Focus and Discourse Representation Theory

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Declaration

I declare that this thesis was composed by myself and that the research reported therein was conducted by myself.

Edinburgh, 13th September 1992

Sophie Cormack
To Annabel Cormack

sine qua non
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Simply to acknowledge is not enough: all these people deserve a permanent pension of chocolate cakes, for which a small helping of words is a pathetically inadequate substitute.

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Thanks, but couldn’t you have made it a bit shorter?

Sophie
The following conventions are used in the text:

Stylistic:

<table>
<thead>
<tr>
<th>Situation</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emphasis</td>
<td>The pronoun is focused.</td>
</tr>
<tr>
<td>Key word (first mention)</td>
<td>The pronoun is FOCUSED.</td>
</tr>
<tr>
<td>Lexical items out of context</td>
<td>The word he is missing.</td>
</tr>
<tr>
<td>Sentences out of context</td>
<td>An alternative continuation would be 'He smiled.'</td>
</tr>
<tr>
<td>Proposal: suggestion as to how a term could be defined (semiformaly)</td>
<td>Proposal (Example): Text here.</td>
</tr>
<tr>
<td>Definition: the final decision on how something is to be defined.</td>
<td>Definition (Example): Text here.</td>
</tr>
<tr>
<td>Problem: points out a possible shortcoming in the theory being discussed.</td>
<td>Problem 1 Text here.</td>
</tr>
</tbody>
</table>

Theory-dependent:

<table>
<thead>
<tr>
<th>Semantic entity (nominal)</th>
<th>Mary, the man in the red hat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real world referent</td>
<td>MARY, TABLE345</td>
</tr>
<tr>
<td>Anaphoric connections in examples</td>
<td>John got three letters. I got two.</td>
</tr>
<tr>
<td>Intonational stress</td>
<td>I LOVE cats.</td>
</tr>
<tr>
<td>Discourse markers</td>
<td>d, D, D</td>
</tr>
<tr>
<td>Semantic relations etc.</td>
<td>ate, p ∈ P, f, NAME</td>
</tr>
<tr>
<td>Variables</td>
<td>α, β, A, Φ, R²</td>
</tr>
<tr>
<td>Ungrammatical</td>
<td>*The men likes butter</td>
</tr>
<tr>
<td>Dubious</td>
<td>?A man who owns it beats a donkey.</td>
</tr>
<tr>
<td>Pragmatically unacceptable/ incoherent</td>
<td># I like cats. John has one of them.</td>
</tr>
</tbody>
</table>

Examples in the text are invented except where otherwise indicated.
Abstract

The thesis puts forward a psychologically plausible and computationally explicit theory of pronoun resolution, concentrating on semantic and focusing effects and their interaction.

Hans Kamp's (1981) Discourse Representation Theory (DRT) was the first of a series of recent formal semantic theories able to describe semantic accessibility conditions on anaphora occurring outside the logical scope of a quantifier. Kamp's original aim was to capture the truth conditions and anaphoric constraints in so-called 'donkey sentences'. DRT also opened up the possibilities of inter-sentential anaphoric connections. Kamp claimed psychological plausibility for DRT. However, in allowing intersentential anaphora DRT permits too many possible anaphoric connections - for instance a discourse containing no triggers for semantic embedding results in a model where every noun phrase is accessible to every anaphor:

(1) I picked up some meringues with the tongs. They were mildly singed but I put them on a plate and gave them to Lisa. They were still very hot. (*tongs)

In text (1), DRT allows the final they to access the tongs, which I claim is psychologically implausible for two reasons. Firstly, because the preferred antecedent for they is the much more salient focused nominal the meringues. Since this choice is also contextually plausible it would block out any less preferred candidates for resolution. Secondly, I argue that the discourse referent for the tongs is in fact no longer available for reference: it has passed from the hearer's memory of the entities being discussed and is only retrievable using a full definite noun phrase.

Discourse focusing can be used to put the necessary constraints on (1), constraining the lifetime of discourse referents and imposing a natural preference ordering on potential antecedents for pronouns. Pronominalisation is used as evidence of focus and a focusing algorithm is constructed based on insights from Sidner (1979; 1981; 1983), Brennan, Friedman and Pollard (1987) and Carter (1987). The newly developed Incremental Focusing algorithm concentrates entirely on focus-maintenance as a strategy for resolving pronouns, and is added to DRT in the form of a partial ordering on discourse referents, where the ordering is determined by the position of the antecedent in the structural hierarchy.

Integrating semantic processing and focusing has four results, firstly, the focusing algorithm is expressed in a formal framework which makes it compatible with obtaining
a semantic interpretation, secondly focusing constraints impose further structure on DRT, hence reducing anaphoric possibilities, thirdly the semantic structure of discourse allows semantic constraints to be put on accessibility of discourse referents to the focusing mechanism, preventing absurd choices for antecedents at the very start. Lastly I give evidence to support the hypothesis that verification of the truth of utterances is calculated with reference to focus structures.

In short, I claim that model-theoretic semantics is necessary to focusing, although focusing operates independently of the actual truth of a discourse, and that the focused/unfocused distinction is crucial to semantic processing, although semantic processing operates independently of the identity of particular discourse markers.
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Chapter 1

Introduction

The Problem

Recent formal semantic theories (e.g. Groenendijk and Stokhof's (1989) 'Dynamic Predicate Logic' (DPL) and Kamp's (1981) 'Discourse Representation Theory' (DRT)) have provided extensions to predicate logic which allow semantic constraints on pronouns to extend across sentence boundaries, while maintaining a traditional model-theoretic interpretation. This makes it possible to give a semantic interpretation to discourse anaphora. However few semantic theories attempt to impose discourse constraints on discourse anaphora (Pinkal 1986 is one exception). As a result, pronouns may be resolved to any existentially quantified antecedent compatible in number and gender. There is no mechanism to rule out antecedents last mentioned dozens of sentences previously, nor to choose between many equally compatible antecedents. For example the pronoun resolution rule given by Kamp (1981) is incomplete; it only stipulates that within semantic bounds a 'suitable' antecedent must be chosen. The rule would only be complete if the word 'suitable' was replaced by a set of instructions for finding the antecedent. This is the goal of algorithms developed in Computer Science for local focusing (e.g. Sidner's (1979; 1981; 1983) algorithms and the Centering algorithm of Brennan, Friedman and Pollard (1987)). Focusing algorithms place constraints on
accessibility of referents for pronominal resolution, by imposing a hierarchical structure on memory for discourse.

But Kamp (1981) was sceptical that focusing algorithms could ever provide a complete guide to pronoun resolution: “However useful some of this work may have been, I have the impression that its theoretical significance is rather limited ... all we can expect to achieve in this area is to articulate orders of preference among the potential referents of an anaphoric pronoun, without implying that the item that receives the highest rating is in each and every case the referent of the anaphor” (p. 318).

An inspection of the existing focusing theories shows that to some extent Kamp’s claim is justified, even optimistic. Focus theories do put an ordering on preferences, but are not yet fully equipped to consider even the range of potential antecedents covered in Kamp and Reyle (1989).

However, focusing theories have a second function; they also put absolute constraints on accessibility by imposing a small, finite memory for pronominal antecedents. It is necessary to assume limited memory if we are to take seriously Kamp’s (1981) claim that Discourse Representation Theory describes the “mental representations which are formed in response to the verbal inputs” (p. 282). If we regard DRT as describing part of the hearer’s cognitive model of a discourse, it must be psychologically plausible. The psycholinguistic data suggests that only a small number of antecedents are actually considered for pronoun resolution, and that there are ways of predicting, from the syntactic, thematic, lexical and pragmatic context, which antecedents will be preferred. That focusing algorithms only deal with preferences is not a theoretical shortcomings, but a reflection of the fact that the hearer does not have direct access to the speaker’s intentions.

So instead of condemning focus theories because they do not deal in certainties, it must be accepted that a psychologically realistic model of language comprehension should be capable of making errors, and of recovering gracefully from them. This is a small price to pay for the advantages of removing most possibilities of pronominal ambiguity from DRT, which in its current state has no disambiguating capabilities at all.
The focusing algorithms of Sidner (1979; 1981; 1983) and Brennan, Friedman and Pollard (1987) do not incorporate semantic constraints on pronouns. All these authors acknowledge the need for imposing semantic constraints on anaphora, but none attempt to show how they might be integrated. Sidner (1981) hints at a solution: “bound variables are assumed to be represented in sentence semantics; when used in conjunction with syntactic disjoint reference rules, pronouns within the scope of the quantifier can be distinguished from non-scoped ones” (p. 226). However, noticing whether an item is in the scope of a quantifier or not is left until after the focusing algorithm has predicted that item as an antecedent for a pronoun. So semantic structure is seen as largely independent of focus structure, with semantic constraints on anaphora being considered only after focusing constraints. This is the opposite to Kamp’s view that pronominal antecedents must be chosen from semantically restricted spaces, the role of a focusing algorithm being to decide which of these semantically plausible antecedents is the correct one.

Another way in which these focusing algorithms differ from Kamp’s view of natural language comprehension is that they are not psychologically grounded: although they do an admirable job of generalising over some very complex data, they were conceived to provide a set of rules for pronoun resolution in computational systems. Neither of the focusing algorithms posits an underlying mental representation of the discourse: the rules for focusing are not motivated by some theory of what the hearer believes. Although both algorithms make use of memory stores, these stores are constrained by computational rather than psychological capacities.

So, Kamp challenges us to see DRT as part of a model of human communication, while doubting the usefulness of incorporating focusing constraints. I see the tentativeness of pronoun resolution as an essential part of the nature of language, which is accurately captured in local focusing algorithms. Yet such focusing algorithms are based on heuristics rather than on any particular cognitive model of communication. The question is whether focusing can give DRT the extra constraints on anaphora which it needs, and whether DRT can provide a suitable representational foundation for focusing algorithms. In order to answer this, we must first resolve the conflict over whether focusing or
The main question addressed by this thesis is whether it is possible to integrate focusing and Discourse Representation Theory. Should some kind of integration prove possible, it is then necessary to ask what the benefits of semantic representation would be for a theory of focusing, and what benefits a theory of focusing would offer to a theory of semantic representation. That is, would an integration of semantic and focusing theories lead to anything more than coexistence of two types of constraints on pronouns?

Goals:
1. To integrate focusing and Discourse Representation Theory.
2. To evaluate what the benefits would be for semantics.
3. To evaluate what the benefits would be for focusing.

The Thesis

The thesis uses pronoun resolution preferences and antecedent availability to illuminate the semantics/pragmatics interface.

I will assume that the human natural language comprehension system has the following properties:

Incrementality Pronouns are resolved on-line, as soon as they are encountered.

Economy The antecedent chosen minimises processing effort. It is the antecedent most likely to correspond with the speaker’s intended referent while being least likely to have serious repercussions if the choice does turn out to conflict with the speaker’s intentions. This assumption is adopted in the spirit of Sperber and Wilson (1986).

Validity It is possible to verify the truth of a discourse with respect to the situation being discussed. The situations which make a particular sentence true according to the system, correspond with the truth conditions imposed by a traditional semantic theory.
I construct a dynamic model of attention using empirical observations and theoretical insights from Computer Science. Such a model is assumed to underlie any focusing algorithm, but those of Sidner (1979; 1981; 1983) and Brennan, Friedman and Pollard (1987) are found incompatible with the assumptions of economy and, more importantly, incrementality. A simpler focusing algorithm is proposed, incorporating those assumptions as primary. Validity is addressed by adding semantic constraints to a model of attention in discourse. A semantic interpretation procedure, based loosely on Kamp (1981), is given for the discourse model.

The fact that some sentences have several possible representations is problematic in a theory committed to psychological plausibility. I suggest, as an alternative to encoding semantic ambiguity as pragmatic vagueness, that semantic ambiguities are also resolved incrementally. Kamp and Reyle (1989) occasionally appeal to syntax as a source of determinism, but I suggest that the strongest determinant of the choice of representation (and hence interpretation) is focus structure. I will show that it follows from the assumption of economy that focused elements take wide scope over unfocused elements. Focus is invoked to explain some of Kamp and Reyle's empirical observations, adding a stronger rationale for their particular choice of construction rules.

The benefit of all this for focusing is that algorithms can be grounded in a semantic representation of the discourse which completely determines the nature of antecedents available for pronouns, rather than, as Sidner envisaged, semantic constraints ruling out antecedents which have already been selected by the focusing algorithm. In fact Sidner's algorithm is unable to consider certain acceptable antecedents, such as those produced by abstraction or modal subordination, because the role of semantics is seen as ruling out, rather than suggesting, possible antecedents.

In the final part of the thesis I explore the alternative way to combine focusing and formal semantics: I begin with DRT and gradually add the information structures needed for focusing. I argue that if DRT is to be regarded as a semantic representation of discourse, it must allow more incremental verification. Assuming incrementality means drawing possibly incorrect conclusions about the meaning of a discourse. However the disadvantages of specifying procedures for recovering from error are considerably
outweighed by the benefits of being able to resolve pronouns and thereby draw some conclusion.

The combined DRT/focusing model proves to be an excellent framework for asking, and answering, questions about the semantics/pragmatics interface. The thesis not only successfully integrates focusing and DRT, but shows that semantics and pragmatics mutually benefit from such an integration. Giving a semantic basis to a focusing algorithm allows semantic constraints on anaphor resolution to be imposed, but also completely determines the form and number of potential antecedents. Incorporating focusing into DRT determines ‘suitable’ antecedents for a pronoun, but also removes the possibility of semantic ambiguity occurring in a psychological or computational system.

Focusing, far from being of ‘limited theoretical significance’ to DRT, transforms it into a powerful theory of language comprehension, weaving together the treatment of semantic and anaphoric ambiguity, which are problematic for any psychologically realistic or flexible computational model.

Summary of Chapters

The thesis falls into two halves. The first half (Chapters 2, 3, 4 and 5) develops a model of focusing in discourse. The second half (Chapters 6, 7 and 8) incorporates a semantics into the focusing model and examines the interaction between focusing and semantics.

Chapter 2 explains the general usage of terms in the thesis. Chapter 3 compares two focusing algorithms from the literature to choose the one which best fits the assumptions of the thesis. Chapter 4 explores the type of mental representation or structural context which would be necessary to support this focusing algorithm. Chapter 5 makes some substantial changes to the focusing algorithm which suit it better to the role it must play in this thesis. What emerges is a new Incremental Focusing model. Chapter 6 shows how semantic constraints on anaphora can be incorporated into the focusing model. I show that the semantics of the model provides the range of potential antecedents for pronouns, while the focusing theory confines and organises them. Semantic ambiguity
results when a sentence can be verified in more than one way. Chapter 7 argues that focus determines how a sentence is semantically verified, so different focusings result in different truth conditions for a sentence. Focused items always take wide scope over unfocused items. Finally, Chapter 8 incorporates the idea of focus into the formal framework of Discourse Representation Theory and discusses what follows as a result. Chapter 9 explores the implications of the results.

The contents of the chapters are summarised in more detail as follows:

**Chapter Two: Preliminaries**

This chapter introduces the terminology and very general historical background of this thesis. I describe how I see the semantics/pragmatics divide, and explain my use of the terms 'pronominal anaphora' and 'focus'.

**Chapter Three: Two Algorithms for Local Focusing**

This chapter compares the focusing algorithms of Sidner (1979; 1981; 1983) and the Centering algorithm of Brennan, Friedman and Pollard (1987). Both help to clarify the idea of focus and its empirical implications. However the Centering algorithm is rejected since it is impossible to apply incrementally, and Sidner's algorithm suffers considerable criticism, despite its excellent coverage of the data, due to its lack of economy. The conclusion is that neither is satisfactory, but some combination of their properties would be ideal. Sidner's basic intuitions are chosen as the starting point.

**Chapter Four: A Representation for Focusing**

This chapter grounds Sidner's algorithm in a semantic representation of discourse. The representation is devised to incorporate the minimal information needed in order to resolve pronouns by Sidner's algorithm. The representation is used to give a new perspective on Sidner's algorithm, and as a result leads to the clarification of the update mechanism.

**Chapter Five: An Incremental Focusing Theory** A new focusing algorithm, allowing incremental anaphor resolution, is developed based on Sidner's original
intuition that use of a pronoun by the speaker indicates to the hearer that
the referent of that pronoun is the item currently in focus. It is argued that
previous focusing algorithms have confused focusing effects with other markers
of salience. The assumption of economy predicts a focus-maintenance preference:
it is less effortful to continue examining the properties of the entity currently
in memory than to shift attention to a new entity. The many influences on
pronoun resolution documented in the literature (e.g. grammatical role, thematic
role, parallelism, perspective etc.) are regarded as secondary. It is therefore
predicted that previously focused (i.e. pronominally recalled) elements will by
default provide preferred antecedents for future anaphora. Because the assumption
of Incrementality rules out consideration of more than one pronoun at a time, the
effect of one pronoun’s antecedent choice on another pronoun’s choice has to be
captured by augmenting the focus stores gradually, rather than waiting until the
end of the sentence. The resulting ‘incremental update’ means that intrasentential
anaphoric connections can be predicted using the same resolution mechanism as
for cross-sentential connections. The new focusing algorithm thus incidentally
improves on Sidner’s algorithm.

Chapter Six: Semantics of Discourse

The incremental focusing model of the previous chapter is augmented with
semantic constraints, which suggest that the role of semantics in focusing is a
primarily ontological one. Semantic interpretation is shown to determine memory
for antecedents. This chapter shows that pronouns are located in both semantic
and pragmatic dimensions, and constrained by both.

Chapter Seven: Focus and Semantic Ambiguity

Recent work (Sgall, Hajičová and Panevová (1986), Partee (1991), Rooth
(1985)) has shown that intonational focus is a guide to the preferred semantic
interpretation of a semantically-ambiguous sentence. I show that the analogy
also holds for discourse focus: patterns of discourse focus, as manifested
by anaphoric/non-anaphoric contrasts, also correlate with particular semantic
interpretations.
I argue that focused elements take wide scope over unfocused elements, and that this is a natural consequence of the way semantic verification routines are determined by the underlying representation of a discourse.

Chapter Eight: Discourse Representation Theory

This chapter gives a short introduction to Discourse Representation Theory (Kamp 1981), including Kamp and Reyle's (1989) introduction of generalised quantifiers to replace the earlier treatment of quantification. Also included are Kamp and Reyle's rules for plurals. Mechanisms necessary for focusing are added to DRT, augmenting it with pronoun resolution capabilities. I speculate on the potential of the new focus/DRT model to account for cross-sentential anaphora in donkey-sentences, paycheck sentences and modal subordination.

Chapter Nine: Conclusions

The final chapter summarises the achievements of the thesis. Its theory of mental representation is outlined in conjunction with its theoretical assumptions and empirical predictions.

The implications of the thesis are discussed for all the component disciplines: semantics, pragmatics, psychology, syntax and Artificial Intelligence. The model proposed in the thesis can offer insights into:
(a) Semantics, by showing that using focus determines semantic interpretation, and that useful new structure can be added to a formal semantic framework to put pragmatic constraints on anaphoric accessibility.
(b) Pragmatics, by formalising a small part of context-sensitivity in a well-defined domain (anaphora resolution).
(c) Psychology, by offering an abstract yet experimentally testable theory of mental representation for discourse processing.
(d) Artificial Intelligence, by suggesting how semantically ambiguous sentences need not pose a problem for the processor, and by suggesting focus preferences and hence preferred readings for such sentences, based on a particular type of knowledge representation hierarchy.
Chapter 2

Preliminaries

The purpose of this chapter is to give a brief overview of the theoretical background against which the thesis is set.

The thesis is directed towards finding a formal framework in which both semantic and pragmatic constraints on pronominal anaphora can be expressed side by side. This chapter examines how the aims and methods of semantics and pragmatics have differed in the past, and how they could be reconciled in a formal theory of human communication. I go on to introduce the pragmatic background to the study of pronominal anaphora. The term 'pronominal anaphora' encompasses a number of different phenomena: I list those of relevance to the thesis and introduce the terminology I will be using in the remainder of the thesis. Next, I survey the different types of knowledge which are thought to influence pronoun resolution. Among these, the two of particular interest are semantic constraints (covered in Chapter 6) and focusing. The word 'focus' has received many meanings throughout its history, some of them even contradictory. I dedicate part of this chapter to clarifying the particular usage I adopt for this thesis. Lastly I return to the original goal of comparing semantics and pragmatics. I can now define the range of the thesis and draw out my itinerary for the rest of the journey.

In short, there are three terms I wish to clarify: pragmatics, anaphora and focus. People
have many different views of these terms, so whatever definitions I give will be slanted by my own beliefs; bear in mind that these definitions do not necessarily apply outside the domain of this thesis.

Goals:

1. To distinguish the goals and subject matter of pragmatics from those of semantics and syntax.
2. To explain what I mean by the term ‘pronominal anaphora’.
3. To give a rough idea of the meaning of the word ‘focus’, as used in this thesis.

2.1 Pragmatics

The main difference between semantics and pragmatics is that semantics treats language as data, abstracting away from its sources and purposes, while pragmatics treats the language users themselves as an integral part of the data. Semantics and pragmatics differ also in the methods used to theorise about the data. Semantics uses formal logics to state how the truth conditional meaning of a sentence or text can be derived from the meanings of individual words in an utterance. Semanticists believe that useful generalisations about language can be made without reference to the language user: these generalisations include describing the meanings of words like and, every and not. Pragmatics, on the other hand, covers an enormous variety of different approaches and phenomena, from sociolinguistics to effects of ‘general knowledge’ on conversation, from maxims of communication to speech acts. At a very general level pragmatics can be described as “the study of the relations between language and context that are basic to an account of language understanding” (Levinson 1983, p. 21), where ‘context’ typically encompasses knowledge about the statuses and intentions of conversational participants, spatial and temporal location of the conversation, medium of communication and subject matter.

Because pragmatics is particularly concerned with language as a means of
CHAPTER 2. PRELIMINARIES

communication, pragmatic theories are also to be concerned with the 'accumulation' of information by the conversational participants, or the change in relevance of different information, as the conversation progresses. Semanticists, like syntacticians, have tended to produce declarative descriptions of texts where the accumulation of words or sentences as a conversation progresses is not considered to be a major factor in determining the interpretation of the sentence or text.

As a result, syntax and semantics have drifted apart from pragmatics. Syntax and semantics both have an established domain, accepted standards of theorising (particular types of formality), and a commitment to study language as an abstract entity in its own right, rather than as part of psychology. Pragmatics, on the other hand, has been lumbered with every other aspect of language, an enormous diversity of different domains, and no generally accepted formal theories.

Although pragmatics too has sometimes studied language as an abstract entity, by its very nature it has had to be closer to psychology. Many pragmatic theories have presented minimal models of the conversational participants. Pragmatic theories make reference to intentions, speech acts, social status, dialect, gender, belief, knowledge, dialogue, attention, deduction, information, metaphor, time, speaker/hearer and environment. All these terms implicitly or explicitly acknowledge the role of language as a tool for human communication.

In recent decades attempts have been made to treat reasoning, presupposition, time and necessity in terms of formal logics. Some of these accounts have even been quite successful. They are now being absorbed into semantics, but consequently abstracted away from the human user.

However, recently formal semantics has been opening itself up for more psychological input. The leap was made by Hans Kamp (1981) who, while putting forward a formal semantic theory which dealt with cross-sentential semantic relations, also proposed an intermediate level of representation between syntactic form and semantic interpretation. He claimed that this intermediate representation was not simply a

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1By 'semantic interpretation', I mean model-theoretic, truth-conditional meaning, as applied to some MODEL consisting of individuals and/or sets and relations between them. Such a model could be
necessary theoretical construct, but could be seen as a mental representation constructed by a hearer in order to understand a string of words. This view is by no means universally accepted, but Kamp’s discourse representation theory has attracted a following among semanticists, particularly those on the borderlines of pragmatics. It has been used with some success to model temporal relations (Kamp and Rohrer 1983), belief (Kamp 1990) and presupposition (Roberts 1988). Ascher (1991) has been one of few to extend DRT’s ability to cope with cross-sentential anaphora, specifically to deal with propositional anaphora, syntactic parallelism and VP-ellipsis.

I believe that pragmatics would benefit from more formalisation, so long as rigour is not obtained at the expense of realism. I intend to show that Reichgelt (1986) was premature in suggesting that “the model-theoretic approach to the mental representation of discourse suffers from a number of essential shortcomings as a psychological theory” (p. 52), and that Kamp’s DRT can be used to illuminate the hearer’s mental representation of discourse as it must necessarily be in order to resolve pronominal anaphora.

2.2 Anaphora

Anaphora was chosen as the object of study because anaphors are easy to detect in text, and are subject to both semantic and pragmatic constraints.\(^2\)

As I have explained, anaphora is one of the areas of pragmatics which has recently become of especial interest to semanticists. But what exactly is anaphora? Every language has some way of abbreviating reference to items under discussion, so that when an item needs to be referred to more than once, it need not be given a full identifying description each time. Bosch (1983) dates the concept of anaphora back to Apollonius Dyskolus, who first made the distinction between anaphora (reference to that which is familiar) and deixis (reference to that which is new). Since then, the study

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\(^2\) The term TEXT is used interchangeably with DISCOURSE for combinations of sentences produced by a ‘speaker’ (who may be a writer) as part of a communication with the ‘hearer’ (reader).
of anaphora has become a large enterprise, with researchers in linguistics, philosophy, artificial intelligence and psychology.

Various classes of anaphora have been recognised (e.g. the bound/E-type/discourse anaphora distinction, implicit versus explicit, verbal versus propositional versus nominal anaphora). The only distinction which I will take as given, for the purposes of this thesis, is the distinction between pronominal anaphora and other types. To explain what pronominal anaphora is, I will give an approximate characterisation of nominal anaphora, as distinct from verbal, propositional and other types of anaphora. I will then move onto the specifically pronominal versions.

Proposal (Anaphora):

Anaphora covers any phenomena with the following characteristic: a lexical item appears in a text, whose reference can only be found by deriving it from the reference of some antecedent phrase in the text.

This proposal will be modified throughout this thesis, and can even now be specified more precisely. For I shall be assuming that the hearer is not normally directly aware of the REFERENT of a phrase, but represents a supposed referent by means of a DISCOURSE MARKER, corresponding to the SPECIFICATION of a phrase.3

For instance, given the discourse:

(2) John broke the window. It made enough noise to wake the nearby constabulary.

Here, the anaphor it picks out the specification of the antecedent sentence ‘John broke the window’, the ‘proposition’. Thus the hearer’s understanding of the anaphoric connection is independent of the hearer’s ability to interpret the text or connect it with some real event in the world.

So a sequence of words may produce several mental representations, or specifications, and can be (optionally) linked with an actual real world REFERENT. The thesis will

3"Cospecification, unlike co-reference, allows one to construct abstract representations and define relationships between them ... Even if a phrase and a pronoun do not cospecify, the specification of the phrase may be used to generate the specification of a pronoun" (Sidner 1981 p. 218).
not on the whole be concerned with referents, but with nominals. All previously produced specifications are antecedent specifications. An anaphor resolves onto or specifies one or more of these specifications, which are then designated its antecedent specifications (antecedents for short). I apologise for often using the word 'refers' informally in place of 'specifies' for the relation between an anaphor and its antecedent.

Anaphors can often be distinguished from other parts of speech. The pronouns he, it and they will always be anaphors (if not deictic), while the city is an anaphor in the sentence 'I once loved a city but the city didn't love me' but not in 'I live in the countryside and Beatrice in the city'. Definite NPs are often anaphoric, as are proper names. Indefinite NPs are rarely anaphoric.

The relation between anaphoric specification and antecedent specification is covered by a class of relations which may be implicit (as with definite noun phrases '...a wedding ...the bride ...'), or explicit and highly constrained, as with pronouns: '...the bride ...she ...'. The type of anaphor used depends on its relationship with the antecedent nominal.

By the time the anaphor needs to be resolved, the relevant antecedent phrase will not necessarily still be remembered, however each possible antecedent will have produced a specification, from which (or combinations of which) the anaphoric specification can be derived.

2.2.1 Nominal anaphora

A nominal is the specification of a noun phrase, the semantic representation of an entity presumed to correspond with a (known or unknown) referent in the world. A nominal appears in this thesis in the form Mary or the blue cat, whereas referents have the form MARY or CAT345, where MARY and CAT345 are unique identifiers of the referent in the world (whether the world is a memory or a percept).

The term nominal anaphora will be used for relations containing anaphors which are derived from nominals, and which generate nominals as specifications also. Examples of nominal anaphors are: it, they, one, one of them, the cat,
2.2.2 Pronominal anaphora

This thesis is specifically concerned with a subset of nominal anaphora in which the anaphoric particle contains no information about the common noun class to which the antecedent belongs.

Examples of pronominal anaphors are: he, she, it, they, him, her, his, hers, them, its, their, theirs, one, one of them, two of them, many of them, most, mine, the tallest, the rest, the blue one.

There are many different forms of pronominal anaphora, which can be distinguished by the relationship between the anaphoric nominal and the antecedent nominal. The following table includes a selection of the pronominal relationships which will be covered in this thesis:

<table>
<thead>
<tr>
<th>Relation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coreference</td>
<td>John has two cats. I saw him taking them for a walk yesterday.</td>
</tr>
<tr>
<td>Summation</td>
<td>When Ross visited his Aunt Cicely, they spent the afternoon talking. Then, as arranged, Nadia arrived. Ross kissed his aunt goodbye, and set off with Nadia to the discotheque, where they danced the night away. (From Hirst 1981 p. 5)</td>
</tr>
<tr>
<td>Genericity</td>
<td>My neighbour has a monster Harley 1200. They are really huge but gas efficient bikes. (From Sidner 1981)</td>
</tr>
<tr>
<td>Abstraction</td>
<td>Ross gave each girl a crayon. They used them to draw pictures of Daryel in the bath. (From Hirst 1981 p. 5)</td>
</tr>
<tr>
<td>Subset</td>
<td>He has loads of books on anaphora but he's only using two of them.</td>
</tr>
<tr>
<td>Coset</td>
<td>John bought a large green chair to replace the previous one.</td>
</tr>
</tbody>
</table>

Types of pronominal anaphora not covered in this thesis include those holding implicit relations with the antecedent:

(3) Ross sat in the corner, knitting madly. Suddenly he threw it down and stormed out of the room.
(4) Ross wanted to nail the boards together, but Sue made him do it with tape.

(Both from Hirst 1981 p. 6)

I also omit the following pronominal anaphors: this, that, such, the former, and singular generics.

2.3 Influences on anaphora resolution

Influences on anaphora resolution have been found in all branches of the study of language, from the very specific influences of semantics and syntax, to the larger spread of possibilities considered in pragmatics and psycholinguistics.

This is a list of those I have compiled so far, starting with the restrictions, and ending with the preferences or markers of salience:

**Syntactic coreference restrictions** Syntacticians have noticed that there are strict syntactic constraints on when two noun phrases in a sentence can be coreferential. (See Chapter 5 for further discussion.)

**Semantic constraints** It has been found that logical operators put strong constraints on what type of anaphoric reference is possible from nominals generated inside and outside the scope of the operators. (These constraints will be described in detail in Chapter 6.)

**Agreement constraints** Anaphors characteristically share some morphological information with their antecedents. Two noun phrases are generally not considered coreferential if they do not agree in gender, number or animacy (in English).

**General Knowledge constraints** It is generally agreed that people can rule out coreference between two nominals 'for pragmatic reasons' — that is, if assuming coreference would lead to contradiction or incoherence in the discourse. This is

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4Not essential, of course: particularly interesting is the case of 'zero anaphors' in Chinese, which have no phonological realisation at all.
of course, one of the hardest areas to formalise — see Carter 1987 for an attempt to integrate an inferential system with a focusing algorithm which provides the antecedent-anaphor pairs to be tested.

**Recency** Among the first efficient algorithms for anaphor resolution was one devised by Hobbs (1978) whose great success came from searching the space of possible antecedents backwards from the anaphor to be resolved, so the further away a noun phrase was from the anaphor, the less likely it was to be chosen as antecedent. Today, many AI systems still use the recency heuristic.

**Order of mention** In interesting contrast to this, psycholinguistic experiments have found that when there are two potential antecedents for a pronoun, the one which was encountered first will be chosen (Gernsbacher and Hargreaves (1988)). (Sanford, Moar and Garrod (1988)) found generally that when there are two compatible antecedents, that which was established first in the discourse is often preferred.

**Grammatical Role Preferences** Hobbs (1978) did not purely operate with a recency heuristic — he also used syntactic dominance to help establish the best possible antecedent. Psycholinguistic experiments have repeatedly shown preferences for subject over object, and main verb roles over those in prepositional phrases. This type of preference formed the basis for the Centering algorithm in Chapter 3 and is discussed also in Chapter 5 in relation to my own algorithm for focusing.

**Thematic Role Preferences** Thematic role is also thought to be a strong determinant of focusing preferences: Sidner used it as a basis for her algorithm (see Chapter 3), drawing on Langacker (1987) and Gruber’s (1976) observations that theme tends to be focused. Experiments by Stevenson et al. (1990) have shown a preference for agent over patient, and goal over source roles. Various experiments have shown that implicit causality in certain verbs (e.g. *punish, annoy*) can affect anaphoric preferences (Garvey and Caramazza 1974, etc.).

**Role type preferences** Garrod and Sanford (1990) have found that pronouns prefer to corefer to the main character in the text. Main characters are generally
introduced early on with a proper name, and frequently mentioned. Subsidiary referents were less preferred: these usually appeared in the text as definite noun phrases (role descriptions like the policeman), were probably not mentioned in the first sentences of the text, and were less frequently mentioned. Sanford and Garrod called such subsidiary referents ‘scenario bound’, because they tended to become inaccessible at the end of the current situation or script taking place within the larger narrative.

**Informativeness** The amount of information given about a discourse element influences its salience: the more information given about an element, the more likely it is to be anaphorically referred to. (This factor will be mentioned again in Chapter 5 and in Chapter 7, section 7.7)

**Focus** The term ‘Focus’ covers a multitude of measures of salience, usually including parts of the above factors, together with some kind of old/new distinction. Chapter 5 is concerned with separating out the purely focus effects from the other factors listed here.

People have attempted to prioritise these influences. Part of the claim of this thesis is that the default determinant of preferences is focus, with the other factors being simply cues by which the speaker indicates a deviance from the default. Whereas the majority of the influences listed above are likely to be independently applicable to each sentence, focus is specifically concerned with signalling relationships between sentences. The next section provides some examples.

### 2.4 Focus

Focusing is a way of putting constraints on the order and number of antecedents considered for resolving anaphors.

Typically, Bosch (1983), when defining discourse anaphora, states that a pronoun is used in preference to a ‘semantically fuller device’ to refer to a previous object where the object being referred to is ‘salient’, “the most salient object at any point is always
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the object the discourse at the point is about" (p. 57). Theories of focusing are an attempt to determine systematically what a discourse or a sentence is 'about', and hence to account for patterns of intonation, anaphora, memory, meaning and inference.

There is a vast literature on focus and its family of not-quite-synonyms, which include topic, presupposition, theme, old or given information. Much of this arose, most surprisingly, from the very heart of conventional syntax. The focus/presupposition distinction lies at one end of the spectrum which has discourse topic at its opposite end. The focus/presupposition distinction was approved by Chomsky (1971), and its relations have very often received a passing mention in linguistics papers. Semanticists have been slightly more reluctant to admit of uses for the distinction. However the Prague School, a group harking back to prechomskyan linguistics, has always treated what they call the topic/focus articulation as central to any linguistic theory. Their point of view has always been shared by a small number of people, and is currently becoming more popular, with the appearance of work like that of Bosch (1983), Rooth (1985) and Partee (1991). All these researchers recognise in their semantic or syntactic theories the need for some coding of the information structure conveyed in a sentence.

However, in the sprawling, chaotic mass of pragmatics there was only one area too murky to merit inclusion in Levinson’s (1983) classic Pragmatics: focus.

"Terminological profusion and confusion, and underlying conceptual vagueness, plague the relevant literature to a point where little may be salvageable" (from the preface)

In this thesis I hope that by bringing semantics and focusing closer together some of the formality of semantics may permeate the foundations of focusing theory. However for now it will suffice to give an intuitive idea of where the term 'focus' as used in this

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5 The topic/comment distinction was used by Chafe (1976), the topic/focus distinction is used by the Prague school, e.g. Sgall, Hajicová and Panevová (1986) to capture the difference between syntactic constituents marked by stress, and those which are unmarked and contextually bound, the word ‘topic’ was used by Van Dijk and Kintsch (1983) for the anaphoric information in a sentence, and by Brown and Yule (1983) for subject (sentence topic) or a more general sense of what a conversation is about (discourse topic).

6 The focus/presupposition distinction was made in Chomsky (1971).

7 See Halliday (1967); “Basically, the theme is what comes first in the clause” (p. 212); in declarative sentences the subject is always the theme.

8 Prince (1981) writes that 'givenness' applies to information where “the speaker assumes the hearer ‘knows’, ‘assumes’, or can infer a particular thing” (p. 230).
thesis can be located in the terminological spectrum.

The term 'focus' has been used for both the old (Sidner 1979; 1981; 1983) and the new (Halliday (1967, p. 204), Partee (1991) etc.) section of a sentence. Since this thesis is based in a large part on the focusing theories of Artificial Intelligence, particularly that of Sidner (1979), I use focus (approximately) for the old information in a sentence. Old information is that which has been previously discussed in the discourse, which for instance may be recalled using pronominal anaphora. Take for example (5):

(5) An egg flew through the air. It hit the vicar’s wife.

In the second sentence, the specification of the anaphor it is the focus, that is, the egg which flew through the air is the focus. This is the ‘given’ information in the sentence, whereas the vicar’s wife is new. The focus makes an explicit link between the first sentence and the second.

The term focusing is used for the process of tracking attention through the discourse⁹. A theory of focusing has two aims: firstly to constrain the available antecedents for anaphoric reference at any particular point, and secondly to place an ordering on the relative accessibility of the antecedents, hence determining the probability of a pronoun being resolved to any particular antecedent. In other words, a theory imposes focusing constraints and predicts focusing preferences. The focusing algorithms developed in AI are committed to using minimal information to determine focusing preferences and constraints, since the utilisation of large amounts of information, particularly lexical or general knowledge, is very expensive in processing terms.¹⁰ However psycholinguistic experiments suggest that human processors too tend not to use general knowledge more than necessary in determining plausible antecedents.

(6) provides a good example:

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⁹“Attentional state, Gross and Sidner’s term for the dynamic representation of the participants’ focus of attention, represents — among other things — which discourse entities are currently most salient. One function of attentional state is to help resolve pronominal references.” (Passonneau 1989 p. 51)

¹⁰“See for example the algorithms of Carter (1987), in which “linguistic knowledge, about syntax, semantics and local focusing, is exploited as heavily as possible, in order to minimise reliance on world knowledge” (from the foreword). Carter calls this the requirement of ‘shallow processing’.
(6) If an incendiary bomb drops near you, don’t lose your head. Put it in a bucket and cover it with sand.

(From Hirst, 1981, p. 56).

Here a mildly implausible antecedent is much preferred as an antecedent for it, rather than the more realistic alternative which happens to be further down the focus hierarchy.

2.4.1 Local and Global Focus

A useful distinction which I will be using in this thesis exists in the same body of literature from which my use of ‘focus’ derives. This is the division of focus into local and global focus. Roughly, local focusing deals with pronominal preferences, and global focus with definite noun phrase anaphora. This is the same dichotomy which Sanford and Garrod (1981) incorporated into their theory of discourse memory: local focus corresponds to their ‘explicit focus’ and global focus to their ‘implicit focus’. Local focus is particularly concerned with relations between sentences, whereas global focus is concerned with relations between ‘focus spaces’ which contain several sentences. In global focusing theories (e.g. Grosz 1981; Grosz and Sidner 1986), discourse is structured by ordering focus spaces in a hierarchy that corresponds to the task structure of the dialogue (Grosz 1981 p. 92). Local focusing tends to limit itself to a small number of focus stores and a hierarchy determined by the grammatical or thematic structure of preceding sentences.

I will confine myself to local focusing (sometimes called ‘centering’). As can be seen from examples (5) and (6) there is a vital link between local focusing and pronoun resolution. Firstly, the item assumed to be the focus is usually pronominal, which means the nominal in focus can only be calculated by resolving the pronoun. Secondly, the focused item is supposed to be the most likely antecedent for future pronominal reference.
2.5 Context

Earlier, pragmatics was defined as the study of context. I am now in the position to describe more accurately the particular subset of contextual information with which I am concerned in this thesis.

Anaphora is distinguished from deixis in having antecedents derived from the linguistic medium in which it occurs. Very generally then, the context relevant to anaphora is the linguistic medium or discourse, where a ‘discourse’ is any continuous text consisting or one of more single sentences, whether spoken or written. Because this thesis does not examine the effect of intonational factors on anaphor resolution, all the examples are assumed to be read, or pronounced without emphatic stress on any particular element, unless stated otherwise.

In accordance with the assumption of incrementality, anaphors may only access antecedents which have already been introduced, rather than those which may be forthcoming. Simply constraining anaphoric context to the preceding discourse is not enough however. Anaphora is interpreted with reference to its own ‘context model’ (Bosch 1983), distinct from general background knowledge. The context models used in this thesis will consist of a small local hierarchy of nominals, mostly confined to nominals mentioned in the previous and current sentences. Only and all the nominals in the context model will be available for pronominal reference. The hierarchy will determine a strict salience ordering on nominals which represents their relative likelihood to act as antecedents for pronouns. The hierarchy is determined on the basis of lexical information, ideally information which is easily accessed, such as syntactic or semantic features, rather than in-depth conceptual details.

The context model for pronominal anaphora is assumed to be embedded in a larger context model of the discourse which includes an accompanying (cumulative) semantic interpretation and a representation of all the knowledge communicated so far by the discourse.
2.6 Focusing and Semantics in this thesis

The focusing algorithms of Sidner (1979; 1981; 1983) and Carter (1987) do not incorporate semantic constraints on pronouns. These authors mention the need for imposing semantic constraints, but none actually attempts to sketch out how they might be integrated. For instance Sidner (1981, p. 226) assumes that her focusing algorithm can choose between alternative antecedents produced by scope ambiguous phrases, but does not give any details of how such a mechanism might work.

On the other side of the semantics/pragmatics boundary, Kamp’s (1981) formal semantic theory imposes no focusing constraints on discourse anaphora, nor can it take account of focusing preferences. It lacks any pronoun resolution mechanism.

How could focusing and formal semantics be integrated in a theory of human language processing? I have already outlined my commitment to incremental processing. I must consider an integrated theory in which both focusing and semantic processing are on-line and procedural. The context in which a pronoun is resolved must be restricted to previous discourse, and the effects of focusing must occur in future discourse.

2.7 Recapitulation

This thesis sets out to examine the semantics/pragmatics interface through observing the phenomenon of anaphora in discourse.

The coverage of the thesis can be stated very generally as follows:

- Focus constraints on discourse. These include constraints on accessibility of discourse referents as well as constraints on which relations (e.g. summation) may legitimately exist between antecedent and anaphoric nominals.

- Focus preferences. Possible sources of ordering on possible antecedents will as far as possible be confined to focus, grammatical and semantic structure.

- Interaction of focus constraints with semantic constraints on accessibility, that is,
if both sets of constraints must apply, how resolution rules could take both into account.

- Effect of focus on the verification conditions of a sentence. The need to deal with semantic processing raises questions about the procedures which might be used for determining the truth conditions of a sentence. It is possible that such semantic processing could be aided by knowledge of focus.

The thesis will deal with the same phenomena as Kamp (1981) and Kamp and Reyle (1989), namely proper names, indefinite noun phrases, singular and plural pronominal anaphora, relative clauses, conditionals and quantified sentences.

Achievements:

- Pragmatics was distinguished from semantics in being concerned with the effect of context on interpretation and generation of sentences.

- ‘Pronominal anaphora’ was found to cover pronoun use, where an antecedent nominal is related to an anaphoric nominal missing an overt noun class.

- The meaning of ‘focus’, as used in this thesis, was roughly determined to be ‘the most salient nominal in the current representation of the discourse’.

Chapter 3

Two Algorithms for Local Focusing

The purpose of this chapter is to provide the necessary background and motivation for the new focusing algorithm developed in Chapter 5. It serves two further functions: introducing in greater depth the conception of focus, and gradually unfolding the data which provides the basis for the rest of the thesis. Thus it serves as literature review, corpus and foundation for my own theories.

I will examine two of the most widely known algorithms for resolving pronominal anaphora. These are Sidner's (1979; 1981; 1983) Algorithm for Focus, and the Centering Algorithm developed by Joshi and Weinstein (1981), Grosz, Joshi and Weinstein (1983) and Brennan, Friedman and Pollard (1987). $^1$ Both algorithms were developed as computational tools to be used in natural language processing systems, rather than as psychological models. However since they involve tracing and predicting human speakers’ attention to discourse entities, the algorithms are detailed enough to offer valuable insight into the kind of cognitive model which would be necessary to result in the behaviour they predict. The resulting cognitive model will be discussed in the next

$^1$These algorithms will be given later in this chapter, but can also be found in Appendix I, together with the algorithm I will develop in Chapter 5.
The focusing algorithm eventually chosen should accord with the two main assumptions of this thesis: incrementality and economy of processing.

The first of these assumptions, incrementality, requires that pronouns be resolved online, rather than waiting until the end of the clause or sentence, though some end-of-clause processing may be necessary.

The second assumption I made in Chapter 1 was economy of processing. Focusing algorithms are almost entirely motivated by such an assumption: they capitalise on the tendency for speakers to continue talking about the same topic from one sentence to the next, and weigh the effort involved in shifting attention against the effort of recovering from error. However there are several other ways in which focusing algorithms can be measured by the assumption of economy: an algorithm which uses minimal information to predict antecedents more accurately is ideal. If predicting antecedents is very complicated (for instance involving several inferences), more processing is assumed to take place. This is only justifiable if such methods substantially reduce the number of incorrect predictions made, since incorrect predictions also involve processing effort: the hearer must interpret sentences twice, cancel wrong assumptions made and so on. Focusing algorithms which require more memory are less economical than those which rely on fewer memories, or use memories which already exist for independent purposes. It is assumed that in psychological as in computational systems, searching a large number of memories is more time consuming, more difficult, than searching few. Likewise, a focusing algorithm which uses a large set of rules to cover many contingencies is considered less economical than one which has fewer rules: each rule takes effort to apply.

Most of the data used to test the algorithms' capabilities consists of batteries of examples devised by their proponents, myself and other investigators. These examples mainly test the constraints on accessibility of antecedents imposed by the storage devices of the algorithms. However they can also suggest preferences between stored antecedents. Intuitions about preferences are supported, where results are available, by properly conducted psycholinguistic experiments. Psycholinguistic experiments can also shed
light on the actual processes of anaphora resolution, strengthening the case for a focusing algorithm whose strategies of pronoun resolution, as well as its eventual choices, are analogous (at some level of abstraction) with the internal processing of human subjects faced with the same information. The analogy is judged to hold if the errors or hesitations made by a human subject produce corresponding backtracking or increased processing effort in an implementation of the algorithm.

It will be assumed that the experimental methods used in the literature are sufficient to draw conclusions about human processing. Reaction times or eye-fixations are used to experimentally determine processing effort involved in resolving anaphors, while relative accessibilities of antecedents are revealed by probing a person's recognition of words as a sentence is read.

Ideally, a focusing algorithm should cover the entire range of phenomena being studied in this thesis. That is, it should be able to resolve both singular and plural pronominal anaphora with antecedents generated by indefinite or definite noun phrases or proper names. Of particular interest is the effect of the structure of preceding discourse, but syntactic and semantic structural constraints are also relevant. It is important that not just simple sentences but conjoined (e.g. conditional) constructions should be covered.

Where a particular algorithm fails to meet the requirements for psychological plausibility, or is difficult to use for my purposes, this will be indicated by highlighting the particular problem raised and pointing out where it will be examined later in the thesis.
CHAPTER 3. TWO ALGORITHMS FOR LOCAL FOCUSING

Goals:

1. To describe Sidner’s algorithm for focusing, and to point out where it conflicts with the assumptions of this thesis.
2. To provide a new version of Sidner’s algorithm optimising compatibility with the assumptions.
3. To describe the Centering algorithm, and to point out where it conflicts with the assumptions of this thesis.
4. To provide a new version of the Centering algorithm optimising compatibility with the assumptions.
5. To compare Sidner’s algorithm with the Centering algorithm, in order to determine which best fits my needs, and which best accounts for the empirical data described in this chapter.

3.1 Terminology

I use algorithm for the entire proposals, i.e. the Centering Algorithm and Sidner’s algorithm. The algorithms have several parts, which are also strictly algorithms but for clarity I will call these subparts mechanisms, for instance the Focus Update Mechanism.

Focusing algorithms constrain possible anaphoric antecedents to various subsets of those introduced in previous discourse. Nominals introduced or reintroduced in the previous sentence are always available, according to both algorithms. For this reason I will call the sentence which has just been processed the matrix sentence, with respect to which the current sentence is processed.

The entire collection of nominals which were overtly specified in the matrix sentence will be called potential antecedents, which are a subset of the available antecedents, some of which may, in Sidner’s algorithm, be available from discourse occurring before the matrix sentence. The entire range of possible antecedents to which an anaphor may be resolved also includes constructed antecedents – nominals which may be referred to by anaphors although they have not been explicitly introduced.

I will use the term focus for the most preferred salient entity, and potential foci
for available but not (yet) focused antecedents. However nominals of both these types are collectively referred to as being in the focus stores, to be contrasted with the forgotten, inaccessible nominals (some of which may be retrieved using definite noun phrase reference).

3.2 Sidner’s algorithm for focusing

3.2.1 Overview

Sidner’s algorithm consists of three main processes (Sidner, 1981 p. 221). The first of these uses the initialisation mechanism to choose foci based on the first sentence of the discourse. Nominals found in this first sentence are put into the focus stores which contain potential antecedents for the next sentence. The second process, the pronoun interpreter, consists of a set of PRONOUN INTERPRETER rules which resolve anaphors using the previously defined focus stores. A third process uses the update mechanism to update the focus stores once a sentence has been interpreted.

3.2.2 Sidner’s Focus Stores

Sidner (1979, 1981) uses several focus stores, which are ordered by salience for anaphoric accessibility. Her main store is the discourse focus, DF. She also uses a second subsidiary focus store, the actor focus, AF. Both these stores contain single items which are a subset of the nominals which Sidner’s algorithm can access from previous discourse.

Determining the foci of the matrix sentence is vital for resolving anaphora. The actor and discourse focus are found by noting the anaphoric and thematic pattern of the matrix sentence. Precise methods for determining the foci are given in section 3.2.5, which describes the focus update mechanism.

Sidner’s algorithm also makes use of two further stores, this time containing ordered lists of nominals, called the potential discourse focus list and the potential
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actor focus list, which will be abbreviated pdfl and pafl respectively. These lists contain all the remaining nominals in the matrix sentence except the focus.

Thus the entire set of nominals from the matrix sentence are available for reference, but the division into foci and potential foci, as well as the ordering with the potential focus lists, allows some nominals to be given preference over others.

In addition to nominals from the matrix sentence Sidner allows pronouns also to access a ‘focus stack’; I shall call this dfs (discourse focus stack). dfs contains all previous discourse foci. There is also a stack for actor foci, afs, holding previous AF values.

So according to Sidner nominals which were generated by previous discourse, but which were not referred to in the matrix sentence and have never been focused, have become unavailable for pronominal reference.

3.2.3 Thematic Information

Much of Sidner’s algorithm relies on thematic information. I have already mentioned that the focus stores are partly determined by thematic information. However the pi-rules applicable to a particular pronoun also depend on the thematic status of the pronoun. The thematic roles which are most important are the agent and the theme of a sentence.

Sidner does not offer a definition of agent, but since she bases her idea of thematic roles on that of Gruber (1976) and Langacker (1987), I assume that the agent is “the entity which willed the action and effected it” (Gruber 1976, p. 43), or “a human actor” (Langacker 1987, p. 28) “who volitionally carries out physical activity resulting in contact with some external object and the transmission of energy to that object” (ibid, p. 4).

Sidner’s theme is derived from that of Gruber (1976). According to Gruber (1976 p. 38) the theme is “the entity which is conceived as moving or undergoing transitions”, where such transitions may be physical or abstract. A list of examples is give below (themes are underlined):
John baked a cake.
Mary wrote a book about trains.
Mr. Harvey killed a chicken.
Margaret threw a bone to the dog.
Don rode a horse.
Julie was born in November.
Mary was enlightened.
The tower collapsed.

In 1981 (p. 223) Sidner uses the term ‘semantic case object’ instead. Langacker (1987) describes a semantic case object as an ‘energy sink’, which due to the subject “undergoes a resulting change of state”.

However Sidner wishes every sentence to have one, and only one, theme. This means that she must extend these proposals so that every verb has a theme argument role: for intransitives this is straightforward, since there is only one candidate, but for transitive verbs she must define a single theme which is distinct from any agent of the sentence.

Recognising the difficulty of this task, Sidner simply offers a rough guide to its meaning: “…the theme can best be generalized as the verb relation that indicates the property of being affected by the action of the verb.” (Sidner 1979, p. 64). Incidentally, this definition is almost identical to the definition of the ‘objective’ case offered by Fillmore (1968). Sidner’s ‘theme’ appears to include what other authors have labelled the ‘patient’ thematic role, (eg. ‘The miners struck gold.’, ‘The tax man interrogated John.’), where no change of state is involved. However in the case of intransitive verbs the theme can take on all the characteristics of an ‘agent’, as in:

(7) John ate.

Since the verb has only one argument, here John must be the theme.

(8) John ate some sausages.

Yet in the similar sentence (8), John is the agent, and the sausages are the theme.

---

2I will assume that conjoined items occupying the same thematic role/grammatical position are stored as a single (but plural) item.
There are also a great many cases where it is doubtful how to apply Sidner's definition. For instance, in what sense are the underlined words in the sentences below 'affected by the action of the verb'?

John ran a mile
I told a story
I know an antique-dealer
Mary is taller than John
Mary won't move the table

The opposite problem can also be encountered, when it seems several entities are candidates for being the theme, as in the following example from Dowty (1989):

(9) Mary sold a book to John for five dollars.

The book and the dollars seem to be undergoing transitions, while John seems to be the 'energy sink' at the end of the action chain.

Sidner's idea of agent can also be problematic, this time for epistemic reasons. If for instance John wished to kill his aunt, and accidentally did so, would John be the agent of the sentence 'John killed his aunt'. If, on the other hand John's aunt wished to experience euthanasia, and effected it by putting poisonous substances into the coffee jar from which John prepared her drinks, would John's aunt be the agent of 'John killed his aunt'?

We have seen that there are great problems associated with Sidner's notion of theme and agent. In fact these problems are not unique to Sidner's definitions: she herself recognised that the whole literature of thematic roles was beset with problems. To this day those problems remain, so much so that (Dowty 1989 p. 105) wrote a detailed critique of the whole area, pointing out that there is no generally agreed system of thematic roles, and arguing that there never would be unless linguists agreed to derive them on linguistic grounds, rather than appealing to the structure of the world.
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Problem 1  Because it relies on thematic information Sidner's algorithm rests on an insecure foundation. However thematic structure does seem to be one of the predictors of salience of antecedents (Stevenson et al. 1990), so the ideal focusing algorithm would be sensitive to the thematic effects of the verb. The problem is raised again on page 96.

When discussing Sidner's algorithm I will use two strategies in order to remain faithful to her intentions: firstly I will use examples from her own work, and secondly, where it is necessary to construct new examples, I will use the following heuristics:

Proposal (Agent):

*The agent will be taken to be the subject of a transitive verb, if the subject is animate.*

Proposal (Theme):

*Theme will be taken as the subject of a sentence unless the subject of the sentence is an agent and there is a direct object, in which case the direct object will be chosen.*

These heuristics are gleaned in part from Dowty (1989), who recalls the general linguistic principle that if there is an agent role among a verb's arguments it always appears in subject position. If there is no agent, the patient or theme tends to be the subject.4

So, to summarise: in subject-verb sentences the theme is the subject. In subject-verb-object sentences where the subject is inanimate, the theme is also the subject. In subject-verb-object sentences where the subject is animate, the theme is the direct object, and the subject is the agent. Some examples are given below:

agent

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3This definition avoids the major problems of determining intentionality, and seems to more adequately reflect Sidner's actual use of the term than the definitions given by Gruber and Langacker.

4I have made one simplification. In the case where there is no agent, if there is an instrument, it is the instrument rather than the theme which takes subject position. The instrument is one of Fillmore's original case roles, possessed by "the inanimate force or object causally involved in the action or state identified by the verb" (From Fillmore 1968 p. 24). An example is 'I hit him with a candlestick', or 'The candlestick grazed his forehead'.
John ran a mile.
I know an antique-dealer.
Mary is taller than John.
Mary wrote a book about trains.
Margaret threw a bone to the dog.
Julie was born in November.

theme
John baked a cake.
John ran a mile.
I know an antique-dealer.
Mary is taller than John.
Mary won't move the table.
Mary wrote a book about trains.
Margaret threw a bone to the dog.
Margaret threw the dog a bone.
Julie was born in November.
The tower collapsed.

It should be noted that the agent and the theme can coincide, in cases where the subject of an intransitive verb is animate.

3.2.4 Initialisation Mechanism

At the beginning of a discourse all the focus stores are empty. There should be no discourse anaphora in the first sentence, though Sidner does acknowledge that there may be cataphora. However after the first sentence has been processed, some predictions can be made about the likelihood of anaphoric references in succeeding sentences. Sidner uses thematic information derived from the verb as the main predictor of the salience of particular nominals. The theme of the first sentence becomes the expected focus of the next, and hence the most likely nominal to be pronominalised in the next sentence. The expected focus is stored in DF.

The expected focus, or theme, heads the expected focus list which contains all the nominals occurring in the first sentence ordered thematically by the Focus Ordering Mechanism:

Focus Ordering Mechanism
1. In an is-a or there-insertion sentence, the syntactic subject will be the most probable focus.

2. In ordinary sentences the most probable focus will be the theme.

3. In verb-complement (intentional) sentences, the direct object of the verb complement will be the most probable focus.

4. The remainder of the list will follow the left-to-right order of other thematic positions filled, with the nominal in agent position being the least probable.

5. The least probable focus of all is the verb phrase.

I will ignore 1, 3 and 5 for the rest of this thesis, since the particular constructions mentioned are not in the data set considered.

This leaves the Focus Ordering Mechanism as the following:

**Definition (Focus Ordering Mechanism):**

The most probable focus will be the theme of the matrix sentence. The remainder of the list will follow the order in which nominals are generated by the syntactic form of the sentence. However the nominal in the agent role will be the least probable focus.

The rest of the expected focus list, i.e. all the nominals occurring in the first sentence except the theme, are stored in PDFL. The expected focus may be confirmed or rejected in the next sentence. Confirmation occurs if a compatible anaphor appears in the next sentence. Sidner writes: "If rejected, the expected focus must be kept available for possible later use" (1979, p. 72). The store for rejected foci is DFS.

An expected actor focus, AF, is also derived from the first sentence. The expected actor focus is the animate agent, if any, of that sentence. The expected actor focus list is analogous to the expected discourse focus list, with the exception that all the items must be animate, and that the agent, being the most likely focus, is not in the list at all, but in AF:

**Definition (Actor Focus Ordering Mechanism):**
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In ordinary sentences the actor focus will be the agent of an action, so the potential actor list is composed of the nominals in the remaining thematic roles, in order of generation.

All the expected actors except the default expected actor (the agent) are stored in order in the PAFL. As with discourse focus, if the expected actor focus is not confirmed in the next sentence, it is put onto the actor stack AFS.

Problem 2 The condition on animacy of actor focus is a little strange. Its implications will be discussed later, but for now what should be noted is that some extra information has to be used while processing the actor focus stores, making calculations involving actor stores less economical than those using discourse focus stores. Such information could be consulted on creating the stores, or during access, but remains an extra burden on processing. Information on animacy is lexical (or morphological in some languages), not transparent to a focusing algorithm based on purely structural considerations. For further discussion see section 3.4.5.

When the update process is complete then the second sentence of the discourse may be processed, using the stores from the first sentence to provide plausible antecedents for anaphors.

3.2.5 Focus Update Mechanism

The Focus Update Mechanism for all other sentences is more complicated than the rules given for the first sentence of the discourse, since it takes into account previous foci and the number of pronouns in the sentence which has just been processed.

If a sentence contains only one anaphor, its referent becomes the discourse focus of the next sentence. If there are two anaphors, the non-agent anaphor is the discourse focus. Sidner does not make explicit which should be the discourse focus if there are two or more non-agent pronouns. Carter (1987), whose algorithm is substantially based on Sidner's, has the actor focus defined as the agent of the most recent sentence which had an agent and discourse focus as the theme of the most recent sentence which had a
theme. However Sidner (p.c. 1992) states that her intention was that the discourse focus should be maintained if at all possible, so in the case of two non-agent pronouns the one cospecifying the discourse focus continues to be focused. If neither pronoun cospecifies the discourse focus (i.e. both cospecify potential foci) I will assume that focus will shift to the pronoun in theme position, or in the highest position according to the Focus Ordering Mechanism (p. 35).

This results in the following definition:

**Definition (Discourse Focus):**

*If a pronoun in the matrix sentence cospecifies the previous focus, DF, that DF is maintained. Otherwise, discourse focus is the referent of the pronoun in the matrix sentence which is most highly ranked by the Focus Ordering Mechanism.*

Actor focus is simpler to determine:

**Proposal (Actor Focus):**

*The actor focus of a sentence is the agent of the preceding sentence.*

The actor focus must always have an animate referent. Actor focus can be maintained through a sentence where it is not explicitly mentioned with a pronoun. As Sidner (1979 p. 156) puts it: "The Actor focus is the agent in the current sentence ..., if one exists, otherwise, the actor focus remains unchanged.". The previous proposal can be completed as follows:

**Definition (Actor Focus):**

*The actor focus is the agent (i.e. the animate subject) of the current sentence. If there is no agent, the previous actor focus is maintained.*

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5(Sidner 1979 p. 152) "Usually there is no need to confirm an expectation of the actor focus because the actor focus is simply the database element associated with the agent case of the verb" and (1981 p. 223): "In most sentences, the noun phrase in agent position contains a descriptive word or name in the head, and specifies a database element, it becomes the actor focus. But when the noun phrase in agent position is a pronoun, it may cospecify with either the actor focus (if one exists), or a potential actor*. 
Discourse and actor focus are stored in DF and AF respectively. Both these stores contain single items which are a subset of the nominals which Sidner's algorithm can access from previous discourse.

Sidner's algorithm also makes use of two further stores, this time containing ordered lists of nominals, the potential (discourse) focus list (PDL) and the potential actor focus list (PAFL), containing the remainder of the nominals in the matrix sentence.

Definition (Potential Focus List):

*The Potential Focus List contains all the nominals in the matrix sentence except the one which is the discourse focus.*

The PDL is ordered according to the Focus Ordering Mechanism on p. 35. The potential actor focus list (called PAFL) will be assumed to be 'updated analogously' as in Carter (1987 p. 111), according to the Actor Focus Ordering Mechanism (which excludes inanimate nominals).

Definition (Potential Actor Focus List):

*The PAFL contains all animate entities in the matrix sentence except the agent.*

In addition to the matrix sentence, Sidner allows pronouns to access a 'focus stack'; the DFS (discourse focus stack). DFS contains all previous discourse foci but normally only the most recently added item is accessible for pronouns. Whenever DF is changed, its previous value is put into the DFS. There is also a stack for actor foci, AFs, holding previous AF values. The function and justification of the stack will be discussed in section 3.4.4. However, one remark should be made about the actor stack. Because the actor focus need not be explicitly mentioned in a sentence, the actor focus store itself

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6 Carter (1987 p. 111): 'the PDF list consists of representations of every entity mentioned in the current sentence other than the DF itself', Sidner "the phrase which confirms the focus; it is not included in the list because it cannot be a potential focus" (Sidner 1979 p. 85). "...order a potential focus list of all the noun phrases filling a thematic position in the sentence, excluding a noun phrase in agent position and the noun phrase which co-specifies the focus if one exists. The last member of the PFL is the verb phrase of the sentence". However this, Sidner's original definition, assumes that the potential focus list also excludes the actor focus, which was not assumed to be the case in Chapter 4 of her thesis.

7 Sidner (1981 p. 223): "A potential actor is a noun phrase which specifies a database element marked as animate and which does not occur in agent position".
acts like a stack. This means that the actor stack item may be very far back in the discourse. Discourses like the following are licensed:

(10) John once went to Wolverhampton. Mary runs a hospice there. It is a city full of smoking chimneys. She treats victims of the pollution. Still, he remembers it fondly.

Here John, the actor focus of the first sentence, is added to AFs in sentence two, when Mary becomes the AF. In sentence three there is no agent, so Mary is maintained as AF. In sentence four Mary is again confirmed as the actor focus. Finally in sentence five the agent anaphor he is used to pop John from the actor stack, despite the fact that John was last mentioned four sentences back. This facility will be examined further in section 3.4.5.

So the range of available (non-constructed) antecedents consists of nominals from the matrix sentence plus DFS and AFs. Because Sidner adds the extra constraint that for pronoun reference, the stack may only be accessed one layer back,8 I shall from now on assume DFS and AFs to have only one member, the most recent discarded focus.

To illustrate Sidner's focus update mechanism, take the (non-discourse-initial) example below:

(11) He threw it out of the bath and called Mary.

Let us assume that he has been resolved to John, and it to a giant plastic spider. Since the sentence has been fully interpreted, update will commence as follows:

The non-agent pronoun in this sentence is the thematic element it. The discourse focus will therefore be its referent, large plastic spider: DF = large plastic spider.

The agent of this sentence, which also happens to be a pronoun, will become the actor focus: AF = John.

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8See Sidner 1979 p. 89.
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The potential discourse focus list will include all elements in the sentence except the discourse focus:

\[ \text{PDFL}=\{\text{bath, Mary, John}\} \]

\text{PDFL} is ordered by the Focus Ordering Mechanism, which ensures that the agent (John) occurs last.

The potential actor focus list will correspondingly be:

\[ \text{PAFL}=\{\text{spider, Mary}\} \]

Note that the bath is excluded because it is not animate.

The following discourse shows how the contents of the focus stores alter through a typical text:

(12) My friend Caroline knows the most unusual people. She even knows an eccentric millionaire. His mansion is just up the road. He lives with a Jamaican who deals in antiques.

The contents of the stores after each sentence can be compared using a table. Abbreviations will be used for the nominals generated by each of the noun phrases, as follows:

<table>
<thead>
<tr>
<th>Noun phrase</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>my friend Caroline</td>
<td>c</td>
</tr>
<tr>
<td>unusual people</td>
<td>p</td>
</tr>
<tr>
<td>the eccentric millionaire</td>
<td>e</td>
</tr>
<tr>
<td>his mansion</td>
<td>m</td>
</tr>
<tr>
<td>the road</td>
<td>r</td>
</tr>
<tr>
<td>the Jamaican</td>
<td>j</td>
</tr>
<tr>
<td>antiques</td>
<td>a</td>
</tr>
</tbody>
</table>

The discourse progresses as follows:
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My friend Caroline knows the most unusual people. She even knows an eccentric millionaire. His mansion is just up the road. He lives with a Jamaican who deals in antiques.

<table>
<thead>
<tr>
<th>Sentence</th>
<th>DF</th>
<th>PDL</th>
<th>DFS</th>
<th>AF</th>
<th>PAFL</th>
<th>AFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>My friend Caroline knows the most unusual people</td>
<td>p</td>
<td>c</td>
<td>p</td>
<td>c</td>
<td>p</td>
<td>p</td>
</tr>
<tr>
<td>She even knows an eccentric millionaire</td>
<td>c</td>
<td>e</td>
<td>e</td>
<td>c</td>
<td>e</td>
<td>c</td>
</tr>
<tr>
<td>His mansion is just up the road</td>
<td>e</td>
<td>m</td>
<td>c</td>
<td>c</td>
<td>e</td>
<td>c</td>
</tr>
<tr>
<td>He lives with a Jamaican who deals in antiques</td>
<td>e</td>
<td>j</td>
<td>c</td>
<td>e</td>
<td>j</td>
<td>c</td>
</tr>
</tbody>
</table>

The first sentence, being discourse-initial, contains no anaphors. Focus stores are filled by proposing expected foci using the focus ordering mechanisms. The agent (my friend Caroline) is the expected actor focus, and the theme (unusual people) is the expected topic of discussion, the discourse focus. After the second sentence the more usual update mechanism is used. There is only one pronoun present, she, so its referent (Caroline) becomes the discourse focus, displacing the previous discourse focus (unusual people), which is pushed onto the stack DFS. However since Caroline is also the agent of the sentence, she is the actor focus too. The third sentence, like the second, contains just one pronoun, but it is not in agent position — in fact there is no agent in the sentence. This means that the previous actor focus (Caroline) is maintained. The discourse focus becomes the pronominally expressed element, the eccentric millionaire, pushing the previous focus (Caroline) onto the discourse focus stack, where it displaces unusual people. The fourth sentence again contains only one pronoun, in agent position, so actor focus and discourse focus converge on the eccentric millionaire, pushing Caroline into the actor stack.

By the time the fourth sentence has been processed, the nominals from the fourth sentence consist of the eccentric millionaire (e), the Jamaican (j) and antiques (a), however according to Sidner’s algorithm the available antecedents also include Caroline (c), who was both a previous actor focus and a previous discourse focus. There is also the option of constructing a plural anaphor, for instance a continuation could be ‘They keep crocodiles’, so constructed antecedents would include the hypothetical pairing [The millionaire and the Jamaican], or (e & j). There are many other possible constructed antecedents, for instance a subset of the generic antiques as in ‘Some of them are very valuable’.

A theoretical point to be noted here is the great similarity between the Initialisation and Update mechanisms, a similarity which Sidner herself pointed out. It would be economical if a final step could be taken to make both identical.
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Problem 3 The difference between the Initialisation Mechanism and the Update Mechanism lies in the determination of DF. In the Initialisation mechanism DF is always the theme of the first sentence, whereas in the Update mechanism the discourse focus is the highest ranking pronoun. It is hard to see how such different conceptions of DF could be reconciled in one unified update mechanism applicable to all sentences of the discourse. This problem occurs in my own algorithm and remains unsolved.

3.2.6 Sidner’s Focusing Mechanism

For each pronoun in a sentence, the function of the focusing mechanism is to propose an antecedent from the stores DF, AF, PDFL, PAFL, DFS and AFS. No information is used at this stage about whether the proposed antecedent is compatible in number, gender or animacy with the anaphor. The proposed antecedent is then output to other modules of the language processor to be checked for semantic, syntactic and agreement constraints, consistency with general knowledge, etc.9 (I will call this the Ratification Procedure). If these constraints are met, then the proposed antecedent is confirmed as the perceived antecedent for the anaphor under consideration, and the appropriate focus store DF, or AF is updated. If Ratification fails, the algorithm backtracks to choose the second most likely antecedent. These steps are pursued independently for each pronoun encountered. When all the anaphors in a sentence have been resolved, DF, AF, PDFL, PAFL, DFS and AFS are updated.

The Ratification procedure cuts down the number of consultations with expensive processes such as general knowledge inference. As Sidner points out (1979; p. 72, p. 235), it offers such processes a known endpoint, which reduces processing load considerably.

The focusing mechanism has two parts. The first part deals with pronouns in non-agent position, which by default cospecify the discourse focus (DF). The second part deals with pronouns in agent position, which default to the actor focus (AF).

9Sidner p. 150: A prediction succeeds if “...the predicted item meets the syntactic, semantic and inference criteria relevant to the sentence. Syntactic criteria include gender, number and person as well as the disjoint reference computation of Lasnik and Reinhart. Semantic constraints include rules of scope".
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Each part goes through a hierarchy of preferences for the referent of a pronoun. At the top of this hierarchy will always be the focus of the previous sentence. That is, focus maintenance is preferred over focus shifting.

Whenever a pronoun is found, the appropriate set of rules, below, are checked in order. If a particular rule can be applied, this predicts a referent for the pronoun. If the Ratification procedure proves this prediction wrong, the mechanism proceeds to the next rule in the sequence. If the prediction is not at odds with syntactic and semantic information, the process terminates at that rule, and the prediction is confirmed.

Sidner’s algorithms (1979, 1981) follow: I have included both 1979 and 1981 versions: although Sidner (1981) is a later version of Sidner (1979), Sidner (1981) does not explain all the motivations for the changes, and as will be seen, it is far from clear that Sidner (1981) is an improvement on Sidner (1979). Sidner (1983) is omitted, since it serves as a compact summary of Sidner (1979).

Rule for pronoun in agent position:

Sidner 1979 (pp. 147 – 148):

1 **FOCUS SETS:** If there is no DF or AF, try to construct a focus set from all animate antecedents.

2 **BACKWARDS NON-ANTECEDENT PRONOUN:** If there is no DF or AF, assume cataphora.

3 **REGENCY RULE:** If the pronoun is sentence-initial and a member of PDFL was last in the previous sentence, resolve the pronoun to that PDFL member.

4 **DOMINANT DISCOURSE FOCUS RULE:** If DF is more longstanding than AF, choose DF.

5 **POTENTIAL ACTOR AMBIGUITY CONDITION:** If the pronoun could co-specify either AF or one (and only one) animate member of PAFL then it remains ambiguous.

6 **BASIC ACTOR RULE:** Predict A

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I have changed Sidner’s naming conventions in places, though the original wording of the rules is kept where possible.
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7 Plural Condition: If the anaphor is a plural one, and AF is singular, predict AF plus an animate member of PAFL, or plus AFS.

8 Alternative Actor Rule: Take the members of PAFL, one by one according to the ranking given in the Actor Focus Ordering Mechanism.

9 Actor Stack Use: See if the pronoun could cospecify AFS.

10 Discourse Focus Rule: Otherwise predict DF.

11 Conversational Association: If the pronoun is plural and the DF singular predict conversationally associated elements of DF. If the pronoun is singular, and there are several different conversational associations, the pronoun is ambiguous.

12 Alternative Discourse Focus Rule: Try a member of PDFL.

13 Backwards Cospecification: Assume the pronoun is cataphoric.

14 Fail: Pronoun has no cospecifier.

Sidner 1981, p. 230:

1 Recency Rule: When a pronoun is in subject position and is the initial phrase in a sentence, and if a member of the potential (discourse or actor) foci occurs as the last phrase in the previous sentence, test the pronoun for cospecifying with that potential focus.

2 Theme Rule: When the pronoun occurs in an embedded sentence, if the embedded sentence is marked as having a theme that is either DF or AF, test the focus in that theme position as the cospecifier of the pronoun.

3 Potential Actor Ambiguity Condition: If the pronoun could cospecify either AF or one (and only one) animate member of PAFL choose AF but indicate ambiguity.

4 Pronominalized Actor Focus Rule: When the actor focus was last mentioned with a pronoun, choose AF. Otherwise try one of PAFL, but the pronoun use is odd.

5 Plural Rule: If the anaphor is a plural one, and AF is singular, try a generic reading (for non-human AF), then predict AF plus an animate member of PAFL, then all PAFL together, DF and PDFL.

6 Basic Actor Rule: Predict AF.
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7 Alternative Actor Rule: Then the members of Pafl, one by one according to the ranking given in the Actor Focus Ordering Mechanism.

8 Discourse Focus Rule: See if the pronoun could cospecify DF.

9 Alternative Discourse Focus Rule: Try a member of Pdfl.

10 Actor Stack Use: Otherwise predict Afs.

11 Backwards Cospecification: Assume the pronoun to be cataphoric.

12 Fail: Pronoun has no cospecifier.

Rule for pronoun in non-agent position

Sidner 1979 (p. 149):

1 Focus Sets: If there is no DF, predict similar sets as referent for the pronoun.

2 Recency Rule: If the pronoun is first in the sentence and a member of the Pdfl was last in the previous sentence, resolve the pronoun to that member of the Pdfl.

3 Plural Condition: If the anaphor is a plural one, and DF is singular, predict DF plus a member of Pdfl or DFS.

4 Basic Rule: Predict DF.

5 Conversational Association: If several conversationally associated elements of DF can be combined, and the pronoun is plural, resolve it to them. If the pronoun is not plural it is ambiguous. If there is one element, choose it.

6 Discourse Focus Ambiguity Condition: If anaphors co-specify both DF and some member of Pdfl, then take as focus whichever is not in agent position. If both are non-agents, retain DF unless only the element of Pdfl is mentioned with a pronoun, in which case move the focus to that member.

7 Alternative Rule: Go through the members of Pdfl one by one as they are ordered by the Focus Ordering Mechanism.

8 Actor Focus Rule: Otherwise, predict AF

9 Alternative Actor Focus Rule: or a member of Pafl.

11 This rule was not included in Sidner's (1979) final version, but given in Chapter 2 of her thesis, p. 78. This early version of the algorithm was simpler, omitting plural rules for instance. The basic ordering was DF, Pdfl, DFS, and implicit relations to these three.
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10 Backwards Cospecification: Assume the pronoun to be cataphoric.

11 Fail: The pronoun does not have a cospecifier.

Sidner 1981 (p. 230):

1 Recency Rule: When a pronoun is in subject position and is the initial phrase in a sentence, and if a member of the potential (discourse or actor) foci occurs as the last phrase in the previous sentence, test the pronoun for cospecifying with that potential focus.

2 Basic Rule: Default condition: predict DF.

3 Alternative Rule: Then PDFL.

4 Actor Focus Rule: Then AF.

5 Plural Pronoun Rule: If the anaphor is a plural one, and DF is singular, try a generic reading (for non-human DF) then PDFL, followed by AF.

6 Focus Related Item Rule: See if a discourse entity has been related to the focus during the discourse.

7 Focus Stack Use: See if the pronoun could co-specify DFS.

8 Backwards Cospecification: Assume the pronoun is cataphoric.

9 Fail: A cospecifier cannot be found for the pronoun.

3.2.7 Examples to illustrate Sidner’s algorithm

This section will give examples to show the working of each of the rules and some of the interactions between them. The rules will be examined both from the theoretical and empirical point of view. The aim is to omit or alter any rules which are uneconomical, or which conflict with the assumption of incremental processing, while maintaining empirical validity.

Sidner’s agent and non-agent rules will be examined together, since so many of them are related.

Both agent and non-agent pronoun rules terminate with the recognition that the
pronoun may be cataphoric, or have a specifier not related to the focus stores ('non-antecedent pronouns'). However neither non-antecedent pronouns nor cataphora will be covered in this thesis.

The basic ordering

An underlying structure can be distinguished in Sidner's pi-rules: the main preference for agent pronouns is the actor focus \( AF \), and for non-agent pronouns the discourse focus \( DF \). Potential focus lists are considered next, and focus stacks later on. One of the last resorts is to use what I shall call the CONTRA-FOCUS: for agent pronouns the discourse focus, and for non-agent pronouns the actor focus. These simpler rules are diluted with some more complicated constraints involving interactions between focus store preferences, or between focus stores and other information from the matrix sentence or the current sentence. However I first look purely at the underlying basic ordering.

For agent pronouns, Sidner (1979) uses the following preference ordering on focus stores: \( AF, PAFL, AFS, DF \) and lastly \( PDFL \). Sidner (1981) uses a similar ordering, except that \( AFS \) is considered after \( PDFL \). That is, for agent pronouns the default choice is the actor focus, followed by potential actors, after which discourse focus and potential foci are considered as cospecifications.

For non-agent pronouns both the 1979 and 1981 algorithms have the basic ordering: \( DF, PDFL, AF \), followed in 1979 by \( PAFL \) and in 1981 by \( DFS \). It is assumed that the omission of \( DFS \) in 1979 is an error.

There are three points to discuss relating to these basic orderings:


- Whether the stack should be considered before (1979) or after (1981) the contra-focus.

- Why Sidner did not include the contra-focal stack in either set of rules.

The first of these points, why \( PAFL \) was omitted from the non-agent pronoun rules, can
be examined with a suitable example: Firstly, let us work through an example of the resolution of a non-agent pronoun.

To return to a previous example (slightly modified):

(13) I made him throw it out of the bath and call Mary.

Where after update $DF=\text{large plastic spider, } PDFL=[\text{the bath, Mary, John, me}, \ AF=\text{me, } PAFL=[\text{John, Mary}]$, and both stacks are empty.

Supposing we were attempting to resolve a non-agent pronoun in a sentence immediately following (13), the basic order in which to consider the focus stores would be (omitting stacks): $DF, PDFL, AF, PAFL$. That is, cospecifiers would be proposed in the following order: large plastic spider, the bath, Mary, John, the speaker, the speaker (again), then $PAFL$. However $PAFL$ will always already have been considered as $DF$ and $PDFL$, since $DF$ and $PDFL$ encompass all the nominals in the matrix sentence, of which $PAFL$ is a subset. Therefore it will always be unnecessary to consider $PAFL$ for non-agent pronouns. The reverse is not true: taking the case of an agent pronoun, the ordering will be: $AF, PAFL, DF, PDFL$, or: the speaker, John, Mary, the large plastic spider, then $PDFL$. In this case, $AF$ and $PAFL$ only pick out animate nominals in the matrix sentence, so the inclusion of $PDFL$ is important (though it may involve some duplication of effort).\footnote{This occurrence of nominals in several stores, or multiple consideration of the same nominals, is a criticism of Sidner's algorithm which I discuss in section 3.4.1.}

It might be thought that the consideration of $AF$ could be dispensed with for non-agent pronouns for the same reason, but it must be remembered that actor focus need not be explicitly mentioned in a sentence, so considering all members of the matrix sentence does not mean that $AF$ has necessarily also been considered.

Sidner's omission of the $PAFL$ consideration in 1981 can thus be justified.

Let us examine the second question, beginning with non-agent pronouns. Why was the decision made to move consideration of the actor stack until after the discourse foci had been predicted (Sidner, 1981)?
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Finding a suitable example to investigate this question is a complex matter. In order to find a case where the algorithms presented in Sidner (1979) and (1981) disagree on the perceived antecedent for the final agent pronoun, it must be the case that: (a) the agent pronoun to be resolved must be animate, as it should be able to cospecify the actor stack; (b) either the discourse focus or a potential focus must likewise be animate and of the same gender and number as the item on the actor stack and the pronoun to be resolved; and (c) the actor focus must be incompatible with the said pronoun.\(^{13}\)

However, if (b) the discourse focus or potential discourse foci are animate, they will be included in the potential actor focus list, which means that the algorithm will already prefer them to the actor stack, whether the actor stack is considered before or after the discourse foci themselves.\(^{14}\)

It is therefore immaterial whether the actor stack consideration comes before or after the discourse focus consideration. However neither actor stack nor discourse foci can be dispensed with, since in some cases agent pronouns may have inanimate (discourse focus) cospecifiers, while in other cases the only possible cospecifier may be an actor from earlier in the discourse (focus stack).

Having discussed the example of agent pronouns, we can now turn to non-agent pronouns to ask the analogous question: whether DFS should be placed before or after the actor focus stores in the preference ordering, or whether, as for agent pronouns, it is immaterial.

To find out if it is possible to distinguish a preference for AF after DFS, a text needs to be constructed in which both DFS and AF are animate and compatible with the non-agent pronoun being resolved, but incompatible with DF and PDFL. Because PDFL must be incompatible with AF, AF cannot be in the matrix sentence, so the only way to produce a discourse under these constraints is to use an actor focus which has been introduced

\(^{13}\)In addition, to prevent conflict with other focusing rules, DF should not have not been more longstanding than AF and the actor focus should not be pronominalised.

\(^{14}\)Illustration:

(14) John tried to rob a little old lady. Mary summoned Henry to help. He ...

In this example, after the second sentence the focus stores are as follows: AF=Mary, DF=Henry, AFS=John, DFS=the old lady, PAFL=Henry, PDFL=Mary. In order to resolve the pronoun he, the first choice, AF (Mary) fails because of a gender clash, but the PAFL (Henry) succeeds.
previously, but is only implicit in the matrix sentence. An example:

(15) Mary went into the office. Jilly offered her some home-cooked food. It consisted mainly of chilli peppers. John said that hot food would excite her.

Before the final sentence the focus stores are updated to the following:

\[ \text{DF} = \text{home cooked food}, \text{PDFL} = \text{chilli peppers}, \text{AF} = \text{Jilly}, \text{DFS} = \text{Mary} \]

To resolve her, which is a non-agent anaphor, the two alternatives are AF and DFS. Unlike the agent pronoun example, a decision must be made as to which of these is preferred. Here it seems to me that the original discourse focus (Mary) is mildly favoured. That is, the discourse focus stores are all being considered before the actor focus stores.

For this reason I will follow Sidner (1979) rather than (1981) in placing DFS before AF. For symmetry, I will use the analogous ordering for non-agent pronouns, with AFs considered before DF, though as I have explained this decision makes no empirical difference.

The third and final question to discuss is why neither agent nor non-agent algorithms consider both discourse and actor stack. The rule for agent pronouns ignores the discourse focus stack, and the rule for non-agent pronouns ignores the actor stack. This means that there may be cases where pronouns are unresolvable even though suitable cospecifiers exist in the focus stores. Of course, it is unlikely that such cases would arise, but I wish to consider them here in order to decide if the omission was made for empirical reasons.

Firstly, I will consider non-agent pronoun cases:

(16) Mary attended a wedding in Cambridge. The bridegroom was very nervous, so he was glad to see her.

The focus stores after processing the second sentence are:
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DF=bridegroom, PDFL=[], DFS=wedding, AF=bridegroom, PAFL=[], AFS=Mary

To resolve the non-agent pronoun her in (16), they are considered in this order: DF, PDFL, DFS, AF.

However the antecedent Mary is not contained in any of these stores: the algorithm therefore fails to find a referent which seems extremely obvious to a human reader. So Sidner’s algorithm as it stands seems to be too restrictive in forbidding actor stack use for non-agent pronouns.15

It is for the same reason that the anaphor in the final sentence of the discourse in Carter (1987 p. 262) cannot be resolved:

(18) Mary was glad to see John playing. She picked some flowers. She threw them at him. He caught them. He told her that he had left school.

The non-agent pronoun her in the final sentence needs access to the AF, but this is forbidden, hence Carter’s implementation fails to interpret the final sentence.

Turning to agent pronouns, let us see if Sidner’s predictions hold out for discourse focus stack inaccessibility.

(19) There was a toy tractor in the shop window. Mary went in to have a look at it. She felt sad. It reminded her of the farm where she used to live.

State of focus stores before resolving the anaphor it in the final sentence:

AF=Mary, PAFL=[], AFS=[], DF=Mary, PDFL=[], DFS=toy tractor

15 However there are cases where not having access to the stack does work:

(17) Mary went down to Cambridge for a wedding. It is a beautiful town. John used to paint watercolours of it in the Spring. But it is too crowded now. The bride was glad to see her.

The focus stores after the penultimate sentence will stand as follows:

DF=Cambridge, PDFL=[], DFS=[], AF=John, PAFL=[], AFS=Mary

To resolve her, they will be considered in this order: DF, PDFL, DFS, AF.

Sidner’s algorithm cannot resolve the final her to Mary, the AFS. This seems to accord with intuition, as it is difficult to resolve the anaphor in the final sentence without rereading the text or using an anaphoric proper name, despite the tense clues.
In order to resolve the anaphor it, the stores are considered in this order: AF, PAFL, AFS, DF, PDL. None of these stores contains the necessary cospecifier. Yet the above discourse seems very acceptable.

As a solution I will include contra-stacks in the basic ordering.

Problem 4 However (17) suggests that further investigation needs to be made of stack behaviour. It may also be the case that bringing actor and discourse focus closer together would resolve some of the problems. For instance, allowing discourse focus to be implicit too might eliminate the need to consider the stack so often, or removing the possibility of having an implicit actor focus might make accessing the stack universally necessary. For further discussion, see section 3.4.5.

Preliminary Focus Considerations

In both Sidner (1979) and Sidner (1981) the basic ordering is preceded by some exceptional cases to be considered beforehand. These will be examined here.

Both agent and non-agent pronouns are subject to a Recency Rule (Sidner 1979, 1981) which allows a sentence-final member of the potential focus list to be most preferred for a sentence-initial pronoun:

Recency Rule (1979): If the pronoun is first in the sentence and a member of the PDFL was last in the previous sentence, resolve the pronoun to that member of the PDFL.

Recency Rule (1981): When a pronoun is in subject position and is the initial phrase in a sentence, and if a member of the potential (discourse or actor) foci occurs as the last phrase in the previous sentence, test the pronoun for cospecifying with that potential focus.

Sidner (1979 p. 144) notes that “The recency rule makes focussing seem somewhat ad hoc”, a comment which is borne out by a close examination of its effects. Carter
(1987 p. 114) found that in an implementation of Sidner's pi-rules its inclusion "led to considerable inaccuracy". He also notes that Sidner herself is inconsistent in applying it.16 Examples Sidner gives (1979 p. 145) are not convincing. (20) is supposed to show the Recency Rule overriding normal focus considerations:

(20) Mary is giving a surprise party at Hilda's house. It's at 340 Cherry Street.

Normal focusing rules would predict the theme, the surprise party, to be the preferred antecedent for the non-agent anaphor it. However, Sidner argues, the more recently mentioned nominal, Hilda’s House is actually more accessible to it, which is sentence-initial. I share Carter's intuition that Hilda's House does not predominate. In fact I believe that the basic focus rule does give the correct choice: the second sentence is about the surprise party, rather than Hilda’s House. However since the party is at her house, this accounts for why it is automatically inferred that Hilda’s House is at 340 Cherry Street also.

Carter omits the Recency Rule, without detriment to his pronoun resolver. I propose to do the same.

A second preliminary rule which is applied to both agent and non-agent pronouns is the rule for Focus Sets (1979). This is, however, not included in Sidner's (1981) algorithm. The rules Sidner gives are:

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FOCUS SETS (AGENT PRONOUN): If there is no DF or AF, try
to construct a focus set from all animate antecedents.
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FOCUS SETS (NON-AGENT PRONOUN): If there is no DF, predict
similar sets as referent for the pronoun.
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16"Sidner ... states conflicting conditions of application on different occasions; e.g. subject position [1979, p144]; sentence-initial [1979, p147]; subject position and sentence initial and second sentence of text [1981, p230]." (Carter 1987 footnote p. 114)
The point of both these rules is to cater for the cases where instead of anaphora occurring, a new referent is introduced. Sidner’s illustration of focus sets, reproduced from 1979 (p. 76), is:

(21) John and Mary sat on the sofa and played cards. Henry read a book. At 10pm they went to Joey’s Bar to hear a new rock group.

The second sentence in this discourse contains no anaphora at all. It is not discourse-initial, and should not be treated as such, since the pronoun they in the third sentence anaphorically refers to both Henry and John and Mary.

The Focus Set rule is intended to ensure that the second sentence is detected as triggering such a summation before John and Mary go out of focus. Because Henry occurs in agent position in the second sentence, Sidner includes the focus set rule for this situation in the agent pronoun rules. However there is no pronoun to trigger the pi-rules at all, so it is doubtful that such a rule is very useful. Sidner’s important insight is that the preferences for summation somehow follow the order of preferences for pronoun resolution.

Sidner’s (1979) Focus Set rules also call for the absence of actor and discourse foci, which I presume refers to the likelihood of the sentence having no pronouns at all. However summation can occur when pronouns are present:

(22) John sat on the sofa and browsed through a magazine. Henry tried to read it over his shoulder. At 10pm they went to Joey’s Bar to hear a new rock group.

Sidner (1981) deals with summation in a slightly different way. This will be discussed later on under Plural Rules, where some possible ways to resolve the problem are suggested.

In 1979 the basic ordering is preceded by a rule which allows DF to sometimes take precedence over AF (Dominant Discourse Focus Rule). In 1979 and 1981 an ambiguity is noted if the pronoun could cospecify both AF and one member of PAFL (Potential
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Actor Ambiguity Condition). In 1981 the first rule is a Theme Rule, and the second a Pronominalised Actor Focus Rule which gives the actor focus extra prominence.

The implications of these rules will now be discussed in order to decide whether they should be preserved for use in this thesis.

The Dominant Discourse Focus Rule (1979) states that under certain conditions DF may actually be preferred for agent pronouns:

| DOMINANT DISCOURSE FOCUS RULE: | If DF is more longstanding than AF, choose DF. |

An example would be: 17

(24) I haven’t seen Jeff for several days. Rupert saw him yesterday. He was in the pub.

After the first sentence Jeff is established as the discourse focus. (The AF is the speaker). The second sentence confirms him in that role, and introduces a new AF, Rupert. In resolving the agent pronoun he in the final sentence, the Dominant Discourse Focus Rule states that the discourse focus, Jeff will be preferred over the actor focus, Rupert, since Jeff was introduced first. Even in contexts designed to favour Rupert, this preference seems robust:

(25) I haven’t seen Jeff for several days. Rupert saw him yesterday. He is pretty good at spotting people.

17 This is derived from the example Sidner gives (1979, p. 152-3):

(23) I haven’t seen Jeff for several days. Carl thinks he’s studying for his exams. Oscar says he’s sick, but I think he went to the cape with Linda.

Although Jeff is the discourse focus, this example does not provide a test of the rule under question, since there are no agent pronouns – Sidner’s focus ordering mechanism (p. 68-69) describes the direct object, here him, of a complement verb, as the theme. However see also the discussion of the Theme Rule (p. 58).
This example seems to induce backtracking, with Jeff being rejected through general knowledge considerations, rather than not being considered at all.\footnote{I do acknowledge that my intuition may be challenged here; it is unlikely that I really have access to my own mental processes in such detail that I can detect backtracking. This would have to be tested experimentally.}

**Problem 5** The main problem with the Dominant Discourse Focus Rule is how 'longstandingness' could be measured. Here I was assuming a simple criterion based on number of sentences ago (along the lines of early Recency focusing algorithms like that of Hobbs 1978). However density of reference might well have an effect, as well as other factors like use of names rather than role descriptions (Sanford, Moar and Garrod 1988). The data set of this thesis includes no way of distinguishing the date of generation of a cospecifier, and such a dating is not a natural product of any other process. This will have to remain a problem to be reconsidered in the final version of the focusing algorithm developed in chapter 5.

For the moment, the Dominant Discourse Focus Rule will remain a problem, and will be excluded from the list of rules, since information about the age of nominals was not among that I assumed on p. 24 to determine antecedent preferences. Sidner (1981) also omits the rule, for reasons not given.

The related preliminary consideration introduced by Sidner (1981) is the Pronominalized Actor Focus Rule:

**Pronominalized Actor Focus Rule:** When the actor focus was last mentioned with a pronoun, choose AF. Otherwise try one of PAFL, but the pronoun use is odd.

The main function of the Pronominalized Actor Focus Rule is to cast doubt on the cospecifier for an agent pronoun being one of PAFL when AF is pronominalised, as in the following example:

(26) John is quite romantic. He gave Bill a book of poems. He ...
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However choosing a member of PAFL, Bill, does not seem particularly odd to me. It should be contrasted with a case where the actor focus (the agent of the previous sentence) is not pronominalised:

(27) Bill is quite romantic. John gave him a book of poems. He ...

Although it seems the potential actor focus Bill is more preferred in this case than in (26), this seems more related to the fact that Bill was a previous discourse focus, than the fact that John is not pronominal. To eliminate this, consider:

(28) John gave Bill a book of poems. He ...

I see no profound difference between the preferences in this example and in the analogous pronominalised version:

(29) John went to visit Bill. He gave him a book of poems. He ...

Although the empirical evidence is not entirely clear, there still seems little justification in introducing a Pronominalized Actor Focus Rule which mimics the preference orderings of the basic rules which are already established.

In Sidner (1981) the first preliminary consideration is the Theme Rule:

**THEME RULE:** When the pronoun occurs in an embedded sentence, if the embedded sentence is marked as having a theme that is either DF or AF, test the focus in that theme position as the cospecifier of the pronoun.

As it stands, this rule is difficult to comprehend. However Sidner illustrates it very clearly (1981 p. 223) with the following example:

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19 There are several reasons why the rule is hard to understand. First it implies we are considering a pronoun in an embedded sentence — thus we must be able to store syntactic/semantic subordination of this type, as well as thematic information, in order to resolve anaphors. Then we assume that the theme of this sentence has already been found and, if pronominal, possibly resolved to the discourse or actor focus. Then it appears to assume that part of the update process has already been carried out, and that the theme-position pronoun can itself provide a focus store which is tested first for the pronoun now being resolved. Hence what is being considered is an intrasentential (maximal sentence) connection, rather than a connection between sentences. However this connection occurs only within the embedded sentence, so it should strictly be part of the syntactic cospecification restrictions.

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I haven't seen Jeff for several days. Carl thinks he's studying for his exams. But I think he went to the Cape with Linda.

The pronoun in the third sentence is the agent of the embedded sentence, however the Theme Rule is introduced to override this, treating he as the theme of the entire sentence instead. This brings the classification of pronouns (as agent or non-agent) in line with the expected foci (agent or theme). The Focus Ordering Mechanism given on p. 35 overrules the default choice of theme for the discourse focus in the case of verbs with complements, in which case the object of the sentence (i.e. the subject of the embedded sentence) becomes the expected discourse focus.

So in the example above, he, being a non-agent anaphor (effectively it is treated as the theme), will be resolved to Jeff, the discourse focus, in preference to Carl, the actor focus.

It seems to me, therefore, that what is needed is not a special Theme Rule for pronouns, overriding the normal focus store preferences, but a redefinition of what it takes for a pronoun to be resolved by the 'agent pronoun rules' or the 'non-agent pronoun rules'.

The algorithm could do with either (a) a definition of agent which includes only the actor of the main clause or (b) another term instead of 'theme' which picks out the aspects necessary to qualify as 'expected discourse focus'.

Problem 6 This raises the whole issue of thematic definitions yet again, and also highlights the need to define a 'sentence', in order to determine whether an embedded sentence should itself contain an agent, theme and independent thematic ordering, or whether thematic roles should be generated by the main verb entirely, avoiding the occurrence of more than one 'agent' position. These questions will be discussed again on page 96.

I will next examine the function of the Discourse Focus Ambiguity Condition for non-agent pronouns, which was described in Sidner (1979 p. 79) but omitted from the final version of her algorithm (except for possessives, which I do not cover here).
Discourse Focus Ambiguity Condition: If anaphors co-specify both DF and some member of PDFL, then take as focus whichever is not in agent position. If both are non-agents, retain DF unless only the element of PDFL is mentioned with a pronoun, in which case move the focus to that member.

This rule deals specifically with a case where a pronoun\(^{20}\) is ambiguous and could refer to either DF or a potential focus. Two scenarios are suggested, one where neither of the competing antecedents is in agent position (31), and one where one of them is in agent position (33).

(31) John bought a bottle of Belgian banana beer. He locked it into the cupboard. But in the morning somebody had stolen it.

When resolving the pronoun *it* in the third sentence, it can specify either the DF, the bottle of Belgian banana beer, or the potential focus the cupboard. Sidner states that the DF is preferred unless *only the potential focus is mentioned with a pronoun.* However the discourse focus will always have been mentioned with a pronoun, by definition, so it will always be favoured. The exception is the first sentence of a discourse, where the discourse focus is the theme:

(32) John locked a bottle of Belgian banana beer into the cupboard. But in the morning somebody had stolen it.

However in order for the potential focus member to have been mentioned with a pronoun, hence overriding the default preference for discourse focus, a previous context must have occurred. Therefore the set of circumstances which would override the DF preference cannot occur.

The second scenario contrasts antecedents with agent versus non-agent roles:

(33) The nurse was very friendly. She gave Mary a glass of whiskey. The doctor threw her out of the hospital.

\(^{20}\)Sidner tells me (p.c. 1992) that what she had in mind was a case where a pronoun was competing with a definite noun phrase, but I shall ignore this contingency as I am not concerned with noun phrases, and this rule is listed as a pronoun interpretation rule.
Here Sidner predicts that whichever antecedent has the non-agent role will be preferred for a non-agent pronoun — that is, Mary will be preferred over the nurse, contrary to the basic focus ordering. It is not clear to me that this is the case. In the following example the preference will be reversed:

(35) The nurse was very friendly. Mary gave her a glass of whiskey. The doctor threw her out of the hospital.

Here Sidner predicts that the preferred antecedent, as in the basic ordering, is the DF, the nurse, followed by the PDFL, Mary.

To me the basic ordering does seem to give the correct answers, so there are no very strong grounds for including this rule either.

The last preliminary rule, which occurs in both Sidner (1979) and Sidner (1981) is the Potential Actor Ambiguity Condition.

1979 Potential Actor Ambiguity Condition: If the pronoun could cospecify either AF or one (and only one) animate member of PAFL then it remains ambiguous.

1981 Potential Actor Ambiguity Condition: If the pronoun could cospecify either AF or one (and only one) animate member of PAFL choose AF but indicate ambiguity.

The idea is that under these conditions an ambiguity will register with the hearer. In (1981) Sidner has a slight preference for the actor focus, but still argues that ambiguity should be apparent.

21 Though contexts can clearly bias it:

(34) The nurse was very friendly. She gave Mary a glass of whiskey. It almost knocked her out. Here the act of giving is unlikely to have resulted in partial loss of consciousness, hence excluding the nurse from consideration. The preference does seem a little fragile: even compatible but less likely continuations seem open to bias (e.g. Nobody could work out where she had got it from).

22 The preference for the nurse over Mary does not appear to be as strong here as in (33), perhaps due to interference from a subject or agent preference. This effect will be mentioned again at the end of Chapter 5.
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Let us look at an example from Sidner 1979 (p. 153):

(36) John called up Mike yesterday. (a) He wanted to discuss his physics homework. (b) He was studying for his driver’s test.

Both continuations (a) and (b) seem very plausible. (a) is marginally more likely as a continuation, I feel.23

Were this rule omitted, the basic ordering would give the same preference ordering. So the only justification for preserving this rule would be if hearers genuinely did have difficulty resolving anaphors where general knowledge could not disambiguate; if, in running text, people failed to jump to a conclusion about the antecedent.

The second sentence in the following example is equally applicable to either antecedent:

(37) John called up Mike yesterday. His mother had died.

However it is uneconomical that after accessing $AF$, a second store, $PAFL$, should be searched for rival cospecifiers. There is also the extra constraint that there must be only one rival cospecifier, so the entire $PAFL$ must be ratified, hence violating the requirement that only one choice should be considered at a time. I shall therefore drop the reference to ambiguity and assume that Sidner’s basic ordering can cope adequately with such examples. The basic ordering favours John over Mike.

Rules involving focus-related cospecifiers

Sidner (1981, 1979) also intersperses the basic ordering with two rules which allow what I have called focus relations. This section has two purposes; firstly I will examine these rules individually, then the overall place of focus relations in the ordering will be discussed.

23 This was also found by Stevenson, Crawley and Kleinman (1991) in experiments which showed a significant subject/agent bias for antecedents generated by proper names over those generated by definite noun phrases.
In Sidner (1979), a Plural Condition for agent pronouns is considered after AF but before PAFL. Sidner (1981) has a different Plural Rule which is encountered before AF. These plural conditions deal with focus preferences when the pronoun to be resolved is plural and hence has the ability to cospecify two or more of the foci of previous sentences by summation.

Similar rules apply also to non-agent pronouns: in 1979 consideration of DF is preceded by the Plural Condition, but in 1981 the Plural Condition occurs directly after considering AF.

The Plural Conditions (1979) are as follows:

**Plural Condition (agent pronouns):** If the anaphor is a plural one, and AF is singular, predict AF plus an animate member of PAFL, or plus AFs.

**Plural Condition (non-agent pronouns):** If the anaphor is a plural one, and DF is singular, predict DF plus a member of PDFL or DFS.

The Plural Rules (1981) are:

**Plural Rule (agent pronouns):** If the anaphor is a plural one, and AF is singular, try a generic reading (for non-human AF), then predict AF plus an animate member of PAFL, then all PAFL together, DF and PDFL.

**Plural Pronoun Rule (non-agent pronouns):** If the anaphor is a plural one, and DF is singular, try a generic reading (for non-human DF) then PDFL followed by AF.

So, the plural rules are only applicable if the pronoun to be resolved is plural but the basic focus (AF for agent pronouns, DF for non-agent pronouns) is singular. When this
situation occurs, Sidner offers various possibilities of summing focus stores to obtain a possible antecedent.

In 1979 such combinations include focus plus a potential focus, and focus plus focus stack. In 1981 a generic reading may be obtained from the basic focus (but only if it is non-human). In addition to focus plus focus stack combinations, Sidner (1981) also allows all potential foci together, and also the contra-focal combinations of focus and potential foci (p. 230).

It is not clear exactly which combinations are permitted, or how they are ordered, except that the focus plus potential focus combination is preferred above the rest.

The role of the pi-rules is to predict which combinations are most likely, so that they can be tested for plausibility by the Ratification procedure. It can therefore be left to the Ratification procedure to ensure that there is a higher level property (e.g. animacy) shared by all conjuncts, which distinguishes them from other NPs in the sentence.24

The role of the focusing algorithm is simply to propose an order in which various combinations are tested.

It is important that Sidner’s algorithm can suggest all and only the combinations which are permitted by discourse structure, and that these are ordered by priority.

Appendix II contains various plural combinations, including those suggested by Sidner. Plural anaphors are tested both in agent position and in non-agent position. However it appears there is no real effect of thematic position. It is beyond the scope of this thesis to examine all the possible combinations, but a pattern does begin to emerge; practically any combination between or within focus stores seems to be possible. The combinations which seem most difficult are those between focus and one member of the potential focus list. This is rich data, in need of further investigation.

Since there is no difference in the pattern of possibilities for agent and non-agent pronouns, this suggests that Sidner’s proposals for plurals are too limited, since they confine themselves almost completely to preferred focus combinations rather than

24The requirements for conjunction are discussed in Lang (1984).
contra-focus combinations.

For now I shall assume that all combinations of stores are possible, with constraints being entirely determined by ratification. However, as regards ordering it would still make sense if combinations including the focus (focus change) were preferred to those excluding it (focus shift).

However when considering where the plural rules should occur relative to the basic ordering, it appears that plural combinations, even those containing focused items, are considered after all other possibilities of focus stores.

\[(38) \quad \text{John hit Mary with a bunch of feathers. They were always rubbing each other up the wrong way.}\]

Here the simple coreference relation to a member of the PDFL (the feathers) is preferred to summation on the AF and DF (John and Mary).

Sidner's 1981 rules also allow generic reference for non-human antecedents. She considers only plural generics: "They (mammals) suckle their young", not singular generics "The mammal suckles its young." The generic ('non-specific reading') rules are mingled with plural combination rules, though the generic is usually a relation to a single antecedent.

As for plurals, generic formations from all six focus stores are illustrated in Appendix II, in both agent and non-agent position. An example is given here:

\[(39) \quad \text{The dogs rushed into the bakery. They are carnivorous. (Dogs in general)}\]

The data from Appendix II shows that generics are possible in both agent and non-agent positions. However, agent generics are preferred.

Sidner constrains generics to non-human entities but it may be possible to obtain generic readings for some human groups:

\[(40) \quad \text{John consulted a psychoanalyst. They earn massive amounts of money treating people like him. (Psychoanalysts in general)}\]
CHAPTER 3. TWO ALGORITHMS FOR LOCAL FOCUSING

However it is certainly not possible to generalise over proper names:

(41) John consulted Mary. *They earn massive amounts of money treating people like him. (?Marys in general)

It is also impossible to obtain generics from pronominalised individuals, even when non human:

(42) A dog came in. It ate six pancakes. They have no morals.

To me, this example suggests a strong preference for pancakes, despite the absurdity of such a reading. The final anaphor they accesses the set created by the introduction of the indefinite, rather than its specific continuation in the second sentence. In other words, the generic pronoun is accessing not the DF store, but the discourse focus stack. Pronouns seem not to have a set automatically associated with them.

As Sidner (1981, p. 225) points out, generics only seem possible when “the speaker wants to turn attention to the non-specific reading” of a noun phrase — a reading that is not possible with proper names. However generics are also possible to construct from definite noun phrases:

(43) John sued the psychoanalyst. They earn massive amounts of money maltreating people like him. (Psychoanalysts in general)

Because it is impossible to obtain generics with proper names and easiest with clearly ‘typed’ or ‘stereotyped’ individuals or groups, it seems that a generic must refer to a set which has been explicitly evoked by the antecedent phrase. The reason for this is given in Chapter 6, p. 268.

It is possible to combine the summation and genericity relations:

(44) The cat and the dog growled at each other. They are traditional enemies. (Cats and dogs)
So as far as the focusing algorithm is concerned, any set associated with the focus stores is accessible for generic reference.

Ordering of generic relations in the focusing algorithm should be more straightforward. The most economical procedure would be to consider generic reference immediately after each focus store is considered for coreference relations. In this way, the contents of the stores would already be salient and accessed, and it would simply be necessary to perform a further inference on them.

And indeed the data suggests that unlike summed plurals, generic plural anaphora seems to be considered as a possibility in the normal focus progression. In the following example the pronoun to be resolved is ambiguous between a discourse focus generic and a potential focus simple plural:

(45)  A bulldog broke into my house yesterday. They often attack my friends. They have no morals whatsoever.

Here although they in the final sentence could access the plural my friends, the generic bulldogs, which is focused, is preferred.

Priorities between summation and generic relations are not so clear:

(46)  John is taking his cat to meet Mary. They like being sociable.

Whether the pronoun they in this example is more likely to refer to John and Mary (and John's cat?) or to cats is not obvious. I have a preference for the plural reading, but I am not sure whether this would pass experimental scrutiny.

Another rule involving focus relations is the rule of Conversational Association (Sidner 1979) which occurs after DF is considered but before PDFL. This does not appear in the rules for agent pronouns in Sidner (1981). Conversational Association occurs between DF and PDFL in 1979, but in 1981, after AF.
1979 Conversational Association (agent pronoun): If the pronoun is plural and the DF singular predict conversationally associated elements of DF. If the pronoun is singular, and there are several different conversational associations, the pronoun is ambiguous.

1979 Conversational Association (non-agent pronoun): If several conversationally associated elements of DF can be combined, and the pronoun is plural, resolve it to them. If the pronoun is not plural it is ambiguous. If there is one element, choose it.

1981 Focus Related Item Rule (non-agent pronoun): See if a discourse entity has been related to the focus during the discourse.

Sidner qualifies these rules a certain amount (1979, p. 148–150):

"Because of the nature of the hierarchical network which includes a representation of the focus, there are many elements associated with the focus ... However, for purposes of pronoun co-specification, none of these associations may be co-specifications for pronouns unless explicitly mentioned in the text."

What she had in mind was an example like the following (p.c. 1992):

(47) We are going to have a big dinner at my house. John will be the cook. Mary will do the baking. He's going to help her with the invitations. My job is to decorate and set the table.

The first sentence sets the scene, with the big dinner being the discourse focus. In the second and third sentences, Sidner argues, John and Mary (in addition to their function as actor foci), are specially marked as associated with the DF, the big dinner. This means that rather than triggering the initialisation mechanism because they contain no anaphors, these sentences can be assumed to maintain the previous discourse focus. In
the fourth sentence the pronouns he and she can access the focus-related items John and Mary, rather than popping the actor stack.

Sidner’s 1979 rules give more detail, but do not account for the references in example (47), but the 1981 rule seems incomplete. What is needed is similar to the rules for focus sets: firstly, conversationally-associated elements must be stored as such. This relation cannot be part of the pi-rules, since conversationally-associated elements are not introduced pronominally. Secondly, the pi-rules must be adapted to access these conversationally-associated elements from this separate store, if considering reference to the DF itself has failed.

In her 1981 algorithm, Sidner only allows elements to be associated with the discourse focus, not the actor focus. It is difficult to imagine entities associated with an actor, rather than a situation, which are not possessively marked. The focus-related rule is also considered sooner in 1979 than 1981. Whether the 1979 rules or the 1981 rules are most accurate cannot be determined without a clearer definition of what makes a particular noun phrase ‘associated’ with a previous noun phrase. It is important that the rule does not become too powerful: the more coherent a discourse, the more sentences tend to share referents and implicit links with the discourse topic. Too many nominals could then be ‘conversationally related’, bypassing the function of the basic focusing algorithm.

(47) can also be interpreted using the actor stack and actor focus/potential foci. Without further evidence either way, I shall assume that discourses can be interpreted without need of a focus-related item rule, and therefore abandon the focus-related item rule.

Having considered three types of focus relations, summation, genericity and conversational associations, it should be possible to generalise to other types of focus relations, such as generic membership and subset.

(48) Several cats were sunbathing on my papers. One of them was black.

Here it is uncertain whether it is one of the cats or one of the papers that is black, but
it is likely that the same preference ordering applies here as for ordinary pronominal anaphora.

Analogous examples can also be found using generic one-anaphora:

(49) Cats calm frayed nerves. John has one.

This example displays an ambiguity: generic one-anaphora applies to either cats or frayed nerves, though it is less likely that John should have one frayed nerve than a cat. As for ordinary generics and 'one of them' subset relations, these cases fall under the basic ordering.

The conclusion on focus-related pronominalisation is that, in all cases except for summation, preferences follow the basic ordering, with a focus relation preferred over coreference to a potential focus.

3.2.8 Summary: Sidner Modified

The previous sections have thoroughly examined Sidner's focus rules, removing each rule which is superfluous or inconsistent with the desiderata I have laid down for a theory of focusing.

What is left is the basic ordering, including contra-focal stacks, as follows:

For agent pronouns consider the focus stores in the following order: AF, PAFL, AFS, DF, PDFL, DFS; for non-agent pronouns the order is: DF, PDFL, DFS, AF, AFS. If the pronoun cannot be resolved to any of these, try summing stores including the focus, excluding the focus, finally try generics.\(^{25}\)

The Initialisation and Update mechanisms have been preserved unchanged.

This simple version of Sidner's algorithm makes what I believe to be correct predictions for all the examples so far discussed except (24), which raised Problem 5: the observation

\(^{25}\)The exact preference ordering for the plural/generic choices has not been finalised in this thesis.
that a discourse focus which was introduced before the actor focus is preferred for agent pronouns, contrary to the basic ordering.

Remaining criticisms mainly concern the algorithm’s lack of parsimony. Firstly there are two foci in a discourse, defined very differently, but requiring that nominals are remembered in two sets of stores, depending on their thematic roles and the animacy or lack of animacy of their referents (Problem 2). Pronouns are resolved according to their thematic positions, which are ill-defined (Problem 1). There are two separate mechanisms for filling stores, one of which is only activated after the first sentence of a discourse, and one which is used in all subsequent sentences (Problem 3).

In addition, problems were noted with the stack, which were temporarily overcome by introducing the possibility of accessing the contra-stacks (Problem 4). To deal adequately with such problems calls for a more complex account such as that offered by Grosz and Sidner (1986), Polanyi and Scha (1984) or Scha and Polanyi (1988).

Problem 3 will serve as a touchstone for the incremental algorithm to be developed in Chapter 5.

However Sidner’s algorithm provides a detailed and efficient mechanism for the resolution of pronominal anaphora. Its main flaw is in having separate rules for agent and non-agent pronouns, a result of the discourse/actor focus distinction, but herein lies a large amount of its success also.

### 3.3 Centering

#### 3.3.1 Centering and focus

The Centering Algorithm (Joshi and Weinstein 1981; Grosz, Joshi and Weinstein 1983 and Brennan, Friedman and Pollard 1987) incorporates two determinants of antecedent preferences. The first of these is focus, the second is grammatical role. These authors, in contrast to Sidner, recognise only one focus of discourse. It may be subsequently referred to pronominally, though it may also be non-pronominally anaphoric. They also
allow focus to shift to other nominals introduced in the matrix sentence.

Brennan, Friedman and Pollard (1987) define focus as:

Definition (Focus):

The focus (backwards-looking center) is the highest ranking nominal from the previous sentence which is also referred to in the current sentence. In discourse initial sentences the focus is set to NIL.\(^{26}\)

Ranking is defined in terms of grammatical role, with subject ranking first, followed by object, indirect object, prepositional object and so on.

(50) John put a box of matches on Mary's head. She rattled it.

So the box of matches is the focus of the second sentence in (50).

If John had been mentioned in the second sentence, then John would have been the focus. However only the two referents Mary and box of matches did occur in the second sentence, and since a box of matches is syntactically higher ranked than Mary in the first sentence, it is designated the focus of the second sentence. This uniquely defines a focus for every sentence. The exact process by which this is determined will be described in the next section.

3.3.2 The Centering algorithm

The Centering algorithm has three stages. The first, construction, builds up the entire space of possible anaphoric connections and focus assignments. The second stage uses filters to constrain this space to just a few possibilities, which are then ranked.

There are four types of focus transition; continuation, retention, shift-1 and shift (which I will call radical shift). They are given below in decreasing order of likelihood:

Continuation The focus of the current sentence is the same as it was the sentence before, and in subject position.

\(^{26}\)Walker, Iida and Cote (1990) treat focus as a variable in the first sentence.
Retention The focus of the current sentence is the same as it was the sentence before, but some other item is in subject position.

Shift-1 the focus of the current sentence is different from the previous focus, but appears in subject position, so the new focus will probably be continued.

Radical shift the focus of the current sentence is different from the previous focus, and not in subject position, so the new focus is likely itself to be shifted in the next sentence in favour of the subject.

So consideration of the focus stores and grammatical placings allows Brennan, Friedman and Pollard (1987) to put a ranking on focus transitions similar to those arising from the use of preference algorithms like Sidner's.

The main purpose of the algorithm is to determine which member, if any, of the nominals in the matrix sentence is the focus. Brennan, Friedman and Pollard (1987) use two focus stores: DF, which contains the focus of the previous sentence, and PDFL:

Definition (Potential Discourse Focus List):

\[ \text{PDFL contains the list of nominals mentioned in the previous sentence, ordered by grammatical role: subject, object, indirect object, etc.} \]

The first element of PDFL is the expected focus of the next sentence, whether or not it is the current focus. Brennan, Friedman and Pollard's PDFL differs from Sidner's in that it includes the element which was the focus, rather than excluding it.

The three mechanisms, Construction, Filtering and Ordering will be illustrated with respect to the following example:

(51) She (Mary) gave John an azalea. He keeps it by his bed.

Mary is the focus of the first sentence. We will examine how the algorithm applies to the second sentence.

Construction
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a. Create a list sentence-NPs of all the NPs occurring in the current sentence. Order sentence-NPs by grammatical role.

Current-sentence='He keeps it by his bed'
Sentence-NPs=[he (subj), it (obj), his (prep)]

b. Take the subset anaphors of sentence-NPs.

anaphors=[he, it]

c. Take the list of potential antecedents from the previous sentence, PDFL, ordered by grammatical role.

previous sentence='Mary gave John an azalea'
PDFL=[Mary (subj), azalea (object), John (indirect obj)]

d. Create a list-of-lists containing all possible combinations of bindings of the anaphors to antecedents (members of PDFL), taking into account agreement constraints

list-of-lists=[ [he=John, it=azalea] ] (just one member)

e. Create a list possible-foci of possible foci from the previous sentence. Possible-foci will contain all the members of PDFL plus NIL, the empty focus.

possible-foci=[Mary, azalea, John, NIL]

f. Create a list of anchors combining all possible pairings of possible-foci with the lists in list-of-lists. In other words, each anchor will contain a possible-focus and a list of pairs, anaphor-bindings

anchors=[ [Mary, [he=John, it=azalea]], [azalea, [he=John, it=azalea]], [John, [he=John, it=azalea]], [NIL, [he=John, it=azalea]] ]

Filtering

For each anchor the following three filters are applied.

a. Filter by contraindices. That is, eliminate anchors in which two anaphors which are syntactically forbidden from being co-referential have the same antecedent.

delete: [<focus>[he=X, it=X]]
No change — anchors=[ [Mary, [he=John, it=azalea]], [azalea, [he=John, it=azalea]], [John, [he=John, it=azalea]], [NIL, [he=John, it=azalea]] ]

b. Take the first element of PDFL which appears as an antecedent of one of anaphors in the anchor. If this is not the same as the possible-focus, then eliminate the anchor.

delete: [X[he=Y, it=Z]], [X[he=Y, it=X]]
Removing all [X[he=Y, it=Z]]:
anchors=[ [azalea, [he=John, it=azalea]], [John, [he=John, it=azalea]] ]
Removing anchors in which possible-focus is not the highest member of PDFL occurring in the proposed antecedents of the anchor:
PDFL=[Mary, John, azalea]
anchors=[ [azalea, [he=John, it=azalea]] ]
If one or more of the anaphors is a pronoun, but the possible focus is not recalled pronominally, eliminate such an anchor.

\[ \text{anaphors} = \{ \text{he, it} \} : \text{more than one pronoun, but the possible-focus is recalled with a pronoun, therefore OK.} \]

**Ranking**

a. Rank the anchors. The one with the highest score is chosen. Its possible-focus and sentence-NPs become the DF and PDFL of the next sentence.

\[ \text{DF} = \text{Mary, possible-focus=azalea, subject of current sentence=} [\text{John}] \]

Therefore this sentence produces a radical shift (DF ≠ possible-focus, possible-focus ≠ subject of current sentence)

N.B. azalea will hence be the DF when the next sentence comes to be processed, but the highest ranking member of PDFL will be John.

From these illustrated examples it can be seen that the centering algorithm neatly captures the preference for focus maintenance. It also incorporates the tendency of the focus to take subject position in a sentence.

However pronoun resolution in example (51) was actually completed by Step (d) of the Construction Rules — the sentence was completely disambiguable using agreement constraints.

A second example, which was used to illustrate Sidner's algorithm, will be chosen to illustrate the behaviour of the Centering algorithm when faced with ambiguous pronouns.

(33) The nurse was very friendly. She gave Mary a glass of whiskey. The doctor threw her out of the hospital.

Let us simply concentrate on the resolution of the pronoun *her* in the final sentence. The DF at this point is the nurse, and PDFL are [nurse, Mary, glass, whiskey]. The anchors produced will be:

(a) [nurse [...her=nurse ...]]

(b) [Mary [...her=Mary ...]]

The anchors with a different possible-focus and antecedent were eliminated by the second
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filter, which ensures that the focus of each sentence is actually an item which occurs within it.

The two anchors will be classified as follows:

(a) is a retention, because DF, the nurse is maintained as possible-focus, but does not occur in subject position.

(b) is a radical shift, because not only is DF not maintained in possible-focus, but possible-focus does not even occur in subject position.

Therefore (a) will be chosen over (b) — the nurse will be the preferred antecedent.

So where agreement constraints do not disambiguate a pronoun, the Centering algorithm can give a preference ordering on potential antecedents.

Let us consider finally the case where the ambiguous pronoun is not in focus position (i.e. less highly ranked than another pronoun). The DF this time is Bill.

Bill found a kitten on his doorstep. He gave it some milk.

(52) Bill found a kitten on his doorstep. He gave it some milk.

Construction

a Create a list sentence-NPs of all the NPs occurring in the current sentence.

b Order sentence-NPs by grammatical role.

c Take the subset anaphors of sentence-NPs.

d Take the list of potential antecedents from the previous sentence, PDFL, in grammatical order.

e Create a list-of-lists containing all possible combinations of bindings of the anaphors to antecedents (members of PDFL), taking into account agreement constraints

```
current sentence='He gave it some milk'
sentence-NPs=[he, it, milk]
sentence-NPs=[he (subj), milk (object), it (indirect obj)]
anaphors=[he, it]

previous sentence='Bill found a kitten on his doorstep'
Potential antecedents=[Bill (subj), kitten (obj), doorstep (ppnp)]

list-of-lists=[ [he=Bill, it=kitten], [he=Bill, it=doorstep] ]
```
Create a list of possible-foci of possible foci from the previous sentence. Possible-foci will contain all the members of potential antecedents plus NIL, the empty focus.

Create a list of ANCHORS combining all possible pairings of possible-foci with the lists in list-of-lists. In other words, each anchor will contain a possible-focus and a list of pairs, anaphor-bindings.

Filtering
For each anchor the following three filters are applied.

a Filter by contraindices. That is, eliminate anchors in which two anaphors which are syntactically forbidden from being co-referential have the same antecedent.

b Take the first element of PDFL which appears as an antecedent of one of anaphors in the anchor. If this is not the same as the possible-focus, then eliminate the anchor.

c If one or more of the anaphors is a pronoun, but the possible focus is not recalled pronominally, eliminate such an anchor.

Ranking
Rank the anchors. Choose the highest ranking anchor.

BILL, [he=Bill, it=kitten] DF=Bill, possible-focus=Bill, subject=Bill

BILL, [he=Bill, it=doorstep] DF=Bill, possible-focus=Bill, subject=Bill

Both these anchors suggest a continuation.
Unfortunately the two remaining anchors are equally ranked, so there is no way to resolve the anaphors in (52). The focus is clearly Bill, but the algorithm has no way to choose between kitten and doorstep as the antecedent of it. This example gives rise to the following observation:

**Problem 7** The Centering algorithm cannot resolve all ambiguous pronoun references, only the one in focus position.

### 3.3.3 The Centering algorithm rewritten as a processing model

In order to compare the Centering algorithm with Sidner's it must be converted into procedural form. This section attempts to do this.

The algorithm as it stands is very far from usable as a serial processing model, for the following reasons:

- Interpretation is not incremental; all pronouns in a sentence are considered at the same time. At present the Centering algorithm cannot resolve any pronouns until the whole of the sentence has been read or heard. Several of the rules involve second passes over the sentence (e.g. the third filter).

- The scoring of anchors should emerge as an epiphenomenon of the preference choices, as it does in Sidner's algorithm. i.e. only the first choice anchor should need to be constructed at all.

- It is psychologically implausible that so many arrays of possibilities could be constructed or remembered (complexity is multiplied the more pronouns in a sentence, the more nominals in the previous sentence, and the more agreement ambiguities there are).

The main reorganisation will be to deal with the third of the above points and to make the algorithm much more economical in the possibilities it considers. Basically,
it should only need to produce one anchor, the final decision on pronoun resolution for
the sentence under consideration.

I also propose, to bring it in line with Sidner’s algorithm, to delay the first
filter (syntactic) until after an antecedent has been proposed for an anaphor (until
Ratification). An alternative is discussed in section 5.7. Similarly, the initial assigning
of anaphors to antecedents will not be mediated by agreement features; agreement
constraints also will be left for Ratification.

The second of the filters will be moved to the beginning to constrain the possibilities
from the start.

The third filter can be omitted for the moment since I am not considering non-
pronominal anaphora.

The refined centering mechanism

In this version of Centering, as in Sidner’s algorithm, once a prediction has been made,
other modules of the language processing system are activated to check for number
or gender clashes and also check syntactic coreference. The algorithm backtracks if
necessary to abandon its prediction and try the next resolution rule.

As soon as the algorithm succeeds it resolves the specified pronoun to the specified
antecedent, and the antecedent becomes the new DF.

1. The centering algorithm uses the store DF and also the store PDFL, consisting of all
   the other potential antecedents from the matrix sentence except the focus, ordered
   by grammatical role.

2. Take the first anaphor in the current sentence (ordered by grammatical role).

3. Try to resolve it to the DF. If this succeeds, it is a Continuation (DF is maintained
   as focus of the current sentence).

4. If this fails try to resolve one of the other anaphors to the DF (This is a retention).
5. Try to resolve the first anaphor in the current sentence to the highest member of PDFL, ordered by grammatical role. (This is a shift-1).

6. If this fails, try to resolve one of the other anaphors to the highest member of PDFL. (This marks a radical shift).

7. Cycle through the last two rules for the second highest member of PDFL, then the third highest, and so on.

This algorithm is still not sufficient for full incremental focusing, that is, to resolve pronouns one by one. It still requires several passes through the sentence, until an antecedent is found which can be the antecedent for either the first anaphor in the sentence (preferred), or one of the others. The algorithm resolves one pronoun only, that which is to provide the focus for the succeeding sentence. All other pronouns are simply resolved using agreement constraints:

Definition (Agreement mechanism):

*Cycle through all unresolved pronouns: for each, cycle through PDFL to find a list of possible antecedents which agree with it in number, gender and animacy. If this list contains only one element, resolve the pronoun to it; otherwise, the pronoun remains ambiguous.*

As was shown for (52), these two algorithms are not sufficient to resolve non-focus-position pronouns.

The centering mechanism is illustrated, as before, for the following example:

(51) She (Mary) gave John an azalea. He keeps it by his bed.

a The centering algorithm uses potential antecedents from the matrix sentence, ordered by grammatical role, and the store DF.

<table>
<thead>
<tr>
<th>PDFL</th>
<th>DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mary (subj), azalea (obj), John (indirect obj)</td>
<td>Mary</td>
</tr>
</tbody>
</table>

b Take the first anaphor in the current sentence (ordered by grammatical role).

<table>
<thead>
<tr>
<th>current sentence</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>He keeps it by his bed.</td>
<td>he</td>
</tr>
</tbody>
</table>
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c Try to resolve it to the DF. If this succeeds, it is a Continuation (DF is maintained as focus of the current sentence).

d If this fails try to resolve one of the other anaphors to the DF (This is a retention).

e Try to resolve the first anaphor in the current sentence to the first member of PDFL, ordered by grammatical role. (This is a shift-1).

f If this fails, try to resolve one of the other anaphors to the first member of PDFL. (This marks a radical shift).

The same result is obtained as was obtained in the original Centering algorithm. The revised algorithm differs from the first in that is even less able to resolve all the anaphors in a sentence: part of this capability is passed to a separate Agreement Mechanism. Otherwise, it produces identical results with somewhat less effort.

A second example will be given, as before:

(52) Bill found a kitten on his doorstep. He gave it some milk.

Assuming Bill is the DF of the first sentence, the algorithm will proceed as follows:

a The centering algorithm uses PDFL from the matrix sentence, ordered by grammatical role, and the store DF.

b Take the first anaphor in the current sentence (ordered by grammatical role).

c Try to resolve it to the DF. If this succeeds, it is a Continuation (DF is maintained as focus of the current sentence).

As before, this text is judged to involve a continuation.

This example shows that the highest ranked focus transitions will actually take less effort to process. Were the above algorithm being put forward as a psychological model
it would actually make predictions in line with the psycholinguistic evidence noted by Van Dijk and Kintsch (1983), Guindon (1985) and others.

Although all the examples given have had a pronoun in subject position in the sentence being processed, the Centering algorithm does not demand that, say, for a Continuation, the focused element be in subject position — it only need be the highest grammatically ordered pronoun in the sentence. Thus examples like the following are still continuations rather than retentions:


A masculine singular pronoun in the next sentence would still be resolved to the DF (Darren) rather than the first member of PDFL (John). This means that the slight interference of the subject antecedent in (35) is as much a problem for Centering as for Sidner’s algorithm.

(35) The nurse was very friendly. Mary gave her a glass of whiskey. The doctor threw her out of the hospital.

Here, I pointed out in footnote 22, it seems that the presence of the nominal Mary in subject position reduces the focus-maintenance preference.27

For a retention, the focus of the current sentence is the same as it was the sentence before, but some other pronominal item is in subject position.

**Summary of the Centering algorithm**

The point of the Centering algorithm is to find the focus of the current sentence, given the preferences for particular types of transition. The Centering theory is irrevocably focus-based, not anaphor based, which means it cannot be incremental. That is,

27Compare:

(33) The nurse was very friendly. She gave Mary a glass of whiskey. The doctor threw her out of the hospital.
pronouns at the beginning of the sentence may not be resolved until the whole sentence has been processed. Moreover, only the anaphor about to be focused is ever resolved. Resolution of other anaphors relies on disambiguation by agreement characteristics. The sole purpose of the algorithm is to detect where the focus has moved to.

The Centering algorithm is rather simpler than Sidner's algorithm; it uses fewer focus stores and fewer rules, though unfortunately this simplicity extends also to its coverage of data. A point by point comparison of the two algorithms is made in the next section.

### 3.4 Comparison of the two algorithms

This section will pick out the main features of both focusing algorithms for a conceptual comparison. Examples will examine the implications of the differences.

#### 3.4.1 Conceptions of local focus

Both algorithms have a notion of focus as a distinctly salient one-element store preferred above other less salient antecedents for the antecedent of a pronoun. Sidner's version is called 'discourse focus', while Brennan, Friedman and Pollard (1987) refer to the 'backward looking center' of an utterance. The focus of a sentence is, very crudely, an information link between that sentence and the one before.

The consequence is that a noun phrase mentioned for the first time cannot provide the focus of the sentence in which it occurs. For Sidner's algorithm the exception is if that noun phrase is introduced in the first sentence of a discourse. Centering, on the other hand, allows the focus to be set to NIL.

For each sentence, focusing algorithms give an ordering on preferences for anaphors.

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28Illustrative quotes: Grosz, Joshi and Weinstein (1983 p. 45) "Cb(S) [the backward looking center, or focus of the sentence S] serves to link S to the preceding discourse", Brennan, Friedman and Pollard (1987 p. 155) "The backward center is a confirmation of an entity that has already been introduced in to the discourse". Later, they state that it can take the value NIL but do not say when or how the algorithm functions in such cases — in fact at the moment such anchors are always ruled out except possibly if there are no NPs in the current sentence. However Sidner's actor focus can be something newly introduced.
in the following sentence, but can never rule out future reference to any NP in that sentence. It cannot be predicted in advance which nominal or nominals will be foci of the next sentence.

(54) Mary ran down Brighton Pier. A man smiled at her.

For example (54), both algorithms will choose as focus Mary, since Mary is the only item of information in common between the two sentences. But Brighton Pier could equally well have been the focus:

(55) Mary ran down Brighton Pier. It is a ramshackle thing nowadays, daubed in white paint and creaking under the weight of two hundred different forms of potted entertainment.

A small difference does emerge here, since Sidner’s algorithm chooses Mary as the actor focus of the first sentence, it will be remembered for reference in the sentence after, while the Centering algorithm has no way to recall an antecedent once it has failed to be accessed in the sentence following its introduction. Centering could not resolve the anaphor she in the following continuation:

(56) Mary ran down Brighton Pier. It is a ramshackle thing nowadays, daubed in white paint and creaking under the weight of two hundred different forms of potted entertainment. She headed joyously for the helter skelter.

The differences between the two algorithms emerge even more strongly when looking at sentences with more than one item of information in common.\(^{29}\) For instance

(57) Mary likes John. But he doesn’t like Mary.

Sidner’s algorithm chooses the pronominalised item, hence John is the focus. Brennan, Friedman and Pollard’s algorithm, on the other hand, takes the focus to be the

\(^{29}\)It is to be remembered that the differences regarding preferences are not yet at issue.
grammatically highest ranked item in the previous sentence, Mary. Their algorithm actually censures this discourse, because unfocused nominals (John) are not supposed to be pronominalised unless the focus is pronominalised, which it is not. Brennan, Friedman and Pollard (1987) suggest that this is not a hard-and-fast rule. However the following example does seem less acceptable:

(58) Mary waved to John. But he didn’t notice Mary.

It is my feeling that Sidner’s algorithm gives the correct prediction here. A second example shows how the algorithms differ in their views of focus:

(59) Mary likes John. But he doesn’t like her.

After this discourse, according to Sidner’s algorithm, John will be the actor focus and Mary will be the discourse focus. So Sidner gives the second sentence two foci. Brennan, Friedman and Pollard (1987) give it only one — Mary (since Mary is in subject position in sentence one, Mary is highest ranked). It is acceptable that John is pronominalised since the focus is pronominalised.

My intuition is that Mary is the focus here, as suggested by the Centering algorithm. John is perhaps a secondary focus.

It was shown in section 3.3.2 that the Centering algorithm is unable to resolve all anaphors in (52):

(52) Bill found a kitten on his doorstep. He gave it some milk.

Let us see how Sidner’s algorithm deals with this example. After the first sentence DF will be set to the theme, the kitten, and AF to the agent, Bill. The PDFL will include

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30It also assumes that the anaphor he is first assumed to have Mary as antecedent, John only being found after backtracking. Stress always seems to suggest that the antecedent is not DF but a member of PDFL. This case conforms with this rule.

31Although it seems there is a change in point of view which is disturbing, imagining continuations Mary still seems the most natural subject of them.
first the doorstep, then Bill, while the PAFL contains simply the kitten. This means that the agent anaphor he will be resolved immediately to the actor focus Bill, and the non-agent pronoun it immediately to the discourse focus the kitten. The Centering algorithm, as was seen in section 3.3.2 resolves he to Bill unproblematically (all other antecedents are eliminated by agreement constraints), but cannot decide between the antecedents kitten and doorstep for it. So an example which is problematic to the Centering algorithm is straightforward for Sidner’s algorithm to resolve. After the second sentence, the ‘center’ is Bill, but for Sidner the main (discourse) focus is the kitten, with Bill as actor focus. So the algorithms differ not only in their resolution processes, but also in what they regard the text to be about: for the Centering algorithm the second sentence concerns properties of Bill, while for Sidner it is a sentence concerning the kitten, with Bill the main actor.

In contrast, let us take an example which was problematic for Sidner’s algorithm, to see how the Centering algorithm would cope with it.

(24) I haven’t seen Jeff for several days. Rupert saw him yesterday. He was in the pub.

Sidner’s problem here is that her algorithm (assuming the basic ordering) predicts Rupert for the antecedent of the final he, whereas her intuition is that Jeff is actually the preferred antecedent. To overcome this she proposed a Dominant Discourse Focus Rule, which allowed the discourse focus Jeff to be preferred over the actor focus Rupert for this agent pronoun, in the case of the discourse focus being more longstanding than the actor focus. I omitted the rule from the final version of her algorithm, arguing that the rule was difficult to implement and not consistent with the general form of the algorithm.

The Centering algorithm, on the other hand, predicts that sentence three is a straightforward continuation, with Jeff, the focus, being retained as antecedent for he. Therefore Sidner’s intuition is captured by the Centering algorithm and not by her own.

From these examples it is clear that focus is regarded very differently by the two
algorithms.

The main contrast between the two algorithms is not their differences in predictions, but their overall aims. Sidner’s algorithm, though presented as a focusing algorithm, is anaphor-centred. Its main aim is to resolve pronouns, with the focus maintenance preference as an outcome of the layout of the algorithm. The Centering algorithm, on the other hand, is completely focus-based. Its main aim is to ensure the conservation of previous foci, and the resolution of the focused anaphor is a result of this. As I pointed out earlier, Centering can provide no mechanism to distinguish between compatible antecedents for non-focused anaphors (see example (52)).

In Sidner’s algorithm, the discourse focus is deduced from anaphoric reference to it in the next sentence. The relevant anaphor is almost always pronominal. Sidner (1979) declares that “Pronouns reflect the element in focus; since the pronoun contains little lexical information, whatever it takes as antecedent must be the focus of the previous sentence” (p. 60).

This is illustrated in (60), where both actor and discourse focus are shifted despite no new referents having been introduced:

(60) John saw Mary in the station concourse. He waved to her. But she walked straight past him.

In the second sentence the resolution of the anaphors is unproblematic. The algorithm predicts unerringly that *He* resolves to *John* and *her* to *Mary*. Using the above update rules, *John* becomes the actor focus and *Mary* the discourse focus after the second sentence has been processed. However when it comes to the third sentence, the algorithm proceeds as follows: the initial choice for resolving *she* is onto *John*, which fails due to a gender mismatch. There are no potential foci (members of PAFL or PDFL), so as a last resort the discourse focus *Mary*, is chosen. Resolving the pronoun *him* is similar: the algorithm starts by predicting the discourse focus and is eventually forced to use the actor focus *John*.

If the update rules above are applied, *Mary* then becomes the actor focus and *John*
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the discourse focus. Two focus shifts will have occurred.

**Problem 8** This inability to hold onto old values of the focus is a flaw of the anaphor-based algorithm, since it is uneconomical to have to reassign the stores, and causes redundancy in the stacks, as was seen in example (12).

This is a problem Sidner does not seem to address, in fact she implies that there is only ever one focus shift which has to be made in the update process:

(1981 p. 221), "...the updating process moves one of the foci to a new element of the discourse, if some anaphor co-specified with that new element while no anaphor co-specified with the phrase already in focus" and (p. 223) "which of the two foci moves depends on whether the pronoun fills the agent case in the verb frame". This insistence on only one focus move is not echoed on p. 221 "The machine updates the discourse and actor foci after each sentence and changes foci when the anaphoric expressions no longer co-specify with the element in focus". The strength of an anaphor-based algorithm is that it can incrementally resolve all anaphors in a sentence. However occurrence of nominals in several stores, or multiple consideration of the same nominals, cannot be prevented.

In the Centering algorithm, the focus is also pronominal, but is determined partly by the value of the previous focus, and partly by grammatical role. This allows the focus to be maintained in (60). However the major flaw of a focus-based theory is that it is not incremental and cannot ensure that all pronouns are resolved. The strength of a focus-based algorithm is that maintenance of store values can be monitored. Brennan, Friedman and Pollard (1987) claim that recognising four kinds of focus transitions gives Centering an advantage over Sidner's algorithm. Although Sidner's algorithm also favours focus maintenance (DF or AF are preferred to potential foci), it only partly reflects a subject bias. Sidner's partial recognition of this constraint can be seen in her definition of the actor focus as the agent (i.e. usually the subject) of the preceding sentence, even when such an element is not pronominal. This means that subject non-pronominals can be preferred to non-subject pronominals, for agent pronouns.
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3.4.2 Focus Update Comparison

When a sentence has been processed, the contents of the focus stores must be altered to give the new possible antecedents for the next sentence. Both algorithms work on a sentence-by-sentence basis, and hence can be regarded as updating when a sentence is completed.

Centering updates as follows: the new DF is the possible-focus of the sentence which has just been processed. PDFL is the list of all other noun phrases in that sentence. These are the only stores used. Unlike Sidner's focus updating, determination of focus emerges out of the resolution process.

Sidner's updating mechanisms are only partially given in Sidner (1979, 1981):

"The Actor focus is the agent in the current sentence . . . , if one exists, otherwise, the actor focus remains unchanged" (Sidner 1979 p. 156). In contrast, "the [discourse] focus becomes whichever anaphor is not in agent position" (Sidner 1979 p. 162). If there is only one pronoun in the sentence, it must be the discourse focus of the next sentence, even if in agent position: "Given an actor focus, anaphora in agent position are not used to retain or to move the discourse focus, as long as other anaphora occur in the discourse" (Sidner 1979 p. 156, my emphasis).

Overall, the Centering algorithm has a more satisfactory update process, partly because it emerges from the algorithm itself, and partly because it is simpler and better defined.

3.4.3 Ordering

Both algorithms put an ordering on the potential focus list PDFL. In the Centering algorithm, this ordering is by grammatical role. In Sidner's algorithm, it is partly by thematic role and partly by linear order (the algorithm for determining order is given on page 35). The order is slightly different for agent as opposed to non-agent pronouns. The difference is not that large, both approximate to linear order in English.

\[\text{In the original Centering algorithm there was also an ordering on sentence-NPs.}\]
Carter refers to ordering within focus lists as 'weak' (as opposed to 'strong' ordering between focus stores). However psycholinguistic evidence suggests that the preferences are real. Significant preferences for antecedents with agent or goal roles, over those with patient or source roles, have been found by Stevenson et al. (1990); Stevenson, Crawley and Kleinman (1991). The 'subject maintenance' effect is also well documented by such people as Smith and Foos (1975) and many others, who found a significant preference for subject position antecedents over object position antecedents. Since subject and agent do not necessarily coincide, it can be established that these are both preferences in their own right.

Thematic and grammatical role of antecedents are not the only 'weak' ordering on potential focus lists which have been studied. It has also been found that causal effects of verb (Caramazza et al. 1977), choice of sentence conjunction, linear order of mention (Gernsbacher and Hargreaves 1988), whether an antecedent is a proper name or a definite noun phrase (Sanford, Moar and Garrod 1988) and syntactic structural parallelism (Frazier et al. 1984; Nelson, Stevenson and Stenning 1992) can all influence the choice of one antecedent over another. It may be that a constraint satisfaction model would be needed to determine the ordering of potential focus lists in a more realistic focusing algorithm.

So although I shall assume a particular ordering I shall not regard that choice as vital to this thesis; I only assume that there is an ordering, however determined.

3.4.4 Stack Behaviour

Some difficulties were pointed out with Sidner’s use of the focus stack (Problem 4). That is, part of the definition of the actor focus permitted it to act like a stack in the case where there are no animate agents in intervening sentences. No equivalent stacking was defined for the discourse focus. This only serves to underline the awkward differences between Sidner’s two focus stores, which will be discussed in section 3.4.5.

However, ignoring the stack-like capacity of the actor focus for now, Sidner’s algorithm does allow pronouns to access antecedents last mentioned prior to the matrix sentence.
By contrast, the Centering algorithm only allows access to the matrix sentence, though Brennan, Friedman and Pollard (1987) do acknowledge that a minority of pronouns may be dealt with by global focusing mechanisms (p. 156).

Hobbs (1978) found that 98% of antecedents for pronouns are taken from the current or matrix sentence, but the remaining 2% must be accessed from previous context (p. 345). He found no particular limit on how far away these contextual antecedents could be. Lesgold, Roth and Curtis (1979) found evidence that accessibility of antecedents from previous context was enhanced when they were previous foci, whereas antecedents which had never been focused were extremely difficult to access.

Since the Centering algorithm incorporates resolution of non-pronominal anaphora, omission of some kind of focus stack capabilities seems rash. Definite noun phrase anaphora is far more likely to be used for unfocused antecedents than for highly focused antecedents, as was shown by Guindon (1985). However the Centering algorithm assumes that all anaphors prefer the DF as an antecedent. The only concession made to the use of pronouns for DF, is that when DF is not pronominally accessed, no other anaphor in the sentence may be pronominally accessed either. This does permit identification of the focus with pronominal elements to some extent, though other elements may also be pronominal, or else the focus may be accessed using a definite noun phrase.

This means that the Centering algorithm treats (61) the same way as (62).

(61)  Mary hit Bill. Bill cried.

(62)  Mary hit Bill. He cried.

The Centering algorithm treats such examples as similar because it is an algorithm based on anaphors (recalled referents), not just pronouns. Sidner’s pi-rules of course say nothing about (61), and although her rules for full definite noun phrases would allow

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33 Joshki and Weinstein (1981) declare that “We do not drop centers but allow for some of them to be temporarily placed in the background.” (p. 386) but the algorithm described by Brennan, Friedman and Pollard (1987) does not describe such a mechanism.
anaphoric reference to the focus, she has no algorithm for handling resumptive proper names.

3.4.5 Actor Focus

Sidner's algorithm encapsulates two very different ideas of focus. The first is the discourse focus, determined by pronominal reference. The second is the actor focus, determined by thematic role. The discourse focus is always present, but the actor focus is optional and may only surface sporadically. Occasionally actors may also be the discourse focus, but this only happens when no other entity is available.

Although it is easy to criticise the decision to have two completely separate mechanisms for agent and non-agent pronouns, it may be that the actor focus idea does capture some of the experimental data. Perhaps the lack of economy is justified. Is there actually a need to track animate actors through the discourse, and give them special priority? Experiments by Sanford, Moar and Garrod (1988) suggest this. Sanford, Moar and Garrod (1988) found that proper names were definitely preferred for anaphoric reference, over definite noun phrases, and that they were not forgotten over episode boundaries. Kamp (1981) also gave proper names a special role in his 'Discourse Representation Theory', which allowed them to be accessed across semantic boundaries and from within scope domains. However these authors based their theories on a distinction between antecedents referred to by proper names as opposed to (in)definite noun phrases; none of them gave animacy or agency as a criterion of accessibility. But psycholinguistic experiments by Stevenson et al. (1990) have shown that agents are preferred to patients and other thematic roles.

So both agency and animacy have been cited as influencing choice of antecedents, other things being equal, but no experiment has shown that agency/animacy overrides choice of discourse focus for agent pronouns.

The rest of this section will use examples both to provide a rationale for Sidner's choices, and then to question them.

First I will illustrate the use of the actor focus as a stack, one example where agents are
given privileged access over other nominals:

(63) John bought a tandem bicycle last week. It is green with pink spots. He painted it himself.

Sidner's algorithm is designed to cover examples like (63), where the antecedent of the pronoun he in the third sentence is obtained from the first sentence, not from the second where John is not mentioned.

According to Sidner's algorithm the actor focus is simply maintained through the second sentence since no actor focus is explicitly mentioned there.

The Centering algorithm, on the other hand, would suggest a retention had occurred between sentences one and two, and a radical shift between sentences two and three (reappearance of an old focus is classified as appearance of a new referent, due to the lack of a stacking mechanism). The implication is that it is not a very coherent discourse, though acceptable. The Centering algorithm forbids the following example entirely:

(64) John bought a tandem bicycle last week. It is green with pink spots. He likes to show off.

I feel that this text is only acceptable when bridging inferences are made between the second and third sentences. It seems that even a link between the third sentence and previous context (i.e. the first sentence) is not enough to make a text coherent. Thus the preference for anaphoric linkage between adjacent sentences as in (63).

Sidner's algorithm has no trouble with this example, though the update process after sentence three will shift John into discourse focus (in addition to actor focus), so it would take marginally longer to process than (63).

In spite of these advantages, Sidner's actor/discourse focus distinction brings many

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34 This linkage occurs in the great majority of actor focus examples, for instance

(65) The secretary was eating lunch. It consisted mainly of chilli peppers. They made her sneeze. Sidner's algorithm makes no allowances for this.
problems. Here is an example analogous to (63) in which animacy and inanimacy are exchanged:

(66) The stick hit the boy. He was really annoyed. It had ruined his concentration.

The only way to resolve this example would be using the DFS, which for the pronoun it is the last of six possible choices.

However to me, (66) and (63) seem entirely analogous. To suggest that they be resolved using completely different mechanisms is absurd. Both use some kind of a stack which allows focused elements to be retained through sentences which do not mention them.

There are several ways Sidner’s algorithm could be modified to incorporate this intuition: the simplest would be to permit the actor focus to take the value NIL for agent-less sentences.

However this observation is just the first in a series of problems with Sidner’s definition of actor focus. The second problem concerns Sidner’s insistence that the actor focus (i.e. the agent of a sentence) be animate. Take example (67):

(67) John hired three painters to decorate the sitting room. They made it look much bigger.

Here the second sentence has an animate subject, so the three painters are assigned the agent role, and hence become the actor focus after (67) has been processed. This can be compared with (68):

(68) John hung three enormous mirrors in the sitting room. They made it look much bigger.

Because the subject of the second sentence is not animate, it cannot be the agent of the sentence. Focus update after this second sentence would therefore assign the three mirrors to be the discourse focus, keeping John as the actor focus. Retaining John would seem necessary to deal with the following example:
(67a)  John hired three painters to decorate the sitting room. They made it look much bigger. He was delighted.

However John can be equally well retained in the inanimate case:

(68a)  John hung three enormous mirrors in the sitting room. They made it look much bigger. He was delighted.

Again, the intuition is that (67) and (68) are identical for focusing purposes. It could perhaps be argued that the verb make must have an animate subject, therefore the mirrors are being treated anthropomorphically. However if it had only been one mirror, the inanimate pronoun it would have been used, so the question of animacy would become one of opinion, rather than being overtly detectable.

These two examples suggest that perhaps animacy is not a necessary condition for the actor focus, though (69) still seems to support the maintenance of agency as a feature.

(69)  The document caused an enormous furore. It demanded the instant closure of the department store. It castigated the manager of the publicity and drove him to drink. It insulted Mary Cole by referring to her successes as 'flirtations with fame'. She was determined to contest it. Altogether it was most unpopular. For the store, it was a disaster.

In (69) the agent case seems to be taken by an inanimate nominal, agent case being characterised by use of intentional verbs (demanded, castigated, insulted etc.), and appearing in subject role. However it is doubtful whether one could seriously ascribe volition to a document, or to three mirrors. Given that the definitions of 'agent' on which Sidner bases her actor focus invariably involve volition, there are only two options open: either to look for a new definition of 'agent', or not to derive actor focus from thematic relations at all.

Let us examine the first option. It is hard to imagine any common semantic property shared by the mirrors in (68) and the painters in (67). However if Dowty is right
that thematic roles are derived from the verb, both must be filling the same role with respect to the event of making John's sitting room look bigger. It must therefore be part of the lexical entry for the verb *make* that its subject takes agent role. This move has the immense advantage of removing the epistemological quibbles mentioned at the beginning of this chapter (concerning John poisoning his aunt). The hearer's task then becomes one of detecting whether the verb is of the type that has an agent role, rather than estimating whether the subject is animate, or has willed and caused the verbal event.

Verbs which take an agent role are generally held to be in the class which includes *kill, eat, drive, run*. Rather than worrying about whether in any particular case the subject performed these actions unwillingly, unconsciously, accidentally etc., they shall simply be labelled *intentional* verbs, along with *think, tell, believe*, etc.. This allows a new definition of agent:

**Proposal (Agent):**

*The agent will be taken to be the subject of a verb, if the verb is an intentional one.*

Of course, the idea of an 'intentional' verb is just as hard to pin down as the idea of an agent which is 'volitionally and causally' responsible for an event. However I believe it shifts the emphasis to its correct place, since thematic roles are essentially derived from the verb. It will therefore *always* be the case that the subject of verbs like *kill, tell, think* will have agent case, even if the subjects are non-human, non-sentient or even inanimate.

Let us consider the set of verbs which are not *intentional*. This includes such verbs as *be, roll, have, float* and *collapse*. However even these may sometimes seem to take intentional force:
The girl was violent.
John rolled the stone down the hill.
Mary had a hot shower.
They floated the beer barrels down the Rhine.
Martin collapsed the tent.

One way to escape from this predicament would be to give these different ‘senses’ of the words their own lexical entries.

The other solution is simply to abandon the whole enterprise and resort to the second option: that is, to define the actor focus (or even the ‘agent’) simply to be the subject of the sentence, thereby bringing Sidner’s algorithm closer to the Centering algorithm.

But even this would not bring Sidner’s problems to an end. A further problem with the actor/discourse focus distinction is illustrated by sentences containing two non-agent pronouns.

(70) John gave Mary a fur coat. She threw it back at him in a fury.

The algorithm performs as follows:

Output from sentence 1:
\[ DF=\text{fur coat}, \, AF=\text{John}, \, PDFL=[\text{Mary}, \text{John}], \, PAFL=[\text{Mary}] \]

Processing sentence 2:
\[ \text{She (agent pronoun)}=AF=\text{John}: \text{rejected due to gender mismatch.} \]
\[ \text{She}=PAFL=\text{Mary} \]
\[ \text{it}=DF=\text{fur coat} \]
\[ \text{him}=DF=\text{fur coat}: \text{rejected due to animacy mismatch.} \]
\[ \text{him}=PDFL=\text{Mary} \text{ rejected due to gender mismatch.} \]
\[ \text{him}=PDFL=\text{John} \]

Update after the second sentence produces the following allocation to stores: \( DF=\text{fur} \)
coat, $\text{AF}={\text{Mary}}$, $\text{PDFL}=[\text{John}, \text{Mary}]$, $\text{PAFL}=[\text{John}]$, $\text{DFS}=[\text{fur coat}]$, $\text{AFS}=[\text{John}]$.

All pronouns can be successfully resolved. Subsequent sentences may make references to any, or all three, of these pronouns. However the update process will store one in $\text{AF}(\text{Mary})$, one in $\text{DFS}(\text{fur coat})$ and the other in the potential focus lists ($\text{John}$). This means that $\text{John}$ will not be able to be stacked in future, forbidding the following text:

(71) John gave Mary a fur coat. She threw it back at him in a fury. She had just attended an animal-rights meeting. How was he supposed to know?

This problem could be solved by putting $\text{John}$ on one of the stacks, but suppose all three pronouns are ‘stacked’:

(72) John gave Mary a bathing costume. It started to rain. She threw it back at him in a fury.

In this case, since there are only two stacks, whichever referents are stored in $\text{DFS}$ and $\text{AFS}$, one referent will be unavailable by the third sentence.

The alternative is to introduce the idea of multiple foci, and to define focus wholly by anaphora. This alternative will be discussed in Chapter 5.

Given all these problems, it is difficult to see why Sidner introduced the idea of an actor focus in the first place. However it is because she uses two foci that she deals in part with the problem of parallelism.

3.4.6 Parallelism

Parallelism is a phenomenon particularly noticeable in conjoined clauses. It is used to describe cases where one clause is syntactically similar to another. It has often been proposed that in such cases pronoun resolution maps directly from the first sentence to the second, with subject pronouns preferring subject antecedents and object pronouns preferring object antecedents. Theories have been constructed on this principle (e.g.
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Asher (1991) and experiments have been designed to support its use in natural language processing (Frazier et al. 1984; Nelson, Stevenson and Stenning 1992).

Examples adapted from Sheldon (1974) are:

(73)  a. William hit Oliver. Then he slapped Sue.
    b. William hit Oliver. Then Sue slapped him.
    c. William hit Oliver. Then he slapped his face.

In these examples the pronoun is resolved to the antecedent which takes the same (or most similar) syntactic role as it in the preceding sentence. In examples (73), he always resolves to William and him to Oliver. The effect of syntactic parallelism is diminished by reducing the syntactic, thematic or lexical similarity between the two sentences.

Sidner herself (1979 p. 229), as well as Carter (1987 p. 118) believed such findings to be a problem for an algorithm insensitive to syntactic structure. However to some extent her algorithm does capture parallelism. Because she uses two foci each of which prefers different antecedents, and because agents generally take subject position, her algorithm requires no backtracking to process examples (73). In addition, it is not at all clear that syntactic parallelism should override thematic constraints, as illustrated with the following examples from Smyth (1992):

(74)  a. Eric liked Martin but he bored Carol.
    b. Eric liked Martin but Carol bored him.

It would therefore be rash to abandon Sidner’s discourse/actor focus distinction, however inelegant, without some thought on the phenomenon of parallelism.

On the other hand the Centering algorithm, which is based on syntactic rather than thematic orderings, fails to incorporate syntactic parallelism. Although the default is for subject anaphors to prefer subject antecedents, object anaphors behave similarly: there is no mechanism making non-subject anaphors prefer non-subject antecedents.
Kameyama (1986) gave a mechanism for incorporating parallelism into the Centering algorithm for Japanese or English. Her proposal was that when a center is retained, it should occur in the same grammatical position as the previous center. Preferably both should be in subject position. Walker, Iida and Cote (1990) claim that Kameyana's solution is unnecessary, as it is achieved by ranking continuations over retentions. However this ranking only makes subject antecedents more likely than non-subject antecedents for the highest ranked anaphor. As I pointed out in example (53), this does not guarantee that a continuation involves subject to subject movement of the focus:


So neither algorithm can deal completely with parallelism, but Sidner's algorithm is better equipped for it.

3.5 Evaluation of the algorithms

In the introduction to this chapter I recalled the two assumptions of this thesis which the ideal focusing algorithm would comply with. In addition I pointed out the range of data it should ideally cover. This section compares the extent to which each of the algorithms meets these requirements.

3.5.1 Range

Neither of the algorithms covers the range of data completely. They differ in what they can account for, as well as how they account for it. I suggest how the coverage of each algorithm could be extended.

Sidner's algorithm includes a larger range of anaphora than the Centering algorithm. Sidner covers (if thinly) all the phenomena with which this thesis is concerned. Her main algorithm deals with third person pronominal anaphora, including plurals. She incorporates summation and genericity in a limited way, but mentions none of the other
anaphoric relations described in Chapter 2, however I showed in section 3.2.7 how to extend the algorithm to incorporate all the necessary relations. Sidner allows anaphors to have pronoun, indefinite, definite or proper name antecedents.

The Centering algorithm is much less detailed, concentrating entirely on anaphors with antecedents which are pronouns, definites or proper names. There is no mention of plurals or of indefinite antecedents. However it does allow for local focusing using anaphoric proper names, definite noun phrases and epithets as well as pronouns. However it is arguable that anaphoric definite noun phrases should be part of a global focusing mechanism which Centering does not incorporate.

The range of different sentence constructions considered is rather large and uncontrolled in Sidner's case, and minimal in the case of Centering. Neither is ideal, as this thesis deals with a range of constructions which include conditionally conjoined sentences and relative clauses.

Sidner's earlier focus ordering mechanisms hinted at some consideration of syntactic structures (e.g. clefts) which might alter focus preferences, but this is not covered later in the thesis, which concentrates purely on thematic relations without regard to grammatical position. The Centering algorithm avoids such pitfalls by using grammatical orderings, but the papers are illustrated with very few examples, none of which show complex sentential structures.

The dearth of experimental and theoretical data on such complex structures means that in this thesis too syntactic structural effects will receive only the most cursory acknowledgment.

An important point which arises from the consideration of multi-clause sentences is the question of when focus update should take place. Stenning (1978) points out that syntactic and semantic theories of anaphora have entirely neglected cross-sentential anaphora, while attempting to explain anaphoric dependencies across clause boundaries. He argues that this has needlessly impoverished their theories, since conjoined sentences seem to share important properties with adjacent sentences. Recent psycholinguistic experiments seem to have been performed interchangeably with separate or conjoined
sentences, though the type of sentence conjunction (e.g. and, but, full stop) has been shown to affect antecedent preferences in some cases. For instance Stevenson et al. (1990) found that agent antecedents were preferred to patient antecedents both within and between sentences, whereas within sentences experiencer was preferred to stimulus and between sentences stimulus was preferred to experiencer.

Problem 9 Sidner's algorithm is not precise in stating when the focus update process should be applied: whether at the end of any sentence-like constituent, or only at the end of true sentences.35

This problem will be addressed in chapter 4.

3.5.2 Incrementality

It was stated as one of the assumptions of this thesis that pronoun resolution is incremental. That is, processing mechanisms should start as soon as a word is encountered, rather than waiting until a clause or sentence boundary. During the course of this chapter, it was seen that the Centering algorithm could not be expressed completely incrementally. The revised Centering algorithm is an improvement all round on the original algorithm, though both are identical in output. But the revised version still falls short of full incrementality.

On the other hand, Sidner's algorithm, with minor changes, is able to resolve pronouns independently, hence (if wanted) in linear order. Sidner's update mechanism, however, is completely non-incremental; it is assumed to take place at the end of the sentence.36

In the Centering algorithm the determination of focus is incremental in that a second pass through the sentence is not required to know which item is to be stored in DF.

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35 This is noted by Carter 1987 p. 119, who points out that Sidner treats as a sentence a line containing of two clauses conjoined with but on Sidner (1979, p. 53), whereas on Sidner (1979, p. 213) a similar construction is divided over two lines and updated separately.
36 Presumably if thematic positions like that of agent had already been interpreted, an actor focus at least could be found quite early on in the sentence — however due to the continued use of the AF store, such knowledge would have to be stored separately, so attempting to make Sidner's update incremental would not be very economical. Sidner (1979) seems to have intended the choice of discourse focus to be one result of resolving a non-agent pronoun, but this cannot in fact be determined so simply, since there may be more than one non-agent pronoun.
Sidner appears to assume that semantic and syntactic constraints can be applied incrementally — that is, the Ratification procedure which includes the implementation of such constraints is applied after an antecedent for a pronoun is suggested, rather than after completion of the sentence. This is in contrast to the approach used by Centering, where the syntactic coreference restrictions are applied to the whole sentence after antecedents have been proposed for all the pronouns.

For an incremental focusing algorithm it would clearly be necessary to impose syntactic and semantic constraints on anaphora as soon as possible, though this does not necessarily mean incomplete sentences should be parsable or semantically interpretable. Some ways to express such constraints incrementally are expressed later in this thesis (syntactic: Chapter 5, p. 181 and semantic: Chapter 6).

3.5.3 Economy

In terms of minimising processing effort the Centering algorithm is clearly more economical. It is more parsimonious, with only one set of rules, not two, and only two stores to be remembered between sentences. However quantity of information which must be stored between each step of the algorithm can be relatively large. The revised algorithm represents an extremely economical alternative.

Sidner's algorithm tends to be uneconomical, with six focus stores and two large sets of rules involving much repetition. However many of the 1979 and 1981 additional rules were deleted because the amount of extra information about antecedents which also have to be stored was not justified by the effect of the rules.

Some of the complexity of Sidner's algorithm is due to its ability to resolve several anaphors in a sentence, so it is not entirely fair to set the two algorithms against each other in this respect. It was suggested that summation would require access to different types of memory about discourse events in addition to the purely discourse structural,

\[37\text{However this contradicts her later claim (1981 p. 221) that her algorithm has 'end of sentence processing', by which she means that pronouns are not interpreted until the entire sentence has been syntactically and semantically interpreted.}\]
but this would also have applied to the Centering algorithm, had it dealt with similar data.

My original ideal, to cover both intra- and extra-sentential anaphora in the same algorithm, is not reached by either algorithm. To be fair, it is not attempted, either. Both algorithms determine possible antecedents for anaphors first, then impose a syntactic mechanism to dispose of any unwanted coreferentiality. Neither algorithm allows for the case where a referent introduced in the current sentence may be accessed by a pronoun later in that sentence. This is a major flaw, if it is considered the role of a focusing algorithm to resolve all anaphors, as Sidner clearly does. An extension to her algorithm in which the focus stores are augmented with intrasentential candidates (Carter 1987), is discussed in section 5.5.

Both algorithms are fairly economical in terms of the information they use for resolving anaphora; they concern themselves mostly with focusing effects, leaving connections with syntax, semantics or general knowledge to a minimum. A small amount of information is required in addition to the focusing hierarchy: the Centering algorithm used gender, number and animacy as well as grammatical role to decide on antecedents. Sidner is particularly successful in making the maximum decision possible before resorting to other modules; she uses purely thematic information. But it does not take much adjustment to give the Centering algorithm the same kind of autonomy.

3.6 Summary

This chapter has supplemented the range of examples considered by both algorithms. A number of problems have been noted as a result: the Centering algorithm was found insufficient to account for much of the data. Sidner's algorithm fared better but faced problems especially concerning the definition of actor focus. Experimental evidence (Guindon 1982; 1985) suggested that local focusing algorithms should concentrate on pronominal reference, that not all antecedents are available in the matrix sentence (Hobbs 1978), and that preferences within focus stores were not due to a single criterion like grammatical or thematic role.
It was found impossible to create an incremental version of the Centering algorithm. This is not only in conflict with the goals of the thesis, but is not supported by experiments by Norris (1982) and others who found on-line word by word reference resolution, and Tanenhaus, Carlson and Seidenberg (1985) and others, who found that referents were at least assigned before the end of a clause.

The only experiments actually based on Sidner's algorithm were carried out by Guindon (1982; 1985) who showed using probes for memory recall, that referents in focus (as defined by Sidner's focus stores) were significantly more easily accessed by the use of a pronoun than a definite noun phrase. Guindon (1982) had previously showed, using the same methods, that referents not in focus were significantly easier to access by a definite noun phrase than a pronoun. Much more precise experiments are needed in order to distinguish between Sidner's and other alternative local focusing algorithms. But no evidence has yet been found contradicting Sidner's basic assumptions.

In summary, Sidner's algorithm appears throughout to fit the evidence better. In terms of incremental processing it is far superior to either of the Centering algorithms. In addition its coverage is greater, it can resolve more pronouns, and it has been extended to include intrasentential anaphora. The only property it loses out on is economy.

For this reason I propose to adopt Sidner's general philosophy as a basis for a new algorithm which overcomes the flaws in Sidner (1979) and Sidner (1981).

Achievements:

- I argued in favour of a simplified version of Sidner's algorithm which dispensed with the special case rules of the original, on the grounds that the simplified version covered most of those special cases adequately.

- I showed that the Centering algorithm could be simplified too, but not enough to guarantee incremental pronoun resolution. I showed that the algorithm could only resolve one pronoun in each sentence.

- Sidner's algorithm was found on the whole to fit my needs better, and to cover more of the empirical data available.
Chapter 4

A Representation for Focusing

In the last chapter I reduced Sidner’s algorithm to its basic ordering. However, because of the thematic orderings she imposes, and the computational format of the algorithm, it is very hard to gain an overall impression of the constraints it imposes on the discourse as a whole. In chapter 1 pragmatics was described as the study of the interaction between context and language. In the particular branch of pragmatics called focusing, the ‘context’ in question consists of a hierarchy of nominals, which assert their influence on language by putting constraints and preferences on anaphoric reference. Such a hierarchy is part of the richer DISCOURSE MODEL from which the hearer can make inferences, construct replies, and obtain emotional (dis)satisfaction.

But what claims does Sidner’s algorithm embody in terms of the context required purely for predicting pronominal antecedents? The information she uses is a mixture of thematic and focus-structural cues. We have seen how these can be utilised in a step-by-step anaphor resolution process, and when new information is laid down to affect future resolution. What we are missing is an overall picture of what the discourse model must look like in order that her algorithm have the effects it does.

I extrapolate from Sidner’s algorithm to this underlying discourse model, not only to clarify her claims, but to move closer to the real aim of this thesis, which is to find a theory of focusing which could plausibly serve as part of a model of human
CHAPTER 4. A REPRESENTATION FOR FOCUSING

communication. The algorithms described in the last chapter aimed only to accurately capture an aspect of behaviour, guided by some general principles such as 'focus maintenance preferences' or 'focus stacking'. However such principles are not simply arbitrary generalisations about language use, but epiphenomena of the structure of human memory. Sidner's algorithm has been tested for self-consistency and predictive power, it has been found compatible with the assumptions of this thesis, but now I go further to ask whether it could serve as the basis for a cognitive model.

---

Goals:

1. To describe the kind of mental representation which would account for the behaviour captured in Sidner's algorithm.

---

4.1 Focus Representation

In the previous chapter focused elements were treated as the contents of several different stores. The terminology reflects the algorithms' need to be computationally implementable.

Guindon (1985) argued that pronominal reference accesses short term memory, and definite noun phrase reference long term memory. However traditional models of memory do not offer much help to a psychologist attempting to model memory for discourse.

Sidner (1979, pp. 19, 55-57) saw her algorithm as describing shifts of attention in an underlying associative network hierarchy. This, she believed “captures some of the basic relations which seem to exist in human memory” (p. 57), though the actual network she uses to illustrate the thesis intentionally resembles a database for computational reasons and is not assumed to be psychologically real. Certainly there is a need to describe how elements in the focus stores are related to the hearer's general knowledge about the world, but I believe what is missing from Sidner's theory is a representation solely of the discourse. Currently its function is served by the hierarchy of focus stores, which carry all the information necessary to resolve anaphora.
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However, as I pointed out in Problem 8, having several discrete stores can result in redundancy, with some antecedents being stored more than once. Psychologically, such redundancy is uneconomical: there is currently no psycholinguistic evidence to suggest people ever consider any particular antecedent more than once.

The solution, I believe, is that people really only store an antecedent once, even if it has been mentioned more than once in a discourse. In other words, the focus representation of the discourse should be more similar to the underlying associative network, and less like the surface syntactic form of the discourse.

Take a discourse like the following:

(75) Yesterday when I was walking in the park a dog leapt on me. It was sort of black with white spots. That dog really reminded me of a dog my aunt used to know.

The first mention of a dog should set up a nominal in the hearer's representation of the discourse. The anaphors it and that dog give the hearer additional information about that same nominal. Nominals will be labelled with DISCOURSE MARKERS (analogous to Karttunen's (1976) 'discourse referents'), in this case d is the discourse marker for the nominal the dog. However the phrase a dog my aunt used to know sets up a new nominal, represented by the discourse marker a. a stands in a certain relation to d, and both could be said to represent actual dogs, either in the real world, or in the speaker's world. However nominals are not simply representations of referents, since there may be no real referent, or the referents of the two nominals might actually be the same individual, WUFFLES, unbeknownst to the hearer and perhaps to the speaker. This gives the following three tier picture:
The relation between nominals and referents is not particularly relevant to this thesis, but the mapping from surface forms to nominals is crucial. Like Prince (1981) I believe that "A text is a set of instructions from a speaker to a hearer on how to construct a particular discourse model." (Prince 1981; p. 235)\(^1\), where "The model will contain discourse entities, attributes, and links between entities." (ibid.). Prince sees discourse entities as similar to the discourse referents of Karttunen (1976); they may be seen as representing Sidner's 'specifications' of entities, or my nominals. A nominal is a discourse entity about which the hearer accumulates information, but in terms of focusing all that needs to be remembered is that a particular nominal, whatever its properties, is salient. So the minimal model required for focusing will not contain any specific information about the interpretation of a nominal, even if that information was derived from the discourse.

The following example gives an idea of how the focusing part is related to the richer model of the discourse which the hearer has constructed.

The sentence currently being processed is:

(76) The woman who wants John's room made me put a note on his door.

Let us suppose all the nominals are newly introduced except for me, the speaker, who has been chatting to the hearer for a while, a certain room in the speaker's flat, which had been mentioned previously, and the woman who wants the room, though the hearer was not previously aware that the person currently occupying the room was called John. However all the hearer can remember is that the woman who wanted the room was a biker. In this case, the three layers of the discourse model can be regarded as follows:

---

\(^1\)Also Webber (1978) (p. 283), and Joshi and Weinstein (1981) (p. 385), who describe the need for "a data structure in terms of a set of entities and relations among them".
That is, the sentence just uttered puts the nominals in a relation to each other as represented by the solid lines. It is this layer from which focus is calculated (as will be explained shortly). The next layer contains information about those nominals which was accumulated from earlier in the discourse, for instance the fact that the woman wanting the room was a biker emerged a few sentences ago and certainly stuck in the hearer's mind. The hearer will probably have accumulated information about the speaker from the speaker's narrative, and also about the room, which is related to the nominal the speaker's flat, which should also appear in this second layer since it is out of local focusing range. The third layer represents the hearer's idea of 'the real world'. The hearer has quite substantial information about the speaker apart from that learned in the current discourse, and may well try and find a referent for John from memories of the speaker's acquaintances.

However, it is only the top layer which concerns me in this thesis. This layer which, as I said, can be seen as an abstraction of the total discourse model which encompasses the second layer too. From now on, I will refer to the top layer of the discourse model as the Focus Network (Fnet). The Fnet encodes the hierarchy of salience which is utilised
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by a focusing algorithm, represented in the form of a mesh of links between discourse referents, with those discourse markers currently attended highlighted in some way.

The Fnet corresponds to the representation a hearer builds up of a text as it progresses. Although the Fnet borrows some characteristics from the tradition begun by Quillian 1968, in his attempt to model human memory for conceptual relations, Fnets differ from both Quillian’s and Sidner’s networks. Theirs were designed to encode the hearer’s encyclopaedic knowledge about discourse entities, rather than focus or attention to discourse elements. For me, the discourse markers in the network link up with general knowledge, but do not assume it. That is, the networks I describe could be built up in the absence of any lexical or general knowledge about the discourse entities at all.

4.2 Semantic nets for sentences

Here I describe in more detail the minimal representational structure (Fnet) underlying a focusing algorithm. Like Sowa (1984) I use nodes to represent nominals, and label the links according to the verb-relations holding between them. Fnets are constructed on the basis of the surface syntactic form of utterances.

Nodes

A node is created for each nominal generated during the discourse. Nominals may be individuals, sets or genera, but whatever their ontological status, they are represented by a single DISCOURSE MARKER in the Fnet. Discourse markers can represent concepts or entities, which may or may not be identified in the speaker’s general knowledge of the world. Discourse markers can also be created for hypothetical entities. The links attached to a node may be seen as describing its properties or relations with other nodes.
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Links

Links will be used to represent relations between nominals. I label these links with the names of verbs, but do not wish to suggest that the links are semantic representations for events. I do not present a theory of verbal reference in this thesis. The links are labelled with the names of verbs because it is the use of the verb which determines whether or not there is a stated link between two nominals or not, and distinguishes one link from another. Links may also be given adjectival or prepositional names.

Directionality

A characteristic of Sidner’s algorithm is that it relies heavily on thematic information. Some way to encode thematic information in the Fnet must therefore be found. Since thematic role is derived from the verb, some way of indicating an effect of links on nodes must be found. Since Sidner really only makes use of the thematic roles of ‘agent’ and ‘theme’, I will represent the agent/theme axis of a verb with an arrow pointing from agent to theme. By Sidner’s stricture, every sentence must have a theme, but existence of an agent is optional. Therefore although every main verb will have an arrow-head pointing to the theme, the arrow-shaft need not emanate from an agentive node. Agentive nodes will therefore be distinguished by an extra v-symbol at the end of the shaft.

So links are directional, with arrows directed towards the theme.

4.2.1 Examples

A node is represented by a letter, as follows:

\[ z \]

Where \( z \) in this case stands for the referent of the word he. So the above diagram encapsulates the hypothesis that a hearer has no other information about a discourse
apart from the fact that it mentions an entity. Actually the hearer does have one more piece of information: the entity is masculine. I shall assume that such information is part of the hearer's lexical semantic knowledge, rather than part of the focusing information conveyed. In most cases, the hearer would anyway be aware of the gender of the antecedent, which is generally inferred or guessed from the initial mention (e.g. John versus Mary, a nun versus a solution). I shall also assume, for now, that phrases like a solution serve only to introduce a single nominal, for example:

This might seem incorrect, since this Fnet does not incorporate the linguistically salient information that s is a solution. There are two good reasons for not including this information: firstly no discourse model can convey what 'a solution' is — this is part of the domain of general knowledge, and secondly, it makes no difference for the focusing algorithm whether s is a solution, a snake or a six-headed gorgon, as long as it is hierarchically encoded and available for pronominal reference.²

So when are the properties of a nominal important? Take the example:

(77) A solution exists.

Here, I do introduce further information into the Fnet.

```
  s
  \exists
\rightarrow exists
```

The nominal for a solution is augmented with an intransitive verb label. It might seem that intransitive verbal links are irrelevant, as they do not introduce new nominals. However such links confer theme role on the entity they describe. In fact, the arrowhead in the above diagram points to the theme, s, the solution. It is important to include

²This is a temporary solution: as we shall see in chapter 6 it is in fact useful to encode more of the categorisation information.
all verbal links for this reason. For convenience, verbal links will be labelled, like this one, though the fact that the verb in question is \textit{exists} is not considered part of the focusing structure.

Suppose a discourse consists of the sentence:

(78)  John hit Mary.

Here two nominals are presented in a certain relation to one another, by virtue of their roles in the event of hitting. \textit{Hit} is a verb which has an agent and a theme (by Sidner’s definition). In this case the nominal \textit{John} occupies the agent role, and \textit{Mary} the theme role. The hearer’s representation would correspond to the following:

\[
j \xrightarrow{\text{hit}} m
\]

Again, the arrowhead points to the theme. This time an extra feature, the tail of the arrow, indicates that \textit{John} has an agent role. I argue that this Fnet contains all and only the focusing information required to resolve pronouns in succeeding discourse (according to Sidner’s algorithm).

I repeat again that it is not the concern of this thesis how the symbols \textit{j} and \textit{m} are linked with the hearer’s knowledge of the real referents of these terms in his knowledge representation of the world. On encountering the word \textit{Mary} at the start of a discourse the hearer might have an image of a girl from work, of the surname Harland, and wearing a fluffy pink dress. On the other hand the hearer might not know anybody called \textit{Mary}, but guess Mary is female, and make certain stereotypical assumptions on that basis. I cannot account for these associations. \textit{m} simply labels whatever image the hearer does construct, whether specific or vague. Whatever the hearer’s personal understanding of the words, I claim that it is separate from the hearer’s representation of the discourse.

Of course, most sentences are rather more complex that the one given above. I shall now give the Fnets for some of the sentences encountered in the previous chapter.

(39) a. The dogs rushed into the bakery
This sentence contains a plural. For clarity I will use capital letters for representations of plural referents\(^3\). The result is very similar to that for (78):

\[ D \xrightarrow{\text{rushed-in}} b \]

(40)  

a. John consulted a psychoanalyst

Indefinites, like proper names, have a specification associated with them (e.g. Sidner 1979 p. 144).

\[ j \xrightarrow{\text{consulted}} p \]

However it is unlikely that \( p \) will be linked to any previously known referent in the hearer’s knowledge of the world. For the purposes of focusing, this is an unimportant difference.

(16)  

a. Mary went down to Cambridge for a wedding

This sentence is slightly more complicated. In fact it is interesting in two ways: firstly it involves three referents, hence two links. And secondly, the final relation does not connect straightforwardly to either of the other two referents.

The link introducing the nominal \textbf{a wedding} is not a verbal one at all. This means it does not impose thematic roles, and is hence not very interesting from the point of view of focusing. However it is important to link the new nominal \textbf{a wedding} to the other two nominals somehow, so a simple undirected link will be used to represent it, distinguished, for convenience, by the prepositional label.

But how should this link be attached to the other two nominals, which are straightforwardly joined to one another with a transitive verbal link? The phrase \textit{for a wedding} seems to elaborate on the event of ‘going down’ rather than to \textit{Mary} or \textit{Cambridge}. I will therefore represent the discourse as follows:

\(^3\)This follows Kamp and Reyle (1989).
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![Diagram](image)

Note that Mary has the agent role, Cambridge the theme role, but the wedding does not have any designated role at all. Sidner's algorithm does not use any further thematic labels to resolve pronouns, relying instead on order of encounter. Strictly, I ought to label further nominals with the time of utterance, such a level of detail would be pedantic at this early stage of the theory.

(60) a. John saw Mary in the station concourse

Similarly to the previous example, it is not clear to what the station concourse should be attached. However there is a genuine ambiguity (PP attachment ambiguity) involved in related sentences like 'John saw Mary with the binoculars': was it John, or Mary, who had the binoculars? Likewise, in my example it is unspecified whether John was, or was not, in the station concourse himself. I shall represent the two possibilities (without further discussion) as follows:

![Diagram](image)

Again, I use a non-directional arrow on the relation between John (or Mary) and the station concourse, since the prepositional phrase does not involve the entities in any thematic role.

(26) a. John is quite romantic

This is another intransitive, almost adjectival, relationship, involving an animate subject. John is both the agent and the theme of the sentence.

![Diagram](image)
That is, this sentence introduces just one nominal.

(28a)  John gave Bill a book of poems

To represent this example I shall treat the book of poems as a single indivisible nominal \( p \) (but see possessives, shortly).

Ditransitives, like prepositional attachments, are problematic. For now I shall represent them (not ideally) with three interdependent relations:

\[
gave \quad j \quad \rightarrow \quad b \quad \rightarrow \quad p
\]

What the representation really needs to show is that a single three way link exists, which confers agent role on John and theme role on the book of poems. Bill has no relevant thematic role in Sidner’s focusing algorithm.

Generics

Genera, like singular and plural nominals, are collective concepts which emerge from the underlying mental representation; however as verbalised concepts they are unitary, therefore need only one symbol associated with them. I shall represent genera with calligraphic letters, as follows:

(49a)  Cats calm frayed nerves

\[
C \xrightarrow{\text{calm}} F
\]

Possessives

Although this thesis is not directly concerned with possessives, they do crop up in some examples:
The possessive relation will be represented with an undirected line, thus:

\[ j \xrightarrow{\text{put}} b \quad \text{on} \quad h \]
\[ M \quad \text{of} \quad m \quad \text{of} \]

The possessive arrows have no heads, because the possessor and the possessed do not have an agent/patient or subject/object relationship. I do not claim that the relationship is non-directional in the sense that the possessor and the possessed are interchangeable — only in the sense that Sidner’s algorithm does not order them relative to one another in the thematic hierarchy.

Negation

Some of the examples used in the previous chapter used negative relations, for instance:

(24a) I haven’t seen Jeff for several days

Sidner treats Jeff as a normal referent, so this sentence will be coded in the usual way, but a line stopping the relation will remind the reader that the relation is stated not to hold between the given entities. Introduction of entities under negation will be brought up again in chapter 6. Without including, for now, the modifier ‘for several days’, the representation of the above sentence will be:

\[ i \xrightarrow{\text{seen}} j \]

The modifier introduces the dilemma we have seen earlier: whether to attach several days to me, Jeff, both, or to the seeing event. In this case I shall choose the last of these alternatives and give the following representation:
The question of how such a representation should be interpreted, indeed whether it is a good representation at all, will be covered in chapter 6.

4.2.2 Summary

What I have done so far is to incorporate into an Fnet all the information about a sentence which Sidner’s focusing algorithm will require to resolve pronouns. The following translation table summarises how this information is symbolised in my diagram format:
<table>
<thead>
<tr>
<th>Part of speech</th>
<th>Example</th>
<th>Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proper Name</td>
<td>John</td>
<td>j</td>
</tr>
<tr>
<td>Definite</td>
<td>the table</td>
<td>t</td>
</tr>
<tr>
<td>Indefinite</td>
<td>a cat</td>
<td>c</td>
</tr>
<tr>
<td>Plural definite</td>
<td>the dogs</td>
<td>D</td>
</tr>
<tr>
<td>Plural indefinite</td>
<td>some cats</td>
<td>C</td>
</tr>
<tr>
<td>Generic</td>
<td>dragons</td>
<td>D</td>
</tr>
<tr>
<td>Intransitive verb</td>
<td>exists</td>
<td>\textit{exists}_0</td>
</tr>
<tr>
<td>Intransitive verb with agent</td>
<td>cried</td>
<td>\textit{cried}_0</td>
</tr>
<tr>
<td>Transitive verb</td>
<td>absorb</td>
<td>\textit{absorb}</td>
</tr>
<tr>
<td>Transitive verb with agent</td>
<td>hit</td>
<td>\textit{hit}</td>
</tr>
<tr>
<td>Prepositional phrase</td>
<td>under</td>
<td>\textit{under}</td>
</tr>
<tr>
<td>Possessive relation</td>
<td>'s</td>
<td>of</td>
</tr>
<tr>
<td>Negative intransitive</td>
<td>didn’t fall</td>
<td>\textit{fall}</td>
</tr>
<tr>
<td>Negative agentive intransitive</td>
<td>didn’t run</td>
<td>\textit{run}</td>
</tr>
<tr>
<td>Negative agentive transitive</td>
<td>didn’t like</td>
<td>\textit{like}</td>
</tr>
</tbody>
</table>

These symbols are combined to give the representations for sentences. Some examples of sentences are given below:
4.3 Modeling more than one sentence

In the previous section I deliberately avoided sentences which contain repeated elements or anaphora. This is because Sidner does not have any special mechanisms to deal with such sentences. They will, however, be studied in section 5.5.

The model can quite easily be extended to represent more than one sentence, similarly to the representation of a single conjoined sentence. However to build multiple-sentence texts requires a policy on anaphora. The next step, therefore, is to incorporate a focusing algorithm.

It is in this section that I introduce incremental construction of Fnets: they are no longer just a static representation of the discourse, but can be seen as partial memories of the discourse which cumulatively record the nominals attended by the hearer, while nominals not attended are lost.
4.3.1 Focusing in Fnets

Although, as I have explained, Sidner (1979) envisages a semantic net behind her focusing algorithm, she does not return to explain how her algorithm allows one to traverse such nets. It is the goal of this section to explain how Sidner's focusing algorithm can be expressed in terms of changes to the Fnets defined in the previous section.

Initialisation

All the examples given above can be seen as representing the first sentence of a discourse. Sidner's initialisation mechanism puts an ordering on the nominals in the first sentence, and from this ordering decides on the contents of the four stores DF, AP, PDFL and PAFL. The focus ordering mechanism places the theme of the sentence first, followed by all other thematic positions in linear order, with the agent appearing last. The highest ranked item is the expected DF, while the other nominals are in PDFL. The animate agent is the AF, and all other animate nominals are in PAFL.

A theme is a node which has an arrow-head directed into it, whereas an agent is a node from which an arrow originates. Any prepositional phrases, possessives, indirect objects etc. which complicate this basic pattern introduce nominals to fill the potential focus lists.

In Fnets, the discourse focus will be circled, and the actor focus enclosed in a double square, as follows:

(50a) John put a box of matches on Mary's head

\[
\begin{array}{c}
\text{John} \quad \text{put} \quad \text{a box of matches on Mary's head} \\
\end{array}
\]

Initialisation is not done until the Fnet for the whole sentence is complete, but once the Fnet is complete, the way I have set it up, all the necessary information, and no more,
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will be available to label the foci. Potential foci are not explicitly labelled. This has the consequence that if reference is made to a potential focus, the algorithm only then initiates a search for these elements. I have made this decision for reasons of economy: given that a sentence may introduce as many as half a dozen potential foci, yet none is particularly anticipated to occur in the next sentence, it seems absurd to set out from the start to find and order them. In fact what I shall be arguing is that the relations naturally impose a partial ordering on them anyway.

Update

The square and the circle will be used for actor and discourse focus throughout the discourse. However because the stack allows previous foci to be remembered, stacked foci will be distinguished from current foci by a single frame, as follows:

(50b) John put a box of matches on Mary’s head. She laughed.

Potential foci will again simply be accessible nodes. Nodes which have become inaccessible (i.e. by virtue of being potential foci from several sentences back, which were never focused) will be represented by being related to the rest of the discourse using a dotted line. I could choose instead simply to delete them (since they are no longer accessible for pronominal reference), but so that a record of the discourse is available for future reference, and because such nodes are accessible for full definite noun phrase reference, I will sometimes retain them in the picture of the progressing discourse.

Therefore when update occurs, the following changes will be made: the new actor and discourse focus will be marked by double frames, the previous foci will be marked by single frames, any potential foci will no longer be accessible (lost links can be shown
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with a dotted line). Inaccessible nominals will be removed altogether, or enclosed in brackets for illustrative purposes.

So, in focusing terms, when the matrix sentence has been fully processed it is represented as a network of nominals, however the hearer only actually attends those which are focused. If a pronoun in the following sentence is not compatible with the attended focus, the processor has the ability to search the unfocused parts of the network from the matrix sentence. If one of those unfocused parts is an acceptable antecedent to the pronoun, it thereby becomes part of the representation of the current sentence, which preserves it. The only memorable elements in the matrix sentence which do not occur in the current sentence are the previous foci: these are stacked.

Let us take the continuation of the text given earlier:

(50) John put a box of matches on Mary's head. She rattled it.

The first sentence was represented as follows:

\[
\begin{array}{c}
\text{John} \\
\text{put} \\
\text{on} \\
\text{of} \\
\text{of} \\
\text{M} \\
\text{m}
\end{array}
\]

After the second sentence, the representation of the discourse will be:

\[
\begin{array}{c}
\text{John} \\
\text{put} \\
\text{on} \\
\text{of} \\
\text{of} \\
\text{(M)} \\
\text{m}
\end{array}
\]

or, with the superfluous, decayed information removed (I will always indicate the stack connection with a dashed line):
Of course, what is missing here is an account of how the second sentence came to augment the first in just the way that it did — and it is this account which Sidner's algorithm (or any complete focusing algorithm) provides.

Resolution

We have seen that at any one time (a) there are two nodes currently being attended (DF and AF), (b) all the unfocused nodes on the small directed sub-graph representing the matrix sentence are also accessible. (c) a node which was activated earlier, is also accessible. All other nodes are inaccessible for pronominal reference.

If a pronoun cospecifies with another item in the text, the pronoun simply brings its accompanying links to elaborate on an already-existing node, instead of creating another node.

A focusing algorithm states which nodes are possible attachment nodes, and which are preferable. Since the focus stores correspond to the nodes currently attended in such a net, a pronoun will by default attach its dependent links to one of the two focus nodes, but if incompatible, to some of the other accessible (potentially-focused) nodes, or to a previously focused node. Sidner's algorithm contains some further conditions: if the pronoun to be resolved carries an arrow emerging from it (i.e. if it is an agent pronoun) it will prefer to attach to the actor focus, whereas if it has an arrow going into it (it is a non-agent pronoun) it will prefer the discourse focus.

To explain, I will work through a longer example:

(12) My friend Caroline knows the most unusual people. She even knows an eccentric millionaire. His mansion is just up the road. He lives with a Jamaican who deals in antiques.
The Fnet for the discourse is built up sentence by sentence. Firstly:

'My friend Caroline knows the most unusual people.'

It is notable here that Sidner does not use semantic constraints to prevent certain referents appearing in the focus stores. So there is no mechanism to prevent the most unusual people being a plural referent like any other (and hence being accessible using the pronoun they). But for this chapter I shall continue to follow Sidner (1979) and assume that this example will receive the following Fnet:

\[
\text{my friend}\rightarrow\text{me}\]

The second sentence is:

'She even knows an eccentric millionaire.'

Let us suppose on encountering the agent pronoun she that the hearer is as a result attending to the actor focus \(AF\). The hearer will therefore assume, unless there is evidence to the contrary, that what the speaker meant by she is that entity being attended. As it happens, there is no evidence against the choice, so the referent of she is immediately identified with the referent of \(AF\), represented by the nominal \(c\). The pronoun brings with it a link to a newly introduced nominal \(c\), an eccentric millionaire. The end of the sentence is reached. Now the nominal the most unusual people (i.e. \(P\)) is stacked, and since she is in agent position as well as being the only pronoun in the sentence \(c\) becomes both actor and discourse focus:

\[
c\rightarrow\text{becomes}\rightarrow\text{AF}\rightarrow\text{me}\]

The next sentence is now encountered:

'His mansion is just up the road.'
This time the non-agent pronoun *his* proves incompatible with the element currently attended (c). A search mechanism is then activated, in order to find any potential foci in the matrix Fnet. Now, since I am claiming that the Fnet is equivalent to some kind of memory network, it makes sense to assume that the nodes adjoining the currently attended entity will be searched before those which are separated from the focus by other nodes. As it happens, there is only one link attached to the focused node, and only one potential focus, e. Since this is compatible with the pronoun *he* resolution is successful, and the Fnet for the new sentence is attached to the e node.

Note that the Fnet notation has not eliminated the problem of redundancy: instead of storing nominals several times, they are stored only once, but the problem has now been passed to the search mechanism, which has no way to detect whether a node has been checked before. For instance, e could have been searched as a PDFL member, or as a PAFL member, since it is inevitably joined to both AF and DP.

No more pronouns occur, so the two new nominals are linked to e and update occurs, wiping all previous structure except for the newly stacked node c, which is also maintained as AF. The actor focus remains on Caroline here because *his mansion* is not the agent of the latest sentence, being inanimate.

![Diagram]

And now another, final, sentence is encountered:

‘He lives with a Jamaican who deals in antiques.’

Since *he* is an agent pronoun, the attended entity is the AF, Caroline. This means that once more the search for potential foci must be set in motion. This time the weaker link between the preserved actor focus (dashed) and e must be followed. This immediately results in a suitable antecedent, and the rest of the sentence is attached to e, which
subsequently becomes both actor and discourse focus. **His mansion**, and the **road** go out of focus, since they were not mentioned in the current sentence.

To summarise, this section showed that Sidner’s algorithm could be seen as resulting from an underlying mental representation in which the focus of attention is continually monitored.

### 4.4 Focus Change

A special feature of Sidner’s algorithm is its ability to cater for some non-coreference relations between pronoun and antecedent.⁴ The two types of relations she covers are summation (focus-sets) and generics. I argue that genericity is one of a small number of set-theoretic relations to the focused nominal, all of which follow the basic ordering. In this section I look at such non-coreference relations in terms of Fnets, and suggest how they could thereby be incorporated into her algorithm for focusing. This leads to a clarification of the focus-maintenance/focus-shift distinction in Sidner’s algorithm.

Let us return to (39), which was used to illustrate genericity in the last chapter:

(39) The dogs rushed into the bakery. They are carnivorous.

The pronoun **they** has agent role, so the predicted antecedent is the actor focus, the **dogs**. However, by the time the verb phrase has been processed, the AF has become infelicitous as a referent. What happens instead is that a generic reading is obtained

⁴Non-coreference relations can be covered, in principle, by the Centering Algorithm; according to Joshi and Weinstein (1981) the center can be ‘functionally dependent’ on the previous sentence.
from the AF. However the nominal the dogs is no longer the AF of the second sentence, but the related nominal for the genus dogs becomes the AF.

Sidner never addresses the resultant question: is this a focus maintenance, or a focus shift?

The update rules clearly assign the genera of dogs to the AF after the second sentence, but because Sidner's algorithm is anaphor-centred it cannot detect whether focus has shifted or not: focus-maintenance is produced by the order of application of pi-rules, not by comparison of possible antecedents with the current DF and AF. However updating of the focus stacks is crucially dependent on whether the focus has been updated or not. That is, if (39) demonstrates a focus shift, then the dogs will be stacked for future reference, but if it displays focus maintenance, then the dogs will not be stacked, and will presumably always be derivable from the genus dogs as long as it continues to be focused.

So it is important to have some kind of monitoring of shifts in the update mechanism. Somehow a focus shift must be distinguished from focus maintenance. The prototypical focus maintenance appears in (79):

(79) Mary came in. She was wearing a helmet.

Here Mary is both actor and discourse focus after the first sentence. The second sentence contains only one pronoun, which happens also to be the agent, so the discourse has the property that, for each of the foci, the nominal in focus in the first sentence is also in focus in the second. As a result, no items are stacked, and no changes need to be made to any of the focus stores except the potential focus list PDFL.

The first sentence has the Fnet:

```
\[
\begin{array}{c}
\text{in} \\
\text{came}
\end{array}
\]
```

This becomes, after the second sentence:
That is, it has not been necessary to move the circles and squares which indicate focus. (80), on the other hand, displays a typical focus shift.

(80) She was wearing a helmet. It was rusty.

Here the discourse focus after the second sentence has moved to the helmet, while the actor focus stays on Mary, since there is no agent pronoun in the second sentence. The Fnet for the complete discourse, including the first sentence given in (79), is:

The focus shift has only occurred in the discourse focus. Actor focus was maintained. In fact each focus can be independently described as being maintained or shifted: as this example shows, there is no overall term to describe the behaviours of both foci.

The discourse focus shift in (80) involved one of the potential foci becoming the discourse focus, as a result of which the previous discourse focus was stacked.

So, when the pronoun which is the new discourse focus has as its antecedent the previous discourse focus, focus maintenance has occurred, but when the pronoun has a potential focus as an antecedent, a focus shift has occurred. A focus shift also occurs when the pronoun which is the new discourse focus has as antecedent the actor focus, or a member of the paf.5

This leads to the following proposals (the terms are applicable to both actor and discourse focus):

5A final possibility is to pop the focus stack, which is probably a type of focus maintenance, but will not be discussed further.
Proposal (Focus maintenance):

When the nominal which was the focus in the matrix sentence is also the focus in the current sentence, focus maintenance has occurred.

Proposal (Focus shift):

When the nominal which was the focus in the matrix sentence differs from the focus of the current sentence, a focus shift has occurred.

So, returning to (39):

(39) The dogs rushed into the bakery. They are carnivorous.

I have already suggested that the focus of the second sentence is the nominal dogs (in general), whereas the focus of the first sentence was the nominal the dogs (under discussion). It is clear that the foci of the two sentences are not the same, but do they qualify as truly 'different'? The two nominals are closely related, in that the dogs under discussion belong to the genus of dogs. Indeed, the pronoun resolution algorithm does not consider any other nominal apart from the focus the dogs, in order to find the antecedent. In some sense, the dogs is the antecedent for the pronoun they, although its referent is of a different semantic type. The nominal for the dogs is not created by the text in the same way that the potential focus the bakery is.

There are other types of pronominal reference which have the same properties. Anaphors like two of them, most, for instance, always have as their antecedents a focused set which nonetheless is different from the nominal created by the anaphor itself. However a pronominal anaphor of this type cannot create nominals out of just any aspect of the focus. Because of the nature of pronominals, they cannot convey the information about their noun class, so all they are capable of is changing focus within the noun class defined by the focus.6

The set of permissible relations is mediated by set-theoretic relations. There are a finite number of relations as follows:

---

6In contrast to definite NPs: 'The pub was full. The bartenders were nowhere to be seen' but not 'The pub was full. ?They were nowhere to be seen'.
Chapter 4. A Representation for Focusing

Subset/membership  Mapping of a set to component individual(s) or subset(s). (The couple went up to the stage. She was given flowers and he a bottle of wine. We were given some chocolates. I ate my one yesterday. Several people came in. Two (of them) were carrying turkeys.)

Genericity Moving from an individual or set to its genus. (John has a labrador/two labradors. They’re beautiful dogs.)

Generic-membership/subset  Choice of one or a set of individuals belonging to a given genus. (Labradors are beautiful dogs. John has one/several.)

Abstraction 1  Moving from an individual in a distributed set to the set itself. (Every man sneezed. They were taking part in an experiment.)

Abstraction 2  Moving from an individual distributed by its dependence on an explicitly distributed set, to the union of those individuals. (Most people I know have a car. They are all volkswagens.)

Summation  Combination of several individuals or sets. (John went shopping with Mary. They bought a tent. John went shopping with his sisters. They bought a tent.)

These relationships, as I indicated, seem be best described using set theoretic relations like $\in$ (member) and $\subseteq$ (subset) and $\cup$ (union). Abstraction involves summing all the individuals satisfying a certain description. For this, I will follow Kamp and Reyle in using the operator $\Sigma$. I will use the symbol $\xi$ to symbolise the relation between a genus and a member of the genus as well as between an individual and a set. This is justified with respect to the semantics in chapter 6. The above relations can be written thus ($a$, $A$, $B$ etc. represent antecedent nominals and $x$, $Y$ etc. the anaphoric nominals):

<table>
<thead>
<tr>
<th>Relation</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Membership</td>
<td>$x \in A$</td>
</tr>
<tr>
<td>Subset</td>
<td>$X \subseteq A$</td>
</tr>
<tr>
<td>Genericity</td>
<td>$a \in X$</td>
</tr>
<tr>
<td>Generic-membership</td>
<td>$x \in A$</td>
</tr>
<tr>
<td>Abstraction</td>
<td>$\Sigma a = X$</td>
</tr>
<tr>
<td>Summation</td>
<td>$a &amp; b \ldots = X$</td>
</tr>
</tbody>
</table>
These are the basic relations, but it is possible to derive more by combining two or more relations. For example, take the text:

(81) Julian got three letters. I got two.

This might appear to involve a new relation, say 'co-set' between the antecedent three letters and the anaphoric nominal, two letters. However the transition can be seen as a combination of genericity (from three letters to the genus of letters), and then generic-membership (from letters to two). The result is movement from one subset to another subset of the same (implicit) genus.

Another example combining relations is:

(82) We were given a chocolate each. I ate mine yesterday.

Firstly it is necessary to move from the distributed individual chocolate each to the larger set of the chocolates given to all of us, using abstraction. Then the membership relation can be used to move from the chocolates we were given to my one of the chocolates we were given.

Set-relations will be shown in \( \text{fnets} \) as non-directional links labelled with one of the set-theoretic functions \( \in \) (member), \( \subseteq \) (subset), \( \& \) (which I use for union) and \( \Sigma \) (abstraction). The following table shows how the examples of the relations given above are represented in \( \text{fnet} \) notation:
### CHAPTER 4. A REPRESENTATION FOR FOCUSING

<table>
<thead>
<tr>
<th>Relation</th>
<th>Example</th>
<th>Fnet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Membership</td>
<td>We bought some chocolates. I ate my one yesterday.</td>
<td>( W^{bought} C )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( me^{ate} c )</td>
</tr>
<tr>
<td>Subset</td>
<td>Several people came in. Two (of them) were carrying turkeys.</td>
<td>( P^{came_0} \subseteq T )</td>
</tr>
<tr>
<td>Genericity</td>
<td>John has a labrador. They’re beautiful dogs.</td>
<td>( j^{has} l )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \varepsilon \in \text{beautiful} )</td>
</tr>
<tr>
<td>Generic-membership</td>
<td>Labradors are beautiful dogs. John has one.</td>
<td>( j^{has} l )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \varepsilon \in \text{beautiful} )</td>
</tr>
<tr>
<td>Abstraction 1</td>
<td>Every man sneezed. They were taking part in an experiment.</td>
<td>( m^{\sum_{o}M^{\text{taking}<em>{part}} e}</em>{\text{sneeze}_{o}} )</td>
</tr>
<tr>
<td>Abstraction 2</td>
<td>Most people I know have a car. They are all volkswagens.</td>
<td>( p^{\text{know}} c )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \Sigma e \subseteq C^{\text{volkswagen}} )</td>
</tr>
<tr>
<td>Summation</td>
<td>John went shopping with Mary. They bought a tent.</td>
<td>( j^{\text{went shopping}} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \varepsilon \subseteq \text{with} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( j &amp; m^{\text{bought}} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \varepsilon \subseteq m )</td>
</tr>
<tr>
<td>Complex</td>
<td>John got three letters. I got two.</td>
<td>( j^{M} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( N^{got&lt;me} )</td>
</tr>
</tbody>
</table>

It is to be noted that from the start I have made the decision that set relations introduce
nominals, though in terms of semantics the relations indicate that in some sense all the anaphoric nominals are a part of the antecedent nominals — part of the meaning of the anaphor is included in the meaning of the antecedent. I have made this decision because, I shall say again, what I am attempting to model is the hearer’s memory of the discourse, as required for pronoun resolution. And my hypothesis is that once the anaphoric nominal has been obtained from the antecedent nominal, it acts, to all intents and purposes, like a completely new referent. And hence we return to the question of update, to ask whether focus relations could be a special case of focus shift, or whether they display more of the behaviour of focus maintenance.

I will use the subset relation as an example. Let us take the following matrix sentence:

(83)  A pack of huskies were gathered.

This sentence introduces a set of huskies, call it $H$, the huskies which were gathered. This is the actor and discourse focus of the first sentence. Now, let us suppose the second sentence introduces a nominal which is related by membership to the focus:

(83a)  A pack of huskies were gathered. One of them had no tail.

Now, a third sentence can continue with the member nominal the husky with no tail:

(83b)  A pack of huskies were gathered. One of them had no tail. It went to the South Pole.

Alternatively, the discourse could have continued talking about the original focused set of huskies which were gathered:

(83c)  A pack of huskies were gathered. One of them had no tail. They went to the South Pole.

It is my intuition that (83c) is a stack use. If I am right, it should become increasingly hard to refer to it, even if the member husky is still focused. If, on the other hand the
membership relation was really a focus maintenance, the set of huskies should remain just as accessible.

(83d) A pack of huskies were gathered. One of them had no tail. It went to the South Pole. #They followed it.

In fact (83d) is barely acceptable, so the hypothesis that focus set relations maintain focus can be rejected in favour of either focus shift or a third option. I believe that focus set relations cause the previously focused nominal to be stacked. However part of that nominal is still preserved, as is illustrated by the summation relation:

(84) John took Mary shopping. They bought a tent.

Summation is the combination of two nodes to create a new conjoined entity. Example (84) is given in the following Fnet:

The dotted lines link elements belonging to the same set — so John is a member of John and Mary, as is Mary, but John and Mary is not a member of John or Mary.

The Fnet has the individual referents for John and Mary stacked, while the conjoined entity John and Mary is both actor and discourse focus. So for instance John, now on the AFs, is also still part of the AF, but in addition has now become part of the DF, to which it was previously unrelated.

Tracking the DF individually, since the focus maintenance/shift terminology applies only to a particular focus, the DF changed from being Mary to being John and Mary.
Normally, when a focus shift occurs, the contents of the DF in the matrix sentence would be completely disjoint from the DF after the current sentence, for instance the DF in (80) shifted from Mary to a helmet. I will therefore distinguish the type of update which occurs in a focus store after a focus set relation as a FOCUS CHANGE.

**Definition (Focus change):**

*When the chosen referent for a pronoun bears a set relation to the referent of the focus, focus change has occurred.*

The previous proposal for focus shift can now be reformulated:

**Definition (Focus shift):**

*When a nominal referent for a pronoun cannot be set-theoretically related to the nominal in focus, focus shift has occurred.*

In (84), focus changes have occurred both in the AF and the DF. John and Mary as individuals have become stacked in favour of a single referent John and Mary, which is both actor and discourse focus. So although John and Mary have been stacked, they are still focused, provided reference to them is by a plural pronoun accessing them jointly. To access them as individuals with singular pronouns, the stacks must be popped.

General principles of processing suggest that when resolving pronouns focus change should be preferred over focus shift (it is easier to continue attending to the noun-concept in memory, than to activate another one), however Fnet structure suggests that focus shift should be preferred over focus change, since antecedents have already been created, even if not currently attended. Focus change would involve creating a new nominal. So it is a matter of debate, which seems to be won by focus shift:7

(85) I bought a bulldog for my friends. They love walking.

---

7In chapter 6 it will be suggested that there are two types of focus changes, those using constructed, and those using generated, nominals; constructed relations are preferred to shifts, but generated nominals are treated as potential foci and therefore are harder to use.
That is, it seems more likely that *they* will be taken to refer to the potentially focused nominal *my friends*, than to the focus-related generic nominal *bulldogs*. However generic reference has the same nominal choices as coreference. In (85) there are three nominals available, of which *a bulldog* is considered first. Generic reference would also be possible to *friends in general*, though not to *I*, which is ruled out for semantic reasons, as will be seen in chapter 6.

A final example will be given, showing how focus change is represented in an Fnet.

(86) John owns a cat. They chase mice.

The Fnet states that John owns an individual *c*, which belongs to the set of cats. Cats chase mice. In the first sentence, John’s cat, the theme, was the discourse focus. In the second sentence focus (as shown by the use of a pronoun) is on the generic set to which John’s cat belongs — the set of cats in general (not a specific set of cats). So the DF has changed, but the generic relation was *facilitated* by the focused element rather than any other element. As in summation, the new focus incorporates some aspects of the previous focus (the old and the new DF concerned cats, rather than dogs or sandwiches). However the new DF differs from the old in number, gender and other semantic features.

In summary, the three kinds of transitions can therefore be distinguished as follows: focus maintenance involves attaching further links to the focused node, focus change involves attaching further links to constructed nodes set-theoretically related to focused nodes, focus shift involves attaching further links to an already existing unfocused (or contra-focused) node. A fourth kind of transition can be added: a focus shift-and-change can be made by shifting to a potential focus and changing it in the same move to make a constructed unfocused entity (87).

---

8This could obviously be linked to a general inferencing system, by which one can infer that *c* (probably) chases mice, but this thesis does not incorporate an inferencing system.
John is an animal lover. He keeps a crocodile. They are cold-blooded.

Focus shift/change/maintenance is always with respect to either the AF or the DF. The terms are applied independently, rather than making a generalisation about the relation of transition from the matrix sentence to the current sentence. This means that there can be nine different transition types between two sentences:

<table>
<thead>
<tr>
<th>DF</th>
<th>AF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maint.</td>
<td>Maint.</td>
</tr>
<tr>
<td>Maint.</td>
<td>Change</td>
</tr>
<tr>
<td>Maint.</td>
<td>Shift</td>
</tr>
<tr>
<td>Change</td>
<td>Maint.</td>
</tr>
<tr>
<td>Change</td>
<td>Change</td>
</tr>
<tr>
<td>Change</td>
<td>Shift</td>
</tr>
<tr>
<td>Shift</td>
<td>Maint.</td>
</tr>
<tr>
<td>Shift</td>
<td>Change</td>
</tr>
<tr>
<td>Shift</td>
<td>Shift</td>
</tr>
</tbody>
</table>

In addition, it must not be forgotten that the focus stack can be popped, though stack operations will be left to section 5.8.

Brennan, Friedman and Pollard (1987) claimed (p. 156) that the Centering algorithm improved on Sidner's algorithm because it could distinguish four different transition types, which were then ranked as showing different degrees of coherence. However I have shown here that Sidner's algorithm can potentially distinguish nine degrees of coherence. What is more, the preference ordering on these transition types (Maint. preferred over Change or Shift) does not have to be imposed by a filtering process, but arises naturally out of the order of application of pi-rules (coreference with the focus is always predicted first). It would also be possible to add a meta-procedure to Sidner's update mechanism, which would explicitly compare old foci with new, and thereby output a coherence measure.
However it would require a complex extra mechanism to overcome Problem 8, the problem of redundancy. If $AF$ and $DF$ exchange their contents from the matrix sentence to the current sentence, as in (60), this emerges as a Shift-Shift contingency.

(60) John saw Mary in the station concourse. He waved to her. But she walked straight past him.

(60) will be regarded as not very coherent. I still feel this is incorrect, and believe that such a situation ought to arise as Maint.-Maint. from the pi-rules. However Sidner’s pi-rules do not currently favour this situation at all, so there is no choice but to rank it with examples where both $AF$ and $DF$ shifted to potential foci.

So in this section I introduced a trichotomy of focus transition types: shift, change and maintenance. I pointed out that an epiphenomenon of the pi-rules is that nine degrees of coherence can be exhibited, with preferences for greater coherence arising naturally out of the order of application of pi-rules. The resulting coherence rankings did not seem appropriate in all cases, and it would not be easy to change this since it is an intrinsic property of Sidner’s pi-rules.

### 4.5 Update Units

One thing which was never made clear in Sidner’s algorithm was when to perform focus update. This section uses F-nets and empirical data to provide a solution to this problem.

#### 4.5.1 Conjunction

As I noted in Problem 3, Sidner does not indicate consistently whether update occurs at the end of the clause or at the end of the sentence. Carter (1987 p. 119) pointed out that she wavers between treating conjunctions as one sentence and as two. One of the instances he noted is from Sidner (1979, p. 53). This was originally given as one sentence, but can be phrased in two without altering the meaning.
(88) a. I went to use some strawberries for dinner, but someone had eaten them all.

b. I went to use some strawberries for dinner. (But) someone had eaten them all.

The difference, in focusing terms, between the two versions of (88) can be visually elucidated in Fnet notation. The following diagrams show accessibility of the various referents after the examples have been processed.

![Diagram showing accessibility of referents](image)

The two versions result in slightly different representations. The reason I have omitted the actor focus from the first version is because there is a difficulty in assigning it. Sidner's focus update mechanism states that the agent of the sentence should be the actor focus, where an agent is 'the animate subject of the sentence'. However there are two animate subjects.

The second observation is that in the first Fnet the pronoun them must be resolved intrasententially, something Sidner's algorithm is not currently capable of. In the second Fnet the antecedent-anaphor connection crosses a sentence boundary, so Sidner's usual procedures apply.

The third difference is in the predictions each representation makes about antecedent accessibility. From the single-sentence version one would predict that all the referents me, s, x and d were accessible, with the theme, s preferred as the focus of following discourse. The double-sentence version imposes more of a hierarchy, with s preferred, as before (this time as DF), followed by the single PDFL someone. However the dinner
and the speaker are predicted no longer to be accessible.\(^9\)

The varying predictions can be empirically tested by determining whether the nominal the dinner is still accessible for pronominal reference in a continuing sentence:

(88a) I went to use some strawberries for dinner, but someone had eaten them all. ?As a result, it was a failure.

The continuation does not seem particularly acceptable to me. If this could be experimentally verified, it would offer strong evidence in favour of clausal update. Clausal update would also solve the awkward problem of determining actor and discourse focus. Since clauses are syntactic constituents based on a single verb, there would be only one subject and direct object, so preventing the occurrence of more than one agent or theme in the matrix Fnet.\(^10\)

The intuition can be strengthened by examining other examples of conjunction. (21) and (89) (adapted from Hirst 1981) were previously treated as sentences, though they combine several different verbal relations at once:

(89) John left the window and drank the wine on the table.

(21a) John and Mary sat on the sofa and played cards.

When augmented with continuations making reference to elements introduced in the first clause and not recalled in the second, it becomes obvious that such continuations are not acceptable:

(89b) John left the window and drank the wine on the table. ?Two minutes later it slammed shut.

---

\(^9\)The speaker is a special case — one can never tell if the word 'I' is anaphoric or not, and its referent is presumably accessible by some kind of deixis all along. The speaker is the ultimate permanent focus.

\(^10\)Stenning (1978) has pointed out that it seems absurd to give sentence boundaries a great deal of importance when identical anaphoric properties can be found in clauses separated by a full stop, or joined with a conjunction.
(21b)  John and Mary sat on the sofa and played cards. It was one of those soft corduroy ones.

Take the first sentence of (21b):

(21a)  John and Mary sat on the sofa and played cards.

When this is treated as two separate update units, the resulting fnet is:

```
[John] \rightarrow [Mary] \rightarrow [on (s)] \rightarrow [played] \rightarrow [C]
```

The fnet is identical to the fnet which would have been produced had the example consisted of two sentences:

(21c)  John and Mary sat on the sofa. They played cards.

Strictly syntactically speaking the second update unit in (21a) is not a clause, since it is not saturated: the subject noun phrase may be regarded as 'ellipsed'. The difference between (21b) and (21c) is that in (21b) the nominal and link generated by the final verb phrase were syntactically obligated to attach to the subject nominal, whereas in (21c) the pronoun did demand that the node and link were attached to some nominal, but attachment to j&m in particular was not obligatory. As it happened j&m was the natural choice, being the actor focus of the matrix unit. However if there had been an alternative attachment node, the pronoun could have attached to the object:

(90)  John ran past a herd of bulls. They chased him.

The corresponding VP-conjunction version is ungrammatical:

(91)  *John ran past a herd of bulls and chased him.
However although the creation of Fnets is necessarily mediated by syntax, focus update on a completed Fnet appears to act exactly as if VP-conjuncts were actually separate sentences. In other words, focus update has no access to the syntactically mediated process of Fnet-construction, and simply acts on the result, by which time any syntactically unsaturated clauses have become saturated.

The question of whether update is sentential or clausal was wrongly formulated. Update occurs on an Fnet after a verbal relation has had all its thematic argument roles filled, or resolved. Clause conjunction and VP conjunction generate saturated relations: it is not a requirement of a saturated relation that its nodes are not also part of other relations.

The update unit has now been determined to be a saturated relation, a semantic, not a syntactic, concept. A saturated unit may contain a single nominal (intransitive), two, or three (ditransitive).\textsuperscript{11} A working definition of a unit can now be given:

Proposal (Unit):

\textit{A unit is a group of nodes associated with a single verbal relation in an Fnet.}\textsuperscript{12}

It is not necessary to impose the condition that such a relation is saturated, since relations are added to the Fnet in such a way as to make them saturated (i.e. resolution of pronouns, and restoration of ellipsed nodes, is a condition of a relation being in an Fnet). Partial Fnets will be introduced in chapter 5.

The reason why I use the word 'associated' in the proposal is because it is not just the obligatory argument nodes of a relation which form a unit, but also any non-verbal relations which are attached to the verbal relation and its obligatory nodes (e.g. prepositional, possessive, set relations). I will not attempt here to provide a failsafe routine for detecting the end of a unit. Such a routine would rely on an incremental parsing device which, like a focusing algorithm, would need a degree of caution before

\textsuperscript{11}In previous diagrams I have represented ditransitives by using several relations, but this is simply because it is not possible to show a three-way relation graphically with a single stroke. Those ditransitive relations should be regarded as different aspects of the same relation: that determined by the verb.

\textsuperscript{12}The phrase 'processing unit' is used by Bosch (1983).
assuming a unit boundary, since further prepositional phrases can be added to a relation even after saturation.

The Fnet for (89a) includes a mixture of verbal and non-verbal relations.

(89a) John left the window and drank the wine on the table.

\[ j \xleftarrow{\text{left}} (w) \xrightarrow{\text{drank}} w \xrightarrow{\text{on}} t \]

The prepositional phrase which generates the nominal \( t \) is part of the unit associated with the verb \textit{drank}, via its attachment to the theme, \textit{the wine}.

### 4.5.2 Subordination

The proposals suggested so far do not apply to the example given by Walker, Iida and Cote (1990) to illustrate ‘clausal’ update.

(92) Taroo told Kim that he would defend her.

(ibid, p. 4)

It is for good reason that my proposals do not apply. The construction suggested by Walker, Iida and Cote (1990) can be altered and extended to give the following text:

(93) Taroo told Kim that he was winning. She was not impressed.

This discourse would be infelicitous if the relation generated by ‘Taroo told Kim’ was treated as a unit, since the nominal \textit{Kim} would have become inaccessible (or at least stacked and considered last in the list of possibilities for agent pronouns). Significantly, the text is in fact very acceptable.
This example suggests that the story I have given is incomplete. Examples like (92) seem to display some of the properties of conjoined sentences, with the complement clause accessing the focus structure of the earlier part of the sentence. Unlike the conjoined examples, the earlier part of the sentence still seems to be accessible after the complement clause unit is complete.

Relative clauses appear to have the same property.

(94) The man sold a newspaper to the woman who lives with John. She read it avidly.

Despite the relative clause occurring after the main clause, potential foci generated by the main clause are still accessible in the next sentence. If anything, the final nominal in the first sentence, John, is the least accessible to the next sentence:

(94a) The man sold a newspaper to the woman who lives with John. She sometimes read it to him.

Here the temptation is to resolve him to the man rather than to John, though I do not believe John is particularly inaccessible, just less accessible.

The two alternative Fnets for the first sentence are:

The first of these is unsatisfactory because it contains two agents and two themes. I have placed focus on the agent and theme generated by the main clause, but if this were the correct heuristic it would require altering the update mechanism.
The second F-net is worse, since it implies that John is more accessible than the man for further reference, which, as we saw, is not the case.

The solution I propose is that relative clauses do open up a new unit, but this unit interrupts, rather than closes off, the main unit. The relative clause creates its own temporary focusing domain. Pronouns in this subordinate domain use the main clause as their matrix sentence, but also can access antecedents in its matrix sentence, as if the main clause in turn was subordinate to its matrix sentence. Pronouns in the main clause can attach to nominals in the subordinate unit but are not very likely to do so, so the fact that some of these subordinate nominals may be focused does not have much effect on main clause pronouns, whereas subordinate pronouns much prefer to attach to superordinate foci. When update occurs at the end of the superordinate unit, the nominals in the subordinate unit do not, as we have seen, become inaccessible, but have the same accessibility as nominals attached by prepositional relations.

One might be tempted to ask whether all relations, such as those produced by prepositional phrases, could be treated as (subordinate) units.

The data is ambivalent:

(95) The man at the window knows John. *It looks out onto a motorway.

A man with a kitten just came in. It is very sweet.

However I will simply assume that they do produce subordinate units, unless I find strong evidence to the contrary. It is particularly important to note that the antecedent clause of a conditional statement is syntactically subordinated to the consequent. It is this which explains the humour in (6):

(6) If an incendiary bomb drops near you, don’t lose your head. Put it in a bucket and cover it with sand.

13What I suggest in chapter 8 is that subordinate clauses are only kept open if the semantics requires use of them in interpreting the maximal unit they are embedded in.
Because the antecedent 'If an incendiary bomb drops near you' is encoded in a subordinate Fnet, the nominals introduced in the main verbal unit created by the consequent 'don’t lose your head' are more salient for future pronominal reference, accounting for the preference of your head as an antecedent for the pronouns in the second sentence.

Obviously, more experimental work needs to be done in this area. One paper which bears on the findings here is Gernsbacher, Hargreaves and Beeman (1989). Gernsbacher et al. concluded from their experiments that hearers represent each clause in a two-clause sentence in its own ‘mental substructure’. While the second clause is being processed, it is more salient for pronominal reference than the first, but when the end of the sentence is reached, attention reverts to the first clause, making the second clause less salient. Unfortunately for my purposes, Gernsbacher et al. did not separate out the sentences in which the first clause was syntactically subordinate from those where the second clause was syntactically subordinate, nor did they draw the subordinate/coordinate distinction, though they did note that clauses which were ‘semantically dependent’ tended to have almost equal accessibility. This hypothesis, which seems contrary to the syntactically based hypotheses of this section, is explored further in the final section of chapter 8.

4.5.3 Update Updated

It has been argued that each unit of an Fnet has its DF and (optional) AF. Syntax determines whether one unit is coordinated or subordinated to the previous unit. If coordinated, Sidner’s update mechanism is triggered. New sentences, conjoined clauses, and VP-conjunction all have this result. If, on the other hand, a unit is syntactically determined to be subordinate (relative, prepositional and complement clauses), update will not occur until after the subordinate unit is complete. The whole subordinate-superordinate unit combination cannot be given an Fnet until the subordinate unit is complete. The result is that the subordinate unit behaves like part of the superordinate unit for update purposes, but the subordinate unit is also capable of making use of the focus hierarchy of the superordinate unit. I argue in the next chapter that the resolution of pronouns in a subordinate unit can be accounted for by an intrasentential focusing
mechanism which also subsumes the cross-sentential capabilities of Sidner's algorithm.

Both coordinate and subordinate units are attached to the existing Fnet by a variety of means: mediated directly by syntax, with obligatory attachment to some particular nominal, or anaphoric (attachment to the most focused compatible nominal).

### 4.6 Summary

In this chapter I have presented part of the hearer's model of the discourse. The question asked in this chapter was what kind of a mental representation would be minimally necessary to result in the focusing behaviour described in Sidner's algorithm.

The answer was that such a model needed to incorporate theme and agent information, nominals and three types of links: verbal, non-verbal (mainly prepositional) and set-theoretic. It was found necessary to define an update unit semantically, but to draw on syntax for the relations (coordinate/subordinate) between units.

Fnets were used to make predictions about (a) ease of accessibility, (b) range of accessibility, (c) semantic dependence between referents and (d) coherence. The Fnets suggested several possible avenues of improvement to Sidner's algorithm, but failed to provide a solution to Problem 8: the problem of nominals being stored more than once in the focus stores was exchanged for the problem of multiple consultations of the same nominal.
Achievements:

- I suggested that improvements to Sidner's algorithm would be easier to motivate by dealing directly with the discourse entities as situated in a cognitive model of the discourse, and showed that the algorithm was amenable to representation in a syntactically-derived semantic network.

- The discourse context relevant to pronoun resolution was described in terms of nominals, relations and four attention markers.

- Sidner's update mechanism was extended in two ways: first possibilities for focus change were added more methodically to the new focus theory, and secondly update point was defined.

I believe the solution to the focus-based/anaphor-based compromise lies in providing the right underlying representation, but that the Fnets proposed in this chapter are still too anaphor-based.
Chapter 5

An Incremental Focusing Theory

In Chapter 3 two focusing algorithms were evaluated. In this chapter these algorithms form the basis for a new incremental focusing algorithm. The new algorithm will be derived at all stages from an underlying discourse representation resembling that developed in Chapter 4.

The Centering algorithm was rejected because of its inherent non-incrementality. However Sidner’s algorithm, despite its incrementality, suffers from some major flaws. Prime among these is the actor/discourse focus distinction, which necessitates separate resolution rules for agent versus non-agent pronouns. The ideal focusing algorithm would use Sidner’s incrementality as a basis, while adopting an idea of focus closer to that used by the Centering algorithm. In the last chapter I argued that focusing algorithms were either focus-based or anaphor-based, both alternatives being less than ideal. Here I sketch out one way to compromise between the two, which allows incremental resolution of pronouns and tracking of foci through discourse.

I concentrate entirely on focusing effects in discourse, separating them from lexical and syntactic influences. This allows me to abandon much of the more theoretically problematic or unformalised parts of Sidner’s algorithm. Pure focusing is something which neither algorithm explicitly aims for or achieves. The Centering algorithm comes nearest, but still confounds focus with syntactic structural influences. Sidner,
on the other hand, wanted to present an algorithm which took into account all possible influences on pronoun resolution, in order to successfully model her intuitions about preferences for antecedents. Inevitably, she found her algorithm unable to account for certain preferences, hence the proliferation of exceptions to her rules which she had to encode separately, and hence her worry that despite the complexity of her algorithm she still failed to incorporate other determinants on preferences such as syntactic parallelism effects.

My goal is less ambitious: I intend to describe purely the influence of focus on choice of antecedents. I believe that focus maintenance is the default choice for pronominal reference, but that many other linguistic strategies are used by the speaker when shifting focus, forcing the hearer to alter expectations.

Goals:

1. To present a fully incremental pronoun resolution algorithm
2. To resolve all pronominal anaphora with the same mechanism.
3. To distinguish the purely focusing effects on pronoun resolution from thematic and grammatical influences.

5.1 Foundations

Translating Sidner's algorithm into net form has tended to clarify, rather than solve, the problems noted in Chapter 3. In Problem 8 I pointed out that Sidner's algorithm really runs into problems by limiting itself to just two foci. There is no evidence to suggest that a discourse should have just two centres of attention, though triple-pronoun sentences are rare enough that Sidner's algorithm copes admirably well with just the two.

One way to successfully capture the data concerning three (or more) pronoun sentences is to introduce multiple foci, and this is the path I take. This means that the actor/discourse focus distinction is no longer tenable. The advantage of abandoning this distinction is that it is troublesome to pin down what an 'actor' is. I believe that the distinction has also been obscuring some basic empirical generalisations. However
abandoning the distinction throws Sidner’s algorithm into disarray and it is hard to imagine that any of the debris would be usable, but I show that Sidner’s original theoretical insights can be maintained and even enhanced.

Like Sidner, I use a focus store (df), a store for potential foci (pdfl) and a focus stack (dfs). Later, I shall be describing these in terms of fnets. I do not state orderings within these stores: for now they may be regarded as clusters, to be accessed in any order, even in parallel. It is not the job of a pure focusing algorithm to state such preferences. The ordering problem will be discussed in section 5.9.

In developing my own algorithm I take as foundational a generalisation noted by several authors, the observation that pronouns more strongly reflect a focus than other noun phrases. It was this observation which led Sidner to define focus of discourse as a (non-agent) pronoun occurring in the previous sentence,1 and led Brennan, Friedman and Pollard (1987) to decide that only if the focus is pronominal may any other element in the current sentence be pronominal. This assumption is also supported by Guindon’s (1982) data (cited in Guindon 1985), in which she found that elements in focus (by Sidner’s definition) were much preferred as antecedents for pronouns: unfocused elements were barely remembered.

So I begin with the following assumption:

**Proposal (Foci):**

*Every pronoun designates its referent as a focus of the matrix sentence.*

This proposal differs from those in Sidner’s and the Centering algorithms in that it allows not just one, or two, but indefinitely many foci to be carried over from the matrix sentence.

In addition:

**Proposal (Potential Foci):**

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1Sidner (1979, p. 60): “Pronouns reflect the element in focus; since the pronoun contains little lexical information, whatever it takes as antecedent must be the focus of the previous sentence”.
The non-pronominal elements from the matrix sentence are the potential foci.

Interestingly, this definition of the potential focus list was also partly anticipated by Sidner (1979 p. 84) “Any new term in the discourse is a potential focus”, and Sidner (1981 p. 222), introducing the idea of potential foci, “Suppose in addition to the ongoing actor and discourse focus, the hearer can consider temporarily any new entities mentioned in the last sentence ...”. This is interesting because in actual fact her PDL includes all the items except the focus, so may well also include not only old items, but pronominal items. So she is not able, in fact, to keep to her vision of the potential focus list, just as she had to complicate her original view of focus. In this way, I feel I am restoring her original intuitions in my own algorithm.

I do not treat definite noun phrases and resumptive proper names as (locally) focused for two reasons, one theoretical and one empirical. The theoretical basis for my choice is that the very use of a definite noun phrase or resumptive proper name suggests that these longer descriptions were necessary in order to identify the correct referent for the hearer. This means that there was a potential for the true antecedent to have been confused with another which was more likely to have been chosen by the hearer, i.e. the focus. The experimental evidence for this comes from Guindon (1985) who found that use of an anaphoric definite noun phrase inhibited hearers from choosing the focus as antecedent.

The distinction between definite noun phrases and pronouns is the traditional boundary between local and global focusing, and this is not a boundary I intend to question for the purposes of this thesis. From the perspective of local focusing, non-pronominal anaphors (such as definite noun phrase anaphors and resumptive proper names) are treated the same way as completely new information. So potential foci may be a mixture of new elements and those reintroduced from previous discourse.

There is one caveat here: sometimes full definite noun phrases are used to access items which are in the focus stores, rather than for items which are completely unfocused. However such items will always come from the PDL or the DFS. It is completely infelicitous for such items to be already in DF. This means that anaphorically recalling
items in the PDFL or DFS is not, by definition, enough to focus them. Only pronominal anaphora can focus items.

(61a) Mary was angry. She hit Bill. Bill cried.

It might seem that focusing on Bill is occurring in the third sentence. I maintain that Bill is not (yet) focused. The speaker is clearly recalling a previously peripheral item to the hearer’s attention, which could signal that it might be the speaker’s centre of attention, but my model is of a cautious hearer: until a pronoun is used, such a suspicion cannot be confirmed. The hearer holds onto previous foci until definite evidence is found for a shift. This principle of focus maintenance prevents the hearer jumping to a conclusion too quickly, while still ensuring (by keeping the potential foci in mind) that a focus shift can be made when necessary.

I predict that after (61a) it is easier to say ‘She …’ than in:

(62a) Mary was angry. She hit Bill. He cried.

According to my proposal, (62a) does, by contrast with (61a), exhibit a focus shift.

Therefore from the hearer’s point of view a sentence may have no focus — such examples are a cue for stack use, as is illustrated in section 5.8. The hypothesis is that although such sentences do not contain explicitly focused elements, the hearer will always assume that the speaker is focused on something, so the previous focus is kept in the background as a likely candidate.

Shifting focus, whatever changes it makes, involves more processing effort than maintaining attention, and does not offer the hearer any immediate benefits, so the Principle of Relevance favours the hearer’s ‘laziness’, as captured in my definitions.

5.2 Initialisation

As for Sidner’s algorithm, the first sentence in a discourse is problematic. My proposals above suggest that the first sentence should simply be treated as having no focus, but
the data suggests that people do in fact attribute a focus to the speaker. This is usually the agent or syntactic subject. In fact nearly all the psycholinguistic data on anaphoric preferences discussed in Chapters 2 and 3 has been obtained from experiments on two sentence pairs where the first sentence contains no pronouns and is the initial sentence in a text. I claim such influences to be out of the domain of focusing, but the awkward fact remains that elements in the first sentence seem to become stacked if not mentioned in the second sentence and are therefore available for pronominal recall in the third sentence. Many of the examples used to illustrate Sidner's algorithm demonstrated this. One example is (66):

(66) The stick hit the boy. He was really annoyed. It had ruined his concentration.

Here the stick, which was never focused according to my criterion, is easily accessible in the third sentence. So like Sidner's algorithm and the Centering algorithm, the Incremental Focusing algorithm neglects the first sentence. The solution would be to make an exception for the first sentence of a discourse by introducing a special initialisation mechanism. In my case this mechanism would probably work best by assuming that all the elements in the first sentence are foci. However I feel that such a solution is probably too simplistic, so I will not attempt to describe the effect of the first sentence at all: it will be treated as having no foci.

5.3 Resolution

In accordance with the principles described in the previous section, my algorithm is a pronoun resolution algorithm which uses the idea of focus to impose constraints and preferences on anaphoric antecedents. It resembles Sidner's algorithm rather than Centering, since the primary purpose of the algorithm is to resolve all pronouns in a sentence, rather than to ensure that a particular focus is maintained.

As in Sidner's anaphor-centered algorithm, focus maintenance preferences will arise naturally from the pronoun resolution algorithm, but I intend to also incorporate the ability of a focus-centred algorithm (like Centering) to monitor the flow of focus
between sentences. I have already explained why I assume the conservative maxim of focus-maintenance over focus shifting, a principle which is more closely followed by the Centering algorithm than by Sidner. I will assume a network similar to the Fnet described in the previous chapter underlying my own focusing algorithm. However I will be making some slight changes in the representation: the representational structures underlying my own algorithm will be distinguished by the name of \textsc{Ifnets}(Incremental Focusing Networks).

\textsc{Ifnets} differ from \textsc{Fnets} in having no record of thematic information. All links will therefore be non-directional, indicating that all nodes are equally ranked apart from the rankings imposed by focusing. The focusing stores will be described shortly, but since there is no actor/discourse focus distinction foci will always be indicated with double circles, and stacked foci with single circles. In all other ways, \textsc{Ifnets} are identical to \textsc{Fnets}, particularly in being composed of coordinate and subordinate units.

So, rephrasing the focus-maintenance preference in terms of \textsc{Ifnets}, the pronoun currently being resolved will by default attach its dependent links to one of the focused nodes, but if none of these choices proves compatible, the pronoun will attach to one of the other accessible (potentially-focused) nodes.

Translating into algorithmic form, following Sidner, I state that the \textsc{PdfL} is considered after the foci \textsc{DF}. I use her Ratification procedure to evaluate potential antecedents. However, unlike Sidner, I do not have separate rules for resolving agent versus non-agent pronouns. The following rule applies to any pronoun to be resolved:

\begin{center}
\textbf{Matrix Rule:} Consider members of the DF list, followed by members of the PdfL list.
\end{center}

In other words, items which were pronominal in the previous sentence will be more salient than items which were introduced in the previous sentence for the first time.

To illustrate this, a one-sentence context will be given for the matrix sentence. The matrix sentence will contain a pronoun and a new item which are compatible in gender, number and animacy. It will be followed by a sentence containing the pronoun currently
being resolved. This pronoun may be resolved to either of the given compatible antecedents. The prediction is that the pronominal antecedent will always tend to be preferred. Several examples will be given to rule out the possibility that the observed biases are due to the grammatical or thematic roles, form or linear ordering of the two possible antecedents.

To ensure that this generalisation does not only apply to agent or subject pronouns, a second set of sentences containing non-agent/non-subject pronouns will be tested.

(96)  

a. **Indefinite agent PDFL, non-agent DF, agent pronoun** John Cox lived on his own. Once a neighbouring farmer invited him round for dinner. But he preferred solitude.

b. **Indefinite agent PDFL, non-agent DF, non-agent pronoun** John Cox lived on his own. Once a neighbouring farmer invited him round for dinner. Having someone to talk to cheered him up.

c. **Agent DF, indefinite non-agent PDFL, agent pronoun** John Cox lived on his own. Once he invited a neighbouring farmer round for dinner. But he preferred solitude.

d. **Agent DF, indefinite non-agent PDFL, non-agent pronoun** John Cox lived on his own. Once he invited a neighbouring farmer round for dinner. Having someone to talk to cheered him up.

This is the first set of examples, showing focused proper names and unfocused indefinites in various roles as plausible antecedents for agent or non-agent pronominal anaphora.

My prediction is that the preference for the antecedent in all these cases will be John Cox.\(^2\)

Sidner predicts that John Cox will be preferred for all of (96) except the first case. In the second and fourth cases, John Cox is preferred because the pronoun to be resolved is

\(^2\)Caveat: The second complicating factor is intonation. The above sentences are presented in written form in order to remove the effects of intonation (which, after all, is not available in written text). However when verbalising the sentences carefully to oneself in order to verify an intuition, there is a temptation to impose some kind of intonation contour. All the above sentences can be intoned in two relevant ways, one stressing the final pronoun, and the other leaving it unstressed. I intend these sentences to correspond to the unstressed intonation pattern (which I believe is the default). Stressing the pronoun overrides the focusing preferences in favour of an unexpected choice of referent. This technique has been used as a test of antecedent preferences: the default antecedent will be chosen when the pronoun is unstressed: when stressed, rival antecedents, such as those from the PDFL, will become preferred.
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in non-agent position, therefore preferring the \textit{DF} as antecedent. In the third case, \textbf{John Cox} is preferred because the pronoun is in agent position and \textbf{John Cox} is the agent of the previous sentence, i.e. the AF. For similar reasons, \textbf{the neighbouring farmer} is preferred as the referent of the agent pronoun in the first text, since a \textbf{neighbouring farmer} is the AF.

So not only do Sidner's predictions differ in one case from mine, but her explanation of one of the three she does agree on is different from mine.

These predictions clearly need empirical verification. Van Dijk and Kintsch (1983) set out to show a preference for topic-maintenance, where “Topic role is established ... through the use of either a pronoun or a definite description” (p. 174). Fortunately they present the figures for individual sentences, from which it is possible to extract those containing tests of pronominal versus non-pronominal antecedents in similar roles to those illustrated in examples (96). Unfortunately the data is only available for agent pronouns, as they obtained the data using \textit{continuation studies}, where subjects indirectly indicated their preferences for certain antecedents by constructing continuations to the given texts using a given subject pronoun.

Examples (97) have been translated from the Dutch, maintaining the original linear ordering. A context was provided before each of the sentences shown, from which the referent of any pronoun could be found straightforwardly.

(97)  
\begin{enumerate}
  \item \textbf{Indefinite agent PDFL, non-agent DF, agent pronoun} A tourist (fem) asked her the road. She —
  \item \textbf{Indefinite agent PDFL, non-agent DF, agent pronoun} A man approached him whistling. He —
\end{enumerate}

(From van Dijk and Kintsch p. 175)

Thirty eight subjects took part in the experiment. They were asked to suggest ‘coherent and correct’, though not necessarily ‘funny or original’ completions to the final sentence. Two judges who were \textit{unaware} of the purposes of the experiment then independently decided which antecedent was intended by each of the subjects, on the basis of the continuation chosen. Cases of disagreement between the judges, or cases where they
agreed that the continuation was uninterpretable, were excluded for the final analysis. Van Dijk and Kintsch found that for the first text in (97), 75% of subjects preferred the topic continuation, while for the second text, 53% of subjects did. Only the figure for the first example was significantly (p<0.05) greater than chance. Two other similar examples containing proper names instead of pronouns resulted in 50% of subjects choosing each of the possible antecedents. That is, only one of the pronoun topics biased choice of continuations above the chance level. The bias in the case of pronoun topics was always towards using the pronominally expressed antecedent.

I will be speculating shortly on why the second text in (97) did not produce a significant focus bias.

It cannot yet be ruled out that the first text did produce a significant result for other reasons apart from a focus-maintenance preference. It may be, for instance, that indefinite noun phrases are not considered likely antecedents for pronouns, so that the pronoun referent is considered by default. However this would not explain why the texts van Dijk and Kintsch tested using definite noun phrases (for which they expected a similar preference to that obtained for pronouns) produced no bias either way for definites in non-agent position.3

Let us control, just in case, for the possible tendency of indefinites not to be preferred. (98) are a set of examples in which the discourse focus is introduced using a definite noun phrase, and the rival antecedent introduced using a proper name rather than an indefinite:

(98)  a. **Proper-name agent** PDFL, **non-agent DF**, **agent pronoun** The manageress of Corporation Carpets went into the office. Jilly offered her some nuts. Two hours later she was dead.

b. **Proper-name agent** PDFL, **non-agent DF**, **non-agent pronoun** The manageress of Corporation Carpets went into the office. Jilly offered her some nuts. It was her birthday.

c. **Agent** DF, **proper-name non-agent** PDFL, **agent pronoun** The manageress of Corporation Carpets went into the office. She offered Jilly

3They did find some bias when the definite was in agent position (64% n.s., 75% p<0.05).
some nuts. Two hours later she was dead.

d. **Agent DF, proper-name non-agent PDFL, non-agent pronoun** The manageress of Corporation Carpets went into the office. She offered Jilly some nuts. It was her birthday.

My prediction is that **DF, the manageress of Corporation Carpets**, will be preferred to the **PDFL, Jilly**, in all these cases.

As before, Sidner predicts that the first case will prefer **Jilly**, and in the other cases **the manageress**.

Van Dijk and Kintsch only have one example which contrasts a pronominally marked antecedent with a definite noun phrase, unfortunately this is one of the cases where Sidner's algorithm and mine agree:

(99) She applied to the director (fem) for her resignation. She —

Van Dijk and Kintsch found 92% preference for continuing with the referent of **she** (p<0.05). The focused antecedent is in agent position, so an agent preference cannot be ruled out. However the strength of the pronoun bias suggests that van Dijk and Kintsch may have been mistaken in suggesting that both pronouns and definite noun phrases are equal ways of establishing a topic. In the only case they tested, they found that 76% of subjects preferred a proper name (in agent position) to a ‘topical’ definite noun phrase.

A second battery of examples will be used, in which the **discourse focus** is introduced using an indefinite and the rival antecedent using a proper name.

(100)  
a. **Proper name agent PDFL, non-agent DF, agent pronoun** In the village there was a farmer who lived on his own. Once John Cox invited him round for dinner. But he preferred solitude.

b. **Proper name agent PDFL, non-agent DF, non-agent pronoun** Once upon a time there was a farmer who lived on his own. Once John Cox invited him round for dinner. Having someone to talk to cheered him up.

c. **Agent DF, proper name non-agent PDFL, agent pronoun** In the village there was a farmer who lived on his own. Once he invited John Cox round for dinner. But he preferred solitude.
d. **Agent DF, proper name non-agent PDFL, non-agent pronoun** Once upon a time there was a farmer who lived on his own. Once he invited John Cox round for dinner. Having someone to talk to cheered him up.

I still claim that the discourse focus (the farmer) will be preferred, despite all the factors biasing against it:

My motivation for rigorously including all permutations of antecedent placements is to point out the underlying similarity of all these examples. I hypothesise that a focus-maintenance preference does influence resolution of pronouns in succeeding sentences, regardless of whether the focused antecedent is in agent or non-agent position, whether the rival antecedent is definite or indefinite, whether the focus was itself introduced using a definite or an indefinite noun phrase, and finally, whether the pronoun to be resolved is in agent or non-agent position.

However I concede that the focus-maintenance bias can be reduced or increased by factors like those above. Indeed my intuition is that the strongest factor reducing the preference for the focus is where the focused antecedent is in object position, and the rival antecedent in subject position. This and other possible biases, I claim, cannot completely obscure the underlying bias towards pronominal items over PDFL items. At the end of this chapter I will sketch out how some of these biases might be incorporated quite happily into a theory of semantic processing alongside the basic focus-maintenance assumption.

Interestingly, general knowledge seems to have quite a small effect (e.g. the obvious inference that eating nuts caused the deaths in (98) does not seem to be made if it would involve shifting focus). This fits in with Sidner’s reasoning that since general knowledge inference is expensive in processing terms, it is better that pronoun resolution should be done first, leaving inferencing as a final step.

What seems clear from these examples is that the thematic/grammatical role of the pronoun to be resolved has no influence whatsoever. This is in direct opposition to Sidner’s algorithm, for which the distinction between agent and non-agent pronouns is a fundamental determinant of antecedent choices. Dropping the agent/non-agent distinction, which is part of the actor/discourse focus mechanism, then will not have
any drastic effect, and indeed permits a much simpler algorithm.

It is interesting to note that so far all the predictions made by my algorithm are identical to those made by the Centering algorithm. This is because the Centering algorithm too favours focus-maintenance (Continuation or Retention) over focus shifts. However my definition of focus differs slightly from theirs, since for me several items may be focused, if they were all pronominalised in the matrix sentence.

I will now go on to show how my algorithm can be applied to a selection of the examples from the previous chapter.

I argued that Sidner’s basic ordering should be kept for the following examples:

(33) The nurse was very friendly. She gave Mary a glass of whiskey. The doctor threw her out of the hospital.

(35) The nurse was very friendly. Mary gave her a glass of whiskey. The doctor threw her out of the hospital.

According to Sidner’s basic ordering, since her (in the final sentences of both examples) is a non-agent pronoun the discourse focus (the nurse) will in both cases be the preferred antecedent. This is the same prediction as made by my algorithm. However Sidner suggested introducing the Discourse Focus Ambiguity Condition:

<table>
<thead>
<tr>
<th>DISCOURSE FOCUS AMBIGUITY CONDITION:</th>
<th>If anaphors</th>
</tr>
</thead>
<tbody>
<tr>
<td>co-specify both DF and some member of PDFL, then take as focus whichever is not in agent position ...</td>
<td></td>
</tr>
</tbody>
</table>

This would mean that although the prediction of nurse would stay for (33), in (35) Sidner intended Mary to be the preferred antecedent.

I have already pointed out that there is a slight tendency for subject PDFL members to reduce the focus maintenance effect, however I still insist that the focus-maintenance effect is primary.

In some cases, my algorithm solves one problem to raise another. Take (60):
(60)  John saw Mary in the station concourse. He waved to her. But she walked straight past him.

This example is problematic for Sidner's algorithm, I argued, not because it fails to resolve all the pronouns, but because the second sentence involves shifting both AF and DF, and the third sentence involves shifting both these stores again — back to their original values. This causes much redundancy in the focus stores, since when resolving later pronouns some alternatives may be considered more than once. I pointed out that this is an inevitable disadvantage of anaphor-based algorithms.

However my algorithm keeps the same foci from the second to the third sentence: a list of two elements created in the second sentence and maintained despite the change in order of mention in the third sentence.

In order to show how such a decision is justified let us look at the IFnet picture for this example. An ambiguity was noted earlier on the attachment site for the prepositional phrase. Since it is irrelevant to the present discussion I shall assume the following representation of the first sentence:

\[ j \xrightarrow{saw} m \xrightarrow{in} sc \]

Since there are no pronouns, nothing is yet focused. After the second sentence the net will look like this:

\[ j \xrightarrow{saw} m \xrightarrow{in} (sc) \]

And after the third:

\[ j \xrightarrow{saw} m \xrightarrow{in} (sc) \]

\textsuperscript{4}Dotted curves are currently unobtainable in xy-pic: the waved-to relation should be unfocused. Likewise, the curves should not have tips, as the incremental focusing algorithm does not utilise thematic information.
Between the second and the third sentence the only change to the hearer's representation need be the addition of an extra relation between the two focused elements. The lack of changes in the focus stores in my algorithm reflects this.

However Sidner’s algorithm performs one function which my algorithm cannot: it puts a preference ordering on the antecedents, and it may be that changing linear order of mention does affect such preferences.\(^5\)

My algorithm can account for some of the cases where Sidner's algorithm produced unsatisfactory accounts (either for empirical or theoretical reasons).

Take Sidner's Pronominal Actor Focus Rule, which was deemed unnecessary:

\[
\text{Pronominalized Actor Focus Rule: When the actor focus was last mentioned with a pronoun, choose AF. Then try one of PAFL, but the pronoun use is odd.}
\]

Here Sidner appears to be making a distinction between pronominalised and non-pronominalised actor focus, which is easily captured in a framework like mine, where pronominalised antecedents are always preferred over non-pronominalised. Of course, I have no concept of actor focus, so the same preference applies to non-agent as to agent pronouns. But let us begin with the agent pronoun examples given in the previous chapter:

(26) John is quite romantic. He gave Bill a book of poems. He...

Sidner’s Pronominalized Actor Focus Rule was designed to make John a much more certain antecedent than Bill, to the point of suggesting using he for Bill would be

\(^5\)I show how my algorithm could be augmented with such capabilities in section 5.9.
distinctly odd. This is in contrast with her basic ordering, which suggests that although John, as the actor focus, is preferred, potential foci like Bill are also plausible antecedents.

However I did note at the time that the potential focus Bill is less preferred in this case than in (28), where the actor focus is not pronominalised:

(28) John gave Bill a book of poems. He …

I pointed out that this seems more related to the fact that Bill was not a previous focus, than the fact that John is pronominally recalled. It seems to me that Bill can be preferred over John, even when John is the actor focus, if Bill is pronominalised:

(27) Bill is quite romantic. John gave him a book of poems. He …

On the other hand, when both Bill and John are pronominalised, preferences are weak, as they were in (28):

(29) John went to visit Bill. He gave him a book of poems. He …

My focusing algorithm can explain such data since pronominalised antecedents are always preferred over newly introduced antecedents. I have not so far given any ordering within these two categories, but preferences within these stores are clearly much weaker than those between.

To apply this to (26):

(26) John is quite romantic. He gave Bill a book of poems. He …

After the second sentence, the foci, DF, will contain [John], while the potential focus list PDFL contains [Bill]. Thus John will be the predicted antecedent of the pronoun he. These priorities are reversed for (27), where Bill will be preferred.

Identical predictions are made for cases where the relevant pronoun is in non-agent position:
John is quite romantic. He gave Bill a book of poems. They often made him cry.

(26b) is analogous to (26), and similarly my algorithm predicts that the focus John will be the preferred antecedent, despite a slight 'pragmatic' preference for Bill.

A second point where Sidner seems to need the distinction between pronominal and non-pronominal antecedents appeared while Sidner was attempting to justify the Dominant Discourse Focus Rule for agent pronouns, which I omitted, with reservations.

**Dominant Discourse Focus Rule:** If DF is more longstanding than AF, choose DF.

This was introduced to account for examples like the following:

(24) I haven't seen Jeff for several days. Rupert saw him yesterday. He was in the pub.

In resolving the agent pronoun he in the final sentence, the Dominant Discourse Focus Rule states that the discourse focus, Jeff will be preferred over the actor focus, Rupert, since Jeff was introduced first.

My solution is that after the first sentence, DF will be empty (there are no pronouns) and PDFL will be [I, Jeff, several days].

The pronoun in the second sentence will have the following preferences (to repeat the matrix rule):

**Matrix Rule:** Consider members of the DF list, followed by members of the PDFL list.

Since DF yields no antecedents, the first item in PDFL, the speaker, will be the preferred antecedent. This fails according to agreement constraints, but Jeff, the second choice, succeeds.
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After the second sentence the only pronominal referent, Jeff, will be transferred to DF, and PDFL becomes [Rupert, yesterday].

The pronoun in the third sentence will therefore be resolved firstly to Jeff, in DF. Rupert is the second choice, being the first member of PDFL. Grosz, Joshi and Weinstein (1983) pointed out that Centering was an improvement on Sidner’s algorithm because it did make the correct predictions in examples like (24). But although my algorithm copes better than Sidner’s algorithm with these problematic examples, the great bulk of Sidner’s algorithm involves preferences within the two categories I recognise, on which I can offer no guidance. So my algorithm resembles the ‘focus-based’ Centering algorithm. An example can be used to illuminate the comparison:

(52) Bill found a kitten on his doorstep. He gave it some milk.

Like the Centering algorithm, my algorithm cannot resolve the anaphor it in the final sentence of (52). However my algorithm differs from that of Brennan, Friedman and Pollard (1987) in designating two foci for the second sentence: Bill and the referent of it. The difference is illustrated in the following continuation:

(52a) Bill found a kitten on his doorstep. He gave it some milk. It purred.

According to the Centering algorithm, the third sentence produces a focus shift (shift-1). However according to my algorithm one of the foci is maintained, so something less than a total shift has occurred. A shift, in my algorithm, would require a member of the PDFL to become focused, as in the following alternative continuation:

(52b) Bill found a kitten on his doorstep. He gave it some milk. Alas, it was sour.

According to the Centering algorithm, this too illustrates a shift-1, not qualitatively different from the shift-1 in (52a).

In summary, my algorithm currently combines the ability of the Centering algorithm to track foci through the discourse, while still resolving pronouns incrementally. But with its single rule it does not impose a sophisticated hierarchy of preferences on antecedents in the way that Sidner’s algorithm does. But then, this has not, so far, been its aim.
5.4 A flaw in the algorithm

My algorithm overcame Sidner's Problem 8 by abandoning the troublesome actor/discourse focus distinction and allowing multiple foci. These multiple foci resemble Sidner's discourse focus in being pronominally detected. Foci are preferred over potential foci.

When pronouns are resolved the same rule (the Matrix Rule) applies for agent pronouns as for non-agent pronouns. This clears up the most uneconomical feature of Sidner's rules: the multiplicity of related algorithms. However whatever ordering I put on my DF list, antecedent preferences will be the same for all pronouns. This means that all pronouns are resolved to the highest ranked focus unless the choice is found unacceptable by the ratification procedure. When general knowledge and agreement constraints cannot be used, this means heavy reliance is placed on syntactic coreference restrictions. Take for example:

(101) Jamie had a disturbing weekend. John took him to visit Bill. He wanted him to meet his son.

The three pronouns in the second sentence are multiply ambiguous. Sidner's algorithm would resolve the first to John (the actor focus), and the second and third to Jamie (the discourse focus). The Centering algorithm would resolve the first pronoun to Jamie (the discourse focus) and not attempt to resolve the rest. My algorithm in its current form would resolve all three pronouns to Jamie, the focus.

General knowledge would rule out Jamie for the antecedent of the first pronoun. My algorithm would then be unable to choose (at present) between John and Bill, both potential foci. Independent of such a choice, the second pronoun would be resolved, this time without problem, to Jamie. Had the first pronoun been resolved successfully to Jamie, the choice for one of the two pronouns would have had to be abandoned due to syntactic coreference conflicts. The third pronoun does not syntactically conflict with any of the others, so would also be resolved by my algorithm to Jamie, giving the final choice of John/Bill, Jamie, Jamie, for the three pronouns.
My intuition is that John is probably the correct choice for the first pronoun and Jamie for the second, but that the third pronoun marginally prefers John. This final preference may be due to general knowledge or ‘pragmatic’ reasons (Jamie is unlikely to be introduced to his own son), but more investigation is needed. In the next sections it will be seen whether these intuitions can be captured by a focusing algorithm, such as Sidner’s, mine, or some form of parallelism.

The problem raised in this section is that my algorithm produces identical preference orderings on antecedents for all pronouns in a sentence, resulting in an uneconomical obstinacy. This also reintroduces the problem of parallelism which was partly overcome by Sidner’s actor/discourse focus distinction.

The solution, I argue, is to introduce an incremental update process which alters preferences on the basis of material which occurs prior to the pronoun in the current sentence, as well as information from the matrix sentence. Such a mechanism is required in any case to deal with intrasentential anaphors like the pronouns in the following sentence:

(102) John rang Mary and told her that he thought she was going bald.

5.5 Adding Intrasentential Anaphora

It would be an enormous benefit if Sidner’s algorithm were able to deal with intrasentential anaphora. Hobbs (1978) found that as many as 90% of pronouns occurred in the same sentence as their antecedents (Hobbs 1978, p. 345).

It has not yet been made evident why the term ‘Incremental’ has been applied to my algorithm in contrast to Sidner’s. So far my algorithm, like hers, allows pronouns in a sentence to be resolved independently of the rest of the sentence, unlike the Centering algorithm, which resolves all anaphors simultaneously. This section will take one step further towards completely incremental focusing.

It was noted in the previous section that the focusing algorithm makes the same
predictions for all pronouns. This problem can be solved by updating the focus stores after every nominal in the current sentence, not just after a sentence has been wholly processed. This means that the focus stores, and hence the antecedent preferences, will not be the same from one pronoun to the next. The second pronoun in a sentence will be interpreted in a different context from the first. It is the change in context, rather than the thematic role of the pronoun, which results in the different anaphoric preferences of what Sidner called 'agent' and 'non-agent' pronouns.

Carter (1987) does extend Sidner’s algorithm to deal with intrasentential candidates (called ISCs) by augmenting the focus stores temporarily prior to resolving each pronoun. However he rejects incrementality, since resolving anaphors in linear order causes difficulties with cataphoric constituents. I will describe and evaluate his solution before suggesting a more incremental version.

Carter resolves anaphors in order of informativeness, resolving definite noun phrase anaphora before pronouns for instance. He does not distinguish pronouns from each other with regard to informativeness, however, so in line with Sidner’s algorithm they may be resolved independently in any order.

When resolving a pronoun, the six focus stores (df, pdfl, dfs, af, pafl, afs) are augmented with the intrasentential candidates (ISCs) as follows (Carter pp. 145–146):

1. ISCs are first ordered by a mixture of grammatical role (using the algorithm from Hobbs 1978) and linear order.

2. If the pronoun could specify the df, then append those ISCs preceding the pronoun to the end of the df register.

3. If the pronoun cannot specify the df, append those ISCs preceding the pronoun to the front of the pdfl list.

4. Append preceding animate ISCs to the end of af.

---

6I have removed the rules for ISCs following the pronoun. Cataphora will not be dealt with in this thesis.
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Note that the ordering of ISCs must be recalculated when resolving each individual pronoun, as the number of items being appended to each of the focus stores increases.

The six stores are then input to Sidner's pi-rules as usual, with preferences determined by the particular set of rules used (agent or non-agent).

Like me, Carter now has several (ordered) discourse foci. The reason he alters the preference orderings slightly for pronouns which can specify the DF, as opposed to those that cannot, is that he uses between-store ordering to reflect strong preferences, and within-store ordering to reflect weak preferences, and believes that the relative preferences do alter in the two cases.

The idea of checking whether a pronoun can refer to the DF before embarking on the official pi-rules directly is highly uneconomical, even if such checking only went so far as surface agreement characteristics. Carter's algorithm is therefore not sufficient for my aims. I will now show that it also is insufficient to account for the empirical data, because it does not distinguish pronominal from non-pronominal ISCs.

Carter's basic preference ordering is, ignoring the difference between weak and strong preferences, as follows:

\[ \text{DF} > \text{ISCs} > \text{PDFL} \]

Firstly let us take an example which has newly introduced ISCs before the pronoun to be resolved:

(103) An insurance salesman visited John and Mary. The neighbours told the police \underline{they} were being robbed.

There is a slight preference here for John and Mary as the antecedent, rather than the ISCs the neighbours and the police. Of course this preference can be strengthened by focusing:

(104) John and Mary were very annoyed. An insurance salesman persuaded them to smash all their windows. The neighbours told the police \underline{they} were being robbed.
Here the extra-sentential candidate, John and Mary is also in focus.

These examples can be contrasted to a case in which the ISC is pronominal to a PDFL member:

(105) The sexton introduced John and Mary to two gypsy women. They said fortune had been good to them.

The definite preference here is for the second pronoun them to be resolved to the same referent as the first pronoun they, despite the availability of the discourse focus John and Mary (chosen by the initialisation mechanism). Even pronominally focusing John and Mary does not appear to override this preference:

(106) John and Mary were very superstitious. The sexton introduced them to two gypsy women. They said fortune had been good to them.

Any hesitation encountered in interpreting such examples occurs when processing the second pronoun, in subject position, which would prefer the discourse focus, but must eventually be resolved to a less preferred PDFL member.

These examples suggest that the preference ordering varies according to the nature of the ISCs, and that the preference ordering suggested by Carter is certainly not right when the ISC is pronominal: a pronoun seems to prefer a pronominal ISC over a compatible DF.

My solution returns to incrementality: I intend to introduce a partly on-line update mechanism, to avoid reordering of ISCs and reallocation of elements to the focus stores with every pronoun considered. I could, like Carter, add the ISCs to the already existing focus stores DF and PDFL. Or I could introduce two new stores for the two categories of ISCs. The option of adding new stores was not one which appealed to Carter since he already had six stores to process. However I only currently have three, of which one, PDFL, could be calculated on-line. Carter’s second reason for preferring to augment already existing stores was that he believed preferences were not strong enough to justify new stores: within store orderings could account for the mild preferences involved.
To determine what was the best solution, I devised a series of examples which will pinpoint what the antecedent priorities are between DF, PDFL, and the two types of ISCs, which I will call FISC (focused intrasentential candidates, which are pronominalised in the matrix sentence) and RISC (remainder of intrasentential candidates, which are non-pronominal). Pairwise comparisons are used because of the confusion which results when pronouns are more than two ways ambiguous.

The Matrix rule which forms the basis for my focusing algorithm already assumes that DF is preferred to PDFL. By an extension to this, it should also predict that DF is preferred to RISC, and FISC to RISC. That is, if pronominal elements reflect focus, and focus is salience, pronominal elements in the matrix or current sentence should always be preferred as referents to unfocused elements in either. All nominals in the matrix sentence are assumed to be accessible while the current sentence is being processed, even to pronouns at the very end of the current sentence.

Examples will be given to support this hypothesis.

**To show that DF is preferred to RISC:**

The preference for focused elements over newly introduced elements was noted by both Sidner (1979, p. 148) and Carter (p. 144).

(107) Shem loves his sister.

To resolve the non-agent anaphor in (107), Sidner's algorithm prefers the discourse focus. In fact, it does not take account of the possibility of intrasentential reference at all; Sidner (1979) did not regard intrasentential resolution to be the job of a focusing algorithm. Carter (1987) embeds an example of the same type in a context which makes the preference clear:

(108) I want to have a meeting this week. Bruce will be the guest lecturer. He will speak on slavery in ant colonies. Mike wants to read his report before the talk.
Carter believes this preference is quite weak, since the example below so easily biases towards Mike:

(109) I want to have a meeting this week. Bruce will be the guest lecturer. He will speak on slavery in ant colonies. Mike wants to invite his friends to the talk.

However such preferences were found to be quite strong in the van Dijk and Kintsch experiment I described earlier.

**To show that FISC is preferred to PDFL**

Now I ask whether a pronoun in the current sentence is preferred to a newly introduced item in the previous sentence. The pronoun could cospecify a previous focus or a different new item.

(110) Mary held the comb out to her camel. It licked its teeth.

(111) The camel leant towards Mary. She offered it her comb. It licked its teeth.

Once the first it has been resolved, interpreting the second pronoun, its, seems relatively easy. Although combs have teeth, the camel is the preferred antecedent in both these cases.

It seems that the FISC, if resolved as expected, is always strongly preferred as an antecedent to PDFL.

**To show that FISC is preferred to RISC**

Finally, I will show that a pronoun in the current sentence is always preferred to a newly introduced item in the current sentence.

(112) Annie walked in. Mary greeted her in her native language.

(113) Annie walked in. She greeted Mary in her native language.

(114) Annie walked in. Mary gave her a picture of herself.
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(115) Annie walked in. She gave Mary a picture of herself.

(116) Annie walked in. Mary hugged her for her brother's sake.

(117) Annie walked in. She hugged Mary for her brother's sake.

In resolving the underlined pronoun, there is a strong preference for FISC over RISC, which is probably reduced in the 'picture of' cases for grammatical reasons. As noted before, there is also a subject preference interfering.

This has covered four of the six pairwise comparisons, leaving only those which cannot be predicted by extending the hypothesis conveyed by the Matrix Rule.

The two remaining comparisons are PDFL versus RISC, and DF versus FISC.

Firstly, does a pronoun prefer newly introduced members of the previous sentence, or newly introduced members of the current sentence, as antecedents?

Carter believed that ISCs in general are mildly preferred to PDFL, but he did not separate RISCs from FISCs. The two examples below contrast the possibilities:

(118) John is a romantic fellow. He gave a bunch of flowers to Mary. Susan says her mother should have got them.

(119) John is a romantic fellow. He gave a bunch of flowers to Mary. Susan says she's a fool for loving him.

In both these examples the final feminine pronoun is compatible with either Mary or Susan. The preference for Susan is strong in (118), whereas in (119) Mary is preferred.

I conclude that if there is a preference it is not strong. Since the algorithm does not particularly predict a preference there is no need to explain how a decision is made on the basis of focus. I will defer judgment until the DF/FISC comparison has been made, since both basically concern the relative salience of the current and matrix sentences.

The final comparison to be made is between DF and FISC. Again, it could well be that there are no clear preferences, but this needs to be determined with reference to examples.
Carter noted (1987, p. 141) that one of the reasons for considering ISCs is that they may indicate a focus shift, as in example (120):

(120) John bought a new car the other day. He also bought a television. The car was so unreliable that he soon wished he'd never set eyes on it. (Carter 1987, p. 140)

Here, the final anaphor it has two possible antecedents, John's new car and John's new television. Although the nominal for the car did not occur in the matrix sentence, where the television did, the new sentence reintroduces the car, which had been stacked, and puts it in a more salient position. Carter's example involves global focusing, but similar examples can be found with local focusing, where an ISC cospecifies a less preferred or potential focus, rather than the discourse focus:

(121) Mary Isley is a friend of mine. She once wrote a book about trains. They are the great inspiration of her life.

The question is, by the time it comes to resolve her, whether the preferred focus is still Mary, or whether the preferred focus has shifted to trains. Such a judgment can only be made (short of reaction time studies) by using ambiguous pronouns. The problem with such examples is that the first pronoun in the sentence will also be ambiguous and would therefore tend to be resolved to the previous focus. It is therefore difficult to disentangle the influence on later pronouns, unless the first pronoun can be disambiguated fully by context:

An example used earlier serves to illustrate this.

(106) John and Mary were very superstitious. The sexton introduced them to two gypsy women. They said fortune had been good to them.

It was observed before that the second pronoun them tends to be resolved to the referent of the first, rather than to the discourse focus of the previous sentence.
Therefore it seems there is a strong preference for FISC over DF which cannot currently be accounted for by my algorithm. The solution is related to Carter's remark that ISCs can sometimes be used to signal a shift in focus. (106) is initially hard to process because the preferred antecedent for they is John and Mary, however this choice is thwarted by contextual oddity, and the gypsies, which were previously unfocused, come into focus instead. If the speaker had used the definite anaphor the gypsies instead, this would not have happened. But the use of the pronoun indicated to the hearer that the speaker (unknown to the hearer) had already been focused on the gypsy women, or shifted focus to them as soon as the third sentence was produced. The hearer is forced to accommodate the fact that the gypsies are the preferred referent for they, which means raising them to a higher salience than John and Mary. It will now be hard to refer pronominally to John and Mary unless syntactic coreference or pragmatic constraints rule out the gypsies as an antecedent.

This latest finding points either to a general store preference of FISCS over DF, or to a recency ordering on foci. On the basis of this finding, I will assume that there is also a preference for FISC over PDFL, in other words that the current sentence is always more salient in the hearer's mind than the matrix sentence.

I will now summarise the discoveries of this section. It was found in general that pronominal elements always take priority over non-pronominal, that items focused in the current sentence take priority over items focused in the matrix sentence, but that no clear preferences appeared between non-pronominal elements of the current sentence versus the matrix sentence.

This gives the overall ordering of FISC > DF > RISC > PDFL, where > signifies 'preferred to'.

This ordering shows how discourse coherence is kept to a maximum without constraining the possibilities of shifting focus. Maintaining connections to previous context using pronominal connections between sentences (expressed in DF and FISC preferences) is preferred to frequent changes of focus (PDFL) or lack of connection with previous sentences (RISC). However once a single link with the previous sentence has been made (FISC), the emphasis on creating more links (DF) is diminished in favour of strengthening
the new focus.

This again embodies the principle of relevance: both maintaining a link, and allowing informativeness. If these preferences are correct, they account for the predominance of single pronoun sentences over no pronoun or two pronoun sentences. They also explain why sentences containing many non-coreferential pronouns are extremely rare: there will be several FISCs to reject before a DF or PDFL member can even be considered.

5.6 Incremental Update

In the previous chapter I argued that the update point should be the unit. In this chapter update has been at least partly incremental, with update occurring after each nominal. However the larger processes of update will still wait until after the end of the unit, in accordance with the empirical data discussed in section 4.5 in Chapter 4. The four stores are continually modified throughout the sentence. Some update occurs every time a nominal is encountered. As I have explained, every new nominal is added to RISC, and every pronominal to FISC. As it stands, this mechanism would lead to the kind of overgeneration which caused the problem of redundancy (Problem 8) in Sidner’s algorithm. For an element of DF, say, which was pronominally recalled in the current sentence would be stored in both DF and FISC. To avoid this problem, the stores DF and PDFL can also be updated whenever a nominal is encountered. Whenever an item is pronominally accessed from DF or PDFL, then that nominal should be deleted from the DF or PDFL. This means that when the end of a unit is reached, the entire DF can be stacked, since it contains no elements which were also mentioned in the current sentence. In addition, the update mechanism will move the current FISC and RISC into DF and PDFL respectively. Members of the old PDFL are simply forgotten.

5.6.1 Update in coordinate units

Although the update mechanism has this task of determining which items are to be stacked and so on, the partial update of FISC and RISC means that the new foci
have already been determined at the end of the sentence, something it was harder for Sidner's algorithm to do because the discourse focus depended on a number of factors: whether there was more than one pronominal item, whether there was an actor focus, and what the previous discourse focus was. My incremental focusing algorithm has the property, like Sidner's algorithm, of favouring focus maintenance because of the resolution preferences, but unlike Sidner's algorithm focus maintenance is not measured with respect to a particular focus (actor or discourse), but with respect to clusters of foci: a meta-process to evaluate the coherence of a discourse could look at the intersection between DF and FISC thus judging (60) as an extreme example of focus maintenance (DF=FISC) rather than of focus shift (AF shifted, DF shifted).

(60) John saw Mary in the station concourse. He waved to her. But she walked straight past him.

One might want the meta-process intersecting the sets also to be sensitive about focus changes, which probably rank as more coherent than focus shifts but less so than focus maintenance, although they may be less likely to occur than focus shifts for processing reasons. This will be explored in more detail in Chapter 6.

The update mechanism described here applies only after the end of a coordinate unit such as that in VP-conjunction, clause conjunction, or sequences of sentences. So focus is dynamic and determined at the same time as pronoun/ellipsis resolution.

When the unit to be updated is subordinate, the rules of the next section apply.

5.6.2 Update in subordinate units

The main verbal unit in which a subordinate unit is syntactically embedded will be called the **MAXIMAL UNIT**. The maximal unit will not be saturated at the point when a subordinate unit is reached, therefore its FISC and RISC will still be due to be augmented with further nominals. A subordinate unit will be syntactically attached to a particular specification (in the cases in which I am interested, a nominal) in the superordinating
unit. A coordinate clause always focuses that to which it is attached, since syntactically determined attachments are treated similarly to pronominally determined ones, and pronominal attachment necessarily produces focusing. However a subordinate clause only causes the nominal to which it is attached to be focused temporarily, that is, for the duration of the subordinate clause. In effect, the subordinate clause describes a separate, but dependent \textit{IFnet}, with its own focusings. So subordinate clauses locally augment the \textit{FISC} and \textit{RISC} of the superordinating unit, but the augmentation is removed after the subordinate unit is complete. If a subsequent sentence wishes to access the potential foci of the subordinate clause, it must do this via the superordinate unit. That is, the nominals in the subordinate unit are only accessed if none of the nominals in the superordinate unit are compatible with the pronoun to be resolved.

5.7 Syntactic Coreference Restrictions

Incremental focus update was introduced to prevent every pronoun in a sentence having the same antecedent preferences. A second way to reduce the chances of two pronouns having the same reference would be to impose syntactic coreference restrictions as part of the pronoun resolution rules, rather than as part of the Ratification procedure.\textsuperscript{7}

Syntactic coreference restrictions (described for instance by Reinhart 1981) can be seen as determining which anaphoric form (pronominal versus reflexive) is suitable depending on the syntactic relation holding between the anaphor and its antecedent. For instance, when the antecedent is in subject position and its anaphor is in object position, a reflexive must be used. However if the antecedent is in subject position in one clause, and the anaphor in object position in another, a pronominal must be used:

\begin{align*}
(122) & \ [\text{Mary}]_i \text{ hurt } [\text{herself}]_i . \\
(123) & \ *[\text{Mary}]_i \text{ hurt } [\text{her}]_i .
\end{align*}

\textsuperscript{7}Sidner (1979 p. 150) leaves syntactic coreference restrictions to ratification, but later suggests that it would be possible to impose the constraints in parallel with pronoun resolution (p. 161–162), rather as is done in the Centering algorithm. In Centering 'contraindexing' (syntactic non-coreference) restrictions are part of the filters which apply after the possibilities have been constructed, but before a final choice is made.
(124) *[Mary], said that John had hurt [herself]i.

(125) [Mary], said that John had hurt [her]i.

So, from the hearer's point of view, although any pronoun will prefer the focus as antecedent, if the anaphor is reflexive it is syntactically constrained to resolve to the subject of its own clause. More relevantly, if the anaphor is pronominal (or indeed a full noun phrase), it is syntactically prevented from resolving to the focus if the focus is the subject of its clause. However this heuristic only covers non-coreference of subject and object: normally syntactic coreference restrictions are stated in a general rule which has a much greater applicability. For the purposes of this thesis, it is necessary to apply syntactic constraints incrementally, that is, assuming that at the point when a pronoun is resolved only the syntactic structure for the preceding section of the sentence is available to impose constraints. Ideally it should be possible to state, for each pronominal, the search domain for possible antecedents. This would differ from Sidner's algorithm in preventing syntactically forbidden antecedents being considered at all. It is rare for linguists to state syntactic coreference restrictions in such a way that they can be applied incrementally, although owing to the right-branching nature of syntax trees, there is no reason why syntactic coreference should not be applied incrementally. Chomsky (1992) is unusual in giving the syntactic constraints on coreference from the point of view of a pronoun, rather than simply as a declarative statement of the relation which must hold between the two noun phrases:

"If $\alpha$ is a pronominal, interpret it as disjoint from every c-commanding phrase in D."

C-command is a relation determined by the tree structure of a sentence, and D is the relevant local domain (again determined by the tree structure and the scope of syntactic constituents). I shall argue that Chomsky's formulation of the rule allows set-relations between a pronoun and its c-commanding antecedent, which ought to be ruled out.

(126) a. *[The democrats], voted one of [them], as party leader.
   b. *[[John], and his sisters] were fond of [him]i.8

8There are borderline cases which do seem to be acceptable:
c. *John consulted [a psychiatrist], only to find he had been totally misinformed about [them].

Chomsky's rule excludes (126) but fails to exclude examples (128):

(128) *Democrats want one to be the ruler.

The problem with Chomsky's rule is that it is not semantically precise. Firstly, by a 'c-commanding phrase' he must mean the 'nominal generated by a c-commanding phrase'. Secondly, the term 'disjoint' is ambiguous: does it mean non-coreferential or having no individuals in common? An alteration is required to state that the antecedent and anaphoric nominals must not bear a set-theoretic relation to one another either. In other words, focus changes must be ruled out as well as focus maintenance within syntactic domains. The only focus changes which are permitted would be complex changes (e.g. coset) where both antecedent and anaphor are set-theoretically related to some implicit set, but are not directly related to one another:

(129) Two balls hit three.

(130) One cat bit another.

From now on, the word 'disjoint' will be assumed to exclude cases where one nominal is a subset or member of the other.

As it stands, Chomsky's formula is not very useful for determining which nodes of an IFnet a pronoun can legitimately unify with. However since the IFnet is generated by syntactic structure, it is possible that all the syntactic information required is available. I will put forward the hypothesis that c-commanding nodes are simply those which already exist in the IFnet, and that 'the relevant local domain' is the update unit which is currently attended (minus subordinate units).

(127) John and Mary went shopping. They bought him a wig and her some false teeth.
Chomsky’s definition of syntactic coreference restrictions can then be restated for testing:

Proposal (Syntactic Constraint):

*When attempting to resolve a pronoun, identify it as disjoint from every existing node in the currently attended unit.*

In the simple subject-object cases then any relation must have its nodes unconnected, unless a reflexive has been used:

\[ j \xrightarrow{\text{wash}} m \]

or

\[ j \not\xrightarrow{\text{wash}} \]

but not:

\[ j \xrightarrow{\text{wash}} j \]

In more complex cases, the proposal makes the following correct predictions:

(131) a. *[John]; put the blame on [him];
    b. *[John]; introduced [him]; to [Mary];.
    c. *[John]; went home and made [him]; a meal.
    d. *[The man]; who [he]; liked best arrived.
    e. [John]; gave Mary a picture of [him];
    f. The man who liked [Rosa]; visited [her];
    g. [Dan]; saw a snake near [him];.
However there are some cases where the proposal fails. It predicts examples (132) to be bad, and example (133) to be good:

(132)  
  a. John gave Mary a picture of himself.
  b. Mary wrote a book about herself.
  c. John pulled the duvet over himself.
  d. The democrats elected one of them as leader.

(133)  *[Mary]i wrote a book about [her]i.

Some of these exceptions seem to be focus related, compare:

(134)  Mary arrived. John gave her a picture of himself.
(135)  Mary arrived. John gave her a picture of him.
(136)  John arrived. He gave Mary a picture of himself.
(137)  John arrived. ?He gave Mary a picture of him.
(138)  Mary arrived. John gave her a picture of herself.
(139)  Mary arrived. *John gave her a picture of her.
(140)  John arrived. He gave Mary a picture of herself.
(141)  John arrived. ?He gave Mary a picture of her.

It seems that pronominals can only be acceptable in situations where there is a focused nominal intervening, so reflexives are not only strongly associated with attachment to the subject, but also with attachment to the focus.
5.8 The Focus Stack

I will not propose a definitive answer to the question ‘What is the Focus Stack?’, but will instead make some observations about the data which led to the introduction of the stack as a theoretical device for storage of previous foci.

Sidner had two stacks, an AFS and a DFS. However it would be awkward for me to follow her lead and have separate stacks for each focus. Since I have an arbitrary number of foci, none distinguished from each other, the only option is to rely on one stack for old foci.

If an item is ‘popped’ off Sidner’s stack, earlier items are lost. However, for pronominal anaphora Sidner imposed the extra constraint that the stack only has one item in it anyway. This could cause problems for me, since one stack is even less capable of dealing with the example (72) which proved problematic for Sidner’s two stacks:

(72) John gave Mary a bathing costume. It started to rain. She threw it back at him in a fury.

One solution would be to have sets of nominals added to the stack, rather than single nominals. When the second sentence has failed to mention any member of DF the whole of DF could therefore be stacked together. However this would be slightly awkward when one member of DF is mentioned, and one not — in this case only a subset of DF would be stacked:

(71) John gave Mary a fur coat. She threw it back at him in a fury. She had just attended an animal-rights meeting. How was he supposed to know?

It seems to be possible also to access two items from the stack which were stacked from two different units:

(142) Narcissus was lying in the grass resting. He reached out for his mirror, but it had vanished. There was a gentle splash. The wind had blown it into the pond, and it lay glistening on the sand beneath the water. He sighed.
The second unit, 'He reached out for his mirror' has Narcissus as focus, but since the third unit 'it had vanished' does not mention him at all (the mirror has become the only DF), he is thereafter stacked. In the third unit, 'There was a gentle splash', the mirror becomes stacked, since it was focused and is now not mentioned. The mirror is popped from the stack in the fourth unit 'The wind had blown it into the pond'. But in the sixth unit, 'He sighed', the stack is popped again to recall Narcissus.

This text clearly illustrates the idea of the stack as a mechanism to 'pause' foci while further units interrupt, rather as a subordinate unit interrupts a superordinate unit. Sidner (1983 p. 301-302) sees the stack as enabling a hierarchy of more global topics. In (142) Narcissus is the highest node in the hierarchy, with the mirror being one possible elaboration on Narcissus’ story, and the splash one elaboration on the mirror’s story, indirectly also giving further details of Narcissus’ story. The phenomenon called ‘topic-dominant-chaining’ (Polanyi and Scha 1984, p. 418) is an example of rapid stack embedding. A topic dominant chain is demonstrated in (143):

(143) Mary took a photograph of the party. John was in the centre. He was holding a flower. It was an anemone. They are very brightly coloured.

Here, theoretically, a pronoun in a subsequent sentence could continue discussing anemones, or else the stack could be popped, the flower John was holding being at the top of the stack, but more deeply stacked items also being accessible, such as John or Mary. However it is more common to pop the stack using definite noun phrase anaphora, which are not covered here, but are dealt with in detail by Grosz and Sidner (1986). In fact Sidner, as I have said, generally assumed that pronouns could only be used to access the stack one layer back, though there are exceptions, as pointed out by Grosz (1981), who studied dialogues concerning engineering tasks. However deep stack access is also possible in written narratives:

(144) She took a deep breath and tested the firmness of her grasp on the wood. When Jobin had first taught her to swim, he had told her always to get in
and out of the water quickly, for it was in the marginal moment — half in a half out of the water — that a person was most vulnerable to shark attack. It was then that the person looked truly like a wounded fish; most of the body was out of the water so it appeared smaller, and what remained in the water (lower legs and feet) kicked erratically and made a commotion like a struggling animal.

She spun, grabbed the gunwhale ...


Popping the stack is more likely when the current unit contains no foci (i.e. no pronominally recalled elements), since a subsequent pronoun will have less choice of nominals to attach to, and will turn to the focus stack if any potential foci are incompatible with a subsequent pronoun. Potential foci may be newly introduced or simply non-pronominal. Compare:

(61a) Mary was angry. She hit Bill. Bill cried.

(62a) Mary was angry. She hit Bill. He cried.

In (61) the second sentence contains no foci, so if the next sentence used a pronoun to access the potential focus Bill, a focus shift would have occurred, whereas if a pronoun was used to access Mary, a focus pop would have occurred. However in (62a) accessing Bill in a subsequent sentence would be focus-maintenance, so accessing Mary would make the transition relatively less coherent. The Centering algorithm treats both these examples as retentions. However Kameyama (1986) when adapting the Centering algorithm to cope with Japanese suggested that focus should perhaps be optional. To bring the Centering algorithm in line with my own, it would be necessary to exclude non-pronominal anaphors for consideration as foci. Therefore the center in the third sentence of (61a) would be set to NIL.

Stack recall is almost inevitable if there are no potential foci either, as in:

(145) Mary put on her bathing costume. She walked into the garden. It began to rain.
Here the third sentence contains no foci or potential foci, so Mary is the preferred antecedent for any pronoun occurring in a fourth sentence.

Another observation about likelihood of stacking follows from the 'focus tree' metaphor: if one focus is higher ranked than another (e.g. by virtue of being mentioned first, as I consider in section 5.9), then it should be difficult to stack the lower ranked focus unless the higher ranked focus is also stacked. This should follow because once a lower-ranked focus has stopped being discussed, and discussion has returned to the higher focus, it is presumed that the elaboration has ended.

(146) Mary wrote a book. She took it to a publisher. They rejected it. She was undeterred.

(147) Mary wrote a book. She took it to a publisher. They rejected it. It was unsuitable, they said.

(148) Mary wrote a book. She took it to a publisher. They told her she was mad. It was totally unsuitable.

(149) Mary wrote a book. She took it to a publisher. They told her she was mad. She was undeterred.

The prediction is that the third example, marked as dubious, should be harder to process because the temporary elaboration on Mary marked by the introduction of Mary's book has apparently ended with a return to Mary (and perhaps a new elaboration on her sanity). I predict that the book would be better recalled using a full anaphoric noun phrase: 'The book was totally unsuitable.' The fourth example should be more acceptable, since it does not attempt to recall the book. Example two shows the elaboration on the book continuing without interruption, while example one demonstrates that stacking Mary is much easier, using a resumptive proper name 'Mary was undeterred' is unnecessary, since Mary is still a higher (if implicit) topic of the discourse. I suggest further that higher, or implicit, topics (stacked foci) can result in the creation of a 'perspective' (see for example Caenepeel 1989). That is, the referent of the stacked focus is somehow implicitly assumed to be seeing, believing, experiencing, or creating the subsequent narrative:
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(150) She looked up. Dark clouds were beginning to gather.

(From Caenepeel 1989)

Here are some more examples:

(151) He put his ear to the door. Somebody was singing.
(152) He was angry. Everybody hated him.
(153) It fell slowly. There was grass far below.
(154) He was afraid. Tigers could kill.

This section has suggested that the stack would best be integrated with more global theories of discourse, adopting Polanyi’s suggestion that pronominal reference can only access the right-boundary of the focus tree. The nature of interruptions seems to be that the fewer nominals they introduce, the easier it is to return to the focus. It also seems to be the case that stacked foci can still play an (implicit) role in the intervening interruptions. I will simply assume that focused entities are remembered in relation to other elements of previous discourse in a hierarchy similar to that displayed in Polanyi’s (1985) ‘focus trees’. The focus tree represents the cumulative development of the discourse; subordinate elements are generated as a result of exploring the properties and relations of the immediately dominating elements. When assertions are made about elements currently in focus, this produces new potential foci which, if taken up by the discourse participants, become subordinate foci.

5.9 Non-focus influences

The algorithm presented so far has argued for a new configuration of focus stores, partly incremental update, and an array of different transition types. However it falls short of being a complete pronoun resolution algorithm. It has only a subset of the abilities of Sidner’s algorithm, though it probably has about the same usefulness as the centering
algorithm, sometimes able to resolve more, and sometimes fewer, of the pronouns in a sentence. I achieved the goal I set myself at the beginning of this chapter, to separate out the purely focusing constraints on pronouns. However focus constraints cannot put a complete ordering on antecedents: I have treated all four focus stores as if they were simply bundles of nominals. In addition I have had to point out occasional biases in the data which cannot be accounted for in my framework, but nevertheless can reduce or enhance the focusing preferences I have described.

This section begins by asking how the focus stores (starting with DF and FISC and going on to PDFL and RISC) could be ordered. After this I explore a selection of the further influences on pronoun resolution and discuss how they might be incorporated into the IFnet-based focusing algorithm theory I have presented in this chapter.

5.9.1 Ordering of Foci

This section discusses ordering within FISC and DF. It is important not to forget that the IF algorithm is extracted from the underlying IFnet. So far, I have stated the algorithm in a form which would suggest that pronouns are attracted to focused nodes, but have no preferences between them. However, just as focus maintenance wins over choice of potential foci, I would like to show that foci which have been established longer are preferred over more recently established foci. There are two ways to construe this statement, either, (Hypothesis A) length of establishment of foci is determined by which nominal was mentioned first in the current unit,9 or (Hypothesis B) length of establishment is determined by which nominal was generated first in the discourse. The third hypothesis (Hypothesis C) is that preferences are determined by other factors, but this will only be adopted if both other hypotheses fail. It would be against the assumptions of my thesis to assume there were no preferences at all, since this would mean pronouns could not be resolved immediately (or at all).

Let us look at some examples where a pronoun has two focused choices for an antecedent,

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9Suggested by experiments demonstrating preferences for subject antecedents, e.g. Smith and Foos (1975).
to see if there are any discernible preferences.

(155) Bill went to visit John. He told him that he had won the pools.

Here preferences are not strong, though it seems there is a mild preference for Bill unless he is stressed, in which case John would usurp the the preference for Bill. These observations would support both hypotheses A and B, since Bill was introduced first in the first sentence, and is recalled in subject position in the matrix sentence. The effect persists in an example like the following, in which Bill was focused for one sentence longer than John:

(156) Bill was bored. He went to see John. He told him that he had won the pools.

In the following example John has been the most longstanding focus, though both John and Bill are focused in the matrix sentence:

(157) John was bored. Bill went to see him. He told him that he had won the pools.

Here I believe the most likely antecedent for he has switched from Bill to John. This is probably because the second pronoun he was resolved to John, who was the only focus at that point, so he preferred the subject (and incidentally longer focused) nominal John. Or it could be solely due to the longer lifetime of the nominal John compared with Bill. These examples seem to suggest that hypothesis C can be abandoned, but has not so far managed to distinguish between hypotheses A and B.

The only way to separate such preferences would be to force the subject pronoun into choosing the non-focused antecedent, and the object pronoun into taking the focused antecedent. Such examples are not easy to analyse, since they often seem odd:

(158) John was angry. He bit Bill. Unfortunately he bit him back. He was bleeding.

The third clause contains the oddity: a subject pronoun which is compatible with the focus is used, but by the end of the sentence it is clear that it cannot coherently corefer
with the focus. However it is quite difficult to repair the assumptions and assume he to be Bill. It is also very difficult to tell whether the final he prefers John or Bill as antecedent.

It is still uncertain whether FISC is ordered by longstandingness of nominals in the discourse (inherited from DF), with later ones being less preferred, or FISC is ordered by the syntactic ordering in the current sentence. The remainder of this section will explore the theoretical implications of the two hypotheses, to argue that hypothesis A is more satisfactory for theoretical reasons.

**Hypothesis A**

Hypothesis A is that focus ordering is determined by the syntactic structure of the matrix unit. This option would be more in line with the behaviour of the Centering algorithm, in which the pronoun to be the ‘backward looking center’ is the one with the highest grammatical role (where subject is ordered before object, object before indirect object etc.). Were I to choose this option, my incremental focusing algorithm could be seen as altering the Centering algorithm (by making it incremental) and extending it (by allowing lesser foci to follow the ‘center’ in preferences). Transition types would be much more complicated, with two foci maintained preferred to one maintained and one shifted, but two foci maintained in the same syntactic roles preferred to two with their syntactic roles exchanged, as in (60).

(60) John saw Mary in the station concourse. He waved to her. But she walked straight past him.

However these preferences would as in Sidner’s algorithm emerge naturally from the focus preferences. For instance in (60) processing the second sentence would involve no backtracking (except the quick rejection of John for her rejected by syntactic coreference restrictions). However in the third sentence, faced with a grammatically ordered DF of <John, Mary>, the processor would backtrack once for she ≠ John, (and a quick coreference failure for him ≠ Mary). An example in which the third sentence mentioned John before Mary would involve one less backtracking.
This hypothesis would have the advantage that FISC could be constructed from left to right: the first pronominal in the unit would remain the preferred focus throughout the whole unit, and would be the preferred DF for the next unit encountered.

Hypothesis B

Hypothesis B is that focus ordering is determined by the length of time a particular nominal has been in focus. Take (60) again.

(60) John saw Mary in the station concourse. He waved to her. But she walked straight past him.

Under hypothesis B processing the third sentence would again involve one major backtrack (on she), but this time the backtracking would be due to the fact that John occurs first in a grammatically ordered DF of &lt; John, Mary &gt;, thus being the preferred antecedent for she.

The hypothesis would have the disadvantage that FISC would need reordering if a more longstanding pronominal was mentioned after a more recently established one.

Two variations on (60) provide one way to contrast the two hypotheses:

(60a) Mary saw John in the station concourse. He waved to her. But she walked straight past him.

(60b) John saw Mary in the station concourse. She waved to him. Then she walked straight past him.

Example (60a) differs from (60) by having the longstandingness of John and Mary reversed, and (60b) differs from (60) in exchanging the grammatical roles of the nominals in the second sentence. (60a) and (60b) are examples where the ordering within the DF after the third sentence differs depending on the hypothesis chosen.

In (60a) the DF after the second sentence will consist of &lt; John, Mary &gt; according to hypothesis A, and &lt; Mary, John &gt; according to hypothesis B. This means that
hypothesis B will resolve the pronoun *she* in the third sentence immediately, while hypothesis A will backtrack.

In (60b) the DF after the second sentence will consist of < Mary, John > according to hypothesis A, and < John, Mary > according to hypothesis B. This time hypothesis A will resolve *she* unproblematically, while hypothesis B backtracks.

Therefore hypothesis A predicts that (60a) will be of the same processing difficulty as (60), but (60b)) will be easier. Hypothesis B predicts that (60a) will be easier to process than (60b) or (60), though (60b) probably involves some problems between the first and second sentences. Basically, the hypotheses differ in what they regard as a focus maintenance. To use Centering terminology, hypothesis A regards the transition between the second and third sentences of (60a) as a retention, and that in (60b) as a continuation. The reverse is true for hypothesis B. Hypothesis A proposes that the transition between sentences two and three can be taken in isolation, without harking back to the history of the nominals *Mary* and *John*, while hypothesis B finds the progression from sentence two to sentence three unimportant, but the relation between sentence one and sentence three (in this case) as vital.

Again, for processing reasons it would seem that hypothesis A would be easier to use, since less information would need to be stored (grammatical roles from the matrix sentence are probably still available, as required for syntactic parallelism effects), whereas hypothesis B would require remembering the age or order of generation of nominals. Although as I have explained both could be implemented quite easily in an algorithm simply by keeping DF in a certain order, it must not be forgotten that I propose using the IFnets as a natural way of ‘ordering focus stores’, so such information must somehow be represented in the IFnet in such a way as to influence pronoun attachment strategies. The IFnet does not currently contain any indication of the age of nominals, but it already incorporates all of syntactic structure except for the actual grammatical role markers. Grammatical role marking has not yet been found to be necessary: either nominals could be given grammatical distinctions, or they could be represented as taking certain grammatical precedences with respect to one another. For now I will choose the second option, as it involves less effort to calculate, since in the data set of this
thesis at least the subject always occurs before the object in a sentence. Grammatical precedence of direct versus indirect objects is anyway controversial. An approximation to grammatical role preferences can then be produced by giving the first nominal in the sentence precedence over the second, and the second over the third. Precedence will be marked by arrows on relations, pointing from first mentioned to second mentioned. Arrows may be imagined as pointing from ‘uphill’ to ‘downhill’, with pronouns preferring to attach to the tail or ‘top’ of an arrow. The advantage of obtaining ‘grammatical’ relations by order of encounter is that prepositional phrases, subordinate clauses and so on will be easy to represent without further complication. As explained in section 5.6, any focusing preferences within a subordinate unit are lower in preference to even the lowest preference in the superordinate unit.

Here are the iFnets for (60) and its variants:

(60) John saw Mary in the station concourse. He waved to her. But she walked straight past him.

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(60a) Mary saw John in the station concourse. He waved to her. But she walked straight past him.
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(60b) John saw Mary in the station concourse. She waved to him. Then she walked straight past him.
These hypotheses could easily be experimentally tested by measuring reading times for the three sentences, with long reading times for any sentence indicating slight hesitation in resolution.

5.9.2 Ordering of Potential Foci

I will assume that the ordering of potential foci can be done similarly, with those in subject position preferred to those in object position, and both these preferred to potential foci introduced in subordinate units.

(159) Mary was the hostess. She introduced John to Bill. He smiled.

Here is an example in which two members of PDFL, John and Bill, are compatible with the pronoun he in the third sentence. Since my decision was to use linear order rather than constructing an elaborate grammatical hierarchy, John will be predicted to be slightly preferred as the antecedent.

Here are three examples showing subject preferences in RISC also:

(160) Mary greeted Annie in her native language.

(161) Mary gave Annie a picture of herself.

(162) Mary liked Annie for her brother's sake.

These examples all have a pronoun in the subordinate unit attaching to a member of RISC in the superordinate unit. The preference is for the first mentioned RISC, a preference which is maintained for passive constructions:
Mary was greeted by Annie in her native language.

The following examples show that a FISC being mentioned first in the sentence is not sufficient for it to be preferred to other RISCs. As I have explained, if the RISC occurs in a subordinate unit then RISCs in the superordinate unit are preferred for subsequent pronouns:

(164) When Mary came in, Annie pointed at her hat.

(165) Mary’s Aunt Annie killed her parrot.

In both examples Annie, the subject of the main verbal unit, is preferred over Mary. In the first example Mary is in a subordinate unit similar to the antecedent of a conditional, whereas in the second example Mary is in a subordinate unit created by a possessive relation to the subject of the main unit.

To conclude this section, the linear ordering put on foci can be extended to cover potential foci. This makes sense, since every relation in the IFnet, regardless of whether it links foci or potential foci, will be given an arrow to indicate the downwards slant of salience as a unit is processed.

5.9.3 Grammatical Role Preferences

The previous sections have shown that it is quite easy to incorporate some kind of linear ordering into IFnets, which, together with the subordination rules, resembles grammatical ordering. There is one consequence I have not discussed, which sheds light on some of the problems in the data used earlier in this chapter.

Let us suppose that in the matrix sentence there was a potential focus in subject position, and a pronominally focused element in object position, as in the following example from (96):

(166) John Cox lived on his own. Once a neighbouring farmer invited him round for dinner. Having someone to talk to cheered him up.
According to my IF algorithm the pronoun him in the third sentence will prefer the focused nominal John Cox rather than the potentially focused nominal the neighbouring farmer. However according to the grammatical role ordering, the neighbouring farmer is more salient than John Cox. Earlier I claimed that the focusing preference would win, though grammatical role could reduce the bias. However van Dijk and Kintsch (1983) did not get 100% compliance to the focus bias. It does seem that sometimes preferences like the subject/first mention preference can actually override the focusing preference. If this happens, according to my theory, the hearer is willing to gamble on some suspicion about the speaker's attention. I argued that a conservative strategy (assuming focus maintenance) would be best for minimising the hearer's processing effort. However this assumes that the speaker's chance of shifting focus is judged to be 50/50. In the absence of any cues, the hearer will be wise to assume focus maintenance. However, if the speaker seems to be weighing the balance towards a focus shift, by using the various strategies covered in this section, the hearer can take a gamble, making more processing effort (shifting focus) in the hope that this will save backtracking later.

But why should mentioning one nominal before another make it more likely to be focused? The answer is intuitively simple: people will be more likely to mention first what is most salient in their mind. This done, they can proceed to inspect that entity in their mind's eye and make further elaborations on it. It is this observation which lies behind much of the literature on theme/rheme and topic/comment distinctions, in which theme/topic is usually the subject of the sentence, and not pronominally determined.

From the hearer's point of view, when a new item is mentioned first in the sentence, this itself causes difficulty, since it cannot immediately be placed in context, attached to an existing IFnet. Thus a kind of temporary store must be set up, in which that single object is inevitably focused. When the focus is mentioned, the temporary store can be emptied and the nominal attached to an IFnet. However it has already been attended for a while, and is therefore more prone to becoming focused in the next sentence than a new nominal introduced after links have already been made to previous context.

There is also the idea, relating to the discussion of the focus stack, that when a new
unit is set up which is not linked to the current focus, this may be seen from the perspective of the focus. Interestingly, Brown and Yule (1983) treat the subject of a sentence as presenting a perspective on the focus, when the focus is not in subject position. Therefore what in Centering is called a retention could be seen as a temporary distancing from the focus to look at it from a different point of view. But such a shift need not inevitably lead to an actual focus shift, so assuming a focus maintenance preference even in such cases would not be a hindrance to the hearer.

5.9.4 Informativeness

A second influence on pronoun resolution is the tendency of focus sometimes to shift from a minimally described object to an elaborately described object. Contrast (167) with (168):

(167) John is a friend of mine. He has a cat. He is vegetarian.

(168) John is a friend of mine. He has a gingerhaired cat with no tail called Mr Biggles. He is vegetarian.

Although the tendency for he to prefer the focus is probably just about sustained in (168), it is definitely reduced compared to that in (167). Simply providing more information about an antecedent seems to make it more prominent. This effect seems in direct contradiction to the focus maintenance preference, since pronouns by their nature are minimally informative, and it is also (in English at least) virtually impossible to attach subordinate units to pronouns.

Let us look at the IFnets for (167) and (168) after the second sentence:

(167) John is a friend of mine. He has a cat. He is vegetarian.

\[
\begin{align*}
\text{John} & \rightarrow \text{has} \\
\text{cat} & \rightarrow \text{He} \\
\text{He} & \rightarrow \text{is vegetarian}
\end{align*}
\]
Although the modifiers of $c$ are subordinate clauses, the weight of properties attached to $c$ seems to make it more salient than in the I$\!$Fnet for (167), where $c$ had no properties (apart from being a cat). Perhaps subordinate units could be regarded as weakly focusing the nominals to which they attach, since within the subordinate units the item to which they are attached is very strongly focused. In psychological terms such a principle makes sense because when the hearer is processing a sentence it is necessary to momentarily attend to every new object mentioned, but if the speaker is providing a lot of information about that object, it will be attended for longer, and weighted consequently as more important to the speaker. As a result, the hearer might compensate away from the focus and gamble on the speaker having shifted (if only temporarily) to a new focus. In dialogue the hearer is even more likely to shift, since the goal is only partly to anticipate the speaker's focus, and the hearer is also permitted to shift focus. Since objects introduced with a great deal of detail are more likely to connect to the hearer's previous memories, the hearer will be inclined to want to know more about the more elaborate objects. Thus it will not only be sheer weight of properties which makes an object stand out for increased attentiveness, but its surprise-value in the context, any intrinsic unusualness, or unusual specificity or individuality (e.g. being mentioned with a name rather than a role description).\(^{10}\)

So the nodes of a unit can be made more salient by making them more distinct, unusual, or informative than other nodes. McKeown (1983) pointed out (p. 583) that a preference for shifting focus to new information (i.e. unfocused information) is exactly what is required for language generation by the speaker, to ensure that if the speaker has more to say about a particular entity, this is done in clusters of relevant properties, rather than

\(^{10}\)See experiments by Garrod and Sanford (1990).
in a disparate series of remarks. Although this thesis does not cover pronoun generation at all, it is interesting to consider whether generation and interpretation have different priorities, and whether this accounts for the conflicts which might result particularly in dialogue. It may be that the informativeness effect would be less evident in monologues or written texts, when the hearer has no power to affect future sentences, so must be purely concerned with guessing the speaker's intentions. On the other hand, if the hearer's intentions are entirely determined by preferences for new information, it would obviously be foolish of the hearer to assume focus maintenance. I believe that for both interpretation and generation some compromise is necessary, with focus maintenance the default. Since focus shifting is usual every few sentences, the hearer must also be sensitive to the speaker's signals. It is here that such heuristics as informativeness, grammatical role and so on can take over and point overwhelmingly away from the focus as preferred antecedent.

5.9.5 Perspective

I have already touched on some possible uses of the notion of 'perspective' in describing focus effects. However the perspective of nominals with respect to one another is not only due to their grammatical alignment or respective places in the focus hierarchy, but may also be determined by particular verbs.

Take the following example:

(169) Bill punished John. He ...

It has oft been noted (Garvey and Caramazza 1974, etc.) that the verb 'punished' tends to make its object the preferred antecedent for the next sentence. It has been argued that this is because part of the meaning of the verb 'punish' includes retribution for some action on the part of the person being punished. Therefore the speaker is likely to explain what the person being punished had done. It is also generally thought that punishment has a much greater significance for the person being punished, than for the punisher, so the verb has probably been used to tell the story of the object than of the
subject.

A different kind of effect can be found also with intransitive properties:

(170) Mary Isley, the Manageress of Corporation Carpets, went into the office. She offered Jilly some nuts. She was very lovable.

Since the discourse starts with Mary Isley as the focus, I believe it is a default assumption that the story is being told from her point of view. When the third sentence is reached, the reader encounters a problem. This sentence cannot be interpreted from Mary Isley’s viewpoint, if it is about her, for the same reason the following discourse is pragmatically odd:

(171) I was the manageress of Corporation Carpets. One day I went into the office and offered Jilly some nuts. I was very lovable.

So the reader is suddenly faced with the choice of switching to a ‘God’s eye view’ in which the writer is more distant from Mary Isley — this would allow the third sentence to be seen as a comment on the focus, Mary. However if Mary’s viewpoint is to be maintained, the third sentence will only be interpretable as a belief (of Mary’s) about the potential focus Jilly. Mary will of course be stacked, and not much less focused in later sentences than Jilly.

That is, since ‘being lovable’ is not a property which can be determined by its possessor, processing difficulty is encountered which may actually favour a temporary focus shift, contrary to the predictions of the IF algorithm.

Lexical perspective effects are clearly important and intimately related to the perspective the speaker is taking on the discourse objects. However the effects are very lexically and culturally dependent, which makes them resistant to formalisation. I will therefore make no attempt to represent them in the IFnets, and will simply regard IFnets as the basis for a robust focusing theory which could function in the absence of any lexical semantic knowledge on the part of the hearer. This achieves the goal I set myself at the beginning of this chapter.
5.10 Summary of the IF Algorithm

Because the algorithm updates with every nominal, a set of rules will be given which deal with pronominal and non-pronominal reference. The algorithm incorporates suggestions for dealing with subordinate units, but is a little sketchy in this area, as more clarification of the data is needed.

Incremental processes:

Whenever a noun phrase is encountered:

If it is non-pronominal, add its nominal to the current RISC (this will be the main RISC if the nominal occurs in the main verbal unit, and a temporary sub-RISC if the nominal occurs in a subordinate unit).

If it is pronominal, transfer a nominal from one of the focus stores into FISC (or a temporary sub-FISC, if the pronoun occurs in a subordinate unit). The preferences are as follows:

1. **Primary Rule:** Predict a FISC member.
2. **Matrix Rule:** Then try DF
3. **Subordinate Rule:** Predict sub-FISC
4. **Subordinate Rule:** Predict sub-RISC
5. **Secondary Rule:** Predict a member of RISC
6. **Potential Rule:** Predict one of PDFL.
7. **Stack Access:** Try the focus stack

Note that the preferences are the same whether the pronoun is in the maximal or some subordinate unit.

End-of-unit update:

Whenever the end of a coordinate unit is reached:

Clear PDFL, stack DF in DFS, move FISC into DF and move RISC into PDFL. Clear FISC and RISC.
At the beginning of a subordinate unit, begin a sub-RISC to deal with the new nominals in that unit.

When the end of a subordinate unit is reached, add its sub-RISC to the end of PDPL, and its sub-FISC to the end of DF.

Note:
The current algorithm is not entirely satisfactory: this type of focusing algorithm, with linear stores, can only approximate to the complex syntactically-derived semantic representations, the IFnets which have the potential to represent much more of a hierarchy: the linear ordering, or serial preferences which have been assumed by this thesis could result from a series of heuristics for traversing the IFnet configuration. As it stands, the algorithm is underspecified with regards to multiple subordination, for instance.

5.11 Conclusion

In this chapter I have presented an algorithm for resolving pronouns purely on grounds of focus preferences. It has been adapted to resolve pronouns incrementally, taking into account possible antecedents from earlier in the same sentence, as well as from previous sentences. I have suggested how this incremental focusing algorithm might be extended to cover non co-referential pronoun use, and use of other information sources such as grammatical structure, thematic relations, specificity and global focusing.

The Incremental Focusing Algorithm incorporates some of the foundational assumptions of both Sidner’s and the Centering algorithm. The algorithm is based in a minimal model of discourse (IFnet) similar to that constructed in the previous chapter for Sidner’s algorithm.

The IF algorithm improved on Sidner’s algorithm in the following ways:

1. A much simpler algorithm was presented, with just one small set of pronoun resolution rules.
2. I removed the need for an agent/theme distinction, which solved Sidner's Problem 1.

3. I abolished the problematic actor focus, removing Problems 2 (effort in detecting 'animacy') and 4 (the optionality of the actor focus allowing too much stacking).

4. Because my foci are all determined the same way (by pronoun use) I offer a simple unified definition of focus, an improvement on Sidner's focus, which has two types, and is difficult to conceptualise.

5. I was able to support some of Sidner's empirical intuitions, most notably to provide an analysis of (24) which avoided Problem 5 (the problem of defining 'longstandingness', without introducing any additional machinery.

6. My use of multiple foci, the reduced number of 'focus stores', and the idea that nominals may be transferred from one focus store to another removed Problem 8, the problem of redundancy.

7. The algorithm can resolve intrasentential anaphora without extra adaptation, and with better empirical coverage than Carter's (1987) version.

It also improved on the Centering algorithm in the following ways:

1. My algorithm allows pronouns to be resolved incrementally, which is impossible using Centering.

2. The IF algorithm allows focusing preferences to be applied to any pronoun, not just one, hence overcoming the major drawback of the Centering algorithm, Problem 7.

3. I showed how a much more complex ordering of focus transition preferences between sentences arose naturally from the pronoun resolution rules.

I was able to present a pure focusing algorithm which did not use thematic or grammatical information to determine foci. However at the end of the chapter I showed how such information could be incorporated into the IFnet in such a way as to affect
pronoun resolution. Even if the ideal pronoun resolution algorithm would be a multiple-constraint-satisfaction algorithm with no guaranteed reliability, I have at least divided some of the constraints more clearly from one another. And if, as I optimistically believe, the psychologically correct focusing algorithm does not calculate constraints in parallel, but is at least partly serial, then I believe what I have provided in this chapter are the default predictions for pronominal antecedents.

My algorithm has the following characteristics:

1. It allows multiple foci.
2. All and only pronouns result in focusing of their referents.
3. Pronouns are resolved on-line.
4. Focus preferences are updated on-line.
5. Focus constraints are updated at the end of a unit (corresponding roughly to a surface clause).
6. All pronouns may be given preferences, providing the pure focusing algorithm is augmented with linear ordering preferences.

The algorithm compares favourably with those discussed in Chapter 3: it combines the simplicity of the Centering algorithm with the ability of Sidner’s algorithm to resolve all pronouns, and adds most of the coverage obtained by Carter’s rules for intrasentential anaphora without sacrificing the constraint of incrementality.

Possible extensions to the theory were suggested which would allow it to incorporate some of the other constraints on pronoun resolution, including global focusing, grammatical role, informativeness and perspective. The non-focus constraint most amenable to inclusion in my model was influence of order of mention within the unit, which approximates to grammatical ordering. It could be that because the IFnets I use ultimately to justify my algorithm are generated via the syntactic structure of a sentence, grammatical role is more intimately connected with focus than I have given it justice for. It may be that Brennan et al. were right to consider two factors, pronominalisation and
grammatical role, in pronoun resolution. If grammatical role were considered an integral part of the focusing algorithm the IF algorithm would actually be able to stand alone as a pronoun resolver, since it would then provide a single preferred antecedent for every pronoun. However it seemed that grammatical role provided antecedent preferences independent of focusing constraints, so for now I will assume the two types of preferences are unrelated and liable to conflict.

Achievements:

- I presented an algorithm which solved the outstanding empirical and theoretical problems encountered in Sidner's algorithm, by introducing multiple foci instead of the AF/DF distinction.
- By dispensing with the awkward role of thematic information, I was able to separate out the purely focusing effects from other influences on pronoun resolution.
- I extended my algorithm to update the focus preferences incrementally, which brought with it the additional advantage that intrasentential anaphora could be resolved with the same mechanism as that used for cross-sentential anaphora.
- I suggested how syntactic coreference restrictions could be incorporated into the resolution rules.
- Possible extensions to the theory were suggested which would allow it to incorporate some of the other constraints on pronoun resolution, including global focusing, grammatical role, informativeness and perspective.

Neither of the algorithms discussed in Chapter 3 deals directly with semantic constraints on anaphora. The authors are clearly aware of the literature, but the Centering algorithm does not incorporate a semantic filter at all, while Sidner leaves semantic checking to the Ratification procedure (1979, p. 150). This means that both algorithms allow pronouns to access referents which are non-existent or hypothetical, such as those generated by indefinite noun phrases in the scope of a negation or a conditional. Such questions as whether a referent actually exists are consigned to last place — after agreement constraints and syntactic coreference restrictions have been met. My algorithm is no better able to detect semantic conflicts.
It is the purpose of Chapter 6 to examine an alternative view of focusing in which semantic constraints are considered as focus store preferences.
Chapter 6

Semantics of Discourse

The Incremental Focusing Algorithm of the previous chapter was developed without incorporating any semantic constraints. Two examples (12 and (24) were given a treatment which I pointed out at the time was inadequate.¹ In the first part of this chapter I show in more detail where the focusing algorithm breaks down as a result, and what is necessary to repair it. I explain informally the use of semantic or ontological contexts in language. In the second part of the chapter I describe how IFnets can be given a traditional model-theoretic interpretation which both gives a meaning to IFnets, and provides a formal definition of semantic contexts. The third part of the chapter shows how the semantics of an IFnet as a by-product licenses the various non-coreferential (set-theoretic) anaphoric possibilities discussed in chapter 4 section 4.4.

¹The two sentences causing the problem were 'My friend Caroline knows the most unusual people' and 'I haven't seen Jeff for several days'.
Goals:

1. To show why semantic constraints on anaphora are necessary.
2. To describe semantic constraints on coreference, by imposing an ontological hierarchy on units.
3. To give procedures for verifying IF-nets with respect to some state of affairs.
4. To see how semantic interpretation determines accessibility of several different set-theoretically related nominals from one noun phrase.

6.1 The need for semantic constraints on anaphora

Sidner (1979 p. 168; 1983b p. 272) recognises the need for semantic constraints on anaphora. However neither of the algorithms I described in chapter 3 actually incorporated any. This means that in some situations the elements in the focus stores may be inappropriate. Both Sidner's algorithm and my own, which is based on hers, will run into problems as a result.

Let us take first a text which the IF focusing algorithm copes well with:

(172) John lived alone, and his dog was very old. It had yellow teeth.

After the first sentence, the following IF-net will have been constructed:

When the pronoun in the last sentence is encountered, the preferred node for attachment will be \( j \), that is, the most likely antecedent is \( \text{John} \), but one other node will be available \( \text{John's dog} \) (potential focus). Since \( \text{John} \) does not agree in animacy with the pronoun to be resolved, the \( \text{dog} \) will be chosen as the antecedent for it. As a result the IF-net will be extended to:
However, suppose the text had been slightly different:

(173) John lived alone, and didn’t have a pet. It had yellow teeth.

At present, the IFnet constructed after the first sentence would be very similar to that resulting from (172):

Here, again, the preferred antecedent is John, but John is incompatible in number and gender with the pronoun to be resolved. The algorithm then turns to the potential focus, a pet, which is compatible. However, intuitively (173) is not an acceptable discourse.

My algorithm being constructed along the lines of Sidner’s algorithm, I could claim that the antecedent a pet would eventually be ruled out by ‘semantic constraints’. But firstly it is unclear how such semantic constraints would be recorded, and secondly it would be more economical if a pet was not stored in PDFL to start with, to save ‘semantic constraints’ being reapplied every time a pronoun tried to access the PDFL. Unlike general knowledge, agreement constraints and so on, ‘semantic constraints’ on pronouns change according to the relative positions of the pronoun and antecedent in a well-defined hierarchy, rather like syntactic coreference constraints.

In this chapter I introduce the idea of a semantic or ontological hierarchy (based on Kamp’s (1981) hierarchy of discourse representation structures) and argue that the point of semantic constraints is to define the ontological form of discourse markers, hence to determine whether they are coreferentially accessible or whether they are only set-related to the antecedent discourse marker.
6.2 Ontology

This section asks what ‘semantic constraints’ are. I examine a small set of constructions containing logical operators: negation (briefly, since it is not part of the data set of this thesis), conditionals and quantified sentences. These constructions are examined from the point of view of their effects on pronominal reference, but these effects will be supported using intuitive ideas of the function of such constructions in discourse, as illustrated in Fauconnier (1985).

The type of IFnets which have been examined in the previous chapter are formed in the default context. These default IFnets contain discourse markers which represent nominals (entities the conversation is about, from the hearer’s point of view) and relations (properties understood to be true of those entities). However there are certain semantic contexts which group together units or sets of units in a subordinate IFnet which does not directly ‘represent’ referents in the world. There are certain restrictions on how the truth of the units in one context relate to those in another, which prevent relations and entities generated in these contexts having a straightforward interpretation as parts of the world.

6.2.1 The Default Context

A sentence containing no semantic operators produces an IFnet which represents the objects and relations claimed by the speaker to exist in the situation described by the text, that is, it may contribute to the hearer’s discourse model or partial knowledge of the world. I refer to this type of IFnet as the DEFAULT CONTEXT, since it provides the frame with respect to which all other contexts are interpreted.

In formal semantic terms, it has often been said that discourse referents in such a default context are ‘existentially quantified’. They represent the nominals which exist in the discourse model. Existential quantification is defined relative to the universe of discourse set up by the initial sentences in a text or dialogue. If the topic of discussion is a railway accident which happened several years ago, then a set or individual will be
considered existential if it was present at the time of the accident and can be referentially identified. If the discourse is telling of a fictional event, existential items are those which are posited as existing in that imaginary realm which is being described. It is because the word ‘existential’ is relative rather than absolute that I prefer to use the phrase default context rather than existential context for the top level of discussion.

The domain of a discourse model is the set of entities and relations which cohabit the same context. Thus in the examples just given, the default context is either a railway accident which happened several years ago, or a fictional narrative. The default domains of the two discourses are defined by those contexts and include all the entities and relations with are existential with respect to that context. The domain in the first context is real but in the past, whereas the domain of the second is imaginary. In many languages, verb inflections will signal to the hearer or reader that the default context differs in some way from the context in which they are currently situated. Of course, the default context may equally well be the current situation, the domain defined by the limits of the speaker’s attention and the hearer’s perception. I consider past, present, future, real or imaginary domains as equally valid bases for the default context of a discourse.²

6.2.2 The Negative Context

We saw earlier that (173) is problematic because it generates an antecedent which is inaccessible despite being in the PDFL according to the focus algorithm.³

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²The default context itself may be notionally embedded in the context of the surroundings of the discourse; the perceptual environment of the discourse and the relevant beliefs of the participants, their moral beliefs and mutual knowledge which may at any time interrupt a discourse or impinge upon it. However this higher level of discourse will not play an important part in this thesis and it will be assumed that the default context is the highest level of abstraction permitted.

³There are counterexamples suggesting that indefinites introduced under negation are not always inaccessible, but I don’t have time to discuss them in the thesis. (From Hirst 1981 p. 6):

(174)  Ross doesn’t have a car. *It is a battered old Skoda.
But:
(175)  Ross doesn’t have a car any more. It was completely destroyed in an accident last week.
or:
(176)  Ross doesn’t have a car, and if he did, it probably wouldn’t run.
(173) John lived alone. He didn’t have a pet. It had yellow teeth.

At present, the following IFnet is the result of processing the first two sentences:

\[
\begin{array}{c}
\text{had} \\
\text{lived alone}
\end{array}
\]

To account for the inaccessibility of \( p \), a new type of context will be introduced: the **negative context**. Entities introduced in this context will be effectively labelled as **non-existent**. Why, one might argue, should non-existent entities be represented in the IFnet at all? The reason is that they can still influence anaphora in succeeding sentences:

(177) John lived all alone. He didn’t have a pet. He found them too hard to look after.

That is, although the referent a **pet** does not license coreferential pronominal anaphora it has enough impact on the hearer to permit a generic set-relation to it.

I wish to argue that the noun phrase a **pet** does not generate a nominal, but solely a discourse marker. From this point the IFnets will diverge from solely being a representation of the world. The hearer’s model of the discourse does contain nominals, representations for entities which the speaker has referred to. That is, the hearer’s discourse model is intended to be a partial model of the speaker’s mental world. But the IFnet contains other kinds of information too, as we have seen, it can encode the information that there is no entity in a particular relation to the referent **John**. Later, we will see that IFnets can abbreviate information which is repeated of more than one individual (quantification), and hold generalisations about the events occurring in the discourse model. The discourse model is what the IFnet purports to describe. Usually a hearer will (according to Grice’s Maxim of Truthfulness) believe the statements in a discourse to be true in the discourse domain. The IFnet enables the hearer to understand anaphoric reference in the discourse. In addition, the hearer may well build up a discourse model of what the world being described must look like, in terms of entities and
events. However instead of building up a discourse model, a hearer has the opportunity to take what is being said in the discourse (represented in an IFnet) and try and verify that IFnet with respect to a mental model which is already available from other sources, such as perception or memory.

Let us take (177) as an example.

(177) John lived all alone. He didn’t have a pet. He found them too hard to look after.

This text results in the following IFnet:

![IFnet diagram](image)

The discourse marker \( j \) must have a referent at least in the speaker’s mental world, but as I have explained, \( p \) does not: the speaker does not have a particular pet in mind at all. But although \( p \) does not have a referent, its presence in the IFnet allows the generic set \( \mathcal{P} \) to become focused.

So how can the hearer tell which entities and relations should be confined by the negative context and thereby regarded as non-referential? Clearly the discourse marker generated by the indefinite \textit{a pet} should be negated, but just as clearly the discourse marker identified by the pronoun \textit{them} should not be negated.

The solution is to embed the entire unit generated by ‘\textit{He didn’t have a pet}’ in a negative context.\(^4\)

(178) John lived all alone. It is not the case that [he had a pet].

\(^4\)Some authors, e.g. Kamp and Reyle, just embed the VP.
The box signifies that any new elements or relations in that box are to be interpreted as not existing except as hypothetical discourse constructs 'had things been otherwise'.

The negative context is allowed to attach to discourse markers from the default context. Newly introduced discourse markers will generally be assumed not to have referents, while previously introduced discourse markers, because they were previously referential, will continue to be interpreted as referential, as will any discourse markers which have an agreed denotation, e.g. those produced by John or green pigs in general.

For example:

(179) John doesn’t like green pigs.

This sentence does not deny the existence of John, or even of green pigs, it simply denies that a certain relationship of liking exists between them. However both discourse markers are represented as occurring in the negative context:

\[
\begin{array}{c}
\text{j} \\
\text{like} \\
\text{GP}
\end{array}
\]

Unfortunately the notation is not as easy to understand as it was in the previous chapter: it would be easy to assume j does not have a referent, since it has not been mentioned before in the text.

One solution would be to represent elements shared by the negated and the default context with an identity link, as follows:

\[
\begin{array}{c}
j \\
\equiv \\
j \text{like} \\
\text{GP}
\end{array}
\]

This 'propositional' notation, as Sowa (1984) calls it, loses some of the appeal of the original notation, which was devised to correspond with a representation of the discourse which did not duplicate nodes, hence enabling properties of the same entity to be explicitly linked: such links are always only implicit in the meaning of the propositional
notation. This propositional notation is very close to that used by Kamp (1981). Chapter 8 states the findings of this chapter (and the rest of the thesis) in Kamp’s propositional notation.

For now, however, I will use the first notation suggested:

\[
\text{John green pigs}
\]

However the IFnets I have been using up to this point are missing some of the information which is needed to interpret what they mean: it is vital to know, for instance, that \( j \) was generated by a \textit{proper name}. This information has hitherto not been important, but now will begin to be included thus:

\[
\text{John green pigs}
\]

Later, when we come to interpreting the meaning of this IFnet, there will be rules which distinguish the interpretation of proper names and generics in such a way that although a whole unit might be ‘negated’, any proper names in that unit will still be equated with referents in the world model. Discourse markers generated by indefinites in the negative context, on the other hand, will not be able to be related to the world model, and will only introduce discourse markers of short duration.

In summary, this sketch of how negation might be incorporated into IFnets has shown that IFnets differ from the discourse model or world which determines what exists in the universe of discourse. In conversation people speculate, dream, infer, disbelieve and otherwise consider many things which the discourse participants do not want to assume actually exist in the situation of which they speak. I have showed how the original default IFnets can be enriched by allowing certain words (such as \textit{not}) to trigger temporary hypothetical states of affairs which are linked to the default IFnet just as non-hypothetical additions are, but need not therefore add to the hearer’s discourse model.
The temporary context produced by a negation operator is of a different ONTOLOGICAL status than the default context. Pronouns in the default context may not access elements introduced in a negative context, but pronouns in the negative context can access items introduced in the default context. What is being described here is an ONTOLOGICAL HIERARCHY.

6.2.3 The ontological hierarchy

An ONTOLOGICAL LEVEL is a semantic context in which all new entities and relations are interpreted as existing with respect to one another (not necessarily existing outside the IFnet). New links attach to existing nodes, hence coreference relations are permitted, within the bounds of focusing constraints.

The highest ontological level is the default context. The ontological hierarchy for a discourse is not predefined and is completely determined by the speaker's use of language. Lexical items such as want, operators such as if, tenses and moods of verbs, and even simple indefinites and plural terms can trigger the founding of a new (lower) ontological level. These levels are usually shortlived but can be prolonged by use of anaphora or appropriate tenses. Occasionally they can become so dominant that the higher ontological levels are forgotten and the current level becomes the default level. Various conversational devices can then restore the original context but the usual device of simply using a declarative present tense statement may no longer function to return to the default (which is why I refer to the current level as having become the default); an example of this would be the use of extended flashbacks in books, films and documentaries. So certain language devices trigger the embedding of new contexts within the default context, or (recursively) within embedded contexts, and it is the function of a semantic theory to describe how (or when) such embeddings should be made.

The rest of this section will describe the two types of embedded context with which this thesis is concerned: conditional and quantificational contexts.
6.2.4 Conditionals

(180) is a typical example of a conditional statement embedded in a discourse.

(180) While Granny Weatherwax approved of night on general principles, she certainly didn’t hold with promiscuous candlelight — if she had any reading to do after dark she generally persuaded the owl to come and sit on the back of her chair, and read through its eyes. So Esk expected to go to bed around sunset...

(Terry Pratchett Equal Rites p. 74)

Conditionals of the form ‘If [clause A] (then) [clause B]’ are described by logicians as expressing a semantic relationship between two propositions, such that in all possible worlds where proposition A holds, then proposition B must hold too.

In terms of IFnets, one could understand this to mean that a conditional instructs the hearer to add clause B to the discourse model, if clause A happens to be already included within it. However this is a misunderstanding of the meaning of a conditional, which is never couched in such specific procedural terms (see semantic interpretation section, below). Applying a conditional to the current IFnet is not a necessary part of the understanding of the conditional. This becomes evident when studying the use of conditionals in dialogue: very rarely does the hearer have the necessary information to verify a conditional. People also have no difficulty in understanding what is conveyed by a conditional statement, and making anaphoric reference to it, even when the antecedent clause is manifestly false. In fact possibilities for using the conditional range from those whose antecedent is known to be untrue, through those where its truth is unknown, to those where the truth of the antecedent is almost certain.

(181) a. If John had lived, he would have been famous.
   b. If it rains, then I will take the bus.
   c. If I have any compassion, I will help this man.
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Still, the uncertainty (however slight) of the antecedent describing any actual relation in the world is the reason for using the conditional in the first place. Concluding that the consequent is true by combining a recently heard conditional with previous knowledge of the truth of the antecedent is part of the general knowledge and inference procedures and not a part of the simple pattern matching capabilities of the IFnet.

So, assuming that the conditional is not a condition on the discourse model, but simply a conversational device, the only relevant properties of the conditional are its anaphoric effects. Of course, these are intimately related to its ontological meaning.

The traditional semantic interpretation of the conditional, which defines it as an operator over possible worlds, hints at its ontological function. However from the point of view of anaphora, clearly what a conditional does is to propose one possible world which stands in for any particular world which the hearer would care to consider. Although this hypothetical world is described by a particular IFnet, it may still be interpreted as applying to any number of possible worlds. In this sense it is no different from the default IFnet. However, the conditional is hypothetical with respect to the default context, so entities generated in the context of the conditional are not deemed to exist in the world.

Every semantic theory interprets the conditional so as to potentially divide those possible worlds in which it is true from those in which it is false. The treatment I am proposing is no different: a conventional semantic interpretation will be given in section 6.3. Due to its meaning the conditional does have ontological impact on anaphora. Both antecedent and consequent are seen to be true in some hypothetical world in which the antecedent holds. This world differs minimally from the world described by the IFnet. This means that (it is assumed) all elements of the IFnet are also part of the hypothetical context, hence all discourse markers in the default context may be accessed pronominally in the conditional context.

(180) While Granny Weatherwax approved of night on general principles, she certainly didn’t hold with promiscuous candlelight — if she had any reading to do after dark she generally persuaded the owl to come and sit on the back
of her chair, and read through its eyes. So Esk expected to go to bed around sunset ...

To return to (180), both Granny Weatherwax and the owl, which exist in the default context, are frequently mentioned in the conditional context, since the hypothetical part of the conditional is not about the existence of these characters, but about their behaviour under certain contingent circumstances. Nominals built up in the default domain are accessible to both antecedent and consequent of the conditional.

(182) There is a lovely house for sale down the road. If Bill buys it, he will be in debt for the next twenty years.

(183) There is a lovely house for sale down the road. If Bill can get a mortgage, he will buy it.

Both antecedent and consequent are part of the same unit, since the antecedent is syntactically subordinated to the consequent. However in subsequent sentences discourse markers generated in antecedent or consequent are semantically blocked for pronominal reference, although according to the focusing algorithm antecedents from both should be accessible (with those from the consequent preferred).

Note how Bill, though first introduced in the conditional, may later be accessed in the default context:

(185) There is a lovely house for sale down the road. If Bill can get a mortgage, he will buy it. However I suspect his bank manager will refuse to issue the mortgage.

The ease with which it can access the lovely house in this example can be contrasted with a non-conditional discourse:

(184) Bill is an investor. Yesterday he viewed a lovely house which is for sale down the road. He is getting a mortgage. He wants to buy it.

Interpretation of such a discourse depends on the hearer having stacked the discourse marker for the lovely house, rejecting the nearer referent, the mortgage, and recalling the lovely house after an interval of one sentence.
This property of proper names to escape the ontological contexts, just as the referents of pronouns do, led to Kamp's (1981) projection rule for proper names, which allows them to create discourse markers which are accessible in the default context. The rule is discussed again in chapter 8. The ifnet for (185) is shown below. As with the negation, I will enclose clauses belonging to the conditional context in a box, to distinguish them from the default domain:

Nothing in the conditional context is certain with respect to the default context. Indefinite noun phrases generated within the hypothetical context refer to hypothetical objects, and are not accessible to the default context.

(186) I have a friend called Percy. If he is in Persia now he is buying a cat. *It is exceedingly hairy.

For instance in example (186), the cat mentioned cannot be referred to in the default context because it does not necessarily exist in that context (the context in which the speaker is making the statement).

This pattern of accessibility is captured by Kamp's (1981) superordination rule for the conditional. The relation between the hypothetical context (consisting of antecedent and consequent) and the default context is one of semantic (ontological) subordination, exactly as we saw for the negative context.

6.2.5 Quantificational contexts

The second type of ontological context relevant to this thesis is that produced by quantified sentences such as (187) and (188):

(187) Three farmers ordered a drink from the bar.
The problem is people interested in magic and mysticism...[get] noticed by the creatures from the Dungeon Dimensions who then try to use them in their indefatigable efforts to break into this particular Reality. *Most people can resist this,* but the relentless probing by the Things is never stronger than when the subject is asleep.

(Terry Pratchett *Equal Rites* p. 111)

Quantificational contexts are created by any kind of plural, in this case I choose the contexts created by **three farmers** and **most people**. Similarly to the conditional context, elements of the default domain can be accessed from within the quantificational context (e.g. the referent of *this* in (188)), but elements created in the quantificational domain (e.g. ‘a drink’ in (187)) cannot be accessed from the default domain. The latter point is illustrated by the unacceptability of the following continuation:

(187) Three farmers ordered a drink from the bar. #It was non-alcoholic.

Quantificational Contexts arise when a relation or property is applied more than once, to several members of a set.

(189) Every beggar I saw today told me he had lost his bus fare.

In (189), *he* is not a particular beggar, but must stand for them all. Likewise, there is no possibility of alluding to ‘the bus fare’ in subsequent default-level discussion, since that bus fare cannot be distinguished without reference to whose bus fare it was, and there is no particular person who fills that role, except **every beggar**; it is ‘every beggar’s bus fare’, not a meaningful concept in the discourse domain. The only discourse markers generated in the quantificational context which can subsequently be accessed by pronouns in the default domain are those generated by proper names.

So a Quantificational Context, ontologically speaking, represents an instance, a generalisation over a set at the default level. Because the instances are not distinct in any way, an individual appearing in such a context has no meaning outside that context.
6.2.6 Summary

In this section we have seen that negation, conditionals and quantified sentences all open up a subordinate ontological space in the current context. Units in that space are not interpreted as directly describing the world, but have various semantic functions with respect to the world. Ontological spaces can have a structured hierarchy of embedded spaces contained inside them, so conditional contexts may contain subordinate negative contexts, and so on.

It was found that proper names, even if their discourse markers are in a semantically subordinate unit, are interpreted as if they had been generated in the default context, i.e. as referential. However indefinites generated in subordinate units do not correspond to particular referents. Subordinate levels are barred for coreferential pronominal access.

These observations will be captured slightly more formally in the next section.

6.3 Semantic Interpretation

The goal of dynamic semantics is to describe how the meaning of a discourse can be built up from the meanings of its component parts. Usually, the parts are sentences, which are themselves composed of syntactic constituents, but in my case, the parts are units of an IFnet. I show that the IFnets can be given a semantic interpretation from which the hearer can determine whether the IFnet is true or false with respect to any particular state of affairs. Therefore the IFnets are shown to embody meaning as well as anaphoric possibilities, similarly to Kamp’s (1981) discourse representation structures in DRT.

The theory which this thesis uses as a semantic basis is that of Kamp (1981) and Kamp and Reyle (1989). Like Kamp (1981) I do not use a complex semantic interpretation procedure, as the exact details are not relevant to the theory. Semantic interpretation is much the same as that used in predicate logic and other standard logics except that, following Kamp, semantic interpretation applies to the IFnet rather than being directly derived from the surface form of the sentence to be verified.
Let us see how the standard semantics would apply to an IFnet in the default context. Basically, what a semantics does is to say what a world (or mental model of the world) needs to be like in order for the IFnet to be a partial description of it. Given such a semantics it is possible to verify a particular IFnet with respect to some particular world.

### 6.3.1 Reference

This section begins to introduce some of the concepts necessary to understand what relation model-theoretic semantics has to mental representation of discourse.

In previous sections I have made a distinction between discourse markers, nominals and referents. However the distinction has never been clarified. In this section it should at least become clear what discourse markers and referents are. As a reminder, here is the notation used to distinguish each:

<table>
<thead>
<tr>
<th>Name</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discourse marker</td>
<td>( z )</td>
</tr>
<tr>
<td>Nominal</td>
<td>the man Mary saw</td>
</tr>
<tr>
<td>Referent</td>
<td>BILL</td>
</tr>
</tbody>
</table>

The discourse marker is a label used in the hearer's abstract representation of the discourse, the IFnet. Its meaning (in this case) is that it represents particular individuals in the world the discourse is about. Let us suppose that the IFnet in question has two units containing the same node \( z \), one which asserts that Mary saw a man \( z \), and one which asserts that \( z \) was running. The nominal the man Mary saw is just another way to encode what the hearer knows about \( z \) which distinguishes it from other discourse markers. Roughly, a nominal is the cumulation of all the units which have ever mentioned \( z \), and as such, nominals may be remembered even after \( z \) is out of focus and appears no longer in the current IFnet.\(^6\) The nominal may be accessed by anaphoric definite noun phrases. However if a discourse marker is created in a negative context, as we have seen, it would not produce a nominal: #the pet John didn't have. Discourse markers in negative contexts do not have referents either. In

---

\(^6\)Nominals are like Heim's (1982) filecards or Seuren's discourse ??'s.
fact nominals usually correspond one to one with referents. The reason they are not identical is because nominals are set up internally by the discourse, but referents are absolute, set up by the speaker or by some shared environment in which speaker and hearer are located. When the speaker says ‘Mary saw a man’, it is probably the case that the hearer has no access to the referent of the phrase a man, or that the speaker’s statement is ambiguous: there are several possible referents. In either of these cases, the hearer can still gather information about the entity being discussed, and may eventually be able to identify its referent. The entity under discussion is a referent, but the speaker may only use words to identify it. For the hearer, who may be unaware of the exact reference of those words, the entity under discussion is a nominal.

IFnets abstract over assumed referents, and since pronominal anaphora accesses discourse markers, not nominals, it is the relation between IFnets and referents which is of particular interest here. IFnets consist of nodes (discourse markers) and links (relations). But what does the world of referents look like? The standard semantic model assumes that the world \( \mathcal{M} \) consists of a domain \( \mathcal{D} \) of individual referents, and some way of assigning labels to particular individuals, and to groups of individuals with a common descriptor.

Entities in the domain have meaning for the speaker and hearer by virtue of the language of communication they share, for instance when the speaker uses the name ‘John’ in a particular discourse it is assumed that the hearer always knows who the speaker is talking about, and when the speaker uses the verb ‘runs’ it is assumed that the hearer can identify which referents can properly be described as ‘running’. In my theory, of course, the hearer does not try to interpret the utterance directly, but first encodes such words in IFnet form, where their atomic meanings can be modified by the meanings of other parts of the discourse before they are semantically interpreted. Shared knowledge about language can be represented as a pairing of IFnet labels with parts of the domain, \( \mathcal{D} \). Such knowledge is an assumed preliminary to semantically interpreting an IFnet.

The formal IFnet language for which I need to provide meanings in the world is derived from the surface form of a sentence, but is more constrained, in that I have only used a small number of different ‘syntactic forms’ compared to the ‘syntactic forms’ possible
in English. The atomic forms have been as follows:\textsuperscript{7}

<table>
<thead>
<tr>
<th>IFnet Syntax</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_{\text{concept}}$</td>
<td>$c_{\text{cat}}$</td>
</tr>
<tr>
<td>$\alpha_{\text{intransitive}}$</td>
<td>$c_{\text{runs}}$</td>
</tr>
<tr>
<td>$\alpha_{\text{transitive}} \rightarrow \beta$</td>
<td>$m_{\text{hit}} \rightarrow j$</td>
</tr>
<tr>
<td>$\alpha_{\text{preposition}} \rightarrow \beta$</td>
<td>$b_{\text{of}} M$</td>
</tr>
<tr>
<td>$\alpha_{\text{relation}} \rightarrow \beta$</td>
<td>$d_{\in} D$</td>
</tr>
</tbody>
</table>

These forms could occur as units on their own, or else several could combine to make a unit with one or more subordinate units. The means of combination is determined by syntactic structure.

When IFnets were used solely to resolve anaphora, it was not necessary, for example, to distinguish between indefinites, definite noun phrases and proper names. Each introduced a single discourse marker with the same anaphoric properties. However now we start to give IFnets a semantics, it will be necessary to distinguish between these three types of discourse marker. It will be assumed that all noun phrases generate a discourse marker with a property. In the case of definites and indefinites the property will be a CONCEPT, while for proper names the property will be a NAME. Concepts and names will have different kinds of meanings. In fact names will always be translated as individuals, and concepts will always be translated as sets. The translation rules will be contained in four sets, NAME, CONC, PRED and PREP, which match labels in the IFnet language with members of $D$, as follows:\textsuperscript{8}

\textbf{Definition (Translation from IFnet vocabulary to referents)}:

\textit{NAME is a set of pairs of the form < name, INDIVIDUAL > where name labels a property of a discourse marker in an IFnet, and INDIVIDUAL is an individual.}

\textsuperscript{7}I omit ditransitives and relations connected to the verbal event.

\textsuperscript{8}This is loosely based on Kamp and Reyle — I have my own reasons for wanting to separate concepts from predicates, and having done so, thought I might as well differentiate prepositions also.
individual referent in $D$. For instance, one member of $\text{NAME}$ might be $<$ John, JOHN $>$, where ‘John’ is some label on an IFnet link, and JOHN is an individual in the situation being described by the speaker.

2. $\text{CONC}$ is a set of pairs of the form $<$ concept, set $>$, where concept labels a link in some IFnet, and set is a set or set of sets of individuals from $D$. For instance, concepts like ‘cat’ are matched with particular sets of individuals, so ‘cat’ may be matched with the set consisting of MINERVA, GEMBER, SMOELTJE, MUS, WILLIAM etc..

3. $\text{PRED}$ is a set of pairs of the form $<$ relation, set $>$, where relation labels a link in some IFnet, and set is a set or set of sets of individuals from $D$. For instance, verbal relations like ‘purs’ are matched with particular sets of individuals, so ‘purs’ may be matched with the set consisting of MINERVA, GEMBER and WILLIAM, while two-place relations like ‘bake’ and ‘likes’ are each matched with a set of ordered pairs of individuals, and three-place relations (e.g. ‘gives’) with a set of ordered triples of individuals.

4. $\text{PREP}$ is a set of pairs of the form $<$ preposition, set $>$, where preposition labels a link in some IFnet, and set is a set of pairs or triples of individuals from $D$. For instance, the preposition ‘on’ could be matched with pairs of individuals, such as $<$ MINERVA, TABLE345 $>$.

‘Between’ is an example of a three-place prepositional relation.

The pairs in $\text{NAME}$, $\text{CONC}$, $\text{PREP}$ and $\text{PRED}$ can equally well be seen as functions mapping labels in IFnets onto individuals or sets in $D$.

From a psychological point of view, all that needs to be said is that speaker and hearer perceive or imagine the world in such a way that they can pick out named individuals, that they can distinguish individuals which have a particular property from those which do not, and that they can tell whether two or more individuals are in a given relationship to one another.

We have seen that the world $M$ consists of a domain $D$ and some way of matching labels in an IFnet (which are created on the basis of English words) with parts of the domain. Different discourses will have different worlds: sometimes a speaker and a hearer will be talking about a different scenario, and sometimes they may have a different common language (usually both go hand in hand). For instance, the label John might pick out John Major in one discourse, and John Lyons in another. Or the set RUNS might contain JOHN in one discourse, but not in another.

$^{9}$Not every referent actually has a name: all they need is to be objectively identified.
6.3.2 Interpretation of an IFnet

Having defined what the world is, we need further information to actually interpret an IFnet. What we have so far is insufficient even to tell us whether 'John runs' is true or not, for it says nothing about how to combine the meaning of John with the meaning of runs. It is the meaning of the IFnets themselves which give the meaning of combinations of words in a discourse.

Most of the expressions used in a text do not have a constant agreed meaning between the speaker and the hearer. For example, the phrases the cat, she and two cats can have different meanings: they can be used for different parts of the domain, depending on the context created by the discourse. When new discourse markers are mentioned for the first time, it is often unclear to the hearer quite which referents the speaker has in mind. In this case, the hearer may have to keep a few possible interpretations in mind. The set of interpretations of a particular IFnet which are possible will be called $F$, with any particular interpretation in that set referred to as $f$.

For instance, if the speaker has mentioned that a cat purred, the hearer might consider interpreting the cat in question as Minerva. Another $f$ would assume a cat was Smoeltje. What formal semantics does is provides a description of the way a hearer can obtain all the information about the meaning of an utterance which would permit the hearer to check the truth of the speaker's statements, to throw doubt on the speaker's assertions, or to draw useful inferences from the partial information available. For instance, if the speaker says 'Ewan is stroking a cat' the hearer might not know which cat was intended by the speaker (maybe he is stroking two at once), but could thereby infer that Ewan is (probably) not asleep. On the other hand if the speaker says 'Henry is stroking Mimo's cat', the hearer need only have the information that Henry is not stroking a cat, in order to judge that the utterance is false. It is not necessary to know if the speaker meant Smoeltje or Gember.

---

10 Of course, once the speaker had managed to say enough about the cat in question for the hearer to uniquely identify (i.e. have only one possible $f$), some mutually agreed identifier, like 'the ginger one which hangs around near the department' could theoretically be added to the list of known translations from IFnets to the world, for use in future discourses between the speaker and hearer. However, ignoring this possibility for now, there will always be expressions which the hearer cannot identify with certainty, or whose meanings vary from sentence to sentence (e.g. pronouns).
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The role of semantics, then, is to be able to state the verification conditions (the truth-conditional meaning) for any IFnet. Because there are an infinite number of possible IFnets, such meaning must be built up from smaller parts. This section will deal with the smallest parts, units, but the next section covers cases where there is semantic subordination involved, and units cannot be interpreted compositionally, but must be interpreted in larger combinations.

The verification conditions for single units are as follows ($\alpha$, $\beta$, $\mathcal{A}$ and $\Phi$ are variables over discourse markers, and name, property, intrans and trans are variables over relations):

Definition (Verification Conditions):

<table>
<thead>
<tr>
<th>IFnet</th>
<th>is true iff there is an $f$ such that:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proper name $\alpha_{name}$</td>
<td>$f$ maps $\alpha$ onto the element $a$ of $\mathcal{D}$ such that $&lt;\text{name},a&gt;$ belongs to $\mathcal{NAME}$</td>
</tr>
<tr>
<td>Generic $\mathcal{A}_{concept}$</td>
<td>$f$ maps $\mathcal{A}$ onto a subset of elements $\mathcal{A}$ of $\mathcal{D}$ such that $&lt;\text{concept},\mathcal{A}&gt;$ belongs to $\mathcal{CONC}$</td>
</tr>
<tr>
<td>Indefinite (singular) $\alpha_{concept}$</td>
<td>$f$ maps $\alpha$ onto an element $a$ of $\mathcal{D}$ such that in the pair $&lt;\text{concept},\mathcal{SET}&gt;$ in $\mathcal{CONC}$, $a$ is a member of the set $\mathcal{SET}$</td>
</tr>
<tr>
<td>Indefinite (plural) $\Phi_{concept}$</td>
<td>$f$ maps $\Phi$ onto a subset $\mathcal{A}$ of $\mathcal{D}$ such that in the pair $&lt;\text{concept},\mathcal{SET}&gt;$ in $\mathcal{CONC}$, $\mathcal{A}$ is a subset of the set $\mathcal{SET}$</td>
</tr>
<tr>
<td>Intransitive $\alpha_{intrans}$</td>
<td>$f$ maps $\alpha$ onto an element $a$ of $\mathcal{D}$ such that in the pair $&lt;\text{intrans},\mathcal{SET}&gt;$ in $\mathcal{PRED}$, $a$ is a member of the set $\mathcal{SET}$</td>
</tr>
</tbody>
</table>
For now, I shall simply assume that an interpretation \( f \) into a world \( \mathcal{M} \) must be found for every unit, in order for the unit to be true in that world.

### 6.4 Incremental interpretation of units

This section gives a rough suggestion of how the syntactic structure of a sentence contributes to the construction of a unit.

Each of the verification rules given above applies to just one unit. It was established in the previous chapters that subordinate units should be processed before superordinate units. In this chapter an extra level of superordination was introduced, giving the following hierarchy from most to least superordinate, determined by grammatical form (also left to right order):

1. name or concept links (e.g. John, cat)
2. complements (i.e. subcategorisations of noun like ‘a teacher of French’)
3. restrictive relative clause or prepositional modifier units
4. nonrestrictive relative clause units
5. verbal links
These units are built up gradually, and construction is interrupted whenever a more subordinate unit is reached in the sentence, until that subordinate unit has been completely processed.

Take for example:

(190)  A man who Mary knew sketched his mother in bed.

The first noun phrase to be encountered begins 'A man'. A discourse marker, say a is set up. This allows the following first unit to be constructed:

\[ \delta_{\text{man}} \]

It will also be noted that the noun phrase is in subject position, thus anticipating, or beginning the processing of, a main verbal unit:

\[ \delta_{\text{man}} \]

Next, a relative clause begins, syntactically determined to be attached to the existing discourse marker a:

\[ \delta_{\text{man}} \]

The relative clause introduces a new discourse marker, call it b, which is unable at this point to be attached to preceding context:

\[ \delta_{\text{man}} \]

This new discourse marker has the property of being named 'Mary', adding a concept to the unattached discourse marker:
At this point, while still processing the relative clause, a verb is encountered. A superordinate unit is constructed, linking $b$ to some other as yet unidentified discourse marker.

However when the main verb of the whole sentence is encountered, rather than another noun, the processor determines syntactically that the relative clause is complete, therefore the two unsaturated links can be unified.\(^{11}\)

Since the subordinate relative clause is now complete, the processor returns to the incomplete main verbal unit:

Then a complement is encountered, attaching (and as a result focusing) the old discourse marker $a$ to some as yet unidentified discourse marker:

\(^{11}\)An alternative would be to join the two by default but have some other noun capable of sundering the hypothesised link.
Finally, both these links are able to culminate in a new discourse marker, c, generated by the noun phrase his mother.

Then a preposition in is encountered, which can either attach to a or c (the subordinate relative clause has already been closed off from the point of view of syntactic attachment). Let us suppose it attaches to the object c:

The last discourse marker to be introduced is d, which does not close off the subordinate phrase until a more superordinate phrase is encountered. First, a more subordinate phrase must be attached:

Then, with the end of the sentence, all units are closed. However, each maximal unit
is anaphorically saturated and can be interpreted semantically as soon as it has been completed.

To combine the truth conditions of each unit, it is necessary simply to extend the truth conditions on the previous unit to include the new constraints. So if unit1 is true iff there is an \( f \) in \( M \) such that \( \text{cond}_1 \), then unit2 is true iff there is an \( f \) in \( M \) such that \( \text{cond}_1 \) and \( \text{cond}_2 \). Unit2 is said to extend the \( f \) of unit1. This is because \( f \) contains a list of mappings of discourse markers to members of \( D \) and the number of such mappings usually increases as new units are added to an IFnet (it stays the same if there are no new discourse markers). However as more conditions are added, the numbers of possible \( f \)'s (proper embeddings) in a particular world tend to decrease.\(^{12}\)

In this example, for instance, there might be several individuals in \textit{man}, but only two that \textit{Mary} knew. And it might be the case that the number of men \textit{Mary} knew who sketched their mothers was none, so the speaker's utterance would fail to be verified, since it is not true that there is an \( f \) which would verify the whole composite unit produced by the sentence. If, on the other hand, the interpretation procedure succeeds in finding individuals in the world model which satisfy all the constraints, the discourse model is said to be properly embedded in the world model. If there is more than one way to satisfy the conditions, there are several proper embeddings.

### 6.5 Interpreting a unit: Examples

In the previous section I explained roughly how an entire IFnet, consisting of several nested units, would be processed. What I do here is to work through some smaller examples explaining exactly how the semantic interpretation for each unit works, and thus how the whole IFnet receives its truth conditions. I will then show how the truth of the IFnet may be found with respect to a particular model of the world.

\(^{12}\)They stay the same if the new unit is true of all the individuals which have satisfied the conditions so far.
6.5.1 Interpretation of Proper Names

Take an example from Kamp (1981, p. 284):

(191) Pedro owns Chiquita.

The IFnet built up from this sentence is a single unit containing two subordinate units:

\[
\begin{array}{c}
P \xrightarrow{\text{owns}} c \\
\text{Pedro} & \text{Chiquita}
\end{array}
\]

Such a representation has no meaning on its own. In the previous chapter we were not concerned with meaning, since all that was required was that the hearer make the correct anaphoric predictions. By building IFnets I was able to state conditions for pronoun resolution, and by resolving pronouns, IFnets could be extended. The notation I used for IFnets was really based on some intuitive semantics: I described a link as 'representing a relation between referents', and a discourse marker as 'representing some entity the hearer assumes to exist in the world'. But until now, these labels have had little function, apart from as a source of generalisations about pronoun resolution. But with the semantics given in the previous section, it is for the first time possible to build up a picture of the world the IFnet purports to describe. We need to search for any interpretation \( f \) of this unit in the world \( M \).

Let us take the first of the two (syntactically subordinate) units:

\[
p \xrightarrow{\text{Pedro}}
\]

This IFnet unit fits the proper name template above:

\[
\alpha_{\text{name}} \xrightarrow{f} \alpha_{\text{name}} \text{ maps } \alpha \text{ onto the element } a \text{ of } D \text{ such that } < \text{name}, a > \text{ belongs to } NAME.
\]

Substituting in the actual symbols, we obtain:
6.5.2 Interpretation of Verbal Relations

I will now finish interpreting the IFnet above, repeated here:

\[
\begin{array}{c|c}
\text{Pedro} & \text{Chiquita} \\
\hline
p \text{owns} & c
\end{array}
\]

The final, superordinate, unit has the following form:

\[
p \text{owns} \quad c
\]

Substituting the particular labels of this IFnet into the verification rules given above, we obtain the condition that:

\[
f \text{ maps } p \text{ and } c \text{ onto elements } a \text{ and } b \text{ of } D \text{ such that in the pair } < \text{owns, SET} > \text{ in } \text{PRE}D, < a, b > \text{ is a member of the set SET.}
\]

In other words, the entire unit is true iff there is an interpretation \( f \) in \( M \) such that:

- \( f \) maps \( p \) onto the element \( a \) of \( D \) such that \( < \text{Pedro, a} > \) belongs to \( \text{NAME} \).
- \( f \) maps \( c \) onto the element \( b \) of \( D \) such that \( < \text{Chiquita, b} > \) belongs to \( \text{NAME} \).
- \( f \) maps \( p \) and \( c \) onto elements \( c \) and \( d \) of \( D \) such that in the pair \( < \text{owns, SET} > \) in
\(*P\text{RED} < c, d >\) is a member of the set \(*SET*\).

The next step is optional: so far, the hearer is in a position to know the truth conditions of the unit, but suppose the hearer wants to know whether the unit is a true representation of some particular world.

The following world (call it \(*M 1*\) will serve to test all the \(*IFnets* in this section. The domain \(*D* of \(*M 1* consists of the following:

\[\text{PEDRO, CHIQUITA, FELIX, FRANCESCA}\]

The \(*IFnet* vocabulary covered is:

\[\text{Pedro, Chiquita, Feliz, Francesca, donkey, owns, beats}\]

The translations are:

\[\text{NAME} = \langle \langle \text{Pedro, PEDRO}, \langle \text{Chiquita, CHIQUITA}, \langle \text{Felix, FELIX}\rangle, \langle \text{Francesca, FRANCESCA}\rangle\rangle\]

\[\text{CONC} = \langle \langle \text{donkey, DONKEY}, \text{where DONKEY} = \langle \text{CHIQUITA, FRANCESCA}\rangle, \langle \text{farmer, FARMER}, \text{where FARMER} = \langle \text{PEDRO}\rangle\rangle\]

\[\text{PRED} = (\langle \text{runs, RUNS}\rangle, \text{where RUNS} = \langle \text{PEDRO}\rangle\]

\[\langle \text{owns, OWNS}>, \text{where OWNS} = \langle \langle \text{PEDRO, CHIQUITA}, \langle \text{PEDRO, FRANCESCA}\rangle\rangle\]

\[\langle \text{beats, BEATS}>, \text{where BEATS} = \langle \langle \text{PEDRO, CHIQUITA}, \langle \text{PEDRO, FELIX}\rangle\rangle\]

\[\text{REDP} = < >\]

Now we can fill in the rest of the information required to evaluate the truth of the unit

\[
\begin{array}{c|c|c}
\text{Pedro} & \text{Chiquita} \\
\hline
\text{owns} & \text{c} \\
\hline
\end{array}
\]

So (191) is true iff there is some interpretation \(f\) in \(*M 1* such that \(f\) maps \(p\) onto the element \(a\) of \(*D* such that \(\langle \text{Pedro, a}\rangle\) belongs to \(*NAME*\), and \(f\) maps \(c\) onto the element \(b\) of \(*D* such that \(\langle \text{Chiquita, b}\rangle\) belongs to \(*NAME*\), and \(f\) maps \(p\) and \(c\) onto elements \(c\) and \(d\) of \(*D* such that in the pair \(\langle \text{owns, SET}\rangle\) in \(*P\text{RED} < c, d >\) is a member of the set \(*SET*\).
We now know that there is a pair $<Pedro, a> \in NAME$, where $a$ is PEDRO, therefore $p$ maps onto PEDRO in the world. By the same process, $c$ is mapped onto CHIQUITA. We also know that the pair $<PEDRO, CHIQUITA>$ is in the set $S$ in the pair $<owns, S>$. There is exactly one $f$ which interprets the IFnet in $M_1$. That is, there is one proper embedding of the IFnet in $M_1$. That is, the $f$ where $p$ maps onto PEDRO and $c$ onto CHIQUITA.

Therefore (191) is true.

So introducing a semantics into IFnets allows the hearer to do two things: firstly know the truth conditions of the IFnet, and secondly evaluate its truth with respect to some situation. For instance, the hearer may decide to see if the sentence is true of the view seen out of a window, which the speaker purports to be describing.

The IFnet can now be seen as making a claim about the world, i.e. that PEDRO owns CHIQUITA.

The sentence (191) can be followed with (191b):

(191b) He beats her.

The new IFnet is:

```
beats

2
owns

Pedro

3
Chiquita
```

Only a single unit needs to be interpreted this time, since the focusing mechanisms of the previous chapter have already determined that the new unit should be attached to the two existing discourse markers. Isolating this unit for clarity, we get:

```
beats

p
c
```
This unit fits the transitive verb template as follows:

\[
\begin{align*}
\text{f maps } p \text{ and } c \text{ onto elements } e \text{ and } f \text{ of } \mathcal{D} \text{ such that in the } \\
\text{pair } <\text{beats, SET}> \text{ in } \mathcal{PRED}, <e, f> \text{ is a member of the set } \\
\text{SET}
\end{align*}
\]

To verify the new sentence, the set consisting of the individual called Pedro (signified by \( p \)) and the individual called Chiquita (signified by \( c \)) must be in the set of things in the 'beats' relationship to one another.

In other words, the two sentence discourse is true iff there is an interpretation \( f \) in \( M \) such that:

\[
\begin{align*}
\text{f maps } p \text{ onto the element } a \text{ of } \mathcal{D} \text{ such that } <\text{Pedro, } a> \text{ belongs to } \mathcal{NAME}, \text{ and } \\
\text{f maps } c \text{ onto the element } a \text{ of } \mathcal{D} \text{ such that } <\text{Chiquita, } a> \text{ belongs to } \mathcal{NAME}, \text{ and } \\
\text{f maps } p \text{ and } c \text{ onto elements } a \text{ and } b \text{ of } \mathcal{D} \text{ such that in the pair } <\text{owns, SET1}> \text{ in } \mathcal{PRED} \\
<\text{a, b}> \text{ is a member of the set } \text{SET1} \text{ and } \text{f maps } p \text{ and } c \text{ onto elements } a \text{ and } b \text{ of } \mathcal{D} \text{ such that in the pair } <\text{beats, SET2}> \text{ in } \mathcal{PRED}, <\text{a, b}> \text{ is a member of the set } \text{SET2}.
\end{align*}
\]

However this can be interpreted incrementally, since all that is required is that the second sentence extends the \( f \) of the previous sentence. The \( f \) of the previous IFnet is the set of mappings into the world which made that IFnet true in the world. For \( M_1 \), the only \( f \) which made the sentence true mapped \( p \) onto PEDRO and \( c \) onto CHIQUITA.

This is written:

\[
f: \begin{bmatrix} p & \mapsto & \text{PEDRO} \\ c & \mapsto & \text{CHIQUITA} \end{bmatrix}
\]

So when verifying (191b), we can tell directly that the new relation will be true if \(<f(p), f(c)>, \text{i.e. } <\text{PEDRO, CHIQUITA} > \text{ is in } \mathcal{PRED}, \text{ which it is.}

### 6.5.3 Interpretation of Indefinites

Kamp also gives the verification conditions for the following related example:

(192) Pedro owns a donkey.

Or:
This differs from (191) only in that the subordinate unit:

\[
\begin{array}{c|c}
\text{donkey} & \text{donkey} \\
\hline
\text{Pedro} & \text{Pedro} \\
\end{array}
\]

fits the following template:

\[
\begin{array}{c|c}
\text{donkey} & \text{donkey} \\
\hline
\text{d} & \text{d} \\
\end{array}
\]

This means that the discourse marker \(d\) cannot be directly mapped onto any individual in the world model. There are several individuals which are donkeys, and the hearer cannot tell which one (if any) was intended by the speaker. However (192) is true if at least one of those donkeys is owned by PEDRO. Each choice represents a different proper embedding of the discourse model in the world model. In this case, \(f_1\) might map \(p\) onto PEDRO and \(d\) onto CHIQUITA, while \(f_2\) might map \(p\) onto PEDRO and \(d\) onto FRANCESCA.

\[
\begin{align*}
\text{Suppose, as before, that the next sentence was:} \\
(192b) \quad \text{He beats her.}
\end{align*}
\]

Again, this fits the transitive verb template:

\[
\begin{align*}
f \text{ maps } p \text{ and } c \text{ onto elements } e \text{ and } f \text{ of } D \text{ such that in the pair } < \text{beats,SET} > \text{ in } PRED, < e, f > \text{ is a member of the set SET}
\end{align*}
\]

Since the new \(f\) must extend the previous \(f\), either \(p\) maps to PEDRO and \(d\) to CHIQUITA or \(p\) maps to PEDRO and \(d\) to FRANCESCA. However the new \(f\) must also verify (192b). Since \(< \text{PEDRO,FRANCESCA} >\) is not in BEATS, \(f_2\) is not able to be extended. However \(< \text{PEDRO,CHIQUITA} >\) is in BEATS, so the new text is verified. So the number of possible
embeddings $F$ has decreased from two to one.

A sentence may contain more than one indefinite:

(193) A cat bit a dog.

The IFnet for this sentence would be verified by finding in the set which $bit$ maps onto, any pair of individuals of which the first belonged to the set of cats and the second to the set of dogs. Each configuration of individuals satisfying the conditions is a proper embedding of the discourse model in the world model.

6.5.4 Interpretation of Plurals

Indefinite noun phrases may be plural. That is, a single concept can be used to pick out more than one individual at once. (194) is an example:

(194) Some farmers ran

The IFnet I have assumed this would result in is:

$$\begin{array}{c}
F_{ran} \\
\text{farmer}
\end{array}$$

The subordinate unit

$$\begin{array}{c}
F_{\text{farmer}}
\end{array}$$

fits the following template:

$$F_{\text{farmer}} \text{ maps } F \text{ onto a subset } A \text{ of } \mathcal{D} \text{ such that in the pair } F_{\text{farmer}} < \text{farmer, set}> \text{ in CONC, } A \text{ is a subset of the set set}$$

The question is, how is the interpretation of the plural set going to be combined with the interpretation of the transitive verb as a set of pairs: the plural set is simply not
a subset of the interpretation of a transitive verb. The solution is to divide the plural set into its component individuals, and verify each individually. This is done by using a quantificational context, and will be discussed in the next section.

6.5.5 Summary

I have covered some ways to semantically interpret IFnets, enough to provide an idea of the uses of formal semantics in a discourse representation. However the main use of semantics in a focusing algorithm is to rule out certain anaphoric possibilities. The next section gives the semantic interpretation for the semantic contexts which were described informally before as being barriers to coreference. The idea is to explain in more formal terms the intuitions I gave earlier about why these contexts should prevent coreference.

6.6 Interpretation in Semantic Contexts

This section covers interpretation of units which create semantic contexts. Since the IFnet notation is not adequate to mark all the information needed for semantic interpretation, this section will not be illustrated. Instead, I will simply provide a brief sketch of how semanticists characterise negative, conditional and quantificational contexts. What these contexts share is that they all put conditions on interpretation at the meta-level: that is, interpreting a unit in the default context involves placing different constraints on the numbers of functions f which must verify the semantically subordinate units.

6.6.1 Interpretation of negation

One way to give an interpretation for a unit containing a negative context (or 'in the scope of a negation') which will suffice for my purposes is to say that the superordinate unit is true iff there is no f which verifies the subordinate (negated) unit.

So:
(195) John does not have a pet.

produces an IFnet which is true iff there is no f which verifies the unit.

\[
\begin{array}{c}
j \xrightarrow{\text{has}} p \\
\downarrow \quad \downarrow \\
\text{John} \quad \text{pet}
\end{array}
\]

As we know, this unit is verified iff there is an f which maps j onto some individual name in the domain D, (say, JOHN), maps p onto some member a of PET, and the pair \(<\text{JOHN}, a>\) is in HAS.

Therefore the negation will be true if there is no f which maps j onto some individual name in D, maps p onto some member a of PET, or if the pair \(<\text{JOHN}, a>\) is not in HAS.

Since John is a proper name label, it will, by virtue of being in the hearer's vocabulary, necessarily pick out some individual. Therefore (195) is true if John does not own a pet, and can be falsified by finding any member a of PET which JOHN owns.

### 6.6.2 Interpretation of quantified sentences

Take (196) as an example:

(196) Every farmer ran.

It is not immediately obvious what IFnet is appropriate to represent (196). In morphological terms, the sentence is singular, yet intuitively every farmer is saying something about a large set of farmers, in fact about all the farmers in the discourse domain.

Kamp (1981) recognises the entire clause as an example of a QUANTIFIED SENTENCE, one in which a statement which is explicitly made about a singular entity in fact is implicitly about a whole set of entities. That is, the sentence is verified by cycling through the set of farmers, and ensuring, for each, that he ran. In other words, every
acts as if it were a meta-condition on the clause 'A farmer ran', forcing every proper embedding of this clause in the model to be verified.

Chierchia (1988) and others subsequently pointed out that this first attempt at a characterisation of the meaning of every was too simplistic.

Suppose (196) had also contained a restrictive relative clause containing an indefinite:

(197) Every farmer who had a horse rode it in the race.

In this case, Kamp's interpretation would be that every proper embedding of 'A farmer who had a horse rode it in the race'. However, one could argue that (197) should be true even if there was a farmer who had several horses but only (due to physical constraints) rode one of them in the race.

It was also not possible for Kamp (1981) to give the correct interpretation conditions for (198):

(198) Most farmers ran.

If this was to be interpreted as was suggested for (196), the meaning of the determiner most would have to be given in terms of proper embeddings: that is, for most proper embeddings of 'a farmer' they should be extendable to 'a farmer ran'. But again, a relative clause can be introduced:

(199) Most farmers who had a horse rode it in the race.

In this case it is even clearer that the number of horses owned by a farmer should not alter the truth conditions of the sentence. We should be considering whether most members of the set of farmers-who-had-a-horse rode in the race, not whether most pairings of farmers with horses rode in the race.

In other words, quantification cycles through members of the set determined by the subject discourse marker, rather than through proper embeddings of the noun phrase
The set determined by the subject discourse marker, whether it is farmers or farmers-who-have-a-horse, will be called the Initial Set (Iset). The subset of the initial set for which the predicate is true will be called the resultant set (Rset), and the remainder of the set, for which the predicate does not hold, the complement set (Cset). The truth of the quantified sentence depends on the quantifier used, which will determine what proportion of the initial set must appear in the resultant set (or what the relative sizes of initial and resultant set must be). For instance, for the quantifier every the Rset must be the same as the Iset, whereas for most the Rset should be over half the size of the Iset.

Take for example the following sentence:

(200) Most people like flowers.

Here the initial set is the set of people under discussion. The resultant set will be the set of people who like flowers, and the complement set will contain those people who do not like flowers. The quantifier most is thought to be used correctly only if the resultant set is larger than the complement set.

The initial set is determined by the noun and its modifiers. These are collectively called the restrictor of a quantifier.

(201) Most people in the department who are vegetarian keep cats.

The initial set in the above sentence is people in the department who are vegetarian; this is the restrictor of the quantifier most. The properties which must apply to most of the initial set are contained in its nuclear scope. The nuclear scope in this example contains the predicate X keep cats.

It is possible to quantify over the object of a sentence:

(202) I like most cats I have ever met.

In this case the initial set is cats I have met, as determined by the restrictor. The nuclear scope is the property that I like X. The complement set is cats I met but
didn’t like.

In order to verify a quantified sentence each interpretation $f$ of the initial set must be individually tested to see if it can be extended to embed the nuclear scope also. This interest in individual instances is reflected even more strongly for quantifiers like *every* which even take a singular argument:

(203) Every vegetarian has a beard.

Kamp and Reyle therefore represent quantified sentences as conditions on individual discourse markers. However the semantic interpretation of quantified sentences ensures that these individual discourse markers are instantiated for each member of the quantified set.

In $\Pi$net notation, a quantifier would be represented by enclosing discourse markers for instances in a box to separate it from the default context:

\[
\begin{array}{c}
\text{v} \\
\searrow \text{b}
\end{array}
\]

That is, ‘every vegetarian has a beard’.

### 6.6.3 Interpretation of Conditionals

Conditionals of the form ‘If [sentence A] then [sentence B]’ are described by logicians as expressing a semantic relationship between two propositions, such that if proposition A is true in the discourse model, than sentence B must be too. In other words, a conditional is true if every proper embedding $f$ of the antecedent can be extended to a proper embedding $g$ of the consequent on $\mathcal{M}$.

### 6.6.4 Summary

I have shown how semantics can be used to map discourse markers onto referents in the world, in order to give verification conditions for units and combinations of units.
Earlier we saw that semantic contexts confine newly introduced indefinites to that context, preventing them from being accessible as antecedents to pronouns in the default context. For a given pronoun, antecedents may come from the same or a higher ontological level, but it is not possible to access antecedents from a lower ontological level, unless they represent names in the world. Expressions of a discourse are semantically interpreted as belonging to the default context if they are proper names or generics. These are the only discourse markers which can be directly translated as individuals or sets in the domain. These can be contrasted with indefinites both singular and plural, which are interpreted in the semantic domain in which they are generated. The difference is that generics and proper names are constants: they always have the same translation in a $\mathcal{M}$, whereas indefinites are variables whose translation is ambiguous (there may be more than one way of properly embedding sentences containing them: each different $f$ might translate the indefinite differently).

In the next section I will show how the verification conditions given in this section predict the possibilities of non-coreferential pronoun use (focus change).

### 6.7 Semantics and Focus Change

So far I have only looked at the possibilities of pronominal coreference within and between ontological levels. This section investigates pronominal relations which are non-coreferential. I argue that the kinds of non-coreferential relations available for a pronoun depend on the parts of the hearer's model of the world which must be attended in order to semantically interpret possible antecedents. I will show how, as a by-product of semantic interpretation, certain set-relations between antecedents and anaphors (even crossing ontological levels) are licensed, while other set-relations are simply not available: such anaphoric possibilities are meaningless. So semantic constraints on anaphora will arise naturally from the requirements of semantic processing.

I will recall the semantic interpretation procedures given previously, and from them predict what noncoreferential relations are possible.
Here is the list of possible non-coreference relations which I recognised on p. 132:

**Membership** Mapping of a set to component individual(s) (*The couple* went up to the stage. *She* was given flowers and *he* a bottle of wine. We were given *some chocolates*. I ate *my one* yesterday.)

**Subset** Mapping of a set to component subset(s). (*Several people* came in. Two (of them) were carrying turkeys. We were given *some chocolates*. I ate *mine* yesterday.)

**Genericity** Moving from an individual to its genus. (*John has a labrador. They’re beautiful dogs.*)

**Generic-membership** Choice of one or a set of individuals belonging to a given genus. (*Labradors* are beautiful dogs. *John has one*)

**Abstraction 1** Moving from an individual in a distributed set to the set itself. (*Every man* sneezed. *They* were taking part in an experiment.)

**Abstraction 2** Moving from an individual distributed by its dependence on an explicitly distributed set, to the union of those individuals. (*Most people* I know have *a car. They* are all volkswagens.)

**Summation** Combination of several individuals. (*John went shopping with Mary. They* bought a tent.)

I will explain, for each antecedent type, which of the above relations are available for pronominal reference, and why.

6.7.1 **Proper names**

| Proper name | $\alpha_{\text{name}}$ | $\text{ifnet}$ | is true iff there is an $f$ such that: $f$ maps $\alpha$ onto the element $a$ of $D$ such that $\langle \text{name}, a \rangle$ belongs to $\text{NAME}$ |

Proper names are interpreted by directly equating them with entities in the world model, given an identifying name. No other parts of the world model are activated in order

---

13 Summation will be discussed separately as it is the only relation which requires more than one antecedent.
to verify proper names, so it is predicted that proper names will not allow any focus changes.

A table of attempts is shown below:

<table>
<thead>
<tr>
<th>relation</th>
<th>example</th>
</tr>
</thead>
<tbody>
<tr>
<td>subset/membership</td>
<td>John smiled. #One of him/them had dimples.</td>
</tr>
<tr>
<td>genericity</td>
<td>John smiled. #They are often happy.</td>
</tr>
<tr>
<td>generic-membership</td>
<td>John smiled. #Mary is in love with one.</td>
</tr>
<tr>
<td>abstraction</td>
<td>John smiled. #They had been to a party.</td>
</tr>
</tbody>
</table>

My assumption appears to be justified: none of the operations can access any meaningful associations of the proper name John. In fact all these operations would require John to belong to a set, and it appears that simply introducing a proper name does not activate any particular set. The only remote possibility of doing so is if the hearer is aware that John belongs to some special group, in which case an implicit generic reference is just about possible:

(204) (Topic of conversation is BLUE-EYED PERSIAN CATS) Tuffy is deaf. They are often deaf.

However even if an implicit generic set is extremely strongly indicated by the meaning of the sentence in which the proper name occurs, it is still virtually impossible to obtain generic reference:

(205) John consulted Mary about his ingrowing toenails. #They are usually very sympathetic.

The easiest reading to obtain here is the one where John's ingrowing toenails were 'usually very sympathetic', followed by a summation of JOHN and MARY. The reading which was intended is not perspicuous, perhaps because it is not entirely unambiguous whether the group to which Mary belongs, who are usually sympathetic, are doctors or chiropracters in general, or a particular practice of doctors, or firm of chiropracters.

In speech particularly, however, vague use of they often occurs and is quite acceptable. It is possible that a theory of global focusing could explain why some generic sets are unusually accessible.
6.7.2 Generics

If \( \text{net} \) is true iff there is an \( f \) such that:

<table>
<thead>
<tr>
<th>Generic</th>
<th>( A^\text{concept}_c )</th>
</tr>
</thead>
<tbody>
<tr>
<td>maps ( A ) onto a subset of elements ( A ) of ( D ) such that (&lt; \text{concept}, A &gt;) belongs to ( \text{CONC} )</td>
<td></td>
</tr>
</tbody>
</table>

Generics, like proper names, are semantically interpreted directly. That is, there is no doubt in the hearer’s mind as to what the speaker was referring to.\(^{14}\) Unlike proper names generics access a set. Since sets are composed of individuals satisfying a common description, it should be possible to cycle through the generic set to find individuals or sets which belong to the genus. I predict therefore that both set-coreference and set-membership should be permitted. But, in line with proper names, it should not be possible to have any relation but coreference or generic membership from a generic noun phrase.

<table>
<thead>
<tr>
<th>relation</th>
<th>example</th>
</tr>
</thead>
<tbody>
<tr>
<td>subset/membership</td>
<td>I like cats. #One of them purrs very loudly.</td>
</tr>
<tr>
<td>genericity</td>
<td>I like cats. They often purr.</td>
</tr>
<tr>
<td>generic-membership</td>
<td>I like cats. John has one.</td>
</tr>
<tr>
<td>abstraction</td>
<td>I like cats. #They purred loudly.</td>
</tr>
</tbody>
</table>

As before, the prediction succeeds. It seems clear that generic reference does not make any specific sets salient. Indeed it would be hard to imagine which sets would be chosen, had specific set reference been possible.

The genericity relation illustrated in the table above is simply coreference to the generic set. The second case, generic membership, is a little more interesting. Here any individual which falls under the generic description can be accessed anaphorically. It is also possible to access a subset of individual members:

(206) Labradors are beautiful dogs. John has one/two/several.

\(^{14}\)I am purely concerned with semantics here, not psychology or philosophy, where the problems of defining the boundaries of a particular description have been recognised for some time and have been shown, in children particularly, to differ from one individual to another.
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The idea of a genus being composed of individuals seems contrary to common sense — the whole idea of a genus would appear to be a common description which can be applied to any individual, past, future, real or imaginary, to test whether it fits the description or not. How can this be reconciled with the semantic interpretation of a generic as the set of individuals fitting the description in question? The answer lies in the fact that the generic set is defined with respect to the discourse domain. The generic sets in CONC could embody the fact that the hearer can instantly identify whether a given individual is in the genus or not: the semantics is not concerned with hypothesising about the hearer’s knowledge. The generic-membership relation could be fitted into either account: assuming the pre-defined set, generic-membership would cycle through that currently activated set to find a subset. Assuming the generic-knowledge account, activation of the ‘generic set’ could activate a generic description or instruction for identifying members of the genus, which could likewise be applied to particular members.

6.7.3 Indefinites

<table>
<thead>
<tr>
<th>IFnet</th>
<th>is true iff there is an $f$ such that:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indefinite (singular) $\alpha_{\text{concept}}$ $\beta$</td>
<td>$f$ maps $\alpha$ onto an element $a$ of $\mathcal{D}$ such that in the pair $&lt;\text{concept},\text{SET}&gt;$ in CONC, $a$ is a member of the set $\text{SET}$</td>
</tr>
</tbody>
</table>

Indefinites are interpreted with reference to a set in CONC and verified if some member of the given set fulfils the conditions of the predicate. There might well be several individuals satisfying the conditions, but the semantic interpretation procedure only needs to consider some individual in the given set (a different individual for each $f$, but the verification conditions represent all variants with a single variable).

This suggests that anaphoric reference might be possible to that semantically-postulated individual, or to the set in CONC, but not to any specific set. As we have just seen, the sets in CONC are generic sets, at least as far as the discourse domain goes. So the relation expected to work is genericity.
The generic reading is by far the easiest relation to obtain, as predicted. The fact that indefinites must be interpreted with respect to a generic set accounts for the fact that generic reference is fine in the following example from chapter 4:

(86)  John owns a cat. They chase mice.

This is in contrast to the attempts to use generic reference to proper names, which, as Sidner noted, is impossible. In effect what the above text is communicating is that John owns an individual $c$, which belongs to the cat-family, and that the cat family is notable for chasing mice. Currently the IFnet for this text would be:

\[
\begin{array}{c}
\text{j owns } c \\
\text{John} \\
\text{cat}
\end{array} \rightarrow \begin{array}{c} \text{chase } M \\
\end{array}
\]

The first sentence of (86) contributed the following part:

\[
\begin{array}{c}
\text{j owns } c \\
\text{John} \\
\text{cat}
\end{array}
\]

However since we have now seen that the indefinite concept actually accesses a generic set which is available for pronominal reference, I shall make a change to the notation to unify indefinite reference with genericity. Instead of the previous IFnet, I shall represent the first sentence of (86) with:

\[
\begin{array}{c}
\text{j owns } c \\
\text{John} \\
\text{cat}
\end{array} \rightarrow \begin{array}{c} \text{c } \epsilon \\
\text{C} \\
\text{cat}
\end{array}
\]
CHAPTER 6. SEMANTICS OF DISCOURSE

It therefore becomes very easy to use the generic reference in the second sentence:

So I have proposed the indefinite individual and the generic set as potential foci. I believe this is in accord with the possibility of pronominal reference: it is simply not a feature of pronouns that they can create implicit relations to their antecedents. So, the translation of indefinite noun phrases involves two units, but as a compensation CCNC can be unified with NAME, since both deal with atomic parts of the world.

Returning to the table of set relations possible from the indefinite, we see that generic-membership is possible too. In this case, however, I will not propose that all the individual members of the generic set are also potential foci: simply that the generic set can be activated and searched — the necessary referents are already there, just in clustered form.

It also seems just about possible (using abstraction) to refer to some specific set of which the indefinite individual is a member. The only way to explain this would be to assume that indefinites can be verified with respect to a contextually defined (or implicitly assumed) set as well as with respect to the generic, as in:

(207) A dog barked. The rest were silent.

I suspect that indefinites like that in (207) are a special case, being reminiscent of the beginning of novels, where it is conventional for the novelist to reveal information gradually, often employing cataphoric constructions, forcing the reader to make presuppositions.  

I conclude that there is no really substantial evidence to suggest that operations on

---

15Perhaps in order to create in the reader the illusion that they are already familiar with the individuals under discussion.
indefinites can involve anything other than genericity or coreference.

All in all, whichever analysis of indefinites is preferred, the prediction that anaphoric reference is determined by verification conditions (i.e. by the meaning, as described by a standard formal semantics) continues to hold.

6.7.4 Plural Indefinites

<table>
<thead>
<tr>
<th>Irnet</th>
<th>is true iff there is an ( f ) such that:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indefinite (plural) ( \phi )</td>
<td>maps ( \Phi ) onto a subset ( A ) of ( D ) such that in the pair ( &lt; \text{concept}, \text{SET} &gt; ) in ( CONC ), ( A ) is a subset of the set ( \text{SET} )</td>
</tr>
</tbody>
</table>

Plural indefinites are also verified with reference to a generic concept, but instead of the consideration of any individual, the concept applies to some set of individuals. So plural indefinites should behave similarly to singular indefinites except that plural anaphors should be used for coreference. In addition, because a plural set is assumed, it should be possible to refer to subsets or single members of it.

<table>
<thead>
<tr>
<th>relation</th>
<th>example</th>
</tr>
</thead>
<tbody>
<tr>
<td>subset/membership</td>
<td>Several guitars were stolen. One of them was mine.</td>
</tr>
<tr>
<td>genericity</td>
<td>Several guitars were stolen. They are a valuable commodity.</td>
</tr>
<tr>
<td>generic-membership abstraction</td>
<td>Several guitars were stolen. ?I have one.</td>
</tr>
<tr>
<td></td>
<td>Several guitars were stolen. ?They were in the loft.</td>
</tr>
</tbody>
</table>

As predicted, practically every relation is available from indefinite plural sets. I have indicated with a question mark those I find dubious.

The one case which goes against the prediction is the infelicity of the generic membership relation. The example failed to be convincing. I suggest that this is because it is so much easier to obtain a set-membership reading instead (in which the speaker has one of the stolen guitars), than to follow the longer route through the generic (the speaker has a guitar). However it is possible to construct examples which rule out set membership:

(208) Several guitars were stolen. Since I have one myself, I sympathise with the owners.
And indeed in (208) the generic-membership relation does function between the indefinite plural antecedent and the pronoun one. However it is odd that it is so difficult to construct plausible generic-membership examples here, when there is apparently no difficulty in reading a co-set relation, as in (209), as generic rather than set membership.

(209) John got two letters. I got three.

Possibly this is related to the structural parallelism of the two sentences in (209). The role of parallelism will be discussed in section 6.9.6.

In line with my decision on singular indefinites, I will use generic set membership as part of the representation of a plural indefinite in IFnets. For instance, the IFnet for the first sentence of (208) would be:

```
g_{stolen} \subseteq G \subseteq \text{guitar}
```

The IFnet for the entire text would therefore follow as:

```
g_{stolen} \subseteq G_{\text{have me}} \subseteq \text{guitar} \rightarrow \text{me symp} \rightarrow O
```

6.7.5 Summation

The only relation I have not discussed so far is summation. Semantic properties did not predict that summation would be permissible in any cases, though in fact proper names can be summed, indefinites can be summed, and generics can be summed:

(210) Pedro is married to Juana. They have three donkeys.
I glued a spoon and a fork onto a box and threw them into the sea.

I glued two spoons and six forks onto three boxes and threw them all into the sea.

Dogs chase cats. They are traditional enemies.

It is equally possible to sum mixtures of these three categories:

John and his three sisters went to Italy. Their parents chased them on a motorbike.

John hates dogs. They don’t get on well.

It appears that it is possible to form a sum of any combination of discourse markers which is not ruled out for reasons of absurdity.

When two or more discourse markers have been activated, or several entities have been activated, they may be grouped together to become definite or indefinite plural sets (indefinite if they contain any indefinite parts). Grouping seems to be possible despite lack of a semantic link between the conjuncts (though see section on Parallelism). So summation is the odd one out of the permitted relations.

6.7.6 Focus change from ontological contexts

So far I have dealt solely with focus changes across the default context. What happens when semantic operators are introduced? What kinds of focus relations are possible between ontological levels, and how might these be related to the verification conditions for semantic operators?

As a reminder, here are the verification rules for conditionals and quantified sentences:

**Definition (Verification of Contexts):**

A conditional sentence is true if every proper embedding of the antecedent in the model can be extended to a proper embedding of the consequent in the model.
A quantified sentence is true if a certain proportion of the elements in the restrictor set meet the conditions in the nuclear scope.

So far there has been nothing in the anaphoric properties of the conditional and quantified contexts which distinguishes them from one another: both prevent coreference to discourse markers generated by indefinites inside the semantic contexts they create, but do not prevent coreference to proper names or generics:

(216) Proper name If John sees a kitten in a pet shop he will buy it. He is a great cat-lover.

(217) Proper name John buys every kitten he sees on sale. He is a great cat-lover.

(218) Generic If John sees a kitten in a pet shop he will buy it. They belong to the genus felis.

(219) Generic John buys every kitten he sees on sale. They belong to the genus felis.

(220) Indefinite If John sees a kitten in a pet shop he will buy it. It will have fleas.

(221) Indefinite John buys every kitten he sees on sale. It has fleas.

Both conditional and quantified sentences here display the same anaphoric properties. Kamp (1981) even claimed that they had certain truth-conditional similarities, making the two sentences below identical in meaning:

(222) Every man who owns a donkey beats it.

(223) If a man owns a donkey he beats it.

But as we saw, the interpretation Kamp (1981) gave for universals failed to generalise to other quantifiers and was replaced by Kamp and Reyle’s (1989) new interpretation. I will show in this section that conditionals and quantified sentences have different anaphoric properties as well as different verification conditions. The reasons for the striking similarity Kamp noticed will be explained in chapter 8, section 8.9.
The intuitive difference between conditionals and quantified sentences is that quantified sentences elaborate the properties of sets in the discourse domain, while conditional sentences deal with a hypothetical domain which need not necessarily relate at all to the discourse domain.

We saw in section 6.3 that when verifying the truth of a quantified sentence, it is always necessary to know for how many elements of the quantified set the given relation is true (in addition, for some quantifiers this must be compared with the total number of elements in the quantified set), whereas for a conditional it is only necessary to note that the given relation is true of any element meeting the condition.

The different methods of verification are reflected in two findings which bring out the differences between conditionals and quantified sentences. Firstly, I believe that the use of a quantifier presupposes the existence of the initial set in the world model. Such a set can have already been explicitly accessed in the discourse, as in the examples below:

(224) I saw ten beggars today. Every one of them had lost his bus fare.

On the other hand, the quantified set may not have been mentioned at all before the quantified sentence:

(225) I walked down the road. Every beggar I saw had lost his bus fare.

Sometimes the set has been partly restricted beforehand, as in:

(226) I saw some beggars today. Every one of them I spoke to had lost his bus fare.

Conditionals, on the other hand, although they often make conditions on sets or individuals which have been mentioned in the default context, do not presuppose that such a set exists. Conditionals are still perspicuous in default contexts which provide no individuals capable of satisfying them, whereas analogous quantified sentences are incomprehensible:
There are no boxing champions who speak eight languages fluently. That is fortunate, because if one turns up, I have to give him a job.

There are no boxing champions who speak eight languages fluently. #That is fortunate, because I have to give a job to every one of them who turns up.

A quantified sentence deals with an instance, but its truth must be evaluated with respect to the discourse world, about which it is making a number of statements. The truth of a conditional, by contrast, is to be evaluated in the contingent world which it sets up, which differs slightly from the discourse world.

This is why abstraction is possible out of a quantified phrase, but not out of a conditional. This second fact is also directly related to the verification differences: as I said, in order to verify a quantified sentence it is necessary to count how many individuals had a given property, whereas for conditionals no tally is required. As a result, the set of individuals with the given property is accessible after the quantified sentence, whereas no such set is ever constructed for the conditional:

If a woman went to the party, she gave John a present. #They had spent ages trying to find something suitable.

Every woman who went to the party gave John a present. They had spent ages trying to find something suitable.

Most women who went to the party gave John a present. They had spent ages trying to find something suitable.

So, the difference between conditionals and quantified sentences, in terms of discourse models, is that quantified sentences elaborate on a set assumed to exist in the world model, to produce a second set which may be pronominally accessed, either as a potential focus, or via a focus change. Conditionals do not elaborate on or produce plural entities, but deal with a hypothetical domain which can only be related to the discourse domain via inference mechanisms.

A conditional will therefore neither introduce new discourse markers nor attach to old ones, beyond those generations or attachments which are demanded by the rules for the noun phrases from which it is comprised.
A quantified sentence, on the other hand, has extra discourse markers associated with the quantified noun phrase(s). A quantified noun phrase introduces in addition to its status as an indefinite, an initial set and a resultant set. The initial set is simply the set from which the singular form of the indefinite is derived by a membership relation: in the simplest case this is the generic set the indefinite necessarily brings with it, however the indefinite may be 'one of' a previously mentioned set. The resultant set is always newly introduced. Both initial and resultant sets appear at the ontological level at which the quantified context with which they are associated was introduced, rather than appearing inside the ontological context.

### 6.8 Presupposition of discourse markers

This section discusses how to separate constructed discourse markers from presupposed or explicitly produced ones. For instance, summation is clearly a constructed process, since it would be psychologically implausible to have all possible summations anticipated with explicit discourse markers. Coreference on the other hand involves no construction at all. The question is, whether relations like abstraction, generic-membership or genericity are pregenerated.

The discourse markers for genericity and abstraction relations must be presupposed, because genera and resultant sets are necessary parts of the meaning of a man and most men respectively.

On the other hand, it would be absurd to treat generic membership, subset/member, summation and coset relations as already existing. This might seem contrary to my earlier assumption that pronominal reference requires the discourse markers concerned already to exist. However, the requisite discourse markers do (in a sense) exist — in the case of summation they are simply not grouped together, while in the cases of generic-membership etc. they are simply not distinguished from the set as a whole. Any plural discourse marker represents a set: its members have simply not been subdivided according to any further properties.
There is one problem with this analysis and that is the empirical observation that genericity and abstraction do not appear to be as easily obtained as this hypothesis would suggest. It seems that coreference is still preferred. The way to account for this without abandoning the hypothesis that generic and resultant sets produce discourse markers is to assume that there is a focus preference ordering on the various potential foci, making simple coreference most salient. Taking the case of indefinites first, it can be noted that it is the individual discourse marker representing the indefinite which is attached to the verbal relation (the maximal unit), while the unit which confines the indefinite to belonging to a particular genus is always parasitic on the main clause, as in:

\[
\begin{array}{c}
\overset{j \text{-owns}}{C} \\
\begin{array}{c}
\text{John} \\
\in \\
C \\
\text{cat}
\end{array}
\end{array}
\]

Using the rule that syntactically subordinate units are less focused from the point of view of subsequent sentences than superordinate units could therefore account for the relative inaccessibility of the generic set. A similar argument applies to quantified sentences, if it is assumed that the main verbal unit is within the quantificational context. This seems fair for (232):

(232) Every farmer owns a donkey.

Clearly the verbal unit is claiming a single relation between singular individuals: the lexical items farmer and donkey are singular, and the verb owns agrees with the singular subject. It is by virtue of the quantification that the verbal relation and the singular individuals become distributed. One natural way to represent (232), with its initial and resultant sets, would be:
Unfortunately it is not possible to represent the fact that $F$ contains only FARMERS, while $T$ contains FARMERS WHO OWN DONKEYS. This problem will be raised again in chapter 8 when a more suitable notation is available for semantic contexts.

The symbol $T$ corresponds to the generic set of farmers, which provides the initial set, while the set $F$ is the resultant set, which contains the entire set of farmers satisfying the predicate. In this case, because the quantifier is every, $F$ will contain the entire set of farmers in the discourse domain, namely $T$, but the hearer can still distinguish the two:

(232a) Every farmer owns a donkey. Southern Italy is full of them. (farmers, not donkeys)

(232b) Every farmer owns a donkey. They keep them in disgraceful conditions.

(232a) shows a generic reference (anaphora to $T$), and (232b) abstraction (anaphora to $F$).

However sometimes it is not so obvious that the verbal unit should fall within the quantificational context:

(233) Most men own donkeys.

There is no sign of singular relations here, and it might be thought that the following was a better representation of this sentence (the word donkeys will be translated as an indefinite plural):
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Funnily enough, abstraction and coreference to the subject seem empirically identical in this example: \( M \) stands in for both subject and resultant set. However a quantifier cannot be interpreted without recourse to individuals. This accounts for the acceptability of the following example:

(233a) Most men own a donkey.

So a quantified noun phrase may be morphologically expressed as singular or plural, which interestingly reflects that fact that quantified noun phrases generate both singular and plural discourse markers.

So, if some set or individual is required to calculate the truth conditions of an utterance, then it produces a discourse marker which becomes a potential focus. Like any potential foci these become inaccessible in later sentences if they fail to become focused. But potential foci produced by generics or abstraction are less accessible than potential foci in the main clause, because of their syntactic subordination. Indeed generated relations do not after all produce focus changes, but simply focus shifts.

Both potentially focused and focused discourse markers may provide the basis for constructed discourse markers which regroup previous discourse markers to create new ones on the basis of further pronominal reference. Construction is of course highly specific, and involves redistribution of individuals or sets, rather than the more sophisticated forms of inference available to definite noun phrase anaphora. It is these constructed relations which result in focus changes, because they are parasitic on previous foci, but nevertheless produce new discourse markers. Since construction involves more processing effort than coreference to potential foci, coreference is always preferred unless the form of the anaphor demands construction. Hence the preference for focus maintenance over focus change noted in chapter 4. I will from now on assume that focus changes are preferred over focus shifts: previous data was confounded by not separating constructed from generated relations.

Because constructed relations are non-coreferential, this means that a slight adjustment must be made to the conditions for anaphoric accessibility. Constructed relations produce their own nominals which cannot access antecedents in subordinate ontological
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contexts, however if they access antecedents from superordinate contexts, it is not always the case that the new derived nominal will be projected up to that level from the ontological context in which it was itself generated, though we will see in the next chapter that this is the default.

What cannot happen is for a discourse marker to be created which is not potentially focused or constructed from existing potential foci.

6.9 Summary of Ontological Effects

So, depending on the verification conditions necessary for noun phrases, there may be several different discourse markers produced for a single noun phrase. It is due to this productiveness that so many different kinds of pronominal reference are possible to what appears to be a single antecedent. However, as we have seen, some types of relations are preferred to others.

<table>
<thead>
<tr>
<th>Noun Phrase</th>
<th>Relations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proper Name</td>
<td>Coref, Sum</td>
</tr>
<tr>
<td>Generic</td>
<td>Coref, Gemem, Sum</td>
</tr>
<tr>
<td>Indefinite Singular</td>
<td>Coref, Gen, Sum</td>
</tr>
<tr>
<td>Indefinite Plural</td>
<td>Coref, Gen, Sub, Sum</td>
</tr>
<tr>
<td>Quantified</td>
<td>Abs, Sum</td>
</tr>
</tbody>
</table>

Key: Coref = coreference, Gen = Genericity, Gemem = Generic membership, Sub = Member/Subset, Abs = Abstraction, Sum = Summation

This section serves simply to summarise these findings by gathering together the different possible situations which make a particular relation possible. This is important since, as will be pointed out, the form of an anaphor often signals what type of relation is required to resolve it.

I end this section with a discussion of summation, which has received little attention so far. I relate it to the phenomenon of parallelism which was first encountered in chapter 3.
6.9.1 Coreference

Pronouns like *it*, *he* and *she* are always coreferential, as is *they* by default (it can also signal genericity, abstraction and summation).

The situations in which coreference occurs are simple. Firstly, *any* discourse marker licenses coreferential anaphora. Generic and proper name discourse markers can be accessed from any ontological level, providing they are focused, potentially focused or stacked. Discourse markers generated by indefinites (singular or plural) can only be interpreted in the same or subordinate ontological levels. This follows from the semantics rather than as in DRT being evident from the actual representation.

6.9.2 Membership/Subset

Phrases like *one of them*, *several of them*, *most of them*, *the tallest (of them)* signal membership/subset relations, in conjunction with compatible tenses. A possible heuristic to distinguish this relation from genericity is that the member/subset must be uniquely identifying (as in *the tallest*) or explicitly signal the presence of a member/subset relation, as in the phrase *of them*, which easily translates into 'belongs to the given set'. One might be tempted to think that the use of the phrase *one of them* meant that the given set ought to be focused as well as the new set, but it is my belief that the pronominal marking covers the whole noun phrase, showing that it is solely the new set which is focused. It is difficult to see how the wording could have been changed without using pronominal reference to the previous set, unless the previous set was not mentioned explicitly. This illuminates the peculiar nature of the focus change, which continues (or begins) to focus a general noun-concept, without actually maintaining focus on the specific group of individuals previously represented.

The only restriction on membership/subset that we have seen is that the antecedent discourse marker is a plural set (rather than an individual or a generic). Since the antecedent is a plural set it must have been generated by an indefinite noun phrase. This means that the membership/subset relation is only possible within an ontological level or from a higher ontological level. The new nominal may be created at the higher
level, or at the level on which it was generated. Take:

(234) John has two cats. If one of them wants feeding, it climbs up the curtains.

If one of them has been taken always to mean a specific cat, then its discourse marker is available at the default level, as in:

(235) Because it is so large, the curtains frequently fall down.

If on the other hand one of them is not taken specifically, if it varies over both cats, then (235) is not an acceptable continuation. Chapter 7 will explain in some more detail when this type of ambiguity arises, and why.

6.9.3 Genericity

My treatment of genericity emerges as identical to that proposed by Webber (1983). The generics covered in this thesis are always accessed using the pronoun they. The main sign of genericity is the use of the present tense, though this is not an infallible guide.

I noted in chapter 3 (p. 66) that it is impossible to obtain generics with proper names and easiest with clearly ‘typed’ or ‘stereotyped’ individuals or groups. This is because a generic refers to a particular well-defined set, to which the antecedent belongs. It follows from the semantic interpretation that indefinites will have generic sets associated with them, while proper names do not. It also follows that generic reference is only possible when relevant groups are mentioned explicitly, for instance take the example:

(236) A St Bernard came into the shop. They are usually very friendly.

Although it is well known that St Bernards are a breed of dog, the only available generic set is ST BERNARDS, rather than DOGS. This is because the semantic interpretation only requires that the referent in question belong to the set of St Bernards: it is left to
the hearer to *infer* (optionally) that the referent is a dog. Because the set of dogs is not activated in order to understand the term *a St Bernard*, there is no set of dogs available for pronominal reference.

### 6.9.4 Abstraction

Abstraction is always signalled by the pronoun *they*, though *they* does not always signal abstraction. Abstraction is only possible from quantificational contexts, where it is a form of coreference from syntactically subordinate units. Abstraction accesses the resultant set which is necessary to interpret any kind of quantification. The resultant set is generated in the ontological level in which the original sentence began to be processed, that is, the ontological level above the level of the verbal relation.

Abstraction is illustrated in the example from Hirst 1981 p. 5:

(237) Ross gave each girl a crayon. They used them to draw pictures of Daryel in the bath.

However the explanation I have given so far can only account for Abstraction 1 — the abstraction resulting in the first pronoun *they*. Abstraction 2, which permits the use of the second pronoun *them* cannot be accounted for by the semantic interpretation of quantification. This is an important problem which will be discussed at the end of chapter 8.

### 6.9.5 Combining Relations

In chapter 4 (p. 132), I pointed out that a 'coset' relation, as illustrated by (238), could be obtained by combining genericity with generic-membership.

(238) John got three letters. I got two.

Complement set reference is also a case of coset, as in:
Most farmers own donkeys but few have geese.

Most farmers have donkeys, the rest have goats.

Both these examples involve generic-coset, but the second has a particularly close relation between the anaphor and antecedent, since the anaphoric referent set must exactly complement the antecedent referent set in the generic set of FARMERS.

Other possibilities for complex relations can now be predicted from the table given earlier and repeated here, which illustrates which relations are available from which type of constructions:

<table>
<thead>
<tr>
<th>Construction</th>
<th>Relations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proper Name</td>
<td>Coref, Sum</td>
</tr>
<tr>
<td>Generic</td>
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</tr>
<tr>
<td>Indefinite Plural</td>
<td>Coref, Gen, Sub, Sum</td>
</tr>
<tr>
<td>Quantification</td>
<td>Abs, Sum</td>
</tr>
</tbody>
</table>

For instance, indefinites result in the creation of a generic set, which is itself open to generic-membership construction, as we have seen. The other construction which can create chains of pronominals is quantification, which creates a resultant set. Since the resultant set is an indefinite plural, quantification may be followed by genericity (and hence generic-membership) or a member/subset relation, permitting the following examples:

(241) **Abstraction then genericity** Most merchants were rich. The peasants thought they should be taxed more. (Rich merchants)

(242) **Abstraction then genericity then generic membership** Several merchants believed in astrology. Demetrious was one. (A merchant who believed in astrology)

(243) **Abstraction then subset** Most merchants wore bright colours. Some of them wore a different colour cloak every day. (Some of the merchants who wore bright colours)

(244) **Abstraction then membership** Most merchants liked to finance new shipping ventures. One of them tried to persuade me to go to sea.
(245) Summation then subset Merchants mingled with peasants in the marketplace. Some of them even formed couples.

So complex relations are formed by chaining the relations permissible given the activated referents (individuals, sets or genera).

6.9.6 A short note on Parallelism

The coset complex relation can create semantic parallelism. Extreme semantic parallelism is created when two units contain no discourse markers in common: when all the discourse markers they contain are semantically disjoint, yet there is some semantic relation between them, as in the example (238) given earlier:

(238) John got three letters. I got two.

The three letters John got, and the two letters I got, are completely independent. The two sentences are unrelated except for the fact that (a) we both got something and (b) in both cases what we got was a small number of letters. This is similar to cases of structural parallelism in discourse, where two units may share some lexical items in common, or simply some syntactic or thematic structure. I have just illustrated a particular kind of lexical similarity: a similar kind of similarity could link the two occurrences of got, which though they do not report the same event, nevertheless both belong to the same class of events (to the same set of pairs in PRED). In order to interpret the anaphor two, an ontological parallel must be created in the way the sets relate to the generic node.

The following IFnet captures the effect:

\[
\begin{array}{c}
(j) \xrightarrow{\text{got}} (L3) \\
\quad \varepsilon \\
\quad (L) \\
\quad \varepsilon \\
me \xrightarrow{\text{got}} (L2)
\end{array}
\]
The opposite effect can be seen with summation: instead of causing parallelism, summation can be triggered by it.

(246) For Christmas Mary got a pair of shears. John got a kitten. They were overjoyed.

Of course, parallelism need not be so distinct: it can occur in sentences with anaphoric links. Nor need parallelism and coset occur across units: both relations can be found within the same unit, and both relations can link discourse markers within the same unit:

(247) John went shopping with Mary. They bought a tent.

(248) John's fish ate mine.

However the effect of parallelism across units has been found to affect preferences for anaphor resolution, and though the story I have offered here is too limited to suggest why, it offers some suggestions about what 'parallelism' might comprise.

6.10 Revised IF Algorithm

The discoveries of this chapter necessitate some changes to the IF algorithm, which are summarised below. A copy of this final version of the algorithm can also be found in Appendix I.

Antecedent choices:

When a pronoun is encountered, choose its antecedent using the following defaults:

1 PRIMARY RULE: Predict a Fisc member.
2 MATRIX RULE: Then try DF
3 SUBORDINATE RULE: Predict sub-Fisc
4 SUBORDINATE RULE: Predict sub-Risc
Choice of derived nominal

The preference is for the pronoun to corefer with its antecedent, but if the form of the anaphor is not compatible with the chosen antecedent then the appropriate construction rule is chosen: they would suggest summation, if coreference failed, two of them would suggest subset, and most generic membership. Summation is as before the odd one out, since choosing one antecedent is not enough, but somehow other antecedents are likely to be associated with the chosen antecedent, making summation a possibility.

In other words, I suggest that construction is considered immediately after a possible antecedent has been found, before ratification takes place, and before any other possible antecedents are considered. This is because choosing a new antecedent takes more processing effort than considering a different type of antecedent-anaphor relationship.

Incremental Update

Whenever a noun phrase is encountered:

If it is definite (a proper name), add its nominal to the current RISC (this will be the main RISC if the indefinite is attached to the main verbal unit, and a temporary SUB-RISC if the indefinite was attached to a subordinate unit).

If it is a singular indefinite, add its (specific) nominal to the current RISC (this will be the main RISC if the indefinite is attached to the main verbal unit, and a temporary SUB-RISC if the indefinite was attached to a subordinate unit), add its generic nominal to a sub-RISC subordinate to the specific nominal.

If it is plural and quantified, add its singular instance nominal to the current RISC, and add its generic (initial set) nominal to a sub-RISC subordinate to the instance nominal, and its plural resultant nominal also to a sub-RISC subordinate to the instance nominal.

If it is pronominal and coreferential, transfer a nominal from one of the focus stores into
FISC (or a temporary sub-FISC, if the pronoun occurs in a subordinate unit).

If it is pronominal and non-coreferential, add its derived nominal to the current RISC (this will be the main RISC if the pronoun occurs in the main verbal unit, and a temporary sub-RISC if the pronoun occurs in a subordinate unit).

End-of-unit update:

Whenever the end of a coordinate unit is reached:

Clear PDFL stack DF in DFS, move FISC into DF and move RISC into PDFL. Clear FISC and RISC.

At the beginning of a subordinate unit, begin a sub-RISC to deal with the new nominals in that unit.

When the end of a subordinate unit is reached, add its sub-RISC to the end of PDFL, and its sub-FISC to the end of DF.

6.11 Conclusion

I have now covered the semantic interpretation for the data set of the thesis, showed how IFNets are constructed on the basis of the interpretations of various constructions, and explored what the implications are for possible pronominal relations. I have shown that the referents used for verification must produce discourse markers which are accessible for anaphoric reference (as potential foci). These discourse markers can be regrouped in various (constrained) ways to construct conceptually new discourse markers. The presence of these discourse markers explains why certain focus changes are permitted, and when.

I have shown how entirely dependent focusing is on semantics, to the point where the entities in the focus stores are entirely determined by semantics. Anaphoric possibilities depend on the meanings of the words in a sentence. It makes sense that if a word is essentially defined with reference to several different concepts, that these concepts should be accessible for pronominal reference. What is more surprising is that formal
semantics, which was not designed with pragmatics or psychology in mind, should correspond so well with the nature of the mental representation of discourse used for pronoun resolution. Formal semantics does aim to capture the nature of language, and clearly that semantics is also fundamental to the way human beings interpret language.

I believe the relation between semantics and anaphora cannot be overemphasised. I have encountered no theory of focusing which points out that semantics underlies the discourse markers which are created. This chapter has served to clarify the interdependence of semantics and focusing, a theme which will continue into the next chapter where I take the opposite approach and show the effect of focusing on semantics.

Achievements:

- A semantic interpretation was given for IFnets, showing how they could be verified with respect to some situation.
- The notion of a semantic context was introduced to account for constraints on coreferential anaphora in the vicinity of negation, implication or quantification.
- It was suggested that all pronominal reference is determined by semantics, with a division into generated and constructed relations.
- This motivated some changes to the IFnet notation, so that all discourse markers were explicitly included.
Chapter 7

Focus and Scope Ambiguity

This chapter explores in more detail the interaction between focus and scope. In the previous chapter I showed that semantic structure determines the accessibility and ontological status of antecedents. Now, I examine the effect of focus on the interpretation of semantically ambiguous sentences.

It is assumed that a necessary part of semantic processing is to enable sentences of a discourse to be evaluated as true/false relative to the hearer's model of the world. So how does a hearer go about verifying a sentence? In chapter 6 I simply assumed that the hearer could find the necessary individuals and sets in the appropriate parts of the domain \( D \): truth conditionals were stated declaratively, not procedurally. I claim that since the hearer is already attending to a certain entity in the world, as instructed by the IFnet model of attention in discourse, the properties of that entity will be the most accessible. It follows that the most economical method of verification is to search the properties of this focused element for the relation in question. The conditions for verification for a sentence may emerge as different depending on which element is focused — it is this, I argue, which results in such sentences being described as 'semantically ambiguous'.

The chapter begins by describing studies of 'focus' in generative linguistics which show that patterns of intonational stress can completely disambiguate semantically ambiguous
sentences. I suggest that the disambiguation potential of discourse focus is similar, but necessarily weaker, since focus shifts must still be permissible. The rest of the chapter will concentrate on a small subset of semantic ambiguities, those found in sentences containing two plural or quantified noun phrases. The two types of semantic ambiguities investigated are quantifier scope ambiguity and distributive/collective ambiguity.

7.1 Intonational focus and semantic ambiguity

To distinguish the use of focus in generative linguistics from that I use in this thesis, which is derived from computer science, I will call the linguistic use intonational focus. The term ‘intonational focus’ has the advantage of picking out one of the major distinguishing characteristics of the concept: its relationship with intonational patterns in the sentence. The second major influence on the concept is syntactic structure.

The concept of intonational focus, under different names, has been part of the literature since the nineteenth century. Unlike discourse focus it is used for the new or notable information in a sentence, and usually receives the intonational stress. The remainder of the information is called the ‘topic’ or ‘presupposition’. How the topic and focus are defined and distinguished varies from theory to theory. For instance in the Prague School, the line between topic and focus is ultimately determined by the interaction between the intonational and dependency structures of the sentence. I do not intend to explore any theory in depth: what I wish to do is to give a superficial overview of the kind of observations which have been made with respect to semantic ambiguity.

It has been observed recently that intonational focus can affect the truth conditions of a sentence Rooth (1985) (introduction); Sgall, Hajjíková and Panevová (1986) (p. 54, 227ff etc.). Partee (1991) and Rooth (1985) are among several writers who have noted that in general, focus falls on items taking narrow scope.

---

1Here, occurring in subject and object position. I treat both generalised quantifiers and plural determiners as ‘scoped’.
The following example is taken from Partee (1991):

(249) Mary always took John to the movies.

Three possible readings of this sentence can be detected by stressing the main words Mary, John and movies, as follows:

(249) a. Mary always took John to the movies.

b. Mary always took John to the MOVIES.

c. MARY always took John to the movies.

The resultant readings are paraphrased below:

1. Every time Mary went to the movies, she took John.

2. Every time Mary took John anywhere, she took him to the movies.²

3. The person who took John to the movies was invariably Mary.

So potential ambiguities can be completely erased simply by changing the intonational patterns of the sentences.

Sgall, Hajíčková and Panevová (1986) explain such biases as resulting from the ‘aboutness’ of (intonational) focus. Focus is on the properties of the contextually given topic. My hypothesis is that discourse focus will have an effect on semantic processing analogous to the effect of intonational focus.

It is natural to ask whether there is any relation between intonational focus and discourse focus. The most superficial observation suggests that intonationally focused items have more in common with the items unfocused with respect to previous discourse, since they are both often used for the newly introduced information in a sentence. Discourse focus, therefore, should be compared with topic. But what exactly is the relationship

²The other reading which is possible here, Every time Mary and John were together, she took him to the movies, will be ignored for now.
between them? One way to investigate this is to see whether discourse focus has any of the same effects as intonational topic/focus does in the above examples.

Example (249) showed that the set of situations considered by a quantificational adverb, always, could be altered by stressing different items in the sentence, resulting in different semantic interpretations.

Example (249) Mary always took John to the movies.

Three alternative readings were obtained by stressing Mary, John and the movies respectively.

Let us examine whether a similar bias can be obtained by substituting an anaphoric/nonanaphoric contrast. Take the reading where Mary was stressed, giving the statement that whenever someone took John to the movies it was always Mary. The hypothesis is that if this reading can be obtained by discourse focusing, the sentence should appear with Mary non-anaphoric and John and the movies focused. A possible context might be:

(250) John went to the movies a lot last year. Mary always took him.

For the movie-stressed reading (Every time Mary took John anywhere it was to the movies), a suitable context might be:

(251) Mary was a good friend of John’s. She always took him to the movies.

And where previously John was stressed (giving the reading: Whenever Mary took someone to the movies it was always John she took), a context might be:

(252) Mary used to go to the movies quite often. She always took John.

It seems to me quite uncontroversial that discourse focus here achieves exactly the same effects as intonational topic did in the previous sentences. In fact while stating
the readings for the stressed examples I often used pronouns to convey their senses unambiguously. Despite sharing this basic property, the relation between intonational topic and discourse focus is not straightforward.

For instance, let us combine intonational topic and discourse focus in a conflicting way:

(250) John went to the movies a lot last year. Mary always took him.

(251) Mary was a good friend of John’s. She always took him to the movies.

(252) Mary used to go to the movies quite often. She always took John.

In these examples, I have placed intonational focus (stress) on one or two of the discourse foci, rather than on the unfocused items where it falls by default. This has the result of overriding the discourse focus bias. (250) and (252) are at first puzzling. If a reading can be obtained for them, it is the one indicated by the intonational focus prediction, plus some kind of causal connection: for (250) the reading is that Mary took John, rather than anybody else, and that this was the reason that he went to the movies a lot. For (252) the reading is that it was Mary, rather than anyone else, who took John, perhaps as a result of being such an enthusiastic cinema-goer. (251), on the other hand, is easily interpretable as expressing contrast or surprise, because stress is placed on two pronouns. That is, the proposition being expressed is that (contrary to expectation) it was Mary who always took John to the movies, rather than John who always took Mary to the movies. The supposition is that it was the movies which were being discussed all along. So using intonational focus here both reverses the discourse focus effect (which proposes the movies as new information) and produces an extra contrastive meaning. So, intonational focus can destroy the proposed influence of discourse focus.

Cases where discourse focused items fall under intonational focus are given brief mention by Sgall, Hajičová and Panevová (1986). They state that pronouns are usually part of the intonational topic, but explain that exceptions can be found for contrastive cases:

(253) I saw two young people there. He kissed her. I recognized only him. (Sgall et al. p. 58)
CHAPTER 7. FOCUS AND SCOPE AMBIGUITY

In this case, they argue, the pronoun he falls under intonational focus and is hence treated as new, though it remains contextually bound.

It seems that the bias of intonational focus is virtually impossible to override, whereas discourse focus effects, because they have to be flexible, have a weaker effect. Intonational focus is one means of overriding discourse focus effects to signal a temporary or permanent shift in perspective or focus, possibly to introduce a contrast. Usually however intonational focus is used (in speech) to enhance discourse focusing.

It does not seem unreasonable that disambiguation should be affected by previous contexts as well as by stress. When reading texts, there are no intonational cues. Therefore some alternative to stress must perform its function of highlighting the focus in written texts. Since semantics, as we have seen, is concerned with delimiting ontological domains, it might well relate to discourse focus, which marks the prior existence of certain sets and individuals.

In summary, the relation between intonational topic and discourse focus is as follows: both have similar scope-biasing effects and both are generally used for presupposed information in a sentence, however changes in semantic interpretation are induced by intonational focus, whereas discourse focus can only give a preference. But as will be seen later, in other situations discourse focus effects can actually override intonational effects.

7.2 Scope Ambiguity

Intonational focus has mainly been used to illuminate sentences containing adverbs of quantification, VP-ellipsis or negation. However the data set of this thesis (conditionals, generalised quantifiers, plural anaphora) has received little attention. Quantified sentences in particular are interesting because they can exhibit scope ambiguity. Depending on whether subject or object of the sentence is interpreted first, different meanings are obtained. This is interesting from the focusing point of view because the meanings differ in the number of discourse entities which are relevant in judging the
truth of the sentence. So deciding which meaning of a sentence is intended is vitally important in understanding or producing subsequent pronominal references.

Sentence (254) exhibits the type of ambiguity under consideration:

(254) Two policemen reported a theft.

The main unit of the IFnet for this sentence is:

\[ P \xrightarrow{\text{report}} t \]

On one reading, it is understood that a particular theft was reported by two policemen. When translated into predicate logic this interpretation of the sentence may be described as giving the object 'wide scope' over the subject. The situation in the world assumed by such an object-wide scope reading would be:

\[ \begin{array}{c}
\text{report} \\
\rightarrow \\
\text{report} \\
p \\
\rightarrow \\
pt \\
\end{array} \]

I will call this the OBJECT-CONVERGENT (OCONV) reading (because I will be arguing that giving the object wide scope does not always result in this reading).

On the other hand, giving the subject wide scope is assumed to result in the following PARALLEL (PAR) reading:

\[ \begin{array}{c}
\text{report} \\
\rightarrow \\
\text{report} \\
p \\
\rightarrow \\
pt \\
\end{array} \]

The understanding is that two policemen each reported a separate theft. That is, the

\[ \text{report} \]

\[ \rightarrow \]

\[ pt \]

3The diagrams used to illustrate situations in the world should not be confused with IFnets — IFnets are the representation of discourse and are more abstract. The situation pictures could be seen as a partial representation of the world, but I regard them simply as shorthand for the verification conditions, to distinguish one reading from another.
thefts have been distributed by the plural determiner.

Although nearly all formal semantic theories give satisfaction rules for both scopings, the sentences are simply assumed to have two different interpretations, which are not distinguished in terms of plausibility. Computational linguists have sometimes assumed that Par readings are 'preferred' to OConv readings, but no semanticist has accounted for the conditions under which an Oconv reading is obtained.

### 7.3 Effect of focus on scope

In this section I show that scope ambiguous sentences like (254) are subject to the biasing effects of discourse focus.

I shall be concerned simply with the subject/object scope ambiguity, rather than any other type of semantic ambiguity which may incidentally occur in such sentences. To avoid confusion with the distributive/collective ambiguity produced in combination with certain verbs, the verbs used in this section should always be read as distributive. The interaction between the two types of ambiguity will be discussed in section 7.9.

To repeat the example:

(254) Two policemen reported a theft.

It has already been established that this sentence is ambiguous between the Par and Oconv readings. My aim is to show firstly that focus biases the preferred interpretation, and secondly to explain why such a bias follows from a cognitive psychological account of discourse processing.

To test for the effect of focus on (254), either of the noun phrases may be replaced by a suitable pronominal anaphor, and some previous discourse given. The remaining noun phrase should be new in the given context.

The alternatives in (254) are to focus on the **two policemen** being discussed, or to focus on a **theft**. To take the second option first, there are several ways of focusing
a theft. However the most obvious one (to pronominalise it) causes the noun phrase to become definite, hence immediately removing any possibility of Par readings. The suitable anaphor is the one which will reproduce the behaviour of the full noun phrase which it replaces, including its ambiguity of scope. For an indefinite, the appropriate anaphor is produced by a subset relation; a theft can be replaced by one of them and two policemen by two of them. It is assumed, in effect, that subset/member pronominal anaphora exhibits the same range from definiteness to indefiniteness as do full anaphoric noun phrases. This preserves the possibility of scope ambiguity, hence allowing the hypothesis to be tested.

In order to facilitate the use of these anaphors, the previous discourse must permit this non-coreferential focus relation. For instance a way of focusing a theft would be to mention a particular group of thefts in the previous sentence. It is equally plausible for one of them to pick a single particular theft only, or to cycle through a number of different thefts, given a larger set of thefts under consideration.4 The context does therefore permit either interpretation of the focused noun phrase.

The policemen-focused and theft-focused contexts used to test the hypothesis are as follows:

(256) **Theft-focused**

We arranged several thefts on Tuesday. Unfortunately, two policemen reported one of them.

This has the following fnet:

\[
\begin{array}{c}
\text{we arrange} & T & \epsilon & \text{report} P \\
\downarrow & \downarrow & \downarrow & \downarrow \\
T & tu & \epsilon & P \\
\end{array}
\]

4The two possibilities are shown in another semantic context, negation. Take the discourse:

(255) There were five suits in the wardrobe. John didn't like one of them.

Here it is possible for one of them to pick out a particular one of the five suits which John took a dislike to, or for one of them to pick out the five suits one by one, producing the reading in which John did not like any of the suits.
CHAPTER 7. FOCUS AND SCOPE AMBIGUITY

(257) Policeman-focused

A bunch of policemen walked in. Two of them reported a theft.

The ifnet for (257) is:

\[
\begin{array}{ccc}
\text{c walked} & \in & \text{p} \\
\subseteq & \epsilon & \text{report}
\end{array}
\]

The contexts differentiate the two readings as follows: the theft-focused examples (256) favour Par readings, while the policeman-focused examples (257) favour Oconv readings.

So in example (254), the focused items tend to distribute the unfocused items, suggesting that they take widest scope.

If one replaces discourse focus with intonational topic in the above examples, corresponding biases are obtained:

(258) Policemen-stressed

TWO POLICEMEN reported a theft.

(259) Theft-stressed Two policemen reported A THEFT.

So it seems that use of discourse anaphora complements the stressed items, fulfilling the prediction that intonational focus takes narrow scope, and discourse focus takes wide scope. As before, examples will be examined where intonational and discourse focus influences are in conflict:

(260) Theft-focused

We arranged several thefts on Tuesday. Two policemen reported ONE OF THEM.

(261) Policeman-focused

A bunch of policemen walked in. TWO OF THEM reported a theft.
When intonational focus is used in opposition to discourse focus, the discourse effects persist, rather than being overridden. When discourse focus is used in the place of intonational topic (or in addition), the same semantic disambiguation effect occurs as noted by Partee (1991), Kadmon and Roberts (1986) etc., with the new information in the sentence tending to take narrowest scope. What is more, the effect of discourse focus in (254) is even stronger than the effect of intonational focus.

A second example supporting these findings is given below, this time with the quantificational context generated from object position:

(262) A landslide buried two villages.

The core of the IFnet for (262) is:

\[
\begin{array}{c}
 V \\
 l^v \\
 \end{array}
\]

Like that for (254) it can be interpreted in two ways:

Sconv:  \( l^v \rightarrow \text{buried} \rightarrow V \)  
Par:  \( l^v \rightarrow \text{buried} \rightarrow V \)

The two contexts are:

(263) Village-focused

Several villages were excavated on this site. A landslide buried two of them.

(264) Landslide-focused

Several landslides have occurred recently. One of them buried two villages.

The prediction is that the village-focused context will favour the parallel reading, and the landslide-focused context the Sconv reading.
Although it seems harder to obtain the convergent reading in these examples than in the subject-quantified sentence, the difference between the contexts is still very marked: the landslide-focused context (264) categorically rules out the parallel reading, while the village-focused context (263) certainly permits it, and possibly favours it. The hypothesis does not account for why the object-focused (village) context seems to allow the subject-convergent reading quite easily. A second factor is biasing the readings. For now it is assumed that this is orthogonal to the focus bias. The table of results is summarised in figure 1.

Figure 1: Scoping biases in subject and object focused contexts

<table>
<thead>
<tr>
<th></th>
<th>focus on subject</th>
<th>focus on object</th>
</tr>
</thead>
<tbody>
<tr>
<td>subject-quantified</td>
<td>(257) strong Par bias</td>
<td>(256) very strong OConv bias</td>
</tr>
<tr>
<td>object-quantified</td>
<td>(264) strong Sconv bias</td>
<td>(263) weak Par bias</td>
</tr>
</tbody>
</table>

[Key: OConv= object convergent, Sconv= subject convergent, Par= parallel]

The data shows that in sentences containing an indefinite and a plural quantified noun phrase, the focused phrase has a tendency to take wide scope over the phrase which is unfocused.

The explanation I propose is similar to that of Sgall, Hajičová and Panevová (1986), who speculate that (intonationally) focused phrases take wide scope because semantic processing involves the inspection of properties and relations, and the form of a sentence is as an assertion of some predicate which is ‘about’ the focus.

In order to determine the truth or falsity of a sentence, the human processor must search for every relevant relation. I argue that relevance is determined with respect to the focus. Relevant relations are those possessed by the focused entity and described by the unfocused portion of the sentence. The IFNet instructs the hearer on what to attend. Hence when semantic processing takes place, it is the focused items which are processed first, even if they occur later in the sentence than unfocused items.

Because the particular item in focus is already activated in memory, the associated properties of that focused node will be easily found. However in order to examine the properties of a newly focused entity, it would first be necessary to shift focus, by moving
attention to an entity connected to the focus, and then activating its properties. Such a shift would result in the defocusing of the previous focus in favour of the new entity.

Semantic processing will be illustrated using the examples given previously. First:

(257) **Policeman-focused** A bunch of policemen walked in. Two of them reported a theft.

In the policeman-focused context, the activated entity is the **bunch of policemen**. The choice is between shifting focus to a **theft**, or performing a **focus change**, focusing in from the bunch of policemen to a twosome subset of the policemen. According to the decision I made in Chapter 6, focus change to a constructed element is more economical than focus shift. So when the subject of the sentence, **Two of them ...** is encountered, focus can be changed from the whole bunch of policemen to a twosome subset of the policemen.

In order to verify the utterance, the hearer must access the true referent of the **bunch of policemen**, and search this set of policemen for the subset satisfying the predicate. Only if that subset contains two members can the sentence be confirmed as true.

To check that an individual policeman satisfies the predicate **...reported a theft**, the policeman must be found to have the relevant property. That is, if the policeman reported one or more thefts, the property will be true of him. This procedure gives the parallel reading, as predicted. The world will be assumed to contain the following relations:

![Diagram](attachment:diagram.jpg)

It would be possible to obtain the Oconv reading by adding an extra procedure to ensure that the theft reported by each of the policemen was the same theft. This would require an additional memory store to record the intersection of all the thefts reported by the policemen. Intersecting the sets is the only way to determine whether one (or more)
particular thefts were reported by all the policemen, since each policeman may have reported several, among which the one known to the speaker is indistinguishable.5

I believe that these SPECIFIC INDEFINITE readings are sometimes obtainable. I will return to this point at the end of this section.

It is nevertheless much more economical to proceed with the non-specific property verification procedure, which results in the Par reading. In conclusion, if the set of policemen is focused, the Par reading results from the most economical means of verifying the sentence.

Now I turn to the theft-focused version:

(256) **Theft-focused** We arranged several thefts on Tuesday. Unfortunately, two policemen reported one of them.

The theft-focused procedure starts with a salient set of thefts. Upon hearing the phrase *Two policemen ...*, a discourse marker will be set up for the two as yet unidentified policemen, each participating in a relation of having reported something, but this referent will not yet be able to be attached to the previous context. The ifnet at this stage will look like this:

\[
\begin{align*}
\text{we arrange} & \quad T \\
\epsilon & \quad \text{on} \\
T & \quad tu \\
& \quad \text{report} P \\
& \quad \epsilon \\
& \quad P 
\end{align*}
\]

Upon reaching the phrase *...one of them*, a link will be able to be made to the activated set of thefts. The phrase specifies that one of the thefts is under consideration, signalling a focus change from a set to an individual. The floating discourse marker for the two policemen can then be joined to that newly focused entity.

---

5The complexity of processing such readings would increase even more if the predicate involved two indefinites, or tuples of indefinites (the latter is discussed later in section 7.5):

(265) Two of them reported a theft and a burglary.

(266) Two of them reported three thefts.
CHAPTER 7. FOCUS AND SCOPE AMBIGUIT Y

Or, to express the hearer's means of verification, the original set of thefts will be searched for having a member, \( t \), which satisfies the predicate **two policemen reported \( t \)**. This will result in the Oconv reading and be verified by the following situation in the world:

\[
\begin{array}{c}
T \\
\in \\
report \\
p
\end{array}
\]

To proceed in such a way as to obtain the Par reading, two members of the set of thefts would have to be found, with the property that they were reported by one policeman each. However this seems absurd, since the phrase *one of them* does not seem, under any circumstances, to be interpretable as **two of them**. If the speaker had wished to convey the parallel reading, it is difficult to imagine why he/she would have chosen to generate the least obvious sentence in the circumstances: if a speaker is focused on thefts, it is much more significant that *two thefts* were reported than that two policemen reported them; *'Two of them were reported by a policeman'* would be the most likely verbalisation.

So by evoking some simple properties which must be possessed by a representation of the hearer's knowledge, it is possible to explain why focused items take wide scope over unfocused. I have also shown that by using a specific indefinite an Oconv reading can be obtained (with more effort) for the subject-focused text, although a Par reading is not possible to obtain for the object-focused text.

Figure 1 is repeated below:

**Figure 1: Scoping biases in subject and object focused contexts**

<table>
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<td>(264) strong Sconv bias</td>
<td>(263) weak Par bias</td>
</tr>
</tbody>
</table>

I shall next show that the model accounts equally simply for the second half of the data set, the object-quantified examples, taking the subject-focused version first:
Landslide-focused  Several landslides have occurred recently. One of them buried two villages.

In this context a set of landslides is already focused, so on encountering the subject noun phrase one of them a focus change is assumed and verification can begin by cycling through the known landslides to see if any have the property that it buried two villages. This corresponds straightforwardly with the Sconv reading, verified by the situation below:

\[
L \rightarrow l^{\text{buried}} v \\
\text{buried} \quad \downarrow v
\]

To obtain the parallel reading would be much more complicated and rather pointless. Firstly, on encountering the phrase one of them it would either have to be left uninterpreted, or else undergo multiplication when predicated distributively of two villages. Add to that the risks involved in shifting, perhaps incorrectly, to two villages as the new focus, and it can be seen why the parallel reading is not an option.

I will now describe the final example, which appears not to support the hypothesis so strongly.

Village-focused  Several villages were excavated on this site. A landslide buried two of them.

In the village-focused context, the salient set is the set of villages which were excavated on a particular site. A discourse marker is first created for a landslide, but this cannot, at first, be connected to previous context. When ...two of them is reached, a change can be made to focus on two of the existing set of villages. The predicate A landslide buried v can then be considered as a property of the two villages.

To verify the sentence, then, the set of villages will be searched to determine whether two of them have the property that they were buried by a landslide.
There is a difference between this example and (256), with which it has so far been analogous. In both examples the subject noun phrase must be remembered in anticipation of some link with the previous sentence. However in the previous example the discourse referent created by the subject noun phrase *Two policemen* could be incorporated in that form into the discourse model. However in (263) the discourse marker created by *A landslide* would have to undergo an *ontological change* in order to obtain the parallel reading. After processing the subject noun phrase only, the IFnet would have the following form:

\[
\begin{array}{c}
\forall \\
 marginalized \\
\end{array}
\]

\[ \text{buried} \]

But after the whole sentence is processed, the following IFnet is obtained:

\[
V \in \{ \text{buried} \}
\]

With the following verification conditions:

\[
\begin{align*}
V & \in \{ \text{buried} \} \\
\text{buried} & \in \{ \text{buried} \}
\end{align*}
\]

In other words, if the discourse marker for *a landslide* moves into the scope of the plural object noun phrase *two villages* it becomes multiplied by two as a result. So if the parallel reading is to be obtained, both a focus change and an ontological change must be made.

The alternative is to give *a landslide* a *specific* interpretation, so that the single discourse marker generated by the subject noun phrase can be maintained all along, although the object still quantifies over it in order to express the distributive nature of the verb. This would allow the verification of the whole sentence to extend the mappings assumed by the subject noun phrase. For this reason, I think the parallel reading is
more difficult to obtain here, and the Sconv reading easier, than the hypothesis would predict. The partial model of the world assumed by a specific indefinite interpretation of the subject noun phrase is as follows:

\[
\begin{align*}
V &\quad \varepsilon \\
&\quad \varepsilon \\
&\quad \text{buried} \\
&\quad \text{buried} \\
&\quad l
\end{align*}
\]

To verify this reading of the sentence, two villages in the focused set must be found which have the property that they were buried by the same landslide.

In summary, the model accounts very well for the data if two further factors are taken into account: firstly the difficulty of quantifying over a discourse element which has already been created in the left-to-right progression through the sentence, and secondly the possibility of interpreting any noun phrase as a specific indefinite, which puts it only trivially in the scope of the quantifier, so it is not distributed.

Figure 1 is extended by including the various processing possibilities, see Figure 2.

**Figure 2: Processing Alternatives**

<table>
<thead>
<tr>
<th>Eg.</th>
<th>Quant</th>
<th>Foc</th>
<th>Reading</th>
<th>Widest Scope</th>
<th>Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>(257)</td>
<td>Sub</td>
<td>Sub</td>
<td>Par</td>
<td>Subject</td>
<td>O-spec</td>
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<tr>
<td>(257)</td>
<td>Sub</td>
<td>Sub</td>
<td>Par</td>
<td>Subject</td>
<td>O-spec</td>
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<td>(256)</td>
<td>Sub</td>
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<td>SConv</td>
<td>Object</td>
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<td>(264)</td>
<td>Obj</td>
<td>Sub</td>
<td>Par</td>
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<td>(263)</td>
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<td>(263)</td>
<td>Obj</td>
<td>Obj</td>
<td>Par</td>
<td>Object</td>
<td>O-spec</td>
</tr>
</tbody>
</table>

Key: OConv=object convergent, Sconv=subject-convergent readings, Par=parallel reading O-spec=make object specific, S-ont=perform an ontological change on the subject.

This figure summarises the processes detailed above. Firstly, I claim that (257), where the subject is both quantified and focused, has two possible readings, but creating a specific indefinite involves more processing effort than assuming a wide-scope reading
for the subject and object distribution, so the Par reading is more likely. Both (256) and (264) have only one possible reading. Example (263) again has two readings, but this time the specific reading, although it might require effort to create, requires less effort to construct than the object wide scope, subject distribution necessary to result in the parallel reading. This is because the parallel reading would require making an ontological change on a part of the model which is already constructed.

In summary, where focus was not on the quantified noun phrase, the hypothesis predicted successfully that the reading would be obtained which corresponded to giving the focused entity wide scope. However when the quantified noun phrase was focused, it was argued that the non-quantified noun phrase could be given a specific interpretation. This resulted in identical truth conditions to those obtained by giving wide scope to the unfocused noun phrase. However I argued that there is a qualitative difference: firstly, those readings were still obtained by giving the focused phrase widest scope, it is just that the unfocused phrase, when specific, failed to be distributed, in the same way that a proper name or definite noun phrase in the scope of a quantifier need not thereby obtain different values every time — they are immune from quantification. As was seen in the previous chapter, proper names can be projected out (see Kamp, 1981) of an ontological subdomain into the default, existential, context. Specific indefinites behave similarly. It is particularly advantageous to assume a specific indefinite interpretation of a subject noun phrase since allowing it to subsequently be distributed by the object would require altering the ontological assumptions made in incrementally interpreting discourse. So it was established that focused elements always take wide scope over unfocused elements.

7.4 Continuing with Scope

In Chapter 6 I showed how semantic contexts constrain pronominal reference in subsequent sentences. So one way to distinguish say Oconv from Par sentences is by the continuations they allow. Anaphoric preferences can be used to empirically test the
hypotheses proposed in the previous section.

Take (267) as an illustration:

(267) Two policemen rode a motorbike.

The predictions from the previous section were that where the object (motorbike) is focused, it will have wide scope over the policemen, resulting in an assumption that the world contains one motorbike and two policemen (the Oconv reading). Since the motorbike is focused, it should also be preferable to continue narration about motorbikes than about policemen.

The following should be easy to comprehend as a coherent discourse:

(268) A procession of motorbikes came down the road. Two policemen rode one of them. It was covered with streamers.

This can be contrasted with a continuation which would only be permissible after the parallel reading:

(269) A procession of motorbikes came down the road. Two policemen rode one of them. Between them glided a huge hearse.

The final pronoun *them* could pronominally refer to the two policemen, or, if the hypothesis is incorrect and the Par reading is obtained, to two motorbikes. However if the hypothesis is correct, even pronominally referring to the two policemen should create difficulties, as the two policemen may well be visualised sitting on the same motorbike (a collective reading).

Difficulty or delay in reading (269) compared to (268) supports the hypothesis, whereas if readers find it more difficult to understand (268) than (269), the hypothesis is definitely untenable. However I believe that experimental findings would support the hypothesis.

Complement set continuations can also illuminate focusing choices:
A procession of motorbikes came down the road. Two policemen rode one of them. The rest were ridden by clowns.

A procession of motorbikes came down the road. Two policemen rode one of them. The rest drove cars.

Here, if focus had shifted to the two policemen, the phrase the rest would be interpreted as meaning the rest of the policemen, making (270) absurd to read and (271) sensible. However the rest is undoubtably referring to the rest of the motorbikes, resulting in some bewilderment in (271).

When the subject (policemen) is focused, it is predicted that it has wide scope over the object. So in such cases one would more readily expect continuations (a) focusing on the policemen and (b) using plural anaphora for the motorbikes. However it must be remembered that the object noun phrase can be treated as a specific indefinite, so singular anaphora to a motorbike may also be acceptable.

Here is an example attempting to obtain the subject wide scope reading by focusing on two policemen, and adding what is predicted to be an acceptable continuation:

A cavalcade of policemen came down the road. Two of them rode a motorbike. Between them glided a huge hearse.

This can be contrasted with:

A cavalcade of policemen came down the road. Two of them rode a motorbike. It was covered with streamers.

However (273) is acceptable under the specific indefinite reading of a motorbike, whereas (272) is not.

Such materials cannot distinguish between the Oconv reading (which is not predicted by the hypothesis) and the specific indefinite reading (which is permitted). However the complement set continuations have the advantage that they can be used to check
which sets are focused. It is focus which distinguishes use of a specific indefinite within a subject wide scope sentence, from object wide scope: in the specific indefinite version the subject noun phrase remains focused, while object wide scope requires focus to shift to the object noun phrase.

(274) A cavalcade of policemen came down the road. Two of them rode a motorbike. The rest drove cars.

(274) should be acceptable on both quantified and specific-indefinite interpretations, since it assumes that focus is on the set of policemen.

(275) A cavalcade of policemen came down the road. Two of them rode a motorbike. The rest were ridden by clowns.

However (275) should be unacceptable on both readings, since it assumes that focus is on the set of motorbikes. Certainly (275) involves at least a double-take when read.

These continuation examples lend further support to the hypothesis that focused items take widest scope.

7.5 Multiply quantified sentences

To integrate the theoretical predictions made by observing examples (254) and (262), a sentence which contains two quantified noun phrases will now be examined.

(276) Two students cited three books.

Focus will fall either on the students, or on the books:

(277) student-focused Some of my students handed in essays today. Two of them cited three books.
(278) book-focused There were some interesting books on the reading list. Two students cited three of them.

It is predicted that when focus is on the students, as in (277), there are two possible readings. In both readings the subject noun phrase takes wide scope because it is focused. The default reading is to distribute the object noun phrase, resulting in the following verification conditions:

This is the so-called Sconv reading.

However it is also possible to regard the object noun phrase as a specific indefinite picking out three particular (though unidentified) books, resulting in the following:

I will call this the ‘interactive’ reading (Int).

When focus is on the books, the books always take wide scope. When the students are permitted to be distributed, the following verification conditions are obtained:

This (Oconv) interpretation is very difficult to obtain because of the ontological shift required on the discourse marker created by the subject noun phrase. However the
students can also be given a specific indefinite interpretation which will correspond with the situation below:

This is the 'interactive' reading again.

So, in all there are three permissible 'readings' of (276), Oconv, Sconv and Int, but four means of verification: both the specific indefinite processes result in the same readings. However the two Int readings, though truth conditionally identical, have different focusing properties. This can be demonstrated using complement set continuations, as before.

When students are focused, the phrase the rest should pick out the complement of the set of students, whereas when books are focused, the rest should pick out the complement set of books.

(279) student-focused Some of my students handed in essays today. Two of them cited three books. The rest . . .

(280) book-focused There were some interesting books on the reading list. Two students cited three of them. The rest . . .

I constructed two examples which should each, according to the theory, be acceptable, coherent and easy to process:

(281) student-focused Some of my students handed in essays today. Two of them cited three books. The rest didn't include a bibliography at all.

(282) book-focused There were some interesting books on the reading list. Two students cited three of them. The rest were totally ignored.
The continuations can be transposed to give two examples which should be less acceptable, less coherent and take longer to comprehend:

(283) **student-focused** Some of my students handed in essays today. Two of them cited three books. The rest were totally ignored.

(284) **book-focused** There were some interesting books on the reading list. Two students cited three of them. The rest didn’t include a bibliography at all.

However (284) seems considerably better than (283), even if not quite as good as (282). The only explanation of this is that the subject of (284) has wide scope.

So although the evidence in favour of the focusing hypothesis is very strong, a case has now been found in which it no longer holds. This happens in a situation which has not so far been encountered: when both subject and object are quantified, the subject being unfocused and the object focused, as in (278).

(278) There were some interesting books on the reading list. Two students cited three of them.

In this example, it seems to be possible for the focused phrase to take narrow scope with respect to the subject of the sentence, and therefore be distributed. What is special about this situation? It seems analogous to the earlier example:

(256) We arranged several thefts on Tuesday. Unfortunately, two policemen reported one of them.

Yet continuation tests on (256) demonstrated that it did not have a subject wide scope interpretation (which would permit plural anaphora to the implicit two thefts).

The difference is that no ontological shift was required to interpret (256) giving the object wide scope, whereas to obtain an object wide scope reading for (278) would involve creating several sets of two students rather than the single one created on hearing the subject noun phrase.
This explains why the object wide scope, subject distributive, reading of (278) is hard to obtain, but it does not explain why this means resorting to a subject wide scope reading. After all, (263) also had a reduced likelihood of producing a reading in which the subject was distributed, for similar reasons.

(263) Several villages were excavated on this site. A landslide buried two of them.

But in (263) the object still took wide scope, with the subject interpreted as a specific indefinite. I cannot put forward the obvious solution that a quantified subject noun phrase automatically opens up an ontological space in which the rest of the sentence must be quantified over, because (256) has a quantified subject, yet (256) only has an object-wide scope reading, not a subject-wide scope reading.

The data is clear, yet there is no theoretical reason why a subject wide scope reading should be preferred over a subject-specific-indefinite reading for (278). But accepting, for whatever reason, that the unfocused subject can be quantificational, this does go conclusively against the hypothesis.

The next question to ask is what the focusing implications are. Clearly by the time the object noun phrase is interpreted it is understood as located inside a quantificational domain. Anaphoric reference to the set focused in the previous sentence (the books on the reading list) is still possible, so processing proceeds smoothly. Although the hypothesis stated that focused elements should take wide scope, this is not due to an inherent inability to be understood as distributed. When justifying the use of one of them as the focused equivalent to an indefinite, I had to show that it was capable of being distributed, in such an example as (255):

(255) John had five suits in his wardrobe. He didn’t like one of them.

Although (255) is by default interpreted as meaning that there was one suit in John’s wardrobe that he disliked, it can also be interpreted, particularly if the object is stressed as meaning that John did not like any of the suits in his wardrobe.

(285) John had five suits in his wardrobe. He didn’t like one of them.
There are a number of ways to rescue the hypothesis that focused items always take wide scope. Firstly the hypothesis could be restated as a default rule (weakened). Or secondly, it could be claimed that in (278) and (285) the object is not in fact focused at all, that instead the subject is focused. It seems that the second option is untenable within the framework of this thesis, since it would require modifying the entire premise on which the Incremental Focusing algorithm is based: that pronominal reference (assuming one of them is pronominal) indicates that the nominal referred to is focused. However it still may be true that one of them is focused in the ontological space in which it occurs, that is inside the negative context, rather than outside. Such focus is impossible to detect with negation, because the negative context cannot be extended, but there are certain constructions, which will be discussed in the next chapter, which do extend quantificational and modal contexts. It is easier to illustrate using modal subordination:

(278) There are some interesting books on the reading list. I guess two students might cite three of them. They ...

The question is whether the final anaphor they prefers the students or the books as its antecedent. I feel in this case that is may be the books.

The idea behind focus change is that there is some level of focus maintenance; though particular nominals might change, the larger set of alternatives from which they are chosen remains constant: if dogs are focused then it is only elements set-related to dogs, such as particular dogs or subsets of dogs, which may be focused at ontologically more embedded levels. The continued attention to the larger set ensures that focus itself transcends ontological boundaries.

The only possible way to allow the second option, then, is to say that (a) focus shifts temporarily to the subject (which therefore receives wide scope) but (b) the object is maintained at some higher level still in focus. This would make some sense as when processing the subject there is not necessarily any guarantee that the rest of the sentence will contain a pronoun, so the shift to the subject has the possibility of being established as permanent in the next sentence. I discussed a related case in Chapter 5:
(61) Mary hit Bill. Bill cried.

However at that time I made a decision that the focus would be stacked, rather than allowing a focus shift which could be premature. For consistency, therefore, option 2 will be abandoned, and I shall choose option 1: the rule that focused items must take wide scope is not mandatory, but a strong default.

As shown in section 7.1, intonational focus is one means to override the focus-wide-scope preference, though as we saw in (256) even stress is not always sufficient to override the focus-wide-scope default.

(256) We arranged several thefts on Tuesday. Unfortunately, two policemen reported ONE OF THEM.

However, in the problematic dual-quantified example, intonational stress does significantly facilitate the unexpected subject-wide-scope reading:

(278) There were some interesting books on the reading list. Two students cited THREE OF THEM.

This does suggest that Partee (1991), etc. are right in suggesting that one of the roles of intonational focus is to force intonationally focused items to take narrow scope with respect to the intonational topic. However, as I have shown on several occasions, intonational focus does not invariably force a narrow scope reading, and can sometimes have a contrastive function (as noted by Rooth 1985). I suspect that the role of intonational focus is at least as complex as the role of discourse focus.

So under certain circumstances, which it has so far been difficult to delimit, focused phrases, contrary to their usual inclinations, can take narrow scope with respect to some other quantifier. However the hypothesis that focus takes widest scope is still by

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7 This makes an interesting parallel with the observation made in Chapter 5, that unfocused phrases in subject position have their own attention-producing properties which make them easier to focus in subsequent utterances, as captured in the Centering algorithm. There it was proposed that when only the subject noun phrase has been processed it is the centre of attention though unrelated to the rest of the discourse, and, particularly if several predications are made of it, the syntactic subjects can cause a focus shift.
far the most accurate predictor of readings even for multiply quantified sentences.

7.6 Generalised Quantifiers

The range of data investigated by this thesis also includes quantifiers which can only be described under a theory of GENERALISED QUANTIFIERS (not in ordinary predicate calculus). These quantifiers differ from the plural quantifiers described above in that they are interpreted relative to the set from which they are derived. I shall therefore refer to them as RELATIVE QUANTIFIERS, as opposed to ABSOLUTE quantifiers. Relative quantifiers are particularly interesting to investigate from the focusing point of view, because they incorporate an explicit ontological change (a focus change, if focused). As an example, take:

(286) Most students signed a petition.

(286) contains the relative quantifier most, which takes members of the initial set of students and creates from it a resultant subset of students who signed a petition. The truth of the sentence is determined by comparing the resultant set with the initial set, to see whether the proportion of the initial set included in the resultant set may be considered as most of it (most is usually taken to mean more than half, but whether this is correct does not concern me here).

The verification of most is therefore dependent on the relative cardinalities of the two sets. The number of individuals in the quantified set could have been stored as a simple counter, but subsequent anaphoric possibilities show that the resultant set must also be calculated and inserted into the discourse model:

(287) I know several beggars. Most of them are quite cheerful. They believe in God and drink beer.

The IFnet for (287) looks like this:
In order to verify (287), $B$ and $R$ must be compared, hence the 'most’ relation. In this case, $R$ is focused, since it is explicitly anaphoric to $B$. However it need not be the case that relatively quantified phrases are pronominal:

(288) In the 1980s most students were very poor. They lived on baked potatoes.

Although the set of students (in the 1980s) must first be found, then the subset of those which are poor, only the single phrase most students creates both sets and defines the transition between them. As I argued in the previous chapter, most students presupposes a generic set of students, so this initial set must appear in the discourse model. After interpreting the first sentence of (288) the discourse model will contain the following:

However $R$ only becomes focused for the hearer, according to the Incremental Focusing Algorithm, after (the subject of) the second sentence has been processed:
The difference between most students and two students is that although both implicitly choose members from a set, in sentences containing the relative quantifier the initial set must be retained for semantic interpretation, rather as any nominals introduced by a restrictive relative clause must be retained to the end of the sentence, whereas those introduced by an unrestrictive relative clause are semantically dispensible as soon as the clause has been interpreted. But although relative quantifiers presuppose a set on which an ontologically related set is dependent, this does not require the resultant set to be focused.

It therefore comes as a surprise to find that when a relative quantifier and an absolute, but focused, phrase occur in the same sentence, the easiest reading to obtain is the one where the relative quantifier takes wide scope over the focused phrase:

(289)   Martin displayed some paintings. Most people liked two of them.

Of course, this particular example falls into the problem pattern noted in the last section, in which it was noted that the subject has a tendency to take wide scope.

The default reading here is that for most people: that person liked two paintings of Martin's. Both the specific indefinite readings and the subject narrow scope reading are very hard to obtain. The narrow scope reading would correspond to a situation in which a different majority of people liked each of two paintings (the number of people liking both not necessarily being a majority). When the subject has wide scope and the object is treated as a specific indefinite it must be the case that for most people, there are two paintings they like, and those paintings are the same for everybody (the number of people liking two particular paintings is a majority). When the object has wide scope and the subject is specific it must be that for each of two paintings the same majority likes one as likes the other. Of course, both specific indefinite readings are truth conditionally and nominally the same, but have different focusing preferences.

So the problem is even more marked here than it was in the absolute quantified sentences. However it is not always the case that relative quantifiers take widest scope over focused

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8Strictly, main unit.
phrases.

(290) The touring company employed a lot of sailors. One of them organised most trips.

In (290) the focused phrase seems, in accordance with the hypothesis, to take widest scope.

To save space, I shall summarise my intuitions about the possibilities in sentences containing a relative quantifier and an absolute quantifier, of which one is focused. The result is shown in figure 3.

Figure 3: Focus and Relative Quantifiers

| Judgment processes focus | Sub-relative, Obj-absolute | | | | | | Sub-absolute, Obj-relative |
|-------------------------|---------------------------|---|---|---|---|---|---|---|---|---|---|---|
|                         | Sconv | Oconv | Int | Sconv | Oconv | Int | Sconv | Oconv | Int |
| Sub-relative, Obj-absolute | subject F | object F | | | | | | | | | | |
| Sconv | Oconv | Int | Sconv | Oconv | Int |
| judgment processes focus | ✓✓✓ | xxx | ✓✓ | xx | o |
| O-ont | O-spec | S-ont | O-spec |
| Subject | F | object | F | | | | | | | | |
| Sub-absolute, Obj-relative | subject F | object F | | | | | | | | | | |
| Sconc | Oconc | Int | Sconv | Oconv | Int |
| judgment processes focus | ✓✓ | xx | o | x | x |
| SO-ont | O-spec | S-ont | O-spec |
| Subject | F | object | F | | | | | | | | |

Key: Sconv = subject convergent reading, Oconv = object convergent reading, Int = interactive reading.

Judgment: Ticks signify readings which are relatively easy to obtain, crosses ones which are difficult, zeros represent medium difficulty.

Processes: ‘ont’ means that an ontological shift is required to obtain the given reading, ‘spec’ means extra processing effort is required since the reading involves a specific indefinite

Focus: A plus sign indicates when the focusing hypothesis predicts a reading to be preferable, a minus sign indicates a reading which is contrary to the hypothesis

Comparing this table with Figure 2, the focus-wide-scope readings have the same distribution: when an ontological shift must be made to interpret an unfocused subject
noun phrase, the focus wide scope reading is almost totally ruled out (the object focused examples). However when an ontological shift would be required to obtain the subject wide scope reading on an unfocused subject, this is the hardest reading of all to obtain.

What is startling about Figure 3 as compared to Figure 2 is that when the distributed subject reading is unobtainable because of the ontological effort required, it is not the specific indefinite reading which is resorted to on the whole, but the unfocused wide scope reading. This is exactly what happened in the problematic (278).

This suggests that for some reason it is immensely difficult to make plural phrases specific, especially if they are obligatorily distributive, like most. In other words, it seems difficult to make the resultant set specific.

What the relative quantifiers have shown is that having to make an ontological shift is not a minor obstacle in processing a sentence. In fact as the phrase to be ontologically shifted becomes more complex it seems to become correspondingly harder to do. So the specific indefinite option is becoming less and less likely as a processing choice as the phrases to be projected become more complex. As a result, it becomes more likely that the unfocused phrase will take wide scope when the focus wide scope reading is ontologically unwieldy to perform.

However the hypothesis that focused phrases tend to take wide scope by default is still accounting for most of the variation in the data.

7.7 Specific Indefinites

This section summarises my hypothesis concerning specific indefinites. I feel some clarification is necessary to explain how my use of the term ‘specific indefinite’ may differ from other uses in the literature. There are two things it is important to note. Firstly that specific indefinites are not necessarily interpreted in the default context, contrary to what Heim (1982) proposed, and secondly, that the use of a specific indefinite does not require that the speaker is aware of the referent of the indefinite noun phrase.

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9Heim suggested, pp. 220–226 that specific indefinites have to take widest scope.
(contrary to Fodor and Sag (1982), p. 381). Unlike Fodor and Sag, I believe that the specific/non-specific distinction is a semantic ambiguity not a lexical ambiguity.

To take the second point first, let us assume that the hearer has just encountered the sentence:

(291)  A problem about the environment occupies every serious politician.

(Kamp and Reyle p. 273)

Such a sentence may easily be generated by a speaker with prior knowledge of the problem in question, but it is extremely difficult to interpret in ignorance of the problem’s referent. It is possible that a hearer could set up a cataphoric referent, in anticipation of a continuation enabling the hearer to identify the referent, hence verify the original statement. Such a continuation might be:

(292)  A problem about the environment occupies every serious politician; the Greenhouse Problem.

However the speaker need not identify the referent, nor even be aware of its identity.

(293)  We have three main parties here, but when it comes down to it most people vote for one of them.

(293) is an example containing a specific indefinite one of them, the referent of which may be known by the speaker ‘the Conservative Party’. However it is also possible that what the speaker meant was that whenever there is an election, it is always the case that one party has a majority. In a sense, what the speaker had in mind was not specific at all. Yet such a reading could not be obtained by giving the subject wide scope (this would give the more trivial reading that most people vote), nor by giving the object wide scope (there is no particular party intended).

A similar ambiguity can be obtained for (294):
In Western democracies, most people live by two principles.

Distributing over subject or object would give the readings:

**Subject wide scope, object distributed** Most people have two principles they live by, independent of everyone else's.

**Object wide scope, subject distributed** There are two principles which happen to be obeyed by most of the population (not the same majority in each case).

Giving the subject wide scope and treating the object as a specific indefinite would give the readings:

**Specific indefinite** In each Western democracy, there are two principles which govern most people (a different two for each democracy).

**Doubly specific indefinite** There are two specific principles which most people live by in all Western Democracies.

The two readings are obtained in these examples because there are two layers of quantification, and the specific indefinite may be projected up to the default context, or simply to the ontological level above the place it was generated.

I feel that the term 'specific' is still appropriate, despite these observations. Intuitively, as the indefinite moves towards the default level, it becomes more specific, closer to becoming anchored to some constant referent like proper names and generics. There is also an obvious link with the informativeness of the noun phrase: the more 'specific' the speaker is, the more likely the hearer will be to assume an individual unfocused indefinite reading. Take the following example:

(295) Several villages were excavated on this site. An enormous landslide which occurred in January buried two of them.

It is so unlikely that two enormous landslides, each engulfing one village, would have occurred in January that the individual unfocused indefinite reading is practically
certain. The hearer will not be surprised to hear singular pronominal reference to the landslide.

Heim (1982) and Fodor and Sag (1982) also noted that ‘descriptive richness’ increased the probability of a phrase being interpreted as specific, as do the adjectives certain and particular. Interestingly, Fodor and Sag also noticed that numerals seem to inhibit specific reference, perhaps, they suggested, because use of a numeral suggests to the hearer that number is more important than identity.

7.8 Distributive and Collective Readings

In the previous sections subject wide scope sentences were distinguished from object wide scope sentences. This section will investigate a further ambiguity which pervades any sentence which contains a quantifier. On page 283 I asked the reader to understand all verbs as distributive rather than collective. Actually several of the above examples could be read collectively also. Take for example (267):

(267) Two policemen rode a motorbike.

The object wide scope reading of this sentence (where only one motorbike is intended) can be read two ways: either the two policemen simultaneously rode the motorbike in question, or they both have access to the same motorbike, which they rode at different times. The collective reading is stronger in this instance. Some verbs forbid collective readings, others forbid distributive readings.

So, collective readings involve a simultaneous or joint activity, while distributive readings involve activities which have single agents (activities can in addition be spread over time or space, but this is not essential). Here are some examples:

Collective (in time) Two men carried the piano downstairs.

Collective (in time) Two bishops met.

Collective A hundred men built the tunnel.
Distributive (over space or time) Two girls broke an arm.

Distributive (over space or time) Two boys kissed Mary.

Distributive (over time) Every member of the family used the car.

It is not possible to generalise so far as to say collective actions take place at the same time, and distributive ones at different times, since as can be seen from the above examples, this is not always true. Instead, the essence of collective readings is that an event takes place which is participated in by more than one agent: that it is not correct to say of any one agent that they performed that action, since no agent completed the action alone. Distributive readings, on the other hand, are verified by finding that each agent individually performed the given action, though the patient of each individual action may have been the same.

Taking an example which is ambiguous:

(296) Two pianists will play this piece.

Here, either the pianists are destined to perform a duet, or else each will give a separate solo. In the first case, the piece in question will only be performed once, while in the second place it will be performed twice.

This is highly reminiscent of the scope ambiguities described above. Yet none of the mechanisms described so far will produce the collective reading: the two pianists always at some stage become separated, and it has been implicit in the above examples that this results in the verb becoming distributed.

So to allow collective readings, two options are open: either separation (quantification) of a plural noun phrase should be optional, or else verbs should be permitted to behave like noun phrases and escape from the distributional force of a quantifier. The second of these two options is the one I propose to take. This is because it is the lexical properties of the verb which result in collective or distributive readings. It therefore seems natural to wait until the verb is processed before distinguishing the two possibilities.
To allow the verb to behave like a nominal, it is necessary to introduce event referents, the semantic equivalent of singular nominals. There are good precedents for introducing verbal discourse referents (Dowty 1989, Schein 1986, among many). Event referents will be generated as soon as the verb in a sentence is encountered, and, I shall assume for a start, may take wide scope over other parts of the sentence, may remain in narrow scope and be quantified over, or may be given a specific interpretation. Unfortunately it may be difficult to distinguish specific from wide scope events, because verbs do not occur in the plural and cannot therefore be distributed. In this sense, events are very similar to singular indefinites like a theft or a landslide. However (in English) verbs may never occur first in a sentence, since they are preceded by the subject.\textsuperscript{10}

I therefore predict that (296) will behave much like (254) and allow a similar pattern of readings.

(296) Two pianists will play this piece.

(254) Two policemen reported a theft.

In the models of the world below the verb referent will be represented by $v$. I will temporarily assume that the event referent encompasses the whole phrase \textit{play this piece}, since the piece is anyway a constant and independent of the reading chosen.

The following represents the situation in the world if it is assumed that a distributive reading was intended (the relation 'in' represents 'participation in'):

\[
p \xrightarrow{\text{in}} v
\]

\[
p \xrightarrow{\text{in}} v
\]

A collective reading would correspond to the following:

\textsuperscript{10}This thesis does not cover weird topicalisations.
So, can the hypothesis that focused elements by default take widest scope be applied to distributive/collective ambiguities? We have already established that focus on a nominal is signalled by anaphora, and lack of focus by an indefinite. So, let us assume that a newly introduced verb is unfocused. This still leaves the question of what focuses a verb.

(297) The haggis was cut open. It took a long time.

Example (297) shows that pronouns can be used to refer to events, in this case the event of cutting open a haggis. Since verbal anaphora is always singular and distribution has been hypothesised to produce more than one event referent, it should be possible to use verbal anaphora to detect collective/distributive readings — collective readings should allow verbal anaphora while distributive readings forbid it.

The first two examples are compulsorily collective, the second two distributive.

(299) John and Mary built a raft. It took two days.

(300) Two men broke a window. It was easy.

These are acceptable, but the following are not:

(301) John and Mary wrote their autobiographies. \( ? \)It took two years.

\[\text{Non-pronominal anaphora is not locally focused, but globally, and since this thesis does not deal with the effects of global focusing on scope I leave it out.}\]

\[\text{It could be argued that verbal anaphora is here not picking up on the event of cutting, but on a semantic construct produced by the entire verb phrase or sentence. However this is simply because it is more natural to label the event with all the elements it is individually defined by.}\]

(298) I saw a man with a green hat. He was eating an icecream.

When I ask \‘Who was eating an icecream?\' I receive the answer \‘The man with the green hat\'. The event, likewise, is often distinguished from other events by its agent and patient.
(302) Two men broke an arm. *It was painful.

It is much harder to use verbal anaphora to a distributive than a collective verb. This makes semantic sense, as the distributive versions are effectively describing two separate events while the collective reading by definition describes only one. It does seem weakly possible to group together related events, as in the autobiography example. It would take a full theory of temporal reference to explain why some events can be temporally summed in this way, which is beyond the scope of this thesis.

So far the analogy between events and indefinites has held up very well. But it remains to be seen whether focusing can bias collective/distributive ambiguity.

The problem with verbal anaphora is that it corresponds to ordinary pronominal anaphora (identity), and cannot travel across ontological spaces. What is needed is some verbal equivalent of one of them. That is, some way of maintaining focus which is flexible between the two readings, and an ambiguous sentence to experiment on.

Take (296) as the example:

(296) Two pianists will play this piece.

It would be expected that focusing on the event of playing this piece would bias towards the collective reading, and focusing on two pianists would bias towards the distributive reading.

Two contexts were devised to test this prediction. Do-anaphora was used as a way of focusing the verb.

(303) Playing-focused Many people want to play this piece. Tomorrow, two pianists will.

(304) Pianist-focused Many pianists entered the competition. Two of them played this piece.
Although not as strong as the biases obtained for subject/object wide scope ambiguities, I claim that focus effects are in evidence here too. In the playing-focused context, I prefer the collective reading (duet), as predicted, whereas in the pianist-focused context the distributive (solo) reading is much preferred.

I have tried also to construct an ambiguous example which includes only one nominal (this is interestingly difficult).

(305) Two nuns went skiing.

(306) **Nun-focused** The nuns had an annual holiday. Two of them went skiing.

(307) **Skiing-focused** Many people in Gilmerton went skiing. For instance, two nuns did.

In (305) the skiing-focused context biases towards understanding that the two nuns set out jointly on a skiing holiday, while the nun-focused context suggests a distributive reading. It is difficult to tell whether ‘specific event’ readings are possible in nominal-focused contexts, or how easily focus shifts. The data is not as clearcut as nominal data, and is subject to tense constraints. The impossibility of having plural event referents means there are limited ways to really consolidate the theory.

However, assuming that collective/distributive ambiguities can be treated as scope ambiguities, the same argumentation holds as to why focused items should tend to take wide scope. If it is assumed that sets of events can be selected for attention, then it makes sense that as a set is cycled through, it will be possible to verify that one event has the property that two nuns took part in it, but not possible to verify that two events were participated in by one nun each, unless extra effort is made to remember the particular nuns involved.
CHAPTER 7. FOCUS AND SCOPE AMBIGUITY

7.9 Interaction between event and scope ambiguity

An interesting observation Kamp and Reyle make is that relative quantifiers seem to force distribution over the verb (Kamp and Reyle p. 714), while absolute quantifiers do not.

I shall start with a simple example, the unacceptability of:

(308) Most judges met.

This can be contrasted with:

(309) Two judges met.

(309) is acceptable, under the collective reading that the two judges met each other, but (308) cannot be interpreted at all. Kamp and Reyle give the following more complex examples of the phenomenon:

(310) a. The lawyers hired a secretary who they liked.
     b. Most lawyers hired a secretary who they liked.
     c. The lawyers hired a secretary who they had agreed on.
     d. *Most lawyers hired a secretary who they had agreed on.

These four examples seem to suggest that in quantified sentences the set of lawyers is unavailable to the relative clause concerning the secretary, which excludes the possibility for a collective reading of the final verb, whereas for simple plurals the set of lawyers is available.

Kamp and Reyle argue that the reason for the failure to interpret sentence (310d) is that the relative clause attached to the object needs to abstract over the set of lawyers (i.e. access the resultant set), but the resultant set cannot be obtained until the entire quantified set has been cycled through. In other words, as Kamp and Reyle put it, abstraction cannot be performed on the set of lawyers because the duplex condition still
contains unreduced conditions (Kamp and Reyle 1989, p. 791). Hence no set referent is available to the relative clause.

However (308) contains no abstraction. The problem can be clarified with respect to the way distributive and collective verbs are modelled. The meaning of owns in $M$ will, like other verbs, be a set. All the intransitives discussed in Chapter 6 were sets of individuals, but collective intransitives are sets of sets. That is, the meaning of the word met is the set of meetings, where each meeting consists of a set of individuals from two upwards. Let us assume that MET in the particular world in which we are interested consists of:

\[ \text{MET} = \langle \langle \text{JOHN, MARY} \rangle, \langle \text{JOHN, FRED, ANN} \rangle, \langle \text{BILL, FRED} \rangle \rangle \]

That is, three meetings happened: JOHN and MARY met, JOHN, FRED and ANN met, and BILL and FRED met. Suppose JOHN and MARY are both, as individuals, in the set JUDGE:

\[ \text{JUDGE} = \langle \text{JOHN, FRED, MARY} \rangle \]

In order to verify (308) it will not suffice to cycle through the members of JUDGE to see if any of them ‘met’, because MET does not have individual arguments, and even if JOHN was considered to have ‘met’, and MARY also, there would be no way to ensure that they participated in the same meeting. So we return to the finding of the previous section: collective verbs are verified by focusing on the event, not on the subject. The only way to verify (308) is to cycle through the sets of meetings, to see if any of them involved most judges. Kamp and Reyle’s dictum is that this is impossible. But the impossibility does not arise because something cannot be predicated of them as individuals (they individually belong to the particular meeting event). The relative quantification fails because by inspecting sets of meetings it is not possible to calculate the initial set with which to compare the resultant set. Focusing on the verbal event removes any possibility of knowing which judges did not meet.

The conclusion is, as Kamp and Reyle observed, that relative quantified NPs are compulsorily distributive: their truth cannot be verified without comparing the ratio of instances for which the predicate is true to instances for which the predicate is false.
For absolute quantifiers, on the other hand, the collective reading is available:

\[(309)\] Two judges met.

Again, each meeting must be inspected to ensure it involves \textit{two people}: this can be simply done by cycling through the participants to see if each one is a person, and if the total number of people is two. That is, a quantificational context can be set up after the verb has focused on the sets of meetings in the world, since the absolute quantifier \textit{two} does not require access to any other sets (e.g. the complete set of people) apart from the set of participants in the meeting.

This means that it is also possible to interpret:

\[(311)\] Two lawyers hired a secretary who they had agreed on.

Providing the first verb is interpreted collectively, the secretary, and the relative clause attached to the secretary, will be interpreted before the set of individuals doing the hiring is broken down, and the number of lawyers counted. Therefore the group of individuals collectively doing the hiring will also be available to agree collectively on the secretary.

The difference between relative and absolute quantifiers is this: relative quantifiers must be interpreted before the verb, whereas absolute quantifiers may be interpreted before or after. Collective verbs must be interpreted before the subject, and distributive verbs after. Therefore it is impossible to interpret a sentence which contains a relative quantified subject and a collective verb.

Before I go on, I just wish to clarify my use of the terms ‘collective’ and ‘distributive’. The reason is that verbs can behave differently towards their subjects and objects. The verb \textit{co-author} for example, is collective with respect to its subject, and distributive with respect to its object, as in:

\[(312)\] Three linguists co-authored two books.
Here the same three linguists are always partaking in a joint activity but the books are written in two separate events. Most verbs have several different types of collective/distributive ambiguities. Take for example:

(313) Two mermaids sang to three fishermen.

The verb ‘sing’ is ambiguous in all possible ways. Both subject and object can be collective, or one can be collective and the other distributive, or both can be distributive. This is summarised in the table below:
### Table: Focus and Scope Ambiguity

<table>
<thead>
<tr>
<th>Subject</th>
<th>Object</th>
<th>No.</th>
<th>Reading</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dist.</td>
<td>Dist.</td>
<td>6</td>
<td>Two mermaids individually sang to three different fishermen</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><img src="image1" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Three fishermen each individually heard two different mermaids sing</td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The same two mermaids each individually sang to the same three fishermen</td>
<td><img src="image3" alt="Diagram" /></td>
</tr>
<tr>
<td>Dist.</td>
<td>Coll.</td>
<td>2</td>
<td>A group of three fishermen were sang to first by one mermaid, and then by another</td>
<td><img src="image4" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Two mermaids each sang to an audience of three fishermen</td>
<td><img src="image5" alt="Diagram" /></td>
</tr>
<tr>
<td>Coll.</td>
<td>Dist.</td>
<td>3</td>
<td>The same two mermaids sang a duet to three different fisherman</td>
<td><img src="image6" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Three fishermen were sang a duet by two mermaids</td>
<td><img src="image7" alt="Diagram" /></td>
</tr>
<tr>
<td>Coll.</td>
<td>Coll.</td>
<td>1</td>
<td>Three fishermen were the audience to one duet</td>
<td><img src="image8" alt="Diagram" /></td>
</tr>
</tbody>
</table>

The 'No.' column gives the total number of events in the world.

Of these, only the version where both subject and object are distributive is scope ambiguous. Or, to put it another way, only when an element is distributive can it open up a quantificational context. Scope ambiguity can only occur when two (or
more) elements open up quantificational contexts. If the verb is obligatorily collective for either subject, or object, or both, then scope ambiguity cannot occur.

The ambiguities which occur in the distributive/collective hybrid readings can be accounted for by specific indefinites, as can the interactive double distributive reading: this is done in DRT in Chapter 8.

It is clear now that it is not the presence of a plural determiner which opens up a quantificational context: a noun phrase with a relative quantifier must do so, but an absolute quantifier just permits a quantificational context to be created if the verb can be distributive for the noun phrase. If the verb is collective, no quantificational context is opened up.

It is now possible to look at the effect of collective/distributive ambiguity in examples like (254):

(254) Two policemen reported a theft.

It has already been found that this sentence is three ways ambiguous: either the object or the subject has wide scope (is focused). If the subject has wide scope the object can be distributed or specific.

Introducing the possibility that the verb can be collective or distributive with respect to subject or object gives four different possibilities: DD, DC, CD and CC. When the subject is collective, there is no quantification at all, so the OConv reading will be obtained for both CD and CC. When the subject is distributive, the object may also be distributive (DD), which results in scope ambiguity: the reading obtained depends on whether subject or object is focused. When the subject is distributive and the object collective (DC), the subject will open up a quantificational context. If the subject is focused the result will be a Par reading, but if the object is focused, use of a specific indefinite will result in the OConv reading:

\[
\text{Par} \quad p \to t \quad \text{OConv} \quad p \to t \\
\quad p \to t \quad p
\]
CHAPTER 7. FOCUS AND SCOPE AMBIGUITY

(313) Two mermaids sang to three fishermen.

Example (313) will have even more different possible ways of reaching its eight readings. These are laid out formally in Chapter 8 section 8.8.4.

The main clue to disambiguation is focus. We have seen that if the subject is focused, subject wide scope readings are preferred, and if the object is focused, object wide scope readings are preferred. I have also suggested that if the verb is focused, collective readings are preferred, if unfocused, distributive readings. I also explained when specific indefinite readings were likely to be obtained. So focusing can substantially reduce or eliminate the number of possible readings considered. However as we have seen this interacts with the way relative quantifiers are interpreted (preventing certain readings) and with the nature of the verb (which can also prevent certain readings, for instance by being compulsorily collective). I also showed that the order in which words in the sentence were encountered influenced the likelihood of obtaining different readings. I illustrate some of these complexities in Chapter 8, section 8.8.4.

7.10 Discussion

This chapter has concentrated on the effect of focus on quantifier scope ambiguities. I found that several additional ambiguities did need to be accounted for, namely specific indefinite and collective readings.

The overall conclusion has been that focused elements always take wide scope. Given the strong focus maintenance preference, it is therefore possible to predict from the patterns of pronominal and nonpronominal elements in a sentence how they will be interpreted, in other words, what ‘reading’ people will obtain from the sentence.

Focus determines which sets are most relevant, triggering particular verification processes. This interacts with the incremental construction of a semantic representation: if certain entities have already been incorporated into the discourse representation, it is hard to change their ontological status. This can force a focus shift. However using a specific indefinite is usually preferable.
As a final note, I wish to point out that in the ‘null context’, the hearer will assume that the subject of the sentence is the focus, as is normal for the first sentence of a discourse (see Chapter 5, p. 155). This, as well as the difficulty of ontological shifting, accounts for the subject-wide scope bias semanticists have often noticed in scope ambiguous sentences without pronominal elements.

This chapter has shown that focus and scope are irrevocably linked: focus completely determines the course of semantic processing. Scope ambiguity is an epiphenomenon of the way focus determines verification paths through the world model.

Achievements:

- I demonstrated that focused discourse elements are semantically processed as having wide scope over less focused items.

- Assuming incremental interpretation and economy of processing accounted for any subject/object asymmetries.

- I found that indefinites could sometimes behave like definite noun phrases and avoid being distributed. These ‘specific indefinites’ differ from proper names, however, in that they need not move all the way up to the default context, but may be locally projected.

- What ‘reading’ would be obtained from a sentence was found to depend on the interaction between verb type (optionally/obligatorily collective/distributive for subject/object), focus, linear ordering and determiner type (indefinite, singular/plural, relative/absolute).
In Chapter 1 I noted that there are two distinct functions of a theory of focusing. The first is to limit the set of possible antecedents for an anaphor, while the second is to impose a preference ordering on the set of possible antecedents.

This chapter takes Hans Kamp’s (1981) Discourse Representation Theory and extends it using the incremental focusing algorithm developed in Chapters 4 to 6.

Kamp (1981) was one of the first people to suggest that psychology and formal semantics could be brought closer together. He challenged the traditional view of semantics by proposing an intermediate representation of a discourse between the syntactic form of a sentence and its semantic interpretation. His claim was that such a level of representation is actually necessary. He showed how certain phenomena which had proved recalcitrant to previous semantic theories could thereby be given their correct meanings.

(314) If a farmer owns a donkey he beats it.

The pronoun it in (314) has been problematic for semanticists to account for in the past, because such pronouns clearly fall within the semantic context set up by the
conditional, yet in predicate calculus the logical scope of the conditional implication (which determines the interpretation of the pronoun) does not extend as far as the pronoun.

DRT's concern with sentences like (314) marks it out as a semantic theory motivated by anaphoric possibilities in human discourse. However, as I pointed out in Chapter 1, Kamp (1981) does not think much could be gained from adding pronoun resolution mechanisms to the theory. However in Chapter 7 I conclusively showed that focus affected choice of semantic interpretation for scope-ambiguous sentences. There are several further reasons for justifying adding focus constraints to DRT: firstly, if DRT is to form part of a natural language processing system in a cognitive or computational system, any reduction in the number of antecedents needing to be considered for pronominal resolution is highly desirable. It would also be necessary to give procedures for finding and testing antecedents, as provided by a focusing algorithm.

The other main reason for adding focus constraints to DRT is not to benefit DRT, but to provide the semantic basis for a focusing theory. The need for a firm semantic base for focusing was demonstrated in Chapter 6. There, I gave a slightly unconventional semantics for IFnets. Given that DRT is an established semantic theory specifically designed for semantically interpreting discourse anaphora, it would be likely that DRT would provide a more stable basis for a focusing theory than the as yet underdeveloped semantics of IFnets.

This chapter consists of a list of changes to DRT motivated by the focusing algorithm. These changes will result in an extended version of DRT (IF/DRT), which can be contrasted with the IFnets as described in Chapter 6. The chapter ends with some speculations on how focusing and semantic constraints might interact in cases of cross-sentential semantic constraints such as modal subordination and donkey-anaphora.
Goals:

1. To briefly describe the properties of DRT as a semantic theory.
2. To add focusing constraints to DRT
3. To compare the final combined IF/DRT model with the IFnet model of Chapters 5 and 6.
4. To explore more cross-sentential semantic constraints on anaphora.

8.1 Discourse Representation in DRT

The basic unit of representation in DRT is the DISCOURSE REPRESENTATION STRUCTURE, or DRS. DRSs consist of two components, a set of discourse referents or reference markers, called the Universe of the DRS, and a set of DRS-CONDITIONS or subordinate discourse representations containing conditions on the discourse referents. DRSs are often called simply boxes, for reasons which will become obvious.

Discourse referents can be singular (small letters) or plural (capital letters).

(315)  Malcolm strokes a kitten.

As an example, the first stage in the analysis of the discourse fragment (315) is represented below:

Malcolm strokes a kitten

As this single condition is processed, it will be reduced to three statements in first order logic:

Malcolm(u)

strokea(u, v)

kitten(v)

The DRS CONSTRUCTION RULES determine how the conditions Malcolm(u),
*strokes*(u, v) and *kitten*(v) are obtained from the original sentence. The DRS can then be semantically interpreted using the DRS-INTERPRETATION RULES, to give the following result:

The sentence (315) is true iff *u* is a discourse referent referring to an individual called Malcolm in the model, *v* is a member of the set of kittens, and *u* is in a relation of ‘stroking’ to *v*.

DRSs can have a structured hierarchy of embedded DRSs contained inside them. Universals and conditionals are one source of structure; they consist of a principal DRS which branches into two subordinate boxes, a righthand DRS and a lefthand DRS. The principal box is the DRS which is superordinate to all other boxes, the lefthand box in a branching pair is superordinate to the righthand one, and boxes which contain others are superordinate to them. It will be seen that these superordination rules constrain anaphoric dependencies within the DRS.

### 8.2 DRS construction rules

DRS-construction rules are applied repeatedly until all the DRS conditions have been reduced, the form in which they may then be semantically interpreted. If a DRS contains conditions which cannot be reduced, it is semantically unacceptable.

I will describe the construction rules in two steps, dealing first with the default context (after Kamp 1981), then with Kamp and Reyle’s (1989) plurals and the conditional and quantificational contexts.

#### 8.2.1 Simple DRSs

The DRS-construction rules are given informally as follows (for greater detail of the mapping between syntactic structure and DRS structure, see Kamp and Reyle, 1989):
Indefinite noun phrase If a condition contains the phrase a α, where α is a common noun, then introduce a new discourse referent x into the universe of the current DRS. Add the condition α(x). Replace the phrase a α by x in the condition.

| a cat purrs | reduces to | c cat(c) c purrs |

Proper name If a condition contains the phrase α, where α is a proper name, then introduce a new discourse referent x into the universe of the principal DRS. Add the condition α(x). Replace the phrase α by x in the condition.

| John likes a girl | reduces to | John(j) j likes a girl |

This in turn can be reduced by the Indefinite rule above to:

| j, g | John(j) | girl(g) | j likes g |

Note how since the principal DRS and the current DRS are synonymous in this example, the proper name and the indefinite discourse referent are generated in the same universe.

Pronoun If a condition contains the word α where α = he, she or it (ignoring case), then add the condition x = y, where x is a temporary discourse referent representing the referent of the pronoun, and y is a suitable discourse referent chosen from the universe of the current DRS or any superordinate DRS. Replace the word α in the original condition with x.

| j | John(j) | reduces to | John(j) x = j x strokes x's cat |

Relative clauses If a condition contains a noun phrase (a) α with a relative clause, then generate a new discourse referent x into the universe of the current DRS. Divide it into three conditions as follows: the first will be of the form α(x), the second will be the result of substituting x into the gap in the relative clause (and deleting the wh-word), and the third will be the result of substituting x for the entire noun phrase in the original condition.

| a man who owns a donkey pays | reduces to | m man(m) m owns a donkey m pays |

Intransitive verbs If a condition contains the phrase αζ, where ζ is an intransitive verb, then replace it with the condition ζ(α).
Transitive verbs If a condition contains the phrase $\alpha \xi \beta$, where $\xi$ is a transitive verb, then replace it with the condition $\xi(\alpha, \beta)$.

- $x \text{ runs}$ reduces to $\text{runs}(x)$
- $x \text{ owns } y$ reduces to $\text{owns}(x, y)$

8.2.2 Semantic contexts

Conditionals If a condition is of the form $\text{if } A \text{ then } B$, then generate two subordinate boxes containing the sentence $A$ in the lefthand box and the sentence $B$ in the righthand box. A clue to semantic interpretation is given by an implication sign between the two.

- If Mary dances then John works
  reduces to

$\text{Mary dances} \implies \text{John works}$

Generalised quantifiers If a condition contains the phrase $Q \alpha$, where $Q$ is a generalised quantifier, then a duplex condition is generated. This consists of two subordinate boxes joined by a diamond containing $Q$ and $x$. The lefthand box will contain a discourse referent $x$ in its universe, and the conditions which would be appropriate if $\alpha$ had been an indefinite noun phrase. The original condition will then have $x$ substituted for $Q \alpha$ and will be entered in the righthand box.

- Most tigers like swimming
  reduces to

$\tau$ tiger($\tau$) most $\tau$ likes swimming

and

John likes most tigers.
8.2.3 Additional construction rules for plurals

The following rules are optional, and may be applied if a plural anaphor is encountered which does not have an obvious antecedent.

**Summation** A new (plural) discourse referent can be introduced which represents the union of the individuals or sets represented by discourse referents which are already accessible. For instance as in:

(316) John took Mary to Acapulco. They had a lousy time.

Kamp and Reyle (1989) represent this as:

<table>
<thead>
<tr>
<th>$u, v, y, Z, U$</th>
</tr>
</thead>
<tbody>
<tr>
<td>John($u$)</td>
</tr>
<tr>
<td>Mary($v$)</td>
</tr>
<tr>
<td>Acapulco($y$)</td>
</tr>
<tr>
<td>$u$ took $v$ to $y$</td>
</tr>
<tr>
<td>$Z = u \oplus v$</td>
</tr>
<tr>
<td>$Z$ had a lousy time</td>
</tr>
</tbody>
</table>

The condition $Z = u \oplus v$ shows that a new plural discourse marker, $Z$ has been formed, which combines $u$ and $v$. It is then possible for $Z$ to have conditions applied to it.

**Abstraction** When a variable has been quantified over, a Principle of Abstraction allows a sum to be formed from all instances of that variable which conformed to the conditions of the duplex condition. An example is shown in Kamp and Reyle:

(317) Susan has found most books which Bill needs. They are on his desk.

is represented:
The discourse marker $Y$ is formed by summing ($\Sigma$) all instances of $y$ which meet the conditions in both sides of the duplex condition. In effect, $Y$ is the same as the resultant set of the quantification.

**Distribution** Predicates with a plural argument may sometimes be broken down by distributing over that argument. If the predicate is a so-called distributive verb, this is compulsory. Other verbs may be distributive or collective. Here is an example:

(318) Two men woke me.

The DRS conditions first reduce this to:

\[
\begin{align*}
|M| &= 2 \\
\text{men}(M) \\
\text{woke-me}(M)
\end{align*}
\]

This gives the reading that I was woken once by two men together.

The distribution rule may then be (optionally) applied to form:

\[
\begin{align*}
|M| &= 2 \\
\text{men}(M) \\
\frac{m}{m \in M} &\Rightarrow \text{woke-me}(m)
\end{align*}
\]

This allows the second reading that I was woken on two separate occasions by different men.

Predicates which apply to plural sets are also treated as distributive. Take for example:
Two dentists got married.

The verb is a collective one, but the individuals concerned must also fulfill the predicate \textit{dentist}, which they can only do as individuals. The DRT representation is thus:

\[
\begin{array}{c|c|c|c|c}
\text{\textit{married}}(D) \\
\mid D \mid = 2 \\
\text{\textit{dentist}}(d) \\
\text{\textit{married}}(D)
\end{array}
\]

However set predication is often abbreviated with a star, the distributivity of it not being written out in full, so a more compact version of the same DRS is:

\[
\begin{array}{c|c|c|c|c}
\text{\textit{dentist}} \ast (D) \\
\mid D \mid = 2 \\
\text{\textit{married}}(D)
\end{array}
\]

\textbf{Genericity} Kamp and Reyle also recognise that indefinites may project a generic discourse referent up to the universe of the principal DRS. This allows sentences such (320) to be interpreted.

\[(320) \quad \text{John has a crocodile. They're very expensive pets.} \]

which is represented:

\[
\begin{array}{c|c|c|c|c}
\text{\textit{John}}(j) \\
\text{\textit{has}}(j,c) \\
\text{\textit{crocodile}}(c) \\
\text{\textit{very - expensive - pets}}(C)
\end{array}
\]

\section{8.3 Examples}

To illustrate superordination and proper name rules, the following is the DRS for a cataphoric conditional:

\[(321) \quad \text{If a woman loves him, Pedro courts her.} \]
The proper name Pedro has been given a referent in the principal DRS, in accordance with the proper name rule. The discourse referent v is therefore available to both the embedded DRSs, while u is only available to the righthand DRS.

In contrast, take the questionable sentence:

(322)  If she loves him, Pedro courts a woman

or:

Here the discourse referent for she is unavailable, since it only occurs in the righthand DRS. DRT predicts that (322) is uninterpretable.

8.4 DRS-Interpretation Rules

The DRS-interpretation rules can only be applied when a DRS contains no unreduced conditions.

These rules are taken from Kamp and Reyle (1989). When they covered plurals, Kamp and Reyle used lattice theory to describe the model $\mathcal{M}$, since this avoided the problem of whether singular discourse markers ought to be individuals or singleton sets. However for simplicity I will gloss over the singleton set/individual problem (and the resulting
confusion as to when to apply the membership operation as opposed to subset) and continue using the notation of set theory.

The world $M$ consists of $D$, $NAME$ and $PRED$ where $D$ and $NAME$ are defined as in Chapter 6 and $PRED$ contains both $PRED$ and $CONC$ from Chapter 6, plus a set of relations $\mathcal{R}$ consisting of pairs of sets standing in a particular relation to one another (e.g. the relation $ALL$ consists of pairs of sets in which the second set contains all the members of the first).

DRS conditions can have any of the following forms:

<table>
<thead>
<tr>
<th>Syntax</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x = y$</td>
<td>$p = d$</td>
</tr>
<tr>
<td>$Y = y_1 \oplus \ldots \oplus y_n$</td>
<td>$X = j \oplus m$</td>
</tr>
<tr>
<td>$</td>
<td>X</td>
</tr>
<tr>
<td>$x \in Y$</td>
<td>$d \in D$</td>
</tr>
<tr>
<td>$\pi(x)$</td>
<td>$\text{Pedro}(p)$</td>
</tr>
<tr>
<td>$\eta(x)$</td>
<td>$\text{donkey}(d)$</td>
</tr>
<tr>
<td>$\zeta(x)$</td>
<td>$\text{runs}(m)$</td>
</tr>
<tr>
<td>$\zeta(x,y)$</td>
<td>$\text{owns}(p,d)$</td>
</tr>
</tbody>
</table>

The following complex conditions are also permitted (among others):

<table>
<thead>
<tr>
<th>Context</th>
<th>Syntax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstraction</td>
<td>$Y = \Sigma y$</td>
</tr>
<tr>
<td>Conditional</td>
<td>$\Rightarrow$</td>
</tr>
<tr>
<td>Quantifier</td>
<td>$\exists x$</td>
</tr>
</tbody>
</table>

Interpretation rules for the simple conditions are as follows:
<table>
<thead>
<tr>
<th>Condition</th>
<th>is true iff there is an $f$ such that:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x = y$</td>
<td>$f$ maps $x$ and $y$ onto the same element of $D$</td>
</tr>
<tr>
<td>$Y = y_1 \oplus \ldots \oplus y_n$</td>
<td>$f$ maps $Y$ onto the set consisting of $f(y_1) \cup \ldots \cup f(y_n)$</td>
</tr>
<tr>
<td>$</td>
<td>X</td>
</tr>
<tr>
<td>$x \in Y$</td>
<td>$f(x)$ is a member of $f(Y)$</td>
</tr>
<tr>
<td>$\pi(x)$</td>
<td>$f$ maps $x$ onto an element $a$ of $D$ such that $&lt; \pi, a &gt;$ belongs to $\text{NAME}$</td>
</tr>
<tr>
<td>$\eta(x)$</td>
<td>$f$ maps $x$ onto an element $a$ of $D$ such that in the pair $&lt; \eta, \text{SET} &gt;$ in $\text{PRED}$, $a$ is a member of $\text{SET}$</td>
</tr>
<tr>
<td>$\zeta(x)$</td>
<td>$f$ maps $x$ onto an element $a$ of $D$ such that in the pair $&lt; \zeta, \text{SET} &gt;$ in $\text{PRED}$, $a$ is a member of $\text{SET}$</td>
</tr>
<tr>
<td>$\xi(x, y)$</td>
<td>$f$ maps $x$ and $y$ onto elements $a$ and $b$ of $D$ such that in the pair $&lt; \xi, \text{SET} &gt;$ in $\text{PRED}$, $&lt; a, b &gt;$ is a member of $\text{SET}$</td>
</tr>
</tbody>
</table>

Interpretation rules for complex conditions are:
8.5 The need for focusing in DRT

The thesis has found three main uses for a focusing algorithm: imposing focus constraints, predicting anaphoric preferences, and determining semantic interpretation. I will briefly illustrate how DRT suffers from the lack of focusing in these three ways.

DRT as described by Kamp (1981) imposes no constraints on discourse anaphora outside the scope of a quantifier. Take the following six sentence discourse fragment:

(323) John took apart the chest of drawers. It was full of clothes pegs. They had been left there by the landlady. It smelt of mothballs. She was terribly acquisitive. They had bits of fluff all over them, from her teddy-bear stuffing exploits.

I believe that the first three sentences show a normal flow of discourse, and that the last three sentences are incoherent or difficult to interpret without rereading the discourse. The reason is that there are several discontinuities of focus.
However, Kamp (1981) would have to represent the discourse (without fully reducing the conditions) as follows:

<table>
<thead>
<tr>
<th>$u, v, W, x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$John(u)$</td>
</tr>
<tr>
<td>$u$ took apart $v$</td>
</tr>
<tr>
<td>$chest - of - drawers(v)$</td>
</tr>
<tr>
<td>$v$ was full of $W$</td>
</tr>
<tr>
<td>$old - clothes - pegs - and - things(W)$</td>
</tr>
<tr>
<td>$W$ had been left there by $x$</td>
</tr>
<tr>
<td>$landlady(x)$</td>
</tr>
<tr>
<td>$v$ smelt of mothballs</td>
</tr>
<tr>
<td>$x$ was terribly acquisitive</td>
</tr>
<tr>
<td>$W$ had bits of fluff all over from $x$’s teddy-bear stuffing exploits</td>
</tr>
</tbody>
</table>

There are no conditionals or universals, so the discourse referents are available all through. DRT makes incorrect predictions about the accessibility of discourse markers, by failing to impose focus constraints.

Now take example (52):

(52) Bill found a kitten on his doorstep. He gave it some milk.

This is represented in DRT as:

<table>
<thead>
<tr>
<th>$b, k, d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Bill(b)$</td>
</tr>
<tr>
<td>$kitten(k)$</td>
</tr>
<tr>
<td>$doorstep(d)$</td>
</tr>
<tr>
<td>$found(b, k)$</td>
</tr>
<tr>
<td>$on(k, d)$</td>
</tr>
<tr>
<td>$milk(m)$</td>
</tr>
<tr>
<td>$gave(?, ?, m)$</td>
</tr>
</tbody>
</table>

I have placed question marks in the subject and indirect object slots of gave, because DRT cannot actually resolve pronouns: the DRS-construction rule for pronouns simply requires that a ‘suitable’ discourse marker is found. A focusing algorithm would resolve the pronoun by imposing an ordering on the discourse markers $b$, $k$ and $d$, and predicting
the discourse marker of highest ranking to be the antecedent of a pronoun. In this particular example, $b$ should be preferred since it is syntactically more salient.

A third way in which DRT would benefit from a focusing algorithm is when determining the representation suitable for sentences like:

\(\text{(324)}\) Three lawyers hired five cleaners.

Kamp and Reyle offer various alternative interpretations for this sentence: collective/distributive ambiguities are covered by making the distribution rule optional. They do not say when to apply it. The subject/object scope ambiguities are largely ignored in Kamp and Reyle: they find it hard to obtain object wide scope readings, and so follow grammatical ordering. However I showed in Chapter 7 that although subject wide scope readings would predominate in sentences where neither noun phrase was focused (due to the ordering of potential foci), when the object noun phrase is focused, object wide scope readings are usually more felicitous than subject wide scope readings. This means that Kamp and Reyle’s DRS-construction rules should be extended to allow for object wide scope sentences, but also that focus structure can be used as a determinant of DRS-construction for both scope ambiguity and collective/distributive ambiguity.

So, a focusing algorithm would restrict the number of accessible discourse referents and of these, make some more accessible than others. In addition, it would make DRS-construction unambiguous.

### 8.6 Adding Focus

This section brings DRT slightly closer to IFnets by introducing basic focusing capabilities into DRT. This will involve some changes to the notation, but will leave the semantic interpretation rules intact.

Focus constraints give discourse markers a limited lifetime. Only pronominal recall can extend the lifetime of a discourse marker. In Chapter 4 I argued that focus update
occurred at the end of a coordinate or maximal unit (rather than a sentence or clause). Focus update causes potential foci which have not become focused to be forgotten, and previous foci to be stacked. To incorporate update into DRT, DRSs must be restricted to the size of a unit. In most cases, this will mean that each sentence creates an individual DRS, however conjoined clauses and VP-conjunction will actually result in more than one DRS, because the unit is semantically rather than syntactically defined. A DRS may thus be coordinate or subordinate to the previous DRS. However this type of coordination and subordination is not ontological, simply focus-structural (and derived from syntax). Coordinate DRSs will be represented as adjacent sequences, while subordinate DRSs will be embedded in the DRS to which they are subordinate. Interpretation rules will be used to distinguish semantic from structural subordination.

Now we have a DRS for every unit, it is possible to impose focusing constraints on sequences of DRSs.

In coordinate sequences, only the coordinate DRS preceding the current DRS is remembered. When the current DRS has been completed, that previous DRS is in turn forgotten. Subordinate DRSs are remembered so long as the principal DRS in which they are embedded is remembered, according to the coordinate DRS constraint. This captures the requirement that pronouns in the same unit have access to the same set of antecedents, but that the set of possible antecedents shifts as interpretation proceeds to a new unit.

![Diagram](image)

In this example, DRS A will be forgotten as soon as DRS B is complete, and DRS B will be forgotten as soon as DRS C is complete.

![Diagram](image)

Here, on the other hand, DRS A will be remembered until DRS E has been completed.
However a coordinate sequence occurs inside A, so DRS B will be forgotten by the completion of DRS D, *But only from the point of view of DRS D.* DRS B can still be accessed from DRS E.1

Because DRSs are actually forgotten, it is assumed that information about discourse objects (i.e. the properties and relations predicated of them) will be stored elsewhere in long-term discourse memory. However if the hearer's only aim is to verify the text with respect to some world, it suffices to remember all the possible f mappings of discourse markers onto the world: the actual conditions which led to those choices may be safely forgotten.

As a result of the focus update mechanism working on DRSs, a change must be made to the universes of DRSs. Currently, the only items appearing in the universe of a DRS are the discourse markers generated in that DRS. All pronoun resolution in DRT is done *from the point of generation* — discourse markers appear only once in some DRS universe — all subsequent pronominal reference is subject to the superordination rules. However if old DRSs are forgotten, the discourse markers in their universes will become inaccessible due to focusing constraints. This is what is needed for potential foci, but focusing or maintaining focus on a discourse marker should prevent it being forgotten. In a focusing algorithm pronoun resolution is done *from the most recent mention*, which enables discourse markers to be pronominally recalled, and hence regenerated in the current unit.

So Kamp's original conception of the universe will have to be altered, in order to accommodate focusing. The question is how this will alter DRT, how crucial is Kamp's universe to DRT? It is difficult to see exactly what function Kamp's universe has: it is not the 'universe of discourse', because it need not contain all the entities which are referred to even in the conditions of that DRS (some may be in subordinate DRS-universes). Nor

---

1The restriction on numbers of coordinate subordinate units is illustrated in the following example, which contains a resumptive relative clause:

(325) The man lives next door, who the press made famous and several people tried to assassinate and who as a result sued #it. It has got me in trouble too.

The third coordinate subordinate unit cannot access antecedents from the first, although the unit coordinated with the maximal unit can.
does his universe serve the function of marking each entity's point of origin, since proper names are projected out of the DRS in which the noun phrase introducing them occurs. It seems to me that the universe serves to group together subsets of discourse markers which have the same accessibility conditions, accessibility conditions which are different from those of any other subset of discourse markers.

In this case, to preserve this view of the universe with focusing as an extra differentiator between discourse markers, universes must contain both newly generated and regenerated discourse markers. This will enable focused discourse markers to be accessible even though they may have been first generated several sentences ago.

So whenever a pronoun is used, it not only accesses a discourse marker, but it transfers that discourse marker to the universe of the DRS in which the pronoun occurs. If the pronoun occurs in a subordinate DRS, but the antecedent discourse marker occurs at the default level (in a principal DRS), then the pronoun will project the discourse marker into the new principal DRS.

Now the update mechanism will correctly dispose of unused potential foci, while still preserving focused discourse referents in the universe of the matrix and current DRSs. However previously focused discourse referents cannot be distinguished from potential foci, so the stack will not function adequately. A distinction between pronominally regenerated and newly generated discourse markers is also required, more importantly, in determining preferences for anaphor resolution.

In the IFnet notation, pronominal referents were distinguished by being 'attended' (represented by double-circling), while potential foci were considered as epiphenomenal to the semantic interpretation procedures. In Chapter 7 further data was found emphasising the importance of distinguishing focused from unfocused elements in the semantics. Focused elements were found by default to take wide scope over unfocused elements (unless giving the focused elements wide scope involved passing a critical threshold of processing effort). In any case, it was argued, whichever elements had taken wide scope were then focused in subsequent sentences. This suggests that focused elements should appear in the principal DRS, while unfocused elements are in subordinate DRSs. Unfortunately this rule does not always hold, since scopeless
sentences have no subordinate DRSs to hold the unfocused elements. Perhaps there is some argument for introducing 'dummy' subordination, but for now I distinguish focused from unfocused elements simply by dividing the universe of each DRS into two halves, the lefthand side containing only focused elements, and the righthand side containing only newly generated or unfocused elements. It is not unusual to have two types of objects in the universe — Kamp himself allows various propositional and event referents to appear beside nominal referents. However it is unusual for two sets of semantically similar discourse markers to be separated in this way. It would be better if the notation could express more naturally the fact that one set of discourse markers (the previously focused) is more accessible than the newly introduced set, but this is not achieved in the thesis.

By contrast, it is possible to express naturally the preferences within the two sets, since although both sets are derived from the same ontological level, some of the discourse markers may be more deeply syntactically or structurally embedded than others. Another change to the formulation of DRT involves putting orderings on the discourse referents within a universe. In DRT all discourse referents which are accessible are equally accessible. Kamp did not regard it as part of DRT to determine preference ratings. I have spoken of preferences between stores, but determining preferences within stores is also part of the job of a complete anaphor resolver. Because these preferences are weak, they are less important. I am regarding the universe as a memory store, so it is not so strange that some kind of linear ordering or probabilistic net should be required to rigidly store the discourse referents. Syntactically subordinate DRS-conditions are equivalent to the subordinate units of the IFnets. The same rules can be applied: a main verbal DRS-condition is not fully interpreted until all subordinate DRS-conditions have been interpreted (in the order in which they are encountered, from beginning to end of the sentence). Fortunately, this corresponds with Kamp's rules for DRS construction.2 However unlike in Kamp's DRT, the principal DRS cannot be later extended, for instance when encountering the next sentence.

2Superordinate conditions rather than being represented in varying stages of completeness will for neatness be listed after the subordinate conditions which interrupt them, so the main verbal condition will always be listed last in a DRS.
As in the IFnets, pronoun resolution takes place on-line. This means that sometimes ontological shifts must be made while a unit is being processed, in order to accommodate the possibilities of pronominal reference and focus maintenance. This was explained in Chapter 7 and will be demonstrated in DRT shortly.

8.7 Alterations to the DRT formalism

This section will explain the necessary changes to the original DRT notation which are required for IF/DRT, under the headings of representation, DRS construction, and DRS-interpretation.

8.7.1 Representation

The combined focus/DRT model uses a notation similar to that of Kamp (1981) in which to express the various relations between discourse referents. Focus update units are represented as DRSs with a set of conditions and a universe. The universe is split with a vertical line into a right hand side (RHS) and a left hand side (LHS): the left hand side contains focused elements, the right hand side unfocused elements. Each side of the universe consists of an ordered set of discourse referents, represented as an ordered list of variables within angle brackets.

The following example shows the representation of the focusing structure for (315).

(315) Malcolm strokes a kitten.

\[
\{(m,k)\}
\]

\[
\begin{array}{c}
\text{malcolm}(m) \\
\text{kitten}(k) \\
\text{strokes}(m,k)
\end{array}
\]

Note how this differs from Kamp’s notation, given on p. 329. The main difference is in the universe, which is split and places an ordering on the discourse referents. The discourse referents were ordered according to when they were generated. The second
difference is in the ordering of DRS conditions: the condition generated by the main verb has been placed last since it is the syntactically dominant unit. This means that both \( m \) and \( k \) have been given mappings onto \( M \) before more conditions are imposed on them. Such an ordering is implicit in Kamp's DRS-construction rules, since the condition for transitive verbs cannot be broken down unless its arguments are discourse markers.

Each successive sentence results in a DRS which is placed immediately adjacent to the right of the previous DRS, so a discourse would appear as a single line of boxes across the page, with the most recent sentence rightmost. When the current sentence is being considered, only discourse markers from the current or matrix DRSs will be accessible, so the representations of previous sentences are not used in the interpretation of the current sentence. Such a constraint is captured by deleting all DRSs except the current and the previous DRSs, and introducing a new subordination rule stating that pronouns within a DRS can only access discourse referents from its own universe, or from the DRS of the previous sentence.

Next, I introduce a distinction between focused and unfocused discourse referents in the universe of a DRS. Pronouns will access discourse markers which already exist and project them into the right hand side of the universe of the DRS in which the anaphor occurs. Moving discourse referents from one universe to another has no effect on the semantics.

DRSS appear with the following form:

\[
\begin{array}{c|c}
\text{DF} & \text{PD} \\
\hline
\text{Conditions} & \\
\end{array}
\]

The discourse in (52) is used as an example:

(52) Bill found a kitten on his doorstep. He gave it some milk.

The DRS after the first sentence will be:
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Note how the main verb condition again occurs last, although it might be thought that the prepositional phrase 'on his doorstep' could be added after the main verb is finished: this is not the case. The main verbal condition is only considered closed when the whole sentence is known to be complete.

This is what the DRSs will look like just as the end of the second sentence is reached (before update occurs):

Note also that the discourse referents \( b \) and \( k \) have been moved from the right hand side of the universe of the first DRS, to the left hand side of the universe of the second DRS. Bill and the kitten have changed from being potential foci to being foci.

I will assume the following notational policy: Changes in ontological level will be represented by embedding. DRSs belonging to the same ontological level will be drawn as adjacent structures, with the lefthand DRSs superordinate to righthand DRSs. Where there is a special truth conditional relationship between such DRSs, that will be represented with a symbol (e.g. \( \rightarrow \)).

8.7.2 New DRS-construction rules

The altered rules are detailed below:
Indefinite noun phrase If a condition contains the phrase \( a \alpha \), where \( \alpha \) is a common noun, then introduce a new discourse referent \( x \) into the righthand side of the universe of the current DRS. Add the condition \( \alpha(x) \). Replace the phrase \( a \alpha \) by \( x \) in the condition.

\[
\begin{array}{c}
| \emptyset \{ \} |
\end{array}
\text{a cat purrs}
\quad \rightarrow \quad
\begin{array}{c}
| \{ \} \{ c \} |
\end{array}
\text{cat(c)}
\text{c purrs}
\]

Proper name If a condition contains the phrase \( \alpha \), where \( \alpha \) is a proper name, then introduce a new discourse referent \( x \) into the right hand side of the universe of the principal DRS. Add the condition \( \alpha(x) \). Replace the phrase \( \alpha \) by \( x \) in the condition.

\[
\begin{array}{c}
| \emptyset \{ \} |
\end{array}
\text{John likes a girl}
\quad \rightarrow \quad
\begin{array}{c}
| \{ \} \{ j \} |
\end{array}
\text{John(j)}
\text{j likes a girl}
\]

This in turn can be reduced by the Indefinite rule above to:

\[
\begin{array}{c}
| \{ \} \{ j, g \} |
\end{array}
\text{John(j)}
\text{girl(g)}
\text{j likes g}
\]

Relative clauses If a condition contains a noun phrase \( a \alpha \) with a relative clause, then generate a new discourse referent \( x \) into the righthand side of the universe of the current DRS. Divide it into three conditions as follows: the first will be of the form \( \alpha(x) \), the second will be the result of substituting \( x \) into the gap in the relative clause (and deleting the wh-word), and the third will be the result of substituting \( x \) for the entire noun-phrase-plus-relative-clause in the original condition.

\[
\begin{array}{c}
| \emptyset \{ \} |
\end{array}
\text{a man who owns a donkey pays}
\quad \rightarrow \quad
\begin{array}{c}
| \{ \} \{ m \} |
\end{array}
\text{man(m)}
\text{m owns a donkey}
\text{m pays}
\]

Intransitive verbs If a condition contains the phrase \( \alpha \zeta \), where \( \zeta \) is an intransitive verb, then replace it with the condition \( \zeta(\alpha) \).

\[
\begin{array}{c}
| \emptyset \{ \} |
\end{array}
\text{x runs}
\quad \rightarrow \quad
\begin{array}{c}
| \{ \} \{ \} |
\end{array}
\text{runs(x)}
\]

Transitive verbs If a condition contains the phrase \( \alpha \xi \beta \), where \( \xi \) is a transitive verb, then replace it with the condition \( \xi(\alpha, \beta) \).

\[
\begin{array}{c}
| \emptyset \{ \} |
\end{array}
\text{x owns y}
\quad \rightarrow \quad
\begin{array}{c}
| \{ \} \{ \} |
\end{array}
\text{owns(x, y)}
\]

Conditionals If a condition is of the form if \( A \) then \( B \), then generate two subordinate boxes containing the sentence \( A \) in the lefthand box and the sentence \( B \) in the
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righthand box.

| () | () |
|------------------|
| If Mary dances then John works |

reduces to

| () | () |
|------------------|
| Mary dances | John works |

**Generalised quantifiers** If a condition is a quantified sentence containing $Q\alpha$, where $Q$ is a generalised quantifier, then a duplex condition is generated. This consists of two subordinate boxes joined by a diamond containing $Q$ and $x$. The lefthand box will contain a discourse referent $x$ in the lefthand side of its universe, and the conditions which would be appropriate if $\alpha$ had been an indefinite noun phrase. The original condition will then have $x$ substituted for $Q\alpha$ and will be entered in the righthand box.

| () | () |
|------------------|
| Most tigers like swimming |

reduces to

| () | () |
|------------------|
| tiger($t$) | t likes swimming |

and

| () | () |
|------------------|
| John likes most tigers. |

reduces to

| () | () |
|------------------|
| tiger($t$) | John likes $t$ |

In accordance with the findings of Chapter 7 I have made the discourse referent $t$ obligatorily focused.
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**Pronoun** If a condition contains the word $\alpha$ where $\alpha = \text{he, she, it}$, then replace the word $\alpha$ in the original condition with $y$, where $y$ is the most highly ranked ratified discourse referent chosen from the universe of the current DRS or any superordinate DRS. See below for a description of 'ranking'. Transfer $y$ from the universe in which it was found into the right hand side of the universe of the current DRS, at the same ontological level as it originated.

Generally, elements in the current DRS are preferred to those in previous DRSs. Elements in the right hand side are preferred to elements in the left hand side. Elements at the beginning of the ordered lists are preferred to elements at the end. The priorities on these three dimensions combine as follows:

1. **Primary Rule:** Try to access a discourse referent from the left hand side of the current universe.
2. **Matrix Rule:** Next try a discourse referent from the left hand side of universe of the matrix DRS.
3. **Secondary Rule:** Then try a discourse referent from the right hand side of the current universe.
4. **Potential Rule:** Finally try a discourse referent from the right hand side of the universe of the matrix DRS.

The discourse referents within these universes must be accessed in left-to-right order: only when none of these discourse referents has proved correct can the next universe be tried.

When a DRS has been fully broken down and the final verbal unit closed off, update will occur: the matrix DRS will be deleted and the current DRS will become the matrix DRS.

The revised focusing algorithm in the previous chapter makes no explicit reference to embedded semantic domains like Kamp’s subordinate DRSs. But from the algorithm it can be deduced that for instance the righthand DRS produced by a quantificational context is equivalent to the maximal unit, whereas the principal and left hand DRSs in such a case both hold syntactically subordinate conditions. It is important not to confuse Kamp’s notion of ‘subordination’ with mine: mine is syntactically determined, Kamp’s subordination belongs to my ontological hierarchy, which determines the potential foci available, but only indirectly the resulting preferences.
8.7.3 New DRS-interpretation rules

Since I have made no changes to any of the conditions, apart from removing the one for temporary anaphoric discourse markers, the semantics remains identical to that given earlier for Kamp and Reyle’s DRT, apart from the interpretation of adjacent DRSs:

<table>
<thead>
<tr>
<th>Condition</th>
<th>is true iff:</th>
</tr>
</thead>
<tbody>
<tr>
<td>( AB )</td>
<td>there is a interpretation ( f ) which can be extended to an interpretation ( g ) which verifies ( B ).</td>
</tr>
</tbody>
</table>

8.7.4 Examples

Here is the example given previously in both Kamp’s DRT and as processed by Sidner’s algorithm, now represented in IF/DRT (it is particularly unproblematic since each sentence is a maximal unit):

(326) John took apart the chest of drawers. It was full of clothes pegs. They had been left there by the landlady. It smelt of mothballs. She was terribly acquisitive. They had bits of fluff all over them, from her teddy-bear stuffing exploits.

The first sentence results in the following DRS:

\[
\emptyset (jc) \\
John(j) \\
\text{chest} - \text{of} - \text{drawers}(c) \\
took - \text{apart}(j, c)
\]

Since the first sentence of a discourse is always unusual, I will only work through the DRS construction in detail for the second sentence. Initially, the second sentence will produce the following extension to the matrix DRS:

\[
\emptyset (jc) \\
John(j) \\
\text{chest} - \text{of} - \text{drawers}(c) \\
took - \text{apart}(j, c) \\
\emptyset (\emptyset) \\
\text{It was full of clothes pegs}
\]
Full of will be treated as a transitive verb, and clothes pegs as a simple noun. However the first constituent to be encountered is a subject pronoun. This will trigger the pronoun resolution mechanism. There are no discourse markers in the universe of the current DRS, so the IF algorithm will try to resolve it to j, the highest ranking discourse marker in the matrix universe, but the ratification procedure will rule this choice out for agreement reasons. The IF algorithm will succeed on its second choice, c. The DRS-construction rule for pronouns will then accomplish several things: it will move the discourse marker c from the matrix universe to the left hand side of the (principal) current DRS, and it will replace the occurrence of it with c, as follows:

\[
\begin{array}{c|c}
   \emptyset & \{j\} \\
   John(j) & \\
   chest - of - drawers(c) & \\
   took - apart(j, c) & \\
   \{c\} & \{\} \\
   c was full of clothes pegs & \\
\end{array}
\]

Since the transitive verb rule cannot yet be applied, the processor will next encounter the object noun phrase, which is an indefinite plural, and is dealt with by the DRS-construction rule for indefinites, which generates a new discourse marker in the right hand side of the universe of the current DRS, adds a new defining condition and replaces the indefinite noun phrase with the new discourse marker:

\[
\begin{array}{c|c}
   \emptyset & \{j\} \\
   John(j) & \\
   chest - of - drawers(c) & \\
   took - apart(j, c) & \\
   \{c\} & \{P\} \\
   clothes - pegs(P) & \\
   c was full of P & \\
\end{array}
\]

Now, finally, the transitive verb can be broken down into the following condition:

\[
\begin{array}{c|c}
   \emptyset & \{j\} \\
   John(j) & \\
   chest - of - drawers(c) & \\
   took - apart(j, c) & \\
   \{c\} & \{P\} \\
   clothes - pegs(P) & \\
   full - of(c, P) & \\
\end{array}
\]

Now the current DRS has been completed, update occurs and the previous DRS is removed (possibly to be stored in long term memory elsewhere), to leave just one DRS to be the matrix for the next sentence:

\[
\begin{array}{c|c}
   \{c\} & \{P\} \\
   clothes - pegs(P) & \\
   full - of(c, P) & \\
\end{array}
\]
The next sentence adds the following DRS:

```
(c) ()  (P) (l)
clothes - pegs(P)  landlady(l)
full - of(c, P)  left - there(l, P)
```

As that next DRS is completed, the DRS created by the second sentence is cast off in its own turn, to make way for the next DRS:

```
(P) (l)  ()
landlady(l)  It smelt of mothballs
left - there(l, P)
```

Again, the DRS-construction rule for pronouns is applicable, and the incremental pronoun resolution mechanism is set in motion. The algorithm will try first to resolve it to P. This fails due to a conflict in number. Next, the algorithm will try to resolve it to I: this will fail due to a gender disagreement. Unfortunately, there are no more discourse markers accessible to the focusing algorithm, so it will fail to resolve the anaphor. It is possible that some steps of the DRS-construction rule for pronouns might be applied anyway, provided a new temporary discourse marker can be created for the pronoun, say α:

```
(P) (l)  (α) ()
landlady(l)  unknown(α)
left - there(l, P)  α smelt of mothballs
```

I will assume something of the kind might be allowable as a last resort, since partial comprehension is still possible. Then, interpretation of the discourse can continue:

```
(P) (l)  (α) ()
landlady(l)  unknown(α)
left - there(l, P)  mothballs(M)
                             α smelt of M
```

And finally:

```
(P) (l)  (α) ()
landlady(l)  unknown(α)
left - there(l, P)  mothballs(M)
                             smelt - of(α, M)
```

Update can be applied as usual, to remove the previous DRS, and the next unit can be
considered:

\[ \text{unknown(}a\text{)} \]

\[ \text{mothballs(}M\text{)} \]

\[ \text{smelt - of(}a, M\text{)} \]

\[ \text{She was terribly acquisitive} \]

Alas, here again the focusing algorithm will fail to resolve the pronoun, and even with a similar repair process to that considered for the matrix sentence, the next and final sentence of the discourse fares no better:

\[ \text{They had bits of fluff all over them, from her teddy-bear stuffing exploits} \]

By incorporating incremental focusing into DRT I have done what I set out to do, which is to impose the focusing constraints on the above text in such a way that its obvious incoherence is detectable in the same way that the semantic incoherence of (322) was detected.

(322) If she loves him, Pedro courts a woman

A second example will be given, this time including a semantic context:

(327) John organised a raffle. Every man who bought a ticket from him lost it.

The first sentence will produce the following DRS:

\[ \text{John(}j\text{)} \]

\[ \text{raffle(}r\text{)} \]

\[ \text{organised}(j, r) \]

The first noun phrase encountered in the second sentence will trigger the DRS-construction rule for quantification:
Then the first of the two subordinate DRSs can be broken down bit by bit, first a ticket will be broken down by the DRS-construction rule for indefinites:

Next, the pronoun rule will be applied to him. First, the pronoun will attempt to resolve onto m, but the ratification procedure will reject the choice because it conflicts with syntactic noncoreference restrictions. There are no focused elements in the matrix DRS, so the next choice will be t, but this disagrees in animacy with the pronoun. The algorithm will then look for discourse markers in the superordinate DRS, but there are none. Then it will search the potential foci in the matrix DRS, in which j is most highly ranked. Since j is compatible with the pronoun, the DRS-construction rule for pronouns will transfer the discourse marker j from the matrix DRS to the left hand side of the current principal DRS:

The ditransitive can be broken down as follows:

---

3 Note how DRT is not fully incremental, so parts of the sentence already appear in the DRSs which my incremental focusing algorithm assumes have not yet been processed. I have used this method because it is more faithful to Kamp and Reyle, but it would be unproblematic to replace it with an incremental DRS-construction routine, should one be developed along the lines of the suggestions I will be making shortly.
DRS-construction can now proceed to the second subordinate DRS, again applying the pronoun rule, this time to it. Again, the first choice, \( m \), from the immediately superordinate DRS, fails. However the second choice, \( t \), agrees: the IF algorithm predicts that the hearer assumes every man lost his ticket, rather than that every man lost John’s raffle. The final result is:

Note that the discourse marker \( t \) does not move up to the principal DRS, because its antecedent was only introduced on a subordinate ontological level.

8.7.5 Summary

This section has made the following changes to DRT:

- I have introduced a new DRS for every maximal focus update unit.
- The current DRS and the one before (the matrix DRS) are maintained in memory but previous DRSs are either forgotten or have their DRS-conditions stored in another form in long term discourse memory.
- Discourse markers are assumed to appear in the universe of later principal DRSs if they are pronominally regenerated.
- Focused discourse markers are distinguished from unfocused discourse markers by introducing a bifurcate universe in every DRS.
• DRS conditions are listed in order of occurrence in the text, with syntactically superordinate conditions last.

• Pronoun resolution takes place on line: that is, only the discourse markers which exist when the pronoun is encountered may be accessed.

8.8 Further developments

There are a number of features of the incremental focusing algorithm which have not yet been incorporated into DRT. This section makes some suggestions for augmenting the IF/DRT model in line with the capacities of IFnets.

The goals of the next section are as follows:

1. To suggest how a focus stack could augment the accessible discourse markers. (Version 2)

2. To introduce non-coreference relations between antecedent and anaphoric discourse markers. All potential foci will be given discourse markers (including generics and resultant sets), and the DRS-interpretation will be altered accordingly. (Version 3)

3. To apply syntactic coreference restrictions directly in the DRS-construction rule for pronouns. (Version 4)

4. To devise meta-construction rules to determine order of application of DRS-construction rules depending on focus. This will involve also incorporating backtracking capabilities. (Version 5)

Of these goals, the construction of versions 3 and 5 is most important. Versions 2 and 4 are less complete and are not necessary in order to understand the intricacies of the connection between semantics and focusing which provides the main thrust of this thesis.
8.8.1 Version 2: Adding a focus stack

To extend the speculations of Chapter 5 section 5.8 into IF/DRT would be relatively straightforward. Firstly, relations between maximal units (DRSS) could be hierarchical, just as the relations between conditions or sub-DRSS are. A fairly formal description of what such a hierarchy might comprise is given by Polanyi and Scha (1984; 1988), who propose various subordination/coordination possibilities. More detail and examples are given in the literature on global focus (exemplified by Grosz and Sidner (1986)).

It is not necessary or realistic to preserve entire stacked DRSS: it is particular discourse markers which become stacked, rather than whole universes or whole DRSS. Whatever representation, the stack will become a kind of addendum to the discourse representation for pronouns, and as I suggested in Chapter 5 it might be best to deal with the stack along with definite noun phrases.

8.8.2 Version 3: Adding Focus Relations

The focus relations are repeated here for convenience:

Membership Mapping of a set to component individual(s) (*The couple went up to the stage. She was given flowers and he a bottle of wine. We were given some chocolates. I ate my one yesterday.*)

Subset Mapping of a set to component subset(s). (*Several people came in. Two (of them) were carrying turkeys. We were given some chocolates. I ate mine yesterday.*)

Genericity Moving from an individual to its genus. (*John has a labrador. They're beautiful dogs.*)

Generic-membership Choice of one or a set of individuals belonging to a given genus. (*Labradors are beautiful dogs. John has one*)

Abstraction 1 Moving from an individual in a distributed set to the set itself. (*Every man sneezed. They were taking part in an experiment.*)

Abstraction 2 Moving from an individual distributed by its dependence on an explicitly distributed set, to the union of those individuals. (*Most people I know have a car. They are all volkswagens.*)
**Summation** Combination of several individuals. *(John went shopping with Mary. They bought a tent.)*

In Chapter 5 I divided focus relations into two types: generated relations (as in the generation of generic sets from indefinite noun phrases), and constructed relations (non-predictable relations, such as summation). In this section I will deal first with constructed relations, then with generated relations. Abstraction 2 is an exception which I will discuss in section 8.9.

I will assume, as for the iFnets, that non-coreferential pronouns create their own discourse referents, which are linked by one of the valid focus relations to the antecedent discourse referent.

**Constructed Relations**

The constructed relations are summation, subset/membership and generic membership. All except summation are immediately distinguished by the form of the anaphor, and require only one antecedent. Summation is a little different, since it necessarily takes more than one antecedent. However it will be assumed in all cases that the first antecedent considered is the current focus.

To represent these constructions in DRT requires introducing conditions which will link the anaphoric and antecedent discourse markers in the proper semantic relationship. Kamp and Reyle already cover summation: appropriate conditions can be introduced for the other relations by allowing discourse markers to stand in the membership or subset relation to one another.

However, Kamp and Reyle do not currently provide a semantics for generic sets. They do acknowledge the existence of generic sets, so I shall consider it justifiable to use the same notation as I used in the iFnets to represent genera, e.g. $G$. The semantics will also be similar, with generic sets picking out common noun sets in $PRED$.

(328) **Labradors are beautiful dogs. John has one.**

Example (328) can be represented in the following pair of DRSs:
As instructed by the incremental focusing algorithm, \( l \) becomes focused, because it is pronominal, even though it is ‘new’ in the discourse.

Subset/membership (of specific sets) will function similarly. An example of summation will be repeated from Kamp and Reyle:

(316) John took Mary to Acapulco. They had a lousy time.

The resulting pair of DRSS are:

\[
\begin{array}{c|c}
(\emptyset) (\mathcal{C}) & (\emptyset) (\mathcal{I}) \\
\hline
\text{beautiful(\( \mathcal{C} \))} & l \in \mathcal{I} \\
\text{dogs (\( \mathcal{C} \))} & \text{has}(j, l)
\end{array}
\]

The IF/DRT model can therefore be extended with some new construction and interpretation rules. Those for summation and singular membership/subset are straightforward:

**Pronoun 2** If a condition contains the pronoun **they** then replace the word **they** in the original condition with \( Y \), where \( Y \) is the sum of the \( n \) most highly ranked compatible ratified discourse referents \( y_1 \) to \( y_n \) chosen from the universe of the current DR or any superordinate DR. Add \( Y \) to the left hand side of the universe of the current DR, and add the condition \( Y = y_1 \oplus \ldots \oplus y_n \). As with simple coreferential pronoun use, the summed discourse marker is projected up to the same ontological level as its antecedents.

**Pronoun 3** If a condition contains the phrase **one of them**, then replace the phrase in the original condition with \( x \), where \( x \) is a member of the most highly ranked ratified plural discourse marker \( A \) chosen from the universe of the current DR or any superordinate DR. Add \( x \) to the left hand side of the universe of the current DR and add the condition \( x \in A \).

**Pronoun 4** If a condition contains the word **one**, then replace the word in the original condition with \( x \), where \( x \) is a member of the most highly ranked ratified generic discourse marker \( A \) chosen from the universe of the current DR or any superordinate DR. Add \( x \) to the left hand side of the universe of the current DR and add the condition \( x \in A \).
(Ordering of the pronoun rules is important, since errors can occur, say if Pronoun 4 was applied to the phrase *one of them*)

There are complications when it comes to plurals, for phrases like *most of them* open up quantificational contexts, just like *most men*. This means that the rule for quantification will have to be altered to cope with both forms. There may be more ingenious solutions than the one I propose, but the one I give here will suffice for my purposes.

I propose the following DRS-construction rule for quantifiers:

If the condition has the form $Q \alpha \zeta$, it reduces to

$$
\begin{array}{c}
\emptyset \\
\{z\} \\
\{x\} \\
\{\alpha\} \\
\{\zeta\}
\end{array}
$$

Here are four examples:
### Condition | Reduces to
--- | ---
Two men have a cat. | $\langle \{m\} \rangle$  
$\langle \{\} \rangle$  
$m \in \text{men}$  
$m \in \text{men}$  
$m \text{ have a cat}$  

Most men who like dogs have a cat | $\langle \{m\} \rangle$  
$\langle \{\} \rangle$  
$m \in \text{men who like dogs}$  
$m \in \text{men who like dogs}$  
$m \text{ have a cat}$  

Every man has a goldfish | $\langle \{m\} \rangle$  
$\langle \{\} \rangle$  
$m \in \text{man}$  
$m \in \text{man}$  
$m \text{ has a goldfish}$  

Most of them have two goldfishes | $\langle \{m\} \rangle$  
$\langle \{\} \rangle$  
$m \in \text{them}$  
$m \in \text{them}$  
$m \text{ has two goldfishes}$  

However the consequence of this is that phrases like *man*, *men* and *men who like dogs* will have to be semantically interpretable as sets. Fortunately *them* is already dealt with by coreference, and it is not too difficult to provide a suitable semantics for *men* and *man* — in fact, the next section argues that it is necessary to interpret them as sets anyway. The problem of relative clauses will be left to section 8.9.

An extra quantifier rule will be necessary to deal with generic subset cases like ‘Most have two goldfishes’:

If a condition has the form $Q \subset$ it reduces to
Where $X$ is the most highly ranked compatible accessible genus.

Indeed, it might prove necessary to incorporate the accessibility conditions for the specific subset version too, in order to prevent the pronoun them causing summation, accessing a generic or otherwise avoiding coreference to a specific plural set.

The full set of new construction rules is stated as follows:

**Pronoun 2** If a condition contains the pronoun they then replace the word they in the original condition with $Y$, where $Y$ is the sum of the $n$ most highly ranked compatible ratified discourse referents $y_1$ to $y_n$ chosen from the universe of the current DRS or any superordinate DRS. Add $Y$ to the left hand side of the universe of the DRS which corresponds with the ontological level of the antecedents, and add the condition $Y = y_1 \oplus \ldots \oplus y_n$.

**Pronoun 3** If a condition contains the phrase one of them, then replace the phrase in the original condition with $x$, where $x$ is a member of the most highly ranked ratified plural discourse marker $A$ chosen from the universe of the current DRS or any superordinate DRS. Add $x$ to the left hand side of the universe of the current DRS and add the condition $x \in A$.

**Pronoun 4** If a condition contains the word one, then replace the word in the original condition with $x$, where $x$ is a member of the most highly ranked ratified generic discourse marker $A$ chosen from the universe of the current DRS or any superordinate DRS. Add $x$ to the left hand side of the universe of the current DRS and add the condition $x \in A$.

**Bare singular** If a condition contains the phrase $Q\alpha$ where $Q$ is a singular relative quantifier (every, each, no etc.) then replace the phrase $\alpha$ with its plural form (this permits it to be interpreted subsequently as a generic).

**Quantification** If the condition has the form $Q\alpha\zeta$, where $Q$ is a relative or absolute quantifier, then it reduces to
Quantification (generic) If a condition has the form $Q \zeta$ it reduces to

Where $\mathcal{X}$ is the most highly ranked compatible accessible genus.

The new conditions are interpreted as follows:

<table>
<thead>
<tr>
<th>Condition</th>
<th>is true iff there is an $f$ such that:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Y = y_1 \oplus \ldots \oplus y_n$</td>
<td>$f$ maps $Y$ onto the set consisting of $f(y_1) \cup \ldots \cup f(y_n)$</td>
</tr>
<tr>
<td>$x \in Y$</td>
<td>$f(x)$ is a member of $f(Y)$</td>
</tr>
</tbody>
</table>

The relation $Q$ holds between the sets $A$ and $B$, where $A$ is the union of all the elements $a$ such that there is an extension $g$ of $f$ which verifies the DRS-conditions $C$, containing (at least) the extra mapping $[x \mapsto a]$ and $B$ is the union of all elements $a$ for which it is also true that there is an extension $h$ of $g$ which verifies $D$.

Generated relations

Genericity and abstraction fall into this category. Both have treatments by Kamp and Reyle. I will follow their treatment of generics, but I choose not to adopt their treatment of abstraction.
Firstly I consider generics. I noted in Chapter 6 that indefinites can be considered as automatically generating the generic set which they are interpreted with respect to. Kamp and Reyle 1989 (p. 741–744) also note that indefinites can be considered to automatically produce generic sets, though they do not explicitly link this with the semantic interpretation. Generic sets are projected up to the universe of the principal DRS, for, like proper names, they have a constant interpretation in the model.

This means discourses like (320) can be represented in IF/DRT:

(320) John has a crocodile. They're very expensive pets.

The first sentence produces the following DRS:

```
(0) (j, c, C)
  John(j)
  crocodile(c)
  c ∈ C
  has(j, c)
```

Although the genus of crocodiles appears among the potential foci, it is ranked lower than c, because it does not appear in the main verbal relation. I have altered the DRS conditions for indefinites from the alternative below favoured by Kamp and Reyle:

```
(0) (j, c, C)
  John(j)
  crocodile(c)
  crocodile(C)
  has(j, c)
```

This is because I feel my choice both removes unwanted redundancy and captures better the essential relationship between the indefinite individual and its generic set. The semantic interpretation procedure will be equivalent, but my representation is more transparent.

To continue with the example, the second sentence will focus the generic set with the following result:
Let us now turn to abstraction. Kamp and Reyle represent abstraction as a summation operation over discourse markers satisfying the conditions in the associated subordinate DRS:

\[
\text{Susan has found most books which Bill needs. They are on his desk.}
\]

This produced a DRS as follows:

\[
\begin{align*}
\text{Susan}(x) \\
\text{Bill}(z) \\
\begin{array}{l}
\text{book}(y) \\
\text{z needs y} \\
\text{z has found y}
\end{array} \\
Y = \sum y \\
\text{z's desk}(w) \\
\text{Y are on w}
\end{align*}
\]

However it is very difficult to see how this could be translated into IF/DRS notation, particularly what the universe of the summed box would look like. In Chapter 6 I assumed that abstraction was simply retrieval of the resultant set which was required to interpret any quantificational context. Abstraction, I argue, is not a subordinating operation, but a superordinating operation. Abstraction moves the discourse into a higher ontological level, out of an embedded context. Kamp and Reyle's representation shows this by having the abstracted set \( Y \) available at the default level. But despite giving the correct truth conditions to abstracted sets, Kamp and Reyle's notation does not make the connection between the resultant set and the abstracted set. In fact,

\footnote{This is my favourite sentence in the thesis.}
Kamp and Reyle do not include the resultant set in their notation at all: it remains invisible except at the level of semantic interpretation. As with the generic example, I will make the semantic interpretation more transparent, and simultaneously solve the problem of pronominal reference.

Quantifiers are verified by comparing the initial Iset with the resultant Rset.

(329) Most people like ice-cream.

In (329) the Iset is the generic PEOPLE which is generated by the plural indefinite set most people. The Rset is the set of people who like ice-cream, which, if the sentence is to be true, must be at least half the size of the set of PEOPLE in $M$. This sentence could be followed by one containing 'abstraction':

(329a) Most people like ice-cream. They visit the dentist often.

The referent of the pronoun they is exactly the same as the resultant set: people who like ice-cream. Moreover, I do not believe such sets are particularly difficult to access, particularly for plural quantifiers like most.

I propose the following DRS for the first sentence of (329):

\[
\begin{array}{|c|}
\hline
\text{(R)} \quad (P, I) \\
\hline
\text{person}(P) \\
\hline
\begin{array}{|c|}
\hline
\text{any} \\
\begin{array}{|c|}
\hline
\text{likes}(p, I) \\
p \in \mathcal{R} \\
\hline
\end{array} \\
\begin{array}{|c|}
\hline
\langle I \rangle \\
\hline
\end{array} \\
\hline
\end{array} \\
\begin{array}{|c|}
\hline
\text{most}(P, I) \\
p \in \mathcal{P} \\
\hline
\end{array} \\
\hline
\end{array}
\]

$P$ represents the initial set, generated according to the generic rule, and $R$ represents the resultant set, necessary to interpret the quantification. $I$ is simply the generic or mass term for ice-cream in general.

This will allow the second sentence to focus the resultant set as follows:
From now on I will include the resultant set among the discourse markers produced in
the potential focus list of the principal DRS.

New construction Rules

**Indefinite noun phrase** If a condition contains the phrase \( a \, \alpha \), where \( \alpha \) is a common noun, then introduce a new discourse referent \( x \) into the *right hand side* of the universe of the current DRS. Add the condition \( x \in \alpha \) to the current DRS. Replace the phrase \( a \, \alpha \) by \( x \) in the condition.

\[
\begin{array}{c}
\{ x \} \\
\{ x \}
\end{array}
\]
\( a \) cat purrs

reduces to

\[
\begin{array}{c}
\{ x \} \\
\{ x \}
\end{array}
\]
\( c \in \text{cat} \\
\text{cat} \) purrs

**Generic** If a condition contains the word \( \alpha \), where \( \alpha \) is a common noun, then introduce a new discourse referent \( \mathcal{X} \) into the *right hand side* of the universe of the principal DRS. Add the condition \( \alpha(\mathcal{X}) \) to the principal DRS. Replace the word \( \alpha \) with \( \mathcal{X} \) in the condition.

\[
\begin{array}{c}
\{ x \} \\
\{ x \}
\end{array}
\]
\( c \in \text{cat} \\
\text{cat} \) purrs

reduces to

\[
\begin{array}{c}
\{ x \} \\
\{ x \}
\end{array}
\]
\( \text{cat}(\mathcal{C}) \\
\mathcal{C} \) purrs

**Generalised quantifiers** If a condition contains the phrase \( Q \, X \, z \), where \( X \) is plural and \( Q \) is a relative or absolute quantifier, then create a duplex condition containing a discourse marker \( x \) in the left hand side of the universe of the left hand DRS, and the condition \( x \in X \) in that DRS. Put \( Q \) and \( x \) in the diamond, and the condition \( x \in X \) in the righthand DRS, with the condition \( x \in R \). Add \( R \) to the right hand side of the universe of the DRS to which the duplex condition is directly subordinate.\(^5\)

So:

\(^5\)There is a problem here: I think that if the set \( X \) is focused, the discourse marker \( R \) should go into the left hand side of the superordinate DRS. I shall indicate this where convenient.
For example the condition:

\[
\emptyset \land \emptyset
\]

Two \( T \) growled at a bear

reduces to:

\[
\emptyset \land \emptyset
\]

\( t \) growled at a bear \( t \in R \)

and

\[
\emptyset \land \emptyset
\]

John likes most \( T \).

reduces to

\[
\emptyset \land \emptyset
\]

John likes \( t \) \( t \in R \)

New semantics

The following interpretation rules should be added to those given earlier:
Condition | is true iff there is an \( f \) such that:
---|---
\( \pi(X) \) | \( f \) maps \( X \) onto a subset \( A \) of \( D \) such that \( \langle \pi, A \rangle \) belongs to \( \text{PRD} \).

\[
\begin{array}{c|c}
\emptyset & \emptyset \\
\hline
\{x\} & \emptyset \\
\emptyset & \{a\} \\
\end{array}
\]

The relation \( Q \) holds between the sets \( A \) and \( B \), where \( A \) is the union of all the elements \( a \) such that there is an extension \( g \) of \( f \) which verifies the \( \text{DRS} \)-conditions \( C \), containing (at least) the extra mapping \( [x \mapsto a] \) and \( B \) is the union of all elements \( a \) for which it is also true that there is an extension \( h \) of \( g \) which verifies \( D \).

Example

I will work through two examples.

(330) Thirty men live here. Most of them have a goldfish.

Let us assume that the first sentence has been represented as follows:

<table>
<thead>
<tr>
<th><img src="image" alt="" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>[</td>
</tr>
<tr>
<td>( \text{live} - \text{here}(M) )</td>
</tr>
</tbody>
</table>

The second sentence will immediately be recognised as quartificational: the first word is a relative quantifier, this produces the following:
The condition in the left hand DRS now needs be be reduced, by using the ordinary coreferential pronoun rule, to access the most highly ranked compatible ratified discourse referent, \( M \), which is in fact the only available discourse referent, so, we obtain:

The discourse referent \( M \) is transferred from the right hand side of the matrix DRS to the left hand side of the current DRS, at the same ontological level. Now, processing can proceed to the right hand DRS. First the syntactically subordinate unit, the noun phrase, must be broken down. It follows the rule for indefinites, projecting a generic set into the principal DRS.
And finally, the verb is reduced:

\[
|M| = 30
\]
\[
\text{live} - \text{here}(M)
\]

The final step in the completion of the duplex condition will be the production of the resultant set, the set of ‘men who have goldfishes’, which will be the majority, but not all, of the ‘thirty men who live here’.

\[
|M, R| = 30
\]
\[
\text{live} - \text{here}(M)
\]

A second example will also be covered:

(331) Every man likes cats.

This time there is no matrix DRS: this could be the first sentence of a discourse. Again, however, a quantificational context can be detected immediately:
This time the condition in the left hand DRS is broken down using the Bare Singular rule, which converts the DRS to:

Now the left hand condition can be fully reduced using the Generic Rule:

Note how the generic information appears in the principal DRS, although the generic was generated from a subordinate DRS. The right hand DRS also contains a generic, so the final result will be:
Semantic interpretation allows the resultant set, the set of men who like cats, to be found also:

8.8.3 Version 4: Adding syntactic coreference restrictions

The simplified rule for preventing obvious syntactic clashes can be transferred directly from IFnets to DRT:

**Proposal (Syntactic Constraint):**

*When attempting to resolve a pronoun, identify it as disjoint from every discourse marker in the arguments of the currently attended condition.*

As with IFnets, the idea of syntactic subordination will stop this proposal ruling out all coreference within the sentence, but the same cases as were discussed in Chapter 5
section 5.7 will fail to be accounted for here.

8.8.4 Version 5: Incorporating focus-dependent construction

Chapter 7 demonstrated that focus (plus linear order) determined how semantically ambiguous sentences would be interpreted. This section suggests how these influences might be incorporated into DRT. In this section I work through example (313), which demonstrates nearly all the complexities involved:

(313) Two mermaids sang to three fishermen.

This example is analogous to Kamp and Reyle’s example (332):

(332) Three lawyers hired five cleaners.

(From Kamp and Reyle 1989 p. 777)

What I intend to do is to show firstly how Kamp and Reyle analyse doubly quantified sentences like (313) and (332), then to introduce the notation I will be needing to do the same analysis in IF/DRT. Finally, I will perform the analysis using the strategies explored in Chapter 7, and make some empirical predictions about the likelihood of different readings being understood by a hearer.

Kamp and Reyle’s analysis

The first step is to create the DRS A:

A: Three lawyers hired five cleaners

The path of possibilities taken from here is as follows (the abbreviations are comp (compulsory) and opt (optional), with the dotted lines indicating speculative readings):
D is a reading where the subject is distributed and the object collective, E where both subject and object are distributed, F where both are collective, and G where the subject is collective but the object distributed. Kamp and Reyle derive them from each other as will be seen below.

Firstly, DRS A is obligatorily broken down into B:

\[
\begin{array}{c|l}
L & \text{lawyer}(L) \\
|L| = 3 & L \text{ hired five cleaners} \\
\end{array}
\]

Then there is a choice of distributing the subject to obtain C:

\[
\begin{array}{c|l}
L & \text{lawyer}(L) \\
|L| = 3 & \\
\end{array}
\]

\[
\begin{array}{c|c}
1 & \text{every} \\
1 \in L & l \text{ hired five cleaners} \\
\end{array}
\]

(C must be reduced further, as will be illustrated shortly)

The other alternative is to keep a collective reading:
F corresponds to the doubly collective reading, where three lawyers jointly hired a firm of five cleaners. It can be optionally broken down into the DRS G:

This is the subject-collective object-distributed reading, where three lawyers jointly hired five separate cleaners (one to clean the bookshelves, one to hoover the floors, one to polish the doorknobs etc.).

Returning to the distributive DRS C, C must be broken down still further into:

This corresponds to the subject distributed, object collective reading, where a firm of five cleaners was hired by three independent lawyers (one lawyer had them cleaning on Tuesdays, one on Thursdays, one on Fridays).

This can be optionally reduced to:
This gives the completely distributive reading, where three lawyers each hired five separate cleaners.

Kamp and Reyle therefore recognise 4 main readings, D, E, F and G. They also admit of the possibility of deriving a further reading from F by distributing over subject and object (in any order), to obtain two equivalent DRs, H.
One further option they discuss is that of distributing over the object as opposed to the subject at the first stage, producing $Z$ instead of $B$:

However Kamp and Reyle find it very difficult to obtain such a reading, and therefore dismiss $Z$ as a possibility.

I will be showing that Kamp and Reyle’s findings correspond with the results one would expect to obtain if the hearer took the subject to be the focus (as would make sense since there is no focus but the subject is the most highly ranked potential focus). However reading $Z$, and its derivatives, can be obtained when the object is focused.

**Notational Changes**

The first thing to do is to incorporate non-distribution as an option for absolute quantifiers. This means adding the following DRS-construction rule to IF/DRT:

**Indefinite plural** If a condition contains the phrase $n \, X$, where $X$ is a plural, and $n$ is a number greater than 1, then add two new conditions $R \subseteq X$ and $|R| = n$, and replace the phrase $n \, X$ by $R$ in the condition. So:
Now we need a semantic interpretation procedure for subset. We also need procedures for dealing with collective verbs, which we can obtain by generalising the procedures for transitives and intransitives which I adopted from Kamp and Reyle (1989) at the beginning of this chapter:

<table>
<thead>
<tr>
<th>Condition</th>
<th>is true iff there is an $f$ such that:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x \subseteq Y$</td>
<td>$f(x)$ is a subset of $f(Y)$</td>
</tr>
<tr>
<td>$\zeta(x)$</td>
<td>$f$ maps $x$ onto an element or set $a$ of $D$ such that in the pair $&lt; \zeta, \text{SET}&gt;$ in $\mathcal{PRED}$, $a$ is a member of the set $\text{SET}$</td>
</tr>
<tr>
<td>$\xi(x,y)$</td>
<td>$f$ maps $x$ and $y$ onto elements or sets $a$ and $b$ of $D$ such that in the pair $&lt; \xi, \text{SET}&gt;$ in $\mathcal{PRED}$ $&lt; a,b &gt;$, is a member of the set $\text{SET}$</td>
</tr>
</tbody>
</table>

Another way in which my notation differs from that used by Kamp and Reyle to analyse (332) is in the representation of distribution. Take for example Kamp and Reyle’s DRS C:

$$\text{C:}$$

$\text{C:}$

It is not open to me to use such a representation, as I want to keep just one type of quantification, rather than having to switch to a different representation to deal with donkey anaphora. If (332) is replaced with (333), then a DRS consistent with C cannot be constructed:
Three lawyers who owned a car crashed it.

The attempted DRSs C' and C'' both fail to capture the donkey-anaphora. The only alternative is:

The problem highlights an inconsistency in Kamp and Reyle (1989): on p. 758 the noun-predicate for the subject is in the principal DRS, to allow its cardinality to be found. On p. 770 it is in the righthand DRS.
It is this later approach which I will take throughout this chapter. My quantificational contexts will look like \( C'' \) rather than \( C' \) or \( C'' \). However this means that as soon as a condition is broken down a decision has to be made as to whether a noun phrase is to be distributed or not: no longer is the collective form the default, from which distribution is optionally obtained. Collection and distribution are a disjunctive option applying to an unreduced noun phrase in a condition.

**My analysis (subject-focused)**

It is now possible to continue with the processing of the semantically ambiguous example (313).

(313) Two mermaids sang to three fishermen.

The procedures I follow are a formalisation of the observations and hypotheses of Chapter 7. I will work through the possible interpretations of (313), first in a version where the subject is focused, and second in a version where the object is focused:

(334) **Mermaid-focused** (Many mermaids came to the beach this week.) Two of them sang to three fishermen.

(335) **Fisherman-focused** (The fishermen were very lucky.) Two mermaids sang to three of them.

The text in brackets shows the preceding context. At the first stage of processing, (334) will be represented as follows (I simplify the preceding context):

\[
\begin{array}{c|c}
(\emptyset) (M, b) & (\emptyset) \\
\text{mermaid}(M) & \text{Two of them sang to three fishermen} \\
\text{beach}(b) & \\
\text{came}(M, b) & \\
\end{array}
\]

FTS-construction proceeds left to right through the conditions. When the phrase **two of them** is found, either the collective rule (for plural sets) or the distributive rule
(for any quantifier) may be applied. Taking the distributive option first, this produces the DRS 1:

\[ \{M,b\} \]

\[ \text{mermaid}(M) \]
\[ \text{beach}(b) \]
\[ \text{came}(M,b) \]
\[ (X) \]
\[ \{\} \]
\[ x \in M \]
\[ x \in X \]
\[ x \text{ sang to three fishermen} \]
\[ x \in X \]

\[ x \in X \]
\[ x \text{ is the resultant set — the set obtained after interpretation of the duplex condition.} \]
Of course, the DRS is not yet fully reduced, so the set \( X \) cannot be determined yet. However, its destiny is to contain the referents for the two mermaids who each ‘sang to three fishermen’. The variable \( x \) considers each of the mermaids which came to the beach, one by one.

After 1, again either the distributive or the collective reading can be applied, to give, in the first instance, the doubly distributive 2:

\[ \{M,b\} \]
\[ \text{mermaid}(M) \]
\[ \text{beach}(b) \]
\[ \text{came}(M,b) \]
\[ (X) \]
\[ \{F\} \]
\[ \text{fisherman}(F) \]
\[ F \subseteq F \]
\[ f \in F \]
\[ f \in R \]
\[ f \text{ three} \]
\[ f \in F \]
\[ x \text{ sang to } f \]
\[ x \in X \]

As before, \( X \) is the set of two mermaids. Note that \( F \), the resultant set of three fishermen which were sang to by a mermaid, is only projected up one ontological level. This means that \( F \) will consist of different fishermen for each of the two mermaids.

To reach Kamp and Reyle’s reading \( H \), a possible course of events at this point is to decide to make the object specific, although it is not focused so there is no particular benefit in doing so. This would result in the following representation:
Note that the resultant set is projected up to the same ontological level as the initial set.

The alternative is the distributive-collective version 3:

Again, $X$ is the resultant set of two mermaids who sang to three fishermen, and $F$ is a set of three fishermen, but this time the fishermen are not distributed, so remain in a group to experience the mermaid’s song. Again, there is a different audience $F$ for each mermaid’s song.

But suppose instead of the distributive option 1 having been taken at the start, the collective option 4 had been taken instead:

Then again there would be two options, either to now distribute the object:
X is a group of two mermaids (they are never distributed, so always sing a duet), and F is the resultant set of three fishermen who each experienced a duet by the same two mermaids.

Or to keep both subject and object collective:

The four DRSs 2, 3, 5 and 6 correspond to Kamp and Reyle’s DRSs E, D, G and F respectively. 2b corresponds to H.

My analysis (object-focused)

However, these are only the readings available when the subject is focused. When the object is focused, the possibilities become more exciting. Here is the object-focused example:

(335) **Fisherman-focused** (The fishermen were very lucky.) Two mermaids sang to three of them.

Here is the DRS for (335) at the first stage of processing (again, the preceding context is simplified):
Again, processing proceeds from left to right. The first phrase to be encountered is two mermaids. As before, this can be either given a distributive reading (7) or a collective reading (8):

7:  
\[
\begin{align*}
\langle \emptyset \rangle \langle F \rangle \\
\text{fishermen}(F) \\
lucky(F)
\end{align*}
\]
\[
\begin{array}{c}
\langle \emptyset \rangle \langle M \rangle \\
\text{mermaid}(M) \\
\end{array}
\]
\[
\begin{aligned}
\langle \emptyset \rangle \langle m \rangle \\
m \in M \\
\text{two}
\end{aligned}
\]
\[
\begin{array}{c}
\langle \emptyset \rangle \langle \rangle \\
m \text{ sang to three of them} \\
m \in M
\end{array}
\]

This time, \( M \) represents the (resultant or collective) set of two mermaids who ‘sang to three of them’.

These unreduced DRSs, 7 and 8, form the basis for the four possible readings for object-focused sentences. Let us begin with those derived from 7. When the processor encounters the phrase three of them a relation to previous context can now be made. Now, according to the principle of focus maintenance which is the foundation of the incremental focusing algorithm, the hearer will endeavour to place the focused item in the principal DRS unless the processing effort required to do so is greater than the effort involved in making a focus shift.

One possibility is to give the focused item wide scope, so making the transition from:
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However this means moving the entire duplex:

This duplex, with its resultant set, $M$, has to be moved out of the principal DRS and embedded one ontological level further down inside the scope of the object. Now the set $M$, instead of being anaphorically accessible as a two item set in the default context, will itself be distributed into three two item sets. This is what in Chapter 7 I termed an ontological shift. Clearly, moving such a large amount of established material would involve considerable effort and disruption. Even less likely is the mirror image to 2b, where the subject is also projected out of the duplex to become specific (call this 9b).

An alternative which is somewhat easier on the processor, but nevertheless allows focus to be maintained, is to retain the existing structure, and to simply project the focused element out of the quantificational context of the subject, to become a specific indefinite.
The discourse marker \( R \), with its two accompanying conditions \( R \subseteq F \) and \(|R| = 3\) do not appear in the nuclear scope of the subject, but are projected into the principal DRS (compare DRS 3). \( R \) represents the set of three fishermen, who this time must all three hear the songs of the same two mermaids, who are collected in the resultant set \( M \).

The use of the specific indefinite will require a new DRS-construction rule, which will be given at the end of this section together with the backtracking rule for ontological shifting.

The final two readings for the object-focused example are derived from DRS 8:

First, the hearer can make an attempt to give the focus wide scope and distribute over it, which means ontologically shifting the condition ‘\( M \text{ sang to three of them} \)’ into a more embedded context:
It is difficult to tell how closely the psychological story could be linked to the actual notation used, but it is likely that the ontological shift necessary here is less costly in processing terms than the ontological shift in 9, since it does not require changing the ontological status of any discourse entities. However it is possible to avoid the effort of even a small ontological shift, by deciding not to distribute over the focused element at all:

\[
\begin{array}{|c|c|}
\hline
\text{fishermen}(F) & (F) \mid (M, M) \\
\text{lucky}(F) & \text{mermaid}(M) \\
M \subseteq M & |M| = 2 \\
R \subseteq F & |R| = 3 \\
M \text{ sang to } R & \\
\hline
\end{array}
\]

This allows both the two mermaids \((M)\) and the three fishermen \((R)\) to appear in the principal DRS, giving the same reading as 6.

Summary

I have been able to follow the strategies suggested for empirical reasons in Chapter 7, in order to explain why some of the object-focused readings are harder to obtain than others. In this section I will be taking all factors into account, to predict a scale of processing ease for all the readings of 313. The following table lists all the readings which were recognised in Chapter 7 p. 317:
<table>
<thead>
<tr>
<th>Type</th>
<th>Reading</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>DD1</td>
<td>Two mermaids individually sang to three different fishermen</td>
<td><img src="image" alt="Model DD1" /></td>
</tr>
<tr>
<td>DD2</td>
<td>Three fishermen each individually heard two different mermaids sing</td>
<td><img src="image" alt="Model DD2" /></td>
</tr>
<tr>
<td>DD3 or DD4</td>
<td>The same two mermaids each individually sang to the same three fishermen</td>
<td><img src="image" alt="Model DD3 or DD4" /></td>
</tr>
<tr>
<td>DC1</td>
<td>A group of three fishermen were sang to first by one mermaid, and then by another</td>
<td><img src="image" alt="Model DC1" /></td>
</tr>
<tr>
<td>DC2</td>
<td>Two mermaids each sang to a group of three fishermen</td>
<td><img src="image" alt="Model DC2" /></td>
</tr>
<tr>
<td>CD1</td>
<td>The same two mermaids sang a duet to three different fisherman</td>
<td><img src="image" alt="Model CD1" /></td>
</tr>
<tr>
<td>CD2</td>
<td>Three fishermen were sang a duet by two mermaids</td>
<td><img src="image" alt="Model CD2" /></td>
</tr>
<tr>
<td>CC1 or CC2</td>
<td>Three fishermen were the audience to one duet</td>
<td><img src="image" alt="Model CC1 or CC2" /></td>
</tr>
</tbody>
</table>

The models signify the situations in the world which are relevant to verifying each particular reading. Each link represents a real world singing event. The number of 'm's or 'f's represent individual mermaids and fishermen: where several letters are grouped
together this indicates that they all took part in the same event.

The pattern types named above are used in the following table which summarises the way the different readings are obtained, and gives the corresponding DRSs in Kamp and Reyle's notation and in mine.

<table>
<thead>
<tr>
<th>Verb Type</th>
<th>Kamp and Reyle</th>
<th>IF/DRT</th>
<th>Focus</th>
<th>Mermaid</th>
<th>Fisherman</th>
</tr>
</thead>
<tbody>
<tr>
<td>DD1</td>
<td>E 2</td>
<td>S-dist, O-dist</td>
<td>8</td>
<td>S-ont, S-dist, O-ont, O-dist, FS</td>
<td></td>
</tr>
<tr>
<td>DD2</td>
<td>Z 9</td>
<td>S-ont, S-dist, O-ont, O-dist, FS</td>
<td>4</td>
<td>S-ont, S-dist, O-dist</td>
<td></td>
</tr>
<tr>
<td>DD3</td>
<td>H 2b</td>
<td>S-dist, O-dist, O-spec</td>
<td>5</td>
<td>FS, S-dist, O-dist, O-spec</td>
<td></td>
</tr>
<tr>
<td>DD4</td>
<td>H 9b</td>
<td>FS, S-ont, O-dist, S-dist, S-spec</td>
<td>5</td>
<td>S-ont, O-dist, S-dist, S-spec</td>
<td></td>
</tr>
<tr>
<td>DC1</td>
<td>Z 10</td>
<td>S-dist, O-spec, FS</td>
<td>2</td>
<td>S-dist, O-spec</td>
<td></td>
</tr>
<tr>
<td>DC2</td>
<td>D 3</td>
<td>S-dist</td>
<td>3</td>
<td>S-dist, FS</td>
<td></td>
</tr>
<tr>
<td>CD1</td>
<td>Z 11</td>
<td>O-dist, FS</td>
<td>2</td>
<td>S-ont, O-dist</td>
<td></td>
</tr>
<tr>
<td>CD2</td>
<td>G 5</td>
<td>O-dist</td>
<td>3</td>
<td>O-dist, FS</td>
<td></td>
</tr>
<tr>
<td>CC1</td>
<td>F 6</td>
<td>-</td>
<td>2</td>
<td>FS</td>
<td></td>
</tr>
<tr>
<td>CC2</td>
<td>Z 12</td>
<td>FS</td>
<td>0</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Key:

- **S-dist**: Distribution of the subject set
- **O-dist**: Distribution of the object set
- **S-ont**: Ontological shift of the subject set
- **O-ont**: Ontological shift of the object set
- **O-spec**: Projecting the object set out as a specific indefinite
- **FS**: Focus shift

The columns headed with a ‘P’ contain estimated processing penalties for performing certain structural changes. Penalties are imposed as follows: plus 1 for a specific indefinite or distribution, plus 2 for a focus shift, plus 1 for an ontological shift of a collective item, plus 2 for an ontological shift of a distributed item.

The motivation for imposing these penalties is somewhat arbitrary, but roughly based on the empirical findings of the previous chapter, and on the amount of structural disruption evident in the notation of DRT. As a result the numbers are really only illustrative, and only experimentation could really determine the costs of the various operations.

The different readings are ranked as follows, depending on which item is focused:
It must be remembered that I have ignored the effect of focusing on event markers. Even without this, incremental focusing can be used to predict which readings of an ambiguous sentence will be preferred. In natural language texts, it will be unusual for a verb to be encountered which does not itself rule out some of the combinations of collective/distributive sets. The influence of the meaning of the verb is likely to be one of the stronger influences biasing readings. This is just one of the complexities which cannot currently be modeled in DRT. However enough material for thought has been presented here. The theoretical background was described in Chapter 7: this chapter shows how the intuitions can be translated into formal rules and even used to make very precise empirical predictions, should that be desirable. It only remains to give the new DRS construction rules required to perform ontological shifts and create specific indeterminates:

Specific Indefinite 1 If a condition contains an indefinite noun phrase, singular or numeric plural, then replace it with a discourse marker $x$ in the condition, and move the indefinite noun phrase into the immediately superordinate DRS.

Specific Indefinite 2 If a condition is of the form:

```
\( \emptyset \emptyset \)
```

then the initial and resultant sets can be projected up to the next ontological level:
Ontological shift 1 If a condition is of the form:

\[ \forall x \in \text{them} \] \( Q \) then it can be shifted to the form:

\[ \forall x \in \text{them} \] \( Q \)

Ontological shift 2 If a condition is of the form:

\[ \forall x \in \text{them} \] \( Q \)

then it can be shifted to the form:

\[ \forall x \in \text{them} \] \( Q \)
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Critique

I am not altogether happy with some of the DRS-construction and interpretation rules I have proposed here: it seems to me that a more economical or accurate system could probably be derived. On the other hand, it is impossible given the idiosyncrasies of natural language to devise a focusing and semantics which will (ideally) apply to all languages, without glossing over some awkward constructions. It would take a thorough study of several languages to ascertain whether it is significant that generic membership does not use the prefix of them. I suspect that it is not significant, but whether this justifies treating 'most had cats' as if it were 'most of them had cats' I am not sure, given that this obscures a fortuitous distinction which would otherwise create more effort for the pronoun resolver.

There are several generalisations I do not feel entirely committed to: firstly, I would be curious to try an alternative way of constructing quantificational contexts, in which the initial set is always predefined. This ties in with Kamp and Reyle's earlier versions of quantification, when the noun-predicate appears in the principal DRS, rather than in the restrictor. The appeal of this earlier approach was that there was no need to make an early commitment to a collective or a distributive noun phrase. In their version, the distributive version was derived from the collective. I favour some approach where both collective and distributive interpretations have the same origin, an approach in which certain essential characteristics could be extracted from the noun phrase without being constrained to treat it as collective or distributive. One possibility I like is that DRSs could be built incrementally at two different ontological levels, the collective and the distributive, by capitalising on the fact that even 'collective' noun phrases are composed of members who must be 'distributed' in order to ascertain their membership of the generic set to which they all belong (every member of lawyer(L) is a lawyer in its own right). Suppose we have the half-built DRS for 'Three lawyers . . .':

$$\{\} \langle L \rangle$$
$$|L| = 3$$
$$\text{lawyer}(L)$$

Another way to represent this is:
So if the next word encountered is **met**, the continuation could be:

If the next word were **liked** the process would be more complicated. The obvious extension leads to the wrong semantics:

In fact this would be the correct semantics had the verb been part of a relative clause attached to ‘Two lawyers’. What is required is to open up another parallel distribution over individuals:
Of course, this prevents donkey anaphora. So this approach would fit well with the need to wait for the verb before deciding on treating a set as collective/distributive, since the verb can prevent certain readings. But taking such an approach means giving up DRT's ability to straightforwardly interpret donkey-anaphora, which would rather destroy the whole point of using DRT at all. It seems that incremental DRS-construction inevitably leads into the failure of donkey-anaphora. The next section offers a possible loophole.

So, all in all, I am not discontented with the route I have been persuaded to follow by the need to preserve donkey-anaphora. If DRT has proved a flexible means of representation for the data set of this thesis, and has allowed a considerable range of focusing effects on semantics to be modeled, as well as providing the means to fit focusing into the semantic framework which it clearly requires.

### 8.9 Semantic Dependence

In this section I group together a subset of the pronominal possibilities which are most obviously missing from the accounts I have given in the rest of this chapter, and offer some brief speculations on possible treatments.

- Non-restrictive relative clauses
- Relative Clause Genera
- Donkey sentences
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- Paycheck sentences
- Modal Subordination and related phenomena

The combined IF/DRT model should be a powerful framework for looking at cross-sentential semantic dependencies, such as are exhibited in modal subordination, paycheck sentences and related phenomena. I also ought to address the possibility of abstraction over non-quantified discourse markers, as is displayed in the following example from Hirst 1981 p. 5:

(336) Ross gave each girl a crayon. They used them to draw pictures of Daryel in the bath.

I believe that this whole class of phenomena which have proved difficult should be treated together as examples of semantic dependence. I believe that when a clause, phrase or nominal is semantically dependent on another, update on the dependent elements is not performed until the elements on which they depend have been completely semantically interpreted. As a consequence of this, the semantically dependent elements may provide potential foci for the following sentence. It is this which permits modal subordination, relative clause genera cross-sentential donkey-anaphora and relative abstraction. This hypothesis has been supported throughout this chapter and the previous chapters, and also by the experiments of Gernsbacher, Hargreaves and Beeman (1989), but remains at present unformalised.

(337) Modal subordination Every vegetarian keeps cats. He also has a beard and grows plants.

(338) Modal subordination A wolf might come to the door. It would eat you. (Craige Roberts)

(339) Relative clause genera A picture Bill painted sold for ten pounds. They usually fetch more.

(340) Abstraction I questioned every man who owned a monkey. Most of them admitted beating it.
Abstraction Ross gave each girl a crayon. They used them to draw pictures of Daryel in the bath.

These examples are all very acceptable. Yet similar examples seem to be ruled out:

(341) Every vegetarian keeps cats. #He is a good friend of mine.
(342) Every man who owned a donkey was very cooperative. #I wanted to give it the questionnaire too.

Taking them one by one, modal subordination involves a coreferential pronoun accessing a semantically subordinate antecedent. Such access was forbidden by Kamp (1981), and I have followed his lead. However it does appear that coreferential anaphors can under some circumstances result in the current DRS being conjoined to the matrix DRS at a lower ontological level. This can occur directly, as in the modal subordination examples above, or it can be mediated via an abstraction relation, as in the cross-sentential donkey anaphora example. This latter example has an interesting resemblance to coset, and I suspect with some ingenuity a system of constraints could be engineered which would account for the possibility of such discourses while ruling out the infelicitous versions.

Relative clause genera reflects the particularly close semantic dependency of a (restrictive) relative clause on the nominal to which it is attached — the nominal cannot be assigned a referent until the relative clause has been processed, and as a result its meaning is affected. This is not the case with non-restrictive relatives, which do not so easily produce the complex generic sets illustrated in (339).

The relative abstraction example shows that although the set of elements associated with the resultant set is not necessary (per se) in order to calculate the truth conditions of the quantified sentence, it is nevertheless highly accessible. This is an exception to the rule I noted in Chapter 6, that truth conditions and potential foci are intimately related. There are two possible causes: either that set is used in actual human semantic processing, or it is produced as an epiphenomenon of the quantificational process. I have already pointed out the close semantic dependence of the relative clause on the nominal to which it is attached. I also mentioned the cross-sentential donkey-anaphora
case, which seems particularly interesting since a DRS which is apparently conjoined at the default level can reopen the previous subordinate domain to access the object of the relative clause. There is the possibility of transitions both between and across ontological spaces. I claimed in Chapter 7 that 'focus transcends ontological boundaries' — it certainly seems that the noun-concept which provides instances at one level, sets at another and genera at the highest, can be accessed under certain conditions to produce antecedents for specific types of pronouns. This is what happens when discourse markers are 'constructed'.

It is possible that the theoretically elusive 'paycheck' sentences are also related:

(343) Abstraction Two farmers ordered a drink. One of them wanted ice in his, but the other wanted it without.

(344) Paycheck sentence John gave his paycheck to his wife but Fred gave it to his mistress.

(187a) Three farmers ordered a drink from the bar. #They wanted ice in it.

(345) #John gave some flowers to his wife but Fred gave them to his mistress.

The first of these four examples contains two simultaneous focus changes, both of which are executed in parallel. The first focus change involves two membership relations from the set of two farmers, while the second involves one generic membership relation and one 'paycheck type' relation. To me this suggests that paycheck sentences could be related to generic membership, and generic membership seems likewise implicated in the treatment of possessives, which have not been covered in this thesis. However a non-possessive example with an indefinite, which generates a generic set, does not have the same properties (345), so the answer is not straightforward. However I am optimistic that for all these examples the concepts of IF/DRT, particularly the two types of subordination, and the concept of focus change, could contribute to a unified and suitably constrained account.

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*Incidentally the two parallel membership relations deal with the whole set, something to which the processor must be sensitive, just as it must be able to detect when two sets are disjoint, as we saw on p. 181.*
8.10 Discussion

Before I conclude this chapter, I want to return to look at the differences between the semantically based-focusing theory developed in this chapter, and the IFnets, which were given a (partial) semantics in Chapter 6.

The IFnets were designed primarily to deal with pronominal preferences, while the extended DRT was built up from a theory intended to cope best with the semantic constraints on antecedent accessibility. The differences which result from their different commitments concern what is made explicit in the representation, and what is left to the semantic interpretation. These differences are summarised below:

1. In DRT projection of proper names and other discourse markers is explicit — in IFnets it is implicit in the semantics.

2. IFnets express explicitly which nominal or event syntactically subordinate units are parasitic on, while in DRT it is implicit in the ordering of DRS-conditions and in the overlap between conditions in terms of discourse markers.

3. When describing IFnets, I omitted to include examples containing relative clauses. This is because my notation was in fact incapable of expressing some of the discourse markers which seem to be available for pronominal reference. Take the following example:

(346) A man who works for the tax office came round today. They are usually very polite.

The second sentence contains a generic pronoun they. However the only generic set generated by the IFnets after the first sentence is that produced by the indefinite a man:
CHAPTER 8. DISCOURSE REPRESENTATION THEORY

When a sentence contains a relative clause, two units are created with one nominal in common. One unit represents the proposition expressed by the main clause, and the other the proposition expressed by the relative clause.

However, what the generic in the sentence intuitively refers to is not men but men who work for the tax office.

4. IFnets represent some sentences in an inherently ambiguous way. Disambiguation is achieved by applying verification rules in an order determined by focus. In IF/DRT, on the other hand, disambiguation has already occurred in the representation: so-called ambiguous sentences can simply be represented in different ways depending on context.

To me, these differences serve to highlight the areas of conflict between truth-conditional and anaphoric approaches to discourse which I have negotiated during the course of this thesis. The most common compromise I have had to make is between economy of interpretation and anaphoric transparency. The most interesting problem, I feel, is the temptation to let focusing take over all anaphoric connections, rather than incorporating the type of semantic dependency which Kamp (1981) introduced in order to account for donkey-anaphora. It remains to be seen whether incrementality and non-compositionality are compatible.

I found both notations hard to work with at times due to their inbuilt declarative nature: neither can distinguish a discourse marker when first generated from the same discourse marker after it has been restricted by a relative clause. The meaning is different, and the rules to interpret it allow for this, but I feel the ideal notation would be more procedural in nature, allowing progress through the sentence to be clearly marked. Semantic interpretation may be applied incrementally, but if so, needs its own mental representation: it would be simplistic to suggest that a hearer simply remembers all the possible interpretation functions, or stores the truth conditions of the entire discourse.

However, my aim has been to remain reasonably faithful to Kamp's original conception, which has been applied with success to many areas. I hope it will be possible now to
examine the interplay of focus and verification in those areas. The combined Focus/DRT framework remains compatible with a model-theoretic interpretation function, it captures the main focusing constraints and most of the focusing rules suggested by the incremental focusing algorithm. As a processing theory it is now much more economical; it is no longer necessary to store the entire history of the discourse, only a small proportion of the discourse referents created.

Achievements:

- **Focusing constraints were incorporated into DRT, by creating unit-based DRSs, which could be forgotten as the discourse progressed.**

- **Focusing preferences were incorporated by introducing a distinction between focused and unfocused discourse referents, ranking them by order of generation, and thereby adding a fully predictive pronoun resolution algorithm to Kamp's DRS-construction rule for pronouns.**

- **Focusing influences on DRS-construction were built in by allowing focused phrases to precipitate use of specific indefinites or ontological shifting.**
Chapter 9

Conclusions

This chapter contains a summary of the main achievements of each of the important chapters, a survey of the implications of the thesis for the various disciplines it ventures into, suggestions for further work, and a summary of the overall achievement of the thesis.

Summary of Chapters

The achievements of the chapters are as follows:

Chapter Three: Two Algorithms for Local Focusing I showed that neither the local focusing algorithm of Sidner (1979; 1981), nor the Centering algorithm of Brennan, Friedman and Pollard (1987) were compatible with assumptions of incrementality and economy. I found that focus-based theories were not compatible with incrementality and anaphor-based theories were inherently uneconomical.

Chapter Four: A Representation for Focusing This chapter introduced a preliminary version of IFnets for Sidner's algorithm. This enabled me to introduce two key concepts: 'focus change' and 'update units'. Recognising focus change was
to be important in Chapter 7, because the member/subset relation between antecedent and pronoun allowed me to preserve the properties of indefiniteness which would not have been possible with a coreferential pronoun. The focus relations also provided the data for the obvious strong link between focus and semantics demonstrated in Chapter 6. The idea of 'update units' helped to shed some light on the role of syntax in focusing, which is clearly important.

Chapter Five: An Incremental Focusing Theory A pure focusing algorithm was developed, which combined the resolution of intra- and cross-sentential anaphora using on-line pronoun resolution and partly incremental update. The compromise between anaphor-based and pronoun-based approaches proved to lie in equating focus with pronominal anaphora, allowing multiple foci, and running the algorithm off a minimal semantic net, the IFnet. The algorithm was justified with respect to the principle of economy from which a general focus-maintenance preference was assumed. The algorithm was given full pronoun resolution capacities by incorporating order of mention (approximately, grammatical salience) as a further source of hierarchical structure.

Chapter Six: Semantics of Discourse I showed that it is essential for a focusing theory to be based in semantics, since the truth conditional meaning of a noun phrase completely determines which discourse markers are created as potential antecedents for pronominal reference, while the truth conditional meaning of semantic operators controls which anaphor-antecedent relations are possible.

Chapter Seven: Focus and Scope Ambiguity In many ways the most important chapter, Chapter 7 showed that focused elements take wide scope over unfocused elements, as a consequence of the way mental representation determines semantic verification routines. I argued that linear ordering interacted with focus in governing the use of specific indefinites to escape distribution.

Chapter Eight: Discourse Representation Theory Kamp and Reyle's version of DRT was extended and altered in line with the discoveries of the previous chapters. The main changes involved introducing a focused/unfocused distinction between
CHAPTER 9. CONCLUSIONS

discourse markers, incorporating a pronoun resolver, giving rules for focus relations and, most importantly, introducing more incrementality into DRS-construction.

Implications

I will briefly suggest how the discoveries in this thesis could benefit the various disciplines from whence it originates.

Semantics The main way in which focusing can help semantic theories in general is by guiding the mapping from natural language to logical form. Taking predicate logic as an example, we have seen that focused noun phrases will generate quantifiers with widest scope, so focus determines ordering of elements in a formula. Focus also governs how formulae are likely to be conjoined.

The benefits for dynamic semantics, particularly DRT, are likely to be even larger. These theories aim to capture a greater range of discourse effects, particularly semantic constraints on discourse anaphora.\(^1\) The focusing theory I have given here provides a simple means to test out pronominal possibilities: these possibilities can lead to useful insights on semantic interpretation of noun phrases. Indeed, it was the possibility of donkey anaphora which inspired Kamp (1981) to devise DRT. Equally important, the impossibilities should help to rule out certain methods of verification.

Pragmatics I see focusing as part of the large and chaotic field of pragmatics. My principle of economy was based on the assumptions about communication made by Sperber and Wilson (1986). One way in which my theory benefits pragmatics is by making a small amount of it explicit enough to see its immediate impact on other disciplines (and vice versa). The minimal semantic nets I used in Chapters 4 to 6 can be seen as part of the larger discourse model a hearer constructs in response

\(^1\) Groenendijk and Stokhof (1989) go so far as to say "Like most authors, we start from the assumption that co-reference and anaphora are, by large semantic phenomena." (p. 45). The qualification, they add, is because syntactic features are also involved in pronoun resolution. Nowhere is any mention of the role of pragmatics.
to a text.

Whilst the validity of the semantic theory can be evaluated with respect to a model expressing relations holding between individuals and sets, the validity of the pragmatic theory must additionally be evaluated with respect to the coherence of the discourse which describes or generates such a model. I provide a simple heuristic to measure the degree of relevance a sentence has to the preceding context (p. 390), though I do not provide any measure of informativeness.

In the specific area of focusing, I hope I have been able to define at least my own usage of the term precisely, and shown that it performs a useful function, despite its complete exclusion from Levinson’s (1983) ‘Pragmatics’.

**Psychology** What I offer psychologists is an abstract yet experimentally testable theory of mental representation for discourse processing. I hope to have shown that the use of formal semantics is compatible with producing a psychologically plausible theory of pronoun resolution, indeed that formal semantics can be quite helpful both in offering ideas and theoretical rigour. I hope that these insights into language can actually reveal more about human thought processes in general, into the nature of memory and attention.

**Artificial Intelligence** My theory suggests that with a focus hierarchy on discourse elements, semantically ambiguous sentences need not pose a problem for the processor. The IF/DRT model does two tasks simultaneously: imposing focus and semantic constraints, as well as profiting from the feedback each can offer the other. In addition, I put forward my incremental focusing algorithm as an algorithm with the simplicity of the Centering algorithm, but with full pronoun resolution capabilities. Because it is incremental, it could augment or replace parallel processing in a system with time constraints on processing discourse.
Further Work

Although I have suggested many uses for the IF/DRT model, it is of course far from being complete. In this section I point out some of the more obvious developments likely to be needed.

One of the most interesting challenges to an incremental pronoun resolver is the phenomenon of cataphora. In some ways, the IF/DRT would absorb cataphora very easily. Simply extending what we have discovered for anaphora, it would be possible to say, for instance, that when a cataphoric pronoun is encountered, the processor will know that its referent is focused. Because of the focus maintenance preference it will also be fairly likely that the referent will itself be pronominal, and have an antecedent further back in the text, which may be semantically related to the cataphor:

(347) Some leaves brushed Mary's face. Catching hold of it, she pulled one of them off.

It is also possible to guess that the nominal for a cataphor will not come from a subordinate context; this means it will be possible to make more predictions about which readings will be obtained in scope ambiguous sentences. The vast majority of cataphors occur in syntactically subordinate phrases: there, too, it should be possible in conjunction with syntactic noncoreference rules to make better predictions about the structure of a DRS.

This brings me onto the second area of weakness in the IF/DRT model, which is its need for a firmer syntactic basis. Ideally, DRS construction should be governed by a mixture of focusing and a suitable incremental parsing model. Unfortunately, incremental parsing is not very common; the a possible candidate would be a parser based on categorial grammar (e.g. Pickering 1991), however there has been very little work on anaphora in this framework, and there is no equivalent of Reinhart’s (1983) c-command rules. Perhaps the IF/DRT model would help to distinguish the semantic and focusing effects which undoubtedly influence the grammaticality judgments of sentences like those given on p. 185.
CHAPTER 9. CONCLUSIONS

It would be useful to link up some of the work which has been done on VP ellipsis and linguistic focus Klein (1986); Rooth (1991): theories originating from syntax often have strong constraints between elements from which discourse focus is totally free. However in the collective/distributive ambiguity section, there did seem to be a tendency for the object and verb to cluster together: these effects are currently beyond the range of the IF/DRT model.

Another area of interest which has persistently emerged as important is structural parallelism (e.g. Asher 1991; Lang 1984; Frazier et al. 1984 etc.). This is another phenomenon which has begun to be studied in several different disciplines over the last decade, but has no unifying thread.

The most obvious next step is to consolidate or modify the theories presented in this thesis, by means of empirical and experimental work using a corpus and naive subjects.

Summary

The incremental focusing algorithm predicts antecedents on the basis of an underlying mental schema built up as the discourse progresses. The model contains minimal representations of the entities explicitly introduced. It is this mental model, I argue, which underlies the availability of antecedents. The model is constructed on the basis of syntactic and semantic information. This serves as a context for resolving future pronouns. Further information must also be accessed to resolve pronouns: lexical information and general knowledge. However this kind of information is more costly to draw upon. There are a great deal of possibly relevant inferences to be made and a range of possible effects on likelihood of different antecedents. Like Carter (1987) I felt justified for this reason in constraining the set of possible antecedents as much as possible beforehand, in order to minimise the search processes required to evaluate a particular choice.

In addition, I imposed on my model the requirements of maximum incrementality and economy. Incrementality was shown not to be a limiting assumption, but to make its own
contribution towards explaining the data, both focus preferences and semantic ambiguity effects. Economy was used to explain transition preferences in simple and semantically complex sentences: the least-effort assumption of focus maintenance could in some situations be abandoned if the effort of shifting was outweighed by other structure-changing operations.

All through the thesis I assume that the hearer has an intelligent strategy for guessing where the speaker's attention lies. Attention is very important, since even in the very small, artificial semantic 'worlds' that we have seen, the complexity and numbers of relations between referents is huge. Whatever the 'world' really looks like, there will be millions of referents and events which might be relevant to the discourse. The speaker must be able to signal to the hearer which particular subsets are relevant. The hearer must be attending the right set of objects in order to interpret the speaker's utterance. It is not surprising then that focus should guide verification. As a result, there may be several different ways to verify one sentence, thereby giving it different truth conditions in different focus contexts. On the other hand, several different methods of verification might have effectively the same truth conditions. So meaning is more than truth conditional, since it depends on the hearer's evaluation of the speaker's intentions as well as the state of the world. The interaction works both ways: the occurrence of pronominal reference gives a clue as to how sentences are interpreted, while the truth conditions of sentences gives a clue to possible pronoun references. Likewise, focus update can offer clues on when a new interpretation function is required for a section of text, while the DRSs proposed to interpret sentences offer clues on when focus update occurs.

My conclusion is that the focusing stores Sidner proposes as necessary between syntactic form and pronoun resolution are intimately related to the semantic representation Kamp proposes as necessary between syntax and verification. Both are attempts to capture the underlying memory structure for discourse.

The main aim of the thesis was to show that pragmatics (focusing) and semantics (particularly quantification) are interdependent in a particularly interesting way. The entities which may be focused are determined by semantic interpretation, and focusing
in turn determines semantic interpretation. I was able to demonstrate this informally in Chapters 6 and 7, and to put forward a formal framework for the theory in Chapter 8. I showed that combining focusing and DRT does not simply result in a model which utilises both semantic and focusing theories, but in a model with capabilities which neither alone possesses.

Achievements:

- The thesis successfully integrates focusing and DRT.
- I show that not only can focusing determine a 'suitable' antecedent for a pronoun, but it also removes the problem of semantic ambiguity occurring in a psychological or computational system.
- I show that a focusing algorithm chooses antecedents from an underlying semantic representation, whose form is determined directly by the truth-conditional meaning of the discourse.
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Appendix A

Sidner’s Algorithm

Rule for pronoun in agent position:

Sidner 1979 (pp. 147 – 148):

1. **Focus Sets:** If there is no DF or AF, try to construct a focus set from all animate antecedents.
2. **Backwards non-antecedent pronoun:** If there is no DF or AF, assume cataphora.
3. **Recency Rule:** If the pronoun is sentence-initial and a member of PDL was last in the previous sentence, resolve the pronoun to that PDL member.
4. **Dominant Discourse Focus Rule:** If DF is more longstanding than AF, choose DF.
5. **Potential Actor Ambiguity Condition:** If the pronoun could cospecify either AF or one (and only one) animate member of PAFL then it remains ambiguous.
6. **Basic Actor Rule:** Predict AF
7. **Plural Condition:** If the anaphor is a plural one, and AF is singular, predict AF plus an animate member of PAFL, or plus AFs.
8. **Alternative Actor Rule:** Take the members of PAFL, one by one according to the ranking given in the Actor Focus Ordering Mechanism.
9. **Actor Stack Use:** See if the pronoun could cospecify AFs.
10. **Discourse Focus Rule:** Otherwise predict DF.
11 **Conversational Association:** If the pronoun is plural and the df singular predict conversationally associated elements of df. If the pronoun is singular, and there are several different conversational associations, the pronoun is ambiguous.

12 **Alternative Discourse Focus Rule:** Try a member of pdfl.

13 **Backwards Cospecification:** Assume the pronoun is cataphoric.

14 **Fail:** Pronoun has no cospecifier.

Sidner 1981, p. 230:

1 **Recency Rule:** When a pronoun is in subject position and is the initial phrase in a sentence, and if a member of the potential (discourse or actor) foci occurs as the last phrase in the previous sentence, test the pronoun for cospecifying with that potential focus.

2 **Theme Rule:** When the pronoun occurs in an embedded sentence, if the embedded sentence is marked as having a theme that is either df or af, test the focus in that theme position as the cospecifier of the pronoun.

3 **Potential Actor Ambiguity Condition:** If the pronoun could cospecify either af or one (and only one) animate member of pafl choose af but indicate ambiguity.

4 **Pronominalized Actor Focus Rule:** When the actor focus was last mentioned with a pronoun, choose af. Otherwise try one of pafl, but the pronoun use is odd.

5 **Plural Rule:** If the anaphor is a plural one, and af is singular, try a generic reading (for non-human af), then predict af plus an animate member of pafl, then all pafl together, df and pdfl.

6 **Basic Actor Rule:** Predict af.

7 **Alternative Actor Rule:** Then the members of pafl, one by one according to the ranking given in the Actor Focus Ordering Mechanism.

8 **Discourse Focus Rule:** See if the pronoun could cospecify df.

9 **Alternative Discourse Focus Rule:** Try a member of pdfl.

10 **Actor Stack Use:** Otherwise predict afs.

11 **Backwards Cospecification:** Assume the pronoun to be cataphoric.
Rule for pronoun in non-agent position

Sidner 1979 (p. 149):

1 **Focus Sets:** If there is no DF, predict similar sets as referent for the pronoun.

2 **Recency Rule:** If the pronoun is first in the sentence and a member of the PDFl was last in the previous sentence, resolve the pronoun to that member of the PDFl.

3 **Plural Condition:** If the anaphor is a plural one, and DF is singular, predict DF plus a member of PDFl or DFS.

4 **Basic Rule:** Predict DF.

5 **Conversational Association:** If several conversationally associated elements of DF can be combined, and the pronoun is plural, resolve it to them. If the pronoun is not plural it is ambiguous. If there is one element, choose it.

6 **Discourse Focus Ambiguity Condition:** If anaphors co-specify\(^2\) both DF and some member of PDFl, then take as focus whichever is not in agent position. If both are non-agents, retain DF unless only the element of PDFl is mentioned with a pronoun, in which case move the focus to that member.

7 **Alternative Rule:** Go through the members of PDFl one by one as they are ordered by the Focus Ordering Mechanism.

8 **Actor Focus Rule:** Otherwise, predict AF

9 **Alternative Actor Focus Rule:** or a member of PAl.

10 **Backwards Cospecification:** Assume the pronoun to be cataphoric.

11 **Fail:** The pronoun does not have a cospecifier.

Sidner 1981 (p. 230):

\(^{2}\)This rule was not included in Sidner's (1979) final version, but given in Chapter 2, p. 78. This early version of the algorithm was simpler, omitting plural rules for instance. The basic ordering was DF, PDFl, DFS, and implicit relations to these three.
APPENDIX A

1. **Recency Rule**: When a pronoun is in subject position and is the initial phrase in a sentence, and if a member of the potential (discourse or actor) foci occurs as the last phrase in the previous sentence, test the pronoun for cospecifying with that potential focus.

2. **Basic Rule**: Default condition: predict DF.

3. **Alternative Rule**: Then PDFL.

4. **Actor Focus Rule**: Then AF.

5. **Plural Pronoun Rule**: If the anaphor is a plural one, and DF is singular, try a generic reading (for non-human DF) then PDFL, followed by AF.

6. **Focus Related Item Rule**: See if a discourse entity has been related to the focus during the discourse.

7. **Focus Stack Use**: See if the pronoun could co-specify DFS.

8. **Backwards Cospecification**: Assume the pronoun is cataphoric.

9. **Fail**: A cospecifier cannot be found for the pronoun.

The Centering Algorithm

**Construction**

1. Create a list *sentence-NPs* of all the NPs occurring in the current sentence. Order *sentence-NPs* by grammatical role.

2. Take the subset *anaphors* of *sentence-NPs*.

3. Take the list of potential antecedents from the previous sentence, *potential-antecedents*, ordered by grammatical role.

4. Create a list-of-lists containing all possible combinations of bindings of the *anaphors* to *antecedents* (members of *potential-antecedents*), taking into account agreement constraints.

5. Create a list *possible-foci* of possible foci from the previous sentence. *Possible-foci* will contain all the members of *potential-antecedents* plus NIL, the empty focus.
6. Create a list of anchors combining all possible pairings of possible-foci with the lists in list-of-lists. In other words, each anchor will contain a possible-focus and a list of pairs, anaphor-bindings.

Filtering

For each anchor the following three filters are applied.

1. Filter by contraindices. That is, eliminate anchors in which two anaphors which are syntactically forbidden from being co-referential have the same antecedent.

2. Take the first element of potential-antecedents which appears as an antecedent of one of anaphors in the anchor. If this is not the same as the possible-focus, then eliminate the anchor.

3. If one or more of the anaphors is a pronoun, but the possible focus is not pronominal, eliminate such an anchor.

Ranking

1. Rank the anchors. The one with the highest score is chosen. Its possible-focus and sentence-NPs becomes the DF and potential antecedents of the next sentence.

Refined Centering Algorithm

1. The centering algorithm uses the store DF and also the store PDFL, consisting of all the other potential antecedents from the matrix sentence except the focus, ordered by grammatical role.

2. Take the first anaphor in the current sentence (ordered by grammatical role).

3. Try to resolve it to the DF. If this succeeds, it is a Continuation (DF is maintained as focus of the current sentence).
4. If this fails try to resolve one of the other anaphors to the DF (This is a retention).

5. Try to resolve the first anaphor in the current sentence to the highest member of pDFl, ordered by grammatical role. (This is a shift-1).

6. If this fails, try to resolve one of the other anaphors to the highest member of pDFl. (This marks a radical shift).

7. Cycle through the last two rules for the second highest member of pDFl, then the third highest, and so on.

The Incremental Focusing Algorithm

Antecedent choices:

When a pronoun is encountered, choose its antecedent using the following defaults:

1 PRIMARY RULE: Predict a Fisc member.
2 MATRIX RULE: Then try DF
3 SUBORDINATE RULE: Predict sub-Fisc
4 SUBORDINATE RULE: Predict sub-Risc
5 SECONDARY RULE: Predict a member of Risc
6 POTENTIAL RULE: Predict one of pDFl
7 STACK ACCESS: Try the focus stack

Constructing a derived nominal is considered immediately after the rule accessing the antecedent nominal.

Incremental Update

Whenever a noun phrase is encountered:

If it is definite (a proper name), add its nominal to the current Risc (this will be the main rule: if the indefinite is attached to the main verbal unit, and a temporary sub-Risc if the indefinite was attached to a subordinate unit).
If it is a singular indefinite, add its (specific) nominal to the current RISC (this will be the main RISC if the indefinite is attached to the main verbal unit, and a temporary SUB-RISC if the indefinite was attached to a subordinate unit), add its generic nominal to a sub-RISC subordinate to the specific nominal.

If it is plural and quantified, add its singular instance nominal to the current RISC, and add its generic (initial set) nominal to a sub-RISC subordinate to the instance nominal, and its plural resultant nominal also to a sub-RISC subordinate to the instance nominal.

If it is pronominal and coreferential, transfer a nominal from one of the focus stores into FISC (or a temporary sub-FISC, if the pronoun occurs in a subordinate unit).

If it is pronominal and non-coreferential, add its derived nominal to the current RISC (this will be the main RISC if the pronoun occurs in the main verbal unit, and a temporary SUB-RISC if the pronoun occurs in a subordinate unit).

End-of-unit update:

Whenever the end of a coordinate unit is reached:

Clear PDFL stack DF in DFS, move FISC into DF and move RISC into PDFL. Clear FISC and RISC.

At the beginning of a subordinate unit, begin a sub-RISC to deal with the new nominals in that unit.

When the end of a subordinate unit is reached, add its sub-RISC to the end of PDFL, and its sub-FISC to the end of DF.
Appendix B

Examples containing plural combinations

A list of examples is given below to show possible versus infelicitous combinations (the combinations being probed are shown in brackets):

Agent pronouns

AF plus PAFL John took Bill to the theatre. They saw 'Arms and the man'. (John and Bill)

AF plus PAFL Julian watched the entire box of lego shower over Rachel. *They couldn't stop laughing. (Julian and Rachel)

AF plus AFS John bought his car in Italy. Mary bought her motorbike there too. They paid good prices for them. (John and Mary)

all PAFL Leonora saw Mary kissing John. They looked very happy. (Mary and John) or all (Mary, John, Leonora)

DF plus AF The dog was whining. John took it for a walk. They passed the old gas works. (John and the dog)

DF plus PDFL John put the lid on the pot. They were exactly the same shade of blue. (The lid and the pot)\(^3\)

\(^3\)Also works with non-discourse-initial examples: [DF plus PDFL] 'John picked out a lid. He put it on the pot. They were exactly the same shade of blue.'
DF plus PDFL John put the box on the table. *They wobbled slightly. (The box and the table)

DF plus PDFL or all PAFL Tamsin ran in. John introduced her to Marilyn. They hated each other immediately. (Tamsin and Marilyn)

DF plus DFS John bought his car in Italy. Mary bought her motorbike there too. They were very cheap. (John’s car and Mary’s motorbike)

PAFL plus AFS Bill bought his car in Italy. John took Mary for a ride in it. *They had the same taste in cars. (Bill and Mary)

all PDFL or AF plus PAFL A bone landed in the alley. Fido snatched it before Tiddles could touch it. *They fought all night. (Fido and Tiddles)

DFS plus AFS John married Mary in the cathedral. I went to see it recently. They had engraved their initials in the vestry. (John and Mary)

The examples are altered slightly to compare non-agent pronouns.

non-agent pronouns

AF plus PAFL John took Bill to the theatre. It cost them a lot. (John and Bill)

AF plus PAFL Julian watched the entire box of lego shower over Rachel. *Even that could not amuse them. (Julian and Rachel)

AF plus AFS John bought his car in Italy. Mary bought her motorbike there too. I persuaded them to tell me where. (John and Mary)

all PAFL Leonora saw Mary kissing John. The street-lamp was shining in their hair. (Mary and John)

DF plus AF The dog was whining. John took it for a walk. An old lady attacked them in the park. (John and the dog)

DF plus PDFL John put the lid on the pot. ?He had mended them the day before. (The lid and the pot)
Tamsin ran in. John introduced her to Marilyn. *He loved them both.  (Tamsin and Marilyn)

John bought his car in Italy. Mary bought her motorbike there too. That accounts for why they fell apart within two months.  (John’s car and Mary’s motorbike)

Bill bought his car in Italy. John took Mary for a ride in it. *He was jealous of their friendship.  (Bill and Mary)

A bone landed in the alley. Fido snatched it before Tiddles could touch it. I tried to make them share it.  (Fido and Tiddles)

John married Mary in the cathedral. I went to see it recently. I found their signatures in the book.  (John and Mary)

Examples containing generics

Some examples are shown below to illustrate the range of generic possibilities:

generic non-human The dogs rushed into the bakery. They do not usually eat bread...  (Dogs in general)

generic John bought a car in Italy. They are essential for getting from one place to another.  (Cars in Italy)

generic John bought a car in Italy. He decided that they were essential for getting from one place to another.  (Cars in Italy)

generic John went to a football match. *They often have strange tastes.  (Johns?)

generic The two Scots went to a football match. *They often have strange tastes.  (Scots in general)

generic An off-duty policemen went to the football match. They are taught to relax in large violent crowds.  (Policemen in general)
An off-duty policemen went to a football match. Unfortunately nobody likes them to be there. (Policemen in general)