\![\phi]\!]^{DPL}\}$$

A binary connective is internally dynamic if the output function of the first conjunct is used as input for the second conjunct. This is the case for $\wedge$ and $\longrightarrow$, but not for standard disjunction:

$$[\![\phi \wedge \psi]\!]^{DPL} = \{\langle g, h\rangle \mid \exists k : \langle g, k\rangle \in [\![\phi]\!]^{DPL} \,\&\, \langle k, h\rangle \in [\![\psi]\!]^{DPL}\};$$

$$[\![\phi \vee \psi]\!]^{DPL} = \{\langle g, h\rangle \mid g = h \,\&\, \exists k : (\langle h, k\rangle \in [\![\phi]\!]^{DPL} \vee \langle h, k\rangle \in [\![\psi]\!]^{DPL})\}.$$

In the semantics for dynamic $\wedge$, we see that k is an output assignment of $[\![\phi]\!]^{DPL}$ and an input assignment to $[\![\psi]\!]^{DPL}$. For disjunction no such assignment is available that is both input and output, reflecting that $\vee$ is considered internally static.

Although we have now seen how dynamic connectives are represented formally, the question whether or not a specific connective *is to be* represented as dynamic, is a purely empirical issue. G&S show data to corroborate their claims about why some connectives are dynamic and others are not, for instance the contrast in (71) is taken to show that $\exists$ is externally dynamic, but $\forall$ is not.

(71) a. A man walks in the park. He whistles.

b. Every man walks in the park. *He whistles.

Whereas all other connectives and quantifiers are accompanied with evidence to illustrate their dynamic status, standard disjunction is claimed to be internally and externally static without any data (G&S, p. 53; Jeroen Groenendijk, p.c.). In order to assess this situation, it would be desirable not only to have a formal implementation of dynamic connectives (as discussed above), but also to have a more precise 'empirical' definition of dynamic connec-

tives, i.e. which data show conclusively that a connective is or is not dynamic. Groenendijk and Stokhof are not explicit about this, but I have attempted to deduce such a definition from what G&S say about various connectives and the corresponding data they present:

(72) A (binary) connective $\star$ is called *internally dynamic* if the following variable binding can be made:

$$\exists x.\underbrace{[A(x)] \star B(x)}.$$

(73) A (binary) connective $\star$ is called *externally dynamic* if the following variable binding can be made:

$$\underbrace{\big(\exists x.[A(x)] \star B(x)\big) \wedge C(x)}$$

Given these definitions, data along the lines of (74) should be suitable to gain insight into the dynamic behavior of disjunction:

(74) a. A man walks in the park. Or he whistles.

b. Either a man walks in the park, or he whistles.

The problem here is that such sentences are most likely to be read as 'A man is such that he either walks in the park or he whistles', that is as (75a) rather than (75b) (which is required in view of (72)):

(75) a. $\exists x.[\mathsf{man}(x) \wedge (\mathsf{walk}(x) \vee \mathsf{whistle}(x))]$

b. $\exists x.[\mathsf{man}(x) \wedge \mathsf{walk}(x)] \vee \mathsf{whistle}(x)$

Presumably, the difficulty in reading (74) in the intended way is taken to be sufficient evidence that this reading does not exist.[10] Such a line of argumentation is quite different from other cases though, in which it is clear that the sentences are ungrammatical in the intended interpretation. Besides these issues with standard (static) disjunction, G&S posit two more (dynamic) types of disjunction. First, a fully dynamic type of disjunction is supposed to account for bathroom sentences (G&S, p. 92). Second, 'program disjunction' (denoted $\cup$) is introduced as an internally static but externally dynamic type of disjunction to account for sentences with split antecedents (discussed in more detail below). The table in (76) summarizes the dynamic behavior of connectives and quantifiers, as assumed by G&S.

(76) *Dynamic behavior of connectives and quantifiers according to Groenendijk and Stokhof*

	internally dynamic	externally dynamic
$\forall$	✓	✗
$\exists$	✓	✓
$\neg$	✓	✗
$\wedge$	✓	✓
$\rightarrow$	✓	✗
$\vee$	✗	✗
$\cup$	✗	✓
$\vee_3$	✓	✓

(where $\vee_3$ indicates the disjunction introduced for bathroom sentences)

[10] Kamp and Reyle (1993:186-7) present some data that bear on internal dynamicity of disjunction. They show that judgments are quite subtle in various contexts:

(i) a. *Bill owns it$_i$ or Fred owns a Porsche$_i$.

b. ??Bill owns a Porsche$_i$ or Fred owns it$_i$.

c. ?Jones has borrowed a bicycle$_i$ or he has rented it$_i$.

d. Jones has borrowed a bicycle$_i$, or perhaps he has rented it$_i$.

Groenendijk and Stokhof's program disjunction In order to deal with SA-sentences a new connective, program disjunction (denoted $\cup$), is introduced, which is considered to be externally dynamic (G&S:88). The semantics of program disjunction is straightforward:

(77) $[\![\phi \cup \psi]\!] = [\![\phi]\!] \cup [\![\psi]\!]$

The following SA-sentence is used as an example by Groenendijk and Stokhof:

(78) A professor or an assistant professor will attend the meeting of the university board. He will report to the faculty.

I will raise two objections against the use of program disjunction for SA-sentences as intended by Groenendijk and Stokhof. My first objection regards the representation of a sentence like (78), claimed to have the following form:

(79) $[\exists x.P(x) \cup \exists x.Q(x)] \wedge H(x)$

Here, P, Q and H stand for the predicates 'professor', 'assistant professor' and 'report to the faculty', respectively. Crucially, the variable x in the second conjunct is supposed to be bound by both quantifiers in the first conjunct. This seems not possible, because it is in contradiction with claims Groenendijk and Stokhof themselves have made earlier: "[o]nly existential quantifiers can have active occurrences, and for any formula, *only one* occurrence of a quantifier in that formula can be active" (p. 59, my emphasis). In (79) however, there are two active quantifiers for the variable x.

My second objection against program disjunction concerns the dynamic qualification it has been given by Groenendijk and Stokhof: unlike all other connectives, it is said to be internally static, but externally dynamic. How can a connective pass on variable bindings

to disjuncts yet to come, but not from its left disjunct to its right disjunct? Assuming for the moment that Groenendijk and Stokhof are right, the definitions of binding pairs (**bp**), active quantifier occurrences (**aq**) and free variables (**fv**) for $\cup$ should reflect this possibility (see G&S:58ff. for discussion of these notions). I come to the following:

(80) Program disjunction

$$\mathbf{bp}(\phi \cup \psi) = \mathbf{bp}(\phi) \cup \mathbf{bp}(\psi)$$

$$\mathbf{aq}(\phi \cup \psi) = \mathbf{aq}(\phi) \cup \mathbf{aq}(\psi)$$

$$\mathbf{fv}(\phi \cup \psi) = \mathbf{fv}(\phi) \cup \mathbf{fv}(\psi)$$

This seems obvious, but it is quite subtle. The first and third line reflect that $\cup$ is internally static: there are no additional binding pairs between the disjuncts. These lines are the same for the corresponding definitions for static $\vee$ (G&S:59). The second line expresses external dynamicity. However, this crucially differs from the other externally dynamic connective, conjunction:

(81) $\mathbf{aq}(\phi \wedge \psi) = \mathbf{aq}(\psi) \cup \{\exists x \in \mathbf{aq}(\phi) \mid \exists x \notin \mathbf{aq}(\psi)\}$ (G&S:58)

The second clause in (81) is just there to disallow double binding of the sort that is supposed to be possible for program disjunction.

It is easy to give an example in which there is an anaphoric relation between two disjuncts, suggesting that program disjunction should be internally dynamic as well:

(82) Mary or a colleague she works with on the project, will attend the meeting of the university board. She will report to the faculty.

In this example there is some binding between a variable x in the second disjunct and a quantifier in the first disjunct. Because of the close similarity between (78) and (82), it would be undesirable to say that they contain different connectives.

4.2 Variable complexes

Although a comprehensive approach to the problem of SA, including the ambiguities discussed in section 2, would require an intensional language, I will consider Groenendijk and Stokhof's (1991) original treatment of the problem, as discussed in section 4.1. DPL is an extensional first-order language, as opposed to Dynamic Montague Grammar (DMG; Groenendijk and Stokhof 1990) which combines classic Montague grammar (1973) with dynamic semantics (G&S 1991:90 discuss some of the differences between DPL and DMG).

In order to avoid the problematic translation in (79) with program disjunction, I propose a different solution. Instead of introducing a new type of disjunction, I add some structure to the pronoun. I propose that pronouns with disjunctive antecedents are in fact *variable complexes*, consisting of two variables. The basic representation would then be $[\exists x.P(x) \vee \exists y.Q(y)] \wedge H(x \otimes y)$. Here, $x \otimes y$ is a variable complex formed from x and y, and it can be bound by the quantifiers $\exists x$ and $\exists y$, as is depicted schematically in (83):

(83) $(\exists x.P(x) \vee \exists y.Q(y)) \qquad (x \otimes y)$

I use the notation $\otimes$ to distinguish variable complexes from ordinary disjunction between formulas. Let me first give translations of some familiar sentences using $\otimes$:

(84) a. If Mary sees a donkey or a horse, she waves to it.

$\exists x.(x = \mathsf{m} \wedge [\exists y.(\mathsf{donkey}(y) \wedge \mathsf{see}(x,y)) \vee \exists z.(\mathsf{horse}(z) \wedge \mathsf{see}(x,z))] \rightarrow \mathsf{wave}(x, y \otimes z)$

b. A professor or an assistant professor will attend the meeting of the university board. He will report to the faculty.

$[\exists x.(\mathsf{professor}(x) \wedge \mathsf{attend}(x)) \vee \exists y.(\mathsf{assistant\text{-}professor}(y) \wedge \mathsf{attend}(y))] \wedge \mathsf{report}(x \otimes y)$

c. If Mary catches a fish, or John traps a rabbit, Bill will cook it.

$\exists xy.(x = \mathsf{m} \wedge y = \mathsf{j} \wedge [\exists w.(\mathsf{fish}(w) \wedge \mathsf{catch}(x, w)) \vee \exists z.(\mathsf{rabbit}(z) \wedge \mathsf{trap}(y, z))]) \rightarrow$

$\exists u.(u = \mathsf{b} \wedge \mathsf{cook}(u, w \otimes z))$

To see how the binding, represented informally in (83), should be implemented technically, let us first consider how binding works exactly in DPL. Recall that in standard PL, the semantics of existential quantification is given as $[\![\exists x.\phi]\!] = \{g \mid \exists k : g[x]k \,\&\, k \in [\![\phi]\!]\}$. Instead of quantification over assignment functions, we can also use the notation $g[d/x]$ for the function that is equal to g, except that $g(x) = d$:

$[\![\exists x.\phi]\!]^g$ is true iff there is some $d \in D$ such that $[\![\phi]\!]^{g[d/x]}$ is true.

This expresses that an assignment g satisfies $\exists x.\phi$ iff there is some individual d in the domain D such that $g[d/x]$ satisfies ϕ. In DPL, these functions $g[d/x]$ are taken as input function for $[\![\phi]\!]^{DPL}$:

$[\![\exists x.\phi]\!]^{DPL} = \{\langle g, h\rangle \mid \exists k : k[x]g \,\&\, \langle k, h\rangle \in [\![\phi]\!]^{DPL}\}$, or equivalently:

$g[\![\exists x.\phi]\!]^{DPL}h$ iff for some $d \in D$, $g[d/x][\![\phi]\!]^{DPL}h$

Hence the reason that x is available for binding outside the syntactic scope of $\exists$ (i.e. that $\exists$ is externally dynamic), is due to the fact that this d is 'preserved' and given to $[\![\phi]\!]^{DPL}$ (if ϕ

is a test $h(x) = k(x) = d$, and in general $d \neq g(x)$).

We would like the binding of variable complexes to proceed in the same way as that of ordinary variables just described. A difference with ordinary variables is that where ordinary variables x are available for binding after $\exists x$, we only want variable complexes $x \otimes y$ to be available for binding after a clause of the form '$\exists x.\phi \vee \exists y.\psi$'.[11] Hence, as will be spelled out in detail in section 4.3, the main parts of the technical implementation of (83) consist of extending the domain of assignment functions to include variable complexes (so that $g(x \otimes y)$ is defined), and giving the appropriate semantics to $[\![\exists x.\phi \vee \exists y.\psi]\!]$ in such a way that $x \otimes y$ is 'preserved' for further binding in the sense discussed above for ordinary variables.

4.3 DPL$^{\otimes}$

DPL$^{\otimes}$ is an extension of standard DPL by adding a set of variable complexes to the syntax of the language, and adding corresponding rules to the semantics.

Vocabulary The vocabulary of DPL$^{\otimes}$ is that of DPL extended by a set of variable complexes. To avoid confusion, we will refer to the standard (D)PL variables (written x, y, z) as 'ordinary' or 'simple variables'. A syntactic rule is added to DPL$^{\otimes}$ to form variable complexes out of two simple variables. A variable complex $x \otimes y$ is a variable in the sense that it can occur inside a predicate just like simple variables, but it is more than a simple variable in the sense that it can be bound by two quantifiers. Formally, the vocabulary consists of a set of individual constants Con, a set of simple variables Var, for each $n \in \mathbb{N}$ a set of n-place predicates $Pred_n$, and a set of variable complexes $Var^{\otimes} := \{x \otimes y \mid x, y \in Var\}$. This means

[11] Since the issue about disjunction ($\vee$, $\cup$, $\vee_3$) is not settled, I am using $\vee$ in an informal way here.

that variable complexes are non-commutative ($x \circledcirc y \neq y \circledcirc x$), and variable complexes cannot be 'nested' ($(x \circledcirc y) \circledcirc z \notin Var^{\circledcirc}$).

Syntax The syntax of DPL$^{\circledcirc}$ is as follows:

- a term is a member of $Con \cup Var \cup Var^{\circledcirc}$;
- for any n, if $t_1, \ldots, t_n$ are terms, and P is an n-place predicate, $Pt_1 \ldots t_n$ is a formula;
- if t_1 and t_2 are terms, $t_1 = t_2$ is a formula;
- if ϕ and ψ are formulas, $\neg\phi, \phi \wedge \psi, \phi \vee \psi$ and $\phi \rightarrow \psi$ are formulas;
- if ϕ is a formula, and x is a simple variable, $\exists x.\phi$ and $\forall x.\phi$ are formulas.[12]

Models A model of DPL$^{\circledcirc}$ is a model of DPL. In other words, a DPL$^{\circledcirc}$ model M is a pair $\langle D, F \rangle$ where D is a non-empty set of individuals, and F a (simple) interpretation function, which can be formally described as $F = F_1 \cup \{F_{2,n}\}_{n \in \mathbb{N}}$, where $F_1 : Con \rightarrow D$ and $F_{2,n} : Pred_n \rightarrow \mathscr{P}(D^n)$.

Assignment functions Assignment functions in DPL$^{\circledcirc}$ are assignment functions of DPL with their domain extended to $Var^{\circledcirc}$, and supplied with a disjunctive condition. Formally, an assignment function g in DPL$^{\circledcirc}$ is a function from $Var \cup Var^{\circledcirc}$ to D, such that either $g(x \circledcirc y) = g(x)$ or $g(x \circledcirc y) = g(y)$ holds for all $x \circledcirc y \in Var^{\circledcirc}$. The set of all such assignment functions is written $G^{\circledcirc}$. For each assignment function $g \in G^{\circledcirc}$, the interpretation of a term

[12] This definition excludes $\exists(x \circledcirc y)\phi$ and $\forall(x \circledcirc y)\phi$ as well-formed formulas, because I do not see a meaningful application for them for our current purposes. However the semantics may well be extended to include such expressions.

t is defined as follows:

$$[\![t]\!]^{\circledcirc}_g := \begin{cases} g(t) & \text{if } t \in Var \cup Var^{\circledcirc}; \\ F(t) & \text{if } t \in Con. \end{cases}$$

Semantics The interpretation function of DPL$^{\circledcirc}$ is $[\![\ ]\!]^{\mathrm{DPL}^{\circledcirc}}_M \subseteq G^{\circledcirc} \times G^{\circledcirc}$, abbreviated as $[\![\ ]\!]^{\circledcirc}$. Most formulas have the same semantics as in DPL:

$$[\![Pt_1 \dots t_n]\!]^{\circledcirc} = \{\langle g, h\rangle \mid g = h \,\&\, \langle [\![t_1]\!]^{\circledcirc}_h \dots [\![t_n]\!]^{\circledcirc}_h\rangle \in F(P)\}$$

$$[\![t_1 = t_2]\!]^{\circledcirc} = \{\langle g, h\rangle \mid g = h \,\&\, [\![t_1]\!]^{\circledcirc}_h = [\![t_2]\!]^{\circledcirc}_h\}$$

$$[\![\neg\phi]\!]^{\circledcirc} = \{\langle g, h\rangle \mid g = h \,\&\, \neg\exists k.[\langle h, k\rangle \in [\![\phi]\!]^{\circledcirc}]\}$$

$$[\![\phi \wedge \psi]\!]^{\circledcirc} = \{\langle g, h\rangle \mid \exists k.[\langle g, k\rangle \in [\![\phi]\!]^{\circledcirc} \,\&\, \langle k, h\rangle \in [\![\psi]\!]^{\circledcirc}]\}$$

$$[\![\phi \to \psi]\!]^{\circledcirc} = \{\langle g, h\rangle \mid g = h \,\&\, \forall k.[\langle h, k\rangle \in [\![\phi]\!]^{\circledcirc} \Rightarrow \exists j.[\langle k, j\rangle \in [\![\psi]\!]^{\circledcirc}]]\}$$

$$[\![\forall x\phi]\!]^{\circledcirc} = \{\langle g, h\rangle \mid g = h \,\&\, \forall k.[k[x]h \Rightarrow \exists j.[\langle k, j\rangle \in [\![\phi]\!]^{\circledcirc}]\}$$

$$[\![\exists x\phi]\!]^{\circledcirc} = \{\langle g, h\rangle \mid \exists k.[k[x]g \,\&\, \langle k, h\rangle \in [\![\phi]\!]^{\circledcirc}]\}$$

The crucial addition to DPL$^{\circledcirc}$ is the semantics of disjunction. As explained in the previous section, we would like a clause of the form '$\exists x.\phi \vee \exists y.\psi$' to set up the variable complex $x \circledcirc y$ for future binding. The following definition sets up the value for $h(x \circledcirc y)$ to be either $h(x)$ or $h(y)$ corresponding to which disjunct has an output function. More precisely, if there is an x that makes ϕ true, then an output function for the disjunctive clause is an output function h for $[\![\phi]\!]$ such that $h(x \circledcirc y)$ has the value $h(x)$; alternatively, if there is a y that makes ψ true, an output function for the disjunctive clause is an output function h for $[\![\psi]\!]$ such that $h(x \circledcirc y)$ takes the value $h(y)$. This is formalized in the following definition:

(85) $[\![\exists x.\phi \vee \exists y.\psi]\!]^{\Diamond} = \{\langle g,h\rangle \mid \Big(\exists k : k[x]g \,\&\, \langle k,h\rangle \in [\![\phi]\!] \,\&\, h(x \Diamond y) = h(x)\Big) \vee \Big(\exists \ell : \ell[y]g \,\&\, \langle \ell,h\rangle \in [\![\psi]\!] \,\&\, h(x \Diamond y) = h(y)\Big)\}$

Before I illustrate this with an example, two important remarks are in order. First, the definition in (85) is *dynamic*, in the sense that output functions of the entire clause are output functions of $[\![\phi]\!]$ or $[\![\psi]\!]$ (with our special condition on variable complexes). However, one can just as well formulate a static variant, in which the input and output functions are the same except for variable complexes (i.e. $g|_{Var} = h|_{Var}$), and just test whether they satisfy $[\![\phi]\!]$ or $[\![\psi]\!]$. This gives us a different view on dynamic connectives. Since $\Diamond$ is not a connective but a syntactic construct, it makes no sense to talk about the dynamicity of $\Diamond$. However, we may now revise the term 'internally dynamic' to 'internally dynamic w.r.t. simple variables' and 'internally dynamic w.r.t. variable complexes', etc. In these terms, the number of disjunctions can be decreased, since each disjunction can have a different dynamic behavior for variables and variable complexes. Although the empirical issues on the dynamic behavior of disjunction are not definitive (as discussed in section 4.2), I will maintain the dynamic version in (85), noting that a static version may be introduced alongside. Empirical data that argue in favor of this position include data such as (43) on page 28 (not discussed in G&S) in which the disjuncts are available for plural anaphora, and the so-called cases of 'single-antecedent anaphora' in which a pronoun refers back to only one disjunct in a clause.[13]

A second remark concerns the compositional nature of the system proposed here. Having

[13]Terminology from Simons (2000). An example of single-antecedent anaphora is the following:
(i) John or Mary will perform tonight. SHE is a great pianist, but HE is just a beginner.

a separate semantic rule for $[\![\exists x.\phi \vee \exists y.\psi]\!]^{\oslash}$ is a less elegant treatment than having a system in which the semantic value of such a clause would follow from its parts. However, I do not see any easy way of achieving this, which is mostly due to the complicated role $\exists x$ would play in such a system (whether or not it modifes variable complexes would depend on the context in which it appears). I have not provided a general disjunction rule $[\![\phi \vee \psi]\!]^{\oslash}$, which would take lower priority than (85), mainly for reasons – described above – that have to do with the difficult dynamic nature of disjunction. I would like to mention here that even if one assumes, with Groenendijk and Stokhof, that both a fully static and a fully dynamic disjunction are required to account for all data, the richer notion of dynamicity in DPL$^{\oslash}$ means we can renounce G&S's 'program disjunction' that was only needed for SA sentences.

Example calculation In order to concretely illustrate the working of variable complexes in DPL$^{\oslash}$, let me give a sample calculation for sentence (84b), repeated below, with predicate names abbreviated:

(86) $[\exists x.(\mathsf{p}(x) \wedge \mathsf{a}(x)) \vee \exists y.(\mathsf{ap}(y) \wedge \mathsf{a}(y))] \ \wedge \mathsf{r}(x \oslash y)$

Assume that John is a professor, Bill is assistant professor, and only Bill will attend the meeting and report to the faculty:

(87) $F(\mathsf{p}) = \{\mathsf{j}\}, F(\mathsf{ap}) = F(\mathsf{a}) = F(\mathsf{r}) = \{\mathsf{b}\}$

Then the computation proceeds as follows:

$$
\begin{aligned}
&[\![[\exists x.(\mathsf{p}(x) \wedge \mathsf{a}(x)) \vee \exists y.(\mathsf{ap}(y) \wedge \mathsf{a}(y))] \ \wedge \mathsf{r}(x \otimes y)]\!] \\
&= \{\langle g, h\rangle \mid \exists k : \langle g, k\rangle \in [\![\exists x.(\mathsf{p}(x) \wedge \mathsf{a}(x)) \vee \exists y.(\mathsf{ap}(y) \wedge \mathsf{a}(y))]\!] \,\&\, \langle k, h\rangle \in [\![\mathsf{r}(x \otimes y)]\!]\} \\
&= \{\langle g, h\rangle \mid \exists k : \Big(\exists \ell : \ell[x]g \,\&\, \langle \ell, k\rangle \in [\![\mathsf{p}(x) \wedge \mathsf{a}(x)]\!] \,\&\, k(x \otimes y) = k(x)\Big) \vee \\
&\qquad \Big(\exists m : m[y]g \,\&\, \langle m, k\rangle \in [\![\mathsf{ap}(y) \wedge \mathsf{a}(y)]\!] \,\&\, k(x \otimes y) = k(y)\Big) \,\& \\
&\qquad\qquad\qquad\qquad\qquad\qquad k = h \,\&\, [\![x \otimes y]\!]_h \in F(\mathsf{r})\} \\
&= \{\langle g, h\rangle \mid \Big(h[x]g \,\&\, [\![x]\!]_h \in F(\mathsf{p}) \,\&\, [\![x]\!]_h \in F(\mathsf{a}) \,\&\, h(x \otimes y) = h(x)\Big) \vee \\
&\qquad \Big(h[y]g \,\&\, [\![y]\!]_h \in F(\mathsf{ap}) \,\&\, [\![y]\!]_h \in F(\mathsf{a}) \,\&\, h(x \otimes y) = h(y)\Big) \,\&\, [\![x \otimes y]\!]_h \in F(\mathsf{r})\}.
\end{aligned}
$$

Now filling in from (87), we get:

$$
\begin{aligned}
&= \{\langle g, h\rangle \mid \Big(h[x]g \,\&\, h(x) = \mathsf{j} \,\&\, h(x) = \mathsf{b} \,\&\, h(x \otimes y) = h(x)\Big) \vee \\
&\qquad \Big(h[y]g \,\&\, h(y) = \mathsf{b} \,\&\, h(y) = \mathsf{b} \,\&\, h(x \otimes y) = h(y)\Big) \,\&\, h(x \otimes y) = \mathsf{b}\} \\
&= \{\langle g, h\rangle \mid h[y]g \,\&\, h(y) = \mathsf{b} \,\&\, h(y) = \mathsf{b} \,\&\, h(x \otimes y) = h(y) \,\&\, h(x \otimes y) = \mathsf{b}\}.
\end{aligned}
$$

As desired, $h(x \otimes y) = \mathsf{b}$, since Bill verifies the second disjunct. It follows that Bill reports to the faculty.

Concluding reflections The approach to the binding of split antecedents proposed here has a number of advantages over earlier solutions, as described in section 3. Although the idea of variable complexes was directly inspired by the way Groenendijk and Stokhof (1991) attempted to deal with split antecedents, and the proposal has been worked out here in DPL

semantics, I would like to stress that the idea of variable complexes in general is not in any way particular to DPL. Any theory that models pronominal binding by the binding between a quantifier and a variable in LF can in principle implement the syntactic construct of a variable complex as well as an appropriate semantic rule.[14]

Having made this point and returning to the DPL treatment pursued here, we find that we can use the familiar first-order language to account for sentences with split antecedents. The additions made to the DPL semantics are intuitively clear and technically relatively straightforward. In our analysis there is no longer the need to introduce an additional disjunctive connective to the language, such as program disjunction in DPL. Although the $\otimes$-construct makes the syntax more complicated, I would like to argue that this innovation is more justified than the addition of a connective. The standard way of treating plural pronouns is by representing them by a special type of plural variable. For instance in Ogata's (2002) treatment of plurals in DPL, plural variables are written in capital letters, and are treated as Linkian sums (e.g. $x \epsilon X$ indicates that x is part of the sum X; see also van der Berg 1996 for a different DPL implementation, and Kamp and Reyle 1993, chapter 4 for DRT). Similarly, in the case of anaphora to a disjunctive clause, the pronoun refers to a 'special' antecedent and hence is denoted by a special variable.

Unlike many other approaches, the current proposal assigns extra structure to the pronoun, not to the antecedent. With taking note of the discussion above about the complicated dynamic nature of disjunction, this avoids some problems discussed in section 3, such as that the discourse referents for each of the disjuncts are no longer available for plural anaphora.

[14] In systems that do not treat indefinite descriptions as introducing existential quantifiers, such as DRT, one might want to explore the idea of translating a 'variable complex' in syntactic complexes of the relevant alternative in that system (e.g. discourse referents in the case of DRT).

For instance, I argued that this is problematic for the theory of Stone (section 3.1) and for DRT (section 3.4). In our proposal, though, any theory of plural anaphora can apply in the normal fashion.

5 Conclusion

In this concluding section, I would like to point to two directions for future work that I consider the most important for the issues discussed in this paper.

The two main questions I tried to answer in this paper, the ambiguities of disjunction in intensional contexts and the role of tense in anaphoric possiblities for disjunctive clauses on the one hand, and the formal treatment of pronominal anaphora to a disjunctive clause on the other hand are clearly related, but in the way I described them in this paper they have not been unified. Because DPL is an extensional theory, DP-disjunction in sentences such as (78) (page 45) is translated as clausal disjunction. An intensional theory that is capable of representing the scopal ambiguities of disjunction, and that also is sensitive to rhetorical structure relations and modal subordination does not seem to be available, and the question raises if such a complicated theory should be developed just to provide a unified account for the issues connected with anaphora to split antecedents. Finding a right balance between furthering our understanding on the two main questions of this paper in their own right, and attempting to understand how the two are related on a technical or theoretical level, I leave to further research.

Finally, I want to return to the case of disjunctive and plural pronouns introduced in section 1. My experiment indicated that both types of pronominal elements are used by

English speakers, but questions related to the nature of these pronouns made me focus on singular pronouns throughout the paper. As a direction for future work, let me return to them at this point, and see what challenges they present.

The cases in which a plural pronoun is used to refer to a disjunctive antecedent may be divided into three cases. The first, least problematic case, is the one in which the pronoun refers to the plural sum of both disjuncts, such as in sentences like (3b) as used in my experiment (discussed in section 1) and repeated below. As discussed earlier, here a standard account of plural anaphora will work. The other two cases are ones in which the plural pronoun really refers to the disjunctive clause itself (not to the summation of its disjuncts). We may want to distinguish between mixed-gender disjuncts (as in (88b)), and same-gender disjuncts (88c–d):

(88) a. The department's £5000 study grant will go to Anne or Mary. They applied well before the deadline.

b. I expect to see Mark or Linda at the party tonight. I will invite them to dinner.

c. The general will send out Frank or Harry to Afghanistan. They will join the troops in the Kandahar region.

d. %If I see John or Bill, I will wave to them.

For mixed-gender antecedents one could possibly appeal to the gender-neutral use of the plural pronoun (see section 1), given that one has a theory about this (as far as I know no formal theory has been put forward). Although not all speakers accept sentences like (88d), the experiment I conducted showed that at least in certain contexts a plural pronoun can be used to refer to a same-gender disjunctive clause (example (88c) is drawn from

my experiment; 50% of the participants judged that (only) the plural pronoun is adequate here, 25% said (only) the singular pronoun is adequate here, while 5% found both pronouns adequate). So both the variable judgments on (88c–d) and the question how to deal with them technically make this a difficult case: *they/them* can simply be translated by a variable complex, but the theory should explain under which conditions this happens and why it cannot always happen.

Similar remarks can be made for disjunctive pronouns: not all speakers seem to like these equally well, they may be used as gender-neutral pronouns, and more needs to be said about their behavior (recall (5) in section 1). In Tellings (2010a), I sketched the idea that disjunctive pronouns in fact fit the syntax of variable complexes, and suggested that normal singular pronouns with split antecedents are underlyingly represented as *he or he*, *she or she*, etc. which for phonological reasons we do not pronounce. This would give variable complexes a syntactic correlate. Although it is by no means clear if this idea would work for all the data, it may be worth pursuing in future work.

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