The Use and Resolution of Intersentential Pronominal Anaphora in Danish Discourse

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Summary

Pronouns occur very often in both texts and dialogues and the interpretation of intersentential pronominal anaphora with individual antecedents has therefore received a great deal of attention in the literature. However, most proposed computational approaches only account for pronouns in English written texts. Pronouns with abstract antecedents, which are very frequent in Danish, have seldom been dealt with. The aims of this thesis are to describe the use of Danish intersentential pronominal anaphors with both abstract and individual antecedents in naturally-occurring texts and dialogues, to propose a formal model of the factors influencing their resolution and to develop an algorithm for resolving them. In the thesis Danish intersentential pronominal anaphors are described on the basis of their occurrences in naturally-occurring corpora and descriptions in traditional grammars. Specific reference characteristics of the various types of Danish pronouns are emphasised and differences between their use and the use of English pronouns are discussed. Theoretical and applied approaches accounting for the use and/or resolution of intersentential anaphora in different traditions are then described and evaluated with respect to the Danish data. These studies comprise pragmatic theories of the use of referring expressions, studies of the information structure of utterances and theories accounting for the hierarchical structure of discourse. Computational approaches for the resolution of individual anaphora drawing on a number of the theories discussed are presented and studies of discourse deixis are outlined. The algorithms for anaphora resolution which were found most promising are tested and evaluated on Danish data, focusing on the phenomena that these algorithms do not account for. On the basis of an empirical study and a number of theoretical and applied approaches, i.a. (Sgall, Hajičová & Panevová 1986, Grosz, Joshi & Weinstein 1995, Kameyama 1996, Eckert & Strube 1999*a*) a strategy for resolving Danish intersentential anaphora in texts and dialogues is proposed. The proposed strategy is new because it accounts for both pronouns with individual and abstract antecedents in both dialogues and written texts. Furthermore it combines the Centering Model which identifies the salience of entities with their degree of givenness in the hearer's cognitive model with the Prague School's account where unknown entities in the focal part of an utterance have the highest degree of salience. In the main part of the thesis I first outline a generic NLP system which the proposed resolution algorithm is assumed to be part of. Then I summarise the main factors accounting for the previously recognised general tendencies in the resolution of Danish pronouns. I establish how these factors interact also on the basis of a survey of Danish pronominal uses and I formalise this interaction in a simplified model, implemented in the so-called DAR-algorithm. Finally I describe and evaluate a test of the proposed algorithm and compare it with other existing algorithms and approaches. The comparison indicates that the DAR-algorithm accounts for more phenomena and performs better on the data than other algorithms which it can be compared with.

Resumé

Pronominer forekommer meget hyppigt i hverdagssproget. Intersententiel pronominal resolution behandles tit i datalinguistiske studier, men disse omhandler ofte kun engelske pronominer med individuelle antecedenter i skrevne tekster. Imidlertid er pronominer der refererer til abstrakte objekter, særdeles hyppige på dansk, især i dialoger, og skal derfor kunne behandles i anvendte natursprogssystemer. Hovedformålene med denne afhandling er derfor: at beskrive brugen af danske intersententielle pronominale anaforer med abstrakt og individuel antecedent i såvel tekst som dialog; at præsentere en formel model der redegør for disse anaforers resolution, samt at foreslå en algoritme der implementerer denne model. Afhandlingen indledes med en fremstilling af intersententielle pronominer baseret på deres forekomster i forskellige typer tekster og dialoger og på beskrivelsen af disse anaforer i danske grammatikker. Særlige egenskaber ved forskellige typer pronominer og forskelle mellem brugen af pronominer på dansk og engelsk fremhæves. Dernæst beskrives teorier om brugen og resolutionen af pronominer fra forskellige fagområder og traditioner. Disse teorier evalueres i forhold til de tidligere beskrevne danske data og omfatter pragmatiske studier der modellerer brugen af anaforiske udtryk i forhold til diskursmodtagerens kognitive tilstand, informationsstukturteorier og teorier til modellering af diskursstrukturen. Herefter gennemgås teorier og algoritmer til behandling af individuelle og/eller abstrakte anaforer som delvis bygger på de diskuterede modeller og studier. Efterfølgende præsenteres afprøvning og evaluering af de mest lovende algoritmer på danske tekster og dialoger. På basis af de empiriske data og et antal af de fremhævede teorier og algoritmer, bl.a. (Sgall et al. 1986, Grosz et al. 1995, Kameyama 1996, Eckert & Strube 1999*a*) foreslår jeg en strategi for resolution af danske intersententielle pronominer i afhandlingens hoveddel. Strategien er ny fordi den behandler pronominer med både individuelle og abstrakte antecedenter i skrevne tekster og dialoger. Desuden kombinerer den Centering-baserede og informationsstruktur-baserede modeller af tilgængeligheden af diskursobjekter i modtagerens kognitive model. Disse modeller er ofte blevet betragtet som uforenelige. I denne del af afhandlingen, gennemgår jeg først arkitekturen af et generisk natursprogsbehandlingssystem som resolutionsalgoritmen er tænkt at være en integreret del af. Dernæst opsummerer jeg de præferencemekanismer der interagerer i resolutionen af danske anaforer og, også på baggrund af resultaterne af en empirisk undersøgelse, foreslår jeg en model for præference-interaktion. Denne model er grundstenen i den foreslåede DAR-algoritme der dernæst præsenteres. Herpå beskriver jeg afprøvningen af algoritmen på både tekster og dialoger og evaluerer afprøvningens resultater. Disse resultater er bedre end resultaterne fra afprøvning af andre sammenlignelige algoritmer på samme data. Desuden dækker DAR-algoritmen flere fænomener end andre algoritmer som den er blevet inspireret af og delvis bygger på.

Chapter 1

Introduction

1.1 Aims of the Research

The present research has been carried out as part of **The Staging of Virtual 3D-Spaces** project, funded by the Danish Research Councils. One of the aims of this project was to investigate the still unexploited interaction possibilities of multimodal systems. In the project researchers at the **Center for Sprogteknologi** had to examine how to achieve a more natural interaction between users and virtual agents than that provided by existing interactive systems.

In the beginning of the project flirting was chosen as an interaction mode for the agents. The project's dramatists provided dialogues between flirting people as possible interaction examples between a human and a system agent. The first dialogues were poetic and much more complex than those allowed in existing interactive systems. This complexity was due among other things to a large number of discourse deictics, i.e. pronouns referring to parts of the preceding discourse. After a while those dialogues were abandoned and "easier" dialogue prototypes were taken into consideration for the project. But my curiosity had been awakened. Pronouns occur very often in both texts and dialogues and the interpretation of intersentential pronouns with individual antecedents has also received great attention in the literature. However, most computational approaches have nearly exclusively been developed to deal with pronouns in English written texts. Some of these approaches have recently been adapted to and tested on a number of languages, but not Danish. This is strange given that the use of intersentential pronouns differs in Danish and English. Although discourse deixis is reported to be a frequent phenomenon in English, it has only rarely been dealt with in theoretical and applied approaches. In Danish discourse deictics seem to be even more frequent in everyday conversation and, if this is the case, they cannot be ignored in natural language processing systems.

Given these premises the main aims of my research have been to investigate and describe the use of intersentential pronouns referring to individual objects and discourse deictics in Danish written texts and dialogues; on the basis of the study of intersentential pronominal anaphora in naturally-occurring corpora and existing theoretical and practical approaches to propose a formal model accounting for the use of both types of anaphor; finally, on the basis of this model, to develop an algorithm for the resolution of Danish intersentential pronominal anaphora in both written texts and dialogues.

1.2 Some Terminology

Nominal referring expressions are called *anaphora*. The term anaphor originates from the Greek $\alpha\nu\alpha\varphi o\rho\acute{\alpha}$ (reference, relation).[1] Thus pronominal anaphors are pronouns which refer back to something in discourse. *Cataphora* are nominal expressions referring to something which follows the referring expression in discourse.

The entities or objects that anaphors refer to are called *referents*, while the most recent linguistic expressions which anaphors co-refer with in discourse are called *antecedents*. In the literature anaphoric referents are also called *discourse entities* (Webber 1991), *reference markers* (Kamp 1981) and *file cards* (Heim 1983).

Pronouns can refer to non-abstract or abstract entities. Abstract antecedents can be abstract nominals, verbal phrases, clauses or larger discourse segments. Reference to abstract entities, independently of the type of antecedent, has been called *situation reference* (Fraurud 1992) and *abstract object reference* (Asher 1993). The same phenomenon, excluding reference to abstract nominal phrases, has been called *impure textual deixis* (Lyons 1977) and *discourse deixis* (Levinson 1983, Webber 1991). Reference to non-abstract entities is also known as *individual reference* and anaphors are called *individual* or *abstract* depending on their antecedent type.

The majority of individual anaphors corefer with some linguistic expression in discourse. In some cases the antecedents are not explicit in discourse and must be inferred from the context.

Most computational approaches assume that the relation between an anaphor and its antecedent is a relation of *coreference*, i.e. the anaphor refers to the same discourse entity as its antecedent. In these approaches resolving an anaphor mainly corresponds to finding its most appropriate antecedent/s. But some types of anaphor, including abstract anaphors, do not simply corefer with their antecedent. Dahl & Hellman (1995) recognise different types of referent-creating

[1] The nominal comes from the verb $\alpha\nu\alpha - \varphi\acute{\epsilon}\rho\omega$ which means "I bring back, I refer".

operations such as *summation*, *complex creation*, *abstraction*, *substitution* and *type coercion*. For example *abstraction* consists in giving a generic interpretation to an anaphor with a specific antecedent, as in the following example provided by Sidner (1981)[217] where the pronoun *they* corefers with *Harley 1200* bikes in general, and not with the specific *Harley 1200*, mentioned in the previous utterance:

(1) My neighbour has *a monster Harley 1200.*
They are really huge but gas-efficient bikes.

Dahl and Hellman suggest that *coreference* is the most simple case of referent-creating operation, indicating a relation of *identity*.

In line with the majority of intersentential computational approaches, in this thesis *anaphora resolution* means finding the most appropriate antecedent. However, the cases where this simplified resolution view is problematic are indicated.

1.3 Scope of the research

This thesis is about the use and resolution of Danish explicit intersentential pronominal anaphora in written texts and dialogues. Both individual and abstract anaphora are included in the thesis, while *zero anaphora*, i.e. anaphora which are not explicitly mentioned by a nominal phrase but are indicated by a gap, are excluded.

Among pronominal anaphors I only deal with personal, possessive and demonstrative pronouns. Thus quantifiers,[2] relative pronouns, adverbial pronominals and ordinals are also beyond the scope of this study. As reflexive and reciprocal pronouns are intrasentential, they are not treated either. Expletive and cataphoric uses of pronouns are also outside the scope of my research.

The analysed language is Danish and the use of pronominal anaphors is investigated on written texts and on transcriptions of face-to-face dialogues. These data are central to the present research and both theoretical and practical approaches are evaluated on them.

Most of the analysed dialogues are two-party dialogues, and I have restricted my study to them. Furthermore their transcriptions do not contain prosodic information, thus prosodic marked and unmarked occurrences of pronouns cannot be distinguished.[3]

[2]Including impersonal pronouns, such as *man* (one), *een* (one) and *hver* (each).
[3]Prosodic marked and unmarked pronouns correspond to stressed and unstressed pronouns respectively.

1.4 Corpora and Collections

Different types of written text and dialogue constitute the empirical data behind the present work. All dialogues have been collected and transcribed by researchers at the University of Copenhagen.

The written texts comprise the **Bergenholtz** corpus, consisting of texts from 1987 to 1990 with approx. 5 million running words (Bergenholtz 1990), henceforth BERGENHOLTZ; a collection of computer manuals of approx. 1 million words, henceforth EDB; newspaper articles from *Berlingske Tidende* 1999, consisting of approx. 20 million words, henceforth BERLINGSKE.[4]

The analysed dialogues belong to three different collections: "Samtale hos Lægen" ("Talking with the doctor"), SL henceforth; the **Bysoc** corpus, BYSOC; "Projekt Indvandrerdansk" (Project Immigrant Danish), henceforth PID.

SL was collected from 1993 to 1995 and consists of transcriptions of the recording of forty-three conversations between Danish adult patients in the offices of two GPs. It contains approx. 89,000 running words (Duncker & Hermann 1996, Hermann 2000). BYSOC was collected in 1987 under "Projekt Bysociolingvistik" (Project Urban Sociolinguistics) and consists of the transcriptions of 80 conversations registered in private homes between a researcher and one or more persons on various subjects. It contains approx. 1,3 million running words (Gregersen & Pedersen 1991, Henrichsen 1998). From the PID collection I have only used the three dialogues between Danish native speakers. They are transcriptions of interviews on subjects such as family and work and consist of approx. 21,000 running words (Jensen 1989).

The majority of the examples in the thesis are taken from these texts and dialogues. Few examples are constructed by me: in these cases the source is not indicated. The dialogue examples are reported in a simplified way, in particular overlapping speech is not indicated.

The English translations of the examples are sometimes supplied with a literal translation where the original Danish word order and the gender of relevant nominal phrases are indicated.

1.5 Contents of the Dissertation

The dissertation is organised as follows.

In chapter 2, I describe the use of Danish individual and abstract pronominal

[4]The EDB texts have been collected by CST researchers under the STO project (Braasch, Christensen, Olsen & Pedersen 1998*a*).

anaphors based on their occurrences in the written texts and dialogues presented in section 1.4 and on descriptions in traditional grammars. Differences between the intersentential use of pronouns in Danish and English are emphasised. In chapter 3, I outline pragmatic models of the use of referring expressions which have inspired a number of computational approaches to pronominal resolution. The degree to which these models account for the uses of the Danish pronominal types described in chapter 3 is also discussed. In chapter 4, studies of the information structure of utterances are introduced and their relevance with respect to an account of a number of pronominal uses is discussed. Chapter 5 describes the relation between hierarchical models of discourse structure and the search space of antecedents and between coherence discourse relations and anaphora resolution. In chapter 6 computational approaches for individual anaphora resolution which rely on the various theories described in the preceding chapters, are presented and discussed. Scandinavian studies of intersentential anaphora are also outlined. Theoretical and computational approaches accounting for discourse deixis are presented in chapter 7 while in chapter 8 the tests on Danish discourse of the most promising approaches outlined in the preceding chapters are described and evaluated.

On the basis of the corpus-based analysis and various theoretic and applied approaches a strategy for resolving Danish individual and abstract intersentential anaphors in written texts and dialogues is proposed in chapters 9-11. These chapters constitute the central part of the thesis. In chapter 9 the architecture of a generic NLP system in which the Danish resolution algorithm is intended to be part of is outlined. The semantic representation of discourse is also discussed. In chapter 10 the various factors to be taken into account for the resolution of Danish pronouns are summarised. How these factors interact is established on the basis of the empirical data, a survey of Danish pronominal uses and the reviewed approaches. This interaction is formalised in a simplified model, which is implemented in the proposed algorithm for the resolution of Danish intersentential individual and abstract pronominal anaphora in texts and dialogues, the DAR-algorithm. The proposed algorithm is detailed in chapter 11. Chapter 12 contains the description of partial and complete tests of the DAR-algorithm. Its performance is then evaluated and compared with the performance of the algorithms tested in chapter 8. The chapter also contains a discussion of the similarities and differences between the DAR-algorithm and the various approaches it draws on. Finally chapter 13 contains the conclusions and indicates areas for further research.

Chapter 2

The Danish Pronominal Anaphora

In this chapter the Danish personal, possessive and demonstrative pronouns are presented, based on the data in the dialogue and text corpora presented in section 1.4 and on the descriptions of pronouns in (Allan, Holmes & Lundskær-Nielsen 1995, Diderichsen 1957[1946], Hansen 1967, Mikkelsen 1975).

The focus is on intersentential anaphora. Because prosodic marking and word order influence the resolution of anaphora these phenomena are also outlined. The description of the prosody of pronouns is mainly based on the accounts in (Hansen & Lund 1983, Heger 1981, Thorborg 1998), while word order is described by the so-called field schema (*Felt skema*) proposed by Diderichsen (1957[1946]) and furthermore developed by Hansen (1977).

In section 2.1 an overview of personal, demonstrative and possessive pronouns is given. Section 2.2 contains an account of the use of third person pronouns referring to individual nominal phrases, both abstract and non-abstract ones. The focus is on the types of antecedent the pronouns refer to and on the agreement constraints these antecedents pose on the pronouns. Section 2.3 describes the use of third-person pronouns in discourse deixis. In sections 2.4 and 2.5 the general prosodic and word order rules for pronouns are outlined. Section 2.6 contains a summary of the facts described in the chapter.

2.1 Danish Pronouns

In this section I present personal, possessive and demonstrative pronouns.

2.1.1 Personal and Possessive Pronouns

Personal pronouns can be divided into two groups according to whether their function in discourse is that of person-deixis or anaphoric reference. First and second person pronouns belong to the first group (Lyons 1977) while third person pronouns belong to the second.

Being (or involving) person deictics, first and second person pronouns are not anaphors, thus they are out of the scope of this dissertation.

Third person personal pronouns refer to an entity/ies previously mentioned in the discourse or which can be inferred from it. These pronouns can also have a deictic use, in which case they refer to entities in the physical context. Third person personal pronouns used as deictics are always stressed. In example (1) the stressed pronoun HAM (him) refers to a male person whom the speaker points to with a gesture or a gaze.

(1) HAM *skal du snakke med*
(HIM shall you speak to)

I only treat anaphoric uses of pronouns.

The singular forms of third person personal and possessive pronouns distinguish among four genders: *feminine*, *masculine*, *common* and *neuter*. The *feminine* and *masculine* genders are semantic because they refer to the sex of the antecedent. The *common* and *neuter* gender instead refer to the syntactic gender of the antecedent. Quirk, Greenbaum, Leech & Svartvik (1985) call the first two genders *personal*, the latter two *nonpersonal*.

Accusative third person pronouns and possessives referring to singular nominals have both a reflexive and a non-reflexive form.

Third person singular pronouns and possessives are shown in table 2.1.

gender	**subject**	**object**	**reflexive**	**possessive**	**poss.reflex.**
feminine	*hun* she	*hende* her	*sig* her-REFL	*hendes* hers	*sin/sit/sine* hers-REFL
masculine	*han* he	*ham* him	*sig* him-REFL	*hans* his	*sin/sit/sine* his-REFL
common	*den* it	*den* it	*sig* it-REFL	*dens* its	*sin/sit/sine* its-REFL
neuter	*det* it	*det* it	*sig* it-REFL	*dets* its	*sin/sit/sine* its-REFL

Table 2.1: Third person singular personal pronouns

Third person possessive reflexives agree in number and syntactic gender (*common/neuter*) with the possessed nominal.

The non-reflexive pronoun's form indicates the number of the antecedent(s) and in the case the antecedent is singular it also indicates its gender (*feminine, masculine, common, neuter*) and the number of the antecedent(s). This is illustrated in examples (2-a)-(2-e).

(2) a. *…de der altså* ***de*** *havde sådan nogle værelser og det var* ***deres*** *hjem ik'*
(…those so **they** had such some rooms and that was **their** home sure)
(BYSOC)

b. ***hun*** *var hjemmegående hvad hvad lavede* ***hendes*** *mand*
(lit. **she** was housekeeper what what did **her** husband)
(**she** was a housekeeper what what did **her** husband do)
(BYSOC)

c. *vi syntes* ***han*** *skulle have for meget det var* ***hans*** *regning var for stor ik'*
(we thought **he** should have too much it was **his** bill was too high, sure)
(SL)

d. *DET er en smuk, klog, sjov og usentimental bog, der vil glæde og varme alle som holder af* ***naturen*** *og* ***dens*** *skabninger.*
(lit. IT is a beautiful, clever, funny and unsentimental book, that will give happiness and warmth to all them who love **nature** (common gender) and **its** (common gender) creatures)
(IT is a beautiful, clever, funny and unsentimental book, that will give happiness and warmth to all them who love **nature** and **its** creatures)
(BERGENHOLTZ)

e. *…at mastodonten Philips netop har meldt sig på markedet med* ***et lignende produkt****.* ***Dets*** *dimensioner er dog noget større.*
(lit. …that the mastodon Philips just has entered the marked with **a similar product** (neuter gender). **Its** (neuter gender) dimensions are however bigger.)
(…that the mastodon Philips just has entered the marked with **a similar product**. **Its** dimensions are however bigger.)
(BERGENHOLTZ)

Most accounts of pronominal anaphora in Danish and in other Scandinavian languages have dealt with reflexive pronouns. Because I focus on intersentential pronominal anaphors, I do not treat reflexive and reciprocal pronouns. However I shorly present computational accounts of pronominal anaphors in Scandinavian languages in section 6.6.

Danish possessives have the same form when they are used as determiners, i.e. they precede a nominal, and when they are used as independent pronouns. Examples are given in (3).

(3) a. *og det havde hans storebror også*
(lit. and that had his big brother too)
(his big brother had it too)
(SL)

b. *det er mine plader, og det er hans*
(lit. it is my records, and it is his)
(these are my records, and those are his)
(BERGENHOLTZ)

c. **A:** *ja er.. er det din eller er det M%%% eller*[1]
(yes is .. is it yours or is it M%%% or)
A: *nej det er min*
(no it is mine)
(BYSOC)

Den, *det* and *de* are also the singular common, neuter and plural definite articles (the) and demonstratives, corresponding to the English *this/these* and *that/those* (see section 2.1.2).

The Case of Personal Pronouns

Personal pronouns have a nominative and an accusative form. Pronouns in nominative form are used as subjects as shown in example (4).

(4) *men* ***han*** *var ældre end min mor i hvert fald...*
(but **he** was definetely older than my mother)
(BYSOC)

Pronouns in accusative form are used as objects and as prepositional complements, as shown in examples(5-a) and (5-b) respectively.

(5) a. ***ham*** *har jeg set ik'*
(lit. **him** have I seen not)
(**him** I have seen, haven't I)
(BYSOC)

b. *så var jeg ja så var jeg gift med* ***ham***
(lit. then was I was I married with **him**)

[1] In (BYSOC) a capital letter followed by a number of % indicates that a proper name is made anonymous. A £ indicates a pause and two or more £'s indicate a longer pause.

(then I was I was married with **him**)
(BYSOC)

The accusative form is often used when the pronoun is subject complement. This is illustrated in example (6).

(6) a. *Jeg ved ikke om det er **ham***
(I do not know whether it is **him**)
(BYSOC)

b. *Men det er **ham**, der skal give tilladelsen*
(But it is **him** that must give the authorization)
(BERLINGSKE)

c. **A:** *Så flyttede I. Hvem er **I**?*
(lit. Then you-plur moved. Who are **you-plur**?)
(Then you moved. Who are **you**?)
B: *ja det er **mig selv og ham** jeg har arbejdet sammen med*
(yes it is **myself and him** I have worked together with)
(BYSOC)

The choice of case for subject complement pronouns depends on the kind of verb they are subcategorised for by. Allan et al. (1995) distinguish between the following cases:

1. the subject complement pronoun is in accusative form in copula answers to *hvem*-questions (who-questions) with a lexical main verb, as shown in example (7).

   (7) **A:** *Hvem har spist kagen?*
   (Who has eaten the cake)
   B: *det er **mig***
   (it is **me**)

2. the pronoun is in nominative or accusative form in answers to *hvem*-questions with *være* (be) or *blive* (become) followed by a nominal phrase. Examples are given in (8).

   (8) a. *Hvem er faderen?*
   (Who is the father?)
   b. *Det er **han/ham***
   (It is **he/him**)

   In cleft sentences, however, the accusative form is obligatory as shown in example (9).

(9) *Det er **ham**, der er faderen*
(It is **him**, that is the father)

3. the pronoun is always in nominative form in answers to *hvem*-questions with *være* (be) or *blive* (become) followed by an adjectival phrase. This is illustrated in (10).

(10) *Hvem er den højeste?*
(Who is the tallest?)
*Det er **han***
(lit. It is **he**)
(**He** is)

Both the nominative and the accusative form can be used in subject position if the pronoun is coordinated with another noun phrase as it is illustrated in examples (11) and (12) respectively. In general the nominative form is mostly used in formal language, while the accusative form is more informal.

(11) *Mine børn og **jeg** har det fint*
(My children and **I** are fine)
(BERGENHOLTZ)

(12) *men £ A%%%% og **mig** var ikke uvenner overhovedet*
(but £ A%%%% **and me** were not in bad terms at all)
(BYSOC)

The nominative form is obligatory in comparison constructions if the finite verb is present in the second comparative element, as shown in (13).

(13) *fordi han er seks syv år ældre end jeg er ik'*
(because he is six seven years older than I am, isn't he)
(BYSOC)

Both accusative and nominative forms are used if the finite verb is omitted in the comparative clause, as shown in examples (14-a) and (14-b) respectively.

(14) a. *han er fem år yngre end **mig***
(he is five years younger than **me**)
(BYSOC)
b. *hun var jo immervæk fem år ældre end **jeg***
(she was after all five years older than **I**)

(BYSOC)

2.1.2 Demonstrative Pronouns

Demonstrative pronouns are usually used as deictics, but they can also be used anaphorically, as it can be seen in example (15).

(15) *Men bilismen - især privatbilismen skal indskrænkes - til fordel for en udbygning af den kollektive trafik (hvor er* ***denne*** *for resten blevet af i Henning Rasmussens indlæg?)*
(lit. But the motoring - particularly the privat motoring must be reduced - for the benefit of an extension of the collective trafic (common gender) (what has by the way become of **this** (common gender) in Henning Rasmussen's contribution?))
(But the motoring - particularly the privat motoring must be reduced - for the benefit of an extension of the collective trafic (what has by the way become of **this** in Henning Rasmussen's contribution?))
(BERGENHOLTZ)

I only treat the anaphoric uses of demonstrative pronouns.

In spoken language demonstratives are always stressed. *Den*, *det* and *de* are always demonstratives when occurring with the two adverbials *her* and *der*. *Den her/det her* and *de her* correspond to the English *this* and *these* respectively, while *den der/det der* and *de der* correspond to *that* and *those*. The Danish demonstrative pronouns are shown in table 2.2.

2.2 Individual anaphors

Usually personal pronouns agree in number with their antecedents. In example (16) the singular pronoun *det* (it) agrees in number (and gender) with the nominal *papir* (paper), while the plural pronoun *dem* (them) agrees in number with its antecedent *røntgenbilleder* (X-rays).

(16) **A:** *okay £££ de der røngtenbilleder der blev taget, dengang, som jeg har et øh ££ papir om*
(okay £££ those X-rays that were taken, at that time, which I have a uh ££ paper about)
B: *mm*
(mm)

<table>
<tr><th>gender</th><th>singular</th><th>plural</th></tr>
<tr><td>common</td><td>den this/that
den her this
den der that</td><td rowspan="3">de these/those
disse these
disses these's
de her these
de der those</td></tr>
<tr><td>masculine
feminine
common</td><td>denne this
dennes this'</td></tr>
<tr><td>neuter</td><td>det this/that
dette this
dettes this'
det her this
det der that</td></tr>
</table>

Table 2.2: Demonstrative pronouns

A: ***det*** *er fra niogfirs og* ***det*** *er så fire år fem år gammelt ik'*
(**it** is from eighty-nine and **it** is then four five years old sure)
B: *ja*
(yes)
A: *har du* ***dem*** *noget sted selv derhjemme*
(lit. have you **them** somewhere self at home)
(do you your self have **them** somewhere at home)
B: *nej ££ jeg har ikke engang set* ***dem****, jeg har kun hørt om* ***dem***
(no ££ I have not even seen **them**, I have only heard about **them**)
(SL)

2.2.1 Pronouns with Collective Antecedents

Pronouns with a collective noun antecedent can either agree syntactically or semantically with their antecedent. If the agreement is syntactic the pronoun is singular, while if it is semantic the pronoun is plural, as illustrated in examples (17-a) and (17-b) respectively.

(17) a. *Folketingets flertal har med disse to ændringer tilsidesat helt fundamentale rettigheder for at stifte* ***familie*** *og være sammen med* ***den****.*
(lit. The majority of parliament has with these two changes overridden two very fundamental rights of founding **family** (common gender) and being together with **it** (common gender))

(The majority of parliament has with these two changes overridden two very fundamental rights of founding a **family** and being together with **it**)
(BERLINGSKE)

b. *I Cambridge mødte jeg sidste år en dansk **familie** fra Esbjerg. Da **de** fandt ud af mit navn busede det ud af manden...*
(lit. In Cambridge met I last year a Danish **family** from Esbjerg. When **they** discovered my name bursted it out of the husband...)
(Last year in Cambridge I met a Danish **family** from Esbjerg. When **they** discovered my name the husband bursted out...)
(BERLINGSKE)

Pronouns referring to the word *par* (couple) are always in plural form. This is illustrated in (18).

(18) ***Et andet par** i boligkøen fortæller, at **de** er villige til at betale omkring 5.000 kroner for minimum tre værelser.*
(**Another couple** on the waiting list for getting apartments say that **they** are willing to pay approx. 5,000 crowns for at least three rooms)
(BERLINGSKE)

Only singular pronouns are used to refer to the word *regering* (government), as shown in (19).

(19) *Gruppen, der har hovedkvarter i New York, sagde, at den holdt den serbiske **regering** ansvarlig for drabene, fordi **den** havde støttet oprettelsen af de halvmilitære grupper i de serbiske enklaver i Kroatien.*
(lit. The group, that has headquarters in New York, said, that it considered **the Serbian government**(common gender) responsible for the killings, because **it** (common gender) had supported the establishment of semi-military groups in the Serbian enclaves in Croatia.)
(The group, that has its headquarters in New York, said that it considered **the Serbian government** to be responsible for the killings, because **it** had supported the establishment of semi-military groups in the Serbian enclaves in Croatia.)
(BERLINGSKE)

2.2.2 Singular Pronouns

Singular pronouns agree in gender with their antecedents. Feminine and masculine pronouns are used to refer to animate (especially humans) antecedents of the corresponding sex, while common and neuter gender pronouns usually refer to non animate entities (both concrete and abstract ones) and agree in gender with the nominal they corefer with. This is illustrated in (20).

(20) a. *og da* (pause) *hilser* ***min far*** *på en dame som* ***han*** *ikke kender*
(lit. and then (pause) greets **my father** a lady that **he** not know)
(and then (pause) my **father** greets a lady that **he** does not know)
(BYSOC)

b. *der boede* ***min mor*** *så til* ***hun*** *blev pensioneret*
(lit. there lived **my mother** so until **she** was pensioned off)
(there my mother lived so until **she** retired)
(BYSOC)

c. *så . . .* ***vandrejournalen*** *har du* ***den***
(lit. then . . . **the case record** (common gender) do you have **it** (common gender))
(then. . . **the case record** do you have **it**)
(SL)

d. *nu vil jeg komme og tage* ***dit blodtryk****. . .* ***det*** *er hundredetyve over femoghalvtreds*
(lit. now will I come and take **your blood pressure** (neuter gender) . . . **it** (neuter gender) is hundred and twenty over ninetyfive)
(now I will come and measure **your blood pressure**. . . **it** is one hundred and twenty over ninety five)
(SL)

Most nouns referring to humans and to animals are common gender. Furthermore many common gender nouns denoting humans are neutral as to the sex of the person they refer to. The appropriate pronoun is used in each case, as shown in examples (21-a) and (21-b) where a masculine and a feminine pronoun are used to refer to the same nominal *kæreste* ((boy/girl)friend).

(21) a. **A:** *men det er godt at være opmærksom på det og godt at snakke om det*
(but it is good to be aware of it and good to talk about it)
B: *ja ... altså ja*
(yes ... surely yes)
A: *med* ***din kæreste*** *for eksempel så* ***han*** *ikke synes du bare er blevet f- skingrende skør oven i hovedet eller hvad* ***han*** *nu kan forestille sig, ikke*
(lit. with **your friend** for example so **he** not think simply that you have gone f- completely crazy or what **he** now can imagine, not)
(with **your boyfriend** for example so **he** does not simply think

that you have gone f- completely crazy or what **he** can now imagine, right)
(SL)

b. *Det er min* ***kæreste****.* ***Hun*** *hedder Karin*
(lit. This is **my friend**. **She** is named Karin)
(This is **my girlfriend**. **Her** name is Karin)
(BERGENHOLTZ)

If the sex of the nominal is unknown or one wants to refer to persons of both sexes, both feminine and masculine pronouns are used as in English.

Feminine and masculine pronouns can also refer to animals of the corresponding biological sex. In example (22) the masculine pronoun *ham* (him) refers to a dog.

(22) **A:** *nej det er min*
(no it is mine)
B: *det er din*
(it is yours)
A: *købt ude på en kennel uf*
(bought in a kennel uf)
B: *nå*
(so)
A: *vi fik* ***ham*** *uden moms*
(we got **him** without VAT)
(BYSOC)

Common gender pronouns refer to common gender nouns which do not denote humans. These nouns can both refer to concrete and abstract entities. In example (23) the common gender pronoun *den* agrees with the common noun *husleje* (rent).

(23) **A:** *hvad er* ***jeres husleje*** *her*
(lit. what's **your rent** (common gender) here?)
(what's **your rent** here?)
B: *fire tusinde*
(four thousand)
A: *er* ***den*** *det*
(lit. is **it** (common gender) that)
(is it)
(BYSOC)

Neuter gender pronouns are used to refer to neuter nouns. This is illustrated in (24).

(24) *Samme aften fandt politiet* ***afskedsbrevet*** *i en taske. Jeanne siger:-* ***Det*** *var meget rodet og uforståeligt . Jeg har kun læst* ***det*** *en enkelt gang.*
(lit. The same evening found the police **the farewell letter** (neuter gender) in a bag. Jeanne says:- **It** (neuter gender) was very confused and incomprehensible. I have only read **it** (neuter gender) once.)
(The same evening the police found **the farewell letter** in a bag. Jeanne says:- **It** was very confused and incomprehensible. I have only read **it** once.)
(BERGENHOLTZ)

Neuter gender pronouns are also used to refer to neuter gender nominals denoting a human, if the sex is unknown or irrelevant. In this case the agreement is syntactic. This is illustrated in (25).

(25) **A:** ***barnet*** *var på... millimeter så stort* ***det*** *skulle være i længden og i hovedstørrelsen og...*
(**the child** (neuter gender) was precisely... as big as **it** (neuter gender) ought to in length and in head dimension...)
(**the child** was precisely... as big as **it** ought to in length and in head dimension...)
(SL)

Neuter gender nouns indicating humans are few, but very frequent. They are *barn* (child), *menneske* (human being, person), *bud* (messenger), *individ* (individual), *vidne* (witness), *medlem* (member) together with compound words where the second element is one of the above nouns, such as *barnebarn* (grandchild) and *postbud* (postman).

If the sex of the human is known or relevant, the appropriate feminine or masculine pronoun is used and the agreement is semantic. An example is given in (26).

(26) **A:** *så øh... jeg kunne gå ud for jeg havde* ***mit barnebarn*** *med* ***på tre et halvt år*** *så..., kunne jeg jo bare holde* ***ham*** *i hånden*
(lit. then uhm...I could go out because I had **my grandchild** (neuter gender) with of three one half year so..., could I just hold **him** in the hand)
(then uhm... I could go out because I was together with **my three and a half grandchild** so..., I could just hold **his** hand)
(SL)

Det (it) can also refer to abstract common gender nouns. Thus common gender abstract nouns can both be referred to by a common gender pronoun and by a neuter gender pronoun, as illustrated in (27). In (27-a) the common gender pronoun *den* (it) is used to refer to the abstract nominal in common gender *den marginale stigning i arbejdsstyrken* (the marginal raising in the labour force), while in (27-b) the nominal *en stor stigning* (a big raising) is referred to by the neuter gender pronoun *det* (it).

(27) a. *Den marginale stigning i arbejdsstyrken er bemærkelsesværdig, da* ***den*** *skal ses i forhold til regeringens seneste skøn i finansredegørelsen...*
(lit. The marginal raising (common gender) in the labour force is remarkable, because **it** (common gender) must be seen in relation to the governement's latest financial review...)
(The marginal raising in the labour force is remarkable, because **it** must be seen in relation to the governement's latest financial review...)
(BERLINGSKE)

b. *Der har været en stor stigning de sidste ti år , og* ***det*** *forekommer hyppigst i byerne...*
(lit. There has been a big raising (common gender) the last ten years, and **it** (neuter gender) most frequently occurs in the cities...)
(There has been a big raising the last ten years, and **it** most frequently occurs in the cities...)
(BERLINGSKE)

A neuter gender pronoun can also refer to concrete common gender nominals, but this use seems to be restricted to cases where the anaphor is subject in copula constructions with the copula *være* (be). Examples are given in (28).

(28) a. *Vi har købt* ***en ny server***. ***Det*** *er en Sun.*
(lit. We have bought **a new server** (common gender). **It** (neuter gender) is a Sun.)
(We have bought **a new server**. **It** is a Sun.)

b. *Der går* ***en mand*** *på gaden.* ***Det*** *er Peter.*
(lit. There walks **a mand** (common gender & animate) on the street. **It** (neuter gender) is Peter.)
(**A man** walks on the street. **It** is Peter.)

Det can also refer to plural words, when they are not people, if the speaker wants to refer to the general type denoted by the words. In (29-a) *det* refers to the two plurals **tæpper og gardiner** (carpets and curtains) while in (29-b) it refers to the two singular common gender nominals *en kop of en tallerken* (a cup and a dish).

(29) a. ***tæpper og gardiner**: **det** er dyrt*
(Hansen 1967)[vol. 2: p. 82]
(**carpets and courtains**: **that** is expensive)

b. *På bordet stod **en kop og en tallerken**; **det** tog hun og satte hen i vinduet;*
(Mikkelsen 1975)[275]
(lit. On the table (neuter gender) were **a cup** (common gender) **and a dish** (common gender); **it** (neuter gender) took she and put on the windowsill;)
(On the table there were **a cup and a dish**; **it** (them) she took and put on the windowsill;)

Both *den* and *det* can be used as expletives.

In some cases the pronominal antecedents are not explicitly in the text, but must be inferred by the context, as it is the case in example (30) from BERLINGSKE where the nominal *par* (couple) implies the existence of two persons, often a man and a woman, the antecedents of the two pronouns *han* (he) and *hun* (she) respectively.

(30) ***Det forlovede par**, **han** serber og **hun** muslim, forsøgte at flygte fra borgerkrigen...*
(**The engaged couple**, **he** Serbian and **she** Muslim, tried to escape from the civilian war...)

2.2.3 Plural Pronouns

Third person plural pronouns refer to plural nominals. An example is given in (31).

(31) *det er der **nogen af de store stærke mænd** der gør **de** kan ikke lide at sige **de** skal ligge ned*
(lit. it are there **some of the big strong men** who do **they** do not like to say **they** have to lie down)
(there are **some of the big, strong men** who do that, **they** do not like to say that **they** have to lie down)
(SL)

In some cases plural pronouns refer to the summation of singular entities. The antecedent entities can be coordinate or split antecedents as illustrated in examples (32) and (33), respectively.

(32) *Jens Christian Jespersen stod frem på TV, fordi han mener, at **en læge og hans kone** bevidst nægter at betale, selvom **de** har pengene til det*
(Jens Christian Jespersen stood forward on TV, because he believes that **a doctor and his wife** deliberately deny to pay, although **they** have the money to do so)
(BERGENHOLTZ)

(33) *En anden ting: Ifølge arabisk muslimsk skik, må **en pige** ikke have noget intimt med **en dreng**, før **de** er blevet gift.*
(lit. Another thing: According to Arabic moslem custom, must **a girl** not have any intimacy ... with **a boy**, before **they** get married.)
(Another thing: According to Arabic moslem custom, **a girl** must not have any intimacy ... with **a boy**, before **they** get married.)
(BERGENHOLTZ)

Plural pronouns can refer to elements listed in the preceding sentence/sentences. In example (34) *dem* (them) refers to the father and the grandfather of the patient in the previous two sentences.

(34) ***Min far** havde for højt blodtryk ... det havde **min farfar** også jeg er bange for at jeg ligner **dem***
(lit. **My father** had too high blood pressure ... it/that had **my grandfather** too I am afraid that I am like **them**)
(**My father** had too high a blood pressure ... **my grandfather** had it too I am afraid that I am like **them**)
(SL)

Plural pronouns can have as antecedent a place (or institution) and refer to the people living or working there. This is a case of regular polisemy, as in example (35) where *de* (they) refers to the people working at the radio news.

(35) *og øh... ££ så sent som i morges, i radioavisen hørte jeg, at **de** netop snakkede om det her*
(lit. and uh... ££ as late as this morning on the radio news heard I that **they** precisely talked about this)
(and uh... ££ as late as this morning I heard on the radio news that **they** precisely talked about this)
(SL)

In some cases the pronoun *de* has no explicit antecedent in the discourse. The antecedent must be inferred by the context, as it is the case in example (36) where the pronoun *de* refers to the people testing blood samples.

(36) **L:** *ja den* (= blood sample) *var normal*
(yes it was normal)
P: *nå den var normal jep den var normal*
(so it was normal yes it was normal)
L: *ja så fik* ***de*** *jo den og hvis den næste her også er normal, så er der ikke sket noget*
(lit. yes so got **they** it and if the next sample here is also normal, then is there not happened anything)
(yes so **they** got it and if the next sample here is also normal, then nothing happened)
(SL)

Thus in many cases resolving plural pronouns requires an analysis of the context in which the anaphor and its antecedents occur.

2.2.4 Demonstrative Anaphora

In the following I look at the anaphoric uses of demonstrative pronouns. Hansen (1967) notices that the demonstrative *den* cannot refer to humans, while *denne* can. He illustrates this with the following example (Hansen 1967)[p.374]:

(37) *Som vidne fremtrådte NN.; denne oplyste...*
(As witness NN. came forward; this explained...)

Mikkelsen (1975) writes that one of the uses of *denne/dette/disse* is to refer to what precedes or follows (cataphoric use) in discourse.

I have looked at the occurrences of *denne/dette/disse* in the Danish corpora and I found that they never corefer with a subject antecedent intrasententially, although they can refer to a part of the subject, as illustrated in example (38), where the demonstrative *dennes* (this') refers to the immediately preceding coordinated nominal *en god veninde* (a good friend).

(38) ***En god veninde*** *og* ***dennes*** *mand sørgede for at flytte Lillian Christensens møbler og de øvrige ejendele fra lejligheden i Brøndbyøster til Æblehaven , da hun for et år siden fik en af de nye ledige lejligheder.*
(**A good friend** and **this'** man took care of moving Lillian Christensen's furniture and the rest of her property from the flat in Brøndbyøster to Æblehaven, when she one year ago got one of the new vacant flats.)
(BERLINGSKE)

When *denne/dette/disse* had a subject antecedent in a preceding clause, there were no antecedent competitors.

The use of a demonstrative anaphor in many cases emphasises the referent. Demonstrative anaphors are also common in situation reference. I discuss this type of reference in section 2.3.

Some examples of the use of demonstratives in the (BERLINGSKE) corpus are in (39).

(39) a. *Vi har bragt en hel del* ***sæder og skikke*** *med os fra hjemlandet, og vi lever efter* ***disse****.*
(We have brought a lot of **customs and manners** from the home country, and we live according to **these**.)

b. *Ejeren, Hans Christian Mikkelsen, driver* ***handelsfirmaet Skan-Ex*** *med tre ansatte på samme adresse, og fødevaresalget er blevet en del af* ***dette****.*
(The owner, Hans Christian Mikkelsen, runs **the trading business Scan-Ex** with three employees at the same address, and selling food has become a part of **this**.)

c. *Når folketingsmedlemmerne ikke sidder på deres pladser, er der al mulig grund til at tro, de har travlt med deres arbejde. Hvis de derimod har tid til at klæbe til taburetten dagen lang, er det fysisk umuligt for dem også at holde den kontakt med* ***vælgerne****, som* ***disse*** *har krav på.*
(lit. When the members of Parliament not sit in their seats, is there all good reason to believe that they are busy with their work. If they on the contrary have time to cling to office all day long, is it physically impossible for them also to keep that contact with **the electors**, that **these** are entitled to.)
(When the members of Parliament do not sit in their seats, there is all good reason to believe that they are busy with their work. If they on the contrary have time to cling to office all day long, it is physically impossible for them also to keep that contact with **the electors**, that **these** are entitled to.)

It should be noted that *denne/dette/disse* do not necessarily refer to the most recent candidate antecedent. When there are more competing antecedents with the same syntactic role one usually refers to the first antecedent by *førstnævnte* (the former) and to the latter one by *sidstnævnte* (the latter). An example of the latter is given in (40).

(40) *Roser skal have masser af vand lige før ferien, ligeledes Hortensia og* ***Rhododendron****, hvoraf især* ***sidstnævnte*** *er meget vandkrævende.*

(Roses must have a lot of water just before vacation, as well as Hydrangea and **Rhododendron**, of which especially **the latter** requires much water.)
(BERLINGSKE).

According to the literature, personal and demonstrative anaphors also occur in different contexts in other Scandinavian languages. In particular Fraurud (1992) reports that Swedish traditional norms for written language state that *denne* (this) must be used to refer to a human antecedent which is not the subject of the clause, while personal pronouns can only be used to refer to subjects. The latter rule is not followed in informal language any more.

(Johannesen 1996) reports that the Norwegian *denne/dette/disse* (this/these) refer to non-subjects intrasententially while they often refer to non-subjects intersententially. She suggests that the local domain of *denne/dette/disse* is different from that of personal pronouns because demonstrative pronouns cannot be cliticised while personal pronouns can.

In the following section I describe the use of singular neuter gender pronouns referring to discourse parts.

2.3 Discourse Deictics

Third person neuter singular personal and demonstrative pronouns (*det, det her, det der, dette*) not only refer to individual nominals, but are also used to refer to abstract objects. Reference to abstract nominals was shortly discussed in section 2.2.2.

In the following I focus on discourse deixis, i.e third gender singular neuter pronouns with abstract antecedents which are not referred to by nominals. These antecedents can be verbal phrases, one or more clauses, one or more sentences, concepts which can be inferred from the preceding discourse context.

The most common discourse deictic is *det* (it/this/that) in both written and spoken language.

The neuter demonstrative *dette* (this), is mostly used in written language and I found only very few occurrences of it as discourse deictic in the dialogue collections.

Fraurud (1992) reports that the Swedish *dette* and *alt det/dette* refer more often to larger discourse segments than *det* (see also section 7.2). I have not found strong evidence of this in the data, but, as Fraurud for Swedish, I found some occurrences of both *alt det* and *alt dette* indicating reference to a list of previously mentioned situations. This is illustrated in example (41) where *alt dette* (all this) refers to all the precedingly mentioned situations illustrating how the Government supports the national church.

(41) *Støtten består i, at man opretholder en lukkelov, der beskytter søndagen, at man sikrer, at præster får en videnskabelig forsvarlig uddannelse på universiteterne i Århus og København, hvor der findes teologiske fakulteter. Staten betaler også 40 pct. af de almindelige præsters løn (ikke præster til særlige opgaver) og hele biskoppernes løn. Staten betaler også konsulentbistand fra arkitekter, bygningssagkyndige, eksperter fra Nationalmuseet, Akademiet for de Skønne Kunster o.a.* ***Alt dette*** *gør man, fordi kirken er en offentlig institution.*
(The support consists in keeping a Shop Act, which protects the Sunday, ensuring that priests get a scientific proper education at the universities in Århus and Copenhagen, where there are teologic faculties. The Government also pays 40 % of the gage of common priests (not priests with particular duties) and the whole gage of bishops. The Government also pays advisory assistance from architects, building experts, experts from the National Museum, the Academy of Fine Arts etc. **All this** is done, because the church is a public institution.)
(BERLINGSKE)

The analysis of the occurrences of *dette* (this) indicates that it is used to refer to the last mentioned situation in the previous sentence, often expressed in a subordinated clause, and not to the whole sentence or to a discourse deictic in the preceding sentence. This is illustrated in the examples in (42). In (42-a) the pronoun *dette* refers to *at gennemføre opkøb af statsobligationer* (to buy government bonds) and not to the whole preceding sentence of the bank refusing to buy government bonds. In (42-b) the first *dette* (this) refers to *vi sætter behandlingen af narkomanerne i første række* (we give first priority to the treatment of drug addicts) and not to the whole sentence or to the deictic *det* (it/this/that) in the main clause. Similarly the second *dette* refers to *man begynder at udlevere narko til de hårdest ramte narkomaner* (one begins to dispense drugs to the hardest hit drug addicts) and not to the whole preceding sentence, *En måde . . . ramte narkomaner.* (A way . . . hit drug addicts) or to the preceding discourse deictic *dette* (this). I have not found in the literature a similar analysis of the discourse deictic *dette* (this), but this use is clearly related to the use of *denne/dette/disse* (this/these) as individual anaphors described in the preceding section.

(42) a. *Japans nationalbank har tidligere udtrykkeligt afvist at gennemføre opkøb af statsobligationer og har i den forbindelse henvist til, at* ***dette*** *vil stride mod bankens regler undtagen under "ekstreme omstændigheder".*

(Japan's national bank has erlier explicitly refused to buy government bonds and has in that context referred that **this** will go against the bank's rules except in "extreme circumstances").
(BERLINGSKE)

b. *Det kræver, at vi sætter behandlingen af narkomanerne i første række. En måde, hvorpå* ***dette*** *kan ske, er, hvis man begynder at udlevere narko til de hårdest ramte narkomaner. Og* ***dette*** *skal selvfølgelig ske under streng kontrol.*
(It requires, that we give first priority to the treatment of drug addicts. One way in which **this** can happen, is, if we begin to dispense drugs to the hardest hit drug addicts. And **this** must of course happen under strict control)

Furthermore the data indicate that *dette* (this) is used as the English demonstratives *this* and *that* to indicate that the pronoun is a discourse deictic in cases where there are competing individual antecedents in the preceding utterance, i.a. (Webber 1991, Gundel, Hedberg & Zacharski 1993, Gundel, Hegarty & Borthen 2001). This is illustrated in (43), where the use of the demonstrative indicates that the pronoun is a discourse deictic referring to the preceding sentence, *43 pct. af danskere ... dårligere år* (43 % of the Danes...worse year) and not an individual pronoun referring to the immediately preceding nominal **et dårligere år** (a worse year).

(43) *På det personlige plan er danskerne blandt de mest optimistiske i den internationale sammenligning. 43 pct. af danskerne tror på, at 1999 bliver et bedre år for deres eget vedkommende end det forgangne, mens kun 10 pct. forventer et dårligere år.* ***Dette*** *er en mindre nedgang i optimismen i forhold til sidste år.*
(lit. On the personal level (neuter gender) are the Danes among the most optimistic in the international comparison (common gender). 43 % of the Danes believe that 1999 will be a better year (neuter gender) for them personally than the preceding (neuter gender), while only 10 % expects a worse year (neuter gender). **This** (neuter gender) is a minor fall in the optimism compared to last year.)
(On the personal level the Danes are among the most optimistic in the international comparison. 43 % of the Danes believe that 1999 will be a better year for them personally than the preceding one, while only 10 % expects a worse year. **This** is a minor fall in optimism compared to last year.)
(BERLINGSKE)

Det her (this) is mostly used to refer to some concept which can be inferred from the context. This is illustrated in example (44), where the deictic *det her* (this) refers to the doctor's suggestion of writing to the patient's dead friend all the things she did not manage to tell her before she died.

(44) **L:** *men øh, men du kunne overveje at skrive et brev til din veninde ££ og selvfølgelig skal du ikke sende det*
(lit. but uh, but you could consider to write a letter (neuter gender) to your friend ££ and of course must you not send it (neuter gender))
(but uh, but you could consider to write a letter to your friend ££ and of course you must not send it)
P: *nej nej*
(no no)
L: *jeg kan godt forstå du ser mystisk ud i ansigtet*
(I perfectly understand that you look suspicious)
P: *ja*
(yes)
L: *men jeg mener det, faktisk*
(but I mean it, really)
P: *nå*
(well)
L: *fordi.. øh*
(because.. uh)
P: *nå ja man kan skrive sig ud af det*
(well yes one can "write oneself out of it")
L: *ja*
(yes)
P: *ja*
(yes)
L: *ja, altså du som du aldrig fik sagt til hende fordi du ikke kom derop engang til, det skulle du prøve at sætte dig at skrive et brev til hende*
(lit. yes, so you that you never managed to tell her because you not came up there once again, that should you try to sit you down to write a letter to her)
(yes, so you that you never managed to tell her because you did not come up there once again, that you should try to write in a letter to her)
P: *ja det kan godt være det var en*
(Yes it could well be an)
L: *der er ikke nogle steder at sende det hen, men det er klart øh det er jo ikke noget jeg har fundet på* ***det her***
(there are no places to send it to, but it is clear uh it is certaily not something I have hit upon **this here**)
P: *nej*

(no)
L: *det er jo noget man ved dem der har forstand*
(it is something one knows them who have knowledge)
P: *ja*
(yes)
L: *på de ting*
(about those things)
P: *ja*
(yes)
L: *der kan hjælpe*
(which can help)

Det der (that) is more seldom than *det her*, and it is mostly used as cataphoric pronoun, which I do not treat here.

Because the most common discourse deictic is *det* from now on I just use it as representant for all discourse deictics in my examples. But the differences between demonstrative and personal discourse deictics are important and must be accounted for in a formal model of the use of Danish anaphors. Discourse deictics are discussed further in chapters 7, 8 and 11.

The uses of discourse deictics are illustrated in the following:

1. *Det* can refer to an infinitive or a clause, as it is the case in examples (45) and (46), respectively.

   (45) *At gå alene, for eksempel på Færøerne. Det kunne jeg godt tænke mig.*
   (lit. To walk alone, for example in the Faroe islands. It/this/that would I like.)
   (To walk alone, for example in the Faroe islands. I would like that.)
   (BERLINGSKE)

   (46) **A:** *Du skal tage en blodprøve*
   (You have to take a blood test)
   B: *Hvorfor det?*
   (Why is that?)
   (SL)

2. *Det* is also used as the subject complement of *være* (be) and *blive* (become), as shown in examples (47) and (48), respectively.

   (47) *Der var den her mand, der mente, han var bondemand. Det var han ikke, for han er jo svineproducent.*

(lit. There was this man, who believed, he was a farmer. That was he not, for he is, you see, a pig breeder.)
(There was this man, who believed, he was a farmer. That he was not, for, you see, he is a pig breeder.)
(BERLINGSKE)

(48) **A:** *Blev du færdig med opgaven?*
(Did you finish the task?)
B: *Ja, det blev jeg*
(lit. Yes, that did I)
(Yes, I did)

3. *Det* refers to a verbal phrase when it is used as the object complement with the auxiliary *have* (have). This is illustrated in (49).

(49) **A:** *Har de set lejligheden?*
(Have they seen the apartment?)
B: *ja, det har de*
(lit. yes, that have they)
(Yes, they have)

4. *Det* refers to a verbal phrase when it is used as the object complement with modal verbs. This is shown in (50).

(50) a. *Da Evas storesøster Annika, der nu er ti, gik i børnehaveklasse, måtte børnene ikke lære bogstaver og tal. Det må de i dag, og det er en god idé*
(lit. When Eva's elder sister Annika, who now is ten, was in the pre-school class, were the children not allowed to learn letters and numbers. That are they allowed to today, and it is a good idea.)
(When Eva's elder sister Annika, who now is ten, was in the pre-school class, the children were not allowed to learn letters and numbers. They are allowed to do that today, and it is a good idea.)
(BERLINGSKE)

b. **A:** *Han kunne svømme, men det kunne hun ikke*
(lit. He could swim, but it could she not)
(He could swim, but she couldn't)

5. *Det* refers to a verbal phrase when it is used as the object complement of the verb *gøre* (do). This verb replaces the lexical verb in the previous clause in cases where the finite of the clause is not an auxiliary or a modal verb,

as shown in (51).

(51) *Jeg koncentrerer mig om det liv, jeg har nu, i stedet for det liv, jeg havde. Det gjorde jeg lige fra starten.*
(lit. I concentrate on the life, I have now, instead for on the life, I had. This did I from the beginning.)
(I concentrate on the life, I have now, instead for on the life, I had previously. This I did from the beginning.)
(BERLINGSKE)

6. *Det* is also used in utterances denying or confirming a preceding allegation or a suggestion if the verb *være* (be) is used in the confirmation/denial. This is illustrated in (52).

(52) *Hun opførte sig som en tåbe, og det er hun også*
(lit. She behaved as a fool, and that is she also)
(She behaved as a fool, and so she is)

7. *Det* can have as antecedent a clause in constructions with attitude verbs such as *synes* (think), *tro* (believe) and *vide* (know), *håbe* (hope) and with verbs which take clausal arguments, such as *sige* (say) and *fortælle*. Examples of this are given in (53).

(53) a. **A:** *er du øm her ved livmoderhalsen*
(does it hurt here by your cervix uteri)
B: *nej... **det** tror jeg nu ikke*
(lit. no...that think I not)
(no...I don't think so)
(SL)

b. **A:** *du kan ligeså godt gå fra så tidligt som muligt selvfølgelig*
(you can just as well go on leave as early as possible of course)
B: *ja, **det** synes jeg*
(lit. yes that think I)
(yes, I think so)
(SL)

c. *og så prøvede jeg så at gå lidt i svømmehallen (1 sek) og **det** prøver jeg sådan ind imellem, men jeg hader **det***
(lit. and then tried I then to go a little to the swimming pool (1 sec.) and **it** try I such from time to time, but I hate **it**)
(an then I tried to go a little to the swimming pool (1 sec.) and I still try from time to time, but I hate **it**)

8. *Det* can refer to more clauses, or to something that can be vaguely inferred from the previous discourse (vague anaphora) as it is the case in (54). In the example the second **det** refers to the fact that speaker **A** wants to pay the school fee to his child and/or allow the child to go in a renowned private school. These facts are not explicitly stated in the dialogue.

(54) **A:** *nu skal vi jo have ?(lille)? drengen til... i skole her til august jo*
(now we must have the ?(little)? boy in school here in august)
B: *ja*
(yes)
A: *så skal han starte på den der Kreb- eller* (ler)
(then he is going to that Kreb- or) (laughs)[2]
B: *skal han det*
(lit. is he that)
(is he?)
A: *ja... han skal,* ***det*** *vil jeg sgu' godt give ham*
(lit. yes... he has, **that/it** will I bloody well give him)
(yes... he has, I will bloody well give **that/it** to him)
(SL)

In the contexts 2-7 the non-subject pronoun *det* often occupies the first position in main clauses.[3] In the analysed data *det* occurred in front position in the given constructions in 96% of the cases.

It is not always possible to determine whether the pronoun *det* is used as individual or as abstract anaphor, as it is illustrated in example (55). In (55) *det* can both refer to *et gammelt firma* (an old firm) and to the clause *Peter arbejdede i et gammelt firma*.[4]

(55) *Peter arbejdede i et gammelt firma.* ***Det*** *hadede han.*
(lit. Peter worked i an old firm (neuter gender). **It** (neuter gender) hated he.)
(Peter worked i an old firm. He hated **that**.)

If the pronoun *det* follows a generic situation, its preferred interpretation is as discourse deictics. This is illustrated in example (56). In the example the pronoun *det* in the second sentence refers to the previous utterance and not to the neuter noun *vaskeri* (laundry).

[2]Here it is referred to Krebsskolen, a private school in Copenhagen.

[3]I discuss word order for pronouns in section 2.5.

[4]The preferred interpretation of the pronoun in unmarked context is, in my opinion, the deictic one, while in marked context it refers to the individual entity. I discuss the significance of prosodic marking for pronominal interpretation in the following section and in chapters 3 and 4.

(56) *Det er dødsygt at sidde på et vaskeri.* ***Det*** *hader jeg.*
(lit. It is dead boring to be in a laundry (neuter gender). **It/that** (neuter gender) hate I.)
(It is dead boring to be in a laundry. I hate **that**.)
(PI)

Abstract anaphors can also corefer with a preceding abstract pronoun, as shown in (57).

(57) **A:** *Jeg elsker [at stå på ski]$_i$. Det$_i$ er sjovt.*
(I love [*skiing*]$_i$. *It*$_i$ is funny.)
B. *Ja, men det$_i$ er også farligt.*
(Yes, but *it*$_i$ is also risky.)

Situation anaphors are often used cataphorically. This is illustrated in (58).

(58) *men skal vi aftale* ***det*** *at du ringer fredag*
(but shall we arrange **it** that you ring on Friday)
(SL)

As mentioned in chapter 1 I do not treat cataphoric use of pronouns in the dissertation.

2.4 Prosodic Marking of Personal and Demonstrative Pronouns

In this section I shortly present the general rules for prosodic marking of personal, possessive and demonstrative pronouns in Danish. In the literature different levels of stress are recognised, but for simplicity I only operate with stressed and non-stressed pronouns. In the examples in this section stressed words are capitalised.

Danish personal and possessive pronouns used as determiners are usually unstressed. This is illustrated in (59).

(59) a. *Hvad laver hun*?
(lit. What does she?)
(What is she doing?/What does she do?)
b. *Han læser en bog*
(lit. He reads a book)
(He is reading a book)
c. *Han lånte hende sin bil*

(lit. He lent her his-refl car)
(He lent her his car)

d. *Han gav hende det*
(lit. He gave her it)
(He gave it to her)

e. *Hun snakker med ham*
(She talks to him)

Demonstrative and possessive pronouns in independent function are always stressed, as shown in (60).

(60) a. *Hvad er* DET*?*
(What is IT (THIS/THAT)?)

b. Det er HENDES
(It is HERS)

Personal pronous used as deictics are also stressed as illustrated by example (1) which is repeated in (61).

(61) HAM *skal du snakke med*
(HIM shall you speak to)

Personal pronouns are stressed in the following cases:

1. when they are topicalised. Examples are given in (62).

   (62) a. DEM *har jeg ikke hørt fra*
   (THEM have I not heard from)

   b. HAM *kan jeg lide*
   (lit. HIM like I)
   (HIM I like)

2. when they occur as constituents in coordinated nominal phrases. This is illustrated in (63).

   (63) a. *Vi har inviteret* DEM *og deres børn*
   (We have invited THEM and their children)

   b. DU *og* JEG *vasker op*
   (YOU and I do the dishes)

3. when they are postmodified, as shown in (64).[5]

[5]Not being anaphors, these uses are outside the scope of this dissertation.

(64) *Jeg kender* HENDE *der går der*
(I know HER who goes there)

4. when they occur in cleft constructions, as shown in example (65).

(65) *Det var* HAM *der tog dine nøgler*
(It was HIM who took your keys)

5. if they are juxtaposed or in contrastive position. This is illustrated in (66).

(66) a. HAN *læste avisen og* HUN *vaskede op*
(HE read the newspaper and SHE did the dishes)
b. *Skal jeg også hente* HAM
(lit. Shall I also get HIM)
(Shall I get HIM also)

Personal pronouns can receive stress in utterances where the speaker gives information about the nominal antecedent which has just been introduced in discourse. An example of this is given in (67).

(67) *Der går en mand på broen.* HAN *er meget gammel*
(lit. There walks a man on the bridge. HE is very old.)
(A man is walking on the bridge. HE is very old.)

Hansen & Lund (1983)[30] illustrate this type of stress with some contrastive examples. Two of these examples are given in (68). In (68-a) the speaker presupposes that the person named *Jens* is unknown to the addressee. On the contrary in (68-b) the speaker refers to a man named *Jens* who is known to the hearer.

(68) a. *Nu skal du høre en historie om Jens.* HAN *er en frække lille fyr...*
(lit. Now shall you hear a history about Jens. HE is a nasty little boy...)
(Now you must hear a history about Jens. HE is a nasty little boy...)
b. *Det var det sidste jeg hørte fra Jens. Han bor nu i Australien.*
(It was the last thing I heard from Jens. He lives now in Australia.)

Hansen & Lund (1983) and Thorborg (1998) propose the following account for the difference between the interpretation of unstressed and stressed pronouns when there are more candidate antecedents in the preceding sentence: the unstressed pronoun refers to the first occurring antecedent, while the stressed pronoun refers to the latter. Thorborg (1998) illustrates this with (69).

(69) a. *Jette tog ud for at tale med sin søster.* HUN *er ved at blive skilt.* (hun: søsteren)
(Jette went out to speak to her sister. SHE is getting divorced). (she: the sister)

b. *Jette tog ud for at tale med sin søster. Hun er ved at blive skilt.* (hun: Jette)
(Jette went out to speak to her sister. She is getting divorced.) (she: Jette)

I think that this explanation does not account for all the uses of stressed pronouns. I suggest that prosodic marked pronouns in Danish can signal that the antecedent is not the most expected discourse element. This is also noticed in the literature for English (see section 3.1.2).[6] Furthermore stressed pronouns can mark a contrastive reading (the two functions of prosodic marking are not mutually exclusive).

To test this assumption I asked eighteen native speakers of Danish to choose the preferred antecedents for the pronouns in the utterance pairs given in (70) and (71). The only difference between the first and second utterance in each pair is that in the first utterance the pronouns are prosodic unmarked, while in the second the pronouns are prosodic marked.

(70) a. *Peter mødte Jan på udstillingen. Han hilste ikke på ham.*
(Peter met Jan at the exibition. He did not greet him.)
b. *Peter mødte Jan på udstillingen.* HAN *hilste ikke på* HAM.
(Peter met Jan at the exibition. HE did not greet HIM.)

(71) a. *Hanne genkendte Maria. Dernæst genkendte Kevin hende.*
(lit. Hanne recognised Maria. Then recognised Kevin her.)
(Hanne recognised Maria. Then Kevin recognised her.)
b. *Hanne genkendte Maria. Dernæst genkendte Kevin* HENDE.
(lit Hanne recognised Maria. Then recognised Kevin HER.)
(Hanne recognised Maria. Then Kevin recognised HER.)

Seventeen out of the eighteen test-persons chose the following interpretations (72-a)-(72-d) for utterances (70-a)-(71-b) respectively.

(72) a. *Peter$_i$ mødte Jan$_j$ på udstillingen. Han$_i$ hilste ikke på ham$_j$.*
b. *Peter$_i$ mødte Jan$_j$ på udstillingen. HAN$_j$ hilste ikke på HAM$_i$.*
c. *Hanne$_i$ genkendte Maria$_j$. Dernæst genkendte Kevin hende$_j$.*

[6] One of the first papers on the relation between intonation and anaphora is in (Akmajian & Jackendoff 1970).

d. *Hanne*$_i$ *genkendte Maria*$_j$. *Dernæst genkendte Kevin HENDE*$_i$.

The preferred readings in the unmarked contexts (examples (70-a) and (71-a)) follow the so-called grammatical parallelism preference, according to which the preferred antecedent of a pronominal anaphor is the nominal phrase that in the preceding utterance has the same grammatical function as the anaphor.[7] The analysed data indicates that parallelism can explain many cases of pronominal use. Parallelism preference is discussed further in chapters 6 and 10.

The preferred interpretations of the marked pronouns in example (70-b) and (71-b) are the antecedents which are not the preferred ones in unmarked contexts. The preferred interpretation of example (71-b) is in contrast with the explanation of the function of prosodic stress in (Hansen & Lund 1983, Thorborg 1998), but confirms my interpretation of these cases of stressed pronouns.

Concluding prosodic marking of pronouns can signal that the referent is not the most expected one in that context, but it can also signal phenomena such as topicalisation, juxtaposition and contrast which are related to the information structure of utterances (see chapter 4).

2.5 Word Order in Danish

Danish word order is usually described by means of the so-called field schema proposed by Diderichsen (1957[1946]). In the following description I mainly follow Hansen (1977) who developed Diderichsen's theory further, but I only focus on the position of nominals.

The field schema for main clauses is given in table 2.3.

Forb. (Conj.)	Fundament (Front)	Nexus (Actualisation)	Indhold (Content)
		v n a	V N A

Table 2.3: Field schema for main clauses

The conjunction field (**forbinderfelt**) is the position of coordinating conjunctions. The front field (**fundamentfelt**) can be occupied by different elements, such as nominal phrases, adverbials, verbs and subordinated clauses. Only a

[7]Although there are cases where the semantic roles have importance for anaphora resolution it has been noted in the literature that syntactic roles are more influential for anaphora resolution than semantic ones (Grosz et al. 1995). The Danish data confirm this. I discuss this point further especially in chapters 10 and 11.

constituent can occur in this position in a clause. In the **v-field** the finite verb occurs, while the subject occupies the **n-field** unless it occurs in the front field.

Actualisation adverbs, such as *jo* (sure), *måske* (maybe) and *nok* (probably), occur in the **a-field**. In the **V-field** non-finite verbs occur while subject predicates, non-prepositional indirect objects, direct objects, object predicates and the existentials in *der*-constructions are placed in the **N-field**. The remaining complements and adverbials occur in the **A-field**.

The schema for the examples in (73) can be found in table 2.4.

(73) a. *Men i dag vil Peter ikke snakke med Anne*
(lit. But today wants Peter not speak with Anne)
(But today Peter does not want to speak with Anne)

b. *Men i dag vil han ikke snakke med hende*
(lit. But today wants he not speak with her)
(But today he does not want to speak with her)

c. *Min mor gav en blomst til Maria i går*
(My mother gav a flower to Maria yesterday)

d. *Hun gav en blomst til hende i går*
(She gav a flower to her yesterday)

e. *Maria har jeg ikke set længe*
(lit. Maria have I not seen for a long time)
(Maria I have not seen for a long time)

f. *Hende har jeg ikke set længe*
(lit. Her have I not seen for a long time)
(Her I have not seen for a long time)

g. *Og måske har Maria også givet Peter et kys*
(lit. And maybe has Maria also given Peter et kiss)
(And maybe Maria has also given Peter a kiss)

h. *Og måske har hun også givet ham et kys*
(lit. And maybe has she also given him et kiss)
(And maybe she has also given him a kiss)

i. *kommer Peter/han ikke i morgen?*
(lit. comes Peter/han not tomorrow?)
(does Peter/han not come tomorrow?)

A non-subject constituent in the front field of the sentence is said to be topicalised. However I do not consider unstressed pronouns in the front field as topicalised elements. This exception is discussed in chapter 4.

Hansen (1977) adds to Diderichsen's schema a field for negated elements (**neg field**) which is in-between the **a-** and the **N-field**. Furthermore he adds a **light field** (**let felt**) to the schema. This field precedes the **a-field** and is occupied

C	F	v	n	a	V	N	A
men	idag	vil	Peter	ikke	snakke	-	med Anne
men	idag	vil	han	ikke	snakke	-	med hende
-	Min mor	gav	-	jo	en blomst	-	til Maria i går
-	Hun	gav	-	jo	en blomst	-	til hende i går
-	Maria	har	jeg	ikke	set	-	længe
-	Hende	har	jeg	ikke	set	-	længe
og	måske	har	Maria	også	givet	Peter et kys	-
og	måske	har	hun	også	givet	ham et kys	-
-	-	kommer	Peter/han	ikke	-	-	i morgen

Table 2.4: Field schema for examples (73-a)-(73-i)

by unstressed indirect and direct object pronouns. Weak pronouns are light elements and move from the **N**-field to the left according to the so-called *vægt princip* (weight principle). The principle states that light elements tend to move to the left in the sentence, while heavy (long) elements tend to move to the right (Diderichsen 1957[1946], Hansen 1977).

The field schema for the examples in (74) are given in table 2.5.

(74) a. *Han gav ham det jo ikke*
(lit. He gave him it surely not)
(He surely did not give it to him)
b. *Min mor gav hende den nok*
(lit. My mother gav her it probably)
(My mother probably gave it to her)
c. *Jeg har ikke givet hende den*
(lit. I have not given her it)
(I have not given it to her)
d. *Peter burde have sendt brevet til hende*
(Peter should have sent the letter to her)

The field schema for subordinated clauses differs from that for main clauses in that two conjunctions, a coordinated and a subordinated one can begin the clause. Furthermore the subject, the actualisation adverb and the finite verb (or the infinitive) occur in this order in the nexus field. This is illustrated in table 2.6.

The fields of subordinated clauses are explained in the following. In the first conjunction field coordinated conjunctions occur, in the second subordinate con-

C	F	v	n	light	a	neg	V	N	A
-	han	gav	-	ham det	jo	ikke	-	-	-
-	Min mor	gav	-	hende den	jo	-	-	-	-
-	Jeg	har	-	-	-	ikke	givet	hende den	-
-	Peter	burde	-	-	-	-	have sendt	brevet	til hende

Table 2.5: Field schema for examples (74-a)-(74-d)

Forb. (Conj.)	Forb. (Conj)	Nexus (Actualisation)	Indhold (Content)
cconj	sconj	n a v	V N A

Table 2.6: Field schema for subordinate clauses

junctions. In the nexus field the subject, the actualisation adverb and the finite verb (or an infinitive) occur in this order (nav). The Content field is the same as for main clauses.

The schema for the examples in (75) are given in table 2.7.

(75) a. *... og fordi Peter ikke kan snakke med Anne nu*
(lit.... and because Peter not can talk with Anne now)
(... and because Peter cannot talk with Anne now)
b. *... og fordi han ikke kan snakke med hende nu*
(lit.... and because han not can talk with her now)
(... and because han cannot talk with her now)
c. *Han lovede straks at sige til*
(He promised immediately to say so)
d. *... hvis du ikke giver Peter brevet*
(lit. ... if you not give Peter the letter)
(... If you do not give Peter the letter)
e. *... hvis du ikke giver ham det*
(lit. ... if you not give him it)
(... If you do not give it to him)

As seen in section 2.1.1 possessives can both occur as determiners and as independent pronouns.[8]

Concluding Danish pronouns occur in the same position as other nominals, with

[8]I refer the reader who is interested in the order of determiners in Danish to (Neville 2000).

CC	SC	n	a	v	V	N	A
og	fordi	Peter	ikke	vil	snakke	-	med Anne nu
og	fordi	han	ikke	vil	snakke	-	med hende nu
-	-	-	straks	at sige	-	-	til
-	hvis	du	ikke	giver	-	Peter brevet	-
-	hvis	du	ikke	giver	-	ham det	-

Table 2.7: Field schema for examples (75-a)-(75-e)

the exception of unstressed pronouns in main clauses which move to the left from the N-position to a light field before actualisation adverbials.

2.6 Summary

First and second person pronouns are deictics and following Walker (1993) I assume that they are always available as part of the discourse model. In this dissertation I only account for the intersentential anaphoric uses of third person personal, possessive and demonstrative pronouns.

Personal pronouns have both a nominative and an accusative case, the former is used for subjects, the latter for objects and prepositional cases. Pronominal subject complements occur in both accusative and in nominative form, depending on the context in which they occur. These contexts were described in section (3).

Third person pronouns agree in number (*singular/plural*) with the antecedent nominal(s). The antecedents of plural pronouns can be plural nominals, coordinated or split (singular and/or plural) nominal(s), list of entities in the preceding clause(s) or nominals denoting places and/or institutions, in which cases the plural pronouns refer to the people living or working in these places and institutions. There are also cases of antecedentless plural pronouns. Here the antecedent must be inferred from the context.

Pronouns with a collective noun antecedent can either agree syntactically or semantically with their antecedent. In the first case they are singular, in the second case they are plural.

Singular pronouns also agree in gender with their antecedents. The following four genders are used: *feminine*, *masculine*, *common* and *neuter*. When the antecedent is a nominal referring to an inanimate entity, the agreement is in most cases syntactic (*common* and *neuter* gender). The agreement is nearly always semantic when the antecedent nominal refers to an animate entity (*feminine* and *masculine* gender). In this case the pronoun agrees with the sex of the entity denoted by the nominal antecedent.

To deal with pronominal anaphors it is thus necessary to have information about number, semantic and syntactic gender.

In some cases the neuter gender singular pronoun *det* (it) can be used generically to corefer with antecedents of different gender or number. Its use is restricted to copula constructions if the antecedent is a human.

Both *den* (it common gender) and *det* (it neuter gender) are used to refer to common gender abstract nominals

There are cases where the antecedents of both singular and plural pronouns are not explicitly referred to in discourse and thus must be inferred from the context.

The demonstrative *den* cannot refer to a human when used as an independent pronoun. *Denne* is used instead. The data indicate that the anaphoric *denne/dette/disse* can only corefer with non subject antecedents in the same clause. Intersententially they can refer to the subjects of the preceding clause, but only when there are no competing antecedents. In this case the demonstrative pronouns emphasise the entities they refer to.

The Danish discourse deictics are *det*, *det her*, *det der* and *dette*. They can refer to abstract nominals and to one or more verbal phrases, infinitives, clauses, discourse segments. They can also vaguely refer to something not explicitly uttered in the previous discourse, but which must be inferred from it. Danish discourse deictics are used in the same contexts as in English, but they are also used in contexts where ellipses or the anaphoric *so* and *too* are preferred in English. The contexts in which Danish discourse deictics often occur were listed in section 2.3.

Dette (this) as discourse deictic is seldom used in spoken language. In written language *dette* (this) is used to emphasise the referent and to indicate that the pronoun is a discourse deictic if there is a competing candidate individual antecedent in the preceding utterance. Furthermore *dette* (this) is often preferred to *det* when it refers to the last mentioned situation in the previous sentence, instead of to the whole sentence or to a discourse deictic in this sentence.

In section 2.4 the general prosodic rules for personal, possessive and demonstrative pronouns were described. Personal pronouns and possessives with a determinative function are usually unstressed, while demonstrative pronouns and possessives in independent function are stressed. Personal pronouns are stressed if they are topicalised, juxtaposed or/and used in contrastive contexts. Pronouns are also stressed if they occupy the N-position in cleft constructions, if they are a constituent in coordinated nominal phrases or if they are postmodified. Personal pronouns can be prosodic marked if their antecedent is an entity that has just been introduced in discourse. Differing from Hansen and Lund I suggest that a stressed pronoun can signal that the referent is not the antecedent which would be preferred in unmarked contexts. This is in line with some analyses of marked pronouns in English, i.a. Ariel (1994).

In section 2.5 the position of Danish pronouns in both main and subordinate clauses were described by means of the field schemas proposed by Diderichsen (1957[1946]) and further developed by Hansen (1977). Danish is a language with fixed word order. Strong stressed pronouns occur in the same positions as other nominal phrases, while light unstressed pronouns have a tendency to move to the left in main clauses.

The fact that prosodic marking of pronouns and the use of demonstrative pronominal anaphors instead of personal pronouns can influence anaphora resolution is accounted for in some of the pragmatic studies of the use of referring expressions which we present in chapter 3. The interaction between word order and prosodic marking of pronouns and how this interaction influences anaphora resolution are furthermore discussed in chapter 4, which deals with theories about the information structure of utterances.

Chapter 3

Pragmatic Theories on the Use of Referring Expressions

Many computational approaches to anaphora resolution have used models accounting for the use of referring expressions proposed in pragmatic theories.[1] Because the theories focus on different aspects they also model different phenomena and this is reflected by the computational models related to them.

In this chapter the theories which have been most influential on computational models of pronominal resolution and which can provide an account of the phenomena related to Danish anaphors are discussed. In particular in section 3.1 models which focus on the cognitive aspects of the use of referring expressions (Prince 1981, Prince 1992, Gundel et al. 1993, Ariel 1988, Ariel 1994) are described and discussed, while in section 3.2 a model emphasising the importance of *topic* for understanding anaphora (Givón 1976, Givón 1983) is outlined. Here *topic* is understood as the main subjects of the current discourse.

Finally in section 3.3 I discuss differences and similarities between the theories focusing on the Danish anaphoric uses which the various theories provide an account of.

[1] There are also pragmatic approaches that account for the use of intrasentential anaphora, as for example the so-called neo-gricean accounts proposed by (Levinson 1991, Huang 1991, Huang 2000). Levinson presents a revision of Grice's theory of conversational implicatures (Grice 1975), defining Q-, I- and M-principles. He then uses these principles to reduce Binding conditions. Huang (Huang 2000) uses Levinson's principles to define a general pragmatic apparatus of intrasentential anaphora resolution. He argues that syntax interacts with pragmatics in the use of anaphora. Thus his pragmatic apparatus provides "a set of complementary, explanatory principles that constrain the interpretation or production of an utterance whose linguistic representation has already been antecedently recognised" (Huang 2000)[213].

3.1 Cognitive-based Approaches

Cognitive-based theories about the use of referring expressions presuppose that a speaker makes an assumption about the status of entities in the addressee's mental state and this influences her/his choice of referring expressions. In the theories models are presented illustrating the relation between the mental state which the speaker/writer assumes about the hearer/reader and the use of referring expressions.

3.1.1 The Familiarity Taxonomy

Prince (Prince 1981, Prince 1992) distinguishes between three interdependent notions of "old/given" and "new" information. In the first notion the given and new information are related to the form in which information is presented in utterances. This corresponds to the notions of *focus/(back)ground*, *theme/rheme*, *comment/topic*, *focus/topic* in information packaging which I discuss in chapter 4. The two other notions are related to the hearer's mental model and the discourse model. The latter model is built up while processing discourse. According to the hearer's and the discourse model information can be **hearer-old** or **hearer-new** and **discourse-old** and **discourse-new**. **Discourse-old** information is also **hearer-old** and **hearer-new** information is always **discourse-new**. However **hearer-old** information is not necessarily **discourse-old** and **discourse-new** information is not always **hearer-new**.

Prince (1981) develops a taxonomy, the **Familiarity Taxonomy**, illustrating to which degree information is assumed to be known to the addressee by the speaker. In the taxonomy entities are new or given, where given means that

> *the speaker assumes that the hearer knows, assumes or can infer a particular thing.* (Prince 1981)[230]

Thus the **Familiarity Taxonomy** refers to the assumed hearer's model. It is illustrated in figure 3.1.

Information is assumed to be **new**, **inferable** or **evoked**. **New** information is classified as **Brand-new** if the speaker assumes that the hearer must create the entity in both his model and in the discourse model. **Brand-new** entities can be linked (anchored) to another NP in discourse. **Unused** entities are entities that the hearer is assumed to have in his own model, but which have to be introduced to the discourse model. **Inferables** are entities that can be inferred. **Containing inferables** are entities which are inferable by a set-member inference contained within the inferable NP itself (e.g. "one of those men"). NPs referring to entities

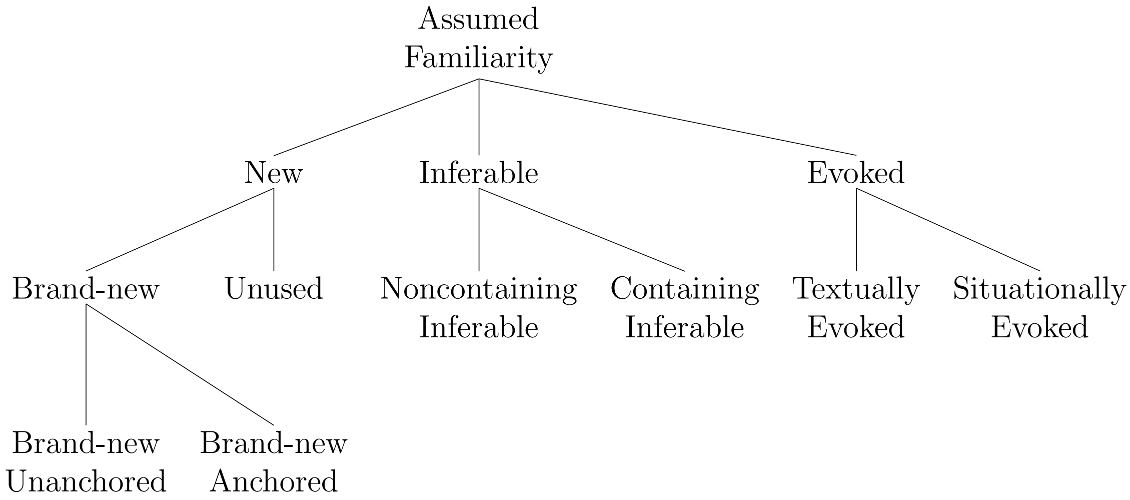

Figure 3.1: The Familiarity Taxonomy

already present in the discourse model are called **evoked** and can be **textually** or **situationally** evoked. The following are examples of the different types of information:

(1) a. *I saw **a car**.* - brand-new
b. ***A man my husband knows** had a terrible accident.* - brand-new anchored
c. *I took a cab. **The driver** was angry.* - inferable
d. ***The windows of our house** are white.* - containing inferable
e. *I met your brother. **He** is tall.* - textually-evoked
f. *Hello, how are **you**.* - situationally-evoked

Prince proposes a **Familiarity Scale** for her taxonomy which is given in 3.2.

Evoked > Unused > Noncontaining Inferable > Containing Inferable > Brand-New Anchored > Brand-New Unanchored

Figure 3.2: Prince's Familiarity Scale

What is interesting in Prince's theory is the identification of the relation between hearer and discourse models and the proposed scale of the assumed familiarity of various entities in the hearer model. An operationalised version of Prince's taxonomy has been used by Strube (1998) to implement functional ranking of discourse entities in the Centering theory. I outline the Centering theory and Strube's version of it in section 6.3.

3.1.2 The Accessibility Marking System

Ariel (1988) criticises the taxonomy proposed by Prince because it does not account for the distribution of referring expressions. She shows that entities corresponding to the same type in the **familiarity taxonomy** have different distributions in texts. In particular Ariel reports that in written texts the antecedents of a pronoun or a demonstrative are often found in the preceding sentence, or, in the case of pronouns, in the same sentence. The antecedent of definite descriptions is more distant, i.e. it occurs in the same paragraph or across the paragraph. All these expressions are textually evoked in Prince's model.

Ariel suggests that natural languages give the speakers means to code the accessibility of the referent to the addressee. The factors which determine the accessibility of referring expressions are, in her opinion, the distance between antecedent and anaphor, the number of competing antecedents, the importance of topicality in antecedent assignments and the role of frames in identifying antecedents. On the basis of the first factor (referential distance) Ariel builds an **accessibility marker** system for referring expressions. In the system each linguistic expression marks a status of accessibility of mental representations.[2]

A simplified version of Ariel's **Accessibility Marking Scale** is given in figure 3.3 (Ariel 1994).

zero < reflexives < cliticised pronouns < unstressed pronouns < stressed pronouns < stressed pronouns + gesture < proximal demonstrative (+ NP) < distal demonstrative (+ NP) < first name or **last name < definite description < full name**

Figure 3.3: Ariel's Accessibility Marking Scale

The accessibility of the expressions decreases from left to right. The highest accessibility markers are the most unmarked linguistic expressions and this unmarkedness is indicated by the sign < in the scale. In fact the main claim behind the **Accessibility Marking Scale** is that natural languages code the degree of

[2] *Unmarked* is understood as prototypical, while the concept of *markedness* presupposes the notion of **formal complexity** as noticed by (Givón 1995) and is connected with structural complexity, low frequency and cognitive complexity.

accessibility by informativity, rigidity and attenuation. The more (lexically) informative, the more rigidly (unambiguously) and/or the less attenuated the form (longer or louder) of a referring expression the lower accessibility it marks. This claim is in my opinion intuitively true.

According to the scale pronouns are **high** accessibility markers, while demonstratives are **mid** ones. Stressed pronouns mark lower accessibility than unstressed ones. Ariel (1994) reports that most of the pronouns with a distant antecedent in her data have discourse topic antecedents, thus they are high accessible because the antecedents are prominent entities in discourse.

Because the **Accessibility Marking Scale** is based on a measurable factor, the model has been tested in a number of languages. Ariel's methodology of measuring the referential distance and the topical prominence of referents has also been applied to Swedish by Fraurud (1992) and to Danish by Ravnholt (1994) (see section 6.6).

From a computational point of view it is useful to know the statistical measures of the distance between a pronoun and its antecedent. Ariel's analysis of stressed pronouns as lower accessibility markers seems to be also valid for Danish. Ariel also points out that the topical prominence of the antecedent is important when determining the degree of accessibility of a referring expression. This notion is exploited in the analysis of referring expressions proposed by Givón (1983) (section 3.2).

3.1.3 The Givenness Hierarchy

Also Gundel et al. (1993) state that the form of referring expressions depends on the assumed cognitive status of the hearer. Different determiner and pronominal forms conventionally signal different cognitive statuses. Gundel et al. (1993) develop a hierarchy, the **Givenness Hierarchy**, of these assumed cognitive statuses and they connect them to precisely identified referring expressions.

The hierarchy and the corresponding English expressions are given in table 3.1.[3] Gundel et al. (1993) argue that their hierarchy is universal, although not all languages have referring expressions for each status in the hierarchy and they provide evidence for this claim by discussing the use of referring expressions in a number of languages. The correlation of form and statuses interacts with the Gricean maxim of quality, i.e. "make your contribution as informative as is required" and "do not make your contribution more informative than is required".

While the statuses in Prince's **Familiarity Scale** and in Ariel's *Accessibility*

[3]Gundel et al. (1993) give the following example of "indefinite this N": *I couldn't sleep last night. This dog (next door) kept me awake.* In the example the speaker intends to say something about a particular dog.

in focus	>	activated	>	familiar	>	uniquely identifiable	>	referential	>	type identifiable
it		*that* *this* *this* N		*that* N		*the* N		indefinite *this* N		*a* N

Table 3.1: The Givenness Hierarchy

Scale are mutually exclusive, the statuses in the **Givenness Hierarchy** are implicationally related, i.e. a form can encode the necessary and sufficient status it belongs to as well as all the higher statuses in the hierarchy (the statuses on its left). The fact that the statuses in the **Givenness Hierarchy** are implicationally related accounts for the cases when a speaker for different reasons chooses to use a referring expression corresponding to a status more on the right side of the hierarchy than required by the hearer's cognitive status.

The model developed by Gundel et al. also differs from Prince's in that in the former inferables do not correspond to a particular cognitive status. Instead they are associated to different linguistic forms depending on the type of the link between them and the associated discourse entities and they inherit the cognitive status of these forms.

This analysis of inferables is, in my opinion, more correct than the one proposed by Prince because even pronouns which are textually-evoked entities in Prince, can occur in discourse without an explicit antecedent. This is the case for the antecedentless plural pronoun *de* (they) in example (36) section 2.2.3 which is repeated in (2).

(2) **D:** *ja den* (= blood sample) *var normal*
(yes it was normal)
P: *nå den var normal jep den var normal*
(so it was normal yes it was normal)
D: *ja så fik* ***de*** *jo den og hvis den næste her også er normal, så er der ikke sket noget*
(lit. yes so got **they** it and if the next sample here is also normal, then is there not happened anything)
(yes so **they** got it and if the next sample here is also normal, then nothing happened)
(SL)

Although **de** (they) has no explicit antecedent in the dialogue, it is common knowledge for the doctor (**D**) and the patient (**P**) that blood samples are sent to a laboratory to be tested. Talking about the results of the patient's blood test brings into focus the representation of the people who make this test and this legitimises the reference to them.

3.2 The Predictability and Continuity of Referring Expressions

For Givón (Givón 1976, Givón 1979, Givón 1983) a central factor for understanding the choice of different anaphoric expressions is topic continuity.

Givón (1976) argues that agreement and pronominalisation are two related processes both connected with topicality. He states that a universal hierarchy of topicality exists indicating "the likelihood of various NP arguments being the topic of sentences, and more particularly the topic in topic-shift constructions" (Givón 1976)[152]. Givón suggests that this universal implicational hierarchy is the result of the following four binary hierarchical relations:

1. HUMAN > NON_HUMAN
2. DEFINITE > INDEFINITE
3. MORE INVOLVED PARTICIPANT > LESS INVOLVED PARTICIPANT
4. 1ST PERSON > 2ND PERSON > 3RD PERSON

The first relation reflects the fact that people tend to speak more about humans than about non-humans. The second relation predicts that old information is more often the topic than new information. The third relation predicts the following "topicality" case hierarchy:

AGENT > DATIVE> ACCUSATIVE

The fourth relation reflects the fact that the speaker is the most highly presupposed argument of discourse. The four relations exhibit a number of interdependencies.

Givón (1983) presents a model accounting for the predictability and continuity of referring expressions, which is based on the analysis of the transcriptions of dialogues in different languages. Givón measures topic continuity on the basis of two factors: the referential distance, measured as the number of clauses/sentences between the referring expression and its antecedent(s) and the persistence (decay) of the subject NPs. Furthermore he distinguishes between two categories of pronominal anaphors, those whose antecedent is in the preceding clause and those having a more distant antecedent. For both types of pronoun Givón marks whether the pronoun follows a *minor* or a *major juncture*. He defines a *minor juncture* as a juncture where the action continues in sequence, indicating thematic continuity. *Minor junctures* can be marked by commas or conjunctions such as *and*, *then*, *so*, *when*, *because*. Examples of minor conjunctions in Danish are given in (3). In (3-a) the minor juncture is indicated by the coordinating conjunction *og* (and), while in (3-b) it is not indicated at all.

(3) a. *med Ronnie fik jeg først at vide jeg var gravid i september og han kom i februar,*
(lit. with Ronnie got I only to know that I was pregnant in september and he came in february)
(with Ronnie I only found that I was pregnant in september and he came in february)
(SL)
b. *spurgt min søster hun er læge*
(asked my sister she is a doctor)
(SL)

Major junctions are often marked by periods (in written language) or pauses or by an introductory phrase, quite often contrastive. They tend to break action and theme continuity. An example of **major juncture** from BYSOC is in (4). In the example the major juncture is signalled by the conjunction *men* (but).

(4) **A:** *der boede nogle mennesker der med H (uf)*
(there lived some people there with H (uf))
B: *ja*
(yes)
A: *hed £ J%%%%%*
(name was £ J%%%%%)
B:*ja*
(yes)
A: *så flyttede de over på hjørnet af S%%%%%%%% og £ Ø%%%% V%%%*
(lit.then moved they on the corner of S%%%%%%%% and £ Ø%%%% V%%%)
(then they moved on the corner of S%%%%%%%% and £ Ø%%%% V%%%)
B:*ja*
(yes)
A: *hvordan fanden var det nu ££ de tog navneforandring på et eller andet tidspunkt så de kom til at at hedde B%%%%%%% £ så flyttede de £ nej*

££ hvordan pokker var det de flyttede over på hjørnet der £ og så ville de ikke hedde H%%%%%% me- nej £ ja de hed altså H%%%%% £ og så f- fik de navneforandring til B%%%%%%% fordi de flyttede over på et hjørne (ler) det er herligt simpelt hen
(how the damn it was ££ they changed their name at some time so their name become B%%%%%%% £ then they moved £ no ££ how the deuce it was they moved on the corner there £ and then they did not want to have the name H%%%%%% mo- no £ yes their name was actually H%%%%% £ and then they changed it to B%%%%%%% because they moved on a corner (laughs) it is simply great)
B: *ja ha ha*
(yes ha ha)
A: *men **han** hedder altså E%%% H%%%%% han er ingeniør deroppe*
(lit. but **he** is therefore named E%%% H%%%%% he is an engineer there over)
(but **his** name is therefore E%%% H%%%%% he is an engineer there over)

From his analysis Givón concludes that pronouns with short referential distance usually occur after minor junctures, while those with referential distance of more clauses often follow a major juncture. Givón considers the first type of pronoun as anaphoric/continuative (normally unstressed), while the latter is contrastive/topic changing, resumptive (normally stressed). Givón presumes that contrastive/topic changing pronouns exhibit a higher persistence measure than other topic changing categories, i.e. left and right dislocation.

On the basis of his investigation Givón develops a **Hierarchy of Referentiality of NP types** (3.4) indicating the predictability (most continuous/accessible topics) of the expressions. Predictability in the hierarchy decreases from left to right.

zero > unstressed/clitic pronoun > stressed/independent pronoun > full definite NP > modified definite NP

Figure 3.4: Givón's hierarchy of referentiality of NP types

Givón presents cross-linguistic evidence in support of his model.

Givón's hierarchy is similar to Ariel's **Accessibility Marking Scale**, although it is less detailed. Givón's and Ariel's theories are compatible. Both state that there is a relation between the linear distance, the number of the competing referents and the thematic status of the protagonist. Givón adds to these elements the continuity of a topic. If a topic is more continuous, there is a higher probability that reduced anaphoric expressions are used. The centrality of topic in Givón's theory and his analysis of types of juncture between clauses and sentences indicate that the structure of discourse also plays a role in understanding the use of referring expressions. Givón only looks at linear distance and type of juncture, but he notices that stressed pronouns can have a resumptive function, indicating that the structure of discourse is not always linear. This aspect is discussed in chapter 5.

3.3 Conclusion

In all the pragmatic models presented in this chapter pronouns are assumed to refer to salient entities in discourse, i.e. to entities that are known (Prince), "in focus" (Gundel et al.), topic prominent (Givón) and accessible (Ariel). Although all the cognitive-based models connect the mental status that the speaker/writer assumes about the hearer/reader with the use of referring expressions, the models focus on different aspects.

Prince's **Familiarity Taxonomy** accounts for the givenness or novelty of entities in the assumed hearer model. Third person pronouns and some kinds of definite nominals refer to textually evoked entities, i.e. entities that are assumed to be known. Because Prince only looks at the givenness aspects in the hearer's model her taxonomy is not enough fine-grained to account for the use of different types of pronoun.

The **Givenness Hierarchy** developed by Gundel et al. accounts for the status of entities in the hearer's attentional model. The statuses in their **Givenness Hierarchy** are not mutually exclusive and they state that inferables do not correspond to a particular mental status, but are connected to different statuses, depending on their form. Gundel et al.'s distinction between "in focus" and "activated" entities, corresponding to personal and demonstrative pronouns is relevant to the study of Danish anaphora, as noticed in chapter 2. Both types of pronoun are textually evoked in Prince's **Familiarity Taxonomy**. Gundel et al. do not provide an account of the difference between stressed and unstressed pronominal anaphors.

Ariel interprets referring expressions as marks of the accessibility of the entities they refer to in the addressee's mental model. Her **Accessibility Marking Scale** is measured on the basis of the referential distance between referents and their antecedent, but the number of competing antecedents and their topical prominence are also aspects which she considers in her model. The most accessible referring expressions are zero pronominals, then reflexives, cliticised pronouns, unstressed, stressed pronouns, proximal and distal demonstratives in the given order. Pronouns can have distant antecedents, but these antecedents are in most cases accessible because they are topically prominent entities. In Ariel's scale stressed pronouns mark lower accessibility than unstressed ones, thus they are signals to the addressee to reject the unmarked co-reference interpretation reserved for zero anaphora and unstressed pronouns. Demonstrative pronominal anaphors also signal lower accessibility than personal pronouns. Both these differences are relevant for pronominal resolution in Danish.

Givón classifies referring expressions according to their predictability/continuity in the discourse context. Givón distinguishes between two uses of pronouns relative to their referential distance and their position in topic continuous or discontinuous contexts. The first type of pronoun is normally unstressed while the second type is possibly stressed. I believe that this is also the case in Danish.

In computational approaches to anaphora resolution the fact that pronouns are easily accessible has been implemented by limiting the scope of intersentential pronominal resolution to the immediately preceding sentence(s), ignoring the cases (numerous especially in dialogues) where pronouns have a referential distance of more than a few utterances. Ariel and Givón measure accessibility of referring expressions using linear referential distance, ignoring the fact that the structure of discourse is not linear, but hierarchical. Thus they cannot account for all cases of pronouns with distant antecedents. Although all models describe relevant and related aspects of referring expressions, Ariel's Marking Scale is the only model where the difference between both unstressed and stressed pronouns on one hand and pronouns and demonstratives on the other hand is accounted for.

Givón notices that stressed pronouns can have a resumptive function, but he does not investigate this aspect further. The fact that the structure of discourse is not linear is important because discourse structure determines the search space of possible antecedents. The relation between structure of discourse and anaphora resolution and the studies exploiting this aspect are presented in chapters 5 and 6. In chapter 6 I also outline computational approaches that follow the pragmatic models of pronominal uses discussed in this chapter.

Some of the phenomena described by the pragmatic studies presented in this chapter are strictly related to the phenomena analysed as information structure of utterances. In the following chapter I outline and discuss these phenomena focusing on the way they influence the resolution of Danish pronominal anaphors.

Chapter 4

Information Structure and Danish Pronouns

In this chapter I discuss phenomena related to the information structure (IS) of utterances which are relevant for Danish pronominal anaphors. Information structure is also called *information packaging*, a term introduced by Chafe (1976) who defines as packaging those phenomena "that have to do primarily with how the message is sent and only secondarily with the message itself, just as the packaging of toothpaste can affect sales in partial independence of the quality of the toothpaste inside" (Chafe 1976)[26]. To illustrate information packaging Chafe (1976) discusses the following packaging phenomena relevant to nominals:

1. **givenness**: the noun is **given** or **new**
2. **contrastiveness**: the noun is **a focus of contrast** i.e. it is contrasted to other entities
3. **definiteness**: the noun is **definite** or **indefinite**
4. **subjecthood**: the noun is the **subject** of the sentence
5. **topicality**: the noun is the **topic** of its sentence. This phenomenon is related to topicalisation in English and topicalisation can be related to contrastiveness
6. **point of view**: the noun may represent the individual whose point of view the speaker is taking

Some of the phenomena which Chafe describes, such as givenness, definiteness and subjecthood are those studied in the pragmatic studies discussed in the previous chapter. However while the focus in these studies is on the assumed mental state of the addressee, the emphasis in information packaging is on the way the speaker chooses to present her message given the assumed mental state of the addressee.

Information structure is accounted for by many theories. In this chapter I present the approach to information packaging presented by Vallduví (1992) and Vallduví & Engdahl (1995) who try to generalise the different theories on information structure and propose to consider information packaging as a mechanism for instructing the addressee about how to update her mental state after each utterance (section 4.1). In section 4.2 I shortly present some aspects of Rooth's theory of focus interpretation in terms of alternative semantics (Rooth 1992) which has been used to account for the use of English stressed pronouns by Kameyama (1998*b*). In section 4.3 I discuss the theory of information structure presented by Sgall et al. (1986) who describe salience of discourse entities in terms of this structure. Their theory provides an account of the preferred pronominal antecedent in cases where other accounts of salience fail in indicating the correct referent.

Although I do not discuss formally how IS is represented in different theories, it should be noticed here that Vallduví & Engdahl (1995) represent it syntactically, Rooth (1992) represents it semantically, while for Sgall et al. (1986) it is a pragmatic aspect which influences the meaning of sentences in general.

The phenomena which many languages use to indicate information structure are word order, intonation and syntax. This is also true in Danish as it is discussed in section 4.4. In section 4.5 I look at these phenomena in relation to the data presented in chapter 2 and discuss how the theoretic approaches proposed in (Vallduví & Engdahl 1995, Sgall et al. 1986, Rooth 1992) can account for some of these data. In section 4.6 I make some concluding remarks.

4.1 Vallduví and Engdahl

In the literature different terms for defining informational primitives have been used, i.a. *focus/(back)ground*, *theme/rhyme*, *comment/topic*, *focus/topic* and *new/given* (Kuno 1972, Daneš 1968, Halliday & Hasan 1976, Sgall et al. 1986).

Vallduví & Engdahl (1995) reduce the different definitions to the two groups *ground/focus* and *topic/comment*. The *ground/focus* distinction divides the sentence into a "non-informative, known, or expected part - the ground - and an informative, new, dominant, or contrary-to-expectation part - the focus." (Vallduví & Engdahl 1995)[p.462]. The *topic/comment* distinction divides the topic, which the speaker announces, from the comment where the speaker says something about the topic. Sentences may consist only of comment, if they are presentational, neutral descriptions or thetic.

Vallduví and Engdahl follow the instruction-based approach to information packaging proposed by Vallduví (1992). In this approach different information packagings are considered as different instructions for updating the addressee's information state, which is described as in Heim's *file change semantics* (Heim 1982). An addressee's information state is a file-like data structure. Files consist of file cards. Each file card contains a number of records or conditions with attributes and relations about the entity that record represents. Four types of instruction are recognised, corresponding to a different *focus-ground* partition. *Focus* is defined as the part of a sentence which the speaker believes is the information to be added to the information state of the hearer. Information in the *ground* is already subsumed by the input information state and indicates how to carry out the information update. The *ground* can be divided into *link* and *tail*. *Link* indicates where the focus should be put in the information state, i.e. it indicates a specific file card, and *tail* indicates how the focus fits in this card.

The four types of possible update instructions are **link-focus**, **link-focus-tail**, **focus** and **focus-tail**. Vallduví & Engdahl (1995) illustrate these types of instruction with the following four examples (p. 468):[1]

(1) a. Tell me about the president in the White House. Anything I should know?
The president [$_F$ hates CHOCOLATE].
b. And what about the president? How does he feel about chocolate?
The president [$_F$ hates] chocolate.
c. The president has a weakness.
[$_F$ He hates CHOCOLATE].
d. You shouldn't have brought chocolates for the president.
[$_F$ He HATES] chocolate.

Link-focus instructions designate a locus of update and indicate that the update must be carried out with an addition of a condition on that locus. In (1-a) the extra condition "hates chocolate" must be added to the known information denoted by "the president". In **link-focus-tail** instructions in addition to the locus of update ("the president") the speaker presents a given condition which the update completes or alters ("the chocolate"). Examples (1-c) and (1-d) have no link. In both cases the link is inherited from the link in the previous discourse. (1-c) only consists of **focus** information, while in (1-d) there is both a focus and a tail (*chocolate*).

In Vallduví & Engdahl (1995) both links and foci can have a contrastive reading. Links and focus in English are associated to different types of pitch accent. Links may appear in their usual position or in left-hand position in the utterance

[1]The capital letters in the examples indicate the lexical item associated with sentential nuclear stress within the focus.

(topicalised links). Vallduví & Engdahl (1995) distinguish between topicalised and non topicalised foci, where the previous ones are both focus and link as it is illustrated in example (2-b). Here *Fido* refers to two discourse elements, a set (the link) and the specification of a value or an element in the set.

(2) a. They named their dog [$_F$ FIDO]
    b. [$_F$ FIDO] they named their dog

The set specified in (2-b) is the set of dog names, probably ordered according to their degree of "clichédness", and the value is "Fido" which is extremely clichéd. The value is focus (new information), while the set is the link (belongs to the ground). The important aspect in this analysis is that information in the focal part of an utterance is at the same time new and given information, independently of the form of the referring expression when it has a contrastive reading. IS information is thus important to determine whether information is new or given in the hearer model.

Vallduví & Engdahl (1995) also distinguish between topicalisation and topic fronting in Swedish. The former phenomenon occurs as in English when a link is moved to the left-hand position in the utterance. Topic fronting occurs when unstressed (weak) pronouns are in the left-hand position. Topic fronted weak pronouns do not have a link function, but signal their status as continuing topics from the previous clause. Vallduví and Engdahl illustrate topic fronting in Swedish with the examples in (3). (3-a) and (3-b) are both possible continuations of (3) (Vallduví & Engdahl 1995)[500] and, according to the authors, there is no difference between them from the point of view of information packaging. This means that unstressed pronouns in front position do not have a contrastive reading.

(3) I går fick jeg en bok
    yesterday 1st-pst-get I a book
    'Yesterday I got a book'
    a. Den ska jeg läse i kväll
       it fut I read tonight
    b. Jeg ska läse den i kväll
       I fut read it tonight
       I will read it tonight

In their paper Vallduví and Engdahl also describe and compare how information packaging is realised in different languages by means of intonation, syntax, word order and, in the case of Japanese, morphology.

Interesting for the study of pronouns is the fact that Vallduví and Engdahl recognise that topicalised entities can be at the same time focus and link, i.e. provide new and given information. Furthermore Vallduví and Engdahl's distinction between topic fronted and topicalised pronouns is also valid for Danish. The interpretation of topicalised elements as referring to both a new value and a known set is also in line with the interpretation of focus in terms of alternative semantics proposed by Rooth (1992) whose theory I shortly discuss in the following section.

4.2 Rooth's Focus Semantics

Rooth (1992) proposes to interpret focus by means of *alternative semantics*. In his theory a focus phrase is interpreted by adding to the usual semantic value of the phrase a semantic value indicating a set of alternatives from which the ordinary semantic value is drawn or a set of propositions which contrast with this value. The constraints introduced by focus interpretation are identified as presuppositions. Rooth discusses focus-related effects such as focusing adverbials, contrast, scalar implicature and questions and answers. For example Rooth states that there is a correlation between questions and the position of focus in answers, because a question determines a set of potential answers (the alternatives).

In Rooth's account a focused phrase α always implies a set of alternatives with at least one element different from the ordinary semantic value of α. This fact has been used by Kameyama (1998*b*) to resolve prosodic marked pronouns in English (see section 6.3.3) and can account for some uses of stressed pronouns in Danish (see section 4.5).

4.3 Information Structure and Salience in the Prague School Tradition

Sgall et al. (1986)[2] describe the information structure of an utterance by its *Topic/Focus Articulation* (**TFA**), the *topic* part consisting of the utterance's contextually bound elements (**CB**) and the **focus** part of its nonbound elements (**NB**). A **CB** element needs not to be assumed by the speaker to be known by the hearer. Sgall et al. (1986) distinguish in sentences a **focus proper** ("the single autonomous lexical unit carrying the intonation center" (Sgall et al. 1986)[178] or if there is no such unit "the most dynamic word in the focus among all those depending on a **CB** word"(Sgall et al. 1986)[185]) and a **topic proper**. Furthermore Sgall et al. (1986) state that the **TFA** articulation of an utterance affects

[2]The Prague School linguistic tradition comprises researchers such as Mathesius, Firbas, Daneš.

the degree of salience of the entities referred to in the utterance.[3] Salience of entities referred to by nominals is defined as **activation** or foregrounding, i.e. activated entities are easily accessible in memory. Sgall et al. (1986) propose rules for determining degrees of salience, based on the studies of Hajičová & Vrbová (1982). In the rules x_a denotes an expression x referring to an object a. $P(x_a)$ says that x is a weak or a null pronoun while $NP_d(x_a)$ says that the referring expression is a definite nominal phrase. The degree of salience of a is expressed as a^n and the maximal degree of salience is indicated as a^{max} while $a^n \rightarrow a^m$ indicates that the degree of salience before an utterance **U** was a^n, while after **U** is a^m.

1. if $P(x_a)$ then $a^n \rightarrow a^m$
2. if $NP(x_a)$ is in the focus of **U**, then $a^n \rightarrow a^{max}$
3. if $NP_d(x_a)$ is in the topic of **U**, then then $a^n \rightarrow a^{max-1}$
4. if $a^n \rightarrow a^m$ then b^{m+2} for every object b that is not directly referred to in **U**, but is immediately associated with an item in **U**.
5. If the leftmost expression in **U** is of the type *as for* x_a, then $a^n \rightarrow a^{max-1}$
6. if x_a is not included in **U**, nor refers to associated objects then $a^n \rightarrow a^{n+2}$

The rules are an attempt of defining salience as weights associated to the different entities. These weights change from utterance to utterance. According to Sgall et al. (1986) only when the difference in degree of salience between two objects is greater than 1 there is no ambiguity in the reference. In the above rules antecedents referred to in the focal part of an utterance and those referred to in the topical part of it are always ambiguous.

The rules for assigning the degree of salience to discourse items are later used in a proposal for resolving and generating referring expressions in Czech technical texts by Hajičová, Kuboň & Kuboň (1990). Their proposal is discussed in section 6.4.

Sgall et al.'s proposal is original because they state that entities referred to in the focal part of an utterance have the highest degree of activation. These entities often correspond to new information which in the pragmatic models of referring expressions discussed in chapter 3 have a lower activation status than "given" information.

It is of course problematic to identify the **TFA** of utterances automatically. As we have seen in 4.1, different languages express information structure using various means. Kruijff (2001) presents a preliminary typological characterisation of how

[3] The authors call entitities *items*.

different languages use variability in word order or tune as strategies to realise informativity, but, of course, the information structure of an utterance can only be decided upon from the discourse context in which it is uttered. In the following section two studies of information structure in Danish are presented in which some general tendencies of information structure in Danish are described.

4.4 Information Structure in Danish

Togeby (1993) and Paggio (1997) describe information structure in Danish by investigating word order, intonation and syntactic constructions. The two authors investigate information structure for different purposes and neither of them focuses on pronominal reference. However they both recognise some general tendencies of information structure in Danish which are also interesting with respect to pronouns.

Togeby (1993) describes information structure by the two primitives *emne* (topic) and *fokus* (focus). The former is defined as the information an utterance takes as its point of departure, while the latter is the information that is pointed out as being relevant.

Paggio (1997) also defines information structure in terms of *topicality* and *focality*. Following Dik (1989) she defines topicality as what the sentence is about (in particular the **primary topic** corresponding to the **topic proper** in (Sgall et al. 1986)), while focality refers to the element/s in a sentence that are emphasised to indicate "some kind of modification of the pragmatic information built by the overall discourse" (Paggio 1997)[32]. Both authors recognise different types of focus, the main types being *new* and *contrastive* focus.

Although the analysis of information structure presented by the two authors differs in several respects, in the following I point out the general tendencies of information structure in Danish, recognised by the two authors, which, in my opinion, are relevant for the study and resolution of pronominal anaphora:

- The primary topic is usually in the leftmost position in a sentence (the subject or the topicalised constituent)
- Focus elements are often in final position. An exception are general temporal and locative adverbials in end-position which usually are not focal and cleft sentences where the focus is structurally marked. In it-cleft sentences a given topic is often presented as focus.
- A contrastive interpretation of a constituent usually occurs in the following cases:

  - in topicalisation
  - when a constituent has extra strong stress

- Nominals following focusing adverbs (Quirk et al. 1985) are in focus.[4] Examples of focusing adverbs are the additive *også* (also) and the restrictive *kun* (only).

Paggio (1997) notices that topicalisation is much more frequent in Danish than in English and that weak pronouns in the front position of a sentence (the front field) seem not to receive a contrastive interpretation. This is in line with the analysis for Swedish pronouns proposed by Vallduví & Engdahl (1995). Furthermore Paggio (1997) notices that adjuncts in the front position of an utterance often have the pragmatic function of creating a setting for the rest of the sentence. This is illustrated in (4).

(4) *I forgårs talte vicepræsident Aleksandr Rutskoj til kongressen...*
(lit. The day before yesterday spoke vicepresident Aleksandr Rutskoj to the congress...)
(The day before yesterday vicepresident Aleksandr Rutskoj spoke to the congress...)
(BERLINGSKE)

Paggio (1997) also claims that extraposed clauses tend not to be focal.

In the following section I connect the word order and prosodic rules for pronouns described in chapter 2 with the information structure of utterances discussed in this chapter.

4.5 Danish Pronouns and Information Structure

In sections 2.4 and 2.5 I described the general rules for word order and prosodic marking of personal and demonstrative pronouns which I shortly repeat here.

Personal pronouns and possessive pronouns with a determinative function are usually unstressed, while demonstrative pronouns and possessive pronouns in independent function are always stressed.

Personal pronouns are stressed if their antecedent is an entity that has just been introduced in discourse. Personal pronouns are stressed if they occupy the N-position in cleft constructions (one of the syntactic constructions indicating focus in Togeby and Paggio) and if they are a constituent in coordinated nominal phrases. They are also stressed if they are juxtaposed, topicalised or/and used in

[4] In the literature focusing adverbs are also called *rhematisers*.

contrastive contexts. Furthermore I suggested that personal pronouns in Danish as in English are stressed if they do not corefer with the antecedent that would be expected in the unmarked context. This is compatible with Rooth's focus semantics because intonational focus on pronouns as on other phrases evokes alternatives, in this case the most expected antecedent in the corresponding unstressed context. It should be tested whether it is always true that strong pronouns refer to focal phrases as suggested in (Hajičová et al. 1990).

Personal and demonstrative pronouns occur in the same position as other nominal phrases. An exception are unstressed (weak or light) pronouns which have a tendency to move to the left in the field schema for main clauses. In particular pronominal constituents corresponding to the constituents in the N-position of Diederichsen's field schema move to a particular light field to the left of actualisation adverbials. Jørgensen (1991) explains this phenomenon by stating that unstressed Danish personal pronouns are clitics and proposes that pronominal clitisation in Danish occurs as follows:

- Unstressed pronouns cliticise on the preceding obligatory element in the clause. This explains why object pronouns cannot move over indirect objects, non finite verb, subject and finite verb, but move to the left of adverbials.
- Clitic pronouns cannot move to the left of another clitic element thus the obligatory order of subject, indirect object and direct object is maintained.
- In the front field clitic pronouns do not move to the left, but to the right and become proclitic of the finite verb. This phenomenon is different from topicalisation.

Jørgensen states that clitic pronouns represent known information, while stressed pronouns are new information. Thus Jørgensen distinguishes unstressed pronouns in the front field that are proclitics of the main verb and stressed pronouns in the same position which are topicalised. This is in line with Vallduví & Engdahl (1995) who distinguish between topicalised stressed pronouns and topic fronted unstressed pronouns in Swedish (section 4.1).

The fact that topic fronted and topicalised pronouns are different phenomena also in Danish is illustrated by the following two examples from conversations between my husband (**father**) and our daughter (**Lucretia**):

(5) a. **father:** *vil du have mere is?*
(would you like to have more ice cream?)
Lucretia: *det* VIL *jeg* GERNE
(lit. it WILL I WITH PLEASURE)
(yes, I would)

b. **father:** *gider du hjælpe Ingmar med at rydde op?*[5]
Lucretia: DET *gider jeg* I HVERT FALD IKKE
(lit. IT like I IN ANY CASE NOT)
(THAT I do REALLY NOT feel like doing)

Det (it/that) in (5-a) is neutral, while *det* (it/that) in (5-b) signals a contrastive interpretation such as "this is the worst thing in the world which you could ask me to do".

The Prague School argues that focal entities have the highest degree of salience. I believe that this is true in Danish in cases where the focal part of the sentence is clearly marked, structurally or by intonation. This roughly corresponds to what Sgall et al. (1986) call the **focus proper**. (Hansen & Lund 1983, Thorborg 1998) notice that stressed pronouns are used to refer to nominals which have just been introduced in discourse. This seems to confirm the observation made by Hajičová et al. (1990) that strong pronouns refer to entities in the focal part of the sentence. An example of salient focal entity is given in (6), where the focal *en gammel mand* (an old man) is the preferred antecedent of the pronoun *han* (he), although it represents new information respect to the candidate antecedent *Nicolai*.

(6) *Nicolai mødte en gammel mand.*
(Nicolai met an old man.)
Han virkede nervøs.
(He seemed nervous.)

Another example of the salience degree of entities in focal position is illustrated in the utterances (7) and (8). The two utterances in (7-a) and (8-b) are semantically similar, but in (8-b) *Emma* is the focus proper. This is indicated by the fact that the nominal is prosodic marked and by the context, in that *Emma* is the information asked for in the preceding question (8-a). Thus the two utterances (7-a) and (8-b) differ in their TFA. The two occurrences of the pronoun *hun* (she) in the following utterances (7-b) and (8-c) are ambiguous. However there is a preference for resolving *hun* (she) to *Maria*, the subject of the preceding clause in (7-a) and to the focal *Emma* in (8-c).

(7) a. *Maria snakkede med Emma.*
(Maria spoke with Emma.)
b. *Hun var glad.*
(She was happy.)

(8) a. *Hvem snakkede Maria med?*
(lit. Whom spoke Maria with?)

[5]Ingmar is Lucretia's little brother.

(Whom did Maria speak with?)

b. *Maria snakkede med EMMA.*
(Maria spoke with EMMA.)

c. *Hun var glad.*
(She was happy)

In chapter 10 I investigate how strong these preferences really are and in which cases entities can be considered focus proper.

4.6 Concluding Remarks

Although information packaging is related to the phenomena studied in the cognitive studies discussed in chapter 3 it describes a different aspect of communication, i.e. the way in which information is presented.

Vallduví & Engdahl (1995) reduce the numerous definitions of information structure primitives proposed in the literature to the two distinctions *ground/focus* and *topic/comment*. The former distinction divides the sentence into a known, or expected part, the ground, and a new, dominant, or contrary-to-expectation part, the focus. The *topic/comment* group distinguishes the topic which the speaker announces from the comment where the speaker says something about the topic. Vallduví and Engdahl consider the form in which the utterance is presented as an instruction to the addressee about which information is new and how it fits into the already given information. The two basic primitives in their theory are *focus* and *ground*. *Focus* is the new information, while *ground* is given information specifying where to add the new information (the *link*) and how the new information fits there (the *tail*). The same entity can be the focus and the link in contrastive constructions, thus it both represents new and given information.

Vallduví and Engdahl analyse information packaging in various languages and notice that in Swedish topicalised (stressed) pronouns should be distinguished from topic fronted unstressed pronouns, which are a phenomenon not related to information packaging. Jørgensen (1991) proposes a similar interpretation in Danish. I follow their proposal.

Rooth (1992) interprets focus phrases as evoking alternatives characterised by a presuppositional constraint. His theory is used for explaining prosodic marked pronouns (Kameyama 1998*b*) and is also compatible with my interpretation of some cases of stressed pronouns in Danish signalling an unexpected referent.

Sgall et al. (1986) present rules for determining the degree of salience of entities referred to in an utterance (understood as accessibility of the entities in memory) based on the information structure (topic/focus articulation) of the utterance.

They claim that focal items are very accessible and, according to their rules, antecedents referred to in the focal part of an utterance and those referred to in the topical part of it are always ambiguous.

I believe that the information structure of an utterance is important for determining the salience of entities in Danish at least in utterances where focus is clearly marked (structurally as in existential sentences and in clefts) or intonationally. This aspect is investigated further in chapter 10.

In line with Vallduví and Engdahl, Togeby and Paggio describe general tendencies of information packaging in Danish by looking at word order, intonation and syntax. The general tendencies they recognise which can be related to the use of Danish pronouns described in chapter 2 are the following: the topic tends to occupy the leftmost position in the sentence, while the focus tends to occupy the rightmost position; topicalised elements mark a contrastive interpretation; in cleft constructions and in there-clauses the element in N-position is the focus.

Thus canonically Danish personal pronouns are unstressed i.e., they indicate known information (the **ground** using Vallduví and Engdahl's terminology). When they are stressed (topicalised or not) they contain also new, unexpected and dominant information. They can have a contrastive interpretation especially if they are topicalised or occur in cleft constructions or in contrasted utterances. A contrastive interpretation occurs also when stressed pronouns signal an unexpected antecedent.

The information structure of an utterance is analysed in the local context in which the utterance is produced, for example in question-answer pairs, and the general structure of discourse has not been included in information packaging studies. As I noticed in chapter 3 pragmatic studies of the use of referring expressions do not take into consideration the structure of discourse. However this structure is important for defining the scope of anaphoric references. Furthermore the coherence and salience of referring expressions are not an isolated phenomenon as the linear models discussed in chapter 3 seem to indicate, but are strictly related with the general coherence of discourse. I outline how the structure of discourse as been modelled in the literature and discuss its relation to the use and the resolution of anaphora in the following chapter.

Chapter 5

Anaphora and the Structure of Discourse

The fact that discourse is hierarchically structured and that its structure is relevant for anaphora resolution has been central in the studies presented by i.a. (Hobbs 1979, Grosz & Sidner 1986, Webber 1991) which have been very influential to many computational approaches to anaphora resolution. The aspects that have been discussed are how the relations holding between discourse parts are important to interpret the meaning of discourse and how discourse structure defines the scope of search for antecedents.

The fact that the meaning of discourse cannot be determined only looking at the content of clauses is well known. The order in which clauses occur and the relations holding between them are some of the factors to be considered when interpreting discourse. As discussed in chapter 1 and 2, there are types of anaphor which are related to their antecedents by more complex relations than identity. For example plural pronouns can refer to the summation of antecedents listed in the preceding discourse. Sometimes these antecedents occur in different sentences as it was illustrated in example (34) in section 2.2.3, repeated in (1). Identifying that the sentences in which the two nominals *min far* (my father) and *min farfar* (my grandfather) occur, are a sequence or list is important for resolving the plural anaphor *dem* (them).

(1) ***Min far*** *havde for højt blodtryk ... det havde* ***min farfar*** *også jeg er bange for at jeg ligner* ***dem***
(lit. **My father** had too high blood pressure ... it/that had **my grandfather** too I am afraid that I am like **them**)
(**My father** had too high a blood pressure ... **my grandfather** had it too I am afraid that I am like **them**)
(SL)

Discourse structure also indicates the scope of search for anaphoric antecedents. An example of the relation between discourse structure and referring expressions is found in (2). In the example the possessive *hendes* (her) corefers with *min veninde* (my friend) which precedes it by more utterances. In these utterances the doctor and the patient reconstruct what the patient has been going through since her friend died and since she was at the doctor's for an outbreak of herpes caused by distress. After this digression the patient continues explaining why she is at the doctor's and thus again refers to her friend (*men nu har jeg altså…* (but now I have really…)).

The structure of (2) delimits the scope of the antecedent search in this case of distant antecedent, so that the antecedent of the anaphor *hendes* (hers) is looked for directly in the discourse segment preceding the digression starting with *jo jeg kan godt huske…* (yes I remember…).

(2) **P:** *og så…*
(and then…)
L: *ja*
(yes)
P: *så sagde du jeg måtte hellere komme ud når det der var overstået jeg ved ikke om du kan huske det jeg mistede* ***min veninde*** *og*
(lit. then said you I would better came out when that was over I do not know whether you can remember it I lost **my friend** and)
(then you said that I would better come when that was over I do not know whether you can remember it I lost **my friend** and)
L: *jo jeg kan godt huske du kom her i januar*
(yes I remember you came here in january)
P: *ja*
(yes)
L: *det bl- øh* (uforståeligt) *to en halv måned siden*
(it be- uh (incomprehensible) two and half month ago)
P: *ja*
(yes)
L: *og der havde du fået det der udbrud*
(lit. and there had you got that outbreak)
(and there you have got that outbreak)
P: *ja*
(yes)
L: *og så snakkede vi om at der er jo tit er en eller anden grund til sådan noget bryder ud ik'*
(lit. and then spoke we about that there is certainly often is one or other reason for such a thing breaks out isn't it)
(and then we spoke about that there is certainly is often some reason for

such a thing breaks out isn't it)
P: *ja*
(yes)
L: *og så fortalte du kan jeg se jeg har skrevet* (1 sekund) *at du var bekymret der var faktisk flere af dine venner der var døde af kræft*
(lit. and then said you can I see I have written (1 second) that you were preoccupied there were actually several of your friends that had died of cancer)
(and then you said I can see I have written (1 second) that you were preoccupied there were actually several of your friends that had died of cancer)
P: *ja* (3 sekunder) *og-og og det-det øh det bliver ved sådan at rumstere i hovedet på mig ik' men selvfølgelig har jeg fået det lidt på afstand det er klart ik'*
(lit. yes (3 seconds) and-and and it-it uh it keeps running in my head really but of course have I a little bit distanced myself from it it is clear isn't it)
(yes (3 seconds) and-and and it-it uh it keeps running in my head really but of course I have distanced myself from it a little bit it is clear isn't it)
L: *ja* (1 sekund)
(yes (1 second))
P: *men nu har jeg altså meget i hovedet i dag for-for nu har jeg lige været* (dyb vejrtrækning) *øh hos en guldsmed hernede hvor jeg fik en-en ring af **hendes** bror han synes jeg skulle have et minde om **hende** ik' og den den var for lille den jeg valgte ik'*
(lit. but now have I really much in the head today because-because now have I just been (deep breath) uh at a jeweller's down here where I got a-a ring (common-gender) from **her** brother he thought I should have a memory of **her** sure and it it (common-gender) was too little that (common-gender) I chose sure)
(but now I have really much in my head today because-because now I have just been (deep breath) uh at a jeweller's down here where I got a-a ring from **her** brother he thought I should have a memory of **her** sure and it it was too little the one I chose sure)
(SL)

The question is how to model the structure of discourse to account for these facts and how to extract this structure automatically. Different models of discourse structure have been proposed focusing on different aspects. In this chapter I outline the most prominent of them discussing whether they account for the meaning of discourse and whether they can be used to define the search space of antecedents in both written texts and dialogues.

I first (section 5.1) describe approaches for modelling discourse structure, based on the coherence and rethorical relations which hold between discourse segments. Identifying these relations is necessary to correctly interpret discourse. Then in section 5.2 an intention-based model developed for defining the search space of antecedents is discussed. In section 5.3 attempts to combine the two approaches (section 5.3) are shortly described. In section 5.4 a proposal to explain accessibility of reference in terms of the structure of discourse and of the operations to build it is outlined. In section 5.5 I look at models which explicitly distinguish the structure of written texts and dialogues accounting for some of the phenomena which are typical for conversations and in section 5.6 I present a study which explains the different uses of referring expressions in texts and dialogues on the basis of the differences between the structures of the two types of discourse. Finally section 5.7 contains some conclusions.

5.1 Discourse Structure and Discourse Relations

In this section I shortly outline two influential theories of discourse structure which model discourse by the relations which link clauses, sentences or other pieces of discourse to each other. These models are based on linguistic studies such as (Halliday & Hasan 1976). The two theories are the "coherence relation theory" proposed by Hobbs (Hobbs 1979, Hobbs 1983) and the Rhetorical Structure Theory, **RST** henceforth, presented by Mann and Thompson (Mann & Thompson 1987, Mann & Thompson 1988).

5.1.1 Coherence Relations and Anaphora Resolution

Hobbs' coherence relation theory for modelling discourse is part of a more general theory where text interpretation is the process of finding the most plausible explanation to a text using an abductive inference model (Hobbs, Stickel, Appelt & Martin 1993) (see also section 6.1.2).

The basic assumption behind Hobbs' coherence relation theory is that text coherence can be characterised by means of the relations holding between segments of the discourse (Hobbs 1979, Hobbs 1983). In the theory the basic elements of discourse are sentential units corresponding to clauses. The union of two sentential units linked by some coherence relation is also a sentential unit. The structure of discourse is built up as a binary tree whose terminal nodes are clauses and whose non-terminal nodes are coherence relations among them. The leaves of the tree preserve the sequence of the clauses in the text or conversation.

Hobbs (1983) distinguishes four groups of coherence relations:

1. Weak causal or strong temporal relations: Occasion, Enablement, Cause

2. Evaluation
3. Linkage between the message and what the Listener can be expected to know in advance: Background (functional, visual), Explanation
4. Expansion relations: Positive (Parallel, Elaboration, Generalisation, Exemplification), Negative (Contrast, Violated Expectation)

The relations are logically defined and can be inferred in the abductive system. The class of expansion relations is generally used to manipulate in some way the inference processes of the listener.

One of the most common discourse relations is **Elaboration** which Hobbs characterised as follows:

> "A segment of discourse S1 is an Elaboration of segment S0 if the same proposition P can be inferred from both S0 and S1, and one of the arguments of P is more fully specified in S1 than in S0." (Hobbs 1979)[page 73]

Varieties of the Elaboration relation are paraphrases and repetitions. A question-answer sequence is a kind of Elaboration as it is illustrated in (3). In the example B's answer elaborates A's question in the required way, i.e. it provides the subject argument of the predicate examine(x) so that the following formula is obtained:

examine(g) $\wedge$ graphologist(g)

(3) **A:** *og hvem eksaminerer så*
(lit. and who examine then)
(and who does examine then)
B: *en grafolog*
(a graphologist)
(PID)

Hobbs describes how it is possible to resolve references against previous context, against a world model and against an alternate representation. In Hobbs' theory of discourse interpretation reference resolution happens naturally as a by-product of applying conversational implicatures based on the coherence of text. I discuss this aspect of Hobbs' theory in section 6.1.2.

The coherence relations theory points out that coreference is bound to coherence. Coherence is partly expressed through coherence relations holding between discourse segments, but also comprises other things such as knowledge of the world and the way utterances are presented. The latter aspect corresponds to the information structure of utterances which was discussed in the preceding chapter.

The identification of coherence relations is not only indispensable to resolve some types of pronominal anaphora but also to correctly interpret related phenomena such as ellipsis.[1] Coherence relations are inferred by the abductive interpretation system in Hobbs' proposal.

5.1.2 Rhetorical Structure Theory

Mann & Thompson (1987) develop **RST** as a framework to generate the structure of large presentational texts. Later on they extend the theory so that it can also be used in text interpretation. **RST** is similar to Hobbs' coherence relation theory. In RST texts are divided into units called spans, which are terminal nodes in an RST tree structure. Thus a span, as a discourse unit in the coherence relation theory, is realised by a text unit (typically a clause) or is a piece of text which has an RST structure. Unit size is arbitrary. Two non-overlapping text spans are related by **RST** relations. The most prominent span in each relation is called the nucleus, while the less prominent one is called the satellite. The set of nucleus-satellite relations is open.[2] Some of the relations recognised are: Antithesis, Background, Conditional, Elaboration, Enablement, Purpose. Few constructions only consist of nuclei (Sequence and Joint relations). RST only permits one relation between two spans. If a text has multiple analyses, the most plausible one in terms of the writer's perceived overall goals is chosen.

In figure 5.1 I give an example of the **RST** relation holding between the two clauses in (4) from the SL collection:

(4) *hvis jeg sidder og læser så.. begynder det at flimre i øjnene*
(If I am reading a book then.. it begins swimming before my eyes)

The utterance in (4) consists of the two text spans:

1. hvis jeg sidder og læser
2. så.. begynder det at flimre i øjnene

Span one is in a **Conditional** relation with span 2, the nucleus. Mann and Thompson do not investigate the structure of dialogues.

[1] The relation between the structure of discourse and the resolution of ellipsis is i.a. discussed in (Hardt 1999, Kehler 2000, Asher, Hardt & Busquets 2001).

[2] Asher (1993) notices that Hobbs describes relations holding between eventualities while Mann and Thompson mainly describe relations holding among propositions. This explains why the set of Mann and Thompson's relations is open-ended.

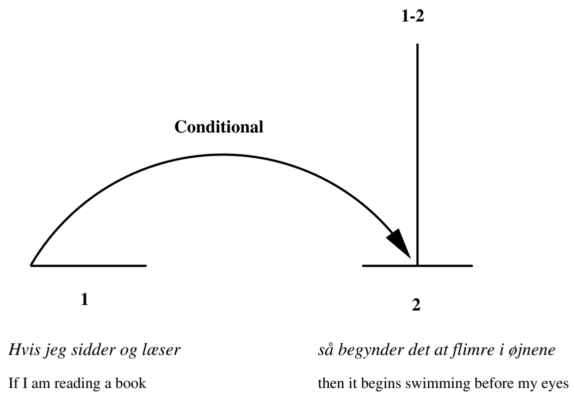

Figure 5.1: **RST** diagram

RST has become popular and the fact that some spans, the nuclei, are more prominent than the others has been used to define the search space of anaphora resolution. In the so-called **Veins Theory** the parts of tree accessible to reference are identified in texts marked with **RST** relations (Cristea, Ide & Romary 1998, Cristea, Ide, Marcu & Tablan 2000). The parts of discourse which are accessible for reference are called **veins** and are defined as chains of discourse units. The algorithm for computing veins consists of a bottom up and a top-down step and predicts that propositions in nuclear nodes percolate up the tree and propositions introduced by satellites to the left of a nucleus remain accessible to all nodes controlled by that nucleus.

Cristea et al. (2000) test their accessibility algorithm by resolving pronominal anaphors in **RST** analysed texts in two ways. First they resolve anaphors defining accessibility linearly, then they use as search space the trees individuated by the vein extraction algorithm. The evaluation of the two tests indicates that the vein-constrained resolution gives as good results as linear anaphora resolution, but at the same time it speeds up resolution consistently.

From a computational point of view the problem with Mann and Thompson's theory, as for other discourse structure theories, is how to automatically extract the **RST** tree from texts. A very promising attempt has been done by Marcu (2000) who automatically recognises the **RST** structure of texts on the basis of a large set of cue words.

5.2 Three-level Discourse Model

Grosz & Sidner (1986) present a model of discourse structure used to determine the search space of anaphora. Their model combines three interacting components: the linguistic structure, the intentional structure and the attentional state. The **linguistic structure** consists of the sequence of utterances in a discourse, aggregated into discourse segments, and of the embedding relations which hold between these segments. These relations are the surface reflection of the relations among elements of the intentional structure.

The **intentional structure** deals with the purpose of the discourse. The intention that motivates engaging in a particular discourse is called discourse purpose (**DP**). Each discourse segment has a discourse segment purpose (**DSP**) which specifies how the actual segment contributes to the achievement of the DP. While the list of possible intentions is open-ended only two structural relations hold between DSPs:

1. **satisfaction-precedence**: DSP1 contributes to DSP2
2. **dominance**: DSP2 dominates DSP1

In the **satisfaction-precedence** relation one DSP must be linearly satisfied before the other, while the **dominance** relation orders discourse in a **dominance hierarchy**.

The third component of Grosz and Sidner's discourse model, the **attentional state**, is modelled as focus spaces and is used to resolve referents between discourse segments which exhibit global coherence. The objects, properties, relations and DSPs that are salient at each point of the discourse are dynamically recorded in the attentional state. The focus spaces available at any time constitute the focusing structure and they are represented as a stack. The attentional state coordinates the linguistic and the intentional structures, and the relationships among DSPs determines pushes and pops from the focus stack. The focus space constrains the range of DSPs related to the current DSP to be searched for possible referents of nominal phrases. Thus when a discourse segment is open its corresponding focus space is pushed onto the focus stack. When the segment is closed its focus space is popped from the stack. Figures 5.2 and 5.3 illustrate how the focus structure which models the attentional state coordinates the linguistic and the intentional structures.

In both figures DSP1 which is the intention behind discourse segment DS1, dominates DSP2 and DSP3, the intentions behind DS2 and DS3 respectively. Figure 5.2 illustrates the focus structure when DS2 is being processed. FS2, the focus space of DS2, has been pushed onto FS1, the focus space of DS1, because DSP1 dominates DSP2. The properties, relations and objects in FS2 are more

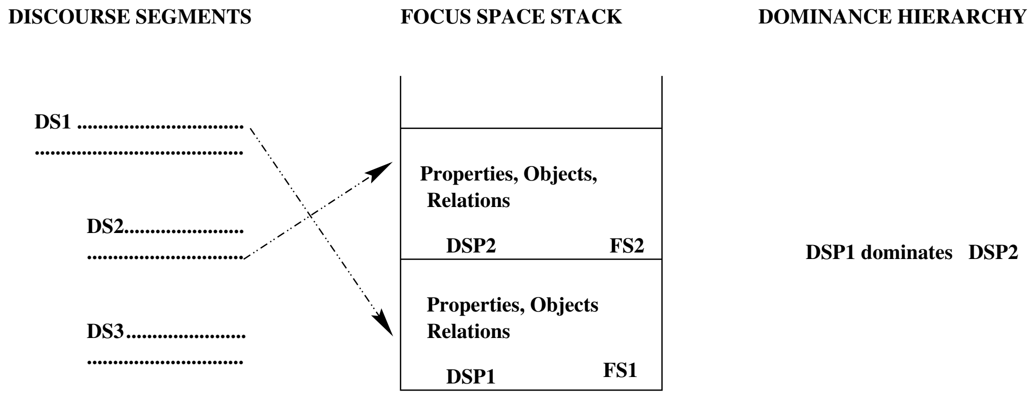

Figure 5.2: Discourse segments, their focus spaces and dominance hierarchy when DS2 is being processed

salient than those in FS1 at this point of discourse. Figure 5.3 illustrates the focus structure when DS3 is being processed. FS2 has been popped from the stack, i.e. its elements are no longer accessible for anaphora resolution, and FS3 corresponding to DSP3 has been pushed onto the stack. Thus anaphoric antecedents must be searched in FS3 and then in FS1 even if DS1 does not linearly precede DS3. This is also the case for the digression in example (2), which as FS2, is removed from the focus stack after being processed, so that the search space for the pronoun *hendes* (her) is the nominal phrase *min veninde* (my friend) in the discourse segment which immediately precedes the pronoun in the the discourse tree, although this segment does not lineraly precede the segment in which the anaphor occurs.

According to Grosz and Sidner information from different knowledge sources determines DSPs, such as linguistic markers, especially cue phrases, utterance-level intentions, general knowledge and intonation. The cue phrase marking the beginning of a new segment in (2) is the conjunction *men* (but). This conjunction is also considered by Givón (1983) as a possible indication of a *major juncture* and pronouns with distant antecedents can occur after such a juncture as discussed in section 3.2.

While the focus stack is used to treat anaphors whose antecedents are in preceding discourse segments, the **Centering** theory has been proposed to account for resolution of coreferences with nominals in utterances inside the same discourse segment. In this case the antecedent search space is simply the utterance preceding the utterance in which the anaphors occur. The Centering theory is described in section 6.3.

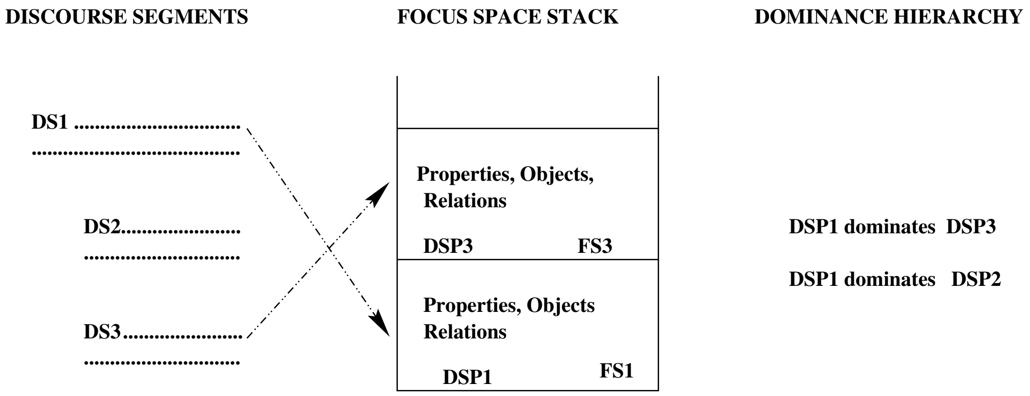

Figure 5.3: Discourse segments, their focus spaces and dominance hierarchy when DS3 is being processed

In the three-level model the main emphasis is on the intentions behind a speaker's utterances following a tradition started with studies in philosophy of language by Grice (Grice 1957, Grice 1968), Austin (Austin 1962) and Searle (Searle 1971, Searle 1975*b*, Searle 1975*a*). Building on their previous work on anaphora resolution Grosz and Sidner show how the hierarchical structure of discourse influences anaphora resolution and in particular how only objects, propositions and relations on the focus stack at each point of discourse can be referred to by anaphors.[3] This assumption has been very influential on anaphora resolution approaches.

The main problem with Grosz and Sidner's theory is the identification of the intentions behind discourse segments (DSPs) which is not spelled out. Segmenting discourse in fragments which reflect subgoals is difficult in task-oriented dialogues, but it is even more problematic when dealing with other kinds of dialogues. Another question is how to treat discourse segments that are only informative, i.e. that do not indicate an intention. Attempts to combine informational and intentional aspects of discourse structure are discussed in the following section.

5.3 Intentional and Informational Relations

The fact that both intentional and informational relations are important in modelling discourse, and especially dialogues, is argued by i.a. (Moore & Paris 1989, Moore & Pollack 1992, Asher & Lascarides 1994, Asher & Lascarides 1999).

[3]I discuss Grosz' and Sidner's work on anaphora resolution in section 6.2.

Moore & Pollack (1992) notice that in some cases the informational and intentional **RST** analysis can result in different trees because they identify different nuclei. One of the examples they discuss is (5).

(5) a. *Come home by five.*
b. *Then we can go to the store before it closes.*

At the information level utterance (5-a) provides a Condition for (5-b), the nucleus, while at the intentional level (5-b) is the satellite providing a Motivation for (5-a), the nucleus.

Moser & Moore (1997) argue that Grosz & Sidner (1986) and Mann & Thompson (1987) make similar points about how the speaker's intentions determine the structure of discourse. In both approaches discourse pieces are hierarchically structured. These discourse pieces are called segments in (Grosz & Sidner 1986) and spans in (Mann & Thompson 1987). According to Moser and Moore there is a mapping between the linguistic structure in the three-level discourse model and the **RST** structure, and they argue that the dominance relation corresponds to the RST nucleus-satellite relation.

The authors also suggest that the dominance relation expressed in the nucleus-satellite duality is only a property of intentional relations. From the point of view of accessibility this means that only the intentional structure influences the construction of a discourse tree and thus the definition of the parts of discourse that are accessible for reference.

Poesio & Di-Eugenio (2001) use Moser and Moore's proposal of mapping the **RST** and the three level model to test the accessibility of referring expressions defined by the latter model on a text corpus marked with RST-relations. The results of their test seem to confirm Moore and Moser's observation that only intentional relations determine the structure of the global focus stack.

5.4 Webber's Discourse Tree

To interpret discourse deictics Webber (1991) presents a discourse model similar to Grosz and Sidner's three-level model. Webber (1991) represents the structure of discourse as a tree composed of discourse segments connected by two binary relations, *parent-of* and *right-sibling-of*. The first relation corresponds to Grosz and Sidner's *dominates* relation while the latter corresponds to their *satisfaction-precedes* relation. Webber does not give a definition of what a minimal discourse segment is in her paper, but in the examples she discusses, the minimal units are clauses.

Discourse segments can be added to the discourse tree by two operations, *at-*

tachment and *adjunction*. *Attachment* is the process of attaching a node N_k as rightmost daughter and corresponds to pushing an element on Grosz and Sidner's focus stack (Grosz & Sidner 1986). *Adjunction* of a node N_k to a node N_i means that N_k becomes the right sibling of N_i and both nodes become children of the same (new) parent node. Adjunction corresponds to popping all stack elements until the one corresponding to N_i and pushing the one corresponding to N_k onto the top of the focus stack. Webber illustrates the adjunction operation with the following example (6):

(6) a. John hates snakes.
b. His next-door neighbor had kept snakes,
c. and he had hated his neighbors.
d. Later in college, his roommate had kept snakes.

The results of applying adjunction operations to the clauses in example (6) are shown in figure 5.4.

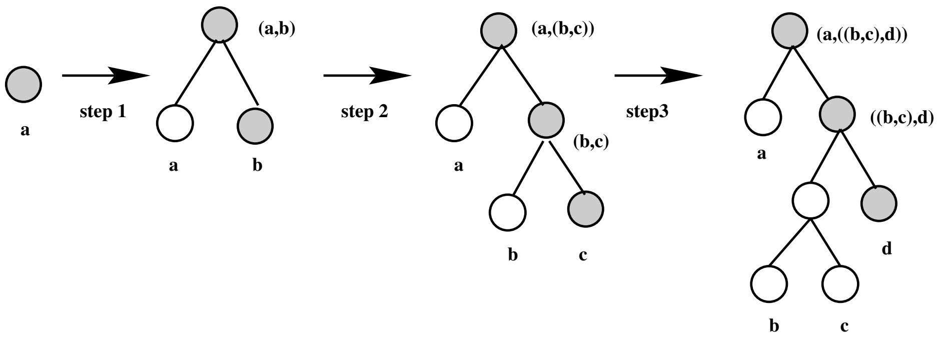

Figure 5.4: Adjunction operations for example (6)

Webber states that only nodes on the right frontier of the discourse tree are in focus and can be referred to by deictic pronouns. I further discuss Webber's work on discourse deictics in section 7.1. The *right-frontier* of the tree is related to both the analysis of accessible discourse parts presented in Polanyi (1988) (section 5.5) and to the focus stack described by Grosz & Sidner (1986) (section 5.2).

5.5 Dialogue Structure

The discourse models presented in the preceding sections have not taken into considerations the structural differences between written texts and dialogues. Such differences are taken into account in the **Linguistic Discourse Model** (**LDM**) developed by Polanyi (1988) which has inspired many applied dialogue systems. As Hobbs, Polanyi represents discourse structure as the recursive sequencing and embedding of discourse units. Differing from Hobbs, however, she distinguishes different types of discourse unit depending on the type of discourse, i.e. texts or dialogues. Each discourse unit type is associated with a formal description.

While the structure of texts is very similar to the discourse structure described by Hobbs, conversations are modelled using *adjacency pairs* as they have been defined by Schegloff & Sacks (1973) in the field of Conversation Analysis. *Adjacency pairs* are sequences of two utterances produced by different speakers and ordered in a first and second part. A first part implies a set of second parts which are said to be conditionally relevant to the occurrence of the corresponding first part. Examples of adjacency pairs are question-answer, greeting-greeting, offer-acceptance/refusal, announcement-assessment. Examples of the first two types of adjacency pair are given in (7).

(7) a. **L:** *hvad kan jeg gøre for dig*
(what can I do for you)
P: *jeg skal bare til kontrol med de der . . . piller*
(I have just come to a check with those . . . pills)
SL

b. **A:** *dav, jeg hedder Iben*
(hello, my name is Iben)
B: *dav, jeg hedder Søren*
(hello, my name is Søren)
(PID)

Polanyi defines two elements of discourse formation, the former are the minimal propositions, i.e clauses including false starts and other linguistic noise,[4] the latter are operator indicating the state of the discourse and the relations among discourse entities and comprise words as *because* and *but*.

The Linguistic Discourse Model theory is implemented as a discourse parser which takes clauses in sequence from left-to-right, assigns a structural description to the discourse and builds a Discourse Parse Tree. A constituent can only be attached at structurally accessible levels in the discourse tree, i.e. to the rightmost nodes immediately dominating the last constituent parsed, as in (Grosz & Sidner 1986, Webber 1991). Interestingly, Polanyi proposal is promising and it would be interesting to build and test genre-specific dialogue grammars for existing written and spoken corpora.

[4]Polanyi (1996) defines the basic unit as a semantic structure expressing a single state of affairs about a discourse world.

Polanyi's idea of defining genre-related grammars for discourse has been followed in a number of applied dialogue systems, such as LINLIN(Ahrenberg, Dahlbäck & Jönsson 1990) and SUNDIAL(McGlashan, Bilange, Fraser, Gilbert, Heisterkamp & Youd 1992), where adjacency pairs have been structured in larger units such as conversational games and transactions which correspond to discourse segments in Grosz and Sidner's discourse model.[5]

Applied dialogue systems have also combined the idea of a dialogue grammar with the study of speech acts proposed by (Searle 1971, Searle 1975*a*) and other phenomena studied in the field of Conversation Analysis such as *turn-taking* mechanisms (Sacks, Schegloff & Jefferson 1974, Schegloff 1979).

Attempts of defining standards for annotating the structure of dialogues have been made by i.a. (Traum & Hinkelman 1992, Ahrenberg, Dahlbäck & Jönsson 1995, Carletta, Dahlbäck, Reithinger & Walker 1997). The most interesting aspect in these proposals is that a dialogue act does not always correspond to a single speech act as in traditional speech act theory, but can have at least two communicative functions, a *forward looking* and a *backward looking* function. The former is the function of introducing new discourse information and expectations, the latter is that of reacting to previous discourse initiatives. Furthermore following (Clark & Wilkes-Gibbs 1986, Clark & Schaefer 1989) conversations have been considered a collaborative act and utterances have to be acknowledged by the listener, before they can be added to the common dialogue model. These aspects have been modelled in the *Grounding Theory* proposed by Traum (1994). Grounding is relevant to anaphora resolution because it can account for the fact that abandoned or unfinished utterances are not accessible for later reference. This strategy for modelling dialogue structure has been followed by ı.a. Eckert & Strube (1999*a*) whose algorithm for resolving anaphora in dialogues is discussed in section 7.4.

5.6 The Use of Referring Expressions and the Structure of Discourse

Fox (1987) accounts for the choice of anaphoric expressions in relation to discourse structure in both English written expository texts and conversations, analysing references to third-person singular human entities.

Fox models the structure of expository texts with **RST** trees and uses them to identify the parts of texts which are open for anaphoric reference at each point of discourse. In particular Fox states that it is only possible to refer to entities

[5] A description and comparison of different dialogue and discourse models can be found in (Navarretta 2000*d*, Navarretta 2000*b*).

in spans that are *active* or *controlling* and these correspond to the elements in the focus stack in Grosz and Sidner's model.

Fox identifies the following basic pattern for anaphora of expository texts (Fox 1987)[139]:

> *A pronoun can be used to refer to a person if there is a previous mention of that person in a proposition (span) that is active or controlling; otherwise a full NP is used.*

This is also compatible with Webber's accessibility definition.

As Polanyi, Fox model the structure of conversations in terms of adjacency pairs. Fox describes how adjacency pairs can be elaborated, expanded or interrupted by other adjacency pairs. She then defines a *sequence* as an adjacency pair and any elaboration on that adjacency pair. A sequence that is completed is said to be *closed*. When a sequence is closed a new sequence can begin, while a non-closed sequence can continue, although there has been an interruption. This is in line with Grosz and Sidner's discourse model.

Fox recognises the following basic distributional pattern of anaphora in conversation (Fox 1987)[139]:

> *The first mention of a referent in a sequence is done with a full NP. After that by using a pronoun the speaker displays an understanding that the sequence has not been closed down.*

In conclusion Fox explains in terms of discourse structure the phenomena recognised in the pragmatic approaches presented in chapter 3. A referent is a topic, in focus or in consciousness (known or inferable) if it has been mentioned in a sequence which is open (conversation) or in a span which is active or controlling (expository texts).

In her study she also finds that there are more instances of long-distance pronominalisation in dialogues than in texts because the level of embedding and the nature of embedding seem not to be so influential on anaphora in dialogues as in conversations. Fox also notices that in the texts full NPs are often used although the referent is in the immediately preceding clause. One of the reasons for this phenomenon is, in her opinion, that full NPs help to recognise the structural units of a text.

Fox's analysis of the relation between anaphors and discourse structure is in line with (Grosz & Sidner 1986), although she does not look at the intentional structure of discourse, but uses some few coherence relations. Her observation that long-distance reference to humans is less bound to the structure of discourse in conversations than in written texts is also valid for the Danish data which I have analysed (see especially chapter 8).

5.7 Conclusion

In this chapter I have outlined models of discourse structure and discussed how this structure influences the use of referring expressions and their resolution. The described models focus on various aspects which have been developed in different frameworks and with different aims. However in all the theories the structure of discourse is hierarchical and it is modelled by a tree whose terminal nodes mainly correspond to clauses. The basic units of discourse are clauses, including unfinished clauses, single words and gestures (Hobbs 1979, Hobbs 1983, Mann & Thompson 1987, Polanyi 1988), or pieces of discourse corresponding to discourse-relevant intentions (Grosz & Sidner 1986) and semantic structures expressing a single state of affairs about a discourse world (Polanyi 1996). It is outside the scope of this dissertation to discuss the different approaches to identify discourse units, but most of them rely on i.a. cue words, intonation and the topics/tasks of discourse.

In Hobbs' coherence relation theory and in RST a large number of discourse relations have been identified, while Grosz and Sidner only describe two relations, mainly inherited from expert systems.

Hobbs suggests that anaphora resolution is a natural part of the process of finding the most coherent interpretation of discourse and that discourse coherence is i.a. expressed through the coherence relations that hold between discourse units (see also section 6.1). Grosz and Sidner, on the other side, suggest that two discourse relations are sufficient to model discourse and to identify entities accessible to reference, i.e. entities in the right frontier of a discourse tree, using Webber's terminology. This discourse model, for Grosz and Sidner, is determined by the intentions behind discourse. Their proposal has been confirmed by the studies of Moser & Moore (1997) and Poesio & Di-Eugenio (2001). Moser and Moore show also that the two types of discourse model are related to each other.

In my opinion Grosz and Sidner's approach, which is in line with Webber's proposal, should be followed as model for defining the search space of antecedents. Their three-level discourse model defines the macrostructure of discourse and is related to the more detailed models proposed by Hobbs and Mann & Thompson, as indicated by i.a. Moser and Moore. The coherence and rhetorical relations, however, are indispensable to determine the meaning of discourse and thus to interpret complex types of anaphor. Thus both models must be taken into account in an anaphora resolution system.

Hobbs and Grosz & Sidner describe conversations and texts with the same model, while Fox and Polanyi distinguish between the two types of discourse. Although it is correct, in my opinion, that the same relations hold between discourse units in texts and in dialogues and that answers somehow elaborate preceding questions, coherence relations cannot be used to account for the fact that conversations are a cooperative task and that in conversations one has to deal with phenomena such as unfinished utterances. These phenomena can be accounted for by the **Grounding** theory (Traum 1994) which operates on a dialogue model based on adjacency pairs. This aspect is discussed further in chapters 7-11.

The fact that the differences between the structure of texts and dialogues are relevant for understanding anaphoric uses is finally indicated by the study of Fox. She describes the use of expressions referring to humans in terms of the discourse structure of texts and dialogues and suggests that the notion of embedding is less influential in conversations than in written texts. Therefore the use of pronouns with long-distance antecedents in conversation is more free and less bound by the hierarchical structure of discourse than in written texts.

Thus I suggest to model dialogues using adjacency pairs. Adjacency pairs dealing with the same topic/task form a discourse segment as in the three-level model. Differing from the dialogue models described in this chapter, however, I also believe that it is necessary to look at the coherence and rhetorical relations which hold between clauses in utterances, between adjacency pairs and discourse segments.

Chapter 6

Computational Approaches to Pronominal Anaphora Resolution

Because anaphora resolution is only one of the many processes involved in the treatment of natural language, most of the approaches presented in this chapter are part of more general theories of discourse and discourse interpretation. Some of the approaches have been implemented in running systems, others have only been manually tested. Nearly all the approaches have exclusively been tested on written texts.

In computational linguistics resolving intersentential pronominal anaphora mainly consists in determining the antecedent domain and choosing among the candidate antecedents. Computational approaches to anaphora resolution rely in various degree on syntactic and semantic aspects, on the pragmatic models presented in chapter 3 and on the discourse models discussed in chapter 5. In this chapter I describe some of the most influential of these approaches. In section 6.1 I describe two quite different strategies for resolving intersentential pronominal anaphors proposed by Hobbs (1978). In section 6.2 I outline the focus-based approaches to anaphora resolution proposed by Grosz (1977) and by Sidner (1983). Many aspects of their individual work have been used in their common theory of discourse structure which was presented in section 5.2 and in the Centering theory which is described in section 6.3. Centering assumes Grosz and Sidner's discourse model, but focuses on reference inside a discourse segment, which is called *local reference*. In section 6.4 I discuss the algorithm for resolving pronominal anaphors presented by Hajičová et al. (1990), based on the definition of degree of salience proposed by the Prague school which was described in section 4.3. In section 6.5 I review resolution strategies combining syntactic, semantic and pragmatic factors with statistic methods, while in section 6.6 I present Scandinavian studies of intersentential anaphora. Finally in section 6.7 I outline the general tendencies represented by all the outlined approaches.

6.1 Hobbs

Hobbs (1978) presents two quite different approaches to pronominal resolution, which he calls the *naive* and the *semantic-based* algorithm respectively. The semantic algorithm is part of a larger abduction-based theory of text interpretation (Hobbs 1979, Hobbs 1983, Hobbs et al. 1993). In this theory anaphora resolution is considered a bi-product of a more general process of exploiting coherence in discourse. One of the aspects of this theory, the coherence relation theory was discussed in section 5.1.1.

6.1.1 The Naive Algorithm

The naive algorithm is exclusively based on the search for a pronoun's co-specifier in the syntactic parse trees of the sentences in a text. The algorithm is in line with the strategy for resolving anaphors proposed by Winograd (1972) in his famous system SHRDLU.[1]

Hobbs' naive algorithm covers both intrasentential and intersentential anaphors. It consists of traversing the syntactic parse tree of the current sentence and, in case of failure, of the preceding sentences in a left-to-right, breadth-first manner. The algorithms implements binding constraints in intrasentential resolution (Chomsky 1980, Chomsky 1981). In intersentential resolution antecedents are proposed in recency order.

Hobbs tests his algorithm on more texts and reports a success rate of 91,7 % when the algorithm is enriched with selectional constraints. The algorithm has also been tested with very good results by i.a. (Walker 1989, Tetreault 1999).

The naive algorithm performs well because it takes into consideration the most common uses of English intrasentential and intersentential pronominal anaphors, but it presupposes a parser providing a correct analysis of the utterances, thus it cannot be applied to unrestricted texts. The naive algorithm performs particularly well on certain types of text such as technical manuals and simple dialogues and is valuable in systems which provide full analyses of sentences. As Hobbs points out, however, the algorithm fails in resolving complex cases of anaphors. These can only be interpreted analysing the discourse context.

Hobbs' algorithm must be modified to account for Danish reflexive pronouns because, as described in 2.1.1, they differ from the English ones. One of the differences between English and Danish reflexives is illustrated in (1). The two

[1] SHRDLU, implemented in LISP, operates on a simulated micro-world containing objects of different shape, size and colour. The user can ask the system to move the different objects in the micro-world. The resolution algorithm is simple, mainly based on syntactic constraints and on the classification of the micro-world's objects.

readings of the ambiguous English utterance (1-a) corresponds to the two unambiguous Danish utterances in (1-b) and (1-c) respectively.

(1) a. $Costanza_i$ asked $Lucretia_j$ take $her_{i/j}$ hat
b. *Costanza bad Lucretia hente sin hat*
($Costanza_i$ asked $Lucretia_j$ take her_j hat)
c. *Costanza bad Lucretia hente hendes hat*
($Costanza_i$ asked $Lucretia_j$ take her_i hat)

Main treatments of reflexivity in Scandinavian languages are shortly discussed in section 6.6.

6.1.2 The Semantic-based Approach

To account for more complex anaphors requiring the analysis of the discourse context, Hobbs proposes a semantic-based strategy to anaphora resolution. In this strategy resolution is an integrated part of a system which provides deep semantic analysis of English. Pronoun resolution follows automatically from a coherence-seeking interpretation. In the semantic-based approach knowledge is expressed in predicate calculus axioms and both forward and backward inferences are used.

Hobbs (1978) notices that his approach is in line with the strategy presented by Wilks (1974) who recognises four levels of pronominal resolution depending on the type of knowledge required. Similarly Hobbs describes four main semantic operations for resolving anaphora. The first operation detects the coherence relations discussed in section 5.1.1, the second operation interprets general words and predicates in context. The third operation is called *knitting* and consists in merging redundant statements. The fourth operation consists of identifying still unidentified entities.

Hobbs discusses how examples of complex pronominal anaphors can be resolved on the basis of these operations. Two of these examples are (2-a) and (2-b) which were originally discussed by Winograd (1972). The interpretation of the second occurrence of the pronoun **they** in the two examples strongly relies on the semantic interpretation of the context. In both sentences it is necessary to know that prohibiting something means not wanting it to happen. In (2-a) it is also necessary to know that demonstrations can result in violence in order to infer the causal relation between fearing violence and prohibiting something that can cause violence. In (2-b) the causal relation indicates that someone advocating something often causes that something to occur and that somebody else not wanting it to happen will prohibit it. The examples also indicate how the causal relation between the first and the second clause in both (2-a) and (2-b) determines the meaning of the sentences and of the pronouns in them.

(2) a. *They$_i$ prohibited them$_j$ from demonstrating because they$_i$ feared violence.*
b. *They$_i$ prohibited them$_j$ from demonstrating because they$_j$ advocated violence.*

In conclusion the semantic system developed by Hobbs presents a strategy for correctly resolving anaphors in cases where there are more appropriate candidate antecedents and the correct antecedent can only be chosen on the basis of the current context. This approach relies on large amounts of knowledge which must be identified and encoded in the interpretation system.

Concluding Hobbs' *naive algorithm* accounts for many general uses of English anaphors. However it cannot correctly resolve anaphors which require the interpretation of discourse. These anaphors are accounted for in Hobbs' second approach.

Because of his simplicity the naive algorithm has been implemented in many applied systems, while Hobbs' semantic approach has inspired studies on anaphors whose antecedents must be inferred by the context, i.a. (Asher 1993, Piwek & Krahmer 2000).

6.2 Focus-based anaphora resolution

Related to the pragmatic theories of relevance are the computational approaches based on the notion of **focus**, which have been presented by Grosz and Sidner, whose three-level discourse model for resolving anaphora presenting *global coherence* was discussed in section 5.2. Focus is here considered a mechanism accounting for the entities which are active/salient (in focus) at a given point of discourse. Thus the meaning of focus in this theories differs from that in the IS tradition.

Grosz (1977) is the first to introduce the focus mechanism to resolve anaphors. She recognises two levels of focus of attention,*global* and *local* focus. Global focus is determined by the total discourse and by the situational settings of an utterance, while local focus is only determined by an utterance and by the utterance that precedes it. Global and local focus account for global and local reference respectively.

Grosz & Sidner (1986) definition of focus spaces discussed in section 5.2 is taken from Grosz defines focus spaces as the subset of a speaker's total knowledge which is relevant to a discourse segment. Anaphors are resolved in the actual focus space. Only one focus space is active at each point of discourse, illustrating the current attentional state, while several focus spaces can be opened. The opened focus spaces illustrate the preceding active spaces containing topics which are still pending. The relationship between focus spaces is determined by the structure of discourse, but in task-oriented dialogues it is determined by the task hierarchy.

Problematic is, in my opinion, the definition of local focus as being exclusively determined by the current and the preceding utterance, because there are cases of local reference where the antecedent precedes the anaphor of more than an utterance. This phenomenon occurs especially in dialogues as also noticed by Fox (1987).

Sidner (1983) provides an algorithm for identifying the local focus of attention. She distinguishes between an *actor focus* and a *discourse focus*. The *actor focus* is the agent in the current sentence, while the *discourse focus* is the main focus. Both actor and discourse focus can be pronominalised. Actor focus is the main focus only when no other item is available for focusing.

The discourse focus is found by confirming or rejecting the expected focus. Sidner notices that in some English sentence types the discourse focus is explicitly indicated. These types comprise cleft, pseudo-cleft and *there* sentences. Furthermore the expected focus in *is-a* sentences is always the subject. In the first sentences in discourse the focus is often the indefinite nominal with the theme role. In other sentences the expected focus is the first member of a default expected foci list (*DEF*-list) computed from the thematic relations of the verb in the following order: theme, all other thematic positions with the agent last, the verb phrase. Sidner also notices that there seems to be a week preference for goal among the remaining thematic positions together with positions where an indefinite occurs. If the theme is a verb complement, the theme from the complement is chosen. The verb phrase is the focus in *do-it* and *do-so* anaphors.

Sidner's focusing algorithm contains rules for confirming or rejecting expected foci and uses various data structures. The chosen co-referent is the highest ranked entity which does not conflict with a commonsense interpretation of the utterance. Differing from Hobbs' semantic-based approach, Sidner only applies commonsense interpretation in the last phase of the resolution process.

Sidner also suggests that parallelism relies on a mechanism that is different from focusing.

While Grosz proposes a way of representing and using global focus, Sidner presents algorithms for resolving anaphora exhibiting local coherence. In Sidner's algorithm both syntactic, semantic and pragmatic factors are considered. The pragmatic factors which she implements have been identified in linguistic and cognitive studies of discourse. The first pragmatic factor regards the salience degree of entities which in English seems to be related with the thematic role of the entities in utterances. The second factor involves pronominal chain preference, i.e. the observation that there is a preference for pronominal reference to an entity that previously has been referred to by a pronoun. Both elements have been inherited by the Centering theory which is described and discussed in the following section.

Interesting is the fact that Sidner states that in cleft and *there*- sentences the discourse focus is explicit. These constructions are often studied in IS theories, because they explicitly mark the utterance's focus in TFA terms. Although Sidner does not make reference to these theories, her observations are in line with the Prague School's suggestion that entities in the focal part of an utterance can have highest degree of salience.

6.3 Grosz, Joshi and Weinstein's Centering Theory

The *Centering Theory* proposed by Grosz et al. (1995), henceforth GJW[2] treats local reference, i.e. coreference with entities in the same discourse segment. Centering combines Grosz and Sidner's research with the *centering model* proposed by Joshi & Kuhn (1979) and by Joshi & Weinstein (1981). The theory presupposes Grosz and Sidner's three-level discourse model described in section 5.2. According to this model the intentions behind discourse allow to divide discourse in discourse segments which exhibit global coherence. The objects, properties, relations and intentions that are salient at each point of discourse are dynamically recorded in the attentional state which is modelled as focus spaces. Global reference between discourse segments is accounted for these focus spaces, while local reference, i.e. reference to entities inside a discourse segment is dealt with by centering.

The Centering theory models the tendency of discourse to "center on" one thing at a time in order to reduce the inferences needed to integrate utterance meaning in the context of discourse. GJW see a connection between the focus of attention, the coherence of utterances and the choice of referring expressions. They also assume that

> utterances are processed left-to-right and that speakers make initial assignments of referent and meaning which may have to be retracted if material coming later in the sentence conflicts.
> (Grosz et al. 1995)[207]

The entities which link an utterance to the others in the same discourse segment, *DS*, are called the *centers* of the utterance.

[2]The paper is a reformulation of (Grosz, Joshi & Weinstein 1986).

Each utterance, U, is assigned a set of *forward-looking centers*, $C_f(U, DS)$ and, with the exception of the segment's initial utterance, a *backward-looking center*, $C_b(U, DS)$. The *backward-looking center* of utterance U_n connects with one of the *forward-looking centers* of the preceding utterance,U_{n-1}.

The *forward-looking centers* are partially ordered to reflect relative prominence. The most prominent elements are those having highest degree of salience. In GJW prominence is simply given by the order in which the elements occur in the utterance. The first element in the list is the preferred center, called $C_p(U_n, DS)$ following (Brennan, Friedman & Pollard 1987).

The following constraints are assumed:

1. There is exactly one C_b in each U. An exception is the first utterance in a discourse segment which has no C_b.

2. Every element of the C_f list for U_n must be realised in U_n.

3. The center $C_b(U_n,DS)$ is the highest-ranked element of the $C_f(U_{n-1},DS)$

Depending on whether the current C_b is the same as the C_b of the preceding utterance and whether it is the most prominent element in the utterance, GJW recognise three types of transition states across pairs of utterances: **continue**, **retain** and **shift**. These transition states are illustrated in table 6.1.

	$C_b(U_n) = C_b(U_{n-1})$ OR no $C_b(U_{n-1})$	$C_b(U_n) \neq C_b(U_{n-1})$
$C_b(U_n) = C_p(U_n)$	CONTINUE	SHIFT
$C_b(U_n) \neq C_p(U_n)$	RETAIN	

Table 6.1: Transition states

The two following rules constrain center movement and realisation:

Rule 1: If any element of $C_f(U_{n-1}, DS)$ is realised by a pronoun in U_n, then $C_b(U_n, DS)$ must also be realised by a pronoun

Rule 2: Center continuation is preferred to center retaining which is preferred to center shifting

The first rule predicts that entities referred to by pronouns are the most salient (topic) ones and implements pronominal chain preference. The second rule states that there is a preference for speaking about the same entity in adjacent utterances. An example of the application of the algorithm is given in (3) taken from (Grosz et al. 1995)[217]. The authors only include in the C_f list elements which agree in gender and number with the pronouns.

(3) a. John has been having a lot of trouble arranging his vacation.

b. He cannot find anyone to take over his responsibilities.
(he=John)
C_b = John, C_f = [John]

c. He called up Mike yesterday to work out a plan.
(he=John)
C_b = John, C_f =[John,Mike]
(CONTINUE)

d. Mike has annoyed him a lot recently.
(him=John)
C_b = John, C_f =[Mike,John]
(RETAIN)

e. He called John at 5 AM on Friday last week.
(he=Mike)
C_b = Mike, C_f =[Mike,John]
(SHIFT)

GJW notice that the addressee perceives CONTINUE transitions as more coherent than RETAIN and SHIFT transitions. Although centering is inspired by Sidner (1983) in that her potential foci list corresponds to GJW's *forward-looking center*, GJW have only a backward-looking center, while Sidner distinguishes between an agent focus and a discourse focus to treat cases where there are two pronouns in the same utterance.

The centering theory provides a simple framework for resolving anaphora resolution inside a discourse segment. GJW claim that the theory reflects the way in which humans resolve anaphors, according to cognitive research. This research indicates that people first propose an assignment of referent, which in some cases must be retracted because it is inconsistent with information coming later in the sentence/utterance. The assumption that centering follows the resolution strategy used by humans has been rejected by i.a. Kehler (1997) who also argues that pronominal reference cannot only be accounted for by centering rules. Other facts such as the textual coherence relations must also be taken into account. I certainly agree with this.

In spite of the critics centering has become very popular. It has been applied to different languages and has been extended to account for some of the phenomena which were not considered in the first formulation of the theory, such as the treatment of anaphors in free word order languages and the relation between intersentential and intrasentential anaphora. In the following I describe some of these extensions.

6.3.1 Brennan, Friedman and Pollard

Brennan et al. (1987), henceforth BFP, operationalise the Centering theory. Therefore the algorithm they propose has often been used instead of the original centering formulation. BFP rank the set of *forward-looking centers* in (Grosz et al. 1986) according to the obliqueness of the grammatical relations of the subcategorised functions of the main verb (subject > object > object2 > complements > adjuncts). This is in line with Givon's topicality case hierarchy presented in section 3.2. Furthermore BFP extend the original Centering strategy to treat some cases of ambiguous pronominal reference which could not be resolved by the original algorithm, as it is the case in example (4) discussed by the authors[3]

(4) a. Brennan drives an Alfa Romeo.
 b. She drives too fast.
 c. Friedman races her on weekends.
 d. She often beats her. (Brennan et al. 1987)[157]

The pronouns in (4-d) are ambiguous, while rule one in GJW fails to make a choice between the co-specification possibilities for the two pronouns. BFP split GJW's *shift* transition state into a *soft-shift* and a *rough-shift* state. In *soft-shift* $C_b(U_n) = C_p(U_n)$ while in *rough-shift* $C_b(U_n) \neq C_p(U_n)$. *Soft-shift* is a more coherent way of shifting than *rough-shift* and thus is ranked highest. A table of the resulting transition types is given in 6.2.

	$C_b(U_n) = C_b(U_{n-1})$ OR no $C_b(U_{n-1})$	$C_b(U_n) \neq C_b(U_{n-1})$
$C_b(U_n) = C_p(U_n)$	CONTINUE	SOFT-SHIFT
$C_b(U_n) \neq C_p(U_n)$	RETAIN	ROUGH-SHIFT

Table 6.2: Transition states

The modified algorithm chooses *Friedman* as the antecedent of the pronoun *she* in (4-d), because soft-shift is preferred to rough-shift, as it is shown in (5).

[3]The pronouns in the example are unstressed.

(5) a. Brennan drives an Alfa Romeo.
C_b=Brennan. C_f=[Brennan,Alfa Romeo]
CONTINUE

b. She drives too fast.
C_b=Brennan. C_f=[Brennan]
CONTINUE

c. Friedman races her on weekends.
C_b=Brennan. C_f=[Friedman,Brennan,Weekend]
RETAIN

d. She often beats her.
C_b=Friedman. C_f=[Friedman,Brennan]
SOFT-SHIFT

The BFP-algorithm consists of the following three steps:

1. **construct** the proposed anchors for a sentence and possible C_b-C_f combinations

2. **filter** by i.a. contra-indices, sortal predicates, centering rules and constraints

3. **rank** by transition orderings

BFP's operationalised algorithm, their modified transition state table and their ranking of *forward-looking centers* according to the obliqueness of the verbal complements have been widely used for testing centering on different corpora and languages. It is not explained in the **BFP**-algorithm how nominals which are not verbal complements must be ranked in the *forward-looking center* list.

6.3.2 Strube and Hahn

Strube & Hahn (1996) extend the centering model to free word order languages. They rank *forward-looking centers* by the functional information structure (IS) of utterances. In their model $C_b(U_n)$ is the given information. The $C_p(U_n)$ corresponds to the topic proper, the elements in U_n not contained in $C_f(U_{n-1})$ are unbound elements and the elements in U_n contained in $C_f(U_{n-1})$ are the contextually bound elements. They describe ranking constraints at three different levels. At the top level are the *context-bound* expressions in U_{n-1} which have ranked highest as potential antecedents of an anaphoric or elliptical expression in U_n. The second level deals with multiple occurrences of (resolved) anaphors, i.e. the bound elements in U_{n-1}. At this level anaphors are ranked higher than possessive pronouns and elliptical antecedents. These are preferred to elliptical expressions and heads of anaphoric expressions. At the bottom level the nominal heads are ordered by precedence relative to their position in the text. The three levels are summarised in table 6.3.

bound elements > unbound elements
anaphora > (possessive pronoun *xor* elliptical antecedent)> (elliptical expression *xor* head of anaphoric expression)
nom_head_1 > nom_head_2 > ... > nom_head_n

Table 6.3: Ranking of information structure patterns

Strube and Hahn report that their study on expository texts indicates that the functional ordering of centers seems to coincide with the grammatical roles of fixed word order languages. Although Strube and Hahn assume a functional model for measuring salience, their model does not consider the possibility of non-bound entities having an high degree of salience as proposed by the Prague School (see chapter 4).

In line with this approach is also the algorithm proposed by Strube (1998). In the algorithm an alternative model for determining the attentional state of a hearer in the centering framework is used. In this model the functions of the *backward-looking center* and *transitions* in the centering theory are replaced by the order of elements in a list which Strube calls the salience list, henceforth the *S-list*. Strube's algorithm treats both intrasentential and intersentential anaphors. The ranking criteria for the elements in the *S-list* are mainly based on the distinction of discourse entities made in (Prince 1981, Prince 1992) (section 3.1.1). Discourse entities are divided into the three groups: *hearer-old* (OLD), *mediated* (MED) and *hearer-new* (NEW). Strube operationalises Prince's **Familiarity Scale** as follows:

OLD entities: *evoked*: pronominal and nominal anaphors, previously mentioned proper names, relative pronouns, appositives; *unused*: proper names and titles

MED entities: inferables, containing inferables, anchored brand-new

NEW entities: indefinite nominals

The tuples (x, utt_x and pos_x) and (y, utt_y and pos_y) in the S-list indicate that the entity x is evoked in the utterance utt_x at the position pos_x and that entity y is evoked in the utterance utt_y at the position pos_y respectively. Given that utt_x and utt_y refer to utterance U_n or U_{n-1}, the following ranking constraints on the S-list entities are valid (Strube 1998)[p.1253]:[4]

[4]I mark ranking precedence with $\prec$ and linear precedence with $<$. Strube indicates both types of precedence with the same sign.

1. if $x \in$ OLD and $y \in$ MED, then $x \prec y$
   if $x \in$ OLD and $y \in$ NEW, then $x \prec y$
   if $x \in$ MED and $y \in$ NEW, then $x \prec y$

2. if $x,y \in$ OLD or $x,y \in$ MED or $x,y \in$ NEW,
   then if $utt_x > utt_y$ then $x \prec y$
   if $utt_x = utt_y$ and $pos_x < pos_y$ then $x \prec y$

Strube's algorithm for anaphora resolution consists of testing the referring expression against the elements in the *S-list* from left to right until the test succeeds. The *S-list* is then updated so that new elements are inserted according to the *S-list* ranking criteria. When the analysis of an utterance is finished all the entities which were not realised in the utterance are removed from the S-list. Strube tests the algorithm on some expository texts and compares its performance with that of the BFP-algorithm and an intrasentential extension of it, called the BFPKameyama-algorithm on the same texts. His algorithm performs better on these texts.

Strube & Hahn (1999) argue that to evaluate anaphora resolution in the centering framework, adjacent transition pairs and their processing cost should be taken into consideration.

In Strube and Hahn's functional interpretation of the centering theory salience is interpreted as *familiarity* in the hearer discourse model and thus their algorithm fails in all the cases where salience degree does not coincide with givenness degree. The algorithm presented in (Strube 1998, Strube & Hahn 1999) is simple and has the advantage of applying to many types of referring expression, both intrasentential and intersentential. In (Strube & Hahn 1996) the distinction of the degree of *familiarity* or *givenness* of different referring expressions is more fine-grained than in (Strube 1998), but in both proposals the antecedents preferred by different types of pronoun are not distinguished. Although the authors call their algorithm a functional approach based on IS information, they only look at whether information is given or new for determining the salience degree of utterances.

Strube's algorithm of course does not account for the use of Danish reflexives.

6.3.3 Kameyama

Kameyama proposes different extensions of the centering framework.

Kameyama (1996) develops a model describing the relation between indefeasible and defeasible rules in a NLP system for discourse interpretation. The pragmatic part of the system for interpreting pronouns uses four main sources of preference: subject antecedent preference, pronominal chain preference, grammatical parallelism preference and commonsense preferences. The former two types of preference are called Attentional Rules and are predicted by the Centering theory, the parallelism preference is classified as one of the Logical Form (LF) rules and predicts that two adjacent utterances are in many cases structurally parallel. The commonsense preferences are called Commonsense rules.

In Kameyama's model a component of the context is the attentional state which consists of i.a. the center state, containing a set of propositions and associated salient entities. The salience of entities in the center state is accounted for with a grammatical function hierarchy, corresponding to the order of the syntactic arguments of a verb, and a nominal expression type hierarchy. The grammatical function hierarchy is similar to i.a. the Accessibility Hierarchy proposed by Keenan & Comrie (1977)[5] and the Topicality Hierarchy proposed by Givón (1979) (see section 3.2). The nominal expression type hierarchy is similar to the **Givenness Hierarchy** proposed by Gundel et al. (1993) (see section 3.1.3). The grammatical function hierarchy affects the output attentional state, while the nominal expression type hierarchy affects the input attentional state. They are given in figures 6.3.3 and 6.3.3 respectively.

SUBJECT > OBJECT > OBJECT2 > others

Figure 6.1: Kameyama's grammatical function hierarchy

zero pronominals > unstressed pronouns > stressed pronouns > definite NPs > indefinite NPs

Figure 6.2: Kameyama's nominal expression type hierarchy

CENTER corresponds to the backward-looking center in the original centering theory and indicates the most salient entity in the actual utterance. The EXP CENTER is the expression of the highest-ranked type in the nominal expression type hierarchy and normally realises the **center** in the output attentional state. The transition types in Kameyama's model are actually only two: "establishing" a new center and "chaining" centers. They correspond to the two SHIFTs and to CONTINUE and RETAIN in BFP respectively. However as in Strube and Hahn's proposal, the transition types between adjacent utterances play no role in determining the preferred interpretation of utterances.

[5]Keenan & Comrie (1977) propose the Accessibility hierarchy to account for "the relative accessibility to relativisation of NP positions in simplex main clauses". Their NP accessibility hierarchy is the following:
SU > DO > IO > OBL > GEN > OCOMP.

Each centering state contains a set of maximally salient entities and the (in)determinacy of this set predicts the (in)determinacy of the preferred interpretation of a pronoun. The set of maximally salient entities is determinate if it contains only an element. In case the set contains more candidate antecedents the so-called defeasible parallelism preference is used. On the basis of a survey of pronominal use, Kameyama suggests that both parallelism preference and attentional rules are overridden by Commonsense rules and by conventional presuppositions. Furthermore the Subject Antecedent preference can override grammatical Parallelism preference when in conflict and both Subject Antecedent preference and Parallelism preference can override Pronominal Chain Preference.

Kameyama (1998*a*) extends centering to intrasentential anaphors. In particular she proposes to break complex sentences into structured sequences of subsequential clauses and then to apply centering to them.

Subordinate clauses are divided into two groups, tensed and untensed. The former are treated as independent utterances while the latter are processed as part of their superordinate clause applying syntax-based resolution approaches. Tensed clauses are further classified in sequential structures, comprising tensed conjuncts and adjuncts whose expressions are on the same level as the expressions in the superordinate clause (so-called sequential intrasentential centering) and in embedded segments which comprise reported speech and non-report complements and relative clauses (hierarchical intrasentential centering). Reported speech is inaccessible to the superordinate centering level, while non-report complements and relative clauses are accessible to the superordinate level, but they are less salient than it is. Kameyama's classification of subordinate clauses is given in figure 6.3.

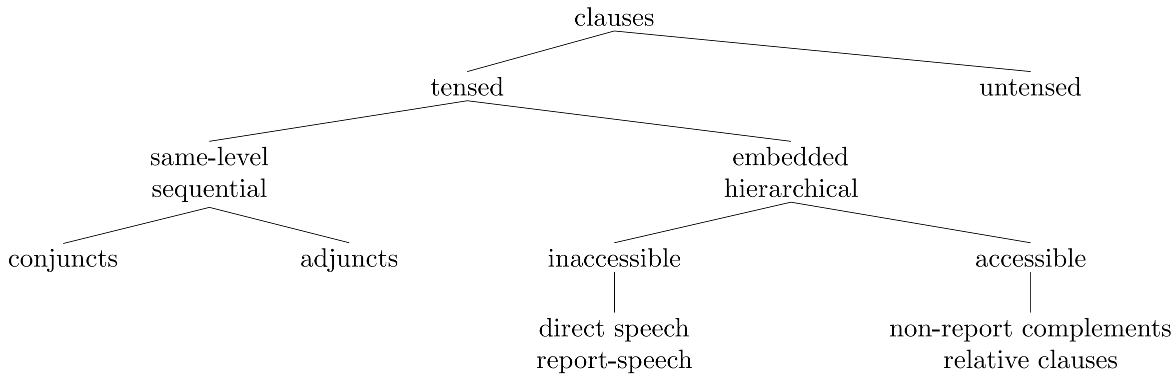

Figure 6.3: Kameyama's classification of subordinated clauses

Kameyama (1998*b*) extends her centering model to treat stressed pronouns. She assumes that unstressed and stressed versions of the same pronoun in the same position in discourse have the same denotational range, but indicate different preferred values. The focus constraint in Rooth's theory of focus interpretation which was shortly presented in section 4.2 is considered to be the salient subset of the domain in the local attentional state determined by the Centering framework. Stressed pronouns signal a different presupposition than their unstressed counterparts. If a stressed pronoun is met, it takes the complementary preference of its unstressed equivalent, if there are competing antecedents.

Kameyama's model uses functional categories as Strube & Hahn (1996) and eliminates the necessity of looking at the transition states in GJW, but it is more complex than Strube and Hahn's. Her extension of centering to clauses in complex sentences and her study of the difference between subordinate clauses is computationally appealing because it reduces the treatment of complex sentences to the sequential treatment of clauses. The relations between clauses are often better defined than the relations between sentences, thus it is less problematic identifying the former than the latter.

Kameyama's proposal of using different preference types for resolving anaphors is in line with the strategies proposed by i.a. (Wilks 1974, Hobbs 1978) (see sections 6.1) and it is interesting because it outspells the relation between the centering theory and other factors which have been found relevant to anaphora resolution.

6.3.4 Other Studies in the Centering Framework

Byron & Stent (1998) apply centering to multi-party discourse. They find that centering can be used for resolving pronominal anaphors in dialogues if the theory is extended to account for dialogue-specific aspects such as the definition of utterance boundaries, the insertion or exclusion of the discourse participants in the list of relevant discourse entities, the identification of a "previous" utterance (must it be uttered by the same speaker?), the definition of a strategy for tackling partial and unbounded utterances and utterances which do not contain discourse entities.

An application of centering to dialogues is described in section 7.4.

Some work has been done to extend centering to global reference, i.a. (Walker 1996, Walker 1998, Strube & Hahn 1997). Walker in particular argues that centering should be extended to treat global reference because centers are often continued over discourse segment boundaries. Furthermore it seems that different persons perceive discourse segment boundaries at different levels of granularity making it difficult to define precisely where these boundaries are.

For these reasons Walker proposes to replace Grosz and Sidner's stack model with a so-called *cache model* of attentional state. The idea of a CACHE is taken from standard computational architectures where it is defined as an easily accessible temporary location for storing information opposed to MAIN MEMORY which represents long-term memory. Walker recognises the following three operations involving the two memory structures:

retained: items in the cache can be preferentially retained

retrieved: items in main memory can be retrieved to the cache

stored: items in the cache can be stored to main memory

The size of the cache is limited, but Walker suggests that the precise size should be determined by future work. When new items are retrieved to the cache, other items must be displaced to main memory. These elements must be the least recently accessed items in the cache, with the exception of those items which are preferentially retained. The elements active in the attentional state at each point must be in the cache or must be retrieved to it.

Walker (1998) shows how the BFP centering algorithm can be integrated in the Cache model. The main point is that pronouns are attempted expanded by unification with entities in the cache. If no antecedents are found, the contents of the cache are reinstantiated by using the pronominal features and the content of the utterance as cues for retrieving matching discourse entities from main memory.

A similar proposal is made by Strube & Hahn (1997) with their *centered segmentation.* Strube & Hahn (1997) propose the following two processes for computing referential discourse segments:

- Determining the set of referents $\mathcal{R}$ considering the entities of the preceding utterance, then those at the end of the hierarchically immediately reachable discourse segment, finally those of the final utterance of any hierarchically reachable, though minimal distant discourse segment.
- Building up the current segment structure DS depending on the reachability patterns that characterise a referent from $\mathcal{R}$ and its possible occurrence in one of the above mentioned centers.

When a discourse segment DS is created at level s its starting and closing utterance are initialised at the current position in discourse. The closing utterance gets continuously incremented as the analysis proceeds until the DS is closed. The end of a discourse segment is found when there are no referents in $\mathcal{R}$ to entities in the preceding utterance and another discourse segment exists at the same or at an higher level of embedding.

New segments are for example opened when no matching referent in hierarchically reachable segments are found. Strube & Hahn (1997) also use the notion of *theme/rheme*, roughly corresponding to topic and focus to recognise discourse segments.

Strube and Hahn's proposal is interesting because it uses the relation between anaphors and antecedents for segmenting discourse. The relation between referring expressions and discourse segments was studied by Fox (1987). Furthermore Passonneau & Litman (1997) notice that the use of referring expressions and discourse segmentation are mutually related processes. This is also in line with Hobbs' interpretation of referring expressions as one of the coherence indicators together with coherence relations (Hobbs 1983).

Both Walker's and Strube and Hahn's proposals are valuable suggestions to extend local reference strategy to global reference. However Strube and Hahn only search for referents in the immediately preceding utterance in the current discourse segment or at the end points of preceding discourse segments and this is problematic, because the analysis of Danish discourse indicates that pronominal antecedents sometimes precede the anaphor of more utterances in the same discourse segment. This phenomenon seems to be more common in dialogues than in texts as discussed in chapter 8 and maybe therefore has not often been taken into consideration.

6.4 Information Structure and Anaphora Resolution

Differing from the majority of theories of salience Hajičová et al. (1990) propose a hierarchy of salience which takes into account the information structure of an utterance as in Sgall et al. (1986). Salience is defined as **activation** or **foregrounding** of the items in the hearer's and speaker's shared discourse model (**SM**), so that the items with highest degree of salience are the most easily accessible in memory. Hajičová et al. (1990) describe the degree of salience of items in an utterance **U** as follows:

1. The nominal phrases referred to in the focus of **U** receive the highest degree of salience.

2. The items referred to by a noun phrase in the topic part of **U** are activated one degree less than those referred to in the focus part.

3. A pronominal reference to an item in the topic part of **U** retains the degree of activation of the item in **SM**.

4. The activation of items not mentioned in **U** fades away. The activation fades away most quickly for those items which had the highest activation.

The authors suggest to use groupings of activated elements in a piece of discourse as an indication of how to divide discourse into segments. On the basis of the hierarchy of salience Hajičová et al. (1990) analyse referring expressions in Czech technical texts and suggest the following strategy for resolving anaphors:[6]

1. the antecedent of a weak pronoun is looked for in the topic of the preceding clause while the antecedent of a strong pronoun is looked for in the focus

2. if there are more competitors after step 1 or if no antecedents are found, search the antecedent in a list of NP's from the preceding text (from the beginning of the actual paragraph) with their respective degree of activation. If no element can be found in the list let the pronoun be unresolved because semantic knowledge must be used

Hajičová et al. (1990) also propose a strategy for generating referring expressions in technical texts. This strategy takes into account the degree of activation of an object **O**, *da(O)* and the presence of competing antecedents i.e. objects whose degree of activation differs only by 1. If *da(O)* is less than the threshold defined as minimal degree of activation (MIN), it is not possible to refer to **O** by pronouns.

Using the **TFA** of an utterance for calculating the degree of salience of entities distinguishes the approach presented by the Prague School from the majority of studies on anaphora resolution. As noticed in chapter 4 I agree with Sgall et al. (1986) that entities in the focal part of an utterance can have highest degree of salience. I investigate in which cases this is true in later chapters.

Another interesting aspect of Hajicova and al.'s work is that they consider the salience of entities as a value gradually increasing and decreasing in the course of discourse. This aspect is implemented in some of the most recent methods for anaphora resolution which are discussed in the following section. The observation that strong pronouns refer to focal objects is in line with the theories that suggest that strong pronouns refer to the element which is not the most salient (topical in these theories), i.a. (Ariel 1988, Kameyama 1998*a*). Using the TFA of utterances in the computation of the degree of salience is interesting, but also problematic because it requires that the TFA is recognised and represented.

[6] I only report the steps involving pronominal anaphors which I work with.

6.5 Combined Computational Approaches

Some researchers have presented resolution strategies which rely on statistics for resolving anaphors in unrestricted texts, or which combine syntactic, semantic and pragmatic aspects with statistic strategies.

Dagan & Itai (1990) develop a method for automatically acquiring cooccurrence patterns from a large corpus. The extracted cooccurence patterns are used for resolving references of the pronoun *it* in randomly selected sentences from the corpus, so that only antecedent candidates that actually occur in the corpus are accepted. Although Dagan and Itai's strategy cannot be used in interactive dialogue systems, it shows the importance of restricting the resolution space to contextually probable constructions.

Carbonell & Brown (1988) argue for the use of a set of strategies for resolving intersentential anaphora. They develop an anaphora resolution system where different sets of constraints and preferences corresponding to different knowledge sources such as sentential syntax, case-frame semantics, dialogue structure and general world knowledge are integrated.

Constraints are applied before preference rules. The local anaphor constraints which they implement are agreement constraints (number, gender, case) and case-role constraints which eliminate candidate referents that violate any case-constraint imposed on the actual anaphor. These are also called selectional restrictions. Precondition and postcondition constraints rely on world knowledge. The recognised preferences are case-role persistence preference, semantic alignment preference, syntactic parallelism preference (in coordinated clauses, adjacent sentences or explicitly contrasted sentences), syntactic topicalisation preference.

If there are no satisfactory candidates in the previous sentence, previous sentences in linear order are taken into consideration.

The combined strategy proposed by Carbonell and Brown has the advantage of considering different strategies to resolve anaphors that cannot be correctly treated by more simplistic algorithms such as Hobbs' naive algorithm and centering-based strategies. The combined strategy is in line with the proposals in i.a. (Wilks 1974, Hobbs 1978, Kameyama 1996). Carbonell and Brown distinguish between the order of application of constraints and preferences, but do not account for the ranking of the different types of preference, as done by Kameyama (1996).

Carbonell and Brown search anaphoric antecedents linearly in the texts, thus they do not take into consideration the structure of discourse for reducing the resolution scope. However they look at simple discourse structures such as coordinated clauses, adjacent sentences or explicitly contrasted sentences in order to apply syntactic parallelism preferences to them.

Lappin & Leass (1994) describe an algorithm for identifying the nominal antecedents of third person pronouns. The algorithm runs on syntactic parsed texts and chooses the pronominal antecedent from a list of candidates on the basis of salience weights derived from the syntactic structure and a dynamic model of attentional state.

Kennedy & Boguraev (1996) modify and extend Lappin and Leass' algorithm applying it to tagged texts enriched with the annotation of the grammatical function of lexical items in the texts. Both algorithms contain the following parts: an intrasentential syntactic filter and a morphologic filter which rule out candidate antecedents on syntactic grounds and agreement features; rules for identifying pleonastic pronouns, a resolution procedure for binding lexical anaphors inside the same sentence, a procedure for assigning salience weights and one for selecting the preferred antecedent. In both algorithms the notion of coreference is represented in terms of equivalence classes of anaphorically related discourse referents. The most important parameter in a coreference class is its salience value which is calculated as the sum of a number of salience factors. The salience of each class is variable, decreasing and increasing depending on the frequency of reference in the class. Because Kennedy & Boguraev (1996) do not have configurational information they calculate disjoint reference inferring on grammatical function and precedence information. The factors which determine salience are grammatical roles (verbal complements order), parallelism of grammatical roles, frequency of mention, recency.

Lappin & Leass (1994) report a success rate of approx. 86% on a manual text, Kennedy & Boguraev (1996) report a succes rate of 75% on different types of text, which is clearly good given the fact that they do not use a full-parsed text. Differing from many pronominal resolution algorithms Kennedy & Boguraev (1996) also identify pleonastic pronouns in order to exclude them from resolution.

Mitkov (1998) develops a method for resolving pronominal anaphors which only requires limited knowledge. The approach is developed for and tested on technical manuals. Mitkov's resolution system takes as input a text that has previously been part-of-speech tagged and identifies the noun phrases which precede a pronominal anaphor in the preceding two sentences. The system checks these noun phrases for gender and number agreement with the anaphor and applies genre-specific antecedent indicators to the possible antecedent candidates. Each indicator gives a score to the noun phrases and the noun phrase with the highest total score is proposed as antecedent. If two noun phrases have the same score, the phrase with the highest score for immediate reference is preferred. Some of the applied antecedent indicators are given in the following:

1. Definite nominal phrases are more likely to be antecedents than indefinite

ones.

2. Nominal phrases representing given information are preferred. These nominal phrases usually appear first in a sentence.[7]

3. A nominal phrase following verbs such as "indicate, show, describe, illustrate" is a preferred antecedent.

4. Lexically reiterated items are given a high score.

5. Nominal phrases occurring in the heading of the actual section are preferred candidates.

6. Non-prepositional nominal phrases are preferred to prepositional ones.

7. Candidates which have the same collocation pattern as the pronoun are given a high score.

8. Candidates immediately preceding the anaphor are preferred.

Mitkov reports a success rate of 89.7 % for technical manuals and has also tested the method with success on Arabic and Polish texts.

Mitkov's approach is interesting because it does not require full-parse of the text, it is robust (an antecedent candidate is always proposed) and because, although some of the indicators are genre-specific, most of them reflect general tendencies about pronominal reference studied in linguistics and cognitive science. In particular preferences 1-5 indicate that entities which are given and prominent should be preferred to unknown entities and that there is a tendency in discourse for topic continuity. Preference 6 indicates that subject, object and indirect objects are more probable antecedents than other complements and adjuncts. This is in line with i.a. Givón's topicality hierarchy. Preference 7 implements a kind of parallelism preference and preference 8 chooses antecedents with lower referential distance following i.a. (Ariel 1988).

It is clear that from a computational point of view the approaches described in this section are valuable because they apply general facts discovered in theories about the use and the resolution of anaphora on running texts, making use of as little resources as possible and combining various theories and strategies.

6.6 Scandinavian Studies on Anaphora

Most of the studies on anaphora in Scandinavian languages have focused on intrasentential pronouns, which cannot be fully accounted for by the Binding

[7] As discussed in chapter 4 also in Danish there is the general tendency of having the topic in the leftmost position of an utterance.

Theory (Chomsky 1980, Chomsky 1981). Reflexive pronouns have been studied in both GB and HPSG, i.a. (Vikner 1985, Neville 2000, Hellan 1986, Hellan 1991). Vikner (1985) suggests that Danish reflexive pronouns and possessives can be accounted for by adding the concept of *subjecthood* to the treatment of pronouns in GB. Neville (2000) follows this idea and proposes an account of reflexives in HPSG. Neither of them however can account for phenomena such as reflexives coreferring to the indirect object in ditransitive constructions. In his account of Norwegian reflexives, Hellan (Hellan 1986, Hellan 1991) uses the relation of *predication* which comprises subjecthood. Herslund (1986) suggests that indirect objects in ditransitive constructions in Danish can be interpreted as a case of predication. Hellan's account of Norwegian reflexives implying a relation of predication between the owner and the possessed object is very interesting and, in my opinion, should be exploited in a formal treatment of Danish reflexives.

Ørum, T.Thrane, Prebensen, Olsen & Jansen (1987) present some of the international literature on anaphora resolution and describe semantic and representational problems related to the treatment of anaphors. Computationally they take as starting point SHRDLU by (Winograd 1972) which they reimplement using Danish as query language.

Fraurud (1988) studies the use of intrasentential pronominal reference in Swedish analysing three types of text. She distinguishes four classes of pronouns in Swedish with respect to animacy and gender: masculine, feminine, t-gender and n-gender. The same distinction is valid for Danish as can be seen in chapter 2, but there are some differences between the two languages. For example Swedish distinguishes between feminine and masculine forms of demonstratives, while Danish does not.

Fraurud annotates the distance and the animacy of the referent of pronouns in her texts and concludes that in most cases the referent of a pronoun is in the same sentence or in the immediately preceding sentence. When the referential distance is greater the antecedent is in most cases animate and topical (one of the two main actors in the text). Fraurud's study and results are thus in line with the proposals in (Ariel 1988, Givón 1976, Givón 1983). Fraurud also investigates the occurrences of plural personal pronouns in the texts and finds that often their antecedents are simple plural nominal phrases. Only in fewer cases antecedents of plural pronouns are split or coordinate antecedents and collective nouns. Also a number of antecedentless pronouns occurred in the analysed texts.

On the basis of her study, Fraurud (1988) proposes a simple resolution algorithm with low computational cost for singular non-reflexive Swedish pronouns. The steps of the algorithm are the following:

1. Take as candidate antecedent every nominal that:
   (a) textually precedes the pronoun

(b) agrees with the pronoun in number, animacy and gender

(c) is not coreferential with the subject of the clause in which the pronoun occurs

(d) is not in a clause where the pronoun is subject

2. Select as antecedent among these candidates:

   (a) the candidate in the text with the shortest referential distance unless in the same clause the subject nominal phrase is also a candidate antecedent. In this case choose the subject candidate if the pronoun is not a demonstrative, otherwise choose the most recent candidate.

Fraurud tests her algorithm on written texts obtaining a success rate of 91%, but she excludes plural pronouns from the test. Analysing the obtained results Fraurud notices that it is not clear whether head nominal phrases should be preferred to non-head nominal phrases, because genitive phrases are often the referent instead of their head phrase or the whole nominal constituent. An explanation could be that genitive constructions often signal a hierarchical relation between two referents.

Fraurud suggests to add the following preference hierarchy for pronoun accessibility to the algorithm:

human < animate < concrete < abstract

Fraurud compares her strategy and results to those of Hobbs' naive algorithm (Hobbs 1978) (section 6.1.1). The main differences between the two algorithms are that Fraurud's algorithm does not require full-parsed texts and that the naive algorithms resolves both intrasentential and intersentential pronominal anaphors, while Fraurud's algorithm only resolves Swedish intersentential pronouns.

Fraurud (1992) proposes to divide the features used in anaphora resolution into two groups, i.e. description features which comprise number and agreement, and referent features which include animacy, sex and complexity. Only plural pronouns and singular male/female pronouns require referent features. Fraurud also analyses aspects of situation reference in English, German and Swedish. A discussion of this study is given in section 7.2.

Because of the similarities between Swedish and Danish, I have tested Fraurud's algorithm on Danish texts. The results of this test are described and presented in chapter 8.

Ravnholt (1994) inspired by Ariel's and Fraurud's work (Ariel 1988, Fraurud 1992) makes an empirical study of the referential distance of definite nominals and pronominals in 22 short Danish texts. The results of his study seem to confirm for Danish the connection between animacy of the referent and referential distance, i.e. also in Danish anaphors with distant referents in most cases refer to animated entities.

6.7 Conclusion

The computational approaches to resolve pronominal anaphora range from simple syntactic strategies such as Hobbs' naive approach and Fraurud's algorithm, to more complex ones combining syntactic, semantic and pragmatic factors. In Hobbs' abductive-based model of text understanding syntactic, semantic and pragmatic constraints and preferences are applied at the same time. Sidner's and Kameyama's models follow a stepwise strategy, so that possible anaphoric antecedents are first reduced on the basis of syntactic and semantic constraints. Non-monotonic reasoning is only applied to the already reduced antecedent search space. Kameyama explicitly exploits the relation between different levels of preferences and the order in which they should be applied.

In some approaches such as Hobbs' syntax-based algorithm, Fraurud's algorithm and Carbonell and Brown's combined approach the anaphoric antecedents are looked for in linear order, while in others the structure of discourse or task determines the search space, as in Grosz' theory and in dialogue models for planning systems. Grosz and Sidner's model combines these two strategies. The search space for global focus is determined by the dialogue and task structure, accounting for phenomena such as interruptions and/or subdialogues. The local search space is the preceding utterance. Local focus is accounted for by the **Centering** theory. Linear search has been implemented in many application, because it is not clear how to automatically determine the structure of discourse. In task-oriented dialogue systems both the global and local focus strategy proposed by Grosz & Sidner (1986) have been implemented. However the task and dialogue domain of these systems are quite small.

Because it is not always clear how to define discourse segment boundaries and because local reference can occur in between different discourse segments Walker proposes to extend the Centering-based approach to resolve global reference by using the so-called *cache model* (Walker 1996, Walker 1998). A similar proposal has been presented by Strube & Hahn (1997) who in their *centered segmentation algorithm* also account for discourse segmentation as a side-process of their functional centering-based resolution algorithm (Strube & Hahn 1996). The strategy of extending Centering to global reference has also been followed by Tetreault (2001).

I believe that these approaches are a valuable alternative to Grosz and Sidner's focus stack also for dealing anaphors in dialogues where the distance between a pronoun and its antecedent is often of more utterances inside the same discourse segment. This contradicts the Centering assumption that local reference can be exclusively accounted for by the entities in the currently processed utterance and in the preceding utterance.

The pragmatic factors that have been seen as central for the resolution of anaphora are the salience or prominence degree of utterances and coherence.

The different approaches have identified salience with the order of verbal complements (BFP), which in English mainly corresponds to the linear order of discourse entities (GJW, Hobbs' simplistic algorithm) and the functional structure of the entities (Strube and Hahn, Kameyama), understood as their givenness status in the hearer model. Researchers from the Prague tradition (Hajičová et al. 1990) also take into account the information structure of utterances and propose that entities in the focal part of an utterance in IS terms have highest degree of salience.

Coherence has been connected with discourse relations and background knowledge (Hobbs), task and discourse structure in global reference (Grosz and Sidner) and salience in local reference (Grosz, Joshi and Weinstein).

The pragmatic studies of anaphora reviewed in chapter 3 have inspired the different definitions of salience. Strube and Hahn use Prince's *Familiarity Scale* (Prince 1981, Prince 1992) as model of salience while BFP use the topic hierarchy of verbal complements presented by i.a. (Keenan & Comrie 1977, Givón 1979). Kameyama orders entities in the output attentional state by the hierarchy of verbal complements while she uses the **Givenness Hierarchy** proposed by Gundel et al. (1993) for ranking referring expressions in the input attentional state. This double ranking permits her to distinguish between the use of different types of pronoun. This distinction was found relevant to the treatment of Danish pronouns (chapters 2-4.

It is clear that to account for all cases of pronominal anaphors syntactic, semantic and pragmatic factors must also be taken into account. Hobbs' abduction-based theory of text understanding is fascinating because it combines different knowledge sources in the process of understanding and points out that anaphora resolution is connected to other phenomena which express coherence in discourse. Because using non-monotonic inference in all the phases of natural language processing is not very attractive from a computational point of view, stepwise approaches where commonsense knowledge is only applied to resolve ambiguous contexts have been preferred in applied systems. In this line are Kameyama's and Sidner's approaches.

However the fact that only the interpretation of the context can account for complex types of anaphor is clear and is particular evident when dealing with discourse deixis, which I discuss in chapter 7.

Reducing the resolution search space for anaphoric antecedents has been one of the main motivations behind the popular Centering theory. In the theory antecedents of intersentential anaphors in the same discourse segment are, as mentioned earlier, only looked for in the preceding utterance. The theory also assumes that there is a discourse entity in each utterance that is more central than the others (the *backward center* or simply the *center*). Here Centering departs from Sidner's model of reference where two central entities, the actor and the discourse focus are recognised.

There is no consensus about whether there must be an entity which is more "central" than others in an utterance (see for example (Poesio, Cheng, Henschel, Hitzeman, Kibble & Stevenson 2000)). I do not believe that this is the case, but the basic assumption behind the Centering Theory, i.e. that people tend to speak about the same entities for a while and that these entities are more central than others inside discourse segments is, in my opinion, intuitively correct and can used in discourse interpretation. This does not mean that centering is the only coherence factor in local reference and that centering-based strategies can account for all cases of pronominal use. In fact centering-based resolution strategies alone often fail in identifying the correct referent when there are more candidate antecedents or in cases where the attentional preferences are overridden by other factors. Because of their simplicity centering-based algorithms have been tested in many languages and have been an useful means of comparing the use of pronouns in these languages. I have also tested centering-based algorithms on Danish data. In chapter 8 I describe this test and I compare the obtained results with the results of tests on English data reported in the literature.

The fact that centering rules only account for some aspects of the use of pronominal anaphors is clearly stated by Kameyama who also proposes to use centering as model for resolving intrasentential anaphors, a strategy which is both linguistically and computationally motivated. In (Kameyama 1996) she explicitly suggests an order in which different preference mechanisms, including centering related preferences, should be applied in anaphora resolution and I believe that her strategy is worth pursuing. This aspect of Kameyama's work is in line with the proposals of many researchers i.a. (Wilks 1974, Hobbs 1978, Carbonell & Brown 1988, Kameyama 1996, Mitkov 1998). These combined strategies for resolving anaphors have been applied to resolve anaphors in large corpora without relying on all the components which compose an NLU system.

All the approaches described in this chapter deal with individual anaphora resolution, although Sidner also investigates constructions such as *do it/so*, where the anaphoric *it* and *so* preferentially refer to a verbal phrase. However third person neuter gender pronouns used as discourse deictics are common in discourse and, as described in chapter 2 they are used in Danish in many contexts where English prefers elliptical constructions. In the following chapter I look at how discourse deixis has been treated in theoretical approaches and in applied systems.

Chapter 7

Discourse deixis

Reference to abstract objects has not been treated as extensively as reference to individual objects in computational linguistics, although it is a very frequent phenomenon as mentioned in chapter 2 and as the analysis of data described in section 8.1 indicates.

In this chapter I look at the most influential studies of abstract reference. In sections 7.1-7.3 I review Webber's, Fraurud's and Asher's analysis of discourse deixis while in section 7.4 I discuss an algorithm for resolving pronominal anaphors with individual and abstract antecedents in English telephone conversations. The algorithm has been developed by Eckert & Strube (1999*b*). In section 7.5 I make some concluding remarks.

7.1 Webber

As seen in section 5.4 Webber (1991) represents the structure of discourse as a tree and argues that only some of the regions in the tree are **in focus** at a given point of the discourse and that these regions correspond to the right-frontier of the discourse tree. One of the examples discussed by Webber to illustrate the accessibility to discourse deictic reference is given in (1). In the example the different clauses are numbered.

(1) 1. It's always been presumed that 2. when the glaciers receded, 3. the area got very hot. 4. The Folsum men couldn' t adapt, and 5. they died out. 6. *That*'s what is supposed to have happened.

In (1) there are four regions in focus with respect to the deictic *that*, i.e. the region associated with clause 5, the region associated with clauses 4 and 5, the region associated with clauses 2-5, and, finally the region associated with clauses

1-5. The identification of the correct referent of the discourse deictic between these regions in the right frontier of the tree requires an analysis of the whole context. Webber writes that the referents of the deictic *that* are probably the regions associated with clauses 4-5 or 2-5 considering the whole story from which example (1) is taken.

Following (Nunberg 1979) Webber distinguishes between what can be pointed to (the demonstratum) and what can be referred to by virtue of pointing (the referent) and she claims that there are referring functions which map from the demonstrata to the intended referents. The addressee must simultaneously constrain the demonstratum and the referring functions to obtain the intended referent. The range of possible referents follows from the range of referring expressions. She illustrates this by (2). The four discourse deictics in (2-a)-(2-d) corefer to the same discourse segment which precedes them. However the four contexts in which the deictics occur indicate that the pronouns refer to different semantic objects. In (2-a) the deictic refers to a speech act, in (2-b) it refers to the proposition expressed in the discourse segment, in (2-c) it refers to the description expressed in the segment and finally in (2-d) it refers to the event denoted by the segment.

(2) Hey, management has reconsidered its position. They've promoted Fred to second vice president.
   a. *That*'s a lie. - SPEECH ACT
   b. *That*'s a false. - PROPOSITION
   c. *That*'s a funny way to describe the situation. DESCRIPTION
   d. When did *that* happen? - EVENT

To account for this phenomenon, Webber proposes that discourse deictics perform an act of *ostension*, i.e. they add new entities into the discourse model. Only in the most simple cases they refer to entities already in the discourse model. The phenomenon of *ostension* is similar to the process of *accommodation* recognised by Lewis (1979) for individual reference. *Accommodation* is the process according to which a hearer associates an individual entity in discourse with the descriptive content of the definite nominal phrase which must be resolved. In *ostension*, however, the process is more complex because the anaphoric pronoun does not have a descriptive content of its own.

The importance of Webber's contribution is that she connects the resolution of discourse deictics to the structure of discourse, restricting the search space of discourse antecedents to those regions which are *in focus* in the discourse model. These regions are the right frontier of the discourse tree. Furthermore Webber's proposal that discourse deictics perform an act of *ostension*, i.e. they create new entities in the discourse model has generally been accepted. Webber also indicates that a deep analysis of the context is often necessary to correctly resolve discourse deictics.

7.2 Fraurud

Fraurud (1992) defines the phenomenon of reference to abstract objects as *situation reference*. Following Vendler (Vendler 1963), she semantically divides situations into eventualities and factualities. Eventualities can be further divided into activities, accomplishments, achievements and states, factualities into facts and propositions. Thus discourse deictics can refer to this variety of semantic objects.

Fraurud distinguishes specific and generic readings of situation reference. In example (3) the pronoun *it* can both refer generically to the discourse entity of kissing, a *situation type*, or it can refer to a specific kissing entity, a *situation token*.

(3) *Kissing is dangerous. It may have consequences.*

Fraurud distinguishes between nominal and clausal antecedents of situation reference. Noun phrases referring to situations can be non-derived nouns such as *accident*, *war* and *funeral*, deverbal nouns such as *quarrel*, *arrival* and *behaviour* and verbal nouns such as *quarrelling*, *arriving* and *acting*. Sentences can consist of one or more clauses (simple and complex sentences). Complex sentences may involve coordination and/or subordination. Clauses can be independent (main clauses) or dependent (subordinated clauses).

Fraurud follows Webber in considering that situation reference performs an act of ostension and also proposes that pronominal chains involve a "sub-type shift" of referent and illustrates this fact with the following English example:

(4) John won the race. I know <u>that</u>, because I saw <u>it</u> happen. But it's still hard to believe <u>it</u>.
(FACT > EVENT > PROPOSITION)

Fraurud accounts for "subtype shifts" by considering the entity introduced into the discourse model by the antecedent expression as a kind of "general" situation referent from which other situation referents specified as events, facts and propositions can be derived. This is in line with Webber's proposal.

Fraurud also follows Webber's right frontier assumption, but claims that Webber's tree structure should be supplied with the notion of subordination and coordination of discourse segments as proposed by Hobbs (1985).

Finally Fraurud argues that complex situation referents consist of the following two types:

1. **sets of situations** which have a cardinality
2. **structured situations** which have no cardinality and designate a unique situation with a complex internal structure

To provide evidence for this distinction Fraurud shows that singular/plural definite NPs and pronouns are used differently to refer to these two types of situation. Only singular pronouns and NPs can refer to structured situations, while plural NPs and pronouns (and only in some cases singular pronouns) can refer to sets of situations. This is summed in table 7.1.

		full definite NP		pronoun	
Referent	Antecedent	plural	singular	plural	singular
structured situation	non-nominal	-	+	-	+
	nominal	-	+	-	+
set of situations	non-nominal	+	-	-	+/-
	nominal	+	-	+/-	+/-

Table 7.1: The number of expressions referring to complex situations

Fraurud investigates the occurrences of situational anaphoric pronouns with non-nominal antecedents in 85 written Swedish non-fictive texts. The Swedish situational pronouns she takes into account are *det* (it/this/that), *detta* (this) and *det här* (this) and *det där* (that). She also looks at occurrences of these pronouns when they are preceded by the quantifier *allt* (all): *allt det* (it all/all that) and *allt detta* (all this). The antecedents of situational anaphors in the texts were found less than one graphic sentence away. In the case of cataphoric discourse deictics, the referents always occurred later in the same sentence. The scope of the situational referents were a part of a sentence, a sentence or more sentences.

Fraurud also proposes the following tentative hierarchy of the likelihood of situational pronouns having a referent of more than one sentence:

det (1.5%)< detta (10.3%)<allt det/allt detta (83.3%)

Apart from this hierarchy, Fraurud does not find any important difference between the use of *det* and *detta*. She notices that *detta* can often replace *det* without affecting the meaning of the sentence. She notices that using *allt detta* instead of *detta* seems not only to indicate that the antecedent is a longer piece of text, but also emphasise the importance of the referent.

As illustrated in chapter 2 also in Danish discourse deictics preceded by the quantifier *alt* often refer to more sentences. However I have identified differences in the reference by the two Danish pronouns *det* and *dette*, which are not described for Swedish by Fraurud.

7.3 Asher

In line with Fraurud's study is Asher's work (Asher 1993) presenting a "semantic and metaphysical analysis" of abstract objects as a necessary basis for studying how people linguistically refer to them. Asher uses Discourse Representation Theory (Kamp 1981, Kamp & Reyle 1993) as his framework. Discourse Representation Theory is shortly presented in section 9.3.

Also Asher builds on the work of Vendler (1963) and proposes a typology of abstract objects based on the following two aspects: the Fregean notion of saturation and the notion of word immanence. Saturated objects are true or false and comprise propositions, facts and events. Unsaturated objects describe properties of something and as such cannot be true or false. Unsaturated objects comprise properties and concepts. Asher focuses on saturated objects. According to the dimension of world immanence objects are divided into word immanent objects such as events, which have spatio-temporal locations, causal power and can have concrete properties, and non-word immanent objects, such as propositions, which do not have any spatio-temporal location.

Linguistically Asher distinguishes between sentential nominals (similar to sentences) and predicate nominals which correspond to common nouns, verbs, common noun phrases and verbal phrases. Sentential nominals are always saturated, predicate nominals can be saturated or not. Asher proposes a typology of saturated abstract objects which is illustrated in figure 7.1.

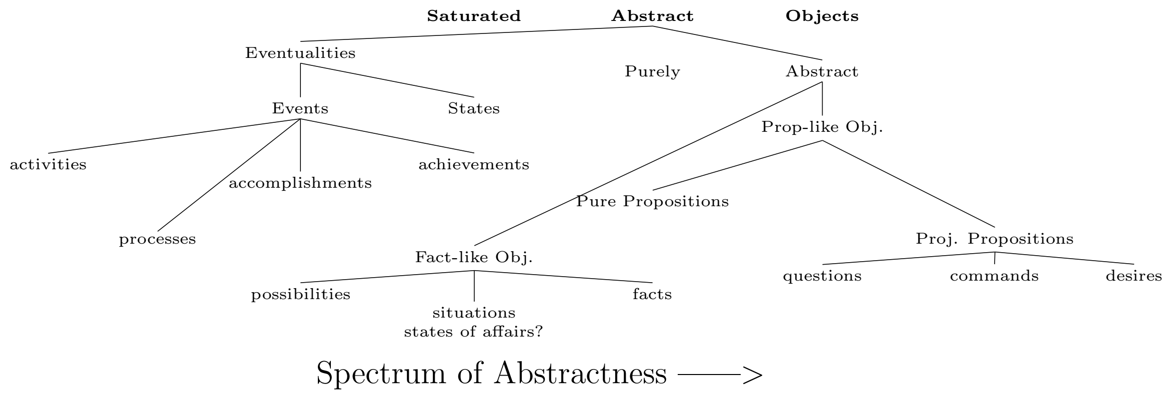

Figure 7.1: Asher's taxonomy of saturated objects

Asher, as Webber and Fraurud, points out the importance of discourse structure for resolving reference to abstract objects. To include this aspect in the representation of the discourse context he extends Discourse Representation Theory. In the extended theory which Asher calls Segmented Discourse Theory (SDRT), DRT segments, DRSs, representing sentences are connected by discourse relations.

Asher distinguishes two types of discourse relations: coherence relations, as described i.a. in (Hobbs 1979, Hobbs 1983), and rhetorical relations (Mann & Thompson 1987, Mann & Thompson 1988). The former are relations between eventualities introduced within the constituents, while the latter are relations between propositions and their list is open-ended.

The basic constituent of written discourse for Asher is a sentence. He notices that the elementary constituents of dialogues are presumably question-answer pairs or turn takings, but he only deals with written texts.

Discourse relations may be explicitly signalled by cue words, but in some cases they must be inferred from the context and factors determining discourse structure are i.a. the content of the constituents, tense and aspect. The relations that must be inferred from the context are the most complex and are called topic-based relations. They include elaboration and continuation.

Asher identifies two constraints on anaphora at the level of discourse structure, **availability** and **well-foundedness**. The former constraint is not only related to Webber's right frontier constraint on the referential accessibility of discourse parts, but also indicates which constituents of a discourse segment are available candidates for entering new information provided by new sentences. Thus **availability** indicates the constituents which possibly can be updated.

Asher also accounts for how discourse structure is responsible for the construction of non-syntactically marked sums of object groups, both abstract and individual object groups. He points out that the resolution of abstract objects and of complex plural pronouns require the same strategy.

From a theoretic point of view Asher's work is inspiring because it provides a linguistically and semantically motivated taxonomy of the degree of abstractness of saturated abstract objects. Asher also accounts for the constraints which discourse structure imposes on reference and he provides an extension of DRT, SDRT, so that the structure of discourse can be added to the semantic representation of DRSs. In praxis it is still an open question how to extract the appropriate discourse relations.

In his more recent work with Lascarides (Asher & Lascarides 1994, Asher & Lascarides 1998, Asher & Lascarides 1999), Asher points out that the cognitive states of the discourse participants must be taken into consideration to correctly identify the structure of discourse. This aspect, however, complicates the interpretation task. Asher and Lascarides propose to use a non-monotonic type of logic to infer discourse relations, similar to Hobbs' abductive model for text understanding.

Although I do not focus on the semantic types of abstract reference in this dissertation, identifying the semantic object referred to by a discourse deictic is important in natural language processing and an analysis of how different types of abstract objects are preferentially expressed in Danish should be accomplished. Some semantic types can be identified from the context in which the anaphor occurs. For example the discourse deictic in *gøre det* (do it) constructions always refers to an eventuality, while in constructions such as *det er sandt/falsk* (it is true/false) it always refers to a proposition. However discovering the correct semantic interpretation is not always so easy.

7.4 Eckert and Strube

Eckert and Strube (Eckert & Strube 1999*a*, Eckert & Strube 1999*b*) present an algorithm for the resolution of both individual and discourse deictic anaphors in a corpus of English telephone conversations, the ES99-algorithm henceforth. The ES99-algorithm is based on the classification of possible anaphor types which comprises individual anaphora (IPro,IDem), discourse deictics (DDPro,DDDem), inferrable-evoked pronouns(IEPro) and vague anaphors (VagPro, VagDem). Inferable-evoked pronouns refer to the use of the plural pronoun *they* indirectly co-specifying with a singular NP which indicates a country or an institution. Vague anaphors are anaphors whose antecedents are not explicitly in the discourse, but can be inferred by its context. Examples of inferable-evoked pronouns and vague anaphors were given in section 2.2.3 example (35), and section 2.3, example (54), respectively. They are here repeated in (5) and (6).

(5) *og øh...* (1 sekund) *så sent som i morges, i radioavisen hørte jeg, at **de** netop snakkede om det her*
(lit. and uh... (1 second) as late as this morning on the radio news heard I that **they** precisely talked about this)
(and uh... (1 second) as late as this morning I heard on the radio news that **they** precisely talked about this)
(SL)

(6) **A:** *nu skal vi jo have ?(lille)? drengen til... i skole her til august jo*
(now we must have the ?(little)? boy in school here in august)
B: *ja*
(yes)
A: *så skal han starte på den der Kreb- eller* (ler)

(then he is going to that Kreb- or) (laughs)[1]
B: *skal han det*
(lit. is he that)
(is he?)
A: *ja... han skal,* ***det*** *vil jeg sgu' godt give ham*
(lit. yes... he has, **that/it** will I bloody well give him)
(yes... he has, I will bloody well give **that/it** to him)
(SL)

Eckert and Strube structure dialogues using a simplification of the top of the speech act hierarchy proposed by Carletta et al. (1997). They only use three dialogue acts: *Initiations*, *Acknowledgements* and *Initiations/Acknowledgements*. *Initiations* convey semantic information, *Acknowledgements* do not contain semantic information, but have the backchannelling function of acknowledging the preceding *Initiation*, while *Initiations/Acknowledgements* contain semantic information and have an acknowledgement function at the same time. An *Initiation* followed by an *Acknowledgement* or an *Initiation/Acknowledgement* constitute a **Synchronising Unit**, **SU**. Longer *Initiations* do not need to be acknowledged and are considered as an **SU**.

Eckert and Strube define an anaphor-type compatibility measure to automatically distinguish between discourse deictics and individual reference. Predicates that are preferentially associated with abstract objects are marked as *i-incompatible* (***I**) while predicates that are preferentially associated with individual objects are marked as *a-incompatible* (***A**). The ***I** predicates identified by Eckert and Strube are the following (Eckert & Strube 1999*b*)[40] :

- constructions where a pronominal referent is equated with an abstract object, e.g. *x is making it easy, x is a suggestion*
- copula constructions with adjectives which can only be applied to abstract entities, such as *x is true, x is right*
- arguments of verbs indicating propositional attitude which take S'-complements, such as *assume*
- object of *do*
- predicate or anaphoric referent is a reason, such as *x is because. . . , x is why. . .*

The ***A** predicates which are identified by the authors are the following (Eckert & Strube 1999*b*)[40]:

[1] Here it is referred to Krebsskolen, a private school in Copenhagen.

- constructions where a pronominal referent is equated with a concrete individual referent, such as *x is a car*
- copula constructions with adjectives which can only be applied to concrete entities, such as *x is expensive, x is tasty, x is loud*
- arguments of verbs describing physical contact/stimulation, which cannot be used anaphorically, e.g. *eat x, smash x*

Individual anaphors are resolved with Strube's centering algorithm (Strube 1998). To resolve anaphors that refer to abstract objects, Eckert and Strube propose to use a so-called abstract object list, the A-list. The A-list is only filled when discourse deictics occur and its contents remain only for one Initiation. The context ranking describes the order in which the parts of the linguistic contexts are accessed and is given in figure 7.2.

1. the A-list
2. within the same Initiation: the clause to the left of the clause which contains the anaphor
3. within the preceding Initiation: rightmost main clause and subordinated clauses to its right
4. within previous Initiations: rightmost complete sentence, if the preceding Initiation is an incomplete sentence

Figure 7.2: ES99's context ranking

Eckert and Strube present one algorithm to resolve personal pronouns and one to resolve demonstrative pronouns. The former algorithm is given in figure 7.3.

The algorithm to resolve personal pronouns distinguishes the following three cases: the pronoun is *I, the pronoun is *A and the pronoun is neither *I nor *A. In the first case the pronoun is probably a discourse deictic and the algorithm attempts to resolve it in the function `resolveDD`. If the function fails the pronoun is classified as vague. If the pronoun is *A, i.e. refers to an individual object the algorithm attempts to resolve it as such in the function `resolveInd` and in case of failure classifies it as vague pronoun. If the pronoun is ambiguous with respect to the type of antecedent, the algorithm first attempts to find an individual antecedent, then a deictic antecedent. If both attempts fail the pronoun is classifies as vague.

The algorithm for resolving demonstrative pronouns is given in figure 7.4. It only differs from the algorithm for resolving personal pronouns in that in case the

```
if (PRO is *I)
 then if resolveDD(PRO)
       then classify as DDPro
       else classify as VagPro
 else if (PRO is *A)
       then if resolveInd(PRO)
             then classify as IPro
             else classify as VagPRO
       else if resolveIND(PRO)
             then classify as IPro
             else if resolveDD(PRO)
                   then classify as DDPro
                   else classify as VagPro
```

Figure 7.3: pronoun resolution algorithm

demonstrative is neither *I nor *A, it first attempts to resolve the anaphor as a discourse deictic and than as an individual pronoun. If the algorithm fails to find an antecedent of a demonstrative this is classified as vague demonstrative.

The function `resolveInd` is Strube's algorithm which was presented in section 6.3.2, while the function `resolveDD` is given in figure 7.5.

`resolveDD` attempts to find the antecedent of the discourse deictic in the elements presented in the context ranking in figure 7.2 in the given order. If the pronoun is the argument of the verb do it is resolved to the VP of the element in the A-list or in the context otherwise it is resolved to the element in the A-list or in the context. In both case the antecedent is added to the A-list.

To evaluate the ES99-algorithm Eckert and Strube manually annotate a corpus of dialogues for synchronising units, dialogue acts, noun phrases, classification of anaphor types and coreference between anaphors and entities. The precision of the individual anaphora resolution is of 68.2%, while the precision of the discourse-deictic anaphora resolution is of 63.6%.

Eckert and Strube report different types of error. Pronouns referring to nominals are always classified as *A, although some nominals refers to abstract entities. The arguments of verbs listed in the *I -predicates were classified as *I even when the verbs were used metaphorically. Antecedents of anaphors are only looked for in the preceding **SU**.

Eckert and Strube claim that it is possible to improve the notion of compatibility by examining the analysis of verbs in psycholinguistic studies and by marking NPs

```
if (DEM is *I)
 then if resolveDD(DEM)
       then classify as DDDem
       else classify as VagDem
 else if (Dem is *A)
       then if resolveInd(DEM)
             then classify as IDem
             else classify as VagDem
       else if resolveDD(DEM)
             then classify as DDDem
             else if resolveInd(DEM)
                   then classify as IDem
                   else classify as VagDem
```

Figure 7.4: demonstrative resolution algorithm

```
resolveDD(PRO):=
foreach elements of context ranking do
   if (PRO is argument to do)
    then if (co-index PRO with VP of element)
          then add VP to A-list; return true
         else if (co-index PRO with element)
               then add element to A-list; return true
```

Figure 7.5: resolveDD

referring to abstract entities. Furthermore they propose to test whether available semantic lexicons provide information about abstract nominals and metaphoric uses of verbs.

The ES99-algorithm is the first algorithm for identifying and resolving both anaphors to individual and abstract objects in dialogues. Individual anaphors are resolved with a centering based algorithm. Because the authors work with dialogues the scope of resolution is not an utterance, but speech act pairs, which roughly correspond to adjacency pairs. Although the idea of looking at the predicates in which the anaphors occur in order to identify their type is interesting because it is based on linguistic studies (Fraurud 1992, Asher 1993), the ES99-algorithm in many cases fails to correctly classify anaphors. This is of course partly due to the fact that the algorithm does not rely on a more deep analysis of the context, here including discourse relations holding between discourse units.

However the ES99-algorithm is an interesting attempt to identify and partly resolve anaphors in practice and it should be tested whether its basic assumptions work in other types of dialogue and language. I describe an adaption of the algorithm to Danish and a test of it in the following chapter (section 8.3).

7.5 Conclusion

All studies of situation reference presented in this chapter assume that reference to abstract objects implies an act of *ostension*, i.e. the appropriate referent in the discourse model is created by the referring expression.

Building on Vendler's work Fraurud and especially Asher analyse the different semantic objects which can be created by situation reference. Asher classifies these semantic objects in relation to their degree of abstractness. Fraurud discusses the necessity of distinguishing between reference to a *situation token* and *a situation type*, corresponding to *de re* and *de facto* readings of individual anaphors. She also proposes that discourse segments introduce a generic antecedent in the discourse model which is then specified by the different anaphors which co-refer with it.

The fact that a deep analysis of the context of discourse is necessary for resolving complex situation anaphora is recognised in all the accounts of discourse deictics.

Webber accounts for the accessibility of discourse deictic antecedents in the discourse model. According to her proposal only discourse segments on the right frontier of the discourse tree are in focus and can be referred to at a given point of the discourse. Fraurud proposes to extend the dialogue structure presented by Webber to include coordination and subordination between discourse segments. Fraurud also argues that **set of situations** which are countable and are usually referred to by plural anaphors should be distinguished from **structured situations** which are uncountable situations having a complex internal structure. These can only be referred to by singular anaphors.

Also Asher provides evidence that for resolving reference to discourse segments it is necessary to look at the discourse relations that hold between discourse segments. For representing the complex structure of discourse in a dynamic semantic framework, he presents an extension to DRT, SDRT, in which discourse representation segments are related by discourse relations. Discourse relations include coherence and rhetorical relations. The former hold between eventualities, the latter between propositions.

In SDTR it is also possible to extend the content represented in a DRS with information provided by subsequent segments which are topic-related to this DRS. This fact, together with Webber's accessibility constraint, is accounted for in a so-called discourse availability constraint on anaphors.

Asher accounts for various types of abstract reference and his study presents an interesting analysis of the relation between linguistic forms and semantic types of both anaphors and referents. The problem with his approach from a computational point of view is how to automatically infer the deep structure of discourse in order to construct a valid SDRT structure.

Some of the suggestions in (Webber 1991, Fraurud 1992, Asher 1993) have been taken up by Eckert and Strube in their ES99-algorithm for automatically identifying and resolving types of situation reference. Although the ES99-algorithm is simple and only looks at the predicate the discourse deictics occur in, it resolves more than 60 % cases of discourse deixis in a corpus of telephone conversations. Resolution failure is partly due to the fact that the ES99- does not consider information about abstract nominals and metaphorical uses of verbs. This information can be provided by semantic lexicons or networks. However the algorithm also fails to find the scope of some referents and in recognising most cases of vague anaphors. These errors cannot be dealt with without looking at the discourse context.

Because the ES99-algorithm is built for dealing with anaphors in a specific corpus of English telephone conversation it is not clear to which extent it can also identify and resolve anaphors in other types of language and dialogue. I investigate how the algorithm works on Danish data in the following chapter, where I also report the results of testing some of the algorithms described in chapter 6 on Danish.

Chapter 8

Anaphora Resolution Algorithms: Tests and Evaluation

Many of the resolution algorithms presented in the literature presuppose the existence of a complete NLP system, or have been developed for a specific application or type of text, thus it is difficult to test them and compare their performance.

To resolve this problem Walker (1989) suggests to manually apply resolution algorithms to different types of text and then evaluate the obtained results against the results obtained by humans. Her proposal has been followed by some researchers and especially centering-based algorithms have been manually tested on a number of languages. The results of these tests have then been compared and used to identify differences in the way pronouns are used in the various languages. I also follow this approach and in this chapter I describe and evaluate the results of the application to Danish data of some of the algorithms for resolving explicit reference described in the two previous chapters. The choice of algorithms has been made according to the following criteria. The algorithms had to be spelled out and I also preferred algorithms that have been tested on languages which are similar to Danish with respect to the use of pronominal anaphors.

The algorithms for resolving individual anaphors which I have tested on Danish data are the two centering-based algorithms proposed by Brennan et al. (1987) and Strube (1998) respectively and Fraurud's algorithm for resolving intersentential Swedish pronominal anaphora (Fraurud 1992). Both the two centering algorithms have been tested on English by Strube (1998). The two algorithms use different strategies for ranking salient entities and thus it is interesting to compare their performance on Danish.

Fraurud's algorithm has been tested on Swedish. Furthermore it is one of the most simple and knowledge-poor resolution algorithms, under many aspects similar to Hobbs' naive algorithm (Hobbs 1978), which is one of the most tested intersentential pronominal resolution algorithms.

Finally I have tested the ES99-algorithm (Eckert & Strube 1999*a*, Eckert & Strube 1999*b*) on Danish dialogues.

The ES99-algorithm for resolving individual and abstract anaphors in a collection of English telephone conversations relies on rules accounting for some very general contexts in which individual or abstract anaphors typically occur. I have adapted these rules to Danish and added few rules which account for the most typical contexts in which discourse deictics occur in Danish, but not in English as described in chapter 2.

In this chapter I also evaluate the results obtained in my tests and compare them with the results described in the literature for English or Swedish. The comparison is of course only indicative given the fact that the texts I have used in Danish are not the same as those used for testing the algorithms on other languages. Furthermore, as noticed by Byron (2001) the results of resolution tests are reported differently, making comparisons problematic.

This observation is true and I also found out that it is not always clear how different authors treat various phenomena. In these cases I have described my choices which may differ from those behind other's tests. For all the above reasons the comparisons between the tests can only be taken as general indications of how the various algorithms perform for Danish compared to English or Swedish.

The chapter is organised as follows. In section 8.1 I present the texts and dialogues which I have used in my tests and I describe the types of pronoun which occur in them. Then in section 8.2 I describe the tests of the two centering-based algorithms developed by Brennan et al. (1987) and Strube (1998)[1] and of Fraurud's algorithm (Fraurud 1992) on different types of Danish written text. The section also contains an evaluation of the obtained results and a comparison of these results with those obtained for English or Swedish (Strube 1998, Fraurud 1992). In section 8.3 I describe the test of the adapted ES99-algorithm on dialogue, evaluate the obtained results and compare them with the results described in (Eckert & Strube 1999*a*, Eckert & Strube 1999*b*).[2] Finally in section 8.4 I make some concluding remarks.

8.1 Some Data

In this section I shortly present the written texts and the dialogues I have used in my tests and I shortly indicate the types of anaphor which I found by manually analysing these data. I marked the pronominal anaphora and their antecedents

[1]Part of these results have been previously presented in (Navarretta 2000*c*).
[2]Part of these results have been previously presented in (Navarretta 2000*a*).

on texts and on the dialogues.[3]

Expletives and cataphors were identified and excluded from all the tests.

The written texts used for testing the algorithms for resolving anaphors with individual antecedents are the following:

- randomly chosen parts of a pc-manual (10,416 running words)
- newspaper articles from *Berlingske Tidende* (9,914 running words)
- extracts from two novels (10,787 running words)[4]

The dialogues used for testing the ES99-algorithm are the following:

- four dialogues from the SL corpus (7,845 running words)
- one dialogue from the PID corpus (5,367 running words)
- an extract of a dialogue with two participants from the BYSOC corpus (10,340 running words)

The occurrences of pronominal anaphors with individual or situational antecedents in written texts and dialogues are shown in tables 8.1 and 8.2, respectively. The following data for each type of text or dialogue are given in the tables:

1. the total number of pronominal individual and abstract anaphors
2. the total number of individual pronominal anaphors
3. the number of plural individual anaphors
4. the number of third singular neuter pronouns (*det/dette*) with an individual antecedent
5. the number of third singular neuter pronouns (*det/dette*) with an abstract antecedent

It can be seen from the tables that in written texts approx. one fourth of all pronouns with individual antecedents are plural. Furthermore the pronouns *det/dette* have an abstract antecedent in two thirds of their occurrences.

[3]The texts were tagged with Brill's tagger with a reduced version of the Danish **PAROLE** tagset (Keson 1998, Haltrup Hansen 2000).

[4]The two novels are *Syv aldres galskab* by Svend Åge Madsen and *Angelas aske* by Frank McCourt, translated to Danish by Jan Bredsdorff.

Type of anaphor	manual	news	novel	$\sum$
Total indiv. & abstr. anaphors	108	115	541	764
total individual anaphors	79	93	500	672
plural anaphors	24	26	119	169
det/dette with individual antecedent	15	7	24	46
det/dette with abstract antecedent	29	22	41	92

Table 8.1: Occurrences of pronominal anaphors in written texts

Type of anaphor	SL	PID	BYSOC	$\sum$
Total indiv. & abstr. anaphors	339	252	204	795
Total individual anaphors	179	130	105	414
plural anaphors	21	25	36	82
det/dette with individual antecedent	101	59	29	189
det/dette with abstract antecedent	160	122	99	381

Table 8.2: Occurrences of pronominal anaphors in dialogues

In the dialogues approx. one fifth of the pronouns with individual antecedents are plural and the number of discourse deictics nearly equals that of pronouns with individual antecedents. This indicates that discourse deictics are more common in spoken than in written language. Also in dialogues approx. two thirds of the occurrences of singular neuter pronouns have abstract antecedents.

The number of antecedentless plural pronouns is much higher in the analysed dialogues than in the texts.

8.2 Test of Algorithms for Resolving Pronouns with Individual Antecedents

In section 8.2.1 I describe and evaluate the tests of two centering-based algorithms while in section 8.2.2 I discuss the test of Fraurud's algorithm. In section 8.2.3 I make some concluding remarks.

Discourse deictics have been excluded from these tests.

8.2.1 Testing Centering-based Algorithms on Danish Data

As described in chapter 6 centering-based algorithms presuppose that discourse is divided into discourse segments following the discourse model described by Grosz & Sidner (1986). The algorithms are applied locally on the utterances inside these segments.

In my test I have followed Strube's testing strategy (Strube 1998) in order to compare the results from his tests with mine. Thus I have considered paragraphs to be discourse segments and clauses to be utterances. Furthermore I have extended the BFP-algorithm to cover complex clauses according to the strategy proposed by Kameyama (1998*a*) (see section 6.3.3). According to this strategy, tensed (finite) clauses are treated independently while untensed (non-finite) clauses are considered to be part of the main clause. Tensed clauses comprise reported speech, non-report speech and relative clauses. The entities in the former type are not accessible to the superordinate level, while the entities in the latter two types of clause are accessible to the superordinate level. However they are less salient than the entities referred to at the superordinate level. The remaining types of subordinate clause are processed at the same level as the superordinate clause.

One problem with the BFP-Kameyama algorithm is that it does not account for the status of nominal and of adjectival complements. In my test I have ranked adjectival complements as objects, while nominal complements have been ranked lower than verbal complements and adjuncts. I have also ranked the nominal prepositional complements which modify a nominal phrase lower than verbal complements and adjuncts.

In all tests I have manually marked the correct antecedents of reflexives and assumed that these were resolved correctly. Thus errors from the application of Strube's algorithm on Danish reflexives have been corrected and have not been considered errors in the evaluation of the algorithm. The results obtained by manually applying the BFP-Kameyama algorithm and Strube's algorithm to the Danish texts are given in tables 8.3 and 8.4 respectively.

In the two tables the success rate of the algorithms on each type of text and on all the texts is given. The success rate indicates as in Strube the ratio of correctly resolved anaphors and the total of anaphors. Correctness is relative to human resolution.

The cases where both algorithms failed involve complex plural antecedents (coordinated and split ones), generic uses of the neuter pronoun *det* (it), plural pronouns without antecedents or with a singular antecedent and cases of ambiguity of antecedents where the wrong candidate was chosen, due to the resolution strategy of the algorithms. Although the results for the two algorithms are similar the cases in which the two algorithms chose the correct antecedent were not

	manual	newsp	novel	$\sum$
No. pronouns	79	93	500	672
No. resolved correctly	73	84	387	544
success rate	92.4	90.32	77.4	80.95

Table 8.3: Success rate for the BFP-Kameyama-algorithm

	manual	newsp	novel	$\sum$
No. pronouns	79	93	500	672
No. resolved correctly	72	84	399	555
success rate	91.14	90.32	79.8	82.59

Table 8.4: Success rate for Strube's algorithm

always the same.

Both algorithms failed in many cases to choose an antecedent in the focal part in the IS of an utterance. This is illustrated by example (1), where I chose *en ældre mand* (an elder man) as the antecedent of the pronoun *han* (he)[5] while both Strube's and BFP-Kameyama algorithm choose *min far* (my father) as antecedent, but for different reasons. In BFP-Kameyama *min far* is preferred because it is the subject of the utterance, thus it is ranked higher than the object *an ældre mand* (an older man) according to the hierarchy of verbal complements. In Strube's algorithm *min far* is a MED entity (anchored brand-new) and thus it is preferred to the indefinite nominal *an ældre mand* classified as a NEW entity in Prince's **Familiarity Scale**.

(1) *Min far mødte en ældre mand. Han stank af sprit.*
(My daddy met an elderly man. He reeked of alcohol.)

Another difference in the resolution strategies of the two algorithms is that in the BFP-Kameyama algorithm chains of pronouns are preferred while in Strube's algorithm pronouns have the same status as all nominals which are classified as OLD entities in Prince's taxonomy, the only discriminating factor being the order in which entities occur in an utterance. An example in which Strube's algorithm fails, while the BFP-algorithm succeeds is in (2).

(2) *Min yndlingshistorie er David og kæmpen, Goliat. David slog* ***ham*** *ihjel*

[5] This choice was also confirmed by the context.

med en slynge, en sten i hovedet. ***Hans*** *hjerne lagde på jorden. . . .*
(My preferite history is David and the giant, Goliat. David killed **him** with a sling, a stone in the head. **His** brain put on the earth. . .)

In the BFP-algorithm *Goliat* is chosen as antecedent of the pronoun *hans* (his), because a RETAIN transition is preferred to a SHIFTING-1 transition as described in section 6.3.1. In Strube's algorithm the first occurring OLD entity in the preceding utterance, *David* is proposed as antecedent.

The better performance of Strube's algorithm is mainly due to cases where the antecedent preceded the anaphor of more than one utterance. In this cases the BFP-Kameyama algorithm failed to find the antecedent. These "distant" antecedents occurred especially in the analysed novel.

Although the results obtained in tests applied to different kinds of discourse in different languages cannot be exactly compared, they give an idea of how well the algorithms work on the different languages. Strube (1998) reports the results of applying BFP-Kameyama and his own algorithm to English texts. In particular he uses a novel and newspaper articles and obtains a success rate of 76.04 % for the BFP-Kameyama algorithm and of 85,43 % for his own algorithm. The results which I have obtained on the same type of Danish texts are clearly similar for both Strube's algorithm and the BFP-Kameyama algorithm. However I had to supply the BFP-Kameyama algorithm with decisions about how to treat nominal and adjectival complements. Both algorithms performed better on the computer manual than on the two other types of text. This is not surprising given the nature of technical manuals. In particular, in the computer manual there were no occurrences of antecedentless plural pronouns, plural pronouns with complex antecedents and pronouns with distant antecedents. Furthermore there were very few pronouns with more candidate antecedents.

8.2.2 Testing Fraurud' Algorithm on Danish Texts

Fraurud (1992) excludes plural pronouns from the test of her algorithm for resolving intersentential Swedish pronouns. I have tested her algorith on Danish in the same way. Also the success rate for this test is given relative to human resolution. The results of the test are given in table 8.5.

The algorithm fails in the same cases as the two centering-based algorithms tested in the preceding section. However, Fraurud's algorithm has a much higher failure rate in cases where a pronoun has more candidate antecedents in the preceding clause. The reason for this is that the algorithm prefers a subject antecedent if there is one, otherwise it chooses the most recent candidate. For example, it prefers an adjunct to the direct object. This resolution strategy is problematic

	manual	newsp	novel	$\sum$
No. sing. pronouns	55	67	381	503
No. resolved correctly	46	46	285	377
success rate	83.64	68.66	74.8	74.95

Table 8.5: Success rate for Fraurud's algorithm on singular pronouns

because in the analysed texts the order of verbal complements seems to be relevant for anaphora resolution. In particular in many cases the object is the preferred antecedent instead of other complements and adjuncts.

Fraurud states that it is unclear whether nominal complements should be ranked lower than verbal complements because in many cases genitive phrases must be preferred to their nominal head. However the data shows that verbal complements and adjuncts in most cases are more salient than nominal complements. In the few cases where nominal complements are the antecedents in the analysed texts there are no candidate antecedents.

In the literature examples are discussed where the preferred antecedent of a pronoun is a nominal complement instead of its nominal head. Of course these types of ambiguity are possible. Sometimes the pronoun is really ambiguous, but more often commonsense knowledge indicates the correct antecedent, as in the constructed example (3). Here the pronoun *den* refers to the prepositional nominal phrase *en stor have* (a large garden) and not to the nominal head *en gammel villa* (an old villa), because it is more plausible that fruit trees are in a garden than in a villa.

(3) *Peter købte en gammel villa med en stor have. Der var mange frugttræer i* ***den***.
(lit Peter bought an old villa (common gender) with a big garden (common gender). There were many fruit trees in it (common gender).)
(Peter bought an old villa with a big garden. There were many fruit trees in it.)

Fraurud reports a success rate of 90,8 % on Swedish stories, reports and articles. Her results are better than mine, but the algorithm works quite well also on the Danish data.

8.2.3 Conclusion

All the three tested algorithms seem too perform similarly for Danish as for English (BFP-Kameyama and Strube) and Swedish (Fraurud), although Fraurud's algorithm performed better in the Swedish test. This may depend on the types of text used in the two tests.

Not surprisingly the results of the tests also indicate that the performance of the algorithms varies from text type to text type. The worst results are those obtained on text types containing an high number of antecedentless plural pronouns, plural pronouns with complex antecedents, pronouns with long-distance antecedents or more candidate antecedents.

The test results indicate that in Danish the verbal complement order, which in most cases corresponds to word order is relevant for resolution. Furthermore verbal complements are more salient than nominal complements. Although these entities are less salient than verbal complements they must be included in a resolution model, because they can be referred to in successive utterances. As noticed by Fraurud a strategy for treating genitive phrases should also be proposed. In Strube's algorithm genitive phrases with the same status in Prince's **Familiarity scale** as their nominal heads are ranked higher because they precede them, but this solution does not always resolve anaphors correctly. The BFP-algorithm does not account for nominal and adjectival complements at all.

In some cases the correct antecedent was an entity in the focal part of an utterance in IS terms. The information structure of utterances is not taken into account by the tested algorithms. Not surprisingly all algorithms failed in choosing the correct candidate antecedent in cases where world knowledge and/or knowledge about the structure of discourse were relevant to resolution. Finally it seems that pronominal chain preference accounted for in the original Centering algorithm and in the BFP-algorithm is relevant for the resolution of Danish pronouns.

8.3 Eckert and Strube's Algorithm and Danish Dialogues

The ES99-algorithm accounts for English anaphors. In the algorithm the contexts in which abstract anaphors typically occur are accounted for in **I-incompatible**, ***I**, predicates, while the contexts in which individual anaphors typically occur are accounted for in **A-incompatible**, ***A** predicates. Adapting these predicates to Danish I have obtained ***danI** and ***danA**. I have also added to the original ***I**-predicates rules accounting for the most common contexts in which discourse deictics occur in Danish corresponding to English elliptical contexts as described in section 2.3. In the following the ***danI** and ***danA** predicates are given. The ***danI** predicates which are not simple translations of the English ones are marked by a *.

***danI** predicates:

1. constructions where a pronoun is equated with an abstract object, e.g., *x er et forslag* (*x* is a suggestion)

2. copula constructions with adjectives which can only be applied to abstract entities, such as *x er sandt* (*x* is true), *x er usandt* (*x* is untrue), *x er rigtigt* (*x* is correct)

3. arguments of prepositional attitude verbs, arguments of verbs which mainly take S'-complements, e.g. *antage* (assume), *sige* (say)

4. anaphoric referent in constructions such as *x er fordi du er holdt op med at ryge* (*x* is because you have stopped smoking) *x er på grund af at du er gravid* (x is because you are pregnant)

5. * object of *have* (have) if the verb was not used as a main verb in the previous clause

6. * object of modal verbs

7. * object of *gøre* (do)

8. * subject complement with *være* (be) and *blive* (become) in answers or in coordinated clauses

Differing from most of the given predicates, rules 7 and 8 are indefeasible, while predicate 6 is nearly always indefeasible, an exception being few uses of the modal *kan/kunne* (can/could).
The ***danA**-predicates are the following:

1. constructions where a pronominal referent is equated with a concrete individual referent, such as *x er en legemsdel* (*x* is a body part), *x er et barn* (*x* is a baby)

2. copula constructions with adjectives which can only be applied to concrete entities, such as *x er rødt* (*x* is red)

3. arguments of verbs describing physical contact/stimulation, which cannot be used metaphorically, e.g. *spise x* (eat *x*), *drikke x* (drink *x*)

The ES99-algorithm presupposes that both **Discourse Segments** and **Synchronising Units** are marked in the dialogues. Therefore I have manually identified and marked **Discourse Segments** and **Synchronising Units** in the Danish dialogues.

Discourse Segments have been identified using topic shift and a few linguistic clues. The obtained **Discourse Segments** have different size.

I have identified dialogue units and **Synchronising Units** using syntax as the main discriminating criterion following the indications in (Eckert & Strube 1999*a*, Eckert & Strube 1999*b*). Expletive pronouns and cataphors are also excluded from this test.

Then I have manually classified the anaphors in the dialogues and identified the antecedents of each anaphor. In their test both Eckert and Strube accomplished these tasks and than compared their respective results. They only included in the test the anaphors whose antecedents they could agree on.

A problem for the application of the ES99-algorithm on Danish data is that the algorithm relies on the distinction between demonstrative and personal pronouns. The former are preferentially resolved as discourse deictics, the latter as individual anaphors. In unmarked contexts it is often not possible to distinguish between the demonstrative and personal pronoun *det* (it/this/that) in Danish. In the test I marked non-subject *det* as demonstrative when it occurred in first position in main clauses in contexts not covered by the ***danI** and ***danA** predicates, although, as discussed in chapters 2 and 4, weak pronouns can also be topic fronted. I have classified pronouns as strong in the above contexts because in the analysed dialogues more than 80% of the occurrences of the non-subject pronoun *det* (it) in these contexts are discourse deictics.

The manual classification of pronouns and demonstratives in the four dialogues can be found in table 8.6.

	SL1	SL2	SL3	SL4	SL5	TR	BS	$\sum$
Individual Pro	22	32	21	72	18	117	91	373
Discourse Deictics Pro	28	16	18	12	20	64	41	199
Infer-Evoked	1	2	0	3	0	4	3	13
Vague DD Pro	4	6	3	1	5	20	27	66
Individual Dem	1	2	0	5	0	9	11	28
Discourse Deictics Dem	7	6	9	5	5	18	20	70
Vague Dem	4	4	2	2	3	20	11	46

Table 8.6: Classification of pronouns

Eckert and Strube calculate the recall of their algorithm a so-called reconciled version of the data, i.e. the number of anaphors whose resolution both annotators agreed upon. I only used my annotation.[6]

The results of the individual anaphora resolution algorithm can be found in table 8.7, while the results of the discourse deictics resolution algorithm are given in table 8.8. These results are presented as in Eckert & Strube (1999*a*).

	SL1	SL2	SL3	SL4	SL5	TR	BS	$\sum$
correctly resolved	16	25	14	58	11	71	63	258
resolv. overall	23	37	22	77	18	134	100	411
human resol.	24	36	21	80	18	130	105	414
Precision	0.696	0.676	0.636	0.753	0.611	0.53	0.63	0.628
Recall	0.667	0.694	0.667	0.725	0.611	0.546	0.6	0.623

Table 8.7: Results of the individual anaphora resolution algorithm

	SL1	SL2	SL3	SL4	SL5	TR	BS	$\sum$
correctly resolved	25	15	17	12	16	52	42	179
resolved overall	36	22	28	19	24	89	68	286
human resolution	35	22	27	17	25	82	61	269
Precision	0.694	0.682	0.607	0.632	0.667	0.584	0.618	0.626
Recall	0.714	0.682	0.63	0.706	0.64	0.634	0.689	0.665

Table 8.8: Results of the discourse deictics resolution algorithm

The precision obtained in my test is worse than that obtained by Eckert and Strube, for individual anaphor resolution (62.8% for the individual resolution algorithm against Eckert and Strube's 66,2%). For the discourse deictic algorithm I obtained a precision of 62.5% against Eckert and Strube's 63.6%. Recall was also slightly worse than that reported by Eckert and Strube. The worse results of the Danish test are partly due to the fact that I tested the ES99-algorithm on more types of face-to-face dialogues, while Eckert and Strube tested it on telephone conversations. Furthermore the ***I**- and ***A** discriminating predicates have been tailored the specific telephone conversations. Although I have extended the Danish version of these predicates they do not cover all contexts which preferentially indicate individual or abstract anaphors.

[6]Precision is calculated as the ratio between no. of correctly resolved anaphors and the total of resolved pronouns. Recall is calculated as the ratio between correctly resolved pronouns and the total of pronouns to be resolved (here the number of pronouns resolved by the human, who excluded vague anaphors).

Because the ES99-algorithm consists of both a classification and a resolution part, I distinguish between two types of error in my test: classification and resolution errors.

Most of the instances of wrongly classified anaphors are due to the fact that the algorithm classifies vague anaphors as discourse deictics and then resolves the pronoun as referring to a preceding predicate or clause. Furthermore the algorithm classifies as discourse deictics generic uses of the pronoun *det* (it), i.e. when the pronoun is used to refer to entities that do not agree with it in gender and/or number. There are a number of these generic pronouns in my dialogues. In the case of generic uses of the pronoun *det* (it) I am not sure whether Eckert and Strube would include these in the test results or not. I have chosen to do so because these pronouns are quite common in Danish. In few cases the algorithm resolved as individual pronouns a discourse deictic, because it found a singular neuter gender nominal in the preceding synchronising unit.

Few errors are due to the fact, already noticed by ES99, that the defined ***danI** and ***danA** predicates do not contain information about nominals referring to abstract objects. More errors were due to the fact that metaphorical uses of some verbs were much common in the dialogues. This was especially the case for constructions such as *det lyder godt*(it sounds well) which in 98% of the cases are used metaphorically, i.e. the pronoun did not refer to a sound, but was a discourse deictic. Most individual resolution errors were due to the fact that the algorithm did not find an antecedent in the **SU** preceding an individual pronoun. The restricted antecedent domain is recognised to be a problem by Eckert & Strube (1999*b*), who notice that some of the errors in their test were caused by this restriction which is used to correctly classifying a number of neuter singular pronouns which are neither ***I**- or ***A** (the majority of them).

In my test the restricted antecedent domain explains many of the errors of the individual resolution algorithm. Thus the bad recall number for individual resolution is also due to the fact that individual antecedents were not found by the algorithm.

In the dialogues, in fact, long distance reference inside a discourse segment is frequent. Long distance reference also occurs in English dialogues according to i.a. (Fox 1987, Poesio et al. 2000).

A partial solution to this type of distant reference could be to assume different antecedent domains for pronouns which can both refer to individual entities and situations and for pronouns that only refer to individual entities. The solution is only partial because the antecedent domain for singular neuter pronouns would still be a synchronising unit, and distant antecedents of singular neuter pronouns would be ignored. Nevertheless, because long distance reference often involves animate entities according to the studies reported in (Fraurud 1992, Ravnholt 1994) and because animate entities are in most cases referred to by masculine and feminine pronouns, the solution which I suggest should account for most cases of long distance reference.

The remaining individual resolution errors are as those found testing Strube's algorithm on individual anaphors, i.e. wrongly resolved plural pronouns with complex NP antecedents or with no antecedents and errors due to the resolution strategy of the algorithm.

Resolution errors of correctly recognised discourse deictics are due to the fact that the algorithm does not rely on a deep analysis of the context. Furthermore it does not take in consideration the relations that link pieces of discourse to each other (Webber 1991, Fraurud 1992, Asher 1993, Kehler 1997). These errors are not surprising and are impossible to cope with in an algorithm of this kind.

The latter kind of errors are simple chaining errors.

Considering the different types of dialogues used in the English and Danish test of the ES99-algorithm and the fact that , the the distinction between demonstrative and personal pronouns which I used was *ad hoc*, the results obtained indicate that the algorithm's strategy of discriminating individual and discourse-deictic pronouns on the basis of the context in which they occur is also valid for Danish. I believe that this strategy can be improved in different ways. Eckert and Strube propose to use knowledge about abstract nominals and metaphorical uses of verbs. I certainly agree in this, but also propose to add more ***I**- and ***A**-predicates to the algorithm because the original ES99-algorithm only relies on few predicates identified from a single corpus. More common ***I** and ***A** predicates can be identified for both English and Danish analysing more types of dialogues and texts.

The decision of whether concrete or abstract entities occur in specific contexts should be taken by looking at the actual number of occurrences of these types of entities in both general and domain-specific corpora and not on the prototypical readings of words.

An other improvement is extending the antecedent domain search for individual pronouns, as proposed previously. I also believe that the ES99-discourse deictic resolution strategy should be revised to account for the differences in resolution of different types of discourse deictic which I accounted for in chapter 2. Furthermore the analysis of the Danish dialogues indicates that many occurrences of deictics in constructions such as *det var godt* (it was good), *det er fint* (it is fine) should not be resolved because they just have the communicative function of acknowledging the preceding discourse. A more specific study of these acknowledging expressions is however necessary to identify them more precisely.

In conclusion the ES99-algorithm strategy of distinguishing contexts in which individual anaphors occur from those in which discourse deictics occur in order to exclude them from individual anaphora resolution algorithms seems to perform similarly on Danish and English data. However the resolution strategies used by the algorithm for resolving both individual and abstract anaphors can be improved and much more knowledge sources can be used to improve the algorithm's performance.

8.4 Concluding Remarks

The analysis of occurrences of pronominal anaphors in Danish texts and dialogues indicates that antecedentless plural pronouns are more frequent in dialogues than in written texts. In spoken language the occurrences of discourse deictics nearly equals the number of pronouns with individual antecedents. In both written texts and dialogues the neuter singular pronouns *det* and *dette* are more often used as discourse deictics than as individual anaphors. Approx. one fourth of all the individual pronouns are plural in both the written texts and dialogues.

The application of the two centering-based algorithms, BFP-Kameyama and Strube's, on different types of Danish written texts seems to indicate that these algorithms perform as well on Danish as on English. The original BFP algorithm has been combined to Kameyama's strategy of applying centering to interclausal anaphors in order to compare it to Strube's algorithm which deals with both interclausal and intersentential anaphors.

Problematic in the BFP-Kameyama algorithm is the fact that the accessibility status of adjectival and nominal complements is not accounted for.

Although the results from the application of the two algorithms on Danish texts are quite similar the cases where the two algorithms failed to choose the correct antecedent in ambiguous contexts are different due to the algorithms' different resolution strategies. In general it seems that the pronominal chain preference, accounted for in the BFP-Kameyama algorithm is also relevant to Danish.

The application of Fraurud's algorithm for resolving individual intersentential Swedish pronouns on Danish data indicates that this algorithm works worse in Danish than in Swedish texts. In general the order of verbal complements seems to be relevant for choosing between candidate antecedents to pronominal anaphors, while Fraurud's algorithm always prefers the most recent antecedent if the subject is not a candidate antecedent. However only Fraurud's algorithm distinguishes between demonstrative and personal pronominal anaphors and proposes the correct antecedent for demonstrative anaphors.

Some errors are due to the fact that the three algorithms do not take into account the IS structure of utterances in their resolution strategies.

In few cases the algorithms failed because they do not rely on a deep analysis of the context. In these cases only the analysis of coherence relations and the use of word and world knowledge can explain the reference.

Not surprisingly, all the algorithms failed to resolve antecedentless plural pronouns, generic uses of the pronoun *det* and plural pronouns with complex antecedents which also require more sophisticated resolution strategies.

An adaptation of the ES99-algorithm to Danish was then described. The adaptation consisted in the translation of the English ***I**- and ***A**-predicates to ***danI**- and ***danA**-predicates and in the formulation of four extra ***danI**-predicates accounting for the most common contexts in which discourse deictics occur in Danish but not in English.

Although the results from testing the adapted ES99-algorithm on three types of face-to-face Danish dialogue were not as good as those obtained by Eckert and Strube, they indicate that Eckert and Strube's strategy of distinguishing between abstract and individual anaphors on the basis of the contexts in which the anaphors occur is also valid for Danish.

Especially the Danish results for individual anaphors were worse than those obtained by Eckert and Strube. The main reason for this is that the ES99-algorithm only looks for individual antecedents in the **Slist** of the preceding synchronising unit. In the Danish dialogues many individual anaphors follow their antecedents more than a synchronising unit, thus the algorithm fails to find these antecedents. The restriction of exclusively searching for antecedents in the preceding synchronising unit is used in the ES99-algorithm for classifying and resolving individual anaphors which occur in contexts allowing for both individual and abstract entities. I proposed to partially solve this problem by using different search spaces for the antecedents of neuter singular pronouns, which can both have individual and situation referents, and for all the other pronouns that can only refer to nominals.

The test also showed that the ES99-algorithm failed to recognise generic uses of the pronoun *det* (it). The most common classification errors involve vague anaphors which are resolved as common discourse deictics. This also involved constructions such as *det er godt* (it is good) *det er fint* (it is fine), *det var ikke godt* (it was not good) which in many cases in the dialogues seem to be simple acknowledgements (positive or negative) of the preceding context. In this cases the discourse deictics only vaguely refer to what has been said until then and should not be resolved.

A common type of resolution error in both the Danish and English test involve, not surprisingly, discourse deictics or individual anaphors which can only be resolved with a deep analysis of the context, which is not possible in this type of algorithm. The results of the test on face-to-face dialogues also indicate that a number of common contexts for distinguishing between individual and abstract anaphors are not accounted for in the existing ES99-algorithm which was tailored a specific type of telephone conversations.

More contexts could be usefully added to the algorithm analysing the uses of discourse deictics in more types of text and dialogue. This would improve the algorithm's performance and make it more general.

Finally, as also noticed by Eckert and Strube the ES99-algorithm can be improved by using lexicons containing information on abstract nominals and metaphoric uses of verbs.

In the following chapter I present a generic NLP system that I assume as the environment for the anaphora resolution algorithm of Danish pronouns which I propose in chapter 11. In the algorithm a Centering-based strategy is combined with other approaches to anaphora resolution in order to account for some of the phenomena which the algorithms tested in this chapter cannot cope with.

Chapter 9

An Architecture for Discourse Processing

As described in chapter 6 resolving pronominal anaphora in an NLP system mainly consists in finding the most appropriate anaphoric antecedents in the preceding discourse. First syntactic constraints and selectional restrictions are applied to identify possible candidate antecedents, then, in cases of ambiguities, different preference mechanisms, such as salience, parallelism and commonsense preferences are employed for choosing a preferred antecedent.

I investigate how different preference mechanisms interact in the resolution of Danish anaphors in chapter 10.

For automatically resolving anaphors the search space for their antecedents must be defined. This search space is in worst cases the whole discourse, although recency is often an indicator of high accessibility. As discussed in chapter 5 the hierarchic structure of discourse can be used to reduce the search space (Grosz & Sidner 1986, Cristea et al. 2000). Furthermore knowledge about the structure of discourse is indispensable for detecting phenomena such as digressions and interruptions, in which cases the linear search of antecedents is misleading. Because coherence in discourse is to a great extent expressed by the relations holding between discourse segments, knowledge of these relations is also relevant for correctly interpreting anaphora, and discourse in general, see i.a. (Hobbs 1979, Fox 1987, Kehler 1997). Establishing how discourse units are related to each other is particularly important to resolve discourse deictics which refer to discourse segments (Webber 1991, Asher 1993).

Interpreting discourse involves syntactic, semantic and pragmatic processing. In many applications, however, full processing of discourse is not possible or desired, thus simple anaphora resolution algorithms are implemented which account for the most general tendencies of pronominal use. Knowledge about how the different aspects influencing anaphora resolution interact is important in both types of implementation.

In the following I assume the existence of a "complete" NLP system of the kind described in i.a. (Alshawi 1992, Allen 1995) as the environment for an algorithm for resolving explicit Danish intersentential pronouns. However aspects of the algorithm which I propose can be implemented independently by assigning weights to different entities according to preference rules in line with the strategies proposed by i.a. (Carbonell & Brown 1988, Lappin & Leass 1994) which were discussed in section 6.5.

In the present chapter I first shortly describe the "generic" NLP system which I presuppose as environment for a resolution algorithm (section 9.1). In section 9.2 I describe the context against which pronominal anaphora are resolved and in section 9.3 I discuss some representational issues. Finally in section 9.4 I make some concluding remarks.

9.1 Processing Architecture

I assume that discourse is composed of units that are processed dynamically in an NLP system. As seen in chapter 5 there is no agreement in the literature about what is the elementary unit in discourse and especially in dialogues. In practice most researchers identify a discourse unit with a clause and its untensed subclauses. In dialogues a discourse unit can also be a word, such as *yes*, *no* and *maybe*, an unfinished clause or an elliptical construction, comprising answers which "fill in" the information required in questions as it is the case in example (1):[1]

(1) *what colour is the bike?*
red[2]

In conversations natural language interplays with other modalities, such as gestures and eye gazes, thus in multimodal systems these other modalities must be included in the discourse model. Head nods, for example, may be used instead for a *yes* or *no*. The different modalities can interplay as it is the case for gestures and deictics. In the dissertation I only look at one modality, language, but the processing architecture that I describe here can be extended to process more modalities see i.a. (Johnston 1998, Paggio, Jongejan & Madsen 2000).

[1]A less simplistic analysis of question-answers in dialogues can be found in (Ginzburg 1995*a*, Ginzburg 1995*b*).

[2]One of the best proposals of how to divide dialogues in units is found in (Passonneau & Litman 1997).

In the studies on intersentential anaphora the basic unit is assumed to be a sentence, although the word utterance is preferred in the Centering tradition. Strube (1998) combines intrasentential and intersentential resolution in his centering-based algorithm, while Kameyama (1998*a*) extends the intersentential resolution strategy to interclausal anaphors, so that a centering-based algorithm is first applied interclausally, then intersententially. I follow this approach.

When an utterance U_i is available to the system it is first processed by an unification-based grammar UG, consisting of syntactic and semantic rules. Constraints are applied here. The agreement constraints on Danish intersentential pronouns have been described in chapter 2 and are discussed further in section 10.1 together with other types of constraint. The grammar outputs a semantic formula, SF_i, in line with the Montagovian tradition (Dowty, Wall & Peters 1981). Sortal restrictions have been applied to SF_i so that semantically incorrect interpretations have been ruled out. SF_i contains the predicates in U_i, and includes the surface syntactic structure of the utterance, **IS** information, together with information of the type of U_i, such as whether it is an assertion, a command or a question. The SF_i is incomplete or **underspecified**,[3] because it contains unresolved elements, such as nominal anaphors, attachment and lexical ambiguities, time and place references.

SF_i is passed on to semantic/pragmatic modules which interpret the formula on the background of both the existing context C_{i-1}, the background knowledge and the task description. The semantic/pragmatic modules output a preferred interpretation PSF_i which is then added to C_{i-1}, producing C_i (see also section 9.3). It is not always possible to find a preferred interpretation, in which case more versions C_i will be returned. One of the semantic/pragmatic modules is that for resolving pronominal anaphors.

Different knowledge sources are used during interpretation, comprising linguistic and world knowledge bases, containing both general and domain-specific information. The context against which discourse is processed is a complex data structure and in the following section I present those of its components which are relevant for anaphora resolution.

9.2 The Context

The context of discourse consists of more data structures representing the content of the discourse, i.e. the preferred interpretations of the utterances until this point, the **Attentional State**, AS_{i-1}, and a list of currently available indexicals, I_{i-1}. The content of discourse is organised in a **Discourse Model** with sets of entities, situations, events and the relations holding among them. The information in the

[3]Underspecification can be interpreted differently, see i.a. (Alshawi 1992, Poesio 1994).

context allows i.a. to infer the antecedents of pronouns in cases in which these antecedents are not explicitly mentioned in the preceding discourse. As seen in chapter 6 this phenomenon is called **implicit focus** by Grosz (1977).[4]

In a dialogue system, the preferred interpretation is passed on to a Dialogue Manager which interprets the user's utterance against the context. Here the context also comprises a **Task Model**, see i.a. (Allen, Schubert, Ferguson, Heeman, Hwang, Kato, Light, Martin, Miller, Poesio & Traum 1995).

According to the conclusion of chapter 5 I assume that the structure of the discourse model[5] is represented as a tree whose terminal nodes are the discourse units, linked by discourse relations. Relations are hierarchical (subordinated units) or non-hierarchical (coordinated units) following Hobbs (1979), whose theory was discussed in section 5.1.1. The tree is built as described in (Webber 1991) (section 5.4).

I also assume that discourse segments on a macro-level describe part of discourse about the same subject/subtask following Grosz & Sidner (1986). In applied systems these segments are often called *topic segments*.

As discussed in chapter 5 conversations and written texts have different discourse structures (Fox 1987, Polanyi 1988). I assume that both texts and conversations can be divided into discourse segments.[6] In practice the following criteria are used:

- a discourse segment often corresponds to a paragraph in written texts
- a discourse segment in dialogues corresponds to what has i.a. been called *transactions* (McGlashan et al. 1992) and *conversational games* (Kowtko, Isard & Doherty 1992) in dialogue systems

The division of discourse in segments also depends on the relation between referring expressions and referents as mentioned in chapter 6.

In dialogues utterances are also related in adjacency pairs. Here I follow the simplified dialogue model described in (Eckert & Strube 1999*a*, Eckert & Strube 1999*b*) (section 7.4).

In the model three general types of dialogue act are recognised, **Initiations**, conveying semantic information which have a forward-looking function, **Acknowledgements**, having the backchannelling function of acknowledging the preceding

[4]The interested reader is referred to i.a. (Clark 1975, Hobbs et al. 1993, Lewis 1979, van der Sandt 1992, Piwek & Krahmer 2000).

[5]I refer to (Webber 1991) for the relation between discourse, discourse model and discourse structure.

[6]Until now people has proposed to divide discourse segments using both linguistic knowledge, the discourse and task model to discover changes of subject and/or task. Linguistic aspects such as cue words and intonation also play an important role (Grosz & Sidner 1986, Marcu 2000).

Initiations and **Initiations/Acknowledgements**, which have both a forward-looking and a backward-looking function. In fact they both acknowledge the preceding **Initiation** and convey semantic information. An answer to a **wh-**question is for example an **Initiation/Acknowledgement**. An adjacency pair, is called a **Synchronising Unit** and consists of an **Initiation** and an **Acknowledgement** or of a longer **Initiation** which does not need to be acknowledged. Examples of how dialogues are divided in **Synchronising Units** are given in section 11.1.

Differing fra Eckert and Strube's model, I also assume that coherence relations f the types described in (Hobbs 1979, Mann & Thompson 1987) hold between **Synchronising Units** and between clauses in **Initiations** and **Initiation/Acknowlegements**. I discuss further the assumed discourse model in texts and dialogues and give examples of it in section 11.1. As noted in chapter 5 only one attempt of automatically marking the coherence relations between discourse units has been made (Marcu 2000), while in applied dialogue systems the dialogue structure is predefined.[7] In (Hobbs et al. 1993) discourse relations are inferred in the interpretation abductive system in the same way as other relations holding between events and entities. Strube & Hahn (1997) propose to identify discourse segments in parallel with anaphora resolution.

I just assume that the system is able to detect the structure of discourse, although at this time there is no standardised way of doing so.

Following (Grosz & Sidner 1986) I distinguish between *global* and *local focus*, where the former accounts for reference between discourse segments while the latter accounts for reference inside a discourse segment. As discussed in chapter 5 *global focus* has been implemented i.a. with the *focus stack* (Grosz & Sidner 1986), *attachment/adjunction* operations on the discourse tree (Webber 1991), the *cache model* (Walker 1998) and *centered discourse segmentation* (Strube & Hahn 1997). In my algorithm I mainly follow the *cache model* where local resolution strategies are extended to resolve global reference.

The **Attentional State** consists of entities and propositions having different salience degree. In this I follow the **Centering Theory** (Grosz et al. 1995). I further discuss the **Attentional State** and the treatment of pronominal reference in chapter 11.

The dynamic interpretation of discourse which I assume is in line with so-called dynamic semantic theories, such as **Discourse Representation Theory**, henceforth **DRT**, (Kamp 1981, Kamp & Reyle 1993), **File Change Semantics** (Heim 1982),[8] **Situation Semantics** (Barwise & Perry 1983) and **Dynamic Predi-**

[7]A general overview of the types of discourse model used in applied dialogue systems can be found in (Navarretta 2000*d*, Navarretta 2000*b*).

[8]The two theories were developed at the same time, but independently.

cate Logic (Groenendijk & Stokhof 1991). In the following I present the main ideas about one of these theories, **DRT** and discuss how these types of theory fit into the described processing architecture.

9.3 The Representation of Discourse

DRT is together with **File Change Semantics** the first of a family of dynamic semantic frameworks. Originally (Kamp 1981) it was developed to handle indefinite descriptions, pronominal anaphors, and conditional phrases containing quantification. In particular Kamp (1981) provides an account for the so-called "donkey-sentences", such as (2).

(2) *If a man owns a donkey, he beats it.*

In (Kamp & Reyle 1993) the theory has been extended to treat other phenomena, such as negation and plural constructions (Kamp & Reyle 1993).

In **DRT** a logical formula representing the meaning of an utterance is graphically represented by a so-called **Discourse Representation Structure** (**DRS**). An example is in (K1), the DRS for the sentence (3).[9]

(3) *Pedro loves a donkey.*

(K1)

x,y
Pedro(x) *donkey(y)* *love(x,y)*

A **DRS** consists of two parts. The first part is the so-called *universe* of the DRS and contains a set of discourse referents or markers. (K1), for example, contains two discourse markers, x and y. The second part is the condition set, Con_K, of the DRS which contains conditions on the discourse markers in the *universe*. These conditions are n-place DRS predicates having the discourse referents as arguments. In (K1) the predicates are *Pedro(x)*, *donkey(y)* and *love(x,y)*.

DRT consists of both a **DRS construction algorithm** and a **correctness definition**. The **DRS construction algorithm** is a set of rules for constructing

[9](K1) is a simplified representation of (3) not containing important information such as tense and aspect.

DRSs. The **correctness definition** consists of a set of instructions for embedding a DRS in a model to calculate truth conditions for the discourse. The **DRS construction algorithm** for a sentence S_i incorporates the syntactic analysis $[S_i]$ of S_i in the set of conditions of the existing context C_{i-1}. The construction algorithm explains how the interpretation of S_i makes use of the context C_{i-1} and how the context becomes a new context C_i. The initial DRS, C_0 is assumed to be the empty set of discourse referents and the empty set of conditions. Different syntactic configurations trigger different construction rules, which perform operations on the common context such as adding discourse markers and conditions. Both top down and bottom up construction rules for **DRT** have been proposed, see i.a. (Kamp & Reyle 1993, Wada & Asher 1986).

A **DRS** can be translated to predicate logic. The formula corresponding to (K1) is the following:

$$\exists xy(x = Pedro \wedge donkey(y) \wedge love(x, y))$$

DRT describes which syntactic structures introduce **discourse markers** (or referents) in the context and how they must be interpreted.

Both nominal phrases and situations introduce discourse markers in the context. The idea of connecting abstract objects with discourse markers (or variables in logic) was proposed by (Davidson 1967) who dealt with the representation of actions in first-order logic. In **DRT** the sentence *Mary loves John* triggers three discourse markers. The first two are triggered by the proper names *Mary* and *John*, the third is triggered by the situation of two individuals loving, as illustrated in (K2).[10]

(K2)
$$\begin{array}{|l|}\hline s,x,y \\ \hline Mary(x) \\ John(y) \\ s{:}\ \begin{array}{|c|}\hline \quad \\ \hline love(x,y) \\ \hline\end{array} \\ \\ \hline\end{array}$$

As seen in chapter 7.1, the problem with reference to abstract objects is that the anaphors create the referent type in the moment they evoke it. I follow Webber (1991) and assume that anaphors referring to situations perform an act

[10]This analysis by Kamp & Reyle (1993) follows (Barwise & Perry 1983).

of **ostension** creating the correct referent in discourse. In the present study however I do not analyse the semantic types evoked by abstract anaphors.

Individual entities are introduced and mentioned in discourse by nominal phrases[11] in the following way:

- Indefinite nominals usually introduce new discourse entities. Karttunen (1976) studies which indefinite phrases create a discourse referent. His main discriminating criterion is that an indefinite noun phrase establishes a discourse referent if "it justifies the occurrence of a coreferential pronoun or definite phrase later in the text" (Karttunen 1976)[366]. Karttunen (1976) suggests, for example, that subject predicates normally do not introduce a discourse entity, that generic indefinites introduce generic entities and that objects whose existence is negated do not introduce a discourse referent. Examples contradicting many of the general tendencies described by Karttunen have been discussed in the literature, thus, at least theoretically, almost all nominals can introduce discourse referents.

- Definite nominals usually corefer with existing entities. The uses of definite descriptions has been extensively studied in both philosophy and linguistics i.a. (A.F.Whitehead & Russell 1925, Donnellan 1966, Stalnaker 1974, Lewis 1979, van der Sandt 1992).

  Discussing these theories is outside the scope of the present work. However it should be noticed that the concept of **accommodation** (Lewis 1979) and the interpretation of anaphors as presuppositions (van der Sandt 1992) are related to the interpretation of pronouns as noticed by i.a. Webber (1991) and Dahl & Hellman (1995).[12]

- Proper names generally corefer with entities already introduced in discourse or somehow known to the speaker. A philosophic theory of proper names is found in (Kripke 1980).

- Plural nominals introduce in discourse a set of entities. Nominal phrases consisting of conjuncted nominal phrases introduce in discourse a set of all conjuncts. The resolution of plural pronouns can be problematic because it involves operations such as summation and abstraction. This was also discussed in chapter 2. The interested reader is referred to (Kamp & Reyle 1993).

[11] Abstract nominals introduce abstract objects. Here I assume that they are marked as such in the lexicon, simplifying the fact that distinguishing between *process* and *result* readings of nominals is in many cases problematic. A systematic study of reference to process nominals in Danish is still an open research issue.

[12] A recent Danish study of definite reference is in (Jørgensen 2000).

A lot of extensions to the different dynamic semantic formalisms have been presented. One example is Asher's **SDRT** theory which extends **DRT** to include discourse relations (Asher 1993) which was discussed in section 7.3. Other examples are the proposals of combining discourse interpretation and **IS** in i.a. (Vallduví & Engdahl 1995, Kruijff & I.Kruijff-Korbayová 2001). As noticed in chapter 4 the different proposals represent **IS** differently, i.e. as part of the syntactic, semantic or pragmatic structure of the utterance.

In the present context it is not necessary to assume an integrated representation of the **IS** and logical form of an utterance. Their representations can be kept in separate data structures as long as their respective components can be mapped to each other. Here I do not commit to any solution.

9.4 Conclusion

In this chapter I have presented a generic processing architecture for a discourse interpretation system in which the pronominal anaphora resolution algorithm which I propose in chapter 11 can be integrated. In the assumed system an utterance is first processed syntactically and semantically and then its corresponding semantic formula is interpreted against the preceding context. The architecture is compatible with the basic idea behind dynamic semantics that interpreting an utterance U_i is a function from context C_{i-1} to context C_i. The context includes i.a. the content of the preceding discourse, comprising sets of entities, situations, events and the relations holding among them, the representation of the current indexicals and the Attentional state. Both linguistic and extra-linguistic knowledge bases are available to the system in the interpretation process.

The semantic formula that is the output of the syntactic and semantic processing is underspecified. Both information about an utterance's surface structure and its **IS** must be available to the resolution system. The information may be included in the logical form as in (Kruijff & I.Kruijff-Korbayová 2001) or may be represented in different, but related data structures.

I assume the discourse model is structured in a tree structure as that described by (Webber 1991). Parts of the tree dealing about the same subject or subtask are called discourse segments. Information about coordinated and subordinated structures is kept in the tree following (Hobbs 1979).

Both global and local reference, i.e. reference to entities in-between and inside discourse segments are accounted for as local reference using the cache model (Walker 1996, Walker 1998). In my algorithm for resolving Danish intersentential anaphors I mainly follow the **Centering** approach (Grosz et al. 1995). The resolution strategy which I adopt is inspired by i.a. the work presented by Kameyama (1996) who integrates a centering-based approach with different preference mechanisms.

The constraints and preferences which interact in the resolution of Danish anaphors are discussed in the following chapter where I propose a model of this interaction used as backbone for the resolution algorithm.

Chapter 10

A Model of Preference Interaction

Given a pronoun in discourse, it is possible to restrict the number of candidate antecedents looking at factors such as the gender and the number of the pronoun and the type of entity required in the specific context in which the pronoun occurs. These factors are called *constraints* and comprise antecedent agreement constraints, syntactic constraints and selectional restrictions. Constraints are, in most cases, undefeasible.

General tendencies in the use and interpretation of pronouns are, instead, called *preferences* and can be used to rank candidate antecedents and, eventually to propose a preferred antecedent. Given their nature preferences are defeasible. The preferences relevant for resolving pronouns which have been recognised in the literature comprise commonsense preferences, conventional presuppositions, parallelism preference and attentional-based preferences, including subject antecedent preference and pronominal chain preference (Kameyama 1996). The latter preferences account for the salience of entities in the utterance which precedes the anaphor. On the basis of the analysis of the Danish data, I have suggested that the IS of utterances is also relevant to identify the salience degree of entities. The importance of IS information to this purpose has been emphasised by Sgall et al. (1986). Commonsense preferences involve commonsense knowledge and conventional presuppositions which are triggered by lexical knowledge.

To use constraints and preferences in applied systems, it is not only necessary to identify the relevant constraint and preference types, but also to establish how they interact in resolution. Investigating these aspects and proposing a model of constraint and preference interaction in Danish are the main aims of the present chapter.

In section 10.1 the agreement constraints for Danish pronouns, mainly based on the description in chapter 2, are outlined and discussed together with other syntactic and selectional constraints relevant for intersentential pronominal resolution. In section 10.2 the preference types relevant for resolving Danish pronouns are discussed and how they seem to interact in Danish is outlined. To confirm these hypotheses, I have made a survey of pronominal interpretation following Kameyama's strategy in (Kameyama 1996). The survey is described in section 10.3 while its results are discussed in section 10.4. Then I propose a model of preference interaction in section 10.5. Section 10.6 contains a summary of the chapter.

10.1 Constraints on Anaphora

Constraints on pronouns comprise antecedent agreement constraints which are outlined in section 10.1.1, syntactic constraints and selectional restrictions discussed in sections 10.1.2 and 10.1.3 respectively.

10.1.1 Agreement Constraints

As discussed in chapter 2 pronominal anaphors include third person demonstrative, possessive and personal pronouns. Personal pronouns agree in number (*singular* and *plural*) and gender with their antecedent. There are two syntactic genders, *common* and *neuter*, and two semantic genders, *feminine* and *masculine*. Gender information is only relevant for third person singular pronouns.

The agreement with **inanimate** entities is often syntactic while the agreement with **animate** entities is often semantic. However it is always semantic if the antecedent is a common gender noun referring to a human. The agreement can be syntactic or semantic if the antecedent is a nominal referring to an animal or a neuter gender nominal which refers to a human.

Third person possessive reflexives (not dealt with in the dissertation) agree in number and syntactic gender (*common*/*neuter*) with the possessed nominal. The form of non-reflexive possessive pronouns indicates the number of the antecedent(s). If the antecedent is singular it also indicates its gender (*feminine, masculine, common, neuter*). In table 10.1 possible antecedent types of plural pronouns are given.

In table 10.2 I show the antecedent types of singular pronouns. As indicated in table 10.2 the pronouns *det*, *det her*, *det der* and *dette* can be used as discourse deictics, in which case they do not refer to individual entities but to a situation. These pronouns can also refer to abstract nominals. Finally as subjects in copula constructions they can also refer to common neuter entities (see examples 2-(28)).

Pronouns	Antecedent Types
de/dem/deres(they/them/theirs/ these/those/these's/those's) *disse/disses*(these/these's) *de her/de der*	plural nominal phrases coordinated nominal phrases split antecedents mass names institution/geographic place

Table 10.1: Plural pronouns

Pronouns	Possible Antecedents
han/ham/hans (he/him/his) *denne/dennes* (this/this's)	masculine NP
hun/hende/hendes (she/her/hers) *denne/dennes* (this/this's)	feminine NP
den/dens (it-common/its-common) *den her/der* (this/that-common)	inanimate NP in common gender
det/dets (it-neuter/it-neuter) *dette* *det her/der* (this/that-neuter)	NP in neuter gender plural or coordinated NPs (generic use) situation

Table 10.2: Singular pronouns

Antecedentless plural pronouns also occur especially in dialogues. I assume that the encodings of nominals referring to an institution/place contain information that the nominal can refer to the people living or working in it.[1] As seen in chapter 2 the antecedents of both singular and plural pronouns need not to be explicitly mentioned in discourse (*implicit* reference). I do not deal with *implicit* reference in the dissertation.

Agreement constraints can be encoded in the lexicon in typed feature formalisms.

10.1.2 Syntactic Constraints on Anaphors

Syntactic constraints describe how nominal phrases may co-refer intrasententially. Constraints on the reference of reflexive pronouns, non-reflexive pronouns, names and so-called empty nominal phrases[2] have been formulated. The most influential syntactic theory on the intrasentential use of nominals is *Government and Binding* (Chomsky 1980, Chomsky 1981). Furthermore constraints on the interaction

[1]This information is available in the SIMPLE lexicon.

[2]See on the treatment of Danish reflexives section 6.6.

between pronouns and universal quantifiers have been investigated, see especially (Heim 1982, Kamp 1981).

A constraint which has been used for resolving interclausal anaphora is the following:

> a pronoun in a clause cannot refer to a nominal phrase in a subsequent subordinate clause

This constraint accounts for the acceptability of examples (1-a)-(1-c) and predicts why (1-d) is less acceptable.

(1) a. Men *Emil Hansens*$_i$ iscenesættelse undgår desværre ikke helt slagsiden, fordi *han*$_i$ stiliserer bifigurerne unødigt.
(But *Emil Hansen*$_i$'s setting does unfortunately not avoid completely lopsidedness, because *he*$_i$ stylises the minor characters unnecessarily.)
(BERLINGSKE)

b. Inden *han*$_i$ fyldte 35 år, var *Brian Nicholls*$_i$ chef for ministeriets økonomisk-statistiske kontor...
(lit. Before *he*$_i$ attained the age of 35, was *Brian Nicholls*$_i$ the head of the ministry's economical-statistic office...)
(Before *he*$_i$ attained the age of 35, *Brian Nicholls*$_i$ was the head of the ministry's economical-statistic office...)
(BERLINGSKE)

c. Inden *diplomaterne*$_i$ forlod Christiansborg Slot, skålede *de*$_i$ i champagne for et godt år med den kongelige familie
(lit. Before *the diplomats*$_i$ left Christiansborg Castle, drank *they*$_i$ champaign to a good year with the royal family.)
(Before *the diplomats*$_i$ left Christiansborg Castle, *they*$_i$ drank champaign to a good year with the royal family.)
(BERLINGSKE)

d. * Men *hans*$_i$ iscenesættelse undgår desværre ikke helt slagsiden, fordi *Emil Hansen*$_i$ stiliserer bifigurerne unødigt.
(* But *his*$_i$ setting does unfortunately not avoid completely lopsidedness, because *Emil Hansen*$_i$ stylises the minor characters unnecessarily.)

10.1.3 Selectional Restrictions

Selectional restrictions are normally used in natural language processing to constrain parses in order to eliminate incorrect constructions. In anaphora resolution selectional restrictions can rule out antecedents which do not have the semantic type required by the head constituent they are subcategorised for. This is illustrated in example (2), where the pronoun *den* (it) is subcategorised for by the verb *drikke* (drink) which requires its object to be liquid. This restriction excludes the two nominals *koppen* (the cup) and *spisestuen* (the dining room) as possible antecedents of the pronoun.

(2) *Tag koppen med teen i spisestuen. Drik den mens den er varm.*
(lit. Take cup-def-commongend with tea-def-commongend in dining room-def-commongend. Drink it-commongend while it-commongend is hot.)
(Take the cup with the tea in the dining room. Drink it while it is hot.)

The main problem with selectional restrictions is that they do not account for metaphorical uses of language. However, selectional restrictions are useful in applied systems. As described in sections 7.4 and 8.3 they can also be used to distinguish between anaphors with individual and situation antecedents. In the **ES99**-algorithm pronouns which occur as arguments of predicates that subcategorise for concrete entities are marked as individual anaphors, while pronouns occurring as arguments of predicates that usually subcategorise for abstract entities are marked as abstract anaphors. The majority of predicates are ambiguous i.e. can both take abstract and concrete arguments and require different strategies to be distinguished.

Selectional restrictions need not encode the prototypical reading of a word, although this is the case in many semantic lexicons. In my opinion, metaphorical readings which are more frequent than prototypical readings in general language or in the actual sublanguage should be encoded in the lexicon as restrictions. I follow this strategy.

10.2 Preference Types

In Kameyama's model of pronominal resolution, attentional, parallelism and commonsense preferences are applied to ambiguous contexts. I follow her approach. Differing from Kameyama who uses Centering-based preferences to determine the salience degree of entities I propose to also look at the IS structure of an utterance as suggested by Sgall et al. (1986) and Hajičová et al. (1990).[3]

In both the Centering and the Prague School framework salience degree is defined as accessibility degree. In the former the degree of accessibility reflects the degree of "givenness" in the hearer model, which is expressed by the type, the grammatical function or the position of the antecedent in the preceding utter-

[3]Kameyama (1996) recognises that IS may affect resolution, but she does not include this aspect in her resolution model.

ance.[4] Different models of salience have been used in the Centering framework (section 6.3), such as word order, verbal complement hierarchy and Prince's **Familiarity Scale**.

Kameyama (1996) distinguishes an input and an output Attentional State. In the former entities are ordered according to a hierarchy of referring expressions while in the latter entities are ordered according to a verbal complement hierarchy. Distinguishing different types of referring expression, and in particular different types of pronoun is relevant for the resolution of Danish pronominal anaphors, as discussed in chapters 2-4.

The highest degree of "givenness" in most theories of the use of referring expressions, corresponds to the highest degree of salience. Givenness is also connected to the degree of persistence of reference in discourse and to the animacy status of the referred entities. Both attentional-based preferences are related to this interpretation of salience.

Researchers from the Prague School claim that entities in the focal part of the IS of an utterance have highest degree of salience and thus compete as possible antecedent with other salient entities. As discussed in chapter 4 entities in the focal part often, but not necessarily, correspond to new information.

I propose that salience/accessibility by default is connected to the concept of givenness as assumed i.a. in the Centering theory whose main assumption is that some entities are more **central** than others in consequent parts of discourse for the simple reason that discourse "is about" them. However speakers change the focus of attention in discourse and this shift can occur inside a discourse segment.

In the original formulation of the Centering theory interrupting the centering chain of reference is of course possible, but it results in a SHIFTING transition state which is less coherent and then has a lower rank than CONTINUE and RETAIN transition states (section 6.3). Thus a more "given" antecedent is always preferred to a less "given" one in ambiguous contexts.

In my opinion, however, speakers can shift the focus of attention from "given" entities in a coherent way, i.e. by explicitly marking the shift with IS related mechanisms, i.e. by marking that some entities are *focal* in the IS meaning of the word. As discussed in chapter 4 different types of focus have been recognised in the literature, the main types being **new** and **contrast** focus. A speaker signals that entities are very salient by explicitly marking them as focal. These explicitly marked entities mainly correspond to what Sgall et al. (1986) call **focus proper**, and henceforth I also use this term to indicate *explicitly focal marked entities*.

[4] Here I use the word "givenness" generically subsuming the different accounts of salience of referring expressions discussed in chapter 3 which all connect the use of referring expressions with the assumed mental state of the hearer.

I propose to consider the following entities as explicitly focal marked :[5]

1. Entities referred to by nominals which are focally marked structurally. In Danish (see section 4.4) structural marking of focus occurs in clefts, existential and topicalized utterances.[6]

2. Entities referred to by nominals which follow focusing adverbs (Quirk et al. 1985). These adverbs, as seen in section 4.4, include additives such as *også* (also) and restrictives such as *kun* (only).

3. Entities marked as focus proper by prosodic marking and/or by the context. This is especially the case in question/answer pairs as illustrated in example (3). In the example the focus proper *Søren* in (3-b) provides the information asked for in (3-a).

   (3) a. *Hvem snakkede Peter med til mødet?*
   (lit. Whom talked Peter with at meeting-def?)
   (Whom did Peter talk to at the meeting?)
   b. *Peter snakkede med* SØREN
   (Peter talked to SØREN)

4. Entities which are just introduced in the discourse by indefinite nominals. The degree of salience is higher if the indefinite nominals have high rank in the verbal complement hierarchy. Subjects are often expressed in *der*(there)-constructions in Danish. Thus the most salient newly introduced entities are referred to by indefinite nominals which have the function of objects (here including prepositional objects).

In the following I call *givenness preference* the preference assigning highest salience to "given" entities, while I call *focality preference* the preference assigning the highest degree of salience to focal proper entities in the IS of the utterance. Givenness and focality preferences may indicate that the same entity has highest degree of salience, because "given" entities can also be focal marked as discussed in chapter 4. In my opinion focality preference is stronger than attentional-based preference types, i.e. both givenness, subject antecedent and pronominal chain preferences.

Kameyama, on the basis of a survey of English pronominal uses, suggests that both parallelism and subject antecedent preference override pronominal chain

[5]The list is tentative, based especially on (Paggio 1997, Togeby 1993), the IS literature and the data which I have analysed.

[6]I refer to chapter 4.4 for the distinction between front positioned entities and topicalised entities.

preference and that commonsense preference overrides all the other types of preference. The Danish data seem to confirm that parallelism overrides attentional-based preferences and there is no doubt that commonsense preference and conventional presuppositions can ovverride all other types of preferences (see also i.a. (Hobbs 1979)). Furthermore it seems that parallel preference also overrides focality preference.

To verify the above described hypotheses and to study how the above mentioned preference types interact with other factors such as animacy of entities, recency and lexical knowledge, I have conducted a survey of the use of Danish pronouns, which is strongly inspired by the work of Kameyama (1996). In the survey constructed examples have been used in order to isolate a few phenomena influencing resolution, although this is only possible to a certain extent because discourse is always interpreted in context and commonsense knowledge cannot be switched of.

The survey which I have made and its results are discussed in sections (10.3 and 10.4). In section 10.5 a model of preference interaction is proposed.

10.3 A Survey of the Interpretation of Pronouns

I asked 32 native speakers of Danish, the *informants* henceforth, to choose the preferred antecedent in 18 constructed examples. Less than half of the informants were linguists.[7] Some of the constructed examples are variations of sentences in the text and dialogue corpora or of examples reported in Danish grammars.

The aspects I wanted to verify are the following:

- whether focality preference, as described in the preceding chapter, overrides givenness preference
- how focality preference interacts with other types of preference especially with parallelism preference
- whether the preference interaction model proposed for English by Kameyama is also valid for Danish
- whether the animacy of entities plays a role in resolution as suggested by i.a. (Givón 1979, Fraurud 1992)

[7] I am not a native speaker of Danish myself. After having worked for a while with anaphors I have also lost "my intuition" when resolving anaphors out of context. This loss of "intuition" was also evident in the comments which some of my linguist colleagues added to their answers, such as *I know that this type of sentence is ambiguous* and *I choose this antecedent because it is the most recent one.*

- what is the role of recency which in the algorithm presented by Fraurud (1992), and in other theories, corresponds to accessibility
- the role of lexical knowledge in resolution

The relation between givenness and focality preferences is investigated by utterances, where a pronoun has two candidate antecedents, one being the focus proper according to the definition given in section 10.2 while the other being higher ranked entity according to different definitions of salience. In particular I investigate cases where the focus proper is a NEW entity (an indefinite nominal) and the competing antecedent is an OLD entity (a proper name or a definite nominal), according to the **Familiarity scale** proposed by Prince (1992). This scale is used as salience ranking criterium in Strube's centering algorithm. I also investigate cases where the NEW focus proper and the OLD candidate antecedent have different syntactic roles and occupy different positions in the utterance. The verbal complement hierarchy and the word order have been used as salience indicators in the **BFP**-algorithm and in the original Centering theory. In Fraurud's algorithm these elements also play a role in that subject candidates are chosen first, followed by the most recent candidate antecedents. The survey examples involving givenness and focality preference are given in the following:

A *Der sad en mand ved siden af Peter i toget.* ***Han*** *så træt ud.*
(lit. There sat a man next to Peter on the train. **He** looked tired.)
(A man sat next to Peter on the train. **He** looked tired.)

In this example the focus proper is also the subject of the utterance. In Strube's algorithm the proper name *Peter* is the preferred antecedent of the pronoun *han* (he), while in the **BFP**-algorithm, in the original formulation of Centering by GJW and in Fraurud's algorithm *en mand* is chosen as antecedent.

B *Peter snakkede med en gammel mand i toget.* ***Han*** *så meget sur ud.*
(Peter talked with an old man in the train. **He** looked very angry.)

In this example the focus proper is the prepositional object, while the known entity is the subject. In all Centering-based algorithms and in Fraurud's algorithm the antecedent to the pronoun *han* (he) is *Peter* (an **OLD** entity, the subject, the first occurring antecedent).

C **A:** *Hvem mødte Peter på gaden i går?*
B: *Peter mødte* SØREN. ***Han*** *havde travlt.*
(**A:** Whom did Peter meet in the street yesterday?

B: Peter met SØREN. **He** was busy.)

In this example both candidate antecedents for the pronoun *han* (he) are proper names, thus OLD entities, but the focus proper, *Søren*, follows textually the subject antecedent, *Peter*, thus in all Centering-based algorithms *Peter* is chosen as antecedent.

D *På fadet stod der en kop og en tallerken.* ***Det*** *tog Maria og satte hen i vinduet.*
(lit. On the tray (neuter gender) stood there a dish (common gender) and a cup (common gender). **It** (neuter gender) took Maria and put in the windowsill (neuter gender).)
(On the tray a dish and a cup are. **It** Maria took and put in the windowsill.)

In this and in the following three examples (E-G) the focus proper is the existential in *der*(there)-constructions. All these examples involve the relation between word order (recency) and focal entities. In this example and in F the existentials *en kop og en tallerken* (a cup and a dish) og *et glas* (a glas) follow the candidate antecedent *fadet* (the tray), while in E and G they precede it and are therefore not the most recent antecedent. This example and the example F are special because in one of the readings the pronoun *det* (it) generically refers to *en kop and en tallerken* (a cup and a dish). Thus the pronoun and its antecedent agree in neither number nor gender.

The present example is a variation of example 2-(29-b) reported in (Mikkelsen 1975)[275]. In all algorithms *fadet* (the tray) is the only possible antecedent of the pronoun *det* (it).

E *Der stod en kop og en tallerken på fadet.* ***Det*** *tog Maria og satte hen i vinduet.*
(lit. There stood a dish (common gender) and a cup (common gender) on the tray (neuter gender). **It** (neuter gender) took Maria and put in the windowsill (neuter gender).)
(There were a dish and a cup on the tray. **It** Maria took and put in the windowsill.)

F *På fadet stod der et glas.* ***Det*** *tog Maria og satte hen i vinduet.*
(lit. On the tray (neuter gender) stood there a glas (neuter gender). **It** (neuter gender) took Maria and put in the windowsill (neuter gender).)
(On the tray there stood a glas. **It** Maria took and put in the windowsill.)

G *Der stod et glas på fadet.* ***Det*** *tog Maria og satte hen i vinduet.*
(lit. There stood a glas (neuter gender) on the tray (neuter gender). **It** (neuter gender) took Maria and and put in the windowsill (neuter gender).)
(There was a glas on the tray. **It** Maria took and put in the windowsill.)

H *En journalist genkendte forsvarsministeren.* ***Han*** *begyndte at løbe.*
(A journalist recognised the minister of defence. **He** began to run.)

In example H as in A the subject is an indefinite nominal, but this nominal is not in a typical focal position. Fraurud's, BFP's and GJW's algorithms choose *en journalist* (a journalist) as antecedent of the pronoun *han* (he), while in Strube's algorithm the preferred antecedent is the definite nominal *forsvarsministeren* (the ministry of defence).

I *Forsvarsministeren blev genkendt af en journalist.* ***Han*** *var meget overrasket.*
(The minister of defence was recognised by a journalist. **He** was very surprised.)

The first utterance of the example contains a passive construction, thus the syntactic subject is not the agent. The agent is expressed by an indefinite nominal. Passivisation alters the information structure of the active clauses. In all the considered algorithms *forsvarsministeren* is chosen as antecedent of the pronoun *han* (he).

In the second group of examples I investigate how parallelism interacts with givenness and focality preferences.

J *Peter mødte Søren på gaden.* ***Han*** *hilste på* ***ham****.*
(Peter met Søren in the street. **He** greeted **him**.)

This is a classic example of parallelism. The first utterance is apparently similar to the second utterance in C. However, the two utterances have different information structures. The two candidate antecedents of the pronoun *han* (he) are *Peter* and *Søren*, both classified as OLD entities. All the considered algorithms choose *Peter* as antecedent of the first pronoun *han* (he).

K *Peter så en mand på gaden.* ***Han*** *råbte til* ***ham****.*
(Peter saw a man in the street. **He** shouted at **him**.)

In examples K-M I investigate the relation between focality preference and parallelism. In all examples one of the candidate antecedents to each pronoun is in the focal part of the IS of the sentence.

L *Peter mødte en mand på gaden.* ***Han*** *hilste på* ***ham****.*
(Peter met a man in the street. **He** greeted **him**.)

M *Peter mødte en mand i toget. Maria hilste på* ***ham****.*
(Peter met a man on the train. Maria greeted **him**.)

In the third group of examples (N-P) I investigate Subject Antecedent preference and its interaction with conventional presuppositions triggered by lexical knowledge. The structures of the three examples are similar, but the main verbs in the main clauses of the three examples are different. In examples N and O this verb is a sight sense-verb, *se* (see) and *kigge på* (look at) respectively, while in the third example the main verb is a non-sense verb, *møde* (meet). All the considered algorithms would choose the subject of the preceding clause as the preferred antecedent of the pronoun *hun* in all three clauses.

N *Sanni så Sussi, mens* ***hun*** *cyklede.*
(Sanni saw Sussi, while **she** cycled.)

O *Maria kiggede på Ann, mens* ***hun*** *løb.*
(Maria looked at Ann, while **she** ran.)

P *Sanni mødte Sussi, mens* ***hun*** *boede i Århus.*
(Sanni met Sussi, while **she** lived in Århus.)

The last two examples investigate whether animacy influences interpretation. In both examples the animate candidate antecedents are referred to in a genitive phrase while the inanimate antecedents are referred to in the genitive's nominal head. In many theories of reference nominal heads are considered more salient than their complements. In models relying on the verbal complement hierarchy, i.a. Brennan et al. (1987), nominal complements are not accounted for. In models where salience degree corresponds to the occurrence order of constituents in an utterance, genitive phrases have higher salience if they precede the nominal head, as it is the case in Germanic languages, i.a. (Grosz et al. 1995). The two examples are given in the following:

Q *De to unge instruktørers produktioner har været en fiasko.* ***De*** *følger ikke tidens mode.*
(The two young directors' productions have been a failure. **They** do not follow the trend of the time)

R *Chefen fandt en masse alvorlige fejl i edb-assistenternes programmer.* ***De*** *var ikke til at stole på.* (The boss found a lot of errors in the programmers programs. **They** could not be trusted)

The examples in the survey are repeated in the following.

A	*Der sad en mand ved siden af Peter i toget.* ***Han*** *så træt ud.* (A man sat next to Peter on the train. **He** looked tired.)
B	*Peter snakkede med en gammel mand i toget.* ***Han*** *så meget sur ud.* (Peter talked with an old man on the train. **He** looked very angry.)
C	**A:** *Hvem mødte Peter på gaden i går?* **B:** *Peter mødte Søren.* ***Han*** *havde travlt.* (**A:** Whom did Peter meet in the street yesterday? **B:** Peter met Søren. **He** was busy.)
D	*På fadet stod der en kop og en tallerken.* ***Det*** *tog Maria og satte hen i vinduet.* (On the tray a dish and a cup were. **It** Maria took and put in the windowsill.)
E	*Der stod en kop og en tallerken på fadet.* ***Det*** *tog Maria og satte hen i vinduet.* (There were a dish and a cup on the tray. **It** Maria took and put in the windowsill.)
F	*På fadet stod der et glas.* ***Det*** *tog Maria og satte hen i vinduet.* (On the tray there was a glas. **It** Maria took and put in the windowsill.)
G	*Der stod et glas på fadet.* ***Det*** *tog Maria og satte hen i vinduet.* (There was a glas on the tray. **It** Maria took and put in the windowsill.)
H	*En journalist genkendte forsvarsministeren.* ***Han*** *begyndte at løbe.* (A journalist recognised the minister of defence. **He** began to run.)
I	*Forsvarsministeren blev genkendt af en journalist.* ***Han*** *var meget overrasket.* (The minister of defence was recognised by a journalist. **He** was very surprised.)
J	*Peter mødte Søren på gaden.* ***Han*** *hilste på* ***ham****.* (Peter met Søren in the street. **He** greeted **him**.)
K	*Peter så en mand på gaden.* ***Han*** *råbte til* ***ham****.* (Peter saw a man in the street. **He** shouted at **him**.)
L	*Peter mødte en mand på gaden.* ***Han*** *hilste på* ***ham****.* (Peter met a man in the street. **He** greeted **him**.)
M	*Peter mødte en mand i toget. Maria hilste på* ***ham****.* (Peter met a man on the train. Maria greeted **him**.)
N	*Sanni så Sussi, mens* ***hun*** *cyklede.* (Sanni saw Sussi, while **she** cycled.)
O	*Maria kiggede på Ann, mens* ***hun*** *løb.* (Maria looked at Ann, while **she** ran.)
P	*Sanni mødte Sussi, mens* ***hun*** *boede i Århus.* (Sanni met Sussi, while **she** lived in Århus.)
Q	*De to unge instruktørers produktioner har været en failure.* **De** *følger ikke tidens mode.* (The two young directors' productions have been a fiasco. **They** do not follow the trend of the time)
R	*Chefen fandt en masse alvorlige fejl i edb-assistenternes programmer.* **De** *var ikke til at stole på.* (The boss found a lot of errors in the programmers programs. **They** could not be trusted)

10.4 Results of the Survey

The results of the survey are shown in table 10.3. For each example the number of informants that chose each candidate antecedent is shown. The sign *?* indicates that the informants could not indicate a preferred interpretation. Following Kameyama (1996) the $\chi^2_{df=1}$ significance is given for each example. It is computed by adding an evenly divided number of the answer "unclear" (?) to each explicitly selected answer. In the last column the level of preference is given. Preference is considered significant if $p < .05$, weakly significant if $.05 < p < .10$ and insignificant if $.10 < p$. I have calculated significance with Pearson's correlation coefficient, see (Woods, Fletcher & Hughes 1986). Being a two-sided test I have doubled the p-value, before calculating significance.[8]

Some of the informants chose *det hele* (the whole) as the preferred antecedent in examples D and E. In the table these answers are counted together with those indicating *fadet* (the tray) as the antecedent. An informant chose *fejl* (errors) as the antecedent to the pronoun *de* (they) in example R. The interpretations of examples A-G confirm that nominals referred to in the focal part of the utterance, where the focal part introduces new entities or is structurally marked, have the highest degree of salience.

The answers to example D indicate that the existentially marked entities *en kop og en tallerken* (a cup and a dish), which also occur in final position, have so high a degree of salience that, although they do not agree in gender and number with the pronoun *det* (it), they compete with the definite candidate antecedent which has the same gender and number as the pronoun. In F where the existential *et glas* (a glas) agrees with the pronoun the preference for the existential is significant.

In E and G the final position of the competing definite nominal *fadet* (the tray) (OLD entity) influences interpretation, so that the answers give no significant preference.

In example H there is no significant preference for any antecedent. The antecedent subject *en journalist* (a journalist) is an indefinite nominal, thus a newly introduced entity, but it is not in the focal part in the IS of the utterance, thus it competes in salience degree with the known object *forsvarsministeren* (the minister of defence). In example I the known subject nominal *forsvarsministeren* (the minister of defence) is preferred to the agent *en journalist* (a journalist) which is unknown, but which has a high status because of its thematic role. In both H and I commonsense knowledge also influences the results.

In example J the two pronouns *han* (he) and *ham* (him) are interpreted according to parallelism preference. The answers to K and L show furthermore

[8]The test is two-sided because the informants had to choose between two candidate antecedents.

	Answers						Preference	
	1.antecedent		2.antecedent		unclear		$\chi^2_{df=1}$	p
A	mand	32	Peter	0	?	0	32	$p < .001$
B	Peter	2	gl.mand	30	?	0	24.05	$p < .001$
C	Peter	0	Søren	32	?	0	32	$p < .001$
D	fadet/hele	9	kop & tallerken	19	?	4	3.12	$.10 < p < .20$
E	kop & tallerken	9	fadet	19	?	4	3.12	$.10 < p < .20$
F	fadet	2	glas	30	?	0	24.50	$p < .001$
G	glas	22	fadet	10	?	0	4.50	$.10 < p < .20$
H	journalist	14	forsvarm.	13	?	5	0.03	$.40 < p < .50$
I	forsvarm.	26	journalist	5	?	1	16.53	$p < .001$
J	P.mødte S.	31	S. mødte P.	1	?	0	28.12	$p < .001$
K	P. råber til m.	27	m. råber til P.	5	?	0	15.12	$.p < .001$
L	P. hilste m.	29	m. hilste P.	2	?	1	22.78	$p < .001$
M	Peter	4	gl. mand	16	?	12	4.50	$.10 < p < .20$
N	Sanni	23	Sussi	5	?	3	10.12	$p < .001$
O	Maria	16	Ann	9	?	7	1.53	$.20 < p < .30$
P	Sanni	21	Sussi	5	?	6	8	$p < .001$
Q	to instruktører	10	produktioner	19	?	3	2.53	$.10 < p < .20$
R	fejl edb-assistenter	1 9	programmer	17	?	5	1.12	$.30 < p < .40$

Table 10.3: Survey results

that parallelism preference overrules focality preference. In the interpretation of M parallelism conflicts with subject antecedent preference, as also noticed by Kameyama (1996) who states that subject antecedent preference can overrule grammatical parallelism when they are in conflict.

The interpretation of the pronoun *hun* (she) in examples N and P conforms with the subject antecedent preference. The interpretations of *hun* (she) in example O did not show such significant preference.

In examples N the verb in the main clause is the sense verb *se* (see), while in O it is *kigge på* (look at). *Se* (see) is more general than *kigge på* (look at) in that it can be considered the hyperonym of the semantic class of "sight" verbs. The main difference between the two verbs is that *kigge på* (look at) implies that the action is intentional while *se* (see) does not. This means that the actor intentionally looks at the object, thus he/she shows interest in the object. In my opinion, this interest moves the attentional focus to the object. The difference between the interpretation of the pronouns in the two examples illustrates the importance of lexical knowledge for pronominal resolution, as for other interpretation issues.

The interpretations of Q and R seem to indicate that animacy influences resolution. However, in some cases genitive phrases with the same animacy status as their nominal head compete with this head as antecedents of the same pronoun. This is illustrated in example (4), which is discussed later in this section. Animacy certainly plays an important role in the use of pronouns, but, as seen in section 10.1.1, it is explicitly indicated in the antecedent agreement constraints when the referent is singular. The analysis of long distance reference in the texts and in the dialogues confirms the studies by Fraurud (1992) and by Ravnholt (1994) which indicate that long distance reference to animate entities is more common than to inanimate entities. The fact that long distance reference in most cases involves animate entities is, in my opinion, a consequence of the Gricean conversational implicatures of Manner. Speakers assume to be understood by the hearers and thus use referring expressions whose referents are believed to be identifiable. The possible antecedents of animate pronouns are mainly humans, while the antecedents of common and neuter pronouns can be both abstract and concrete objects. Neuter singular pronouns can refer to almost all types of entity. Because the choice of antecedents to pronouns referring to animate entities is much more restricted than that of other pronouns, long distance reference to these entities is more often justified.

In the dialogues I analysed, cases of long distance reference always involved humans and in most cases there were no candidate antecedents in the discourse, thus the referent could be identified on the basis of simple antecedent agreement constraints. In the written texts (especially in the novel) this was not always the case, but the antecedents of distant pronouns were central to the story, thus they were global referents following Grosz & Sidner (1986).

Another interesting fact concerning animacy is that all the antecedentless plural pronouns I found referred to animate entities.

From the analysis of written and spoken data (see chapter 8) it is evident that nominal complements are less salient than their heads. Of these complements, however, I believe that genitive phrases are the most salient. Pronominal references involving genitive phrases in the analysed data were rare, thus I have no real evidence for this assumption in the data. In the present context I suggest that the particular status of genitive phrases is related to the fact that they are linked to the nominal head by a subject-like relation.[9] In the constructed example (4), in fact, one of the candidate antecedents of the pronoun *han* (he) is the entity referred to by the genitive phrase *Peters*. The choice of *Peter* as antecedent of the pronoun, in one of the two interpretations of the pronoun, conforms with parallelism in that *Peters far* (Peter's father) is interpreted as *Peter has a father*.

[9] I do not speak here of function nominals where the genitive phrase often has the agent's role.

(4) *Peters far er ofte ude at rejse, og han ser ham derfor ikke så tit.*
(lit. Peter's daddy is often traveling, and he sees him therefore not very often.)
(Peter's daddy is often traveling, and he therefore does not see him very often.)

Concluding, the results of the survey confirm the hypothesis that *focal* preference interacts quite systematically with *givenness* preference. Furthermore the data indicate how *focal* preference and attentional-based preferences interact with parallelism preference.

The results of the survey also indicate that if existentials are the most recent candidate antecedent, their accessibility degree is higher than if they are not. This may depend on the fact that the final position in Danish, and in many other languages, is often related to entities in the focal part in the IS structure of the utterance (see also chapter 4). Fraurud and other researchers connect salience degree of non-subject entities in the preceding utterance with recency. The analysed data (see especially chapter 8) and the results of the survey indicate that the most recent candidate antecedents in the preceding utterance are not necessarily the most salient candidates. I believe that the salience degree of "recent" candidate antecedents is related to the fact that these antecedents are in the focal part of the utterance and thus often occur in the final part of utterances.

Animacy influences the use of pronouns, but it is more relevant for global and implicit reference than for local reference. I take animacy into account when proposing the search space for the resolution algorithm.

In the following section a tentative model of preference interaction is given.

10.5 A Model of Preference Interaction

From the analysis of the data in texts and conversations and the results of the survey of pronoun interpretation I propose a tentative model of the interaction between grammatical parallelism, givenness, attentional and focality preferences. The model of the interaction between preferences is given in table 10.4. In 10.4 I use the sign $\supseteq$ to indicate that the preference on the left of the sign can overrule the one on the right of the sign.

According to the interaction model, givenness preference can be overruled by focal preference. Parallelism preference can override both pronominal chain preference, and focality preference. I have not included in the model Kamayama's assumption that subject antecedent preference can override parallelism rules when in conflict because I have not found strong evidence for this in the data. In the data a subject antecedent preference overruling parallelism preference was indicated by the use of a strong pronoun (see examples 2(71)). The model is clearly a simplification. Interact does not always mean overrule. Furthermore there are aspects such as the deep role of verbal complements which I have not taken into account at all.

Commonsense Preferences Conv.Presup.	$\supseteq$	Grammatical Parallelism Preference	$\supseteq$	Focal Prefer.	$\supseteq$	Pron. Chain Preference	$\supseteq$	Givenness Preference

Table 10.4: Interaction of preferences

In the algorithm proposed in the following chapter commonsense knowledge preferences and conventional presuppositions involving both world and word knowledge are not accounted for, but must be applied when more candidate antecedents are returned by the algorithm.

10.6 Summary

In this chapter I have discussed the constraints and preferences used in the resolution algorithm which is presented in the following chapter. Agreement constraints were outlined on the basis of the description of the data in chapter 2. The importance of selectional restrictions for both resolving individual anaphors and for distinguishing between pronouns with concrete and abstract antecedents was pointed out. Selectional restrictions must account for the most common readings of words in the actual domain and type of discourse.

Preference types illustrating general tendencies in the interpretation of pronouns were outlined. These types comprise commonsense preferences and conventional presuppositions which can override all other types of preference, i.e. parallelism preference and attentional-based preferences. The latter are connected to the definition of high degree of accessibility in theories such as Centering.

A high accessibility is usually equated with a high degree of salience, the latter very often identified with the "givenness" of entities in the hearer model. I propose to combine this account of the degree of salience/accessibility in terms of "givenness" with the proposal by Sgall et al. (1986) and Hajičová et al. (1990) who affirm that entities in the focal part of the IS of an utterance have the highest degree of salience. The two approaches have often been considered incompatible because focal marked entities in many cases coincide with new information.

In my proposal "givenness" of entities indicates salience by default. However, the speaker can indicate that an entity is salient by marking it as focus proper. The contexts in which this explicit focal marking occur in Danish were tentatively proposed on the basis of the study of information structure discussed in chapter 4 and the data analysed, see especially chapters 2 and 8. These contexts comprise topicalised entities, existentials in *der*(there)-constructions, other constructions where prosodic marking and/or the context clearly indicate that some entities are the focus proper, such as answers to wh-questions, newly introduced objects and prepositional objects, and nominals following focusing adverbials. I called *givenness* preference the preference for assigning a high degree of salience to "given" entities, while the preference assigning the highest degree of focus to focal marked entities is called *focal* preference.

The results of a survey of the interpretation of pronouns investigating the interaction between different preference types were presented. In the survey native speakers of Danish had to choose a preferred referent to pronouns with more candidate antecedents.

The results of the survey seem to confirm that **focal** preference interacts quite systematically with *givenness* preference and parallelism preference. Furthermore the interaction between parallelism preference and attentional-based preferences proposed by Kameyama also seems to be valid for Danish.

Recency of entities in the preceding utterance seems only to be important if it is related to the IS of the utterance because in Danish as in other languages the preferred position for focal entities in an utterance is the final position. However recency indicates a higher degree of accessibility for entities that are more distant from the anaphor than an utterance. Finally, the results of the survey confirm that lexical knowledge is quite important for anaphora resolution.

Animacy mostly influences phenomena such as long distance reference, so that the majority of distant antecedent occurrences involved animate entities, confirming the studies in (Fraurud 1992, Ravnholt 1994). Furthermore all occurrences of antecedentless plural pronouns referred to animate entities.

On the basis of the results of the survey and of the data analysed (see especially chapters 2 and 8) a simplified model accounting for the interaction of preferences in resolution was presented. In the model commonsense knowledge and conventional presuppositions (including lexical knowledge) can override all other types of preference. Parallelism preference can override both focality preference and givenness preference. Finally focal preference overrides givenness preference. The model of preference interaction is used in the algorithm for resolving Danish intersentential anaphora described in the following chapter.

Chapter 11

A Resolution Algorithm for Danish Intersentential Pronominal Anaphora

In this chapter I propose an algorithm for resolving **explicit pronominal reference** in Danish written texts and dialogues called the DAR-(Danish Anaphora Resolution) algorithm. The DAR-algorithm follows the Centering approach, but combines it with other traditions accounting for aspects such as the salience of focal entities and parallelism. In cases of ambiguity the DAR-algorithm proposes a preferred antecedent, but also returns other candidate antecedents so that commonsense knowledge preference and conventional presuppositions can be applied and, possibly, resolve the ambiguity. The algorithm strongly relies on the work presented in i.a. (Grosz et al. 1995, Kameyama 1996, Kameyama 1998*a*, Hajičová et al. 1990, Eckert & Strube 1999*a*, Eckert & Strube 1999*b*).

Both individual and abstract anaphors are distinguished in the DAR-algorithm, but the algorithm does not rely on the analysis of the context which is necessary to correctly resolve anaphors such as plural pronouns with complex antecedents and inferable pronouns. Plural pronouns referring to people working/living in an institution/place, which are called inferable-evoked by Eckert & Strube (1999*b*), however, can be resolved encoding the regular polisemy of the antecedent in a semantic lexicon. See also sections 2.2.3 and 10.1 for a discussion of this aspect. However, the DAR-algorithm does not attempt to individuate these types of complex anaphor and excludes them from the resolution process. This strategy is inspired by the ES99-algorithm (Eckert & Strube 1999*a*).

The DAR-algorithm is developed for processing anaphors in both written texts and dialogues. It presupposes two different discourse structures for resolving anaphors in the two types of discourse, reflecting some of the main differences between them which are relevant for anaphora resolution. These differences were discussed in section 5.6 and chapter 8. The structure of discourse determines the search space of the algorithm. Thus different antecedent search spaces are used for resolving anaphora in written texts and dialogues.

The chapter is organised as follows. In section 11.1 the two discourse structure types presupposed by the algorithm for resolving anaphors in written texts and dialogues are described. How each structure type influences the search space of the algorithm is explained and examples of discourse segmentation are presented. In section 11.2 the Attentional State which the DAR-algorithm operates on is outlined, while in section 11.3 the predicates for identifying individual and abstract anaphors are given. The proposed predicates include those described in section 8.3. New predicates have been identified analysing the occurrences of pronouns in both written texts and dialogues and looking at the encodings of a computational lexicon. In section 11.4 the algorithm for resolving intersentential individual and abstract pronominal reference in Danish texts and dialogues is presented. How the algorithm works on sample texts and dialogues is described in section 11.5. Finally section 11.6 contains some conclusions.

11.1 Discourse Structure and Search Space

The minimal units in both written texts and dialogues correspond mainly to clauses with their non finite subclauses. As discussed in chapter 9, these units also comprise unfinished clauses, single words and sounds, such as *mmm* and *øh*, in dialogues. In multimodal dialogues discourse units include non linguistic elements such as gestures and eye gazes or the combination of units from different modalities.

I presuppose the resolution strategy proposed by Kameyama (1998*a*) who extends the centering framework to resolve interclausal anaphora. According to this strategy intersentential anaphors are resolved after interclausal anaphors have been resolved. The DAR-algorithm only describes the intersentential resolution process.

In written texts the immediate search space for an intersentential pronoun x in utterance U_n is the preceding utterance U_{n-1} for singular neuter gender pronouns, while for other pronouns is first U_{n-1} and then, in case of failure, the preceding utterances in the right frontier of the discourse tree searched for in recency order.

In dialogues the immediate antecedent search space of an intersentential pronoun x in utterance U_n is the previous utterance, U_{n-1}, if U_n is the second element in the current **Synchronising Unit**, SU_m. If U_n is the first utterance in SU_m the immediate search space for x is the preceding **Synchronising Unit**, SU_{m-1}. The search space in dialogues is inherited from the ES99-algorithm. However also in dialogues the search space for antecedents of pronouns which are not singular neuter gender are all the synchronising units in the right frontier discourse tree, when the algorithm cannot find an antecedent in the immediately preceding synchronising unit. It should be noted that the "preceding" utterance or syntactic unit does not necessarily precedes the utterance in which the pronoun occurs linearly, but it may just precede it in the discourse structure tree.

In the following I just write utterance unless the distinction between utterance and synchronising unit is important.

Another difference between the structure of dialogues and written texts is that in dialogues utterances must be acknowledged to be included in the context, in line with the *Grounding* theory proposed by Traum (1994). As discussed in section 5.5, this requirement permits to remove from the context utterances which the speaker does not complete because s/he corrects her/himself or because s/he is interrupted by another conversation participant. There may also be utterances which are explicitly rejected during discourse and in some cases also the entities referred to in these utterances must be excluded from successive reference.

(1) contains an interrupted utterance, **B2**. The pronoun *det* in **B2** is not added to the context.

(1) **A1:** *nå også også med dine arbejdere herude*
(so also also with your workers out here)
B1: *ja ja*
(yes yes)
A2: *nå*
(so)
B2: *det (uf)*
(it (uf))
A3: *mm ££ ja hvor mange er du egentlig chef for*
(mm ££ yes how many are you really the boss of)
(BYSOC)

An **Initiation** (**I**) which is the first member of a synchronising unit must be acknowledged. An **Acknowledgement**, **A**, has no semantic content while an utterance which both acknowledges the preceding **I** and has its own semantic content is an **Acknowledgement/Initiation**, **A/I**. An **A/I** is then both part of the preceding synchronising unit and starts a new synchronising unit. An **I** can be implicitly acknowledged. This happens when a speaker continues talking and her preceding utterance has not explicitly been rejected.

In the dialogues, I have considered dialogue acts such as *ja* (yes) and *nej* (no) simple acknowledgements when they are not answers to yes/no questions or they do not specifically confirm/deny preceding utterances. In these cases, in fact, *ja* (yes) and *nej* (no) have the same acknowledgement function, the former being used to acknowledge a positive utterance, the latter a negative utterance. The acknowledgement function of the negation *nej* (no) is illustrated in (2), where the patient, **P** saying *nej* (no) acknowledges the preceding utterance by the doctor **L**.

(2) **P:** *jeg hader at gå i svømmehallen (1 sekund) (fniser)*
(I hate going to the swimming baths (1 second) (giggles))
L: *ja så er det jo ikke særlig nemt at få overtalt sig selv*
(lit. yes, so is it not particularly easy to talk oneself round)
(yes, so it is not particularly easy to talk oneself round (to go there))
P: *nej (leende)*
(no (laughing))
(SL)

The structure defined by synchronising units only describes the interaction level of dialogue. Discourse relations hold between clauses in utterances, between utterances, between synchronising units and larger segments of discourse. Under this respect the structure of dialogues and texts is the same (see the conclusion of chapter 5).

In the following I give an example of how extract (3) from an interview published in the newspaper *Politiken* on November the 12th 2000 is divided into utterances (**Us**) and synchronising units (**SUs**). While in the original interview the interviewer's utterances were unquoted and the interviewee's utterances were quoted, in (3) I explicitly indicate the two speakers so that a **J** stands for the journalist and an **I** stands for the interviewee.

(3) ***Interview: Peter Zobel. Politiken mandag:***
(Interview: Peter Zobel. Politiken Monday:)
J:
Peter Zobel, Jeudans forsøg på at købe Norden har vakt opsigt, hvad synes du om måden, de skrider frem på?
(lit. Peter Zobel, Jeudan's attempt (common-gender) to buy Norden has attracted attention. What think you of the way (common-gender) in which they proceed?)
(Peter Zobel, Jeudan's attempt to buy Norden has attracted attention. What do you think of the way in which they proceed?)
I:
Man kan hurtigt få lagt nogle ord i munden - om man synes, det er en fjendtlig overtagelse eller ej, det har jeg ikke rigtig en holdning til. I engelsksprogede lande har man jo noget, der hedder 'hostile bid'. Det er karakteriseret ved, at man ikke taler med bestyrelsen, og det er ikke sket her. Men det er vi helt afslappede overfor.
(lit. One can quickly be put some words into the mouth (common-

gender) - whether one thinks that it (neuter-gender) is a hostile take over (common-gender) or not, this (neuter-gender) have I not really an opinion (common-gender) on. In English speaking countries have they surely something called 'hostile bid' (neuter-gender). It (neuter-gender) is characterised by one not speaking to the management (common-gender), and this (neuter-gender) has not happened here. But it (neuter-gender) are we completely relaxed about.)
(One can quickly be put some words into the mouth - whether one thinks that it is a hostile take over or not, I do not really have an opinion on this. In English speaking countries they surely have something called 'hostile bid'. It is characterised by not speaking to the management, and this has not happened here. But we are completely relaxed about this.)
J:
Hvordan har du det med, at din families gamle virksomhed Codan arbejder sammen med Jeudan?
(How do you feel about your family's old firm Codan working together with Jeudan?)
I:
Det er jeg iskold over for, det er jo forretning. Og der har Codan altså følt, det var en attraktiv handel.
(lit. It (neuter-gender) do I not care about, it (neuter-gender) is business (common-gender), you know. And there has Codan then felt, it (neuter-gender) was an attractive deal (common-gender).)
(About it I do not care, it is just business, you know. And then Codan has also felt, it was an attractive deal.)
J:
Det er blevet sagt, at overtagelsen er lige lovlig smart?
(lit. It has been said, that the take over (common-gender) is rather too smart?)
(It has been said, that the take over is rather too smart?)
I:
Nej, det kunne jeg da selv have fundet på...
(lit. No, it (neuter-gender) could I surely self have thought about)
(No, I could have thought about it myself...)

The **SUs** and **Us** in the interview are the following:
SU_0: U_0
Peter Zobel
SU_1: U_1
U_1: (**I**)
Jeudans forsøg på at købe Norden har vakt opsigt,

(Jeudan's attempt to buy Norden has attracted attention,)
SU_2: U_2 U_4[1]
U_2 (**I**) *hvad synes du om måden, de skrider frem på?*
(What do you think of the way in which they proceed?)
SU_3: U_3
U_3 (**I**)[2]
Man kan hurtigt få lagt nogle ord i munden
(One can quickly be put some words into the mouth)
SU_4: U_4
U_4 (**A/I**)
om man synes, det er en fjendtlig overtagelse eller ej, det har jeg ikke rigtig en holdning til.
(whether one thinks that it is a hostile take over or not, I do not have an opinion on this.)
SU_5: U_5
U_5 (**I**)
I engelsksprogede lande har man jo noget, der hedder 'hostile bid'.
(In English speaking countries they surely have something called 'hostile bid'.)
SU_6: U_6
U_6 (**I**)
Det er karakteriseret ved, at man ikke taler med bestyrelsen
(It is characterised by not speaking to the management,)
SU_7: U_7
U_7 (**I**)
og det er ikke sket her.
(and this has not happened here.)
SU_8: U_8 U_9
U_8 (**I**)
Men det er vi helt afslappede overfor.
(But we are completely relaxed about this.)
SU_9: U_9 U_{10} U_{11}
U_9 (**A/I**)
Hvordan har du det med, at din families gamle virksomhed Codan arbejder sammen med Jeudan?
(How do you feel about your family's old firm Codan working together with Jeudan?)
SU_{10}: U_{10}
U_{10} (**A/I**)
Det er jeg iskold over for,
(About it I do not care,)

[1] The parenthetical U_3 is not included in this SU.
[2] U_2 is parenthetical.

SU_{11}: U_{11}
U_{11} (**I**)
det er jo forretning.
(it is just business, you know.)
SU_{12}: U_{12}
U_{12} (**I**)
Og der har Codan altså følt, det var en attraktiv handel.
(And then Codan has also felt it was an attractive deal.)
SU_{13}: U_{13} U_{14}
U_{13} (**A/I**)
Det er blevet sagt, at overtagelsen er lige lovlig smart?
(It has been said, that the take over is rather too smart?)
SU_{14}: U_{14}
U_{14} (**A/I**)
Nej, det kunne jeg da selv have fundet på.
(No, I could have thought about it myself)

I have considered *Peter Zobel* as a dialogue act (SU_0) where the journalist claims attention from the interviewee, *Peter Zobel*. Utterance U_3 is parenthetical, thus embedded in the interviewee's answer to the preceding question (U_2). This is an illustration of how the hierarchical structure of discourse interplays with the macrostructure represented by the synchronising units. Eckert & Strube (1999*b*) do not include discourse relations in their treatment of dialogues. Thus my approach differs from theirs in this respect.

U_4 is an example of an Acknowledgement/Initiation, because it acknowledges U_2 and, at the same time, has its own content and thus also begins a new syncronising unit, SU_4. In the interview extract there are no simple acknowledgements.

The second example in (4) is from the SL-corpus.

(4) **L:** *normalt kunne man jo sige at de der scanninger er meget præcise*
(lit. Normally could one say that those scannings are very precise)
(Normally one could say that those scannings are very precise)
P: *ja*
(yes)
L: *og det, det stoler man jo på*
(lit. and this, this relies one surely on)
(and this, on this one surely relies)
P: *mmh*
(mmh)
L: *men altså jeg har da, været ude for, at det har snydt...*
(but then I have experienced that this has cheated...)

The synchronising units and utterances in (4) are the following:
SU_1: U_1 U_2
U_1: **I**
L: *normalt kunne man jo sige at de der scanninger er meget præcise*
(Normally one could say that those scannings are very precise)
U_2: **A**
P: *ja*
(yes)
SU_2: U_3 U_4
U_3: **I**
L: *og det, det stoler man jo på*
(and this, on this one surely relies)
U_4: **A**
P: *mmh*
(mmh)
SU_3: U_5
U_5: **I**
L: *men altså jeg har da, været ude for, at det har snydt...*
(but then I have experienced that this has cheated...)

U_2 and U_4 are examples of simple acknowledgements.

11.2 The Attentional State

In the following I describe the Attentional State on which the DAR-algorithm operates. Following Kameyama (1998*a*) an input and an output attentional State are distinguished. However, differing from Kameyama, I use Ariel's **Accessibility Marking Scale** (given in figure 3.3) to model the input attentional state. As pointed out in chapters 2 and 3 Ariel's scale distinguishes types of pronoun and this distinction is relevant for the resolution of Danish pronouns. The simplified fragment of Ariel's scale which is relevant to the DAR-algorithm is repeated in figure 11.1. The elements on the left of the scale are the least marked and, consequently, the most accessible ones.

cliticised < unstressed pronouns < stressed pronouns < proximal demonstrative < distal demonstratives

Figure 11.1: Pronouns in Ariel's Accessibility Marking Scale

The differences in reference between pronominal types which were emphasised in chapter 2 are the following. Weak (cliticised and unstressed) pronouns usually refer to the most salient entity in the utterance. Strong (stressed and demonstrative) pronouns emphasise or put in contrast the entities they refer to and/or indicate that their antecedents are not the ones which would be chosen in the corresponding unmarked context (are not the most expected ones). According to this analysis strong pronouns can have both a backward-looking and a forward-looking function. If a stressed pronoun has only one candidate antecedent in the preceding utterance, it has only a backward-looking function, while it has both functions if there are more candidate antecedents. The difference between personal pronouns and demonstrative pronouns are accounted for in the DAR-algorithm.

In written language and in transcriptions of dialogues where prosodic information is not available it is not possible to distinguish between stressed and unstressed pronouns. Thus it can be problematic to recognise demonstrative and personal uses of the pronouns *den*, *det* and *de*. In most cases they are treated as weak pronouns.[3]

In the output Attentional State entities from the preceding U_{n-1}/SU_{m-1} are ranked according to their salience degree. Following Eckert and Strube's proposal two lists are used in the algorithm, one for individual entities, which I call the *Ilist* and one for abstract entities called the *Alist*. In the *Ilist* entities are ordered according to both givenness and focality preference (see section 10.2).

The order according to givenness preference roughly corresponds to the verbal complement order which, as concluded in chapter 8, in most cases reflects the accessibility degree of nominals in Danish. The verbal complement order is also used to rank entities by Brennan et al. (1987) and by Kameyama (1996).

Differing from centering-based algorithms, however, I also propose to follow (Sgall et al. 1986, Hajičová et al. 1990) who state that entities in the focal part of an utterance (in the IS meaning of the word) have the highest degree of salience. I restrict this assumption to entities that are explicitly focally marked, roughly corresponding to what Sgall et al. (1986) call **focus proper**. I also propose that focality preference overrules givenness preference. In section 10.2 I tentatively proposed the cases in which entities can be considered focus proper and thus have the highest degree of salience. Only in these cases entities in the focal part of an utterance are ranked highest in the *Ilist*.

[3]In practice, it may also be difficult to clearly distinguish between stressed and unstressed pronouns in spoken dialogues. Investigating prosodic marking of pronouns in English task-oriented dialogues, Wolter & Byron (2000) find out that prosodic cues in these dialogues seem to depend strongly on speaker variation. Similar problems may also exist in Danish. These aspects should be investigated before prosodic information is used.

Because topicalised elements[4] which are focus proper, often occur in front position in main clauses (see section 2.5) word order in Danish in many cases also reflects the degree of accessibility of entities.

The ordering of entities in the *Ilist* according to both givenness and focality preference is illustrated in figure 11.2.

PFocus > SUBJECT > OBJECT/PrepOBJECT > OBJECT 2 > OTHER COMPLEMENTS > ADJUNCTS

Figure 11.2: Order of verbal complements in the *Ilist*

More detailed hierarchies of complements and adjuncts than the one given in 11.2 have been proposed in the literature for different purposes.[5] In the algorithm "other verbal complements" and adjuncts are simply ranked according to their occurrence order in the utterance.

The hierarchy in 11.2 does not account for nominal and adjectival complements. I rank adjectival complements as prepositional objects and, as proposed by many theories and confirmed by the analysed data (chapter 8), I assume that nominal complements have lower salience degree than their nominal heads, thus they are ranked lower in the *Ilist*. The mutual ranking of nominal complements corresponds to their occurrence order in the utterance. In this aspect I follow the ranking proposed by Strube & Hahn (1996) in their functional centering approach (see section 6.3.2). Genitive phrases which in Danish, as in other Germanic languages, usually precede their nominal head "naturally" receive a higher status than other nominal complements. Also prepositional complements which modify nominals have lower ranking than the nominals they modify. The order of nominal complements is illustrated in figure 11.3.

$$NCOMPL_1 >_{prec} NCOMPL_2 >_{prec} \ldots >_{prec} NCOMPL_n$$

Figure 11.3: Order of nominal complements in the *Ilist*

In the original centering theory only entities in U_{n-1} are considered as antecedents in local reference. However, the theory does not state that there must be a

[4] As proposed in chapter 4 I distinguish between topicalised and topic-fronted pronouns. The former are considered focus proper while the latter are just weak pronouns in the front field and are not focus proper.

[5] As noticed in chapter 6 most of the hierarchies proposed in the literature are semantic i.a. (Jackendoff 1972, Jackendoff 1990, Grimshaw 1990). However, the analysis of pronominal uses in English (Brennan et al. 1987, Kameyama 1996) and my analysis of the use of Danish pronouns indicate that the obliqueness hierarchy of complements and adjuncts is more relevant for resolution than the hierarchy of thematic roles.

nominal center in an utterance. In the present approach utterances may have null centers. Furthermore, differing from the strategy proposed by Eckert & Strube (1999*a*), pronominal antecedents do not need to be found in the preceding utterance/synchronising unit inside a discourse segment, although this is often the case especially in written language. The salience degree of entities, however, fades away if they are not referred to for a while in a discourse segment.

The analysis of pronouns in texts and dialogues indicates that the salience degree of non-referred-to individual entities fades away much quicker in written texts than in dialogues. Recency is relevant in these cases. This interpretation is also in line with the results of the analysis of the use of pronouns in written texts and dialogues done by Fox (1987) as discussed in section 5.6. The salience degree of situations fades away very quickly.

To account for distant antecedents I use Walker's cache model (Walker 1996) as proposed in section 8.3. The antecedents of individual pronouns which cannot occur as discourse deictics are searched first in the *Ilist* for U_{n-1} and, in case of failure, in those of the preceding utterances (synchronising units in dialogues) in recency order in the right frontier of the discourse tree (Webber 1991). As in Walker's *cache model* it is assumed that there is a mechanism which moves the Attentional state (the *Ilists*) in between the cache and the main memory.

The abstract entities which are referred to by a discourse deictic in U_{n-1} or SU_{m-1} are encoded in the *Alist*. The elements in the *Alist* are removed from it after an utterance (a synchronising unit in dialogues) has been processed if they were not referred to in it.

Eckert & Strube (1999*a*) propose an order for searching antecedents of discourse deictics. This order, which they call context ranking, is repeated in figure 11.4.

1. A-list
2. within same **U**: clause to the left of the clause containing the anaphor
3. within previous **U**: rightmost main clause and subordinate clauses to its right
4. within previous **U**s: rightmost sentence or rightmost complete sentence if an **U** is just an acknowledgement such as *ja* (yes), *nej* (no)

Figure 11.4: Order of search for antecedents to discourse deictics

The context ranking in 11.4 i.a. accounts for the fact that in dialogues an utterance does not always contain a complete clause. Thus the algorithm looks to all preceding utterances until a completed main clause is found.

Eckert and Strube distinguish personal and demonstrative pronouns in their algorithm, but they only use this distinction to rank the searching of individual and abstract antecedents. If the pronoun is personal, the ES99-algorithm first looks for an individual antecedent and only if it does not find one looks for an abstract antecedent. If the pronoun is demonstrative, the ES99-algorithm first attempts to find an abstract antecedent. The search ordering reflects the fact that a demonstrative is often used to indicate the abstract reading in contexts where there is a possible ambiguity between an individual and abstract reading of a pronoun, i.a. (Webber 1991, Gundel et al. 1993). This difference seems also to be valid in Danish, but, as discussed in chapter 2, the data also indicate that there are other differences between the reference type indicated by personal and demonstrative discourse deictics. These differences are summarised in the following.

Det (it/this/that) is the most common discourse deictic in both texts and dialogues. It is often used in contexts where only the discourse deictic reading is possible (see section 8.3) or where the context indicates that the abstract reading should be preferred.

Dette (this) is mainly used as discourse deictic in written language and often indicates a reference to the last mentioned situation. The antecedent is often the rightmost subordinate clause in the preceding utterance, and not a discourse deictic in it or the whole utterance. These are always the preferred antecedents in the ES99-algorithm according to the context ranking given in figure 11.4.

The differences in reference between the two discourse deictics *det* (it) and *dette* (this) are parallel to the differences between the two pronouns when they refer to individual antecedents.

The discourse deictics *det her* and *det der* are often used to refer to a larger segment of the preceding discourse, or something that can be inferred from discourse.

Finally reference to more utterances/situations can be indicated by the use of a discourse deictic preceded by the quantifier *alt* (all). Examples of all these uses were given in section 2.3. These differences cannot be accounted for by Eckert and Strube's algorithm.

As noticed by Webber (1991) (section 7.1 example (1)) identifying the precise discourse subtree referred to by discourse deictics does not only require a deep analysis of the whole discourse context but, in some cases, it is not even possible for humans.

For this reason the DAR-algorithm proposes a preferred antecedent, if possible, but also indicates the ambiguity in ambiguous contexts. In this respect it differs from most simple resolution algorithms. The type of pronoun modelled in the input attentional state determines the resolution strategy. If the discourse deictic is the pronoun *det* (it/this/that) the context ranking proposed by Eckert and Strube is applied for searching discourse antecedents. If the pronoun is the proximal deictic *dette* (this) the rightmost clause in the preceding discourse is proposed as possible antecedent, but it is also indicated that the pronoun can be *vague*. The discourse deictics *det her* (this) and *det der* (that) and the pronouns *det* and *dette* preceded by the quantifier *alt* (all) are always classified as *vague*. Here *vague* does not only mean that the pronoun vaguely refers to something which must be inferred, as in the ES99-algorithm, but also that the pronoun possibly refers to more utterances and thus must be resolved using contextual information.

Kameyama in her centering-based algorithm uses both the input and output attentional state to determine the center. In the present account I mainly use the differences between pronoun types and state that pronouns have a higher accessibility state than other entities. The latter fact is used to implement pronominal chain preference. In an account of all types of referring expressions the whole accessibility hierarchy is relevant.

11.3 Individual and Abstract Entities

The contexts in which individual anaphors and discourse deictics usually occur are used by the DAR-algorithm to distinguish between the two pronominal uses following the strategy proposed by Eckert & Strube (1999*a*). However, as concluded in chapter 8 the ***I**- and ***A** predicates defined in the ES99-algorithm do not describe all the typical concrete and abstract contexts in neither English nor Danish. On the basis of the analysis of reference in both Danish texts and dialogues and on the encodings of computational lexicons at CST[6] I have identified a larger number of predicates than Eckert & Strube (1999*a*). Some of the individuated predicates are only valid for Danish (see i.a. those presented in section 8.3), but many of them (or more precisely their English adaptations) are also valid for English.

The constructions which allow for both clausal and individual complements are dealt with in the resolution algorithm.

In applied systems the different predicates must also be tuned to the particular type and sublanguage of the discourse. The **danI* predicates given in 8.3 are

[6] I have mainly used the syntactic encodings in the **Parole** lexicon (Braasch, Navarretta & Sørensen 1998*b*) so that verbal, adjectival and nominal syntactic constructions which only take individual complements are added to the **danA* predicates, while those exclusively taking clausal complements are added to the **danI* predicates. I also looked at the semantic encodings in the **Simple** lexicon (Pedersen & Nimb 2000), but because only some readings of lexical units (often the prototypical ones) are encoded in this lexicon to date, it does not contain all the information needed by the DAR-algorithm.

also included. In the following the predicates proposed by Eckert and Strube are marked with an *.

1. * constructions where a pronoun is equated with an abstract object, e.g., *x er et forslag* (x is a suggestion), *x er et faktum* (x is a fact), *x er en hændelse* (x is an event/accident)

2. * copula constructions with adjectives which can only be applied to abstract entities, such as *x er sandt* (x is true), *x er usandt* (x is untrue), *x er rigtigt* (x is correct)

3. * arguments of prepositional attitude verbs, arguments of verbs which mainly take S'-complements, e.g., *tro* (believe), *antage* (assume), *mene* (think), *sige* (say)

4. * anaphoric referent in constructions such as *x er fordi du er holdt op med at ryge* (x is because you have stopped smoking) *x er på grund af at du er gravid* (x is because you are pregnant)

5. object of *gøre* (do)

6. subject complement with *være* (be) and *blive* (become) in answers, in co-ordinated clauses or in subsequent clauses

7. object of modal verbs, as in *x skal man* (x shall one), *x vil man* (x will one)

8. object of *have* (have) if the verb was not used as a main verb in the previous clause

9. constructions where the subject is an abstract object such as *x sker* (x happens), *x skyldes* (x is due to/results from)

10. in copula constructions where the adjective can both refer to an individual NP and to an abstract object, such as *x er godt* (x is good), *x er dårligt* (x is bad) the anaphor co-refers with an abstract object if the previous utterance contains a raising adjective construction (or constructions where a clause is the subject) and the utterance/clause describes a generic situation

11. in constructions where the anaphors are objects of verbs such as *elske* (love), *hade* (hate), *foretrække* (prefer) the anaphor co-refers with an abstract object if the preceding utterance contains a raising adjective construction (or constructions where a clause is the subject) and the utterance describes a generic situation (see rule 10)

12. in constructions of the type *det lyder godt* (it sounds good) *det lyder dårligt* (it sounds bad) *det* corefers with a discourse segment unless the previous utterance/clause contains a nominal or a verb referring to sounds

Rules 9-11 deal with pronouns that can both have an abstract and a non-abstract referent. Rule 11 is illustrated by the following two examples:

(5) a. *Peter ejede det store røde hus ved købmandsbutikken. Det hadede han.*
(lit. Peter owned the big red house near the grocer's store. It hated he.)
(Peter owned the big red house near the grocer's store. He hated it.)

b. *Det er dødsygt at sidde på et vaskeri. Det hader jeg.*
(lit. It is dead boring to be in a laundry. It hate I.)
(It is dead boring to be in a laundry. I hate it.)
(PID)

In example (5-a) the algorithm chooses *det store røde hus ved købmandsbutikken* (the big red house near the grocer's store) as the antecedent of *det*, while in example (5-b) it chooses *at sidde på et vaskeri* (being in a laundry) instead of *et vaskeri*.

It must be noted that in cases as example (5-a), it is often not possible to determine whether the anaphor refers to an individual NP or an abstract object without a deeper analysis of the discourse and in some cases the anaphors in these contexts are really ambiguous. Obviously the discriminating strategy of the DAR-algorithm cannot detect these facts.

Rule 11 is special because it says that the metaphoric use of the verb **lyde** (sound) is more common than its non-metaphoric uses and thus its metaphoric reading should be used in natural language processing, unless the current discourse is about sounds.

As noticed in section 8.3, rules 5-7 are indefeasible. The part of rule 3 describing contexts in which prepositional attitude verbs occur is also indefeasible.

The **danA* predicates translated from the **ES-algorithm** are marked by an *****.

1. * constructions where a pronoun is equated with a concrete individual referent, such as *x er en legemsdel* (*x* is a body part), *x er et barn* (*x* is a child)

2. * arguments of verbs describing physical contact/stimulation, which cannot be used metaphorically, e.g. *smadre x* (smash *x*) *spise x* (eat *x*), *drikke x* (drink *x*)

3. * copula constructions with adjectives which can only be applied to concrete

entities, such as x *er rødt* (x is red), x *er langhåret* (x is longhaired)

4. complements of nominals which only subcategorise for concrete entities such as *vaccine mod* x (vaccine against x),

5. complements of adjectives which only subcategorise for concrete entities such as *let for* x (easy for x), *svært for* x (difficult for x), *fuld af* x (full of x)

11.4 The Resolution Algorithm

In the following I describe the DAR-algorithm. The algorithm presupposes that the structure of discourse defining reference accessibility, as described by Webber (1991), has been identified. Two different antecedent domains are assumed by the algorithm, depending on whether the pronoun is or is not singular neuter. The antecedent domain for singular neuter pronouns is the preceding utterance/synchronising unit. The antecedent domain for all other pronouns consists of the utterances in the right frontier of the discourse tree at that point.

The data structures the DAR-algorithm operates on are the *Ilist* and the *Alist*. The former contains the nominals referred to in the preceding utterance ranked according to their degree of salience. The leftmost element in the list is the most salient one in the utterance preceding the pronoun. Information on gender, number, animacy and other semantic types necessary to implement selectional restrictions is provided for each nominal. In the *Ilist* information about the grammatical role of the nominals is also given and focus proper elements are indicated. The simplified *Ilist* for the utterance (6) is given in 11.5.

(6) *Peter snakkede med en gammel mand i toget*
(Peter talked with the old man in the train)

$$[\ \exists(x2)(mand(x2)\ \&\ gammel(x2)\ \&\ prepobj(x2)\ \&\ focus(x2)\ \&\ number(x2,sing)\ \&\ gender(x2,com)\ \&\ sex(x2,mas)),\ (Peter(x1)\ \&\ subject(x1)\ \&\ number(x1,sing)\ \&\ gender(x1,com)\ \&\ sex(x1,mas)),\ (tog(x3)\ \&\ adjunct(x3)\ \&\ number(x3,sing)\ \&\ gender(x3,neut)\ \&\ sex(x3,no))]$$

Figure 11.5: Ilist example

The *Ilist* for (6) contains the representation of the three nominals *en gammel mand* (an old man), *Peter* and *toget* (the train). The first element in the list is the focus proper which as the highest degree of salience.

The *Alist* contains the abstract objects referred to by a discourse deictic in the preceding utterance. The simplified *Alist* for the second utterance in example (7) is given in 11.6.

(7) *Han kunne svømme. Det kunne hun ikke.*
(lit. He could swim. It could she not.)
(He could swim. She couldn't.)

The discourse deictic *det* (it) in (7) refers to the predicate *svømme* (swim) in the preceding utterance.

$$[det = [svømme]]$$

Figure 11.6: Alist example

Both the *Ilist* and the *Alist* are empty when the algorithm starts.

The DAR-algorithm consists of two different functions RESOLVEDET and RESOLVEIND. The former is applied if the actual pronoun x is third person singular neuter, while the latter is applied in all the remaining cases. The main structure of the algorithm is the following:

if x is *singular* & *neuter*
  then go to RESOLVEDET(x)
  else go to RESOLVEIND(x)

RESOLVEIND takes the pronoun x as argument and looks for possible antecedents in the *Ilist* for the preceding U_{n-1} or S_{m-1}, after having applied syntactic constraints and selectional restrictions to the elements of this list (first step in the function which is given on pages 186 and 187). Three different cases are considered in the second step of the function:

A: no antecedent has been found in the immediate search space

B: an antecedent has been found: return it

C: more antecedents have been found

If no antecedent has been found in the actual *Ilist* (case A), the algorithm looks for the highest ranked antecedent in recency order in the *Ilist* of the preceding utterances/synchronising units. The algorithm searches the discourse subtree respecting Webber's right frontier rule (step 6). If no antecedent is found, the pronoun is classified as *inferable*. Pronouns classified as *inferable* comprise plural pronouns with complex antecedents and pronouns whose antecedents must be inferred by the context.

If only one antecedent has been found in the *Ilist* for U_{n-1}, or SU_{m-1}, (case B), the algorithm returns this antecedent, and the resolution succeeds (commonsense preference needs not to be applied, because there is no ambiguity).

If more candidate antecedents are found (case C), ResolveInd performs a number of tests which allow the implementation of the preference interaction model proposed in section 10.5. The different tests check whether parallelism, focality, pronominal chain and/or givenness preference must be used to propose a preferred antecedent in unmarked contexts (steps 3 and 4). More precisely, the algorithm first tests whether U_n and U_{n-1} are parallel. Parallelism is investigated in coordinated utterances, adjacent utterances or explicitly contrasted utterances. In these cases if the main finite verbs in the utterances subcategorise for the same complement types the two utterance are parallel. The two utterances in (8) are parallel. A simplified grammatical structure of the two sentences is given in 11.7.

(8) *Peter så en mand. Han råbte til ham.*
(Peter saw a man. He shouted at him.)

$\exists(e1)(se(e1, x1, x2)$ & $(Peter(x1)$ & $subject(x1)$ & $number(x1, sing)$ & $gender(x1, com)$ & $sex(x1, mas))$ & $\exists(x2)(mand(x2)$ & $object(x2)$ & $number(x2, sing)$ & $gender(x2, com)$ & $sex(x2, mas)))$

$\exists(e2)(råbe(e2, X, Y)$ & $(han(X)$ & $subject(X)$ & $number(X, sing)$ & $gender(X, com)$ & $sex(X, mas))$ & $(ham(Y)$ & $object(Y)$ & $number(Y, sing)$ & $gender(Y, com)$ & $sex(Y, mas)$ & $refl(Y, no))$ & $not(equal(X, Y)))$

Figure 11.7: Syntactic structure of the two utterances in (8)

The two utterances are both adjacent and their main verbs subcategorise for a subject and an object.

If U_n and U_{n-1} are parallel and one of the candidate antecedents has the same grammatical role in U_{n-1} as x in U_n, this "parallel" antecedent is marked as the preferred one in the unmarked context.[7] In the remaining cases, i.e. if U_n and U_{n-1} are not parallel or if no candidate antecedent has the same grammatical role as the current pronoun, the preferred antecedent in the unmarked context is the highest ranked candidate antecedent in the *Ilist*. Pronominal antecedents are here given the highest priority, according to pronominal chain preference, if they are not the focus proper. Thus parallelism preference overrules the other preferences, while focality preference overrules pronominal chain and givenness preference. Finally pronominal chain preference overrules givenness preferences when in conflict.

[7] In example (8) the pronoun *han* (he) agrees in gender and number with the nominal *Peter* and has the same grammatical role as it.

At this point (step 5) the algorithm chooses a preferred antecedent on the basis of x's pronominal type, in line with Ariel's **Accessibility Marking Scale**. If x is a weak pronoun the preferred antecedent in the unmarked context proposed in the preceding steps of ResolveInd is returned together with the list of the remaining candidate antecedents. If x is a strong pronoun the highest ranked candidate antecedent which was not marked as the preferred one in the unmarked context is returned together with the candidate antecedent list.[8]

Because of the ambiguity, commonsense knowledge and conventional presuppositions should be applied at this point in the system.

ResolveInd is the following:

1. apply constraints and selectional restrictions to entities in the *Ilist* for U_{n-1} (or SU_{m-1})
   mark the candidate antecedents

2. case candidate antecedent-list

empty	go to 6
1 element y	return y
$\geq$ 2 elements	go to 3

3. if U_{n-1} and U_n are parallel
   then if among the candidate antecedents there is a y with the same
   grammatical role in U_{n-1} as x in U_n
   then mark y as antecedent
   go to 5
   go to 4

4. mark as preferred antecedent the highest ranked candidate antecedent y in the *Ilist*
   if y is not a pronoun or the focus-proper
   then if some of the candidate antecedents are pronouns
   then choose the highest ranked pronominal candidate in the *Ilist*
   and call it y
   go to 5

5. if x is a weak pronoun
   then return y and Y, the list of the remaining candidate antecedents,
   else return z, the highest ranked antecedent in the *Ilist* which was

[8]Intrasententially, however, the pronoun *denne/dette/disse* (this/these) cannot refer to a subject antecedent unless this antecedent and the demonstrative pronoun are both part of the subject constituent, as it was illustrated in example (38) in chapter 2. I have not included this exception in the intersentential DAR-algorithm, but I have applied it in the tests of the algorithm.

not marked as the preferred one in the preceding step (3 or 4)
and Y, the list of the remaining candidate antecedents

6. % (no candidate antecedent were found)
   if the preceding utterance was not the first one in the right frontier
   of the discourse tree
   then go to the U_p (SU_q in dialogues) which immediately precedes the just
   searched U/SU in the current discourse segment respecting
   the right frontier rule
   search for antecedents in the *Ilist* for this U_p/SU_q by applying
   constraints and selectional restrictions to its elements
   if there are candidate antecedents
   then return y, the highest ranked antecedent in the *Ilist*
   else go to 6
   else return

The main structure of the function ResolveDet is the same as that of the es99-algorithm (Eckert & Strube 1999*a*, Eckert & Strube 1999*b*). ResolveDet tests whether the pronoun x is **danI* (x has an abstract antecedent), **danA* (x has an individual antecedent) or neither, i.e. it can both refer to an individual or abstract antecedent.

If x is **danA* (x probably refers to an individual entity), the algorithm looks for its antecedents by applying the function ResolveInd-Det. If the pronoun is **danI* (x probably refers to a situation), the algorithm looks for an abstract antecedent by applying the function ResolveDD.

Finally, if the pronoun is neither **danI* nor **danA* the algorithm looks at the pronominal type of x.

ResolveInD-Det is identical to ResolveInd except for the following. If no antecedent to the pronoun x is found in the preceding **U/SU** the function returns to the main algorithm, without searching in the preceding discourse. Thereafter the pronoun is classified as *generic-inferable*, if the pronoun is **danI*. If the pronoun is ambiguous with respect to its individual or abstract status, the algorithm attempts to resolve it as a discourse deictic.

The function ResolveInd-Det is given in the following:

1. apply constraints and selectional restrictions to entities in the *Ilist* for U_{n-1} (or SU_{m-1})
   mark the candidate antecedents

2. case candidate antecedent-list
   empty   return
   1 element y return y

≥ 2 elements go to 3

3. if U_{n-1} and U_n are parallel
   then if among the candidate antecedents there is a y with the same
   grammatical role in U_{n-1} as x in U_n
   then mark y as antecedent
   go to 5
   go to 4

4. mark as preferred antecedent the highest ranked candidate antecedent y
   in the *Ilist*
   if y is not a pronoun or the focus-proper
   then if some of the candidate antecedents are pronouns
   then choose the highest ranked pronominal candidate in the *Ilist*
   and call it y
   go to 5

5. if x is a weak pronoun
   then return y and Y, the list of the remaining candidate antecedents,
   else return z, the highest ranked antecedent in the *Ilist* which was
   not marked as the preferred one in the preceding step (3 or 4)
   and Y, the list of the remaining candidate antecedents

The ResolveDD function distinguishes between types of pronoun in a more fine-grained way than the corresponding function in the es99-algorithm. If the pronoun is weak, the preferred antecedent is looked for among the elements indicated in the context ranking in 11.4 in the given order, as in the ES99-algorithm. If the pronoun *det* is **danI* in contexts 5-8 (i.e. it is the object of the verb *gøre* (do), modals, *have* (have) or the subject predicate in copula constructions) it is resolved to the VP of the element in the *A-list* or in the context given in 11.4, otherwise it is resolved to the element in the *A-list* or in the context given in 11.4. The resolved pronoun is put on the front of the *Alist* and the function returns.

If the pronoun is *dette* the function proposes as preferred antecedent the rightmost subclause in the preceding utterance or synchronising unit and puts it on the front of the *Alist*. If there is no such clause, the function returns and the pronoun is classified as *vague*.

If the pronoun is *det her/det der* or if x is preceded by the quantifier *alt* (all) the pronoun is similarly classified as *vague*. The pronouns are classified as vague, because they probably refer to a larger discourse portion and cannot be resolved correctly by the algorithm. Differing from the es99-algorithm, the dar-algorithm always indicates that there might be an ambiguity bound to discourse deictics, so that commonsense knowledge can be applied by the system. ResolveDD is given in the following:

```
case x preceded by alt
                x is vague; return
    x = det her/der
                x is vague; return
    x = det
                foreach element of context ranking in figure 11.4 do
                        if x occurs in contexts 5-8
                          then if (coindex x with VP of element)
                                 then add VP to A-list;
                                      return true
                          else  if (coindex x with element)
                                 then add element to A-list;
                                 return true
    x = dette
                if there are more clauses in U_{n-1} or in SU_{m-1}
                  then  return the preceding clause
                  else  return
```

The ResolveDet procedure is the following:

```
case x is *danA
        if ResolveInd-det(x)
          then exit
          else  x is generic − inferable
                exit
    x is *danI
        if ResolveDD(x)
          then exit
          else  x is vague − deictic
                exit
    x is not (*danA or *danI)
        if x is weak
          then if ResolveInd-det(x)
                 then mark ambiguity
                 else  if ResolveDD(x)
                         then mark ambiguity
                         else  x is generic − inferable − vague pronoun
          exit
          else if DD(x)
```

then mark ambiguity
else if $\text{ResolveInD}(x)$
then mark ambiguity
else x is $vague - deictic$
exit

11.5 Some Examples

In this section I illustrate how the algorithm works on some examples. In the analysis expletives and cataphors are not included. The first example, (9), is an extract from a computer manual.

(9) *Du har svært ved at se musemarkøren på skærmen. Hvordan klarer du det? Ikke mindst hvis du har en passiv-matrix-skærm, kan det være et problem at holde styr på musemarkøren. Og når du prøver at flytte musen hurtigt frem og tilbage for at se om musemarkøren dukker op, så vil du kun se noget flimmer. Det skyldes skærmens langsomme opdateringsfrekvens; musemarkøren flytter sig hurtigere, end skærmen kan opdateres. Kører du windows, findes der en løsning, der hedder musespor. Det er ikke sikkert, du bryder dig om den, men hvis du bruger den, bliver det lidt lettere at finde musemarkøren...*
(lit. You have difficulties in seing the mouse-cursor (common-gender) on the screen (common-gender). How do you manage this (neuter gender)?
Not least if you have a passiv-matrix-screen (common gender), can it (neuter gender) be a problem (neuter gender) to control the mouse-cursor (common gender). And when you try to move the mouse (common gender) quickly forward and backward to see whether the mouse-cursor (common-gender) appears, then will you only see some flicker (neuter gender). It is due to the screen's (common gender) slow update-frequency (common gender); the mouse-cursor (common gender) moves quicker than the screen (common gender) can be updated. Run you windows, is there a solution (common gender) called mouse-tracks. It (neuter gender) is not sure, you like it (common gender), but if you use it (common gender) becomes it (neuter gender) a little easier to find the mouse-cursor (common gender)....)
(You have difficulties seing the mouse-cursor on the screen. How do you manage this?
Especially if you have a passiv-matrix-screen, it can be a problem to control the mouse-cursor. And when you try to move the mouse quickly forward and backward to see whether the mouse-cursor appears, you only see some flicker. That is due to the screen's slow update-frequency; the

mouse-cursor moves quicker than the screen can be updated. If you run windows, there is a solution called mouse-tracks. It is not sure that you like it, but if you use it, it is a little bit easier to find the mouse-cursor.. . .) (EDB)

When the discourse segment in example (9) starts, both the *Ilist* and the *Alist* are empty. The first utterance U_1 *Du har svært ved at se musemarkøren på skærmen* (You have difficulties seing the mouse-cursor on the screen) does not contain pronominal anaphors. After U_1 has been processed, the *Ilist* contains the two nominals *musemarkøren* and *skærmen* in the given order, while the *Alist* is empty as shown in figure 11.8.[9] In the figure for simplicity the elements in the *Ilist* are shown as they occur in discourse, and not as represented in figure 11.5.

U_1: Du har svært ved at se musemarkøren på skærmen.
Ilist: [musemarkøren, skærmen]
Alist:[]

Figure 11.8: Attentional state after utterance U_1 has been processed

In the second utterance, U_2, *Hvordan klarer du det?* (How do you manage it?), a singular neuter gender pronoun *det* (it) is encountered, thus the function RESOLVEDET is applied. The context in which the pronoun occurs is ambiguous with respect to its reference to an individual or an abstract nominal (it is neither **danA* nor **danI*). The pronoun *det* is weak, then the algorithm attempts to find an individual antecedent applying the function RESOLVE-IND-DET. The function fails because all the elements in the *Ilist* of the preceding utterance U_1 are excluded as antecedents when agreement constraints are applied. At this point the function RESOLVEDD is applied. The preceding clause, U_1, is proposed as antecedent and *det* is inserted into the *Alist*. The simplified attentional state after U_2 has been processed is illustrated in 11.9.

U_2: Hvordan klarer du det?
Ilist:[]
Alist:[det=U_1]

Figure 11.9: Attentional state after utterance U_2 has been processed

The third and fourth utterances, U_3 and U_4, do not contain any pronominal anaphor. The attentional state after each utterance has been processed is given in figures 11.10 and 11.11, respectively. The entities in the main clause, which

[9] I have considered the pronoun *du* (you) as a deictic referring to the addressee. It could also be interpreted as a generic pronoun in which case it should be included in the *Ilist*.

follow textually the entities in the subordinate clauses, precede these in the *Ilist* for the whole utterance.

U_3: Ikke mindst hvis du har en passiv-matrix-skærm, kan det være et problem at holde styr på musemarkøren. *Ilist*:[et problem, musemarkøren, en passiv-matrix-skærm,] *Alist*:[]

Figure 11.10: Attentional state after utterance U_3 has been processed

U_4: og når du prøver at flytte musen hurtigt frem og tilbage for at se om musemarkøren dukker op, så vil du kun se noget flimmer. *Ilist*: [flimmer, musen, musemarkøren] *Alist*:[]

Figure 11.11: Attentional state after utterance U_4 has been processed

Utterance U_5 contains the pronoun *det* (it), which is **danI*, thus the pronoun is interpreted as discourse deictic referring to the preceding utterance, U_4. The predicate x *skyldes* (x is because) can subcategorise for both an individual and an abstract subject. However, I have classified it as a **danI* predicate because in this context the pronoun *det* in most cases referred to an abstract object in the analysed data. The algorithm chooses the discourse deictic interpretation, but indicates that the pronoun is ambiguous.[10]

The attentional state after utterance U_5 has been processed is shown in 11.12.

U_5: Det skyldes skærmens langsomme opdateringsfrekvens; *Ilist*: [skærmens opdateringsfrekvens, skærmen] *Alist*:[det=[du vil kun se noget flimmer]]

Figure 11.12: Attentional state after utterance U_5 has been processed

Utterances U_6 and U_7 do not contain any pronoun. The *Ilist* and *Alist* for utterance U_6 are given in 11.13.

The attentional state after U_7 has been processed is illustrated in figure 11.14. The most salient entity in U_7 is the focus proper *en løsning, der hedder musespor* (a solution called mousetracks).

In utterance U_8 there are two occurrences of the pronoun *den* (it (common-gender)). The only possible antecedent in the *Ilist* for U_7 is the existential *en*

[10]In U_5 the antecedent of the pronoun could be the preceding nominal *noget flimmer* (some flicker).

U_6:musemarkøren flytter sig hurtigere, end skærmen kan opdateres
Ilist: [musemarkøren, skærmen]
Alist: []

Figure 11.13: Attentional state after utterance U_6 has been processed

U_7: Kører du windows, findes der en løsning, der hedder musespor.
Ilist: [en løsning der hedder musespor, musespor, windows]
Alist:[]

Figure 11.14: Attentional state after utterance U_7 has been processed

løsning, der hedder musespor which is then returned as antecedent. The attentional state at this point is given in 11.15.

U_8: det er ikke sikkert, du bryder dig om den, men hvis du bruger den, bliver det lidt lettere at finde musemarkøren.
Ilist: [den=en løsning der hedder musespor, musemarkøren]
Alist:[]

Figure 11.15: Attentional state after utterance U_8 has been processed

In the following I illustrate how the DAR-algorithm processes the first four synchronising units of example (3), whose division in **SUs** and **Us** I discussed in section 11.1. These synchronising units are repeated in the following.
SU_0: U_0
Peter Zobel
SU_1: U_1
U_1: (**I**)
Jeudans forsøg på at købe Norden har vakt opsigt,
(Peter Zobel, Jeudan's attempt to buyi Norden has attracted attention,)
SU_2: U_2 U_4[11]
U_2 (**I**) *hvad synes du om måden, de skrider frem på?*
(What do you think of the way in which they proceed?)
SU_3: U_3
U_3 (**I**)(Parenthetical)
Man kan hurtigt få lagt nogle ord i munden
(One can quickly be put some words into the mouth)
SU_4: U_4
U_4 (**A/I**)

[11]The parenthetical U_3 is not included in this SU.

om man synes, det er en fjendtlig overtagelse eller ej, det har jeg ikke rigtig en holdning til.
(whether one thinks that it is a hostile take over or not, I do not really have an opinion on this.)

The *Ilist* and *Alist* after SU_0, *Peter Zobel*, has been processed are empty.

The *Ilist* after SU_1 has been processed contains the four entities *Jeudans forsøg, opsigt, Jeudan* and *Norden* as shown in 11.16.

SU_1:
Jeudans forsøg på at købe Norden har vakt opsigt
(Jeudan's attempt to buy Norden has attracted attention,)
Ilist: [Jeudans forsøg, opsigt, Jeudan, Norden]
Alist:[]

Figure 11.16: Attentional state after SU_1 has been processed

SU_2 contains a pronoun *de* (they) in the relative subclause. There are no possible antecedents of this pronoun in the main clause, thus the intersentential algorithm is applied. After agreement and selectional restrictions are applied there are two candidate antecedents *Jeudan* and *Norden*, both names of companies, which then allow an evoked-inferable pronoun. Thus the plural pronoun refers to people working in one of the two companies. The algorithm proposes the highest ranked antecedent in the *Ilist* as antecedent. This antecedent is *Joudan*. The attentional state after U_2 has been processed is in 11.17.

U_2:
hvad synes du om måden, de skrider frem på?
(What do you think of the way in which they proceed?)
Ilist: [måden, de=(people working at Jourdan)]
Alist:[]

Figure 11.17: Attentional state after U_2 has been processed

The synchronising unit SU_3, *Man kan hurtigt få lagt nogle ord i munden* (One can quickly be put some words into the mouth), is parenthetical and does not contain any pronominal anaphor. SU_3's attentional state is given in 11.18.

The following utterance, U_4: *om man synes, det er en fjendtlig overtagelse eller ej, det har jeg ikke rigtig en holdning til* (whether one thinks that it is a hostile take over or not, I do not really have an opinion on this), is an Acknowlegement/Initiation, i.e. it acknowledges the preceding U_2 and constitutes a new synchronising unit SU_4. SU_4 contains two occurrences of the pronoun *det* (it).

SU_3:
Man kan hurtigt få lagt nogle ord i munden
(One can quickly be put some words into the mouth)
Ilist: [man, ord, munden]
Alist:[]

Figure 11.18: Attentional state after SU_3 has been processed

The first occurrence is classified as **danI* because it is equated with a nominal referring to an abstract entity, *overtagelse* (taking over). The ResolveDD function searches for antecedents in the *Alist* for the preceding U in the discourse tree, which is U_2. The linearly preceding SU_3 is parenthetical and, after being processed, it is removed from "the focus stack", using the terminology in Grosz & Sidner (1986).

The *Alist* for U_2 is empty. The algorithm searches for an antecedent in the preceding clause and, then, in the preceding synchronising unit, SU_1. Only using word and world knowledge, it is possible to understand the relation between *overtagelse* (taking over) and part of the content in SU_1 *Jeudans forsøg på at købe Norden* (Jeudans attempt to buy Norden), i.e. a company buying another is a take over.

The second occurrence of the pronoun *det* (it) in SU_4 is intrasentential. It is a case of pronominal reduplication in fundament position (Thomsen 1998), where the pronoun reduplicates the interrogative clause. Pronominal reduplication occurs also with individual anaphors as illustrated in (10).

(10) *Peter, HAM kan jeg ikke lide*
(Peter, HAM I do not like).

This phenomenon is also known as left dislocation.

The *Ilist* and *Alist* for SU_4 are given in 11.19. In the figure I have called the two occurrences of *det*, *det1* and *det2* respectively.

In the following I give the *Ilist* and *Alist* after the **SUs** in example (4) are processed. These were discussed in section 11.1 and are repeated in the following.
SU_1: U_1 U_2
U_1: **I**
L: *normalt kunne man jo sige at de der scanninger er meget præcise*
(Normally one could say that those scannings are very precise)
U_2: **A**
P: *ja*

SU_4:
om man synes, det1 er en fjendtlig overtagelse eller ej, det2 har jeg ikke rigtig en holdning til
(whether one thinks that it is a hostile take over or not, I do not really have an opinion on this)
Ilist: [en fjendtlig overtagelse, en holdning til det2=[om man synes, det er en fjendtlig overtagelse eller ej]]
Alist:[det2=*om man synes, det er en fjendtlig overtagelse eller ej*, det1=SU_1=*Jeudans forsøg på at købe Norden*]

Figure 11.19: Attentional state after SU_4 has been processed

(yes)
SU_2: U_3 U_4
U_3: **I**
L: *og det, det stoler man jo på*
(and this, on this one surely relies)
U_4: **A**
P: *mmh*
(mmh)
SU_3: U_5
U_5: **I**
L: *men altså jeg har da, været ude for, at det har snydt...*
(but then I have also experienced that this has cheated...)

The *Ilist* and *Alist* after SU_1 has been processed are given in figure 11.20.

SU_1:
normalt kunne man jo sige at de der scanninger er meget præcise
(Normally could one say that those scannings are very precise)
Ilist: [man, de der scanninger]
Alist:[]

Figure 11.20: Attentional state after SU_1 has been processed

The Initiation of SU_2, U_3: *og det, det stoler man jo på* (and this, on this one surely relies), contains the pronoun *det* (it), which is neither **danI* nor **danA*. Thus the DAR-algorithm looks for an individual antecedent in the previous synchronising unit SU_1. Because no individual candidate antecedent is found in the *Ilist* for

SU_1, the algorithm attempts to resolve the pronoun as a discourse deictic.[12] The *Alist* for SU_1 is empty thus the algorithm attempts to find an antecedent in the previous clause U_2. U_2 is an acknowledgement, than the algorithm proposes as antecedent the first rightmost complete utterance in SU_1 *de der scanning er meget præcise* (those scannings are very precise). The resulting attentional state is given in 11.21.

U_3:*og det, det stoler man jo på*
(and this, on this one surely relies)
Ilist: [man]
Alist:[det=[de der scanning er meget præcise]]

Figure 11.21: Attentional state after U_3

The same attentional state is active after U_4, *mmh*, has been processed.

In U_5, *men altså jeg har da, været ude for, at det har snydt...* (but then I have also experienced that this has cheated...)
the pronoun *det* is neither **danA* nor **danI*. No individual antecedent is found, then the algorithm proposes as antecedent the entity in the *Alist* of the preceding synchronising unit. The *Ilist* and *Alist* after SU_3 has been processed are given in figure 11.22.

SU_3: *men altså jeg har da, været ude for, at det har snydt...*
(but then I have also experienced that this has cheated...)
Ilist: []
Alist:[det=[de der scanning er meget præcise]]

Figure 11.22: Attentional state after SU_3

In the following I present how the DAR-algorithm deals with different preference types using short examples.

The two utterances in example (11) are parallel.

(11) *En mand i Store Rørbæk ser den eftersøgte gå rundt i sin have. Han siger til ham: "Du har ikke noget at gøre her"...*
(A man i Store Rørbæk sees the fugitive walk around in his garden. He tells him: "You have nothing to do here"...)
(BERLINGSKE)

[12]If the strategy of considering the front-positioned object personal pronoun a demonstrative is followed as proposed in chapter 8, the algortihm first attempts to resolve *det* as discourse deictic.

After the first utterance, U_1, has been processed the attentional state is as shown in figure 11.23.[13]

U_1:*En mand i Store Rørbæk ser den eftersøgte gå rundt i sin have.*
(A man i Store Rørbæk sees the fugitive walk around in his garden.)
Ilist: [en mand i Store Rørbæk, den eftersøgte, manden's have]
Alist:[]

Figure 11.23: Attentional state after U_1

Utterance U_1 and U_2 are parallel, thus the algorithm returns as preferred antecedent to the subject pronoun *han* (he), the subject candidate antecedent *en mand i Store Rørbæk* (a man in Store Rørbæk).

Strube's algorithm in this case assigns the wrong antecedent to the pronoun, because the indefinite nominal is ranked lower than the definite *den eftersøgte* (the fugitive).

The attentional state after U_2 has been processed is illustrated in 11.24.

U_2: *Han siger til ham: "Du har ikke noget at gøre her"...*
(He tells him: "You have nothing to do here"...)
Ilist: [han=en mand i Store Rørbæk, ham=den eftersøgte]
Alist:[]

Figure 11.24: Attentional state after U_2

Example (12) contains interclausal anaphors where pronominal chain preference determines the choice of the antecedent.

(12) *Ifølge politiassistenten greb den unge mand ham i halsen, hvorefter han slog ud efter ham i nødværge.*
(lit. According to the police officer grasped the young man him around the neck, after which he hit at him in self-defence.)
(According to the police officer, the young man grasped him around his neck, after which he hit at him in self-defence.)
(BERLINGSKE)

In the first clause in (12), the highest ranked antecedent is the subject *den unge man* (the young man), however the RESOLVEIND function proposes the entity

[13]The reflexive *sin* is syntactically ambiguous in this utterance. I have put the contextually disambiguated interpretation in the *Ilist* where the reflexive corefers with the man in Store Rørbæk.

referred to by a pronoun as antecedent (step 4 in ResolveInd). Thus the pronoun *ham* (him) referring to the police officer is the preferred antecedent. This interpretation is also confirmed by commonsense knowledge, because the man hitting the other did it in self-defence. The police officer's was attacked and had to defend himself, according to his version of what happened.

The **BFP-Kameyama** algorithm and the traditional Centering approach would here propose the correct antecedent, while both Strube's and Fraurud's algorithms would propose *den unge mand* (the young man) as antecedent. In Strube's algorithm, in fact, a definite nominal is ranked higher than an indefinite nominal, while in Fraurud's algorithm the subject is always preferred unless the referring pronoun is demonstrative *denne/dette/disse*.

(13) is an example where focality preference overrides givenness preference.

The pronoun *han* (he) in the second utterance U_2 of example (13) has two candidate antecedents, the subject *dommervagten* (the judge on duty), which is a definite nominal and the object *en 28-årig mand fra Århus* (a 28-year old man from Århus) which is indefinite.

(13) *Dommeren i Hørsholm fængslede i onsdags en 28-årig mand fra Århus. Han sigtes for sammen med en 44-årig, der blev fængslet før påske, at være gået ind på samlingen og uantastet at have taget de to billeder ned fra væggen.*
(The judge on duty in Hørsholm arrested last Wednesday a 28-year old man from Århus. He is charged for, together with a 44-year old man, who was arrested before Easter, having entered the gallery and unchallenged having taken the two pictures from the wall.)
(berlingske)

In (13) the indefinite nominal *en 28-årig mand fra Århus* (a 28-year old man from Århus) is the focus proper, according to the focus proper list proposed in section 10.2 . Focus proper entities are the highest ranked in the *Ilist*. Thus the dar-algorithm proposes *en 28-årig mand fra Århus* as the preferred antecedent of the pronoun *han* (he) in (13). The context in which the pronoun occurs also confirms this interpretation.

In all centering-based algorithms and in Fraurud's algorithm *dommevagten* (the judge in duty) is proposed as antecedent. In the **BFP**-algorithm and in Fraurud's algorithm *dommervagten* (the judge on duty) is chosen because it is the subject of the preceding utterance. In Strube's algorithm *dommevagten* is preferred as antecedent, because a definite nominal is ranked higher than an indefinite nominal, according to Prince's **Familiarity** scale. In the original Centering framework *dommervagten* precedes textually the other candidate antecedent and is also proposed as antecedent of the pronoun *han*.

(14) is an example where focality preference overrides both pronominal chain and givenness preference. This is in line with the preference model proposed in section 10.5.

(14) *Endnu mens Isabella Rossellini var barn, forelskede hendes far sig i en indisk kvinde og fik børn med hende.*
(lit. While Isabella Rossellini was still a child, fell her father in love with an Indian woman and got children with her.)
(While Isabella Rossellini was still a child, her father fell in love with an Indian woman and had children with her.)
(**berlingske**)

In (14) the pronoun *hende* (her) has two candidate antecedents: the genitive pronoun *hendes* (hers) referring to *Isabella Rossellini* and the indefinite propositional object *en indisk kvinde* (an Indian woman). The latter is considered focus proper and is ranked highest in the *Ilist* according to focal preference. Focality preference overrides pronominal chain preference which is implemented in step 4 of the function ResolveInd.

Both Strube's and the original Centering approach propose *hendes* (hers) as antecedent to *hende* (her). The **BFP**-algorithm does not account for genitive phrases in the salience ordering of entities, but the pronominal chain preference rule would indicate *hendes* (hers) as the preferred antecedent. Fraurud's algorithm, on the contrary, correctly proposes *an indisk kvinde* as antecedent. This nominal is chosen because it is the most recent antecedent and the competing candidate *hendes* is not the subject of the sentence.

In the last example, (15), I illustrate how the DAR-algorithm deals with demonstrative anaphors.

(15) *...Efter at have gennemgået Det Kongelige Teaters elevskole debuterede han* (= Bjørn Watt-Boolsen) *i Knud Sønderbys "En kvinde er overflødig" 1943, hvor han med succes erstattede Mogens Wieth under dennes sygdom.*
(lit. ...After having gone through The Royal Theatre's drama school he (= Bjørn Watt-Boolsen) made his début in Knud Sønderby's "A woman is superfluous" 1943, where he with success substituted Mogens Wieth under this' sickness.)
(...After having gone through The Royal Theatre's drama school he (= Bjørn Watt-Boolsen) made his début in Knud Sønderby's "A woman is superfluous" 1943, where he with success substituted Mogens Wieth under his sickness.)
(BERLINGSKE)

In (15) the pronoun *dennes* (this') has two possible antecedents the pronoun *han* (he) which corefers with the preceding *han* referring to Bjørn Watt-Boolsen and the object *Mogens Wieth*. The former antecedent is ranked highest in the *Ilist* because it is the subject. However because *dennes* (this') is a demonstrative the less ranked candidate antecedent, *Mogens Wieth* is proposed as antecedent (step 5 in RESOLVEIND). The only algorithm which also proposes *Mogens Wieth* as antecedent is that developed by Fraurud.

Applied to the survey examples in chapter 10, the DAR-algorithm chooses as preferred antecedents the same antecedents which are preferred by the majority of the informants and indicates that the reference is ambiguous in 16 out of 18 examples. The cases in which the algorithm fails in correctly resolve the pronoun, involve the generic *det*. The two problematic examples, called D an E in section 10.3, are repeated in (16).

(16) a. På fadet stod der en kop og en tallerken. **Det** tog Maria og satte hen i vinduet.
(On the tray a dish and a cup were. **It** Maria took and put in the windowsill.)

b. *Der stod en kop og en tallerken på fadet.* ***Det*** *tog Maria og satte hen i vinduet.*
(There were a dish and a cup on the tray. **It** Maria took and put in the windowsill.)

In both examples the focus proper *en kop og en tallerken* (a cup and a dish) is excluded from the *Ilist* because it does not agree in number with the pronoun. Because there is a neuter singular nominal in the same utterance, *fadet* (the tray), this is chosen as antecedent and the ambiguity is not discovered. The problem, as noticed in section 10.1, is that the pronoun *det* (it) can refer to all types of entities. Whether it is possible to individuate more precisly cases where the generic *det* occurs is still an open question.

11.6 Summary

In this chapter I have described the DAR-algorithm for recognising and resolving individual and abstract anaphors in written texts and dialogues. The algorithm draws on different approaches and algorithms, i.a. (Grosz et al. 1995, Kameyama 1996, Eckert & Strube 1999*a*, Ariel 1994, Webber 1991, Walker 1996, Hajičová et al. 1990).

The DAR-algorithm presupposes two different discourse structures for resolving anaphors in texts and dialogues. Both structures were described in section 11.1.

The main characteristic of the structure of dialogues is that utterances occur in adjacency pairs, here called synchronising units. An utterance in dialogues most be acknowledged to be added to the discourse context. This is in line with the *Grounding* theory (Traum 1994) and allows i.a. to account for unfinished utterances.

The immediate search space for intersentential anaphora in written texts is the utterance preceding the anaphor, while in dialogues it may be the preceding utterance or the preceding synchronising unit, depending on the type of utterance in which the pronoun occurs. Examples of the structure of different types of discourse were also discussed in this section.

The main data structures which the algorithm operates on and which represent the current Attentional state were then presented in section 11.2. An input and an output attentional state are distinguished. The input attentional state is ranked according to part of Ariel's **Accessibility Marking Scale** of referring expressions. The DAR-algorithm uses the rankings of types of pronoun to account for differences in reference between the various pronominal types in Danish. The output attentional state consists of two data structures. The first data structure is called the *Ilist* and contains the individual entities in the utterance preceding the pronoun. These entities are ranked according to givenness and focality preference. Givenness preference corresponds to the order of verbal complements as proposed by i.a. Brennan et al. (1987). The second data structure, called the *Alist*, contains abstract entities referred to by a discourse deictic in the preceding utterance in texts and in the preceding synchronising unit in dialogues. Individual and abstract anaphors are discriminated on the basis of a number of predicates, called **danA*- and **danI*-predicates described in section 11.3. The predicates have been identified analysing Danish data and looking at the encodings of the PAROLE lexicon.

In section 11.4 the DAR-algorithm was given and its different functions were described. The algorithm's main structure discriminates between anaphors which refer to abstract objects, anaphors which refer to individuals and anaphors which can refer to both, following the strategy by Eckert & Strube (1999*a*). Individual resolution is based on the preference model which I proposed in section 10.5. If there are more candidate antecedents the DAR-algorithm proposes a preferred antecedent in unmarked contexts on the basis of this preference model. The proposed antecedent is chosen if the pronoun is weak. If the pronoun is strong the highest ranked antecedent in the *Ilist* among the remaining candidate antecedents is chosen, instead. In both cases the algorithm indicates the ambiguity so that commonsense preference and conventional presuppositions can confirm or reject the proposed interpretation.

The discourse deictic resolution algorithm looks at the different types of discourse deictic and, on the basis of these types, resolves or classifies the pronoun as vague deictic. The discourse deictic typology used by the DAR-algorithm is more fine-grained than that used in the ES99-algorithm. It accounts for the differences in reference between weak and strong pronouns and between different strong pronouns in Danish. In section 11.5 I illustrated how the algorithm works on examples containing different pronominal types and involving various preference types.

In the following chapter tests of the DAR-algorithm on written texts and dialogues are described and their results are evaluated.

Chapter 12

Test and Evaluation

In the present chapter I describe how I have tested the DAR-algorithm on the texts and dialogues which were used in the tests presented in chapter 8. The DAR-algorithm classifies and partially resolves both individual and abstract anaphors in written texts and in dialogues, thus it differs from the algorithms which were tested in that chapter. Strube's and Fraurud's algorithms and the **BFP-Kameyama** algorithm only resolve individual anaphors and have been tested on written texts. The ES99-algorithm deals with individual and abstract pronominal anaphors, but it was developed for dialogues, more precisely for specific English telephone conversations. I have tested this adapted version of the ES99-algorithm on face-to-face Danish dialogues. Therefore it is not possible just to compare the performance of the DAR-algorithm with that of these algorithms.

To make some comparisons, however, I have tested both different parts of and the whole DAR-algorithm on the written texts and dialogues used for testing other algorithms.

First I have only applied the individual resolution part of the algorithm on written texts and dialogues. Expletives, cataphors and discourse deictics are excluded from these *partial* tests.

I compare the results of the partial test on written texts with the results obtained testing other individual algorithms on the same data.

Then I have applied the whole DAR-algorithm on both texts and dialogues. Only expletives and cataphors are excluded from these tests. The results of the test on dialogues are then compared with the results obtained testing the adapted ES99-algorithm on the same data.

The chapter is organised as follows. In section 12.1 I describe the partial tests of the DAR-algorithm. I evaluate the obtained results and compare them with the performance of other individual resolution algorithms. Section 12.2 contains a description of the complete tests of the algorithm and an evaluation of the obtained results.

In section 12.3 I discuss similarities and differences between the DAR-algorithm and the many approaches it is built on. Finally in section 12.4 I make some concluding remarks.

12.1 Partial Tests of the DAR-algorithm

In this section I describe and evaluate the tests of the individual resolution strategy of the DAR-algorithm on written texts and dialogues. The written texts and dialogues were presented in section 8.1. In all tests I have followed Kameyama's strategy of first applying the algorithm interclausally, then intersententially. However, the errors from the interclausal and intersentential application of the algorithm are not distinguished.

The individual resolution part of the DAR-algorithm consists of the two functions RESOLVEIND-DET and RESOLVEIND, the former resolving singular neuter pronouns, the latter all other pronouns. Thus in the partial tests I maintain different search domains for neuter singular pronouns and all other pronouns. If the algorithm does not find a pronominal antecedent the pronouns are classified as generic-inferables. The results obtained by applying the function RESOLVEIND and RESOLVEIND-DET to written texts are given in table 12.1. The table is organised as follows. The first row indicates the type of text, the second row contains the number of correctly resolved pronouns, the third row gives the number of pronouns that the algorithm resolved, the fourth row gives the number of pronouns which should be resolved according to human resolution. The fifth row indicates the obtained precision while the sixth row shows the recall value. Because the algorithm is supposed to recognise, but not resolve antecedentless plural pronouns and generic uses of the pronoun *det* (it), the number of pronouns to be resolved, according to human disambiguation, and the number of pronouns resolved by the algorithm are not the same. The figures for both precision and

	manual	newsp	novel	$\sum$
no. correctly resolved	75	86	414	575
no. resolved overall	79	86	486	651
no. resolved by human	79	88	478	645
precision	0.949	1	0.852	0.883
recall	0.949	0.977	0.866	0.891

Table 12.1: Results of the partial test on written texts

recall (88.3% and 89.1% respectively) indicate that the individual resolution and recognition part of the DAR-algorithm performs quite well, given the type of algorithm.

All generic pronouns are recognised correctly in this test, but in one case an occurrence of *det* (it) with a distant antecedent has been classified as a generic pronoun.

The algorithm fails in many cases to recognise antecedentless and inferable plural pronouns, because it finds a plural nominal in the preceding discourse and proposes it as an antecedent.

Most of the resolution errors are due to the fact that the algorithm chooses a wrong antecedent because it does not rely on commonsense knowledge and on the interpretation of the context. These errors include plural pronouns with complex antecedents and pronouns with more candidate antecedents. However, the algorithm indicates the possible ambiguity so that commonsense knowledge preferences and conventional presuppositions can be applied to confirm or reject the proposed solution.

The resolution of pronouns in direct reported speech in the novel poses problems. A number of errors were chain errors.

The best performance among other algorithms for resolving individual anaphors on the same texts was obtained by Strube's algorithm which correctly resolved 82.59% of the anaphors, as described in section 8.2.

The better performance of the individual DAR-algorithm is partly due to the fact that most occurrences of the generic *det* and some antecedentless plural pronouns are recognised and excluded from resolution. A second reason is that the "individual" DAR-algorithm accounts for more preference types than the other algorithms I tested in chapter 8.

The results of the partial test on dialogues are given in table 12.2 which is organised as table 12.1.

	SL1	SL2	SL3	SL4	SL5	TR	BS	$\sum$
no. correctly resolved	19	30	15	66	11	81	74	296
no. resolved overall	23	31	21	77	16	120	93	381
no. resolved by human	23	35	20	74	16	121	95	384
precision	0.826	0.968	0.714	0.857	0.688	0.675	0.796	0.777
recall	0.826	0.857	0.75	0.892	0.688	0.669	0.779	0.771

Table 12.2: Results of the partial test on dialogues

Both the recall and the precision of the individual resolution on dialogues are worse than those obtained on written texts. This is not surprising given the nature of dialogues. Dialogues are less structured than texts and their interpretation relies even more on contextual knowledge than the interpretation of written texts. Furthermore in the current dialogues the number of pronouns with distant antecedents, antecedentless plural pronouns and generic pronouns is higher than in the written texts.

The recognition and resolution error types in this partial test are of the same types as in the preceding test on written language.

12.2 Complete Tests of the DAR-algorithm

In this section the tests of the whole DAR-algorithm on written texts and dialogues are described and their results are evaluated.

Testing the algorithm on dialogues I adapted the same strategy as in the test of the ES99-algorithm described in section 8.3, i.e. I marked occurrences of the non-subject *det* (it) as demonstrative pronouns when they occurred in first position in main clauses in contexts not covered by the ***danI** and ***danA** predicates. Testing the written texts, instead, I always treated the pronoun *det* as a personal pronoun, because in written language the demonstrative deictic *dette* (this) is used.

The results obtained applying the algorithm on written texts are shown in the two tables 12.3 and 12.4 which contain the results for individual anaphors and discourse deictics respectively.

	manual	newsp	novel	$\sum$
no. correctly resolved	74	82	404	560
no. pronouns resolved	80	90	481	651
no. resolved by human	79	88	478	645
precision	0.925	0.911	0.84	0.86
recall	0.937	0.932	0.845	0.868

Table 12.3: Results of the individual DAR-algorithm on written texts

The results of the test are quite positive, compared with the precision and the recall of the individual part of the algorithm which were given in table 12.1.

The ***danI** and ***danA** predicates identify correctly abstract and individual anaphors in the majority of the cases. Recognition failures nearly always involve the pronoun *det* in contexts which are not described by the ***danI** and ***danA** predicates. In these cases the pronoun is recognised and resolved as an individual pronoun because the algorithm finds a singular neuter nominal in the

	manual	newsp	novel	$\sum$
no. recognised correctly	20	12	31	63
no. resolved	25	19	43	87
no. resolved by human	26	17	34	77
precision	0.8	0.632	0.721	0.724
recall	0.769	0.706	0.912	0.818

Table 12.4: Results of the abstract DAR-algorithm on written texts

preceding utterance and proposes it as an antecedent. The DAR-algorithm, however, indicates the ambiguity. This kind of failure is illustrated with example (1) from the computer manual.

(1) *Ændrer du skriftstørrelsen, så ændrer du selve dokumentet. Det kan du se, når du udskriver det.*
(lit. Change you the font size (common gender), then change you the actual document (neuter gender). It/this/that can you see, when you print it)
(If you change the font size, then you change the actual document. This can be seen, when printed.)
(EDB)

In the second utterance of (1) there are two occurrences of the pronoun *det* (it). The first occurrence is a discourse deictic referring to the preceding utterance, the second occurrence is an individual pronoun coreferring with *selve documentet* (the actual document). The algorithm resolves both pronouns as individual pronouns, i.e. *selve dokumentet* (the actual document) is proposed as antecedent for the first *det*, while the second *det* corefers with it. Thus both pronouns are resolved incorrectly.

Considering the non subject *det* in the front position as a demonstrative as I have done for dialogues would correctly resolve the discourse deictic in (1). However, before extending this strategy to written texts, it is necessary to investigate whether the majority of the occurrences of *det* in the front position in contexts which are neither ***danI** nor ***danA** actually refer to an abstract object.

In this test the algorithm also classified generic pronouns as discourse deictics. The remaining types of individual classification and resolution error are similar to those for the partial test on texts. The precision for this partial test was 88.33% and the recall was 89.15%. In the test of the whole algorithm the precision is 86.02% and the recall 86.82%. These results are promising because in the test of the whole DAR-algorithm both individual anaphors and discourse deictics are dealt with, thus the number of pronouns to be recognised and/or resolved is much higher than in the partial test.

The precision for discourse deictic resolution is 72.41% while recall is 81.81%. As noticed above the algorithm in most cases correctly recognises individual and abstract anaphors, but the algorithm often proposes a wrong discourse segment as the antecedent of the discourse deictic *det* (it).

The fact that the DAR-algorithm cannot always identify the correct antecedents of discourse deictics is not surprising, because their resolution often requires a deep analysis of the context.

Much more research should be done on discourse deixis. As it was the case for the ES99-algorithm also the DAR-algorithm fails to recognise vague anaphors in many cases. Instead it classifies them as discourse deictics and proposes a preceding discourse segment as antecedent.

In the last test I have applied the DAR-algorithm on dialogues. Tables 12.5 and 12.6 show the results for the individual and the discourse deictic resolution, respectively.

	SL1	SL2	SL3	SL4	SL5	TR	BS	$\sum$
no. correctly resolved	19	30	14	64	11	78	73	289
no. resolved overall	25	31	19	79	16	124	92	386
no. resolved by human	23	35	20	74	16	121	95	384
precision	0.76	0.968	0.737	0.81	0.688	0.629	0.793	0.749
recall	0.826	0.857	0.7	0.865	0.688	0.645	0.768	0.753

Table 12.5: Results of the individual DAR-algorithm on dialogues

	SL1	SL2	SL3	SL4	SL5	TR	BS	$\sum$
correctly resolved	29	18	21	12	23	50	41	194
no. resolved overall	39	23	24	16	30	79	66	277
human resolution	35	22	27	17	25	82	61	269
Precision resol.	0.744	0.783	0.875	0.75	0.767	0.633	0.621	0.7
Recall resol.	0.829	0.818	0.778	0.706	0.92	0.61	0.672	0.721

Table 12.6: Results of the abstract DAR-algorithm on dialogues

The precision and recall obtained for individual anaphors are 74.87% and 72.11% respectively. The comparison of these results with the 77.69% precision and

77.08% recall obtained in the test of the individual resolution part of the algorithm on the domain of individual anaphors indicates that the discrimination of individual and abstract anaphors of the DAR-algorithm also works quite well on dialogues.

The classification and resolution errors in the present test are of the same types as those described for the test of the DAR-algorithm on written texts. Singular neuter pronouns with antecedents preceding them more than an utterance were more frequent in the dialogues than in the texts. They are all classified and resolved as abstract anaphors. It should be noted that the algorithm performed worst on one dialogue from the PID collection. In this dialogue there were few occurrences of the pronoun *det* (it) used as generic pronoun which the algorithm classified as discourse deictics.[1] This resulted in a high number of chain errors and indicates one of the limits of the DAR-algorithm.

As the *es99*-algorithm, also the *dar*-algorithm did always propose an antecedent to the pronoun *det*, in constructions such as *det er godt* (it is good) *det er fint* (it is fine), *det var ikke godt* (it was not good). In some cases, however, I marked them as vague, because they seem to be simple acknowledgements (positive or negative) of the preceding context and, thus, should not be resolved. More work should be done in dialogues ro identify when these constructions can be considered as simple acknowledgements and when they cannot.

The results obtained testing the adapted ES99-algorithm on the same dialogues were the following: for individual anaphors precision 62.8% and recall 62.3%; for discourse deictics precision 62.6% and recall 66.5% (section 8.3) .

Thus the DAR-algorithm performs much better than the ES99-algorithm on the same dialogues. The improvements are mainly due to the following factors. The DAR-algorithm uses much more discriminating predicates than the ES99-algorithm. It relies on more lexical knowledge and it recognises and excludes more types of "problematic" anaphor from resolution. The strategy of the DAR-algorithm correctly resolves more types of individual anaphora. Finally the DAR-algorithm uses an unrestricted antecedent domain for all pronouns which are not neuter and singular.

The DAR-algorithm inherits the restricted antecedent domain for singular neuter pronouns from the ES99-algorithm. This restriction allows for the classification of contexts which are not covered by the ***danI** and ***danA**-predicates, but it also impedes the correct resolution of pronouns whose antecedents do not occur in the same utterance or in the preceding synchronising unit. The classification of generic pronouns does not work well combined with the classification of discourse deictics.

[1] In the dialogues a number of occurrences of generic det (it) could be due to transcription errors. Whether this is the case should be investigated further.

The classification part of the algorithm can still be improved if more discriminating contexts and more lexical knowledge resources are used. However, an algorithm as DAR which does not rely on the analysis of the coherence relations holding between discourse units and on the context in general cannot resolve complex types of anaphor. Thus the algorithm must be supplied with a module applying commonsense preferences and conventional presuppositions based on word and world knowledge and on the identification of other coherence-mechanisms, such as the relations holding between discourse segments.

Interesting is the fact that the DAR-algorithm works satisfactorily on both texts and dialogues, although it performs much better on the first type of discourse.

12.3 Comparison with Other Approaches

As noticed in the preceding sections the DAR-algorithm strongly relies on various approaches and theories. In the following I shortly discuss the similarities and the differences between my algorithm and the many approaches it draws on.

Hobbs (1978) showed that the resolution of many pronominal anaphors can be accounted for in simple algorithms, because the use of these anaphors can be accounted for by general models described in various linguistic and pragmatic studies. Some anaphors, however, can only be resolved interpreting the preceding and current discourse context on the basis of both word and world knowledge (Hobbs 1983).

The DAR-algorithm resolves only the first type of anaphor correctly, but it accounts for more anaphoric uses than most algorithms of its type. Furthermore, in cases of ambiguities, these are indicated by the DAR-algorithm so commonsense preferences and conventional presuppositions can be applied to, possibly, resolve the ambiguity. This stepwise strategy differs from Hobbs' combined interpretation strategy and is taken from Kameyama (1996).

The interpretation of discourse, and thus of anaphors, strongly relies on the individuation of the coherence relations holding between discourse segments, i.a. (Hobbs 1979, Asher 1993, Kehler 1997). The individuation of the hierarchical structure of discourse is also important to define the search space of anaphoric antecedents (Grosz & Sidner 1986, Webber 1991). The DAR-algorithm relies on the hierarchical discourse model proposed in (Grosz & Sidner 1986, Webber 1991).

Written and spoken language have different macrostructures.[2] The relation between the use of anaphors and the different structures of texts and dialogues is

[2]Written texts and dialogues are different in many respects. I have only accounted for some of these differences in the thesis. Furthermore I have only considered two-party dialogues and I have not looked at phenomena such as overlapping speech and multimodality.

studied by Fox (1987). To account for these differences the DAR-algorithm presupposes two macrostructures for texts and dialogues. The macrostructure assumed for texts is mainly that described by (Grosz & Sidner 1986). The macrostructure assumed for dialogues is that proposed by Eckert & Strube (1999*a*) who are inspired by the work of i.a. (Carletta et al. 1997, Traum 1994).

Differing from both Grosz and Sidner and Eckert and Strube the coherence relations of the type described by (Hobbs 1979, Mann & Thompson 1987) are also assumed to hold between discourse and their identification is considered indispensable for resolving some types of anaphor. The structure defined by coherence relations and the macrostructure of discourse are respectively related, but in the thesis I have only specified the latter.

The Centering theory follows Grosz and Sidner's discourse model and accounts for the resolution of local reference, i.e. reference between entities in the same discourse segment (Grosz et al. 1995). The DAR-algorithm is based on the Centering Theory's basic assumption that some entities at some point of discourse are more central (salient) than others and that people tend to speak about these entities for a while. Since local reference in Danish data cannot always be accounted for by the entities in the same utterance or in the utterance preceding the anaphors - as assumed by Centering - the DAR-algorithm follows the Walker's proposal of extending centering to global resolution (Walker 1998). In the DAR-algorithm the extended antecedent domain only involves pronouns that cannot be discourse deictics.

Strube's centering algorithm deals with both intrasentential and intersentential English anaphors. In the DAR-algorithm I only account for intersentential and interclausal anaphors following the strategy of extending centering to the resolution of interclausal anaphors proposed by Kameyama (1998*a*).

Centering-based algorithms implement salience (centrality) of entities in discourse by pragmatic models describing the relation between referring expressions and the "givenness" of the entities they refer to, i.a. (Prince 1992, Ariel 1988, Givón 1979). High degree of "givenness" corresponds to high degree of salience. I call the ordering of entities according to the definition of salience in Centering *givenness preference*.

Differing from Centering-based approaches, however, I integrate the givenness preference with a so-called *focality preference* where I operationalise the Prague School's assumption that entities in the focal part of the IS of an utterance have the highest degree of salience (Sgall et al. 1986, Hajičová et al. 1990). These entities often correspond to "new" information in the hearer model, but they may also be "given". This is in line with the definition of information structure in i.a. (Vallduví & Engdahl 1995).

Focality preference states that focal entities in predefined cases are more salient than "given" entities. These cases were tentatively listed on the basis of the analysed data and of IS studies of especially Danish, i.a. (Paggio 1997). In the DAR-algorithm "given" entities are by default very salient, but because speakers explicitly can change the default salience degree of entities by IS-related mechanisms, givenness preference is overruled by focality preference.

The majority of resolution algorithms only looks at the type of the antecedent. The DAR-algorithm also takes into account the type of pronominal anaphor, because this influences the choice of antecedents. Also differences between prosodic marked and unmarked pronouns are considered, although I did not work with corpora containing prosodic information. The DAR-algorithm further developes approaches originally proposed in i.a. (Ariel 1988, Fraurud 1992, Kameyama 1998*b*).

Finally, I have proposed a model of the interaction of focality and givenness preferences with other preference and constraint types influencing resolution. These comprise parallelism preference, commonsense preference, pronominal chain preference, subject antecedent preference, agreement constraints and selectional restrictions. The DAR-algorithm implements all except commonsense preference. This must be applied on the ambiguous antecedent cases which are always indicated by the algorithm. The DAR-algorithm is inspired by Kameyama's work, although she does not consider focality preferences in her proposal.

A difference between the DAR and other algorithms is that the former deals with individual and abstract anaphors on both texts and dialogues. The only algorithm which treats individual and abstract anaphors on a specific collection of telephone conversations is the ES99-algorithm developed by (Eckert & Strube 1999*b*, Eckert & Strube 1999*a*). However, Sidner (1983) also treats specific types of abstract anaphor.

The DAR-algorithm inherits the strategy of identifying and partially resolving individual and abstract anaphors from the ES99-algorithm. However, the ES99-algorithm relies on a restricted number of predicates discriminating between individual and abstract anaphors. Instead the DAR-algorithm relies on a larger number of predicates accounting for many cases of individual or abstract pronominal occurrences. Some of these predicates account for constructions specific to Danish, while others are less language-specific.

The DAR-algorithm also uses a different antecedent search space and different resolution strategies than the ES99-algorithm.

The results of the test of the DAR-algorithm and of a number of other algorithms (Strube 1998, Fraurud 1992, Brennan et al. 1987) on individual anaphors indicate that the DAR-algorithm performs better on Danish texts because it accounts for more linguistic aspects which are relevant for anaphora resolution than other centering-based algorithms and than Fraurud's Swedish algorithm. The DAR-algorithm also performs better than the ES99-algorithm on face-to-face dialogues.

However, the DAR-algorithm is more complex than these other algorithms and like all the algorithms I have compared it with, it fails to resolve individual and abstract anaphors whose resolution requires the analysis of the discourse context. This analysis must be supplied by context-based resolution strategies.

Although parts of the algorithm are tailored to Danish pronouns, I believe that many of the aspects it accounts for are also valid for other languages. Especially the integration of different preference types and the generalisation of the ES99's approach for recognising and resolving discourse deictic should be adapted and tested on other languages.

12.4 Conclusion

In section 12.1 I tested and evaluated parts of the DAR-algorithm on both written texts and dialogues. The results obtained by this partial test on texts indicate that the algorithm performs better than other similar algorithms on Danish texts, but as these other algorithms it fails in resolving anaphors whose resolution require the interpretation of context. However, the DAR-algorithm attempts to recognise some of these anaphors and exclude them from resolution.

The results of the partial test on dialogues indicate that the algorithm also performs well on this discourse type, although the results obtained on dialogues are clearly worse than those obtained on written texts. The different nature of the two types of discourse and the fact that inferable anaphors are more common in dialogues than in texts explain the differences in performance.

The tests of the whole DAR-algorithm on both texts and dialogues were then described and evaluated. The results of these tests are promising and indicate that the strategy of identifying discourse deictics and individual anaphors works on both texts and dialogues. The results of the resolution of individual anaphors when the test domain is enlarged to comprise discourse deictics do not differ extraordinarily from the results obtained in the partial tests. This indicates that the discriminating strategy inherited from the ES99-algorithm performs well on both types of discourse.

Because discourse deictics refer to discourse parts their resolution often relies on the identification of coherence relations among discourse units. Therefore discourse deictic resolution performs worse than individual resolution, even though a number of deictics are correctly identified by the algorithm and, consequently, excluded from resolution. Furthermore, because individual anaphor resolution has been extensively studied in the literature, the individual resolution strategy of the DAR-algorithm builds on a higher number of studies than the discourse deictic resolution part.

A few improvements can still be made to the algorithm, such as identifying more discriminating predicates. However, these improvements only affect recognition of "problematic" anaphors and not their resolution.

Finally I discussed the theories and approaches the DAR-algorithm draws on and indicated the main differences between them. I concluded that the DAR-algorithm performs better than other algorithms of its type because it inherits different aspects from the various approaches to account for more preference types influencing anaphora resolution. However, for the same reason, the DAR-algorithm is more complex and relies on more knowledge than other algorithms of its type. The DAR-algorithm has only been tested on Danish data. It should be noted that some parts of the algorithm are tailored to Danish. This is the case for the treatment of demonstrative pronouns. Also the preference interaction model has been built on the basis of the analysis of Danish data. To what extent it is also valid in other languages must be investigated.

Finally the strategy to recognise and resolve both individual and abstract anaphors on both written texts and dialogues is new. It is mainly based on the account of similarities and differences in the two types of discourse and is not language dependent and should be tested on other languages. Because the results obtained in the first tests of the DAR-algorithm are very promising, it would be interesting to test adapted versions of it to other languages.

Chapter 13

Conclusion

The main objectives of this thesis were to investigate the use of intersentential individual and abstract pronominal anaphora in Danish naturally-occurring discourse, to propose a formal model of their use and finally to develop an algorithm for resolving these anaphors.

In the thesis the main uses of individual and abstract anaphors have been described on the basis of their occurrences in a number of corpora and collections of written texts and dialogues and their descriptions in traditional Danish grammars. In the proposed account differences between the referential characteristics of various Danish pronouns have been pointed out. These differences have not been previously described in the literature. Dissimilarities between the use of intersentential pronouns in Danish and English have also been emphasised.

A model accounting for the use and resolution of pronominal anaphors has been proposed and the DAR-algorithm for resolving them in texts and dialogues has been outlined. The DAR-algorithm and other known resolution algorithms have been tested and evaluated on different types of text and dialogue. The results of these tests indicate that the DAR-algorithm performs better than the previously proposed algorithms on these data. The main reason for this better performance is that the DAR-algorithm accounts for more linguistic factors than other comparable algorithms which it, however, also draws on. Some of these factors are language-specific, some are more general. Furthermore the DAR-algorithm is unique in both recognising and resolving individual and abstract anaphors in written texts and dialogues, using different structures for modelling the two types of discourse.

The strategy behind the proposed approach builds on a large number of theoretic and computational approaches from different traditions, comprising cognitive studies, linguistics, psycholinguistics, computational linguistics and artificial intelligence. The factors which are taken into account in the approach involve morphology, syntax, semantics, prosody, cognitive models of the assumed mental state of the hearer, the information structure of utterances, linguistic knowledge, the structure of discourse and the analysis of context. The simplified model of preference interaction which I have proposed takes into consideration all these aspects, but the DAR-algorithm does not implement resolution based on commonsense preference and conventional presuppositions which require a non-monotonic inference mechanism and large amounts of background knowledge. However, the algorithm indicates ambiguous antecedent cases which require the application of commonsense preference so that the proposed interpretation can be confirmed or rejected. In this and other aspects the DAR-algorithm builds on the inspiring work by (Kameyama 1996, Kameyama 1998*a*, Kameyama 1998*b*).

New aspects in the presented approach are also the combined account of the two apparently contrasting theories of salience of entities proposed in (Grosz et al. 1995, Ariel 1988, Givón 1976) and (Sgall et al. 1986) respectively, together with the assumption of different structures of dialogues and written texts. The assumed discourse structure are mainly based on the proposals by (Eckert & Strube 1999*b*, Grosz & Sidner 1986, Walker 1998, Hobbs 1979).

Although the main objectives of the thesis have been fulfilled, there are various aspects which require further treatment and the present research has also indicated a number of unresolved problems.

In the thesis only two-party dialogues have been taken into account. Reference in multi-party dialogues should also be investigated and accounted for.

The analysed dialogues do not contain prosodic information. The assumptions in the thesis about the differences in reference of stressed and unstressed pronouns have mainly been based on theoretical studies and on very few empirical data. They should be tested on a larger amount of data.

Although different types of dialogue have been used in the research, they do not cover the variety of interaction situations in our everyday life. I hope that a large corpus of different Danish conversation types will be collected and made available for research. It would be useful to test and refine the proposed approach on such a corpus.

Reference to abstract objects, including their semantics, require further investigation in both Danish and other languages and the resolution of "complex" anaphoric types which I have assumed to be accounted for "outside" the DAR-algorithm also demands a lot of research.

I have only dealt with anaphoric uses of pronouns. However, from an applied point of view, it would be useful to find strategies for identifying expletives in discourse. These strategies should then be combined with the DAR-algorithm.

Finally the DAR-algorithm has been written for accounting for Danish pronouns.

It would be useful to adapt the algorithm to other languages and then test it and the general assumptions behind it on these languages.

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