Logic,

Information

&

Conversation

Printed by Print Partners Ipskamp, The Netherlands
Cover Design and Lay Out by Paul Piwek in LaTeX

Logic, Information and Conversation

PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Technische Universiteit Eindhoven, op gezag van de Rector Magnificus, prof.dr. M. Rem, voor een commissie aangewezen door het College voor Promoties in het openbaar te verdedigen op dinsdag 10 november 1998 om 16.00 uur

door

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geboren te Venlo

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To my parents

Acknowledgments

First, I would like to thank my supervisors Don Bouwhuis, Harry Bunt and Robbert-Jan Beun for giving me the opportunity to write this dissertation.

Thanks are due to René Ahn, Tijn Borghuis, Anita Cremers, Emiel Krahmer, Mariët Theune and Kees van Deemter for commenting on the contents of one or more chapters. Special thanks to Emiel with whom I had the pleasure of co-authoring two papers which form the building blocks of chapter 3. I cannot imagine how I could have written this dissertation without having been exposed to Emiel's positive and energetic approach to doing research. Furthermore, I recall with pleasure the long philosophical discussions with René in the train between Tilburg and Eindhoven (one should not underestimate the time it can take the Dutch railways to get from Tilburg to Eindhoven). I consider myself very fortunate to have had the opportunity to benefit from Kees' ability to spot the weak points of a theory. His comments, though often critical, were always constructive.

I would like to thank the following people for asking pertinent questions and making useful suggestions at some point during the preparation of this dissertation: Nicholas Asher, Hans Kamp, Leen Kievit, Peter Krause, Steve Berman, Barbara Partee, Remko Scha, Marc Swerts, Jacques Terken, Jan van Kuppevelt, Margriet Verlinden, Henk Zeevat, Ede Zimmermann and everybody I forgot to mention. Furthermore, thanks are due to all the people at IPO and the Computational Linguistics Group at Tilburg University who made those places such pleasant environments to work in.

The research reported in this dissertation was carried out for the largest part at the Centre for Research on User-System Interaction (IPO) of the Eindhoven University of Technology, and for a smaller part at the Computational Linguistics Group of Tilburg University. My PhD. project was part of the DENK project (Dialogue Management and Knowledge Transfer). DENK was financed by the Co-operation Centre of Tilburg and Eindhoven Universities (SOBU).

Finally, thanks to Eric, Erwin, Bert and Dimitri for helping me to get my mind off work in the discos of places such as Geldern, Marmaris and L'Escala.

Brighton, September 1998

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Introduction

The aim of this book is to contribute to the development of a theory of conversation. On the surface, a conversation is a sequence of (possibly overlapping) utterances. We are interested in the question *what makes such a sequence into a conversation?* This question is approached by likening the utterances of a conversation to the moves in a *game*. Thus, we ask: *what kind of a game is a conversation?* Wittgenstein (1953) was one of the most prominent proponents of the idea that language use is a game-like activity.

A game can be characterized in terms of the *states of the game* and the *rules* that regulate the transitions between the states of the game. Therefore, in order to model conversation as a game, henceforth a *conversational game*, we need to specify the states and state dynamics of this conversational game (cf. Hamblin, 1971; Stalnaker, 1978 and Lewis, 1979). In part I of this book, we introduce the formal tools to do so. Part II deals with the state changes that individual utterances give rise to. Finally, in Part III we focus on the influence of conversational rules on sequences of utterances.

Before providing a summary of each of the aforementioned parts, we describe the assumptions underlying our model of conversations. We deal with issues of adequacy of a conversational model and introduce logic as a tool for modelling conversations. Furthermore, we indicate what part of the context in which conversations occur is covered by the conversational state. Finally, we provide some background about the notion of information that is used throughout this book.

Adequacy

The adequacy of a conversational game as a model of conversations depends on how well it accounts for the patterns that occur in naturally occurring conversations. These patterns are the data that the game is to explain. The patterns that we take as a basis will be derived from both naturally occurring and constructed conversations, where the latter are intended as conversations that could have occurred naturally.

Conversation analysts (e.g., Sudnow, 1972) and discourse analysts (e.g., Stenström, 1994) have examined naturally occurring conversations and provided detailed descriptions of the patterns that occur in such conversations. These descriptions are mainly in terms of a non-technical vocabulary that is directly related to the everday ways of speaking about conversation. The description of a pattern may use a vocabulary consisting of the terms such as ‘question’, ‘answer’, ‘request’, etc.

Although the descriptions that are arrived at in this way are valid, they rely heavily on the judgements of the person that analysed the conversation. This informer labels certain utterances as questions, others as answers, etc. In doing so, he or she uses his or her implicit understanding of the utterances at hand. A model in terms of a game is intended to provide an explicit basis for such high level descriptions. This is achieved by relating the move —i.e., the state transition— that an utterance gives rise to directly its syntactic and prosodic *surface form*.

In addition to the aforementioned naturally occurring conversations, constructed fragments of conversation are useful as a means for testing the predictions of a theory. The adequacy of the theory can be put to the test by checking whether the analysis that the theory assigns to some fictitious stretch of conversation corresponds with the judgements of a human informer. Ideally, such judgements should be elicited through questions which directly match the everyday concepts of the naive informer (see, in particular, section 3.4).

The sort of adequacy that we have discussed up till now is indifferent with respect to the relation between the conversational game and the mental states of the persons that are involved in a conversation. Since naturally occurring conversations involve real people, it is legitimate to inquire into the relation between a conversational game and the mental states of the interlocutors.

To get things into perspective, consider the relation between a description of the game of chess and the mental states of some individual that is playing the game. The description of the game (the board, the chess pieces and the legal moves) need not say anything about the way a player represents this game internally. Human players should, however, be able to represent the game somehow. Similarly, it makes no sense to provide a description of a conversational game which cannot be played by human beings.

For practical purposes, a description of the conversational game which allows a computer programme to play the game is attractive. It makes it possible to explore the patterns that are accounted for by the conversational game. The exploration can be carried out by having the computer programme play with a copy of itself (see, e.g., Power, 1979) or with a human being. The model described in this book has been developed partly on the basis of our experiences with an implementation of a conversational game. This implementation was carried out as part of the DENK project (see Ahn et al., 1995; Bunt et al., 1998).

Logic as a Tool

In order to provide an adequate model of conversations, we need the tools to construct such a model. What requirements does the nature of conversations impose upon such a tool? Primarily, conversations involve the exchange of information. The conversational state keeps track of the information that has been exchanged in the course of a conversation and the information that was already public before the conversation started.

In the course of this book, we will show that much of language behaviour can be explained in terms of the quest for *consistent information* by conversational partners. In order to strive for consistency, it is necessary to disinguish consistent from inconsistent information. Since an inconsistency might be implicit in some body of information, a tool is needed for bringing inconsistencies into the open.

At this point, *logic* enters the picture. Logic —the study of correct reasoning— provides the means to bring to light the inconsistencies that might be hidden in a body of information, such as a conversational state. Given a body of information, it tells us how to set up a chain of inferences which leads up to some piece of information that was implicit in the body of information. For instance, the *modus ponens* rule of logic says that on the basis of Φ and Φ *implies* Ψ, we may infer that Ψ. The following argument, which reveals the implicit information that 'One can not drive in Mike's car', is licensed by the modus ponens rule:

(1) If the motor of a car is broken, then one cannot drive in it. The motor of Mike's car is broken.
THEREFORE One can not drive in Mike's car.

Now, if the rules of logic allow us to infer some piece of information and its negation from a body of information, then that body of information is inconsistent.

Conversational States and Context

In the chapters to come, the notions of a context and a conversational state are used interchangeably. The term context is, however, often used in a much wider sense than the one that we employ. In this section, we point out in which respects our notion of context is more restricted than the usual one.

Commitment In our view, the conversational state or context directly constrains the behaviour of the interlocutors: they are supposed to strive for actions that are

compatible with the informational content of the conversational state. We discuss this role of conversational states in detail in part III. There, we distinguish between the compability of physical actions versus communicative actions with the conversational state. For instance, we propose that if the conversational state contains the information that one of the interlocutors is going to perform some action, then the conversational game prescribes that he should indeed perform that action (e.g., after an interlocutor has said that he is going to the cinema, this action is recorded on the conversational state as a commitment of the interlocutor). The compatability of communicative actions with the conversational state is explicated primarily in terms of consistency. For instance, the presuppositions of a communicative action should be consistent with the information that is already part of the conversational state (cf. Stalnaker, 1978; chapter 3, this book).

In line with the aforementioned view on the conversational state, and following Hamblin (1970), we use the term *commitments* for the informational items that make up the conversational state. In part III, we propose that *if an interlocutor A asserts some sentence S which expresses the proposition* Φ*, then it will become a public commitment that A is committed to* Φ. Let Γ be the conversational state after the assertion, and $C_A\Phi$ means *A* is committed to Φ. In that case, we can write $\Gamma \vdash C_A\Phi$ to state that $C_A\Phi$ holds in the conversational state Γ. We call $C_A\Phi$ the *utterance meaning* and Φ the *sentence meaning* of the aforementioned utterance of the sentence *S*.

At this point, let us address the relation between the term 'commitment' and such everyday words as 'belief' and 'intention'. Should we equate commitment with what we normally call belief? In other words, should the utterance meaning $C_A\Phi$ be equivalent to $B_A\Phi$ (i.e., *A* believes that Φ)? Moore's Paradox appears to provide some evidence for that position. The paradox involves the following sentence:

(2) It rains, but I do not believe that it rains.

That is, a sentence of the form Φ*, but I do not believe that* Φ. Moore points out that although the sentence meaning is not self-contradictory, the utterance as a whole does seem to be self-contradictory. We can explain this by assuming that $B_A\Phi$ is the utterance meaning of a declarative sentence with a sentence meaning Φ and a speaker *A*. The utterance meaning $B_A(p \wedge \neg B_A p)$ of (2) (where p is the proposition *it rains*) is indeed self-contradictory, given some plausible axioms for belief (see Thijsse, 1994;1998).

Thijsse (1994;1998), however, points out that the formalisation of utterance meaning in terms of B_A is deficient. In particular, it cannot account for the anomaly of 'It rains, but I do not know that it rains'. After careful analysis of examples likes the latter, Thijsse proposes that the utterance meaning of a declarative sentence with content Φ and speaker *A* is $B_A K_A \Phi$ (where $B_A K_A$ stands for *A believes to know*. It may be paraphrased as ‘A is convinced that’). This finding can be incorporated into our framework by adding an axiom to Γ which says that *for any proposition* Φ, $C_A \Phi$ *is equivalent to* $B_A K_A \Phi$.

Interestingly, there are also utterances involving the verb ‘intend’ which appear to be pragmatically anomalous. Consider, for instance:

(3) I will open the door, but I do not intend to do it.

On the basis of example (3) we might be tempted to conclude that a person intends to do something if he or she believes that he or she will do it. This would give us a handle to explain the anomaly of (3). Compare, however:

(4) I will loose the match, but/although I do not intend to loose it.

If intention and belief in a future action were indeed the same, then (4) would have to be anomalous. The utterance meaning would then fit the pattern $B_A(p \wedge \neg B_A p)$ from which a contradiction can be derived. It seems that for an agent to intend to do something, it is not sufficient that the agent believes that he will do it. We propose the following analysis: for an agent to intend an action, he or she should not only believe in performing the action, but also have *control* over the action.

The anomaly of (3) now follows from the fact that people are normally assumed to be in control of whether they will or will not open a door. Therefore, the negation of ‘I intend to open the door’ — which we analyse as I believe I will open the door and I have control over myself opening the door’— can only mean that ‘I do not believe that I will open the door’[1], which gives us an utterance meaning of (3) which is equivalent to the utterance meaning of Moore’s example.

For (4), the denial of the intention comes down to the denial of being in control, not to the denial of the belief that one will loose.[2] Thus we get: *I am convinced of the following: I will loose the match, and I believe that I will loose it and that I have no control over whether I loose it*. In this case, no inconsistency can be derived on the basis of the utterance meaning. This is in line with the intuition that the sentence can be uttered felicitously.

Common Ground In line with the pioneering work of Stalnaker (1974;1978) and Lewis (1979), we take the conversational state or context to consist of the information that is *public* to the conversational partners, i.e., their *common ground*. Intuitively (and according to the best known formalizations of the term common

ground, cf. Clark, 1996), if some piece of information is common ground, then it is also common ground that it is common ground. Furthermore, it will also be common ground that it is common ground that it is common ground, and so on.

This property of the common ground is appropriate for the conversational state. The conversational state is updated in the course of a conversation. After the following exchange: ‘*A:* The earth is flat *B:* Yes, she is’, we might ask the interlocutors which information has been exchanged as a result of the conversation. We contend that the answer would be that it has become public (amongst *A* and *B*) that the earth is flat. What is more, it has also become public that it is public that the earth is flat (and so on).

There is another property of the common ground which turns out to be crucial for the modelling of conversational structures (see chapter 6). The property is that if it is common ground that *A* is committed to Φ and that *B* is committed to Φ, then it is common ground amongst *A* and *B* that Φ. In other words, if it is common ground that *A* and *B* share the information Φ, then Φ is common ground.

For modelling the structure of conversations, the first mentioned property of the common ground plays only a minor role. On the basis of the first and the second property we can, for instance, predict that after *A* has said that the earth is flat, it is uninformative with respect to the conversational state for *B* to say that *A* is committed to the earth’s flatness.

Clark (1996) distinguishes between the *communal* and the *personal common ground*. Whereas the latter is directly based on joint perceptual experiences, the communal common ground consists of information that people share by virtue of being part of a cultural community. Communities can be based on, amongst other things, language, nationality, profession, religion and hobbies.

Although conversations always take place against the background of a communal common ground, it is the personal common ground which is directly acted upon in a conversation. Whereas the personal common ground changes in the course of a conversation, the communal common ground is normally static within the bounds of a conversation. The distinction between the *dynamic* and the *static* part of the context can also be found in Bunt (1994), who speaks of the *local* and the *global* context, respectively.

We do not take the common ground to be an entity that exists independently of the individual language users. This means that when we describe the rules and states of a conversational game, we should bear in mind that a player in a conversational game will always act on the basis of *his or her representation* of the conversational state. This allows for situations where different players have different representations of the conversational state.

Context in DENK We take the conversational state or context to consist of public information, where each informational item represents a public commitment. This notion of context is sufficient for defining a conversational game, but falls short when it comes to specifying how an agent could *play* such a game. A full system for playing conversational games has been implemented in the DENK project[3] (Bunt et al., 1998). This book was written as part of the DENK project. Let us explain how the notion of context that we describe here fits into the broader notion of context that is employed in the DENK project.

The DENK architecture is based on a simple conversational situation involving two interlocutors and a domain of conversation. The domain of the conversation consists of (1) that part of the world that the conversation of the interlocutors is about and (2) that part of the world which they can directly *manipulate* and *observe*. Ideally, the part of the world that can be talked about and the part that can be manipulated and observed are the same. This does not mean that every *aspect* of the domain that can be talked about can also be observed directly. For instance, regularities in the world (e.g., every time event e_1 occurs, event e_2 occurs as well), can be talked about, but are not accessible via direct observation: a single observation cannot verify a statement that quantifies universally over times (though it may falsify it).

In DENK, the context is equated with the conversational domain, the representations that the interlocutors maintain of the domain and the state of the conversation. In addition to what we call the conversational state, this wider notion of context involves the domain of conversation and the representation that each interlocutor privately maintains of this domain. Whereas the conversational state determines the legal moves that are available to an interlocutor, the remaining context provides the information for choosing a particular move from the available set of legal ones.

Consider, for instance, a situation in which interlocutor *A* has asked *B* a question. In that case, the conversational state will require that *B* reacts in an appropriate way to the question, for instance, by providing an answer. Furthermore, the answer should be compatible with the information that is already part of the conversational state (see chapters 4 and 6 for details). In other words, a legal move by *B* might consist of an answer that is compatible with the conversational state.

Within these boundaries *B* still has a lot of freedom with regards to determining the actual answer. Suppose that *A* asked 'Are there still any cookies in the cupboard'. 'Yes','no' and 'I do not know' would be legal responses by *B*. Which of the three is the actual answer might be based on *B*'s *private information* about the domain of conversation. *B* might choose to provide an answer that is licensed by *B*'s private information. For instance, if *B* thinks that there are cookies in the

cupboard, then *B* says so. The DENK prototype employs precisely that tactic. However, other tactics are conceivable. If *B* knows that there is only one cookie left and wants to eat it, *B* might answer 'no' although *B* knows that there still is a cookie.

Note that in the latter situation, *B* is still adhering to the conversational rules. However, *B* violates a rule that might be said to be presupposed by the conversational game, i.e., *try to make your contribution one that is true*. Grice (1975) termed this the maxim of Quality.[4]

Our notion of a conversational state excludes the information that is privately available to the interlocutors. Furthermore, we do not distinguish between public information obtained through conversation and public information obtained by means of joint perceptual observations on the domain of conversation. In the DENK system, observations on the domain are explicitly dealt with.

The setup which we have described —i.e., two interlocutors and a domain of conversation— may be called the generalized DENK situation. The DENK architecture itself was conceived of as a new paradigm for human-computer interaction. Take a situation in which a user can directly interact with some application. Now, the DENK architecture is obtained by adding a cooperative assistant to this situation. This assistant, which is a software agent, is able to converse with the user about the application and directly interact with the application.

The connection with the generalized DENK situation is obvious: the interlocutors are the user and the cooperative assistant and the domain of conversation corresponds to the application. For the DENK prototype, the application consists of the simulation of an electron microscope. A cross-section of the microscope and its control panel are graphically displayed to the user. The user can directly manipulate this microscope or engage in a conversation with the cooperative assistant about the application. The language of the user is a fragment of English. The assistant handles questions, (indirect) requests and assertions. Furthermore, the assistant is able to directly manipulate the application (in response to requests from the user) and observe the state of the application (in order to answer questions from the user).

The cooperative assistant is implemented in PROLOG. It consists of four main modules: a syntactic analyser which uses a grammar which is written in an extension of HPSG[5] (Verlinden, forthcoming), a semantic interpreter, which builds up an underspecified representation of an utterance and uses contextual information to fill in the underspecified parts (Kievit, forthcoming), a dialogue manager, which controls the interaction process, and determines the reaction on the basis of a representation of the context (see the references at the end of this chapter), and finally a module for reasoning about the domain and observing it (see Ahn, forthcoming).

Information and Context

The cooperative assistant of the DENK project maintains formal representations of the context. These representations belong to a class of formal systems known as *Pure Type Systems* (PTS; Barendregt, 1992). PTS is a generalization of *typed lambda calculus* (Curry, 1943; Church, 1940). In particular, in DENK the informational content of the conversational state, which is dealt with in this book, is modelled in PTS.

Incidentally, the formal objects that PTS provides for modelling conversational states are called *contexts*. Such a formal context in a PTS is a sequence of introductions of objects. Each of these introductions is of the form $V : T$, where V is a variable and T is the type of the variable. The variable V stands for an arbitrary object of type T. Therefore, we will often speak of the (arbitrary) object V.

A PTS context contains *information* in the following sense: it records which types are inhabited, i.e., for which types there are objects belonging to those types. We can do logic in a PTS because propositions can be seen as types. This insight is known as the *proposition as types* interpretation of typed lambda calculus (Curry and Feys, 1958). Propositional types are inhabited by proofs. In other words, if the context introduces an object as belonging to a particular proposition, then this object should be seen as standing for a proof of the proposition.

PTS encompasses rules which describe how the objects and the types that are available in a context can be used to *construct* new objects and types. Consider a context Γ containing the introductions $a : p$ and $f : p \to q$. In words, according to the context Γ there is a proof a for the proposition p and a proof f for the proposition $p \to q$. In line with Heyting's constructivist explanation of implication (Heyting, 1956), a proof for $p \to q$ corresponds to a method for obtaining proofs of q from proofs of p. In terms of a PTS, this is translated into: *a proof for* $p \to q$ *is a function from proofs of* p *into proofs of* q. Thus, f can be used to construct a proof of q from the proof a of p by applying f to a; we obtain the proof $f \cdot a$ ('$\cdot$' stands for function application) of q. The notation for '$f \cdot a$ is a proof of q given context Γ' is: $\Gamma \vdash f \cdot a : q$.

We have seen that PTS allow us to do calculations with introductions: information that is implicit in a body of information can be made explicit. Let us now address the question 'In what sense does an introduction $V : T$ represent a piece of information?' For that purpose, we have to go beyond the boundaries of the formal system of PTS.

Our main premiss is that information does not exist independently of an agent to whom the information is *meaningful*. The formal objects for representing informational items are introductions of the form $V : T$. Now, what information does an introduction $V : T$ represent to an agent? In other words, what is the *meaning* of $V : T$ to the agent? The answer is straightforward: the agent takes $V : T$ to mean (stand for the information) that there is some object of the type T.[6]

This answer can be developed in different directions. The agent can consider the type T to be part of a scheme of classication of *reality*, i.e., 'the external world'. In that case, $V : T$ *means to the agent* that there exists an object in the external world which fits the type T. Alternatively, the agent might use T to classify its *experiences*. In that case, $V : T$ would mean to the agent that an experience of type T occurred.

The latter approach has, however, serious limitations when it comes to modelling communication between agents. What would it mean for the information of $V : T$ to be transferred from one agent to the other? Since experiences are private to the agents, T will never mean the same thing for two different agents. In particular, if an agent is convinced that the meaning of $V : T$ resides strictly with its own experiences, then it will find it impossible to share the information associated with $V : T$ with others, since these experiences are alien to the others.

We conclude that the information that is conveyed by an introduction $V : T$ *to an agent* (i.e., according to the agent's *subjective* point of view) and that can be communicated is *objective* in nature; the information is about a reality that is external to the agent.[7] Paradoxically, if we look at the meaning of an introduction $V : T$ from a perspective that is external to the agent (i.e., from an *objective* point of view), then the information associated with $V : T$ becomes *subjective*. Let us explain.

We must ask the question, 'How does an agent obtain information about the world?'or more specifically 'How does an agent acquire the information that there exists an object of some type T? As objective observers of the agent, we may see the agent interact with the outside world and recognize certain objects as instances of T. This ability to recognize inhabitants of a type is entirely personal to the agent. Thus, from an external point of view the meaning of $V : T$ is subjective. The agent itself, however, cannot take this stand without becoming a solipsist, i.e., without denying the possibility of communication with other agents.

We have used 'the meaning of $V : T$' and 'the information that $V : T$ stands for' interchangeably. In our view, meaning and information are one of a kind. There is no direct relation between this approach to information and the notion of information that is used in *information theory* (Shannon, 1948).

Information theory is concerned with the transmission of messages from an information source to a destination. Information is thought of as a choice of one message from a set of possible messages, each of which is associated with the probability of its occurrence. According to information theory, if there are N possible messages with the probabilities $p_1, \ldots, p_N$, then the *amount of information* conveyed by a particular message with probability p_X is $log_2 \frac{1}{p_X}$. This definition of amount of information is at odds with our notion of information. It predicts, for instance, that nonsense words are more meaningful than real words, since the former are less likely to occur than the latter.[8]

Although there is no direct relation between our notion of information and that of information theory, information theory might fit in at a different level. Let us assume that utterances that are in line with conversational rules are more likely to occur than those that are not. In that case, information theory would predict that the latter type of utterances convey more information than the former type of utterances. This prediction is in line with Grice's notion of implicature. Grice (1975) defines implicatures as follows:

> 'A man who, by (in, when) saying (or making as if to say) that *p* has implicated that *q*, provided that (1) he is presumed to be observing the conversational maxims, or at least the Cooperative Principle [Grice's conversational rule of thumb]; (2) the supposition that he is aware that, or thinks that, *q* is required in order to make his saying or making as if to say *p* (or doing so in *those* terms) consistent with this presumption; and (3) the speaker thinks (and would expect the hearer to think that the speaker thinks) that it is within the competence of the hearer to work out, or grasp intuitively, that the supposition mentioned in (2) is required.' (Grice, 1975)

In terms of our conversational games, we might say that an implicature is that information that has to be added to the conversational state in order for the current utterance to be in line with the conversational rules (see (10) on page 124 for an example). Thus, an utterance that violates the conversational rules can be used to convey extra information on top of that what has been said. If utterances that are not in line with the rules are indeed less probable than utterance that are in line with the rules (at the moment, this is only a hypothesis), then there might be a link to Shannon's information theory; it predicts that the latter convey less information than the former.

Logic, Information and Conversation

This book divides up into three parts: Logic, Information and Conversation. In the first part we provide the main tool for analysing conversations: logic as it is formalized in PTS. The second part consists of three studies into the mechanisms

of information exchange in discourse in general. Finally, in the third part we focus on issues that are specifically tied to information exchange in conversations.

Part I — Logic

In part I of this book, Pure Type Systems (PTS) are introduced. PTS provides us with the formal framework for doing logic. It will be used in the second and the third part of this book to model different aspects of conversation. We opt for an introduction of PTS by comparing it with Discourse Representation Theory (DRT; Kamp, 1981). DRT is a widely used formalism for representing linguistic context and therefore an ideal stepping stone to PTS. PTS, which is less well-known in the linguistics community, can be seen as a generalization of DRT.

In chapter 1, we discuss DRT as a means for analysing the context-driven interpretation of anaphora in discourse. We draw attention to the role that consistency plays in this interpretation process, and address some objections that may be raised against the use logic for modelling conversations.

In chapter 2, we introduce PTS. This introduction is carried out in two stages. First an informal introduction is provided which relates PTS to DRT. Second, a formal description of PTS is provided.

Chapter 2 concludes with an extension of PTS. Our extension of PTS is motivated by the insight that in addition to consistency, the notion of *normality* deserves some attention. In everyday life people assume for most of the time that things are not out of the ordinary. This enables them to quickly reach conclusions without considering all the possible exceptional circumstances which would invalidate the conclusions. Several formalism have been proposed to deal with this type of reasoning, notably Reiter's default logic (Reiter, 1980). In chapter 2 we provide an extension of PTS which caters for reasoning about 'normal objects'. Our proposal will cover a wide range of non-standard inference patterns whilst maintaining the basic well-studied features of PTS.

Part II — Information

In part II, we investigate how information is conveyed by means of individual utterances. We provide an analysis of *anaphora*, *answerhood*, and *accentuation*. Our claim is that each of these phenomena can be seen as involving the introduction of an *informational gap* which has to be filled with information from the context: an anaphor introduces a gap which is supposed to be filled with information from the common ground, a question introduces a gap for which the informer has to provide a filler (i.e., an answer) on the basis of information which is private to him or her, and an accent on an assertion introduces an alternative version of the assertion with a gap at the place of the accent. This gap has to be filled with information from the common ground.

We study the relation between such gaps and the information that is supposed to fill them. In particular, whether information is consistent with the common ground is shown to constrain the suitability of information as the filler of a gap. For instance, reconsider the inference in (1). This inference can be used to eliminate one of the possible interpretations of anaphoric use of 'the motor' in the following exchange:

(5) A: Why did Tom drive Mike's car and not his own?
B: Because the motor had broken down.

The interpretation of 'the motor' as the motor of Mike's car is ruled out because it leads to an inconsistency. On the basis of the contraposition of the rule'if the motor of a car is broken, then one cannot drive it' (i.e., 'if one can drive a car, then its motor is not broken') and *A*'s utterance, we conclude that the motor of Mike's car is not broken. This conclusion is in contradiction with the identification of the motor in *B*'s utterance with the motor of Mike's car. We predict that for that reason, an interpreter will prefer the alternative reading which associates 'the motor' with the motor of Tom's car.

The aim of part II as a whole is to demonstrate the underlying unity of anaphora, answerhood and accent. In the individual chapters we put forward analyses of each of these phenomena that improve upon the analyses that have been proposed in the literature.

In chapter 3, we provide a formal account of the interaction between anaphora and world knowledge. In particular, we address Clark's examples of *bridging* (as in 'John entered the room. The chandelier sparkled brightly', where 'the chandelier' is anaphoric to an object that is only implicit in the antecedent discourse).

The proposal that is put forward in chapter 3 is based on a reformulation of Van der Sandt's account of presuppositions as anaphors (Van der Sandt, 1992). We reformulate the account in PTS. The advantages of this reformulation are demonstrated by applying it to several notoriously difficult cases of *presupposition projection*.

In chapter 4, a formalization of answerhood is presented. It is based on the idea that a question presents a gap in the information of the questioner, and that determining whether an answer fills the gap (given a context) comes down to performing a deduction in a proof system (in particular, a PTS).

Our approach brings together two notions of answerhood which are well-represented in the literature. First, we show that our approach generalizes those theories that start from the idea that answerhood should be explicated in terms of

the possibility to *unify* a question and its answer (e.g., Katz, 1968, Scha, 1983). Second, the *dynamic* and *contextual side* of answerhood, as reflected in, for instance, Hintikka's and Groenendijk and Stokhof's approach to answerhood (Hintikka, 1974; Groenendijk and Stokhof, 1984) , is formalized. The chapter leads to a full formalization of the notion of indirect answerhood (as in 'A: Who watched the match? B: Chris did, if he managed to get leave for the afternoon').

In chapter 5, we provide an account of accents as inducing alternative assertions. This proposal covers the implicatures that are usually thought to be associated with accented utterances (e.g., 'The children were taken to the circus. The smáll children enjoyed it' implicates that *it is not the case that the 'non-small' children enjoyed it*).

The main asset of the proposal is that it also extends to the *interactions between anaphora and accents*, which have been brought to light by Van Deemter (1992). It is shown that the notion of an alternative assertion, in combination with some plausible assumptions concerning anaphora resolution of actual and the alternative assertions of an utterance, is sufficient to account for Van Deemter's examples.

Part III — Conversation

Whereas in part II we investigate how information is conveyed by means of individual utterances, in part III, sequences of utterances are central. In particular, we put forward a model which describes how an utterance constrains the range of subsequent utterances in a conversation. For that purpose, we use Hamblin style conversational games (Hamblin, 1970). Hamblin was one of the first to provide a formal account of conversations, but see also Stenius (1967). More recent work on conversational games can be found in, for instance, Carlson (1983) and Beun (1994a).

In chapter 6, we provide three types of conversational rules: update, content and reaction rules. Update rules provide a general characterization of the updates of the conversational state that utterances give rise to. The content rules specify the difference between the updates corresponding to utterances with declarative, imperative and interrogative sentence type. The reaction rules constrain the legal moves that are avaible in a conversational state. We show that the system of update and reaction rules can be used to model a range of conversational structures that have been reported by conversation and discourse analyst. In particular, our account provides an incremental account of subdialogues, as opposed to the mainly non-incremental accounts from the literature. Finally, we deal with the satisfaction of presuppositions in conversations.

In chapter 7, we address the problem of conveyed meanings. The conveyed meaning of an utterance is the information that is communicated by means of the utterance without being literally said. We defend the distinction between literal and conveyed meaning and account for the relation between conveyed meaning, in particular the conveyed meaning which is associated with so-called indirect speech acts, and literal meaning in terms of a system of defeasible rules of thumb. We show that a simple system of such rules can account for a wide range of conveyed meanings.

Sources

Most of the ideas that are put forward in part II and III of this book have been presented in some form elsewhere. Chapter 3 is based on Krahmer & Piwek (1998) and Piwek & Krahmer (1998). Chapter 4 is based on Piwek (1997a). Some of the ideas in chapter 5 can also be found Piwek (1997b). Preliminary formulations of the proposals in the chapters 6 and 7 can be found in Piwek (1998a) and Piwek (1998b).

Implementation

This book is not only based on the aforementioned publications, but also derives from implementation work that has been carried out as part of the DENK project (Ahn et al., 1995; Bunt et al., 1998). The implementation work relates in particular to the chapters 3, 6 and 7. Details concerning the implementation can be found in Kievit & Piwek (1995), Piwek (1995), Piwek (1997c), Beun & Piwek (1997), and Kievit & Piwek (1998). Since in many respects this book goes beyond the implementation — the implementation formed the stepping stone to much of what can be found in this book— the details of the implementation are not discussed in this book. The focus in this book is on theoretical contributions to the areas of formal semantics and pragmatics.

I

Logic

1 Context and Consistency

"Facts," murmured Basil, like one mentioning some strange, far-off animals, "how facts obscure the truth. I may be silly—in fact, I'm off my head—but never could believe in that man—what's his name, in those capital stories?—Sherlock Holmes. Every detail points to something, certainly; but generally to the wrong thing. Facts point in all directions, it seems to me, like the thousands of twigs on a tree. It's only the life of the tree that has unity and goes up—only the green blood that springs, like a fountain, at the stars. (Quoted from: G.K. Chesterton: The Tremendous Adventure of Major Brown)

A predicament similar to that of Chesterton's detective is shared by the interpreter of natural language: an utterance in isolation can mean a thousand things; a more determinate meaning exists only by virtue of the rich background against which the utterance was produced. Imagine overhearing the following fragment of a conversation:

(1) *B:* It can't have broken down. The motor is brand new. She replaced it just a week ago.

Now, one might infer that *B* is talking about a car which the person referred to with 'she' owns. There are, however, many alternative interpretations. For instance, the sentences might have been uttered after the following utterance:

(2) *A:* Mary's lawnmower broke down.

Clearly, *B*'s utterance has no definite meaning outside of the context of its use. The context dependence of language use is also manifestly present in the interpretation of the two occurrences of 'it' in (1). The first 'it' refers to the lawnmower, whereas the second 'it' is about the motor of the lawnmower. In other words, here we have an expression ('it') which does not always have the same interpretation.

1.1 Context and Interpretation

The idea that the interpretation of an utterance depends on the context is not particularly surprising. Around 1970, however, a new dimension was added to the study of natural language interpretation. In addition to the approach to the interpretation as partly being fixed by the context, the interpretation process was thought of as *changing* the context: Thus the era of *dynamic semantics* got started. Amongst the first explorers of this new paradigm were Karttunen (1976), Lewis (1979) and Stalnaker (1974, 1978), but see also Hamblin (1970) and Gazdar (1981).

Karttunen (1976) put forward the idea that indefinites are used by the speaker to introduce a new discourse referent into the discourse. This discourse referent can then be referred to later on, for instance, by means of a pronoun or a definite description. Karttunen uses the following metaphor: during the interpretation of a text, a file is built up which contains all the individuals that have been introduced in the text, and which records for every individual the things that have been said about it. Karttunen also observed that whether an individual in this file is available for future reference is not a straightforward matter. Consider:

(3) a. $\star$ John did not buy a car. It is in the garage.
    b. $\star$ If john has enough money, then he buys a car. It is in the garage.

These examples illustrate the fact that normally discourse referents that have been introduced within the scope of a negation or implication are not accessible from the outside (the '$\star$' indicates that the discourses are intuitively anomalous). In the early eighties, Irene Heim and Hans Kamp independently framed the first formal theories which account for, amongst other things, the aforementioned property of discourse referents (Heim, 1982; Kamp, 1981). Of these theories, we review the theory which Kamp proposed. It has become known as Discourse Representation Theory (DRT). DRT has been applied to a variety of linguistic phenomena (e.g., tense, aspect and plurals; see Kamp & Reyle,1993).

DRT consists of three parts. The first and the last part correspond to the traditional distinction in formal logic between a language and its (model-theoretic) interpretation. The middle part involves the notion of context change, which is essential for the analysis of multi-sentence discourse.

Firstly, a *formal language* is given for representing the contexts which a person traverses when she processes (hears/reads) a discourse. A context consists of the representation which the interpreter of a discourse constructs on the basis of the sentences of the discourse. In DRT, contexts are referred to as Discourse Representation Structures (DRSs).

Secondly, a set of *construction rules* is provided which, given a sentence *S* and a DRS *D*, describes how to construct the structure that represents *D* updated with the information conveyed by the sentence *S*. Thus, the interpretation of each sentence in a text gives rise to a new DRS:[9]

(4) $\boxed{\text{DRS}_0} \rightarrow S_1 \rightarrow \boxed{\text{DRS}_1} \rightarrow \ldots S_n \rightarrow \boxed{\text{DRS}_n}$

Thirdly, there is a *model-theoretic interpretation* for DRSs. The interpretation allows one to determine whether a DRS is true or false with respect to a model of the world. A DRS can be looked upon as partial model of the world. A DRS is said to contain true information about the world, if it can be *embedded into* a model of the world.

The following sentence presents a very simple example:

(5) John drives a vehicle.

The content of (5) is to be represented with a DRS. A DRS K consists of a set of *discourse referents* (abbreviated as U_K) and a set of *conditions* on these referents (abbreviated as Con_{U_K}). The discourse referents can be seen as representatives for the individuals which are *introduced* in the discourse, and the conditions can be seen as assignments of properties to these individuals. Now, suppose that (5) is the first sentence of a text that is to be interpreted. In that case, we set out with an empty DRS:

(6) $\boxed{}$

The noun phrases 'John' and 'a vehicle' both give rise to the introduction of a so-called discourse referent or discourse marker (x and y, respectively). The descriptive content of the noun phrases is represented with conditions on these discourse referents. Finally, a condition is added which represents the relation between the discourse referents that is expressed by the transitive verb 'drive'[10]:

(7)

x y
John(x) vehicle(y) drive(x,y)

Let us informally explain the idea of a model-theoretic interpretation of a DRS. A model M is a tuple $\langle D, I \rangle$, consisting of a domain of individuals D and an interpretation function I. The interpretation function maps n-ary predicates

of some formal language L onto a set which is a subset of D^n. For instance, a two-place predicate is mapped onto a subset of $D \times D$. In words, the two-place predicate (a relation) is mapped onto a set of pairs of individuals. This set represents those pairs of individuals which stand in the aforementioned relation to each other.

Suppose that the only predicates of the DRT language are 'John', 'vehicle', and 'drive'. Then a possible model for this language is $D = \{a, b, c, d\}$, and $I(John) = \{a\}$, $I(vehicle) = \{b\}$ and $I(drive) = \{\langle a, b\rangle\langle c, d\rangle\}$. Now, we can relate the information represented by the DRS (7) to this model. In particular, we can check whether the model verifies the information contained in the DRS. The information is verified if there exists a mapping f from the referents in the DRS to the individuals in the domain, such that for each of the conditions $P^n(z_1, \ldots, z_n)$ ($n > 0$) it holds that $\langle f(z_1), \ldots, f(z_n)\rangle \in I(P^n)$. The reader may find out for him or herself that the aforementioned model indeed verifies (7). Alternatively, the DRS is not verified by the following model: $D = \{a, b, c, d\}$, and $I(John) = \{a\}$, $I(vehicle) = \{b\}$ and $I(drive) = \{\langle c, d\rangle\}$.

Let us now turn to a more complicated example, which involves reference to earlier introduced discourse referents. For that purpose, we employ an extended version of DRT which has been proposed in Van der Sandt (1992). Van der Sandt assumes that there is a construction algorithm which yields an underspecified DRS, which contains representations of one or more unresolved anaphoric expressions. When all these anaphors have been resolved, a proper DRS remains, which has a standard model-theoretic interpretation.[11] Let us consider the following example, and its Van der Sandtian representation:

(8) a. If John buys a pantechnicon, he'll adore the vehicle.

b.

x pantechnicon(x) buy(john,x)	$\Rightarrow$	adore(john,y δ [y vehicle(y)]

DRS (8.b) consists of a complex condition, containing two sub-DRSs (see definition 9), one for the antecedent and one for the consequent of the DRS. The antecedent DRS introduces a referent x. This x stands for a pantechnicon which is bought by John (where 'John' is represented by a constant, *john*, for the sake of simplicity). The definite description *the vehicle* presupposes the existence of a vehicle. In other words, the definite description is an anaphor that needs to be bound to a referent for an earlier introduced vehicle. This is modelled by adding an embedded, so-called presuppositional DRS to the consequent DRS. It introduces a referent y which is a vehicle. The embedded presuppositional DRS is marked with a δ in order to set it apart from ordinary DRSs.

The consequent DRS additionally contains the condition that this presupposed vehicle is adored by John. To *resolve* the presuppositional DRS, we do what we would do to resolve a pronoun: look for a suitable, accessible antecedent. A discourse referent is a suitable antecedent if the descriptive material of the presuppositional DRS applies to the discourse referent. In DRT the notion of accessibility is defined in (10). First, we provide the formal definition of a sub-DRS on which the definition of accessibility depends.

(9) (SUBORDINATE DRS) (Quoted from Kamp & Reyle, 1993:154)

1. K_1 is *immediately subordinate* to K_2 iff either
   (a) Con_{K_2} contains the condition $\neg K_1$; or
   (b) Con_{K_2} contains a condition of the form $K_1 \Rightarrow K_3$ or one of the form $K_3 \Rightarrow K_1$ for some DRS K_3.
2. K_1 is *subordinate* to K_2 iff either
   (a) K_1 is immediately subordinate to K_2; or
   (b) there is a K_3 such that K_3 is subordinate to K_2 and K_1 is immediately subordinate to K_3.
3. K_1 is weakly subordinate to K_2 iff either $K_1 = K_2$ or K_1 is subordinate to K_2. As before, we write $K_1 \leq K_2$ for weak subordination.

(10) (ACCESSIBILITY) (Quoted from Kamp & Reyle, 1993:155) Let K be a DRS, x a discourse referent and γ a DRS-condition. We say that x is *accessible from* γ *in* K if x belong to U_{K_1} where

1. $K_1 \leq K$, and
2. for some K_2, γ occurs in Con_{K_2}, and either
   (a) $K_2 \leq K_1$; or
   (b) there is a DRS K_3 and a DRS $K_4 \leq K$ such that $K_1 \Rightarrow K_3$ is in Con_{K_4} and $K_2 \leq K_3$.

For (8.b), we find a suitable and accessible antecedent: the discourse referent x introduced in the antecedent *is* accessible and suitable since a pantechnicon (i.e., a removal truck) is a vehicle. Exactly *how* the information that pantechnicons are vehicles can be employed in Van der Sandts theory is not obvious. For now, we will simply assume that we can *bind* the presupposition (but see chapter 3), which results in the following DRS, which can be paraphrased as 'if John buys a pantechnicon, he'll adore it'.

(11)

x pantechnicon(x) buy(john,x)	$\Rightarrow$	adore(john,x)

In principle, anaphoric pronouns are always bound. For presuppositions this is different: they can also be accommodated, provided the presupposition contains sufficient descriptive content. The idea that presuppositions can be accommodated was first coined by Lewis (1979). He proposed the following *rule of accommodation for presuppositions*:

(12) "If at time t something is said that requires presupposition P to be acceptable, and if P is not presupposed just before t, then—*ceteris paribus* and within certain limits—presupposition P comes into existence at t."

Let us now see what accommodation means according to Van der Sandt. Reconsider example (8) again: on Van der Sandt's approach (globally) *accommodating* the presupposition associated with *the vehicle* amounts to removing the presuppositional DRS from the consequent DRS and placing it in the main DRS, which would result in the following DRS.

(13)

y
vehicle(y)

x pantechnicon(x) buy(john,x)	$\Rightarrow$	adore(john,y)

This DRS represents the 'presuppositional' reading of (8.a), which may be paraphrased as 'there is a vehicle and if John buys a pantechnicon, he'll adore the aforementioned vehicle'. Now we have *two* ways of dealing with the presupposition in example (8), so the question may arise which of these two is the 'best' one. To answer that question, Van der Sandt defines some general rules for preferences, which may be put informally as follows:

1. Binding is preferred to accommodation,
2. Binding is preferred as low as possible, and
3. Accommodation is preferred as high as possible (thus, preferably in the main DRS).

The third preference rule seems to suggest that there is more than one way to accommodate a presupposition, and indeed there is. To illustrate this, consider:

(14) It is not true that I adore John's pantechnicon, since he doesn't have one!

Here, the definite NP *John's pantechnicon* presupposes that John has a pantechnicon. If we globally accommodate this presupposition (that is, the presupposition 'escapes' from the scope of the negation and is placed in the main DRS), we would end up with an inconsistent DRS, expressing that John has a pantechnicon, which is contradicted by the *since*-clause. Van der Sandt (1992:367) defines a number of conditions on accommodation, of which *consistency* is one:

(15) (ADMISSIBLE RESOLUTIONS) (Van der Sandt, 1992:367) Let K_0 be the incoming DRS, K_1 the merge of a DRS with K_0 and K'_1 a possible resolution of K_1. The resolution of K_0 to K'_1 is subject to the following conditions in order to be admissible:

1. K'_1 is informative with respect to K_0, that is K_0 does not entail K'_1.
2. Resolving K_0 to K'_1 maintains consistency.
3. Resolving K_0 to K'_1 does not give rise to a structure in which
   (a) some subordinate DRS K_i is entailed by the DRSs which are superordinate to it,
   (b) $\neg K_i$ is entailed by the DRSs which are superordinate to it.

Since in the case of (14) global accommodation yields an inconsistent DRS, *local accommodation* of the presupposition is preferred, where local means within the scope of the negation. The result can be paraphrased as 'it is not true that John has a pantechnicon and that I adore it, since he doesn't have one'. The DRS for the 'it is not true that John has a pantechnicon and that I adore it' is:

(16) $\boxed{\neg \boxed{\begin{array}{c} x \\ \hline \text{pantechnicon(x)} \\ \text{of(john,x)} \\ \text{adore(I,x)} \end{array}}}$

1.2 Consistency and Logic

In the previous section, we saw that consistency checks play an important role in the interpretation process. In this book, we will encounter many more situations in which consistency checking is an integral part of the interpretation process.

Logic is usually characterized as the science of correct reasoning. Reasoning is precisely what is needed for consistency checking: given a body of information we want to find out whether it is possible to arrive at a contradiction $(\Phi \wedge \neg\Phi)$ by reasoning from these pieces of information. Thus, logic is to play a central role when it comes to the analysis of language use in both discourse and conversation. DRT is a logical system. In its original version, it accounted for reasoning in model-theoretic terms. Some conclusion (a DRS) follows from some premisses (another DRS), if all models that verify the premisses also verify the conclusion.

More recently, proof-theoretical accounts of reasoning have been given for DRT (e.g., Saurer, 1993). Such accounts do not rely on models, but rather relate a class of DRSs with a certain syntactic form by so-called deduction rules to another class of DRSs, which are said to follow from the aforementioned DRSs.

In this book, the second approach to reasoning will be pursued. In the next chapter, a proof-system that subsumes DRT is described. There we also motivate our choice for that system.

For now, we want to address some objections that may be raised against the enterprise of employing logic, and more specifically, a proof-theoretical approach to logic, as a basis of a system of conversation.

The Undecidability of Consistency

It may be objected that the consistency checks that we suggest have little value, because they are not foolproof. For a sufficiently rich logic, e.g., classical predicate logic, consistency checking is not decidable, i.e., there is no algorithm which can determine for an arbitrary set of propositions whether it is consistent. This is due to the fact that whether some proposition follows from a certain set of premisses is no longer decidable. Although there exist algorithms which yield the correct output if a proposition does indeed follow from the premisses, for such an algorithm there will be propositions which do not follow from the premises and which the algorithm does not recognize as such, i.e., the algorithm does not halt for such propositions.

For practical purposes, one will therefore simply have to stipulate that the algorithm stops searching after a certain time. At that moment, there might, however, be an inconsistency lurking just behind the horizon. The question is how serious this is, giving the fact that we want to model human behaviour in conversations. Are human beings always consistent in their beliefs? The answer is clearly 'no'.

We may also ask how consistency enters into the behaviour of human beings. We argue that human behaviour is not so much governed by the fact that their underlying beliefs are consistent, but rather by the *normative* rule that they ought to be consistent. It is exactly this hypothesis that enters into the process of interpretation in conversation: interpreters should eliminate an inconsistency when they find one. In the event that an inconsistency turns up, a human being will discard those pieces of information that gave rise to inconsistency without throwing away all the hard work. Curry (1951) provides an excellent illustration of this from the history of mathematics:

> "Even if an inconsistency should be discovered this does not mean a complete abandonment of the system, but its modification and improvement. As a matter of fact, essentially this happened in the past; for if we were to formulate the mathematics of the eighteenth century we should find that it was inconsistent; yet we have not abandoned the results of the eighteenth century mathematicians." (Curry, 1951:62)

We suggest that a proof system might be the appropriate tool to model the means by which an inconsistency may be discovered. More specifically, Pure Type Systems (PTS) also provide the handles for the 'modification and improvement' of a body of information. This is due to the fact that proofs are explicitly represented in PTS. Whenever an inconsistency can be constructed in a PTS, then there will be a proof object which points to the sources of the inconsistency.

Practical Reasoning and Logic

Even if we grant that logic functions as a normative framework, which describes what people ought to strive for in their actual behaviour and what they assume others to seek for, one might still think that there is an unbridgeable gap between actual behaviour and the normative prescriptions of logic.

One should, however, note that if in communication or interpretation two objects are semantically related, the relation need not be a logical one. In fact, we argue that although logic plays an important role, much of interpretation is rooted in other mechanisms, notably the non-logical notion of *salience*. Basically, a relation between two objects can be established simply by virtue of the one being salient in the context of the other.

(17) John bought that book, because he knew the author.

In (17), the referents of 'that book' and 'the author' are related, and provide for the coherence of the text. If a book is mentioned, and thereby a discourse referent for it is made salient, then a referent for the author of that book also becomes more salient. In this case, that means that the referent for the author of the book is available as an antecedent for the presuppositional expression 'the author'.

So, although there definitely is a role for logic, we should keep in mind that it has to share the credits with others. In particular, *salience* which might be rooted partly in the physiological build up of human beings and for another part in experience, should have its proper place besides logic.

There is another problem with logic, that derives from the limitations of classical formal logic. People often jump to conclusions, they use the absence of certain information as a license to draw a conclusion. There is the notorious example of the bird Tweety, which is thought to be able to fly, as long as no information is supplied that contradicts Tweeties ability to fly. In the final section of the next chapter we address the problem of reasoning from ignorance, or jumping to conclusions.

2 Pure Type Systems

We have seen that the notions of consistency and inference are crucial to any model of context that is to be employed for the modelling of conversation. In this chapter, we describe a framework which is well-suited for this task. This framework consists of a class of proof systems that are know as Pure Type Systems (PTS, see Barendregt, 1992). It is a generalization of different systems of (explicitly) typed lambda calculus, such as the Automath Languages (De Bruijn, 1980; Nederpelt et al., 1994), Constructive Type Theory (Martin-Löf, 1984), and the Calculus of Constructions (Coquand, 1985). Before going into the details of PTS, let us give four reasons for using PTS as our framework.

First, Ahn & Kolb (1990) show that PTS can be seen as a higher order generalization of Discourse Representation Theory (DRT; Kamp, 1981; Kamp & Reyle, 1993). This means that many of the results that have been obtained using DRT, in particular on anaphora resolution, are compatible with the framework that we employ in this book (see, for instance, chapter 3).

Second, PTS is a proof system with well-studied meta-mathematical properties, due to the fact that it was developed in mathematics and is a main topic of investigation in theoretical computer science. Thus a formalization in PTS can serve as the basis for a computational model of conversation.

Third, in PTS, proofs are represented explicitly in the object language. It is claimed by Van Benthem (1991) that this saves us from the 'problem of logical omniscience'. In PTS, to determine whether a proposition holds, given a context (roughly speaking, a set of premisses), a proof object has to be *constructed*. The complexity of the proof object can be seen as encoding the amount of effort needed to prove the proposition. Proof objects are helpful in another way: they provide a means for dealing with inconsistencies. Since we work within a system which is not decidable[12], it becomes of decisive importance that inconsistent contexts can be repaired, whenever an inconsistency turns up. This is exactly what proof objects allow us to do: they locate the sources of an inconsistency.

Fourth, PTS is suitable for incorporating not only higher-order logics, but also modal logics. The formal properties of Modal PTS have been studied in Borghuis (1994). Modal logics are useful for modelling of conversation. In conversation, the partners exchange information about their commitments. Commitment can, like belief, be modelled in a modal logic. See, in particular, chapter 6 of this book.

2.1 Informal Exposition

We introduce PTS by comparing it with DRT; this comparison is based on Ahn & Kolb (1990), who present a formal translation of DRSs into PTS expressions. In PTS, there is a formal object called a *context*. Such a context is a sequence of introductions. Introductions are of the form $V : T$, where V is a variable and T is the type of the variable.

In DRT, the pivotal formal object is the Discourse Representation Structure (DRS). We demonstrate the close relationship between DRSs and PTS contexts by going through an example. Consider (1.a) and its DRT representation (1.b).

(1) a. John drives a vehicle.

b.

x
vehicle(x) drives(john,x)

The discourse referents in a DRS can be seen as a particular kind of introduction in a PTS context: a discourse referent corresponds to the introduction of a variable of the type *entity*.

The type *entity* should only be used in the introduction x:*entity* if *entity*:*type* is already part of the context. More generally, an expression may only be used in the type T of an introduction $V : T$, after the expression itself has been introduced. This way, one introduction depends on another introduction, hence a context is an ordered sequence of introductions.

The type *type* also requires introduction. The introduction is, however, not carried out in the context; it is taken care of by an axiom which says that *type*:$\Box$ (where $\Box$ is to be understood as the 'mother of all types') can be derived in the empty context ($\varepsilon \vdash$ *type* : $\Box$).

DRT's conditions correspond to introductions $V : T$, where T is of the type *prop* (short for proposition, which comes with the following axiom: $\varepsilon \vdash$ *prop* : $\Box$). For instance, the introduction y : (*vehicle* $\cdot\, x$) corresponds to the condition *vehicle*(x). The type *vehicle* $\cdot x$ (of type *prop*) is obtained by applying the type *vehicle* to the object x (The '$\cdot$' (representing function application) is left-associative, thus $f \cdot x \cdot y$ should be read as $(f \cdot x) \cdot y$.). Therefore, it depends on the introductions of x and *vehicle*. Since *vehicle* $\cdot\, x$ should be of the type *prop*, vehicle must be a (function) type from the set of entities into propositions, i.e., *vehicle* : *entity* $\rightarrow$ *prop*.

The introduction y : (*vehicle*$\cdot x$) involves the variable y (of the type *vehicle*$\cdot x$). The variable y is said to be an inhabitant of *vehicle* $\cdot x$. Curry and Feys (1958) came up with the idea that propositions can be seen as classifying proofs (this is known as the 'propositions as types — proofs as objects' interpretation). This means that the aforementioned introduction states that there is a proof y for the proposition *vehicle* $\cdot x$.

The second DRS condition (*drive*(*john*, x)) can be dealt with along the same lines. Assume that *drive* is a predicate which requires two arguments of the type *entity*, this yields z : *drive* $\cdot\, x \,\cdot$ *john*. In sum, the PTS counterpart to the DRS (1.b) consists of the following three introductions:

(2) x : *entity*, y : *vehicle* $\cdot\, x, z$: *drive* $\cdot\, x \,\cdot$ *john*.

Dependent Function Types In DRT, the proposition *Everything moves* is translated into the implicative condition $[x \mid thing(x)] \Longrightarrow [\ \mid move(x)]$. In PTS, this proposition corresponds to the type (Πx : *entity.move* $\cdot\, x$), which is a so-called *dependent function type*. It describes functions from the type *entity* into the type *move* $\cdot\, x$. The range of such a function (*move* $\cdot\, x$) depends on the object x to which it is applied. Suppose that we have an inhabitant f of this function type, i.e., f : (Πx : *entity.move* $\cdot\, x$). We then have a function which, when applied to an arbitrary object y, yields an inhabitant of the proposition *move* $\cdot\, y$. Thus, f is a constructive proof of the proposition that *Everything moves*.

Of course, function types can be nested. Reconsider the predicate *drive*. We suggested to introduce it as a function from entities ('the driver') to entities ('the thing being driving') to propositions. One could, however, argue that the second argument of *drive* ('the thing being driven') can only be a vehicle. In that case, *drive* would have to be introduced as a function from entities to entities to another function (i.e., the function from a proof that the second entity is a vehicle to a proposition), that is *drive* : (Πy : *entity*.(Πx : *entity*.(Πp : *vehicle* $\cdot\, x$.*prop*))). We will abbreviate this as :

(3) *drive* : ([y : *entity*, x : *entity*, p : *vehicle* $\cdot\, x$] $\Rightarrow$ *prop*)

Deduction A PTS encompasses a number of deduction rules with which one can determine the type of an object in a given context. These rules can also be used to search for an object belonging to a particular type. In other words, the rules enable us to check whether in a context Γ it can be derived that an expression E (i.e., a variable or an object that has been constructed out of several variables) is of type T (notation: $\Gamma \vdash E : T$). We call $E : T$ a statement. Statements are different from introductions in two respects: First, a PTS context can by definition only contain introductions and no statements. Second, introductions are of the form $V : T$, where V is a variable and T a PTS expression, whereas statements are of the form $E : T$, where E is an expression and T a type.

In this introduction, we focus on three deduction rules. The first rule is rather straightforward; it says that if we have a sequence of introductions that ends with the introduction $V : T$, then it follows from that sequence of introductions that V is of type T (where a variable is $\Gamma-$fresh if it has not already been introduced in Γ):

(4) (start) $\dfrac{\Gamma \vdash A : s}{\Gamma, x : A \vdash x : A}$ x is $\Gamma-$fresh & $s \in \{\Box, type, prop\}$

The second rule says that if we can derive $A : B$ in Γ, then we can also derive it from Γ extended with and introduction $x : C$, where C is properly typed.

(5) (weaken) $\dfrac{\Gamma \vdash A : B \quad \Gamma \vdash C : s}{\Gamma, x : C \vdash A : B}$ x is $\Gamma-$fresh & $s \in \{\Box, type, prop\}$

Let us sketch a situation in which these rule can be employed. Suppose we have some context Γ_1 containing the introduction p : *neigh* $\cdot\, r$. Furthermore, assume that we want to find out whether an inhabitant of (in other words, a proof for) *neigh* $\cdot\, r$ can be derived in Γ_1. This problem can be stated as follows: We are in search of a substitution $[S]$ such that:

(6) $\Gamma_1 \vdash X$: *neigh* $\cdot\, r[S]$

In (6), the capital X is a so-called *gap*. The task is to find a substitution $[S]$ for this gap such that (6) can be derived. A substitution is a list of assignments of PTS expressions to gaps, e.g., $[G_1 := E_1, \ldots, G_n := E_n]$ (where $G_1, \ldots, G_n$ are gaps and $E_1, \ldots, E_n$ are PTS expressions). (6) can indeed be deduced if we assume that $[S]$ is equal to $[X := p]$.

If the introduction p : *neigh* $\cdot\, r$ is the last one of Γ, then we can directly apply the (start) rule to show that p : *neigh* $\cdot\, r$ follows from Γ. Otherwise, we will first have to apply the (weaken) rule one or more times. We apply the rule 'backwards'. Assume that $\Gamma_1 = \Gamma, x : C$ and p : *neigh* $\cdot\, r = A : B$. In that case, the new goals that we have to prove are $\Gamma \vdash A : B$ and $\Gamma \vdash C : s$. For the moment, we do not consider the second goal.

The first goals is directly satisfied, if p : *neigh* $\cdot$ *r* is the second last element of Γ_1. Note that we obtain Γ by peeling of the last element of Γ_1. Therefore p : *neigh* $\cdot$ *r* will be the last element of Γ. That makes it possible to apply the (start) rule. It should be evident that if p : *neigh* $\cdot$ *r* occurs even further to left in Γ_1, then repeated application of the (weaken) rule, will eventually lead to a situation in which the (start) rule can be applied.

With a proof system which is limited to the (start) and (weaken) rule, one can only check whether an object is of a particular type by determining whether an introduction to this effect is an element of the context. A PTS however, has more deduction rules. One of them allows us to combine the information of different introductions. The rule below merges the Modus Ponens scheme of classical Propositional Logic with function application:

(7) (elim) $\dfrac{\Gamma \vdash F : (\Pi x : A.B) \quad \Gamma \vdash a : A}{\Gamma \vdash F \cdot a : B[x := a]}$

For instance, if a context Γ contains the introductions $g : ([y : \textit{horse}] \Rightarrow \textit{neigh} \cdot y)$ and $b : \textit{horse}$, then we can use this rule to find an inhabitant of the type *neigh* $\cdot$ *b*. In other words, our goal is to find a substitution $[S]$ such that $\Gamma \vdash P : \textit{neigh} \cdot b[S]$. The substitution $[S]$ should assign a value to the gap P.

The deduction rule tells us that $(g \cdot b)$ can be substituted for P, if $\Gamma \vdash g : ([y : \textit{horse}] \Rightarrow \textit{neigh} \cdot y)$ and $\Gamma \vdash b : \textit{horse}$. Both can be deduced using the (start) and (weaken) rules, because we assumed that $g : ([y : \textit{horse}] \Rightarrow \textit{neigh} \cdot y)$ and $b : \textit{horse}$ are members of Γ. Thus, we conclude that $\Gamma \vdash (g \cdot b) : \textit{neigh} \cdot b$.

We use $\vdash_\Delta$ for the deduction of more than one statement in a context. $\vdash_\Delta$ is defined as follows:

(8) $\Gamma \vdash_\Delta S_1, \ldots, S_n \Leftrightarrow \Gamma \vdash S_1, \ldots, \Gamma \vdash S_n.$

Σ-types Σ-types (Löf, 1984) are useful for framing a dynamic and compositional semantics in PTS (see Ranta, 1994). The inhabitant of a Σ-type is a pair of objects. Suppose the Σ-type is $(\Sigma x : A.B)$ (where $A : type$ and $B : prop$), then a pair inhabiting $(\Sigma x : A.B)$ consists of an object of type A and a proposition of type B. Thus the assertion of *A man walks* can be translated into $p : (\Sigma x : man.walk \cdot x)$. We have the operators π_1 and π_2 which can be applied to p in order to obtain an object of type man and a proof that the man walks, respectively.

With a combination of Π and Σ-types the renowned donkey sentence (*If a man owns a donkey, he beats it.*) can be represented in PTS (*Cf.* Sundholm, 1986).

(9) $(\Pi p : (\Sigma x : man.(\Sigma y : donkey.own \cdot x \cdot y)).beat \cdot (\pi_1 \cdot p) \cdot (\pi_1 \cdot (\pi_2 \cdot p)))$

This formula should be read as follows: if we have a proof that there is a man and a donkey and the man owns the donkey $(\Sigma x : man.(\Sigma y : donkey.own{\cdot}x{\cdot}y))$, then we have a proof that the man beats the donkey: $beat \cdot (\pi_1 \cdot p) \cdot (\pi_2 \cdot (\pi_1 \cdot p)))$.

2.2 Formal Exposition

In this section a formal specification of PTS, based on Barendregt (1992), is given. Firstly, we introduce the set of sorts:

(10) (SORTS) $\mathcal{S} = \{type, prop, \Box\}$

The three special types $type$, $prop$ and $\Box$ are called *sorts*. $type$ and $prop$ are themselves of the sort $\Box$ (see the axioms in definition 17 on page 17). In the following definitions V is a set of variables such that:

(11) $V \cap \{type, prop, \Box\} = \emptyset$

(12) (PSEUDO-TERMS) $T := \mathcal{S} \mid V \mid (T \cdot T) \mid \lambda V : T.T \mid \Pi V : T.T$

(13) (INTRODUCTIONS) $I := V : T$

(14) (PSEUDO-CONTEXTS) $\Gamma := \epsilon \mid \Gamma, I$

In other words, a pseudo-context is a sequence of introductions. Γ, I is the sequence which is obtained by appending I to the sequence Γ. ϵ is the empty sequence.

(15) (PSEUDO-JUDGEMENTS) $J := \Gamma \vdash T : T$

(16) (RULES) $\mathcal{R}_\Pi \subseteq \{\langle x, y\rangle \mid x \in \mathcal{S}, y \in \mathcal{S}\}$

These rules should not be confused with the deduction rules which we will give below. The rules in $\mathcal{R}_\Pi$ are used by a deduction rule called formation $(form)$. This deduction rule can be used to construct function types. The choice of $\mathcal{R}_\Pi$ determines what kind of functions can be constructed. For instance, if $\langle type, \Box\rangle \in \mathcal{R}_\Pi$, then predicates can be constructed, i.e. functions from objects to propositions. If $\langle type, prop\rangle \in \mathcal{R}_\Pi$, then quantification over entities is possible. The reader may check that $blue : (\Pi x : entity.prop)$ requires $\langle type, \Box\rangle$ and $a : (\Pi x : entity.move \cdot x)$ requires $\langle type, prop\rangle$.

(17) (DEDUCTION RULES) The Rules which axiomatize the relation $\vdash$ are specified below. The usual notions of fresh variable (Γ-fresh: a variable which does not occur in Γ) and substitution (The replacement of all occurences of a variable in a term with another variable) are used. The notion of beta-equality ($=_\beta$) which we will use is defined below.

(axioms) $\epsilon \vdash type : \Box \quad \epsilon \vdash prop : \Box$

(start) $\dfrac{\Gamma \vdash A : s}{\Gamma, x : A \vdash x : A}$ x is $\Gamma-$fresh

(weaken) $\dfrac{\Gamma \vdash A : B \quad \Gamma \vdash C : s}{\Gamma, x : C \vdash A : B}$ x is $\Gamma-$fresh and $s \in \mathcal{S}$

(form) $\dfrac{\Gamma \vdash A : s_1 \quad \Gamma, x : A \vdash B : s_2}{\Gamma \vdash (\Pi x : A.B) : s_2}$ $\langle s_1, s_2 \rangle \in \mathcal{R}_\Pi$

(intro) $\dfrac{\Gamma, x : A \vdash b : B \quad \Gamma \vdash (\Pi x : A.B) : s}{\Gamma \vdash (\lambda x : A.b) : (\Pi x : A.B)}$ $s \in \mathcal{S}$

(elim) $\dfrac{\Gamma \vdash F : (\Pi x : A.B) \quad \Gamma \vdash a : A}{\Gamma \vdash F \cdot a : B[x := a]}$

(conv) $\dfrac{\Gamma \vdash A : B \quad \Gamma \vdash B' : s \quad B =_\beta B'}{\Gamma \vdash A : B'}$ $s \in \mathcal{S}$

(18) (ONE STEP BETA-REDUCTION) $(\lambda x : A.M) \cdot N \rightarrow_{1\beta} M[x := N]$

(19) (BETA-REDUCTION) $E \rightarrow_\beta E'$ iff $E \rightarrow_{1\beta} E'$ or $E = E'$ or $\exists E'' : E \rightarrow_\beta E'' \wedge E'' \rightarrow_\beta E'$

(20) (CONGRUENCE) $P \equiv_\alpha Q$ iff Q has been obtained from P by a finite (perhaps empty) series of changes of bound variables (i.e. variables which are within the scope of a pi or a lambda. E.g., the variable x in $\lambda x.x$ can renamed into y, which yields the congruent term $\lambda y.y$).

(21) (BETA-EQUALITY) $P =_\beta Q$ iff Q is obtained from P by a finite (perhaps empty) series of β-reductions and reversed β-reductions and changes of bound variables: $P_0 =_\beta P_n$ iff there exist $P_1, \ldots P_{n-1}$ such that for $0 \leq i \leq n-1$: ($P_i \rightarrow_{1\beta} P_{i+1}$ or $P_i \leftarrow_{1\beta} P_{i+1}$ or $P_i \equiv_\alpha P_{i+1}$).

(22) (LEGAL TERM) A pseudo-term E is a (legal) term if a pseudo-context Γ and a pseudo-term T exist so that $\Gamma \vdash E : T$ is derivable.

(23) (LEGAL CONTEXT) A pseudo-context is a (legal) context if there are two terms E and T such that $\Gamma \vdash E : T$ is derivable.

(24) (LEGAL JUDGEMENT) A pseudo-judgement is a (legal) judgement if it is derivable.

(25) (SUBJECT REDUCTION THEOREM) If $\Gamma \vdash E : T$ and $E \rightarrow_\beta E'$ then $\Gamma \vdash E' : T$. ($E_0 \rightarrow_\beta E_n$ iff there exist $E_1, \ldots, E_{n-1}$ such that for all $0 \leq i \leq n-1$: ($P_i \rightarrow_{1\beta} P_{i+1}$).

Sigma–types Sigma–types do not belong to PTS proper as defined in Barendregt (1992). They can, however, be accommodated for through the following extensions:

(26) (BETA-REDUCTION$'$) Beta-reduction ($\rightarrow_{1\beta}$) is defined as follows:

$(\lambda x : A.M) \cdot N \rightarrow_{1\beta} M[x := N]$;
$\pi_1(\langle A, B \rangle) \rightarrow_{1\beta} A$;
$\pi_2(\langle A, B \rangle) \rightarrow_{1\beta} B$.

(27) (RULES$'$) $\mathcal{R}_\Pi \subseteq \{\langle x, y \rangle \mid x \in \mathcal{S}, y \in \mathcal{S}\}$, $\mathcal{R}_\Sigma \subseteq \{\langle x, y \rangle \mid x \in \mathcal{S}, y \in \mathcal{S}\}$

(28) (PSEUDO-TERMS$'$) $T := \mathcal{S} \,|\, V \,|\, (T \cdot T) \,|\, \lambda V : T.T \,|\, \Pi V : T.T \,|\, \langle T, T \rangle \,|\, \Sigma V : T.T \mid \pi_1 T \mid \pi_2 T$

Furthermore, the rules Σ-form, Σ-intro, π_1 and π_2 have to be added to the set of rules of definition 17 on page 17.

(29) (Σ-form) $\dfrac{\Gamma \vdash A : s_1 \quad \Gamma, x : A \vdash B : s_2}{\Gamma \vdash (\Sigma x : A.B) : s_2}$ $\langle s_1, s_2 \rangle \in \mathcal{R}_\Sigma$

(Σ-intro) $\dfrac{\Gamma \vdash a : A \quad \Gamma \vdash b : B[x := a] \quad \Gamma \vdash (\Sigma x : A.B) : s}{\Gamma \vdash \langle a, b \rangle : (\Sigma x : A.B)}$ $s \in \mathcal{S}$

(π_1) $\dfrac{\Gamma \vdash p : (\Sigma x : A.B)}{\Gamma \vdash (\pi_1 p) : A}$

(π_2) $\dfrac{\Gamma \vdash p : (\Sigma x : A.B)}{\Gamma \vdash (\pi_2 p) : B[x := (\pi_1 p)]}$

2.3 Contexts of Interpretation

In the chapters 3, 4 and 5, we frequently speak of the context of interpretation. This context of interpretation is modelled as a type-theoretical context Γ. For the purpose of those chapters, Γ may be identified with what the interpreter thinks to be the common background of the interlocutors.

Following Stalnaker (1978), we assume that a felicitous utterance has to be consistent and informative with respect to the common background of the interlocutors. Consistency and informativity of the information that is communicated by means of an utterance can be modelled in PTS. For that purpose, we first introduce the formal counterpart of information given a context Γ. This formal counterpart is called a segment:

(30) (SEGMENT) A sequence of introductions A with zero or more gaps is a *segment iff* there is a substitution instance $A[S]$ of A such that Γ extended with $A[S]$ is a legal context.

We may distinguish between open and closed segments.

(31) (OPEN SEGMENT) An open segment is a segment with one or more gaps.
(CLOSED SEGMENT) A segment with no gaps.

After this formalisation of information given a context Γ, we now proceed to define the notions of consistency and informativity.

(32) (CONSISTENCY) A segment A is consistent with respect to Γ *iff* there is a substitution S such that it is not the case that there is a proof p such that $\Gamma \otimes A[S] \vdash p : \bot$

In words, there should be a substitution instance $A[S]$ of A such that it is not possible to derive a proof for the false in Γ extended with $A[S]$. $\bot$ is a type which should have no inhabitants. If a proof does exist, the context needs to be repaired. We can use $\bot$ to express the negation of a proposition. The negation of the proposition p is $p \to \bot$. In words, a proof for 'not p' is a function which given a proof for' p' returns a proof for the false. Note that a context is inconsistent if it contains a proof for a proposistion $a : p$ and its negation $b : p \to \bot$. In that case, we can construct a proof $(b \cdot a)$ for $\bot$.

(33) (INFORMATIVITY) A segment A is informative with respect to Γ *iff* there is no substitution S, such that $\Gamma \vdash_\Delta A[S]$.

Thus, an (open) segment is only informative with respect to Γ if the segment or a substitution instance of it cannot be derived from Γ. Take, for instance, the assertion of the proposition 'a man walks'. The corresponding representation is: $X : man, P : walk \cdot X$. The X (from the indefinite) and the P (which is to be filled with a proof of the proposition) are gaps: they will be instantiated with fresh variables in case the assertion is added to Γ. Now, notice that the informativity condition on utterances makes the assertion 'infelicitous' if there already is a man in Γ and a proof that this man walks. In other words, if there is a substitution S such that $\Gamma \vdash X : man, P : walk \cdot X[S]$. Practically, this means, for instance, that the text 'A man walks. A man walks' is predicted to be infelicitous (assuming that only informative and consistent utterances are felicitous).

2.4 Reasoning and Normality

There is some tension between the logicians' notion of an ideal reasoner, who has infinite time and other resources (e.g., energy) at her or his disposal, and the situation of the average human being. In daily life, where conclusions have to be drawn quickly on the basis of a limited amount of information, it is impossible to reason solely with the information for which one has strong positive evidence. One often jumps to a conclusion, thereby ignoring exceptional circumstances which might invalidate the conclusion.

This practice seems at odds with the traditional systems of logic. For instance, in standard propositional logic, once a conclusion has been drawn, it holds for all time. This is not the kind of status which information which is partly based on ignorance could ever have. After all, in the future one might discover that the conclusion that was drawn does not hold, due to some exceptional circumstances of which one had no knowledge.

To overcome the aforementioned discrepancy between 'practical' reasoning and formal logic, the field of formal logic has been extended with so-called nonmonotonic logics.[13] In a nonmonotonic logic, the addition of new information to a set of premisses may have as a result that certain conclusions can no longer be drawn. In particular, *default logic* (Reiter, 1980) was devised for situations in which an exception to a (default) rule is added to the premises, thus blocking the derivation of conclusions arrived at by application of the rule. What the solutions of this type have in common is that they consist of a proposal to amend the standard notion of logical consequence. In other words, new logics are invented/discovered.

In this section, we want to tackle the problem from a somewhat different angle which leads to no modifications of the logic itself. The proposal is based on the assumption that the focus of attention should be on the way people *use* standard logic in practical situations rather than on changes to the logic itself. To clarify our point let us first see what is common practice in the field of nonmonotonic logics. Consider:

(34) a. $\Gamma \vdash_{nm} \phi$
b. $\Gamma, \psi \nvdash_{nm} \phi$

(34.a) tells us that in some context Γ it can be nonmonotonically derived that ϕ holds. (34.b) says that when Γ is extended with ψ, the conclusion ϕ can no longer be drawn. Thus, the simple addition of new information makes old information obsolete.

Our alternative to nonmonotonic logics is based on the idea that when an agent jumps to a conclusion ϕ, the agent makes the assumption that 'things are normal'. Let Δ stand for this assumption. In a context Γ, the agent may derive the conclusion ϕ in Γ extended with Δ:

(35) $\Gamma, \Delta \vdash \phi$

Here, '$\vdash$' stands for the classical notion of derivability. Now suppose that the agent subsequently receives some new piece of information, say ψ. The agent may accept this new information and extend Γ with it. It might be the case that Γ, ψ, Δ is inconsistent. In this situation, the assumptions in Δ are no longer reasonable: they yield a contradiction in combination with the explicitly introduced information ψ. This means that Δ has to be retracted. This in turn means that ϕ is no longer derivable. Thus, instead of using a nonmonotonic notion of derivability, we have modelled jumping to a conclusion by means of an underlying mechanism of adding and ,if required, retracting the assumption that things are normal. In the next section, we explain what it means to assume that things are normal.

Our approach is related to abductive inference. An abductive inference is of the form:

(36) IF $P \rightarrow Q$ AND Q, THEN P.

The idea behind this scheme is that we know that Q and are seeking for an explanation of Q. Given the rule that $P \rightarrow Q$, Q is explained when we assume that P, since the rule and P allows us to derive Q. In Krause (1995), abduction is formulated in type-theory for the purpose of presupposition resolution.

(37) An explanation Δ of some conclusion C is an extension of Γ such that $\Gamma \otimes \Delta \vdash C$ and $\Gamma \otimes \Delta$ is consistent.

Abduction is used to find an explanation for some given conclusion C. We propose the following modification. Assume that we start out with the question whether C instead of the observation C. We query a context Γ to resolve this question. Suppose that neither C nor the denial of C follows from Γ. In that case, we might try to extend Γ with some *reasonable* assumptions (Δ) and check again whether the question can now be resolved. Here, Δ is not used as an explanation, but rather as bridge between the question and the context.

Reasonable Assumptions and Normality

In our view, the assumption that things are normal is reasonable assumption for practical purposes. Formally, we construct a statement which says that things are normal using the following function:

(38) $normal : ([x : entity, p : entity \rightarrow prop, p' : entity \rightarrow prop] \Rightarrow prop)$

'$normal$' is a function which given an entity and two predicates p and p' on entities returns a proposition. The resulting proposition should be read as: the object x is a normal p with respect to p'. p' divides the set of objects denoted by p into two blocks: the p's and the $\neg p'$s. We can now give a *quantitative* interpretation of normality: normality means that an object is part of the largest block in the partition. We cover the case that the object is not a member of p at all as follows: we stipulate that in that case the object is a normal p with respect to p'.

(39) (FACT) $normal(x, p, p')$ is equivalent with $normal(x, p, \neg p')$ under the aforementioned interpretation.

The fact can be formalized within the system through the following two axioms,where $pred$ abbreviates $entity \rightarrow prop$:

(40) $l : [a : pred, b : pred, x : ent, normal \cdot x \cdot a \cdot b] \Rightarrow n : normal \cdot x \cdot a \cdot \neg b$
$r : [a : pred, b : pred, x : ent, normal \cdot x \cdot a \cdot \neg b] \Rightarrow n : normal \cdot x \cdot a \cdot b$

Furthermore, we propose that the most basic form of a rule[14] which employs normality conditions instantiates the following schemes:

(41) $[X : entity, Q : P \cdot X, R : normal \cdot X \cdot P \cdot P'] \Rightarrow P' \cdot X$

Let us now use this machinery to account for the most elementary type of jumping to conclusions, i.e., the *defeasible modus ponens*. A typical 'inference' of this type is from *Birds can fly, and Tweety is a bird* to *Tweety can fly*. The inference is defeasible because the new information that *Tweety cannot fly* invalidates the conclusion that *Tweety can fly*.

We start out with a context Γ which contains the following pieces of information (*Birds fly* and *Tweety is a bird*):

(42) a. $f : [x : entity, p : bird \cdot x, q : normal \cdot x \cdot bird \cdot fly] \Rightarrow fly \cdot x$

b. $t : entity, a : bird \cdot t$

Our goal is to find a proof for the proposition $fly \cdot t$. Such a proof can be constructed if we extend Γ with the information that Tweety is a normal bird with respect to the property *fly* ($normal \cdot t \cdot bird \cdot fly$):

(43) $\Gamma, n : normal \cdot t \cdot bird \cdot fly \vdash f \cdot t \cdot a \cdot n : fly \cdot t.$

Now suppose that we come to know that *Tweety does not fly*. This information, represented type-theoretically as $b : fly \cdot t \to \bot$ is added to Γ. At this point the assumption that Tweety is a normal bird with respect to the property *fly* is no longer reasonable; it leads to a contradiction:

(44) $\Gamma, b : fly \cdot t \to \bot, n : normal \cdot t \cdot bird \cdot fly \vdash b \cdot (f \cdot t \cdot a \cdot n) : \bot$

This leads us to the second most important variety of jumping to conclusions, the *penguin principle*. This principle is exemplified by the inference from Birds can fly, Penguins cannot fly, Penguins are birds and Tweety is a penguin to *Tweety does not fly*. To account for this principle we first need to introduce a new axiom:

(45) $sub : [a : pred, b : pred, c : pred, x : ent, p_1 : (a \cdot x \to b \cdot x),$
$p_2 : normal \cdot x \cdot b \cdot c] \Rightarrow normal \cdot x \cdot a \cdot c$

This rule can be used to derive, for instance, that if something is a normal bird with respect to flying, then it is a normal penguin with respect to flying. Now notice, that a bird can only be a normal penguin with respect to flying if the bird is not a penguin. If it is a penguin, then it cannot be both in the largest blocks of birds divided by fly (meaning that it is a normal bird with respect to flying and penguins divided by fly a (which means that it is a normal penguin with respect to flying). In particular, it cannot be in *bird*, *fly*, *penguin* and *not fly* at the same time. Thus if we derive that some bird is a penguin and we had already assumed that the bird was normal with respect to flying, then we end up in a contradictory situation. We make use of this fact in our account of the *penguin principle*.

$f : [x : entity, p : bird \cdot x, q : normal \cdot x \cdot bird \cdot fly] \Rightarrow fly \cdot x$
(Birds fly)
$g : [x : entity, p : penguin \cdot x, q : normal \cdot x \cdot penguin \cdot \neg fly] \Rightarrow$
$\neg fly \cdot x$
(Penguins do not fly)
$h : [x : entity, p : penguin \cdot x] \Rightarrow bird \cdot x$
(Penguins are birds)
$t : entity$
$b : bird \cdot t$
(Tweety is a bird)
$\Delta = n : normal \cdot t \cdot bird \cdot fly$
(Tweety is a normal bird with respect to flying)

Conclude: $f \cdot t \cdot b \cdot n : fly \cdot t$
(Tweety can fly)

New information: $c : penguin \cdot t$
(Tweety is a penguin)

Consequence of adding the new information:
$\bot$ can be derived:
$(g \cdot t \cdot c \cdot (l \cdot (sub \cdot penguin \cdot bird \cdot t \cdot n_1))) \cdot (f \cdot t \cdot b \cdot n) : \bot$

In words, if we would simply add the information that the bird t is a penguin, we could, using the sub axiom, derive that the bird is a normal penguin, and therefore does not fly. Since we can derive that it flies on the basis of the assumption that it is a normal bird, we arrive at an inconsistency. Therefore, we need to look for an alternative assumption to extend the context with, which does not lead to a contradiction. An extension that is possible is:

(46) $n' : normal \cdot t \cdot penguin \cdot \neg fly$

This extension supports the conclusion that t does not fly.

Implications of the proposal

To check our proposal in more detail let us look at some further inference patterns which we have taken from Pelletier and Asher (1997).

(47) (DEFEASIBLE TRANSITIVITY) Birds Fly, Sparrows are birds **Therefore** Sparrows fly

'Birds Fly' translates into (42.a). We can represent that formula schematically as $[B, N] \Rightarrow F$. 'Sparrows are birds' corresponds to $S \rightarrow B$, and finally we abbreviate 'Sparrows fly' as $[S, N] \Rightarrow F$. The latter formula can indeed be proven on the basis of the former two. Informally, the proof goes as follows. Assume that S. We can now prove B, using $S \rightarrow B$. From B and $[B, N] \Rightarrow F$, we can prove $[N] \Rightarrow F$. If we now withdraw the assumption S, then we arrive at the conclusion $[S, N] \Rightarrow F$. Similarly, (48) is supported by our proposal, because white birds are birds.

(48) (DEFEASIBLY VALID) Birds fly **Therefore** White birds fly.

Note that we can easily check whether these inference patterns hold, on the basis of the classical logical derivations that can be performed in PTS. This advantage is obtained by treating the normality rules as standard type-theoretical implications (Dependent function types).

The Nixon Diamond is one of the more notorious inference patterns.

(49) (NIXON DIAMOND) Nixon is a quaker and a republican. Quakers are normally pacifists and republicans are not.

The question is whether it holds that Nixon is a pacifist or that he is not a pacifist. The logical representation of the discourse as such licences neither of these inferences: Q, R, $[Q, N_Q] \Rightarrow P$, $[R, N_R] \Rightarrow \neg P$. The assumption that N_Q (Nixon is a normal quaker with respect to pacifism) leads to the conclusion that Nixon is a pacifist. Alternatively, the assumption N_R (Nixon is a normal republican with respect to not being a pacifist) leads to the conclusion the Nixon is not a pacifist. We can, however, not maintain both assumptions at the same time.

Another interesting consequence of our proposal is that we cover two ways in which a deduction can be blocked. Consider the rule that doctors normally earn a big salary ($[D, N_D] \Rightarrow BS$). That is, doctors that are normal with respect to earning big salaries, earn big salaries. Now take some doctor named John. We infer (assuming N_D) that he earns a big salary. This can be cancelled by saying that he doesn't ($\neg BS$). We could, however, also come to know that John is working in a rural area (RD, for Rural Doctor). Now, it could very well be that such doctors are not normal with respect to earning a big salary ($RD \rightarrow \neg N_D$). We infer that John is not a normal doctor with respect to earning big salaries ($\neg N_D$). Thus, we have to withdraw the assumption that John is a normal doctor with respect to earning big salaries. But note that at this point we have no information with respect to John's salary: for all we know, it might still turn out to be big.

Finally, let us sketch the difference of our approach with circumscription (McCarthy, 1980). Circumscription can be used to minimize abnormality. What we do may be described as maximizing normality. Pelletier and Asher (1997), draw attention to the following problem with circumscription. Consider:

(50) Birds fly. Sam is a bird. Therefore Sam flies.

The problem with circumscription is that if we obtain the information that there is some bird that does not fly, then the inference is blocked. In the minimal model there is now one bird which doesn't fly and which might be equal to Sam. Therefore the conclusion that Sam flies can no longer be drawn. Our system allows us to add birds that are not normal with respect to flying and still assume that the bird that is queried is a normal bird with respect to flying. The assumption that Sam is a normal bird with respect to flying and the information that there is a bird which does not fly are not contradictory.

II

Information

3 Presuppositions and Proofs

Language users transfer information by producing utterances. There are different ways of transferring information by means of utterances. In particular, there is a distinction between information that is *presented* by means of what the speaker *asserted* and information that is *conveyed* by means of what the speaker *presupposed* when producing the assertion.

The distinction between that what is asserted and that what is presupposed goes back to the writings of Gottlob Frege. In his 'Ueber Sinn und Bedeutung' (Frege, 1892) he considers the assertion of 'Kepler died in misery'. Frege claims that whereas the assertion *presupposes* that the name 'Kepler' has a reference, it is *not* part of the (propositional) content of the assertion.

Frege argues as follows in favor of his position. Suppose that *the name 'Kepler' has a reference* is part of the content of the assertion. On this assumption, the denial of the assertion should be "Kepler did not die in misery or the name 'Kepler' does not have a reference". However, the more simple 'Kepler did not die in misery' is the actual denial of 'Kepler died in Misery'. Therefore, *the name 'Kepler' has a reference* is not part of the content of the assertion of 'Kepler died in misery'.

Frege calls the information that *the name 'Kepler' has a reference*, which is conveyed without being asserted, the presupposition of the assertion.[15] Frege's use of the denial of a sentence has become a standard means to identify the presuppositions of a sentence. It is known as the negation test.

Frege discusses presuppositions in connection with names such as 'Kepler' and definite descriptions. Since Frege, many more constructions have been labelled presuppositional. The following list comes from Beaver (1997, 943–944): Definite NPs, Quantificational NPs, Factive Verbs and Noun Phrases, Clefts, Wh-questions, Counterfactual conditionals, Intonational stress, Sortally restricted predicates, Signifiers of actions and temporal/aspectual modifiers, Iterative adverbs and Others (such as implicatives and verbs of judging). In this chapter, we focus

on the presuppositions associated with Definite NPs, Quantificational NPs and Factive Verbs.

Tests and lists of constructions tell us little about the role that presuppositions play when language is put to use. In the early 70's, this issue was addressed by Robert Stalnaker. He put forward the idea that a presupposition of an asserted sentence is a piece of information which is assumed by the speaker to be part of the common background of the speaker and interpreter (Stalnaker 1974). Ideas along similar lines were put forward by, amongst others, Karttunen (1976) and Seuren (1975). Eventually, these ideas gave rise to what has become known as the presuppositions as anaphora theory (Van der Sandt, 1992). According to Van der Sandt, a presupposition just like an ordinary anaphor has to be bound to an antecedent that is available in the (linguistic) context (which is subsumed by Stalnaker's common background).

Van der Sandt's anaphoric account of presupposition is generally considered to be the theory which makes the best empirical predictions for the so-called projection problem of presuppositions, i.e., how the presuppositions of a complex sentence can be accounted for in terms of the presuppositions of the parts of that complex sentence.

Van der Sandt proposes to *resolve* presuppositions just like anaphoric pronouns are resolved in *Discourse Representation Theory* (DRT, Kamp & Reyle 1993). Van der Sandt contends that there is also an important difference between pronouns and presuppositions: when there is no antecedent for an anaphoric pronoun, the sentence containing the pronoun cannot be interpreted, however when there is no antecedent for a presupposition —and the presupposition provides sufficient descriptive content (we prefer: provides sufficient means to identify the referent, since the referents of names can also be accommodated)— then the presupposition can be *accommodated*, i.e., added to the context (see also 12 on page 6).

For instance, *A* might say to *B* that Wim Kok is the prime minister of the Netherlands. If *B* never heard of Wim Kok, there will be no antecedent. In that situation, *B* might simply update his context with a fresh antecedent for Wim Kok. This combination of resolution and accommodation constitutes the empirical strength of Van der Sandt's approach.

Like most research in this area, Van der Sandt's work concentrates on the interaction between presuppositions and the *linguistic* context (i.e., the preceding sentences). In this chapter, we provide an account of the interaction between presuppositions and context which goes beyond the direct linguistic context. Consider the following examples, which illustrate the importance of the non–linguistic context for presuppositions:

(1) a. If John is married, his wife probably walks the dog.
b. If John buys a car, he checks the engine first.
c. If Spaceman Spiff lands on planet X, he will be annoyed by the fact that his weight is higher than it would be on earth. (Beaver 1995)

Example (1.a) contains a definite description, *his wife*, which triggers the presupposition that John has a wife. For the correct treatment of this example, a rather trivial piece of world knowledge is needed: if a man is married, he has a wife. But, if we do not take this piece of world knowledge into account, the theory of Van der Sandt (1992) is not able to treat being *married* as an 'antecedent' for the presupposition triggered by *his wife*. Being married creates an (implied) antecedent for *his wife*.

A more substantial usage of world knowledge is required for example (1.b), which is an example of the notorious *bridging phenomenon* (Clark 1975). The definite description *the engine* presupposes the existence of an engine. Since there is no proper antecedent for this definite description, the theory of Van der Sandt (1992) predicts that the presupposition is accommodated. But this fails to do justice to the intuition that the mentioning of a car somehow licenses the use of *the engine* and that the engine is part of the car which John buys.

Example (1.c) also illustrates the need for world knowledge. The *the fact that S* construction presupposes *S*. This means that the consequent of (1.c) contains a presupposition stating that Spaceman Spiff's weight is higher than it would be on earth. Since there is no obvious way to bind this presupposition, Van der Sandt's account predicts that it is accommodated.

The claim that world knowledge has an influence on presupposition projection is hardly revolutionary. For instance, Van der Sandt seems to assume that world knowledge somehow influences presupposition projection (Van der Sandt 1992:375, fn. 20), but he gives no clues on how world knowledge interacts with his theory of presuppositions. The central question addressed in this chapter is *how* to account for the influence of world knowledge on presupposition projection.

We demonstrate that employing the class of mathematical formalisms known as *Pure Type Systems* (PTS) allows us to answer this question. We present a new presupposition resolution algorithm based on PTS. In spirit, our approach nicely fits in with the idea of presuppositions as anaphors. This is due to the fact that in PTS, proofs are explicitly represented as objects, which makes it possible to model antecedents to anaphors as proof objects.

Our approach is different from the Van der Sandtian approach in the following respect: we try to restrict the tampering with the structure of an 'utterance' as part of the resolution process. By tampering with the structure of an utterance, we mean that the representation of the meaning of the utterance is structurally

changed by inserting (accommodating) an antecedent into it (in particular, we get rid of intermediate accommodation, and reformulate local accommodation in non–structural terms). [16]

We show that the use of PTS allows us to account for a number of data that are beyond the Van der Sandtian theory (in particular, concerning presuppositions in disjunctions and conditionals). The success of the account can be ascribed to the combination that PTS provides of context representations as sequences of introductions of objects, and higher-order logical deduction to construct the implicit objects that can be present in such a context. These implicit objects model the antecedents that can be arrived at by means of world knowledge.

The remainder of this chapter consists of the following sections: in section 3.1, we describe the deductive approach to presuppositions that we advocate. For that purpose, we introduce the notion of a presupposition as a *gap*. In the subsequent sections, we discuss some of the advantages of the present perspective by focussing on the interaction between world knowledge and presupposition projection. In section 3.2, we focus on presuppositions occurring in conditionals and disjunctions. Section 3.3 gives an account of the bridging phenomena. Section 3.4 addresses the issue of the determinacy of bridges which are constructed using world knowledge. The claims that are made in this section are supported by means of a small exploratory experiment. Section 3.5 contains some comparisons of our proposal with related work from the literature. Section 3.6 contains our conclusions. This chapter contains an appendix in which our resolution algorithm for presuppositions is presented (section 3.8) and an appendix in which the aforementioned exploratory experiment is described (section 3.7).

3.1 Presuppositions as Gaps

Van der Sandt (1992) proposes to resolve presuppositions, just like anaphoric pronouns are resolved in DRT (see also section 1.1). For this purpose he develops a meta-level resolution algorithm. The input of this algorithm is an *underspecified* Discourse Representation Structure (proto DRS), which contains one or more unresolved presuppositions. When all these presupposition have been resolved, a *proper* DRS remains, which can be interpreted in the standard way (see section section-context-interpretation).[17]

A proper DRS is the end product of the interpretation of a sentence with respect to a main DRS. Ahn & Kolb (1990) show that this end product can be translated into a corresponding PTS context. Van der Sandt's presuppositional DRSs can be seen as a kind of proto DRSs of which the presuppositional representations have not yet been resolved. Only after binding and/or accommodation of the presuppositional representations a proper DRS is produced. Analogously, in PTS terms, a construction algorithm could translate a sentence into a proto type before a proper type is returned. This proper type (i.e., proposition) can then be added to the main context by introducing a fresh proof for it. Consider the following sentence:

(2) If a Chihuahua enters the room, the dog snarls.

The appropriate proto type for (2) is:[18]

(3) $[x\!:\!entity, y\!:\!chihuahua\cdot x, z\!:\!enters\cdot x] \Rightarrow$
$(snarl\cdot Y)_{[Y:entity, P:dog\cdot Y]}$

Thus, if x is an entity and y a proof that x is a Chihuahua and z is a proof that x enters, then there exists a proof that Y snarls, where Y is a *gap* to be filled by an entity for which we can prove that it is a dog. The presuppositional annotation consists of a sequence of introductions with gaps.

Before we can evaluate the PTS representation (3) given some context Γ, we first have to resolve the presupposition by filling the gaps. For this purpose, we have developed a resolution algorithm which makes essential use of deduction in PTS (see section 3.7). The first thing we do after starting the resolution process, is try to fill the gap by 'binding' it. The question whether we can bind the presupposition triggered by 'the dog' in example (2) can be phrased in PTS as follows: is there a substitution S such that the following can be proven?[19,20]

(4) $\Gamma, x\!:\!entity, y\!:\!chihuahua\cdot x, z\!:\!enter\cdot x \vdash_{\Delta}$
$(Y\!:\!entity, P\!:\!dog\cdot Y)[S]$

In words: is it possible to prove the existence of a dog from the global context Γ extended with the local context (the antecedent of the conditional)? The answer is: that depends on Γ. Suppose for the sake of argument that Γ itself does not contain any dogs, but that it does contain the information that a Chihuahua is a dog. Technically, this means that (5) is a member of Γ:

(5) $f\!:\!([a\!:\!entity, b\!:\!chihuahua\cdot a] \Rightarrow (dog\cdot a))$

Given this function, we find a substitution S for (4), mapping Y to x and P to $(f\cdot x\cdot y)$ (which is the result of applying the aforementioned function f to x and y).[21] So we fill the gaps using the substitution S, remove the annotations (which have done their job) and continue with the result:

(6) $[x\!:\!entity, y\!:\!chihuahua\cdot x, z\!:\!enter\cdot x] \Rightarrow (snarl\cdot x)$

Thus, intuitively, if an interpreter knows that a Chihuahua is a dog, she will be able to bind the presupposition triggered by the definite *the dog* in (2).

Now suppose the interpreter does not know that a Chihuahua is a dog or is of the opinion that Chihuahuas simply are not 'proper' dogs. That is, Γ does not contain a function mapping Chihuahuas to dogs. Then, still under the assumption that Γ itself does not introduce any dogs, the interpreter will not be able to prove the existence of a dog. She can then try to accommodate the existence of a dog by replacing the gaps Y and P with fresh variables, say y' and p', and extending the context Γ with $y'\!:\!entity, p'\!:\!dog\cdot y'$. Of course, it has to be checked whether this move is *adequate*, i.e., whether the result of accommodation is consistent and informative. For more details on the resolution algorithm the reader is referred to section 3.7.

3.2 Conditionals and Disjunctions

One attractive feature of the PTS view on discourse is that we get 'discourse markers' for propositions for free. This is useful, for instance, in the case of propositional presuppositions, such as the one triggered by *the fact that S* construction in example (1.c). According to Stalnaker (1974), a proposition which is presupposed should be part of the context (common background). In terms of PTS , this means that a proof for the proposition should be derivable in the context. The latter interpretation agrees nicely with the dictum of presuppositions as anaphors: the proof of the proposition acts as the required antecedent (cf., Ranta, 1994).

In order to make this idea more precise, let us give the proto type for example (1.c). For the sake of simplicity we treat 'annoyed by the fact that' as a (complex) predicate: *annoyed* is a function which when applied to a person, a proposition and a proof for the proposition yields a new proposition, formally: $annoyed\!:\![x\!:\!entity, q\!:\!prop, r\!:\!q] \Rightarrow prop$. Now we can represent (1.c) as the PTS proto type (7).[22]

(7) $[p\!:\!land\cdot sp\cdot plx] \Rightarrow$
$(annoyed\cdot sp\cdot(weigth\_higher\cdot sp)\cdot P)_{[P:weight\_higher\cdot sp]}$

Conditionals

The basic structure of the proto type (7) is $\Phi \Rightarrow \Psi_{\pi}$. The presupposition resolution algorithm which is described in section 3.7 proceeds as follows. The algorithm first tries to bind the presupposition in the context of Γ, extended with the representation of the antecedent of the conditional. In this case, the conditional's antecedent seems to provide no proper antecedent for the presupposition. World knowledge can, however, change the picture dramatically. Suppose that the interpreter knows that *if something lands on planet X, then its weight will be higher than it would be on earth*, formally $f : ([x : entity, q : land \cdot x \cdot plx] \Rightarrow weight\_higher \cdot x)$. In that case, the presupposition can be bound. The appropriate substitution for the presupposition P, namely $f \cdot sp \cdot p$, is obtained by using world knowledge and the information given in the antecedent of the conditional.

Now, suppose there is not sufficient information in the context to find a binder for the presupposition. Then some piece of information will have to be accommodated. First, the algorithm attempts to globally accommodate the presupposition. This results in a rather awkward reading, paraphrasable as 'Spaceman Spiff's weight is higher than it would be on earth, and if he lands on planet X, it will annoy him (that his weight is higher than it would be on earth)'.

Beaver (1995) explains this awkwardness by pointing out that the sentence will typically be uttered in a situation where Spiff is hanging somewhere in space. Most of us know that in space one is weightless. So for the average interpreter, global accommodation of *Spiff's weight is higher than it would be on earth* is blocked: adding this proposition to a context containing the information that Spiff is weightless will enable the interpreter to derive an inconsistency (given some other fairly common pieces of information, e.g., 'on earth one is not weightless').

If *global* accommodation is ruled out, there are two possibilities left according to Van der Sandt (1992): *intermediate* and *local* accommodation. Intermediate accommodation is, however, not entirely uncontroversial. For instance, (Beaver, 1995) presents some counter examples. This led us to exclude intermediate accommodation from our algorithm. We will motivate this decision in more detail after our discussion of (7).

In section 3.7, we deal with local accommodation using two clauses: one for situations in which the presupposition occurs within the consequent of an implication and one for situations in which the presupposition occurs within the antecedent of an implication. We differentiate between the two cases, because the first type of local accommodation that we propose is non-structural (i.e., it does not lead to changes in the structure of the proto type of the utterance that is being processed; only the global context is incremented with the missing piece of information), unlike Van der Sandt's local accommodation.

The first type of local accommodation works basically as follows: Given a PTS expression of the form $\Phi \Rightarrow \Psi_\pi$ (as (7)), the algorithm adds $\Phi \Rightarrow \pi$ to the *global* context, i.e.: we model local accommodation as global accommodation of a *conditional* presupposition. The advantage of this non-structural version of

local accommodation can be illustrated using the following example from Beaver (1995).

(8) It is unlikely that if Spaceman Spiff lands on planet X, he will be annoyed by the fact that his weight is higher than it would be on earth.

Van der Sandt's local accommodation produces the following interpretation for this sentence: 'It is unlikely that if Spaceman Spiff lands on planet X, his weight will be higher than it would be on earth and he will be annoyed by this fact'. Beaver (1995) remarks that Van der Sandt's reading does not entail that *if Spaceman Spiff lands on planet X, his weight will be higher than it would be on earth* (it even suggests the opposite), whereas it intuitively should. According to our re-definition of local accommodation the latter sentence is supported by the (adjusted) global context.

The second kind of local accommodation that we present in section 3.7 is structural in nature. It covers those data which have been advanced in favour of the position that presuppositions are part of the content of an assertion (Russell, 1905):

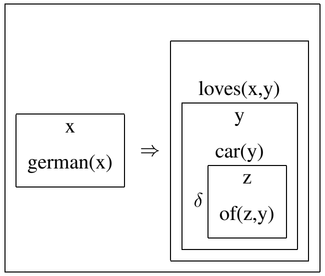
(9) The King of France is not bald, since there is no King of France.

In this case, the presupposition that *there is a King of France* needs to be accommodated within the scope of the negation, because addition of it and the information that *there is no King of France* to Γ yields an inconsistent context. Thus 'The King of France is not bald' ($\phi_\pi \Rightarrow \perp$), is rewritten into *it is not the case that there is a King of France who is bald* ($(\pi \otimes \phi) \Rightarrow \perp$). There is no way to model this kind of accommodation non-structurally.

We have seen that we need at least on type of structural accommodation. Van der Sandt, however, uses a second type of structural accommodation which he calls intermediate accommodation. We speak of intermediate accommodation when the presupposition is neither accommodated at the place where it was triggered, nor in the main DRS. Rather, the presupposition is accommodated somewhere in between these two locations. Intermediate accommodation is particularly interesting when it leads to the addition of a presupposition to the *antecedent* of an implicative condition. Consider , for instance, the following example which Van der Sandt has put forward in defense of intermediate accommodation:

(10) Every German loves his car.

The proto DRS belonging to this sentence is:

(11) 

Van der Sandt points out that the preferred reading for (10) is the one where the sentence is true in case all car owning Germans love their car. This reading is obtained by adding the presupposition to the antecedent of the implicative condition: *if x is a German and there is a car y belonging to x, then x loves y*. Thus intermediate accommodation yields the correct reading. In other words, domain restriction is modelled in terms of intermediate accommodation. Van der Sandt's local accommodation yields a reading which is only true if *every German owns a car*. This is due to the fact that the existence of a car is accommodated in the consequent of implicative condition.

At first sight, our (first) type of 'local' accommodation produces exactly the same incorrect reading: we would accommodate that *every German owns a car* (i.e., $\Delta \Rightarrow \pi$) into the main context Γ. We contend, however, that this problem is resolved when we adopt a more adequate representation for 'Every German'. So let us work out in more detail what such a representation should look like.

Let us assume that all quantificational NPs with a strong or accented determiner are presuppositional (cf. De Jong, 1987; Krahmer & Van Deemter, 1997). More precisely, 'Every German' is associated with the presupposition that *there is a contextually given set of Germans*: $[G : entity, P : Germans \cdot G]$. The idea is here that G should pick up a plural individual consisting of Germans.[23] Thus the formal representation of (10) is:

(12) $[x\!:\!entity, p\!:\!member \cdot x \cdot G]_{[G:entity,P:germans\cdot G]} \Rightarrow$
$(love \cdot Z \cdot Y_{[Y:entity,Q:car\cdot Y,R:of\cdot Z\cdot Y]})_{[Z:entity]}$

Now, we can first resolve $[G : entities, P : germans \cdot G]$. In case there is no contextually salient set of Germans in the context, we have to globally accommodate such a set. Let us assume that the set in question is g; so we apply the substitution $[G := g]$. Subsequently, we have to resolve $[Z : entity]$. In this case, in Γ extended with the antecedent of (12), we can fill in Z with the x

that is introduced by the antecedent. Finally, we have to resolve the last of the presuppositions:

(13) $[Y : entity, Q : car \cdot Y, R : of \cdot x \cdot Y]$

There is no substitution available for the gaps in this segment in Γ extended with the antecedent. So let us now see what local accommodation amounts to. In case of local accommodation we have to extend the global context Γ with:

(14) $f : [x\!:\!entity, p\!:\!member \cdot x \cdot g)] \Rightarrow [y : entity, q : car \cdot y, r : of \cdot x \cdot y]$

This is an abbreviation for the following three functions (see fn. 34).

(15) a. $f_1 : [x\!:\!entity, p\!:\!member \cdot x \cdot g] \Rightarrow entity$
b. $f_2 : [x\!:\!entity, p\!:\!member \cdot x \cdot g] \Rightarrow car(\cdot f_1 \cdot x)$
c. $f_3 : [x\!:\!entity, p\!:\!member \cdot x \cdot g] \Rightarrow of \cdot x \cdot (f_1 \cdot x)$

In words, we extend Γ with (a) a function from members of the set of salient Germans g to entities; (b) a function providing a proof that the entities mentioned in (a) are cars; and (c) a function that provides a proof that each of the cars associated by function f_1 with a German in g, belongs to that German. To summarize: we have added to Γ the information that each of the Germans in g owns a car. Thus we avoid accommodating that '*Every* German owns a car'. After having updated Γ, we proceed with the resolution of the proto type. The final result is:

(16) $[x\!:\!entity, p\!:\!member \cdot x \cdot g)] \Rightarrow (love \cdot x \cdot (f_1 \cdot x))$

In words, all the Germans x in g love their car $f_1 \cdot x$. So there are prospects that intermediate accommodation might after all not be required. Note that the account we have given *cannot* be framed in DRT as it stands: it makes essential use of functions. Y is bound to $f_1 \cdot x$. In DRT, it is not possible to introduce discourse referents for functions of a particular type.

Up till now, we have only shown that intermediate accommodation is not really required for certain examples. Beaver (1995) shows that intermediate accommodation leads to wrong results for certain discourses. So let us see how our account fares for these discourses. Consider:

(17) (How many team members and cheerleaders will drive to the match?)

⋆ Few of the 15 team members and none of the 5 cheerleaders can drive, but *every team member will come to the match in her car*. So expect about 4 cars. (Beaver, 1995:115)

Here, Van der Sandt's intermediate accommodation leads to a reading where the antecedent is restricted to the set of car-owning team members. It fails to predict the oddity of (17). Beaver points out that this problem is beyond repair, since the version of (17) where the domain restriction is made explicit is perfectly acceptable:

(18) (How many team members and cheerleaders will drive to the match?)

Few of the 15 team members and none of the 5 cheerleaders can drive, but *every team member who owns a car will come to the match in her car*. So expect about 4 cars. (Beaver, 1995:115)

So, what does our account have to say about (17)? We predict that the following piece of information is a possible candidate for accommodation into the main context: *Every team member of the salient set of team members owns a car*. The reading of the sentence in italics in (17) now turns out to be: *Everyone of the just introduced team members will come to the match in the car that belongs to him/her*. But evidently, all this adds up to an inconsistent main context (remember that the main context already contains: *Few of the 15 team member can drive*). Thus our version of local accommodation is ruled out. Since no other resolution is possible, we predict that the discourse is odd.

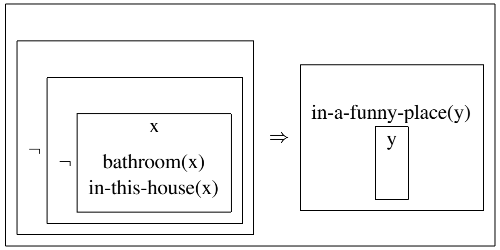
Disjunction

In our algorithm, we do not explicitly deal with disjunction. We can, however, leave the algorithm intact and exploit the logical equivalence between $\Phi \vee \Psi$ and $(\Phi \Rightarrow \bot) \Rightarrow \Psi$. For that purpose, we have to postulate that a natural language sentence of the form 'A or B' is translated into a proto type of the form $([A] \Rightarrow \bot) \Rightarrow [B]$, where $[A]$ and $[B]$ stand for the type theoretical segments corresponding to A and B, respectively. There are independent reasons for this particular representation of 'or': it has been pointed out by Krahmer & Muskens (1994) that this representation together with the rule for double negation of classical logic $(((\phi \to \bot) \to \bot) \to \phi)$ enables the treatment of some apparently refractory data. Representative for these data are the 'bathroom sentences', such as:

(19) Either there is no bathroom in this house, or it's in a funny place. (Attributed to Barbara Partee)

Let us give the corresponding DRS for this sentences (assuming that 'or' is translated in terms of negation and implication):

(20)



To arrive at the appropriate reading of (19), we need to bind y to x. In standard DRT, x is, however, not accessible for y. We might add an ad hoc rule which erases double negation, thus making the x in the antecedent accessible after all. Krahmer & Muskens (1994) point out that this would mean that the aim to account for the bathroom sentence *within* dynamic semantics is abandoned, since the dynamic interpretation (in terms of assignment pairs) of $[\,|\,\neg[\,|\,\neg K]]$ and K are different (note though, that their *truth-conditions* are the same). The solution provided by Krahmer & Muskens is to alter the semantics of DRT. In this new DRT (dubbed Double Negation DRT), the dynamic interpretations for $[\,|\,\neg[\,|\,\neg K]]$ and K are the same.

As opposed to standard DRT, the proof-theoretical framework that we advocate supplies us with the correct predictions right from the start. All we need is the assumption that we are working within a system of classical logic, i.e., the rule for double negation should hold. Let us assume that the rule is enforced through an axiom:

(21) $ax : ([p\!:\!prop, q\!:\!((p \to \bot) \to \bot)] \Rightarrow p)$

In words: for every proposition p, if there is a proof (q) for $((p \to \bot) \to \bot)$, then the axiom allows us to construct a proof $(ax \cdot p \cdot q)$ for p itself. This brings us in position to deal with the proto type for (19):

(22) $[q\!: ([r\!: ([x\!:\!entity, p\!:\!bathroom \cdot x] \Rightarrow \bot)] \Rightarrow \bot)] \Rightarrow$
$in\_funny\_place \cdot Y_{[Y:entity]}$

The resolution of the pronoun 'it' noun comes down to finding a substition S which assigns a bathroom to Y, which is inferred on the basis of q (i.e., that it is not the case that there is no bathroom).

(23) $\Gamma \otimes q\!: ([r\!: ([x\!:\!entity, p\!:\!bathroom \cdot x] \Rightarrow \bot)] \Rightarrow \bot) \vdash Y : entity[S]$

There is indeed such a substitution. This substitution assigns the following object to Y:

(24) $\pi_1(ax \cdot (\Sigma x : entity.bathroom \cdot x) \cdot (\lambda h.(q \cdot (\lambda x.(\lambda y.h \cdot \langle x, y\rangle)))))$

The fact that this proof looks rather complex is due to the fact that the double negation rule (21) can only be applied to propositions of the form $((p \to \bot) \to \bot)$, where p is a proposition. In our representation, however, p is a segment. Therefore, the proof involves a construction of the proposition corresponding to this segment (i.e., a Σ-type).[24]

Thus, the bathroom sentence is correctly interpreted purely by the use of classical logic within our framework. The same can be said about the 'umbrella sentence':

(25) John didn't remember not to bring an umbrella, although we had no room for it. (From Karttunen, 1976:370)

Here too, 'it' can pick up the antecedent that is introduced within the scope of two negations.

Note that the translation of disjunctions is not symmetrical. Consider:

(26) The King of France is bald or there is no King of France.

This sentence is not assigned a binding reading. The proto type for this sentence is: $((\Phi_\pi) \Rightarrow \bot) \Rightarrow (\pi \to \bot)$. Note that global accommodation is ruled out on the basis of the acceptability condition on consistency (see section 3.7, 58): global accommodation of π would mean that the global context is inconsistent with a subterm of $((\Phi_\pi) \Rightarrow \bot) \Rightarrow (\pi \to \bot)$, i.e., $(\pi \to \bot)$.

Thus, we are forced to employ our second version of local accommodation (the structural variant) to this sentence: $((\Phi_\pi) \Rightarrow \bot) \Rightarrow (\pi \to \bot)$ comes out as: $([\pi \otimes \Phi] \Rightarrow \bot) \Rightarrow (\pi \to \bot)$. The paraphrase of this interpretation is 'If it is not the case that the King of France is bald, then there is no King of France', which is indeed the correct interpretation of (26).

To finish our discussion of disjunction, let us consider one final example that is problematic for standard DRT:

(27) The barn contains a chain saw or a power drill. It makes an ungodly racket. (Kamp & Reyle, 1993:205)

Kamp and Reyle contend that the 'It' in the second sentence refers 'to the machine, whatever its precise nature or function' (Kamp & Reyle, 1992:206). They propose to amend the construction algorithm such that it will introduce the appropriate referent to the main DRS. The details of the new construction rule are left as a topic for further investigation. Here, we want to point out that our treatment of disjunction in combination with the double negation rule already provides us with a solution to the problem. Let us explain this using propositional logic only. Take the following translation keys:

(28) p = *There is a chain saw in the barn*,
q = *There is a power drill in the barn*,
u = *There is a machine in the barn*.

Let us assume that our interpreter has the following background knowledge: (i) $p \to u$ and (ii) $q \to u$. The first sentence in (27) can now be translated into (iii) $\neg p \to q$ (i.e., $p \vee q$). The background information, the double negation rule and the representation of (27) together allow us to infer that u.[25] So, we can infer that there is a machine in the barn. The machine that is thus inferred can serve as the antecedent of 'It' in (27).

3.3 Bridging

In this section, we illustrate the formal interaction between world knowledge and presupposition resolution by focusing on the bridging phenomenon. So, what is bridging precisely? Clark (1975) describes it in terms of an interpreter who is looking for an antecedent, but cannot find one directly in memory. 'When this happens, he is forced to construct an antecedent, by a series of inferences, from something he already knows. (...) The listener must therefore bridge the gap from what he knows to the intended antecedent.' (Clark 1975:413).[26] We want to make these general ideas more precise. In particular, we want to spell out the notion of inference that is involved. Clark himself contends that the bridging-inferences are similar in nature to what Grice (1975) has called implicatures.

From the current perspective, there are two kinds of inferences relevant for bridging. The most straightforward one would simply be inference in PTS. We take it that a PTS context Γ represents the information an agent has directly in memory. Inferred information corresponds with objects that can be constructed from objects in Γ using the deduction rules of PTS. However, there is also a second kind of inference in the approach to presuppositions sketched above: accommodation (which bears a close resemblance to abduction in the framework of Hobbs et al. 1993). We claim that both kinds of inference play a role in bridging. Let us discuss each in somewhat more detail.

Inference as Deduction in PTS

We will contend that bridging amounts to using world knowledge to fill gaps. Consider example (1.b) again, here reprinted as (2.a). Its PTS representation is given in (2.b).

(29) a. If John buys a car, he checks the engine first.

b. $[x\!:\!entity, y\!:\!car\cdot x, z\!:\!buy\cdot x\cdot j] \Rightarrow (check\cdot Y\cdot j)_{[Y:entity,P:engine\cdot Y]}$

Before we can add this expression to some context Γ, we have to resolve the presuppositional expression. We first search for a substitution S such that (30) can be proven:

(30) $\Gamma, x\!:\!entity, y\!:\!car\cdot x, z\!:\!buy\cdot x\cdot j \vdash_\Delta (Y\!:\!entity, P\!:\!engine\cdot Y)[S]$

Let us assume that Γ does not contain a sufficiently salient engine. Then the interpreter will try to bridge the gap from what he knows to the intended antecedent. When does he succeed in this, i.e., when can the engine be understood as a bridging anaphor licensed by the introduction of a car? The answer is simple: if the interpreter knows that a car has an engine. Modelling this knowledge could go as follows: Γ contains two functions: one function which maps each car to an entity, $f\!:\!([a\!:\!entity, b\!:\!car\cdot a] \Rightarrow entity)$, and one function which states that this entity is the car's engine $g:([a:entity, b:car\cdot a] \Rightarrow (engine\cdot(f\cdot a\cdot b)))$. Using these two functions, we find a substitution S in (30), mapping Y to $f\cdot x\cdot y$ and P to $g\cdot x\cdot y$.

We can look at the resulting proof-objects as the 'bridge' which has been constructed by the interpreter; it makes the link with the introduction of a car explicit (by using x and y) and indicates which inference steps the user had to make to establish the connection with the engine (by using the functions f and g). Thus, we can fill the gaps, assuming that the proofs satisfy the conditions on informativity and consistency.

Inference as Accommodation

Let us now consider a somewhat more complex example.

(31) John walked into the room. The chandelier sparkled brightly. (after Clark, 1975:416)

Let us assume that the first sentence of (31) has already been processed, which means that the context Γ at least contains the following introductions: $x : entity, y : room\cdot x, z : walk\_in\cdot x\cdot j$. Now, we want to deal with the PTS representation of the second sentence:

(32) $q\!:\!shine\cdot Y_{[Y:entity,P:chandelier\cdot Y]}$

We want to resolve the presupposition triggered by *the chandelier* in the context Γ (assuming that Γ does not introduce any chandeliers). When would an interpreter be able to link *the chandelier* to the room John entered? Of course, it would be easy if she had some piece of knowledge to the effect that every room has a chandelier (Γ would contain functions which produced a chandelier for each room). However, such knowledge is hardly realistic; many rooms don't have a chandelier.

In a more realistic scenario, the following might happen. The interpreter tries to prove the existence of a chandelier, but fails to do so. However, she knows that a chandelier is a kind of lamp and the existence of a lamp *can* be proven using the room just mentioned and the background knowledge that rooms have lamps. Formally, and analogous to the *engine*-example, one function which produces an entity for each room; $f\!:\!([a\!:\!entity, b\!:\!room\cdot a] \Rightarrow entity)$, and one which states that this entity is a lamp; $g:([a:entity, b:room\cdot a] \Rightarrow (lamp\cdot(f\cdot a\cdot b)))$. Since the speaker has uttered (31) the interpreter will *assume* that (one of) the lamp(s) in the room is a chandelier.

Notice that according to this picture both the anaphor *and* the antecedent play a role in constructing the bridge. In terms of the PTS approach: the interpreter *infers* that the room which John entered contains an entity which is a lamp (applying the aforementioned piece of knowledge; the functions f and g), and then binds *part* of the presupposition by filling the Y gap with $f\cdot x\cdot y$ (the inferred lamp). The remaining part of the presupposition (that the lamp is in fact a chandelier) is now *accommodated* in the usual way by filling the P gap with a fresh variable.[27,28]

Summarizing: if the 'bridge' between would-be anaphor and would-be antecedent is fully derivable using world knowledge, the presupposition can be bound. Thus, binding plays a more substantial role than in Van der Sandt's original theory, as presuppositions can be bound to both inferred and non-inferred antecedents. On the other hand, if the 'bridge' between anaphor and antecedent is not fully derivable, the 'missing link' will be accommodated. So, accommodation is still a repair-strategy, as in Van der Sandt's original approach, but now there is generally less to repair. In most cases, accommodation will amount to 'assuming' a more specific description of a deduced object (in this case, that the lamp whose existence has been proven is actually a chandelier).

3.4 Constructing Determinate Bridges

Clark (1975) claims that bridging is a determinate process. In theory, however, background knowledge will license a number of bridges. In PTS terms, there will often be more than one way to fill a presuppositional gap. Clark discusses the following example:

(33) Alex went to a party last night. He is going to get drunk again tonight.

Here ‘again’ triggers the presupposition that Alex was drunk before. According to Clark, we are supposed to assume that ‘every time Alex goes to a party, he gets drunk’. In our opinion, this assumption is too strong, we feel that one would merely assume that Alex was drunk at the party he visited last night. But that is not the point here. Clark (1975:419–420) notices that there are theoretically conceivable alternatives for his assumption which interpreters would, however, never construct:

> ‘(...) we could have assumed instead that every time he [Alex, PP] goes to party he meets women, and all women speak in high voices, and high voices always remind him of his mother, and thinking about his mother always makes him angry, and whenever he gets angry, he gets drunk’

We would like to stress that the problem of determinacy is not restricted to bridging. Consider the following example from Lewis (1979:348):

(34) The pig is grunting, but the pig with the floppy ears is not grunting.

Apparently, this sentence can only be uttered when there are (at least) two pigs in *direct memory*. Nevertheless, each of the expressions can be understood as referring to a determinate pig. Lewis argues that salience is the relevant notion here: he argues that *the pig* is the most salient pig, while *the pig with the floppy ears* is the most salient pig with floppy ears. In other words: the interpreter has to find the most salient antecedent for the respective descriptions in order to guarantee determinedness. However, in the case of bridging, salience is a necessary, but certainly not a sufficient condition to guarantee determinedness. We therefore propose to use two (groups of) conditions to come to a determinate bridge, related to the *effort* an interpreter needs to construct a bridge and the *plausibility* of the constructed bridges.

The effort condition

To begin with the former: as noted above, Clark (1975:420) claims that interpreters do not draw inferences ad infinitum, and to model this he proposes a general stopping rule, which says essentially that the interpreter builds the shortest

possible bridge that is consistent with the context. We take this constraint to subsume two conditions. The first of these conditions boils down to the following rule: use your informational resources as economically as possible. In PTS terms: if a gap can be filled with more than one proof object, fill it with the one with the lowest complexity.

The complexity of a proof object is defined as the number of unbound variables in the β-normal form of the proof object (a λ-term is in β-normal form if it does not have a term of the form $(\lambda x.e_1) \cdot e_2$ as a subexpression). A variable which occurs as part of a proof object and which is not bound by a λ operator corresponds to an object in Γ. (λ abstraction introduces a hypothetical object into a proof, e.g., we can proof $p \to q$ from q by starting with a proof a for q and then introducing a hypothetical proof x for p : $(\lambda x : p.a) : (p \to q)$. Thus we obtain a function, which when it is applied to some proof y of p yields a proof for q, namely $(\lambda x : p.a)y = a$.)

Our complexitity measure takes into account the amount of information needed from Γ to construct the proof- object and also how many times an object has been used. Assume for instance that $\Gamma = p : prop, q : prop, a : p, f : p \to q$ (in words, p and q are propositions, and a is a proof of p and f is a proof of $p \to q$, respectively). We denote the complexity of object o by $C(o)$. For the proof a of p we have: $C(a) = 1$. For q we have $C(f \cdot a) = 2$. Note that for the tautologies of the system there are proofs whose complexity is equal to zero (we need no premisses to prove them).

As a (rather informal) illustration, consider the following example:

(35) The young parents were strolling through the park. The father carried the baby.

Let us assume that the interpreter has evaluated the first sentence and added its representation to Γ, thus, Γ contains an introduction for the young parents, say x. Now say that the interpreter has (at least) the following background knowledge: every pair of young parents contains a father (call this function f_1), and every pair of young parents contains a mother (f_2) and everyone has a father (g). If the interpreter now looks for an antecedent for the presupposition triggered by ‘the father’, she will find $f_1 \cdot x$ (the father amongst the young parents), but also $g \cdot (f_1 \cdot x)$ (the father of the father), and $g \cdot (f_2 \cdot x)$ (the father of the mother). However, the proof-object $f_1 \cdot x$ is clearly less complex (makes thriftier use of the informational resources) than the last two proof-objects, and therefore the interpreter uses this object to fill the presuppositional gap, and not the other two.

The second condition subsumed by Clark’s stopping rule can be put as follows: make as little assumptions as possible (i.e., accommodate as little as possible). Example (33) provides an illustration of this second condition, which on the current approach follows from the general view of accommodation as a repair strategy (modelled by a preference for resolution/binding over accommodation). Factors like recency are also related to minimising effort; e.g., it takes more effort to build a bridge to an antecedent occurring ten sentences ago then to one occurring in the previous sentence.

The plausibility condition

Suppose that we can fill the gap associated with a bridging anaphor with two objects which are indistinguishable under the effort-conditions: the utterance is ambiguous between two different assertions. However, if one of the assertions is less plausible than the other, this helps us to select a determinate reading. Consider the following mini-dialogue:

(36) A: Why did Tom drive Mike's car and not his own?
B: Because the engine had broken down.

A's question presupposes that Tom drove Mike's car and not his own. The description the engine can either be licensed by Mike's car or by Tom's car. If *A* uses the background knowledge that one cannot drive a car with a broken engine, he will be able to derive an inconsistency from *B*'s answer (combined with the presupposition of his question) when he takes Mike's car as an antecedent for the engine, but not when the engine is part of Tom's car. Based on consistency requirements, only the interpretation of *B*'s utterance which answers *A*'s question is selected. The question that this example raises is whether relevance (e.g., answerhood) often is a side-effect of consistency, which we take to be a minimal condition of plausibility. Another illustration of the plausibility condition is the following:

(37) Mary traded her old car in for a new one. The engine was broken.

In this example, the engine can be licensed by both Mary's old car and by her new car. Nevertheless, one has a very strong tendency to interpret the engine as referring to the engine of Mary's old car.

To check these intuitions, we conducted a small enquiry via email among Dutch subjects with (a Dutch version of) (37) as well as some other examples (see section 3.8). After reading example (37), the subjects were presented with the following query:

(38) *Of which car was the engine broken?*

◯ The old one
◯ The new one

Subjects were asked to provide the first answer that came to their mind The results were almost unequivocal: 2 subjects choose the new car, while 48 interpreted the engine as referring to Mary's old car. How can we account for this? One possibility is this: the 48 subjects have the knowledge that a new car (normally) has a working engine. If an interpreter has such background knowledge, then she will be able to derive an inconsistency when the description the engine is linked to Mary's new car. Hence this resolution is not plausible, and thus rejected in favour of the other resolution.[29]

In the two examples discussed so far, two possible readings remained after applying the effort condition, one of which could later be ruled out due to plausibility (consistency) with the side-effect that the selected reading is relevant (i.e., provides an explanation for the event described in the first sentence). However, it can also happen that exactly one reading remains under the effort conditions, although this reading is rather implausible, e.g., it is inconsistent with the world knowledge of the interpreter. Consider, for instance the following example from Asher & Lascarides (1996:16).

(39) a. I met two interesting people last night who voted for Clinton
b. The woman abstained from voting in the election.

The only available antecedent for the woman in (39.b) is one of the two people mentioned in (39.a). As Asher and Lascarides point out, the only available binding reading results in an inconsistency that makes the discourse sound strange. Nevertheless, this (inconsistent) reading is the preferred (only) one. They use this example to indicate a difference with the abductive framework proposed in Hobbs et al. (1993). In that framework, presuppositional and asserted material are treated on a par. As a consequence Hobbs et al. predict a reading in which an antecedent for the woman is accommodated. Here our approach makes the same prediction as Asher and Lascarides' approach. The plausibility condition selects the most plausible reading from the readings which passed the effort condition (those readings requiring least effort). Obviously, if only one reading survived the effort condition, it is by definition the most plausible reading.

The picture that emerges is one where interpretation involves two stages: first a stage where some readings (if any) are selected on the basis of effort and then a second stage in which the interpreter selects the most plausible reading. Accommodation is only an option if the effort condition yields no binding reading whatsoever.

Note that this approach gives a particular meaning to the idea that an interpreter tries to make sense of what has been said. The process of making sense is constrained by simple effort conditions. In other words, although for a particular utterance there may be theoretically possible readings that make sense (e.g., are explanatory with respect to the preceding discourse), these readings may simply not be available, because there are other readings which, although they make less sense, present themselves more readily to the interpreter. Let us illustrate this with another example. Consider:

(40) a. John moved from Brixton to St. John's Wood.

b. The rent was less expensive.

It was found in an experiment by (Matsui 1995) that people interpret the rent as anaphoric to the rent in St. John's Wood. What is more, Matsui's experiment showed that this preference even overrides the default knowledge present in the subjects of the experiment that the rents are generally more expensive in St. John's Wood than in Brixton. Asher & Lascarides (1996:10) argue that: '(...) intuitively, one prefers explanations of intentional changes (in this case, moving house) to simple background information that sets the scene for the change.' If the rent is anaphoric to the rent in St. John's Wood, we get an explanation for John's removal.

But are Asher and Lascarides right? Imagine an alternative situation in which the interpreter has no information about the rents in Brixton and St. John's Wood. Now consider the following discourse:

(41) a. John moved from Brixton to St. John's Wood.

b. The rent was more expensive.

If we apply Asher and Lascarides' analysis to this example ('explanation preferred'), then the prediction is that an interpreter should prefer a reading where the rent refers to the rents in Brixton, since the rents in Brixton being more expensive than those in St. John's Wood would provide a good reason for John's removal. In the aforementioned observational study we tested Asher and Lascarides' prediction by the following query (In order to eliminate the role of background knowledge we have constructed an example with two little known Dutch towns, i.e., Horst and Maasbree):

(42) John moved from Horst to Maasbree
The rent was more expensive.

Where is the rent more expensive?

◯ Horst
◯ Maasbree

Again subjects were asked to provide the first answer that came to their mind. The results for this particular question were as follows: Horst: 8, Maasbree: 42. These results (χ^2=23.12, p$<$0.001) are the opposite of Asher and Lascarides' prediction. We believe that for these examples, the rent is simply interpreted as the rent of John's new domicile in Maasbree/St. John's Wood.

Let us now sketch an explanation in terms of our framework. The basic idea is that the effort condition suggests the most salient antecedent as the most likely candidate. In this case, salience is influenced by the temporal interpretation of the two sentences. In particular, the notion of a reference event, as proposed in, e.g., Hinrichs (1986) may play a central role. In line with the rules provided by Hinrichs, this reference event will be located immediately after the moving event. In other words, for the reference event it holds that John is living in Maasbree and thus he is paying the rent in Maasbree.

According to Hinrichs, if a sentence expresses a state, then the reference event of the previous sentence should be temporally included in this state. Thus, the state expressed by 'The rent was more expensive' should include the referent event where John lives in Maasbree. This is what makes the reading where the rent refers to the rent in Maasbree the most preferred reading.[30]

With regard to plausibility, neither the reading where the rent refers to the rent in Horst nor the one where it refers to the rent in Maasbree is implausible (leads to an inconsistency), thus the reading preferred by the effort condition is retained. Note that the same story can be told for Asher and Lascarides' example. Sometimes, plausibility can, however, override the ordering suggested by effort. Consider:

(43) John moved from Horst to Maasbree. The rent was too expensive.

In this case, the reading where John moves to a place where the rent is too expensive for him has little plausibility; background knowledge like one cannot pay things which are too expensive will rule out this reading.

3.5 Related Work

In this section, we compare our proposal with some related work from the literature. Various authors have studied presuppositions from a proof-theoretical perspective. In Ranta (1994), Constructive Type Theory is extended with rules for definite descriptions. Krause (1995) generalizes Ranta's proposal by modelling presupposition resolution in terms of abductive inference in Constructive Type Theory.

Krause (1995) presents an elegant framework for presupposition resolution in Type Theory. His approach is different from ours in the following ways. Our aim was to keep as close to Van der Sandt's presuppositions-as-anaphora theory as possible, in order to exploit its intuitive appeal. Krause's work is more distant from the presuppositions-as-anaphora theory.

Furthermore, the coverage of our proposal is different from that of Krause's. Krause does not consider data that are accounted for by Van der Sandt in terms of intermediate and local accommodation and disjunctions. Furthermore, he does not deal with the role of the notions of plausibility and effort on the interaction between presuppositions and world knowledge.

As part of the DENK project, Ahn (1994) and Beun & Kievit (1995) use PTS for dealing with the resolution of definite expressions. Whereas we have focussed on the projection problem and the role of world knowledge, Beun & Kievit (1995) deal with the choice of an antecedent in situations where not only linguistic context and background knowledge are available, but also the physical context plays a role. Furthermore, they provide an analysis of the difference between pronouns, descriptions with a definite article and demonstratives (based on empirical studies that were carried out in the DENK project and reported in, e.g., Cremers, 1996; Piwek & Cremers, 1996; Piwek et al., 1996 and Beun & Cremers, forthcoming).

Also as part of the DENK project Kievit & Piwek (1998) deal with the resolution of presupposition in dialogue. They integrate the resolution algorithm for presuppositions with a mechanism for the interpretation of answers to clarificatory questions. This mechanism, which is based on unification of the clarificatory question and its answer, has been implemented in the DENK system.

An alternative to the use of PTS is the extension of DRT itself with a proof–system. See, e.g., Saurer (1993) for such a proof system for DRT. There are several reasons for preferring PTS over such a deductive variant of DRT. The main advantage of PTS is that it is a standard proof system developed in mathematics with well-understood meta-theoretical properties; see also chapter 1 for more arguments in favor of PTS.

Moreover, there are some advantages directly tied to the purposes of this chapter. Firstly, propositional presuppositions turn out to require no amendations of the presuppositions as anaphora approach due to the presence of proof objects for propositions in PTS. Secondly, our approach to bridging makes natural use of the presence of proof objects, for instance, in the formulation of determinateness

conditions on bridges. Thirdly, in section 3.2 we provided an alternative to intermediate accommodation. The formal means for such a move (i.e., dependent function types) are not present in DRT. A related point is that higher order logic can be embedded into PTS, whereas expressive power of DRT is the same as first order predicate logic.

We are aware of four formal approaches to bridging: the abductive approach (Hobbs, 1987 and Hobbs et al., 1993), the lexical approach (Bos, Buitelaar & Mineur, 1995), the rhetorical approach (Asher & Lascarides, 1997), the situation-theoretic and the model-theoretic approach (Milward, 1996)

Abduction

We have analysed example (31), here repeated as (44), in terms of PTS deduction and accommodation, where the latter is similar to the notion of implicature argued for by Clark.

(44) John walked into the room. The chandelier sparkled brightly. (after Clark, 1975:416)

An analysis of (44) in terms of implicature has also been presented in Hobbs (1987). Though our approach is similar to his in spirit, it differs in the details. Hobbs suggests the following basic scheme for implicature:

If P is mutually known,
$(P\&R) \rightarrow Q$ is mutually known,
and the discourse requires Q,
Then assume R as mutually known and conclude Q.

In case of (44), we have:

P = there is a lamp;
Q = there is a chandelier;
R = in the form of a branching fixture.

Uttering the first sentence makes it mutually known that there is a lamp. Hobbs now explains the use of the definite 'the chandelier' in the second sentence as follows: the interpreter accommodates that this lamp has the all the defining properties of a chandelier, and thus can derive the presence of a chandelier.

Let us now summarise the out approach. We also assume that the first sentence introduces a lamp. And similarly, the definite in the second sentence requires the presence of a chandelier. Furthermore, we assume that it is part of the world knowledge of the interlocutors that chandeliers are lamps. The idea is now that the interpreter is licensed to assume that the lamp in question is a chandelier in virtue of (a) the fact that the linguistic context contains a salient readable thing, (b) the fact that chandeliers are lamps and (c) the fact that a chandelier is presupposed.

One important difference is that we do not require a decomposition of 'chandelier' into a lamp in the form of a branching fixture. A further difference with the approach of Hobbs et al. is that on our approach it is the independently motivated presupposition resolution algorithm which drives the bridging process.

Is bridging a lexical phenomenon?

Bos, Buitelaar & Mineur (1995) treat bridging as a lexical phenomenon. They combine a version of Van der Sandt's presupposition resolution algorithm with a generative lexicon (Pustejovsky, 1995). In this way each potential antecedent for a presupposition is associated with a so-called qualia-structure indicating which *concepts* can be associated with the antecedent. As they put it, a qualia-structure can be seen as a set of lexical entailments. Our main objection to this approach is that not all implied antecedents are lexical entailments. The examples in (45) illustrate the importance of non-lexical background knowledge.

(45) a. Chomsky analysed a sentence on the blackboard, but I couldn't see *the tree*.
b. Yesterday somebody parked a car in front of my door, and *the dog* howled awfully.

For most people trees have as much to do with sentences as dogs to do have with cars. Yet, both these examples can have a bridging reading, given a suitable context. Example (45.a) requires some basic knowledge concerning formal grammars which most readers of this paper presumably will have. For them, (45.a) is a perfectly normal thing to say under its bridging reading (because all of them have a mental function mapping sentences to trees). Likewise, (45.b) can be understood in a bridging manner given the right background knowledge. Suppose, it is well-known between speaker and interpreter that the former lives opposite a home for stray animals somewhere in the countryside, and all cars which stop in front of this home for lost animals either drop a dog or pick one up. In this context, the interpreter will have no trouble constructing the required bridge (since she has a mental function which produces a dog for each car stopping in front of the speaker's door).

Bridging as a Byproduct of Rhetorical Structure

In section 3.4, we already discussed the work of Asher & Lascarides (1997), who claim that bridging is determined by rhetorical structure. We have illustrated that the predictions of Asher and Lascarides in connection with the examples (40) and (41) are not in accord with the results we obtained in a small observational study.

This is not to say that we fully reject the claim of Asher and Lascarides that discourse structure is a factor in bridging inferences. We only question the importance that is assigned to discourse structure. Asher & Lascarides (1996:1) claim that bridging is a 'byproduct of computing rhetorical structure'. We have advanced an alternative view where world knowledge in combination with (more 'low-level') factors such as effort and plausibility play the first fiddle in the interpretation process.

Situations and Models

In Milward (1996), contexts are identified with 'parts of the world that are brought to the hearer's attention'. Formally, such parts of the world are seen as partial models or situations. Milward attempts to identify the advantages of such a situationbased approaches.

He begins with an examination of bridging inferences. Interestingly, he adduces the chandeliers example (44) in favour of situational approaches. He points out that 'it is not particularly likely for a room to contain chandelier, but highly likely that a chandelier is in a room'. In section 3.3, we have shown that this presents no fundamental problems to our approach: the room and the chandelier are linked via the fact that rooms are likely to contain lamps. However, Milward produces another example which does seem to raise a problem:

(46) The police stopped the car since they thought the trailer looked unstable (Milward, 1996:544)

Milward notes that this example cannot be dealt with by approaches to anaphora resolution which are based strictly on 'prediction', i.e., where an anaphor is always filled in with some previously introduced object. In (46), it seems that 'the trailer' provides a further specification for the earlier on introduced car: trailers are higly likely to be pulled by a car, but given a car, the presence of a trailer is less likely.

On the basis of the fact that example (46) involves predication, Milward argues that it is beyond the scope of any representational approach. The example that he provides is basically an instance of a kataphor or forward reference. It is beyond the scope of this book to provide a detailed account of such forward references.

The claim that they cannot be modelled representationally can, however, be easily refuted. An analysis of kataphora in DRT is presented in Van Deemter (1990).

Other examples that Milward has put forward involve presuppositions in disjunctions. In particular, he considers disjunctions as exemplified by example (27) on page 41. We have already demonstrated that those examples do not pose any problems for our account. Finally, we would like to consider the following example from Milward (1996) (similar examples have been put forward by Groenendijk et al. 1995 in favour of a model-theoretic approach):

(47) When a Sicilian and a Corsican get engaged, the girl's parents are usually more concerned than the boy's.

The trap that any representational approach should avoid is that either 'the girl' or 'the boy' is *directly* bound to 'the Sicilian' or 'the Corsican'. In situation or model-based approaches, this is achieved quite naturally because all possibilities are simply enumerated: the Sicilian is a girl and the Corsican a boy or the Sicilian is boy and Corsican is a girl.

We can account for (47) in terms of a bridging inference: the event of two persons getting engaged supplies a set of two inferred objects: a girl and a boy. The persons that are getting engaged are both a member of this set and are not equal to each other.

To conclude, it seems that the representational approaches and the situational approaches differ with respect to the way alternatives are treated: the representational account employs 'underspecificied' representations whereas the situational approaches use 'enumeration' of (a possibly infinite number of) possibilities'. Our guess is that it is impossible to find any data that definitively decide between the enumerative and the representational approach. The nice thing about having two different perspectives on presupposition is that they highlight different phenomena. Thus, together they bring a bigger chunk of data to the surface than each of them separately could.

3.6 Conclusions

We have discussed an algorithm for presupposition resolution within a deductive framework. The algorithm is in line with the basic tenet of Van der Sandt's presuppositions as anaphors theory. Presuppositions are treated as gaps, which have to be filled using contextual information. This information can come from the linguistic context, that is the preceding sentences (as in Van der Sandt 1992). But presuppositional gaps can also be filled using the non-linguistic context, i.e., world knowledge.

As an illustration of the formal interaction between world knowledge and presupposition, we have applied the deductive approach to presuppositions in conditionals/disjunctions and Clark's bridging cases. We showed that our algorithm produces the correct predictions for several data of presuppositions in disjunctions and conditionals which have been found to be problematic for other dynamic semantics approaches to presupposition (e.g., the renown 'bathroom' and 'umbrella sentences'). Furthermore, we have tried to show that intermediate accommodation can be modelled in terms of a non-structural variant (i.e., which does not tamper with the representation of the utterance itself) of Van der Sandt's local accommodation.

We dealt with bridging by first discerning two types of bridging: if the *bridge* between presupposition and would-be antecedent is fully derivable using context (including world knowledge), the presupposition associated with the anaphor can be bound. This means that binding plays a more substantial role than in Van der Sandt's original theory, as presuppositions can be bound to both inferred and non-inferred antecedents. If the bridge between anaphor and antecedent is not fully derivable, the missing link will be accommodated. So, accommodation is still a repair strategy, as in Van der Sandts original approach, but now there is generally less to repair. In most cases, accommodation will amount to assuming that an object of which the existence has been proven satisfies a more specific description (in the case of (31), that the lamp whose existence has been proven is a chandelier).

It is well known that bridging is not an unrestricted process. Therefore we have tried to formulate two general constraints/filters on the bridging process partly inspired by the informal observations from Clark (1975): effort (the amount of 'mental energy' the interpreter needs to construct a bridge) and plausibility (the relative admissibility of the constructed bridges).

We have modelled the effort constraint in PTS terms as follows: if a gap can be filled by more than one proof object, order them with respect to proof complexity (the one with the lowest complexity first). Moreover, use the informational resources as frugal as possible (accommodate as little as possible). This latter condition is hard-coded, as it were, in the Van der Sandtian resolution algorithm. We take it that factors like recency and salience are also relevant here.

The plausibility condition is modelled as a simple consistency condition, with relevance as a side-effect. We have seen that these two simple conditions help in arriving at a determinate bridge. The precise formulation of these two conditions and the interplay between them will be the subject of further research. Additionally, we are interested in further empirical validation of our proposal along the lines of the observational study described in this chapter.

Our approach to bridging resembles the abductive approach of Hobbs et al. (1993), but there are also a number of important differences. We take it that the presuppositionhood is the driving force behind bridging. As a consequence we make a strict separation between presupposed and asserted material, thereby avoiding the problems Hobbs and co-workers have with examples like (39). Additionally, we are not committed to lexical decomposition, like *chandelier is a lamp with a branching fixture*. The knowledge that chandeliers are lamps is sufficient.

We have argued that bridging is not a purely lexical process (as opposed to Bos et al. 1995), and that bridging is not a byproduct of rhetorical structure determination (as opposed to Asher & Lascarides 1997). This is not to say that lexical matters or rhetorical relations have no relevance for bridging, we feel that they are two of the many factors which play a role in bridging.

Finally, we addressed some of the criticisms that have been levelled at 'representational' theories of discourse interpretation (e.g., Milward, 1996). We showed that the limitations of some 'representational' approaches concerning bridging and disjunction are not inherent to the so-called representational paradigm as such.

3.7 Appendix: The Resolution Algorithm

Suppose that Φ is the PTS representation of the current utterance, and that we want to resolve the presuppositions which Φ contains (if any) with respect to a global context Γ. The following algorithm, written in *Pseudo* PROLOG, tells us how this resolution process works:

$$\texttt{do\_resolve}(\Phi, \Gamma, \Phi') \text{ :- } \quad \texttt{resolve}(\Phi, C, \Phi'),\ \texttt{adequate}(\Phi', \Gamma).$$

We the result of resolving the proto type Φ is the type Φ'. The result of the resolution should be adequate. The notion of adequacy is defined in (48) below.

In the clauses below, which specify the predicate `resolve`, we use C as a variable for representing the context in which the resolution takes place. This context consists of the global context Γ extended with temporary assumptions which may have been introduced by, for instance, the antecedents of conditionals.

The *basic* clause goes as follows:

$$\texttt{resolve}(\Phi, C, \Phi) \text{ :- } \texttt{atomic}(\Phi).$$

If Φ atomic, i.e., it is not of the form $\Pi V : \Phi.\Psi$ (for which we also use the abbreviation $[V : \Phi] \Rightarrow \Psi$) and it contains no presuppositional annotations, then the result of resolving Φ in the context of C is Φ. Here is the recursive clause, which deals with Π-expressions.

$$\begin{array}{ll}\texttt{resolve}(\Pi V : \Phi.\Psi, C, \Pi V : \Phi'.\Psi') \text{ :- } & \texttt{resolve}(\Phi, C, \Phi'),\\ & C' = C \otimes (\Gamma - C),\\ & \texttt{resolve}(\Psi, C' \otimes V : \Phi', \Psi').\end{array}$$

In words: when the resolution algorithm encounters an expression of the form $\Pi V : \Phi.\Psi$ in the context C then it first resolves all the presuppositions in Φ, and only when Φ is totally devoid of presuppositional annotations is the algorithm applied to Ψ, where Ψ is resolved with respect to the modified context, which is the original C possibly extended with the accommodation of presuppositions which arose in Φ[31] and with $V : \Phi'$.[32] ($\otimes$ stands for concatenation). The first clause to deal with resolution proper is the one for *binding*.[33]

$$\begin{array}{ll}\texttt{resolve}(\Phi_\chi, C, \Phi') \text{ :- } & \texttt{binder}(\chi, C, S),\\ & \texttt{resolve}(\Phi[S], C, \Phi').\end{array}$$

Where `binder` is defined as follows:

$$\begin{array}{ll}\texttt{binder}(\chi, C, S) \text{ :- } & S \in \{S^* | C \vdash \chi[S^*]\},\\ & \texttt{preferred}(S).\end{array}$$

When there is more than one possible binding, it is determined which is the most preferred one (where preference is defined in terms of the number of intervening introductions, the complexity of proof-objects, etc.). If there are two equally preferred bindings, an unresolvable ambiguity results. If it is not possible to bind a presupposition, we try to *globally accommodate*:

$$\begin{array}{ll}\texttt{resolve}(\Phi_\chi, C, \Phi') \text{ :- } & \texttt{adequate}(\chi[S'], C),\\ & \texttt{add}(\chi[S'], \Gamma),\\ & \texttt{resolve}(\Phi[S'], C \otimes \chi[S'], \Phi').\end{array}$$

Here and elsewhere S' is the assignment which maps any gaps in Φ to Γ-fresh variables of the right type. Thus: if it is possible to accommodate the presupposition, then we may add it to the context Γ, and go on resolving any remaining presuppositions in Φ with respect to the new, extended context. `adequate` checks whether the result of accommodation in a certain context (in this case the global one, Γ) meets the Van der Sandtian conditions (see (15) on page 7):

(48) (ADEQUACY)

i. CONSISTENCY: $V : T$ is *consistent* in the context of Γ if it is not the case that there is an E such that $\Gamma, V : T \vdash E : \bot$ (that is, adding $V : T$ to Γ makes $\bot$ provable).

ii. INFORMATIVITY: $V : T$ is *informative* in the context of Γ if it is not the case that there is an E such that $\Gamma \vdash E : T$ (i.e., T does not follow from Γ already).

iii. For a context Γ and a type $\Pi V : T.C$, there is no V' such that $V' : C$ violates i. or ii. with respect to the context $\Gamma \otimes V : T$, and C does not violate iii. with respect to $\Gamma \otimes V : T$.

Notice moreover, that Van der Sandt's *trapping-condition* (which states that no variable may end up being free after resolution) is encoded in the PTS framework itself: a variable cannot occur in a context when its type is not declared.

If binding *and* global accommodation are not possible, Van der Sandt recommends *intermediate accommodation*. In section 3.2, we have argued that this type of accommodation might be superfluous. Let us nevertheless show how it would look in a type–theoretical setting:

$$\begin{array}{ll}\texttt{resolve}(\Phi_\chi, C, \Phi') \text{ :- } & \texttt{not empty}(C - \Gamma),\\ & \texttt{adequate}((\chi \Rightarrow \Phi)[S'], C),\\ & \texttt{resolve}((\chi \Rightarrow \Phi)[S'], C, \Phi').\end{array}$$

Thus: if we are in an embedded configuration (that is: there is a difference between Γ (the global context) and C (the extension of the global context with a local context), and the result of intermediate accommodation is adequate, then we use intermediate accommodation and continue the resolution process with the result.

Finally, here is are our alternatives for *local accommodation*.

$$\begin{array}{ll}\texttt{resolve}(\Phi_\chi, C, \Phi') \text{ :- } & \texttt{not empty}(C - \Gamma),\\ & \Delta := C - \Gamma,\\ & \texttt{adequate}(f : (\Delta \Rightarrow \chi)[S'], \Gamma),\\ & \texttt{add}(f : (\Delta \Rightarrow \chi)[S'], \Gamma),\\ & \texttt{resolve}(\Phi[S'], C \otimes f : (\Delta \Rightarrow \chi)[S'], \Phi').\end{array}$$

$$\begin{array}{ll}\texttt{resolve}(\Phi_\chi, C, \chi' \otimes \Phi') \text{ :- } & \texttt{empty}(C - \Gamma),\\ & \chi' := \chi[S']\\ & \texttt{resolve}(\Phi[S'], C \otimes \chi', \Phi').\end{array}$$

Here we distinguish two cases: $\Phi_\chi \Rightarrow \Psi$ and $\Phi \Rightarrow \Psi_\chi$. In the first case the presupposition depends on a 'hypothetical' context ($\Gamma \otimes \Phi$); in the second case it is the presupposition itself which creates the 'hypothetical' context (these are the cases were a presupposition is cancelled). Notice that Van der Sandt's local accommodation of χ in $\Phi \Rightarrow \Psi_\chi$ is modelled as global (!) accommodation of a function $f : \Phi \Rightarrow \chi$ (where f is Γ-fresh).[34]

EXAMPLE: Suppose we are in a context Γ, and the representation of the current sentence is $\varphi \Rightarrow \psi_\pi$, and let us assume that both φ and ψ are atomic. We feed this representation to the resolution algorithm and apply the recursion clause. Then we attempt $\texttt{resolve}(\varphi, \Gamma, \Phi')$. Since φ is presupposition free, the basic clause tells us that we may resolve φ as φ (thus: nothing happens). We now try $\texttt{resolve}(\psi_\pi, \Gamma \otimes \varphi, \Phi')$. At this point, various things can happen:

(i) the context $\Gamma \otimes \varphi$ contains a suitable antecedent. In that case, we remove the annotation and substitute the newly found antecedent for the *gap* in ψ.

(ii) suppose the context $\Gamma \otimes \varphi$ contains no suitable antecedent. If by filling the gap(s) in π with fresh variables of the right type (using the aforementioned substitution S'), we can extend the global context Γ with $\pi[S']$ (that is: $\Gamma \otimes \pi[S']$ is adequate), then we do so. In that case we continue with $\texttt{resolve}(\psi[S'], \Gamma \otimes \varphi \otimes \pi[S'], \Phi')$.

(iii) It can also happen that the result of extending Γ with $\pi[S']$ is not adequate. Then we might attempt intermediate accommodation. As $(\Gamma \otimes \varphi) - \Gamma$ is not empty, we can check whether $(\pi \Rightarrow \psi)[S']$ is adequate in the context of $\Gamma \otimes \varphi$. If so, we continue with $\texttt{resolve}((\pi \Rightarrow \psi)[S'], \Gamma \otimes \varphi, \Phi')$. Using the recursion and the basic clause we find that Φ' may be set equal to $(\pi \Rightarrow \psi)[S']$. Ultimately, in this case, we find that resolving $\varphi \Rightarrow \psi_\pi$ yields $(\varphi \Rightarrow (\pi \Rightarrow \psi))[S']$, which is equivalent to $((\varphi \otimes \pi) \Rightarrow \psi)[S']$.

(iv) Last, *and* least (according to Van der Sandt's principles), we may apply the clause for local accommodation. In that case, we set Δ equal to $(\Gamma \otimes \varphi) - \Gamma$, and extend the global context with the conditional weakening of π: $(\varphi \Rightarrow \pi)[S']$. This global accommodation of the conditional presupposition obviously has the same logical effect as local accommodation.

BRIDGING: COMBINING ACCOMMODATION AND BINDING

The algorithm as it has been presented above does not cover the bridging cases where both bind and accommodation are called for. For that purpose let us present the appropriate clauses for GLOBAL ACCOMMODATION and NON-STRUCTURAL 'LOCAL' ACCOMMODATION (these are intended to replace the corresponding clauses we presented above):

$$\begin{array}{ll}\texttt{resolve}(\Phi_\chi, C, \Phi') \text{ :- } & \texttt{adequate}(\beta[S'], C),\\ & \beta[S'] \texttt{ is a subsequence of } \chi[S'],\\ & \texttt{binder}(\chi, C \otimes \beta[S'], S),\\ & \texttt{add}(\beta[S'], \Gamma),\\ & \texttt{resolve}(\Phi[S], C \otimes \beta[S'], \Phi').\end{array}$$

$$\begin{array}{ll}\texttt{resolve}(\Phi_\chi, C, \Phi') \text{ :- } & \texttt{not empty}(C - \Gamma),\\ & \Delta := C - \Gamma,\\ & \texttt{adequate}(f : (\Delta \Rightarrow \beta[S']), \Gamma),\\ & \beta[S'] \texttt{ is a subsequence of } \chi[S'],\\ & \texttt{binder}(\chi, C \otimes f : (\Delta \Rightarrow \beta[S']), S),\\ & \texttt{add}(f : (\Delta \Rightarrow \beta[S']), \Gamma),\\ & \texttt{resolve}(\Phi[S], C \otimes f : (\Delta \Rightarrow \beta)[S'], \Phi').\end{array}$$

3.8 Appendix: The Questionnaire

Read the piece of text and then answer the question. Tick the answer that comes first to mind.

(1) John moved from Horst to Maasbree
The rent was more expensive.

Where is the rent more expensive?

◯ Horst
◯ Maasbree

(2) Mary traded her old car in for a new one.
The engine was broken.

Of which car was the engine broken?

◯ The old one
◯ The new one

(3) Pete went to the hairdresser on the Vleesstraat
and not to the hairdresser living next to him.
It is much more expensive there.

Which hairdresser is more expensive?

◯ The hairdresser living next to Pete
◯ The hairdresser on the Vleesstraat

(4) John liked the Ferrari better than the Porsche.
The colour didn't appeal to him.

Which colour didn't appeal to John?

◯ The colour of the Porsche
◯ The colour of the Ferrari

The questionaire was distributed via email to all people at IPO (Center for Research on User–System Interaction, Eindhoven). It was returned by 50 native speakers of Dutch. It included participants from a number of different backgrounds: (computational) linguists (4 in number), perception scientists (vision, auditory), physicists, computer scientists, psychologists, ergonomists, secretaries and management. The subjects were instructed to tick the answer that came first to their mind. The queries above are translations into English of the original Dutch versions.

The Results

(1) Horst: 8; Maasbree: 42
(2) the old one: 48; the new one: 2
(3) The hairdresser living next to Pete: 34; The hairdresser on the Vleesstraat: 15; No preference: 1
(4) The colour of the Porsche: 48; The colour of the Ferrari: 2

Three non-native speakers (English, German and French) also send in their replies. The results for them were:

(1) Horst: 0; Maasbree: 3
(2) the old one: 2; the new one: 1
(3) The hairdresser living next to Pete: 1; The hairdresser on the Vleesstraat: 2
(4) The colour of the Porsche: 3; The colour of the Ferrari: 0

4 Answers and Contexts

> *If I ask who discovered America, I am none the wiser as to what I have done when told that I have requested information. What information? Why, of course, information as to who discovered America. In short, our desire to receive an answer when we ask a question is, like our desire to be believed when we assert a proposition, neither universally present nor in any way constitutive of the meaning or content of what we ask or assert. What is it, we must go on to inquire, that we want believed? What is it that we want answered?* (Cohen, 1929:352)

In the past fifteen years, context-dependence and context change have become central to the trade of formal semantics. In particular, it has become common ground that these notions are essential for the treatment of anaphora, indefinite noun phrases and presuppositions (see, e.g., Heim (1982), Kamp (1981) and Van der Sandt (1992)). The importance of context for the notion of answerhood has been pointed out in Hintikka (1974).

In this chapter, we propose a formalization in PTS of several notions of *answerhood*. This formalization treats answerhood as being essentially context-dependent (in section 4.1, we describe in detail in which respects answerhood is context-dependent). For this purpose, we take the informal definition of answerhood presented in Groenendijk & Stokhof (1984) (henceforth, G&S) as our point of departure:

> A proposition gives an answer to a question in an information set, if the information set to which that proposition is added offers an answer. (G&S: 154)

The formalization of the definition will involve a framework for modelling information sets, i.e., contexts, propositions and questions. Furthermore, within

this framework what it means for a context to answer a question will have to be spelled out.

The main contribution of this chapter with respect to formalizing answerhood is a formalization of *indirect answers*. G&S provide a partial formalization of indirect answers in possible-world semantics[35]. We provide a *full* formalization. Furthermore, we use the fact that proof systems operate on syntactic structure (which allow for a more fine-grained analysis of meaning than standard possible worlds semantics) to isolate a certain class of computationally attractive indirect answers.

On the conceptual side, our approach functions as a bridge between approaches to answerhood which take context into account and a class of context-independent accounts which deal with questions as structures with gaps (or variables) and answers as the objects that can fill such gaps (e.g., Cohen, 1929; Jespersen, 1933; Katz, 1968; Scha, 1983 and Prüst et al., 1994). For instance, the structure underlying the wh-question 'Who walks?' is *person X and walk X*. Answers, such as 'John', can fill the gap *X* and count as true answers if the sentence which is obtained by filling the gap is true. We marry this idea with context-dependence, by requiring that a filler does not have to be presented directly by the answer, but should be derivable (in a proof-theoretic sense) from the context extended with the answer.

The chapter is structured as follows. In section 4.1, we present some reasons for taking context into account in any definition of the notion of answerhood. In section 4.2, we describe how questions and answers can be represented in the PTS language. In section 4.3, a formalization of several notions of answerhood is given. It is demonstrated how the formalization accounts for the role of context with respect to answerhood as described in section 4.1. In section 4.4, we deal with some further pragmatic aspects of answerhood, such as presupposition, specificity and relativity (to the cognitive resource of an interpreter). In particular, Finally, our conclusions are listed in section 4.5.

4.1 The Role of Context

In this section, we discuss four reasons for incorporating a notion of context into a definition of answerhood.

First, whether a question can be posed depends on the background. There seems to be no point in asking a question whose answer is already part of common background of the interlocutors (keeping rhetorical questions aside). For instance, if the interlocutors share the information that *nobody has seen Mary*, then the question 'Who has seen Mary?' is inappropriate.

Second, there are answers that only present a filler to the gap of a question in a certain context. For example, in a situation in which John asks 'Where is Mary's car?' and it is part of the context (more specifically, the common background) that *If Mary is at home, then her car is in the garage*, John's question can be answered with the sentence 'Mary is at home. This answer does not, on its own, present the filler for the gap which belongs to the wh-constituent 'where'.

Third, some answers rule out certain fillers, rather than presenting them. This sort of answer will be called a negative answer. For example, 'Where is Mary?' can be answered with the sentence 'She is not at home'. Here context change plays an important role: the answer changes the context into one in which 'At home' is no longer a possible filler.

Fourth, there are answers which raise new questions whose answers bring the questioner closer to an answer for the original question. Such answers are called *indirect answers*. Consider 'Mary's car is in the garage if she is at home' as an answer to the question 'Where is Mary's car?'. G&S point out that the answer changes the context in such a way that the questioner has a new question at his or her disposal ('Is Mary at home?'). If this new question is answered positively, then also the original question is resolved.

4.2 Representing questions and answers in PTS

Traditionally, questions are divided into three categories: (1) Yes/no-questions such as *Does John walk?*, (2) choice questions such as *Does John walk or does Mary walk?* and (3) Wh-questions, such as *Who entered the room?*, *What did John eat?*, *Where does Mary live?*, *When did the bells ring?*, *Which woman entered the room?*[36]

We start by giving an account of wh-questions and show how the questions belonging to the categories (1) and (2) can be analysed along the same lines.

Wh-questions are also known as constituent questions, search questions and *x*-questions. The name *x*-question was proposed in Jespersen (1933). Jespersen argues that wh-questions, like algebraic equations, feature some unknown quantity. For instance, the variable x in the equation $x = 1 + 1$ seems to fulfil the same function as the wh-constituent 'what (number)' in 'What (number) is the sum of 1 and 1?' Both the variable x and the word *what* mark a gap in the formula/sentence. This gap can be filled with a value. A value is said to be a solution or an answer, if filling the gap with the value yields a formula or sentence. We speak of a true answer if the resulting formula is true.

According to Bäuerle and Zimmermann (1991), the idea that a question is a structure which contains one or more well-defined gaps was first proposed in

Cohen (1929). This idea reemerged in one form or another in the theories of, amongst others, Katz (1968), Scha (1983), Prüst et al. (1994) and Ahn (1994).

We already saw that gaps are implicitly present when we do theorem proving with PTS. In chapter 2, we show how a substitution for a gap can be found with respect to a context Γ by using the deduction rules backwards. The idea is now to use this technique to check whether a context provides an answer to a question (this is the central concept in G&S's definition of the question-answer relation).[37]

Note that as a consequence of this approach, the basic kind of answer that a context can offer (i.e., the filler of a gap) is not exhaustive. In other approaches (notably G&Ss), the basic type of answer is taken to be strongly exhaustive. For instance, a basic answer to 'who walks' is taken to be a proposition which (1) states for exactly those persons that walk, that they walk and (2) states that no one else walks (the closure condition).[38] In terms of our approach, exhaustiveness can be reconstructed by requiring that an answer which is interpreted exhaustively, is associated with an update of the context with a closure condition which states that the fillers supplied by the answer are the only fillers for the question. In other words, any other fillers give rise to an inconsistent context (for details see section 4.4). Note that we do not take truth or falsity of the answer into account: we concentrate on exhaustivity relative to the questioner's context.

Questions are now formalized as open segments. *A segment* is a sequence of introductions. *An open segment* is defined as a sequence of introductions with at least one gap. Consider, for instance, the question *Who walks?* We assume that there is some interpretation function which translates this question (given a context of interpretation) into the open segment: $X : \mathit{person}, P : \mathit{walk} \cdot X$. Furthermore, suppose that the introductions $\mathit{john} : \mathit{person}, p : \mathit{walk} \cdot \mathit{john}$ are a part of some context Γ. In that case, the question is answered in Γ. In other words, there is a substitution $[S]$ such that:

$$\Gamma \vdash_{\Delta} X : \mathit{person}, P : \mathit{walk} \cdot X[S]$$

The substitution in question is $[X := john, P := p]$. This substitution fills the gaps that occur in the representation of the question. Notice, that there is a difference between the X and the P gap. The former is the gap whose value the questioner is interested in: it is filled by $[S]$ with a referent for John. P is a gap which is filled with a proof that this person walks. The questioner is not interested in the identity of this proof: it is sufficient for him to know that there is a proof. Henceforth, we will write the former type of gaps in bold face and call them *marked* gaps to distinguish them from the second type of gaps.[39] Thus the representation of *Who walks?* is $\mathbf{X} : \mathit{person}, P : \mathit{walk} \cdot \mathbf{X}$. Furthermore, sometimes we will write $\mathbf{X} : \mathit{person} \mid P : \mathit{walk} \cdot \mathbf{X}$, where '$|$' separates that part of the representation which corresponds with one or more wh-constituents (in this case, $\mathbf{X}$: *person*) from the rest of the representation.

Yes/no-questions can be seen as a special kind of wh-question. For instance, the question *Does Mary walk?* corresponds to the following structure: *F is equal to (It is true that) or F is equal to (It is false that), and F Mary walks*. This interpretation corresponds to the following open segment:[40]

$$\mathbf{F} : \mathit{prop} \rightarrow \mathit{prop},$$
$$G : \mathit{equal}(\mathbf{F}, \lambda x : \mathit{prop}.x) \vee \mathit{equal}(\mathbf{F}, \lambda x : \mathit{prop}.x \rightarrow \bot),$$
$$Q : \mathbf{F} \cdot (\mathit{walk} \cdot m)$$

The translation of choice questions involves the selection functions (e.g., $\lambda x.\lambda y.x$ and $\lambda x.\lambda y.y$). For instance, the translation of *Does John walk or does Mary walk?* is

$$\mathbf{F} : \mathit{prop} \rightarrow (\mathit{prop} \rightarrow \mathit{prop}),$$
$$G : (\mathit{equal}(\mathbf{F}, \lambda x : \mathit{prop}.\lambda y : \mathit{prop}.x) \vee \mathit{equal}(\mathbf{F}, \lambda x : \mathit{prop}.\lambda y : \mathit{prop}.y)),$$
$$Q : (\mathbf{F} \cdot (\mathit{walk} \cdot j)) \cdot (\mathit{walk} \cdot m)$$

We have shown how the three basic types of questions can be represented in PTS. Let us now turn to the representation of answers.

We assume that answers to questions are asserted propositions. The assertion is formalized as a representation of the proposition together with a gap which can be instantiated with a fresh proof for the proposition. For instance, the assertion of ‘John walks’ corresponds to: $P : walk{\cdot}john$, where $walk{\cdot}john : prop$. Note that there is a gap indicating where a proof for the proposition can be filled in. Such a fresh proof (e.g., p) is substituted for P when the assertion is accepted by the addressee and therefore added to the context Γ, yielding Γ' ($= \Gamma \otimes p : walk{\cdot}john$).

A proposition can be expressed by a variety of linguistic objects; the prototypical object is the full sentence. However, in answers to questions, ellipsis frequently occurs: ‘A: Who walks? B: John’. In this case, the name ‘John’ is used to express the proposition *that John walks*. The example illustrates that the question is required to compute the propositional content of the answer. We assume that also the answers ‘Yes’ and ‘No’ express propositions: e.g., given the question ‘Does John walk?’, the answer ‘Yes’ expresses the proposition *that John walks*.

If we construct a formal representation of a sentence, then a noun phrase is mapped to a gap. This gap is basically an underspecified representation of an object. In case of a definite noun phrase, the gap needs to be filled with a particular object from the context. For instance, assume that a context Γ (which is common to the interlocutors) is given. Γ contains exactly one introduction of a brown book (c : *book*$, p$: *brown* $\cdot\, c$). Now consider the assertion of ‘The brown book is fascinating’ which translates into Q : *fascinating* $\cdot\, X_{[X:book, P:brown\cdot X]}$. The subscripted annotation describes which object has to be filled in for X in the formula Q : *fascinating* $\cdot\, X$. This means that a substitution $[S]$ has to be found such that $\Gamma \vdash X : book, P : brown \cdot X[S]$. In the aforementioned context, the substitution in question is $[X := c, P := p]$. Application of this substitution to Q : *fascinating* $\cdot\, X$ yields the following representation of the assertion: Q : *fascinating*$\cdot c$. If the addressee accepts this assertion, then it is added to the context. This means that Q is instantiated with a fresh proof object for the proposition: q : *fascinating* $\cdot\, c$. In chapter 3 of this book, Van der Sandt’s (Van der Sandt, 1992) resolution algorithm for presuppositions is adapted for PTS along the lines sketched above.

If an indefinite noun phrase occurs in an asserted sentence, then the gap which corresponds to it does not have to be filled with a particular object from the context. The indefinite noun phrase stands for an indefinite/arbitrary object. When the asserted sentence is added to the context (i.e., accepted by the addressee), a fresh object (corresponding to a discourse referent in DRT) is added to the context.

It is beyond the scope of this chapter to define a full mapping from natural language expressions to (open) PTS segments. We have limited ourselves to pointing out the basic characteristics of the segments for representing questions and answers. A mapping is, however, described for a fragment of natural language in Kievit (1997). This mapping has been implemented as part of the DENK dialogue system (see Ahn et al., 1995 and Bunt et al., 1998).

4.3 Formalizing answerhood

G&S formalized their definition of answerhood in possible-world semantics. They model the information set of an agent as a set of possible worlds, i.e., those worlds which are compatible with the information available to the agent. A question is taken to be a partition on this set (see also Hamblin (1971) for the use of partitions to model questions). For instance, a yes/no-question such as ‘Does John walk?’, partitions the information set I into a subset I_1 of worlds in which *John walks* and a subset I_2 of worlds in which *he doesn’t walk*. A proposition P now counts as an answer if I' (I after it has been updated with P, i.e., all worlds which are incompatible with P are thrown out of I) is a subset of I_1 or of I_2. In other words, either *John walks* or *John doesn’t walk* holds in the new information set.

This sketch of G&S’s formalization allows us to give a description of their treatment of indirect answers. Below, this treatment is compared to the formalization of this notion of answerhood in PTS. We assume that the context (Γ) corresponds with the information that the questioner assumes to be the common ground of the interlocutors. For more details on the notions of context and common ground that we employ, see chapter 1. In defining answerhood, we proceed as follows: we start with a definition of positive answers, which is stepwise extended to cover the different types of context-dependence of answers.

Positive answers and inference

We start by giving a definition of the notion of a positive answer.

(1) (POSITIVE ANSWER) A segment A is a positive answer for an open segment Q in a context Γ, iff there is a substitution S such that:

1. $\Gamma \otimes A \vdash_{\Delta} Q[S]$;
2. For all S' which differ at most from $[S]$ in their assignments to non-marked gaps, $Q[S']$ is informative with respect to Γ.

The definition says that A positively answers Q if a substitution instance of the question Q is derivable in the context extended with the answer A. We use the term 'positive answer' to express that such an answer presents a specific substitution instance to the question at stake.

Note that the consistency condition for utterances (definition 32., p. 19) rules out answers which make the context inconsistent. Similarly, the informativity condition (definition 33., 19) rules out certain uninformative answers. It does, however, not cover all types of uninformative answers. For that purpose, we need condition 2. of definition (1).

Consider, for example, the open segment (2).

(2) $\mathbf{X} : \mathit{person}, P : \mathit{walk} \cdot \mathbf{X}$

This open segment corresponds to the question in (3).

(3) Who walks?

Suppose that in some context Γ there is a positive answer for this question. In other words, there is a substitution $[S]$ such that $\Gamma \vdash (2)[S]$. Assume that $[S]$ assigns the object *john* to the gap **X** and some proof of the proposition *that John walks* to the gap *P*. With respect to this context Γ the assertion 'John walks quickly' may be informative: Γ enables us to derive that *John walks*, but not that *he walks quickly*. Nevertheless, with respect to the question this assertion provides no new information: it does not introduce somebody of whom we did not yet know that he walks.

Condition 2. ensures that in the aforementioned situation, 'John walks quickly' does not count as an answer. This is due to the fact that the condition requires that the assertion has to introduce a new filler for the *marked gaps* in the question. Although, the assertion does allow us to compute a new substitution instance for the question (assuming that 'John walks quickly' entails that 'John walks'), this substitution instance is not informative with respect to the marked gaps in the question.[41]

Let us now have a closer look at condition *1.* Consider again the question 'Who walks?'. According to our definition 'John walks' is a positive answer to (3). The formal representation for this answer is $Q : \mathit{walk} \cdot john$. If this introduction is added to the context Γ, then there is a substitution $[S]$ such that (we assume that also the conditions *2.* is fulfilled):

(4) $\Gamma \otimes q : \mathit{walk} \cdot john \vdash_{\Delta} \mathbf{X} : \mathit{person}, P : \mathit{walk} \cdot \mathbf{X}[S]$

The substitution in question is $[\mathbf{X} := john, P := q]$. In this case, there is a straightforward relation between the representations of the question ($\mathbf{X} : \mathit{person}, P : \mathit{walk} \cdot \mathbf{X}$) and the answer ($q : \mathit{walk} \cdot john$) $\mathbf{X} : \mathit{person}, P : \mathit{walk} \cdot \mathbf{X}$. They can be unified by applying the aforementioned substitution. In fact, this is what the proof system does in order to verify the derivation; the selection rule is applied in this case. This reveals the relation between our approach and the work by Katz (1968) up to the work by Prüst et al. (1994) in which unification is put forward as the basic mechanism for explaining the relation between questions and answers. Unification is the basic operation of a simple proof system which allows only for application of the selection rule. Let us now indicate the limits of such simple proof systems. Consider example (5) as a reply to question (3).

(5) John's car is broken.

We represent this sentence as follows, assuming that 'John's car' is represented in the context by the variable *john′s_ car*:

(6) $R : \mathit{broken} \cdot john's\_car$

Evidently, no unification is possible between (2) and (6). Thus, unification rules (5) out as a positive answer. Now, suppose that it is common background that *if John's car is broken, then he walks*:

(7) $\Gamma \vdash f : ([a : (\mathit{broken} \cdot john's\_car)] \Rightarrow \mathit{walk} \cdot \mathit{john})$

Given such a Γ, we would like to predict that (5) counts as a positive answer. This is precisely what can be done by employing a deductive system such as PTS. If we take $[S]$ = $[\mathbf{X}$:=*john*, P:= $f \cdot r]$ then it holds that

(8) $\Gamma \otimes r$: *broken* $\cdot$ $john's\_car \vdash_\Delta$ (2) $[S]$

In this case, a substitution for P is obtained by combining the background information and the answer. This is witnessed by the proof object which is assigned to P: this proof object consist of r (the proof object introduced by the answer) and f (the proof object of the conditional that is a member of the common background Γ).

Negative answers

G&S, who take exhaustive answers to be the primary type of answers, introduce partial answers as answers which rule out one or more exhaustive answers.

Analogously, we define a negative answer as an answer which rules out one or more positive answers to a question. For instance, 'John doesn't walk' is a negative answer to question (3), since it rules out the answer 'John walks'. The definition of a negative answer is given below. It contains the operator *NOT* which is first defined.

(9) (NOT) *NOT*$(\ldots \mid A_1 : B_1, \ldots, A_n : B_n)$ is equal to $(\ldots \mid N : ([A_1 : B_1, \ldots, A_n : B_n] \Rightarrow \bot))$.

The operator *NOT* transforms the part of the representation of the question which does not come from a wh-constituent into its negation. Let us illustrate the use of *NOT* with an example. (10.a) is an abbreviation of (10.b):

(10) a. *NOT*$(\mathbf{X}$: *person* $\mid P$: *walk* $\cdot\, \mathbf{X})$
b. $\mathbf{X}$: *person* $\mid N$: $($*walk* $\cdot\, \mathbf{X}) \Rightarrow \bot$

(11) (NEGATIVE ANSWER) A segment A is a negative answer for an open segment Q in a context Γ, iff there is a substitution S such that:

1. $\Gamma \otimes A \vdash_\Delta$ *NOT*$(Q)[S]$;
2. For all S' which differ at most from $[S]$ in their assignments to non-marked gaps, $NOT(Q)[S']$ is informative with respect to Γ.

For instance, if in context Γ the question (3) is posed, then we have a negative answer for this question if a substitution can be found for (10.b) in Γ extended with the answer. Suppose the answer is *John doesn't walk*. Formally, this answer is represented as n : $($*walk* $\cdot$ *john*$) \rightarrow \bot$. Now the substitution [$\mathbf{X}$*:=john, N:=n*] can be found.

Indirect answers

G&S characterize indirect answers as providing the questioner with new ways for getting an answer to the original question. For instance, if the questioner asks whether ϕ, then *if* ψ *then* ϕ provides an indirect answer, because now the questioner can obtain an answer to the original question by finding out whether ψ holds. The indirect answer suggests a new question (i.e., whether ψ). If the questioner discovers that ψ holds, then the original question has automatically been answered.

G&S formalize the notion of indirect answer roughly as follows: Given an information set *I* and a question *Q*, *A* is an indirect answer *iff* there is some question *R* in *I*$'$ (*I* updated with *A*), such that more answers to *R* are (partial) answers to *Q* in *I*$'$ than in *I*. Furthermore, the following condition has to hold: *R* and *Q* should not be conversationally equivalent.

This definition has two weak points. First, it is computationally rather impractical: it requires coming up with a new question. There is nothing which guides us in the search for such a question. Second, there is the notion of conversational equivalence. Two questions are conversationally equivalent if 'the questioner has to assume that an informant will be able to answer the one question truthfully iff she is able to answer the other truthfully as well. So, if a proposition gives rise to a new question which is conversationally equivalent to the original one, the entire point of providing an indirect answer vanishes' (G&S:164). The problem is that G&S do not provide a formal definition of conversational equivalence. It does, however, play an important role, as they themselves illustrate with the following thought experiment.

Suppose we have an information set with respect to which the following two atomic propositions ϕ and ψ are totally independent. Now it is impossible that *that* ϕ provides an indirect answer to the question *whether* ψ. It does so, however, if we do not take conversational equivalence into account: if ϕ is added to the information set, then *whether* ψ does depend more on the question *whether if* ϕ *then* ψ (since a positive answer to the question also provides an answer to the original question, whereas it did not in the information set to which ϕ had not yet been added).

We show that the aforementioned two problems can be solved in our approach. Let us first to turn to the problem on how to determine which new question becomes interesting after an indirect answer. In a syntactic approach this can be read of from the structure of the representation of the answer in case of a *conditional* answer.

A conditional answer is a specific sort of indirect answer. For instance, the aforementioned indirect answer *if* ψ *then* ϕ to the question *whether* ϕ is a conditional answer. It translates into $f : ([p : \psi] \Rightarrow \phi)$. The relevant information is $p : \psi$, i.e., the (abstraction) domain of the Π-type.

Conditional answerhood can be tested as follows: add not only the answer $f : ([p : \psi] \Rightarrow \phi)$ to the context but also, temporarily, the relevant information $p : \psi$. Subsequently, check whether in this context $(\Gamma \otimes f : ([p : \psi] \Rightarrow \phi) \otimes p : \psi)$ the question is (positively/negatively) answered. In this case, the question can indeed be answered in the thus extended context; a proof can be constructed for ψ (i.e., $f \cdot p$). In other words, there is an $[S]$ such that in the context it can be derived that:[42]

$F : prop \rightarrow prop$,
$G : \mathit{equal}(F, \lambda x : prop.x) \vee \mathit{equal}(F, \lambda x : prop.x \rightarrow \perp)$,
$Q : F \cdot \psi[S]$

Let us now provide a formalization for the notion of conditional answerhood.[43] For that purpose, we first have to define a function for obtaining the abstraction domain of a Π-type, such that it can be added to $\Gamma \otimes A$. We do, however, have to be careful. $\Gamma \otimes A$ should not become inconsistent in the process of doing so. Thus, the function returns only those introductions which do not yield an inconsistent context. Formally, the segment consisting of the introduction of the abstraction domain of the conditional answer which can be added to the context is returned by the function Φ.

(12) (Φ-SEGMENT) Given a statement $A = f : ([x_1 : T_1, \ldots, x_n : T_n] \Rightarrow B)$ and a context Γ:

$\Phi(A) = x_1 : T_1, \ldots, x_m : T_m$ for $m \leq n$ if

1. $\Gamma \otimes A \otimes x_1 : T_1, \ldots, x_m : T_m$ is consistent; and
2. (a) $m = n$ or
   (b) $\Gamma \otimes A \otimes x_1 : T_1, \ldots \otimes x_{m+1} : T_{m+1}$ is inconsistent.

With the help of Φ, we can now define conditional answerhood.

(13) (CONDITIONAL ANSWER) A statement A (= $f : [x_1 : T_1, \ldots, x_n : T_n] \Rightarrow B$) is a conditional answer for an open segment Q in a context Γ, iff there is a substitution S such that:

1. $\Gamma \otimes A \otimes \Phi(A) \vdash_\Delta Q[S]$;
2. For all S', $Q[S']$ is informative with respect to Γ, where S' differs at most from $[S]$ in the assignment to unmarked gaps.

or

1. $\Gamma \otimes A \otimes \Phi(A) \vdash_\Delta \mathit{NOT}(Q)[S]$;
2. For all S', $\mathit{NOT}(Q)[S']$ is informative with respect to Γ, where S' differs at most from $[S]$ in the assignment to unmarked gaps.

Basically, we check whether Γ extended with the answer and the antecedents of the answer (assuming they can be added without losing consistency) provides a positive or negative answer to the question.

Notice, that this definition also allows us to deal with answers containing universal quantifiers, since these are also represented as Π-types. For instance, the answer 'Everyone' to the question 'Who walks?' translates into $g : ([x : person] \Rightarrow walk \cdot x)$. Checking whether this is an answer according to the definition amounts to temporarily extending the context with $x : person$ and $g : ([x : person] \Rightarrow walk \cdot x)$. Notice that after that operation, a substitution can be found for the formal representation of the question ($\mathbf{X} : person, P : walk \cdot \mathbf{X}$). The substitution in question is $[\mathbf{X} := x, P := g \cdot x]$.

We have now defined conditional answers. We will use the definition as a basis for a definition of indirect answerhood: an indirect answer is a conditional answer or an assertion which, when added to the context, allows us to derive a (new) conditional answer (Note that this means that conditional answers are a subset of the set of indirect answers). Before we present the formal version of the definition, we first define the notion of contextual equivalence . This notion is needed in the definition of indirect answers to avoid the problem of conversational equivalence.[44]

(14) (CONTEXTUAL EQUIVALENCE) Segment A is contextually equivalent to segment B in context Γ iff

1. $\Gamma \otimes A \vdash B$; and
2. $\Gamma \otimes B \vdash A$.

(15) (INDIRECT ANSWER) A segment A is an indirect answer for an open segment Q in a context Γ, iff A is a conditional answer to Q in Γ or there is an A' such that:

1. $\Gamma \otimes A \vdash_\Delta A'$;
2. It is not the case that $\Gamma \vdash_\Delta A'$;
3. There is at least one substitution $[S]$ such that

(a) A' is a conditional answer to Q in the context Γ for substitution S; and

(b) There is no S' which differs at most from $[S]$ in the assignment to unmarked gaps such that $\Phi(A')$ and $Q[S']$ are contextually equivalent with respect to $\Gamma \otimes A$.

Let us give an abstract example of an indirect answer. Suppose that Γ contains the following introduction: $f : [x : \alpha, y : \beta, z : \gamma] \Rightarrow \delta$. The question at stake is *whether* δ, and the informer provides the answer $a : \alpha$. If we extend the context with the answer, then we can derive $f \cdot a : [y : \beta, z : \gamma] \Rightarrow \delta$, which is a conditional answer with respect to $\Gamma \otimes a : \alpha$ (and could not be derived in Γ). In G&S, the fact that $a : \alpha$ is an indirect answer is accounted for by the fact that in the context extended with this answer the question *whether (if* β *and* γ *then* δ*)* becomes relevant.

The question now arises of whether our definition of indirect answerhood covers all instances of indirect answers that G&S cover with their definition. According to their definition, an indirect answer *A* leads to a context in which there is at least one question which was not present in the previous context and whose answer *X* also (partially) answers the original question *Q*. In our framework, this means that there should be a substitution $[S]$ such that (conditions on informativity are not relevant at this point of the discussion and therefore left implicit):

$\Gamma \otimes A \otimes X \vdash_\Delta Q[S]$; or
$\Gamma \otimes A \otimes X \vdash_\Delta NOT(Q)[S]$.

In words, the context $\Gamma \otimes A$ extended with the answer X to the new question, should yield a positive or negative answer to the original question Q. But this corresponds to having a substitution $[S]$ such that:[45,46]

$\Gamma \otimes A \vdash_\Delta p : ([X] \Rightarrow \Sigma(Q[S]))$; or
$\Gamma \otimes A \vdash_\Delta p : ([X] \Rightarrow \Sigma(NOT(Q)[S]))$.

The two formulae after $\vdash_\Delta$ are in fact, according to our definitions, conditional answers to Q. Therefore, the answer A fulfils the criteria for being an indirect answer: adding A to the context yields a context in which a conditional answer can be derived.

The next question that may be raised is whether our definition (15) is also infected by the problem of conversational equivalence. The sketch we have given up till now does suggest that we have a problem. Consider, for instance, the aforementioned $\Gamma \otimes A \otimes X \vdash_\Delta Q[S]$. Any A will count as an indirect answer to

Q, if we do not somehow exclude certain Xs. Otherwise we could always choose an X which simply corresponds to a substitution instance of Q. Now, in case of conditional answers, the possible values of X are constrained by the answer itself: X can be read of from the syntactic structure of the answer. This, however, does not hold for the other indirect answers. Let us demonstrate in the next paragraph how condition (15.b) imposes the right restriction on admissible Xs for the latter cases.

Reconsider the situation in which the two atomic propositions ϕ and ψ are independent with respect to some context Γ. Somebody asks *whether* ψ. Let us see whether according to our definition of indirect answers, ϕ is an indirect answer in this situation. At first sight, it does indeed seem to be so, since there seems to be a conditional answer to *whether* ψ which can be derived in $\Gamma \otimes p : \phi$. The type of the answer is $(\phi \to \psi) \to \psi$.[47] This answer meets the condition (15.a) and thus definition 13: if this answer and a proof for its antecedent $(\phi \to \psi)$ are added to $\Gamma \otimes p : \phi$, then a proof for ψ can be derived. We have, however, not yet taken the condition (15.b) for indirect answers into account; it says that the substitution instance thus obtained of *whether* ψ –i.e., ψ– should not be contextually equivalent to $\Phi((\phi \to \psi) \to \psi) = (\phi \to \psi)$ with respect to $\Gamma \otimes A$. It can, however be easily verified that they are contextually equivalent (for the reader's convenience, we have omitted the proof objects):

$\Gamma \otimes \phi \otimes \phi \to \psi \vdash \psi$ and
$\Gamma \otimes \phi \otimes \psi \vdash \phi \to \psi$.

Thus, we may conclude that the condition (15.b) on contextual equivalence rules out ϕ as an answer to *whether* ψ and frees us from the problem of conversational equivalence.

Finally, we would like to introduce a new type of answers that is not addressed by G&S. Let us give an example. Suppose that it can be derived in Γ that *if* ϕ *then* ψ. Furthermore, the question again is *whether* ψ. Now, the assertion of *not* ϕ seems informative for the questioner: this answer rules out one line of investigation for the questioner, i.e., looking for an answer to ϕ in order to find an answer to ψ. We will call this sort of answer a *preventive* answer, because it is intended to prevent the questioner from searching for an answer in the wrong direction.[48] In our framework, this sort of response or answer can be easily formalized:[49]

(16) (PREVENTIVE ANSWER) Segment A is a preventive answer to open segment Q in Γ iff there is some segment A' such that:

1. A' positively answers Q in Γ;
2. A' does not positively answer Q in $\Gamma \otimes A$.

4.4 Further Pragmatics of Questions and Answers

In section, we address a number of further pragmatic aspects of questions answers. The issues are pragmatic in nature, because they involve the context in which propositions count as answers or not.

Presuppositions of Questions

It is often assumed that wh-questions carry existential presuppositions. For instance, 'Who walks?' is said to presuppose that *somebody walks*. A consequence of this claim is that 'Nobody walks' does not count as a regular answer to the aforementioned question. We agree with Groenendijk & Stokhof (1997), who find this an undesirable consequence. In our approach 'Nobody walks' does not count as a positive or negative answer. It does, however, classify as an indirect answer (assuming that 'Nobody walks' can be translated as *All persons do not walk*, i.e., $[x : person] \Rightarrow ((walk \cdot x) \rightarrow \bot)$).

Although questions do not impose constraints on the context in the form of existential presuppositions, there is a rather obvious constraint associated with questions or better the act of posing a question (leaving rhetorical questions out of consideration): the question should not already be answered with respect to the common background of the interlocutors. A question Q has been answered in Γ, if there is no possible assertion A which counts as an answer (positive, negative, preventive or indirect) to Q. In other words, Γ contains an exhaustive answer to Q. The fact that no assertion anymore counts as an answer for Q with respect to Γ boils down to the following for any given assertion: (i) the assertion does not lead to a substitution instance for the question, or (ii) it rules out a substitution instance which was already ruled out, or (iii) it renders the context Γ inconsistent. It are exhaustive answers which turn Γ into a context for which (ii) and (iii) hold. Such answers can be obtained from normal answer by application of the closure condition, which, informally speaking, says that the information provided by the answer is all the information that the questioner can obtain about the question without ending up in an inconsistent context. Let us define precisely what the closure condition is given some assertion A, in response to a question Q, which yields the substitutions $S_1, \ldots S_h$ under positive or indirect answerhood (such that each S_i differs only in the assignment to marked gaps, and the results of the assignments are not β-equal), making use of the temporary assumptions $\Phi(A'_1), \ldots, \Phi(A'_n)$ in case of indirect answers (where $\Sigma_2([X_1 : T_1, \ldots, X_n : T_n]) = \lambda R.(\Sigma X_1 : T_1. \ldots (\Sigma X_n : T_n.R) \ldots)$; see chapter 2 for an explanation of Σ-types):

(17) (CLOSURE CONDITION) Given an assertion A, a question Q and a context Γ and assuming that $X_1, \ldots, X_k$ are the marked variables in Q, the closure condition is $f : (Q \Rightarrow \Sigma_2(\Phi(A'_1 \otimes \ldots \Phi(A'_n)) \cdot ((X_1 = (X_1[S_1]) \wedge \ldots \wedge X_k = (X_k[S_1])) \vee \ldots \vee (X_1 = (X_1[S_h]) \wedge \ldots \wedge X_k = (X_k[S_h]))$, where $S_1, \ldots S_h$ are the substitutions which A yields under positive or indirect answerhood (such that each S_i differs only in the assignment to marked gaps, and the results of the assignments are not β-equal), making use of the temporary assumptions $\Phi(A'_1), \ldots, \Phi(A'_n)$ in case of indirect answers.

Let us illustrate how the definition works by giving a concrete example. Suppose that we have the question 'Who talks?'($\mathbf{X} : person, P : talk \cdot \mathbf{X}$) and the reply 'John and Mary talk' ($r : talk \cdot j, q : talk \cdot m$). Suppose the questioner interprets this answer exhaustively. In that case, definition (17) provides the recipe for the closure condition which then has to be added to the context. So let us instantiate the closure condition schema provided by (D. 17):

(18) $f : ([X : person, P : talk \cdot X] \Rightarrow (X = (X[X := j, P := r]) \vee X = (X[X := m, P := q])))$ which reduces to:
$f : ([X : person, P : talk \cdot X] \Rightarrow (X = j \vee X = m))$

In words: *All persons who talk are equal to John or to Mary*. The definition also takes care of indirect answers such as 'Every preacher talks'. This answer, when interpreted exhaustively, leads to a closure condition (based on definition 17.) which can be paraphrased as follows: *For every talking person there is a preacher who is equal to that person* ($f : [X : person, P : talk \cdot X] \Rightarrow \Sigma(Y : person.\Sigma(Q : preacher \cdot Y.X = Y))$).

We have assumed that the basic kind of answers are not exhaustive, and that they can be made exhaustive by adding the closure condition. We assume that whether a closure condition is added may hinge on the mode of presentation of the answer. Take the following conversation:

(19) A: Who talks?
B: John, ehhh .... Mary and Pete.

It is clear, that after *B* has said 'John' the closure condition should not yet be added. *A* will, however, at that point have recognized that 'John' supplies a positive answer to the question.

Preferred Answers

We have presented different sorts of answers without dealing with the question which sort of answer is preferred in a given dialogue situation. Preferences do, however, seem to exist. For instance, given the question *whether* ψ and the fact that ϕ can be derived in Γ, the conditional answer *if* ϕ *then* ψ seems less preferred than the straightforward answer ψ. In this case, the conditional answer raises a question which has already been answered, and therefore seems to introduce an unnecessary detour for arriving at the positive answer (ψ). Nevertheless, we have to be careful. Sometimes, a conditional answer may be useful because it supplies the questioner with a rule which can also be applied in situations different from the current situation. For instance, the question 'Are we almost out of air?' may be answered with 'If the dial is in the red, then we are almost out of air', although it is already common background that *The dial is in the red*. This way, the next time the dial is in the red, the questioner can the deduce that we are almost out of air.[50]

The specificity of an answer may be another factor which determines the suitability of an answer in a given situation. For instance, question (3) can be answered with such divergent answers as:

(20) A man walks.

(21) That man walks. (& pointing)

(22) The tallest man walks.

(23) John walks.

In particular, the first answer is less specific than the other three. It does not allow the questioner to select one particular real-world individual. The other answers are more specific, but in different ways. Answer (21) is specific, because the referent for the man is linked to a real object through a pointing gesture. Answer (22) provides a description which uniquely identifies one individual. Finally, (23) contains a name which stands for a real-world individual.

Answers and the Truth

In order to discern a true from a false answer, an answer has to be evaluated with respect to a language external reality. This could, for instance, be done by exploiting the translation between a PTS context and DRSs (Ahn & Kolb, 1990). For DRSs, a truth-conditional semantics is available. Alternatively, one could check whether the answer can be derived in the PTS context of some omniscient being Ω (i.e., God, cf. Ahn and Kolb, 1990). These are both technical solutions, depending on an absolute notion of truth, instead of embedding truth into a theory of human behavior. The latter sort of theory might give an account of how a context Γ of an agent maintains the context in light of new (perceptual) information.

Processing Answers

In this section, we indicate how to turn our framework into a computational model of answerhood. Our framework is based on a proof system which can be implemented. It suffers, however, from the problem that any proof system suffers from that deals with a logic which is as strong as predicate logic: it is not decidable. This means that we need heuristics in order to make the system run properly (i.e., not go into a non-terminating search process now and again).

The heuristics (for instance, specifying the search depth or order of search) can be seen as being associated with an agent $\mathcal{A}$. In our definitions, we can then replace any occurrence of $\Gamma \vdash_{\Delta} C$ with

Agent $\mathcal{A}$ can compute $\Gamma \vdash_{\Delta} C$.

This means that whether something counts as an answer comes to depend on the processing capabilities of $\mathcal{A}$, and thus the notion of answerhood is relativized with respect to the questioner. In other words, answers which a person cannot grasp are no answers to that person.

4.5 Conclusions

PTSs are suitable for formalizing the notion of answerhood in such a way that the context-dependence of answers is properly accounted for. The formalization which has been presented is based on the idea that a question presents a gap in the information of the questioner, and that determining whether an answer fills the gap (given a context) comes down to performing a deduction in a proof system.

Our approach is shown to build on two notions of answerhood which are well-represented in the literature. First, we show that our approach generalizes those theories that start from the idea that answerhood should be explicated in terms of the possibility to unify a question and its answer (e.g., Katz, 1968, Scha, 1983). Second, the dynamic and contextual side of answerhood, as reflected in, for instance, Hintikka's (Hintikka, 1974) and G&S's approach to answerhood, is formalized. The formalization on the basis of PTS allows for a finer-grained analysis when it comes to dealing with indirect answers. The fact that our approach operates on the logical (syntactic) form of answers (as opposed to the operations on possible worlds as employed by G&S) allows us to isolate conditional answers from indirect answers. The former are an interesting class of answers which are computationally more feasible than indirect answers. Furthermore, we show how the notion of conversational equivalence can be formalized in our framework. This enables us to fully define indirect answerhood.

The framework which we have described is a generalization of DRT. This means that, for instance, the treatment of anaphora fits nicely into it. Also the treatment of presuppositions as anaphora can be worked out in the framework (see, chapter 3). Here there is a difference with the possible-worlds framework employed by G&S which is not suited for these purposes. Their framework is, however, currently being extended in this direction.[51]

Finally, a practical advantage of the formalization that has been presented is that the formal definition can be fitted into a computational model, which is applicable in question-answering systems of the future. Work remains to be done on formulating pragmatic constraints for ordering answers with respect to their appropriateness.

5 Accents and Alternatives

Lewis just caught the tail-end of things. 'So it'll be a waste of time – staying on here much longer. You won't expect me to go into details, of course, but I can tell you that we've finished our investigations in this house'.

If the 'this' were spoken with a hint of some audial semi–italicization, it was of no moment, for no one appeared to notice it.

(Quoted from: C. Dexter: Death is now my neighbour)

In this chapter, we examine what information accentuation conveys to the interpreter of an utterance.[52] We focus on two different types of information that have been associated with accents. First it has been claimed that accent influences the *resolution of anaphora* (Van Deemter, 1994a); accentuation is supposed to provide information about the suitable antecedents of anaphoric expressions. The term 'anaphoric expression' is used in the Van der Sandtian (1992) sense, i.e., it includes presupposition triggers such as definite descriptions. Secondly, accent has been taken to indicate *contrast* (e.g., Chomsky, 1971).

The main contribution of this paper is a unified account of both types of information that can be conveyed by means of accent. The account can be seen as a taking up a treatment of accent that Grice outlined in his 'Further Notes on Logic and Conversation' (Grice, 1989:50–53). The relation between our proposal and Grice's outline of a treatment is elaborated on section 5.4. In the literature, separate accounts can be found for each of the two types of information. The contributions in this area by Van Deemter (1994a) and Rooth (1992) exemplify what has been achieved.

Van Deemter (1994a) deals with the influence of newness accent on *anaphora resolution*. Newness accent is understood as an accent that highlights new information. Van Deemter treats it separately from contrastive accents, as in 'Máry likes Bách, whereas Jóhn likes Mózart' (accent is indicated with an apostrophe. Note that we will not exhaustively mark every accent that occurs in a sentence;

in this chapter, we mark only the accents of which we are examing the interpretation). Consider (1):

(1) a. John fed the animals. The cats were hungry.
    b. John fed the animals. The cáts were hungry.

The preferred interpretation of (1.a) is a reading where the discourse referent of 'The cats' (henceforth $\mathcal{R}$(the cats)) is identical to the discourse referent of 'the animals' ($\mathcal{R}$(the animals)). In other words, the expression 'The cats' is associated with a discourse referent that was already introduced in the preceding discourse. (1.b) allows only for interpretations where $\mathcal{R}$(the cáts) $\neq$ $\mathcal{R}$(the animals). Thus, the 'The cáts' is associated with a discourse referent that is *not-identical* with a discourse that was already introduced earlier on. Therefore, we speak of 'The cáts' as a *non-identity anaphor*. More specifically, $\mathcal{R}$(the cáts) may be a proper subset of $\mathcal{R}$(the animals) or $\mathcal{R}$(the cáts) and $\mathcal{R}$(the animals) may be disjoint altogether.

On the basis of these observations, Van Deemter proposes that newness accent on an anaphoric expression indicates a non-identity anaphor. According to van Deemter (1994a:16), "…, a new conglomerate of elements counts as a 'new' discourse entity even if all the elements are taken from an entity that constitutes given information".[53] For instance for (1.b), if $\mathcal{R}$(the cáts) is interpreted as standing in the subset relation to $\mathcal{R}$(the animals), we speak of $\mathcal{R}$(the cáts) as a new discourse referent, although all the elements of $\mathcal{R}$(the cáts) are taken from $\mathcal{R}$(the animals). Any discourse entity that was already introduced earlier counts as *given* information.

Secondly, there is Rooth (1992), which contains a formalization of the idea that accent induces *contrast between alternatives*. Imagine that the following conversation takes place after an exam which Mats, Steve and Paul took.

(2) George: How did it go?
    Mats: Well, I′ passed.

In this situation, George seems licensed to infer that neither Steve nor Paul passed the test. More generally, we might say that Mats suggests a contrast between himself and Steve and Paul. To explain this, Rooth proposes to associate sentences with a so-called focus semantic value in addition to the ordinary semantic value (the latter is the proposition expressed by the sentence). In this case, the focus semantic value corresponds to the set of propositions of the form *x* passed, i.e., the alternatives to the proposition that the speaker actually expressed.

With these focus semantic values at our disposal, the inference that Steve and Paul did not pass can be modelled as a Gricean implicature (see this book, page

xxi) on the basis of Quantity Maxim. This maxim says that speakers should make their contribution neither less nor more informative than is required (for the current purposes of the exchange). The idea is that there is a scale on the set of alternatives $\{passed(x) \mid x \in C\}$, where C equals $\{mats, steve, paul\}$. C is a subset of E, the domain of individuals. C is obtained from E via contextual restriction (Rooth does not spell out how to obtain the contextual restriction on E). By asserting the proposition ‘Mats passed’, Mats denies all propositions which are higher on the aforementioned scale (i.e, the stronger propositions ‘Mats and Steve passed’ and ‘Mats and Paul passed’). Now, from the fact that *it is not the case that Mats and Steve passed* and the information that *Mats passed*, we can infer that *Steve did not pass*. Similarly, we can infer that *Paul did not pass*.

The theories of Van Deemter (1994a) and Rooth (1992) account for different data. It is not immediately obvious that there should exist one theory which covers all these data. In this chapter, we propose an analysis of accent that can explain the relation of accent to both non-identity anaphora *and* implicatures. For that purpose, we introduce the notion of an *alternative assertion*.

Consider again example (2). The intuition was that the accent somehow licenses us to infer that *Neither Steve nor Paul passed the test*. We propose to account for this intuition as follows. Taking up Grice’s (1989:50–53) outline of a proposal (cf. this book, section 5.4), we assume that a sentence of the form *x́ does y* is directly associated with a so-called alternative assertion that says that *for all z in some contextually salient and suitable set of individuals C, Δ z does y*, where, for the moment, we assume that Δ is instantiated with ‘it is not the case that’. After instantiating Δ, we obtain: *for all z in some contextually salient and suitable set of individuals C, it is not the case that z does y*.

The conclusion that *C* consists of Paul and Steve is now arrived at as follows. The available candidates for *C* are {*Steve, Paul, Mats*}, {*Steve, Paul*}, {*Paul, Mats*}, {*Steve, Mats*}, {*Paul*}, {*Steve*} and {*Mats*}.We assume that to the members of C, the complement of the concept ‘I’ should be applicable. In other words, the members of C should be ‘non-speakers’ (assuming that ‘I’ denotes the speaker).

Thus, we are left with {*Steve, Paul*}, {*Steve*} and {*Paul*} as possible candidates for *C*. {*Steve*} and {*Paul*} are ruled out on the basis of our formalization of the quantity maxim which, roughly speaking, says ‘prefer the largest set’. Thus, we arrive at the alternative assertion that *Paul and Steve did not pass*.

The same ingredients can be used to account for the relation between accent and non-identity anaphora. Note that the alternative assertion associated with the second sentence of discourse (1.b) is: *for all z in some contextually salient set of individuals C, it is not the case that z is hungry*. The idea is that the interpreter

of the discourse has to identify the discourse referents for *both* ‘the cáts’ and *C*. We argue that on the basis of general constraints on anaphora resolution, all admissible interpretations amount to a non-identity reading for ‘the cáts’. For instance, note that if we bind *C* to $\mathcal{R}$(the animals), it becomes impossible to bind *the cáts*to the animals as well (hence, non-identity). This is due to the fact that the descriptive content associated with *C* is that all members of *C* should not be cats.

In the remainder of this chapter, we work out the details of our proposal. First, in section 5.1, we discuss the treatment of anaphors to plural objects in DRT, since such anaphors feature in example (1). In section 5.2, we describe how to construct alternative assertions and elaborate on their role in anaphora resolution. After these preliminaries, we then provide our precise account of (1) and (2). In section 5.3, some further applications of the proposal are presented. Section 5.4 contains some comparisons of the proposal with treatments of accent from the literature. Our conclusions can be found in section 5.5.

5.1 Presupposition and Plurality

To deal with anaphors to plural objects, we have to introduce some formal tools from the framework of DRT that have not yet been discussed. Let us do this by considering the following small discourse.

(3) John came in. Somewhat later Peter came in. Finally, Mary arrived. They had a drink.

Following Kamp & Reyle (1993), we assume that the proper names ‘John’, ‘Peter’ and ‘Mary’ each introduce a discourse referent. In (4.a) the DRS resulting from processing the first three sentences is depicted. (4.b) contains the representation of the discourse after the unresolved representation of the fourth sentence has been added to the main DRS.

(4) a.

x y z
John(x), Peter(y) Mary(z), came-in(x) came-in(y), arrived(z)

b.

x y z
John(x), Peter(y) Mary(z), came-in(x) came-in(y), arrived(z) had-a-drink(U) δ $\boxed{\text{U}}$

Following common practice, we have used a capital (U) for the plural discourse referent which occurs in the presuppositional DRS which is marked with the δ (cf. chapters 1 and 3). Now, the question is how this presuppositional DRS can be resolved. There is no directly accessible and suitable plural object available. Kamp & Reyle propose that such an antecedent is, however, implicitly present: it can be constructed out of the available singular discourse referents in accordance with the following rule, where U_K stands for the set of discourse referents of DRS K and Con_K stands for the set of conditions of the DRS K. The notion of sub DRS is the usual one (see chapter 1, definition (9) on p.5).

SUMMATION *(Kamp & Reyle, 1993:341)*

TRIGGERING CONFIGURATIONS K′ is a sub-DRS of the DRS K (possibly K itself) and $v_1, \ldots, v_k$ $k \geq 2$ are discourse referents occurring in K and accessible from K'.

OPERATION Introduce a new non-individual discourse referent Z into $U_{K'}$ while introducing into $\mathrm{Con}_{K'}$ the condition $Z = v_1 \oplus \ldots \oplus v_k$.

Thus, an antecedent can be constructed for U by summing x, y and z. The resulting DRS looks as follows:

(5)

x y z V

John(x), Peter(y), Mary(z)
came-in(x), came-in(y), arrived(z)
$V = x \oplus y \oplus z$
V = U
had-a-drink(U)

This account of the example left out one detail: the summation rule would also have allowed us to construct the alternative plural objects $x \oplus y$, $y \oplus z$ and $x \oplus z$. The preferred reading for the discourse in (3) is, however, the one represented in (5). Therefore, we propose the following condition on the resolution of plural anaphors (*cf.* Van Eijck, 1983 for a similar condition):

(MAX) MAXIMALITY

If U and V are suitable and accessible antecedents and $U \subset V$, then prefer V over U as an antecedent.

In other words, a plural anaphor should pick up the 'largest' suitable and accessible antecedent (a further constraint on summing individuals might be that the summed individuals must not differ too much in salience, e.g., ceteris paribus, it should be prohibited to sum a recently introduced individual with one that was mentioned half an hour ago).

Antecedents that have been constructed via summation are just one out of many types of antecedents that can be constructed out of the explicitly present discourse referents in a DRS. See, in particular, chapter 3 for more details on the construction of antecedents using world knowledge. In this chapter, we make use of one further type of implicit antecedents. These are constructed by introducing a part (roughly speaking, a subset) of a plural individual that has been explicitly introduced. In the rule below, a neutral referent —following Kamp & Reyle (1993)— is a discourse referent which not fixed on being singular or plural.[54] Typographically neutral referents are set apart from the other discourse referents by the convention that they are written in greek characters.

(PART) PARTING

TRIGGERING CONFIGURATIONS K′ is a sub-DRS of the DRS K (possibly K itself) and V a discourse referent occurring in K and accessible from K'.

OPERATION Introduce a new neutral discourse referent α into $U_{K'}$ while introducing into $\mathrm{Con}_{K'}$ the condition $\alpha \subset V$.

5.2 Alternative Assertions

Accent is a prosodic means for highlighting part of an utterance. Though all examples in this chapter deal with accent, we aim at principles that should eventually cover a larger class of highlighting devices including, for instance, word order and gestures. Nevertheless, we will say a few words about the realization of accent, before we provide our analysis of the information that is conveyed by means of accent.

Accent Realization and Types of Accent

There is an extensive literature on the realization of accent. Here, we briefly discuss the widely used framework of Janet Pierrehumbert (Pierrehumbert, 1980; our source is Pierrehumbert and Hirschberg, 1990). Accent is analysed in terms of the stress pattern and the tune of an utterance. *Stress* reveals itself in the duration, amplitude, and spectral characteristics of speech segments. Utterances are associated with a stress pattern. This stress pattern is defined as the relative prominence of the syllables. It is independent of the *tune* of an utterance. Tunes can be described as sequences of low (L) and high (H) tones. A tone can be aligned with a stressed syllable. Such a tone gives rise to a pitch accent.

In this chapter, we focus our attention on the following two pitch accents: L+H* and H* (where the '*' indicates alignment with a stressed syllable). The former has often been associated with topic or link of a sentence, and the latter with the focus or new information (we return to these notions in section 5.4). In our theory of accent interpretation, we do not distinguish between these accents. This is in line with a current trend in the speech community to question the perceptual and cognitive difference between H* and L+H* accents (based on personal communication with my colleagues at IPO working on speech; see also Pitrelli et al., 1994:125 and Ross & Ostendorf, 1996:163).

We assume that the accents that we deal with include both newness and contrastive accents. One mechanism is proposed for computing the information that is conveyed by an accent. This information takes the form of an alternative assertion. We do, however, discern three types of alternative assertions. Reconsider, example (2), here repeated as (6):

(6) George: How did it go?
Mats: Well, I′ passed.

We claimed that the alternative assertion that Mats conveys is 'Steve and Paul did not pass'. We speak of the strong contrastive interpretation of (6). The alternative assertion appears, however, to be dependent on the intonational contour of the rest of the utterance. For instance, the aforementioned alternative assertion is too strong if there is a fall on 'passed'. In that case, a more appropriate alternative assertion is: 'The speaker doesn't know whether Steve and Paul passed'. Even weaker alternative assertions appear to exist; consider the following sentence and assume that it is discourse initial:

(7) Yesterday, Jóhn went to London.

According to Van Deemter (1994a), the accent on 'Jóhn' is a newness accent. *John* was not yet introduced earlier on and is therefore new in the discourse. In our view, intuitively the speaker intends to focus the attention on *John* by means of highlighting the expression that refers to *John*. This is achieved as follows: the accent on 'Jóhn' induces an alternative assertion with an alternative presupposition. The alternative assertion can be paraphrased as 'For any person other than John, it is not relevant to the point that the speaker is trying to make whether that person went to London yesterday'.

We contend that the function of so-called newness accent is contrastive in the following sense: the speaker emphasizes explicitly the focus of his or her attention by using the accent. This focussing is achieved by means of the alternative assertion, which explicitly states that objects other than the referent of the accented expression are not the focus of attention. Metaphorically speaking we might say that an object is put into the foreground by pushing the other objects into the background.

We assume that an interpreter is somehow able to choose between alternative assertions of the form 'It is not the case that . . .', 'The speaker doesn't know whether . . .' and 'It is not relevant to the point that the speaker is making whether . . .' whether it be on the basis of the intonational contour of other parts of the utterance, the perceived strength of the accent (it seems that a very strong accent more easily triggers the first type of alternative assertion), or other indicators.

Finally, let us consider the notion of *unit accentuation*. It has been found that the accent on a single word is sometimes used by the speaker to put emphasis on the entire constituent of which the word is a part (Chafe, 1974:114, fn. 6). In 'The mayor of Óxford', the accent on 'Óxford' may be used to emphasize *Oxford* (contrast with *Cambridge*, *London*, etc. may be conveyed), but also *the mayor of Oxford* (contrast with *John*, *my neighbour*, etc. may be conveyed ,as in: 'My neighbour likes gardens. The mayor of Óxford doesn't'). Unit accentuation is not dealt with in this chapter. It posits no problem for our account, but would lead to a technically complicated rule whose explanation would interfere with the main point that we are making in this chapter.[55]

Computing Alternative Assertions

Our proposal consists of three ingredients. Firstly, we provide a recipe for computing the unresolved alternative assertion[56] induced by an accent. Secondly, we propose a minor modification of Van der Sandt's (1992) resolution algorithm, such that representations of the unresolved actual and alternative assertions can form the input to that algorithm. We preserve the basic principles underlying Van der Sandt's algorithm. Thirdly, we propose a condition on the resolution of the anaphoric material in actual and alternative assertions.

We show how the three ingredients account for the data dealt with by Van Deemter and Rooth. In particular, we re-analyse the discourses in (1) and (2). Under (AAA) below we provide an algorithm to compute an alternative assertion on the basis of the actual assertion of some utterance. The scope of our proposal is restricted to utterances containing some accented word which is a name, pronoun or has a descriptive content; we leave accent on 'logical' words such as 'and', 'or', 'every', etc. out of consideration .

Firstly (see I), the concept that is associated with the accented word is replaced with an alternative concept. We define the notion of an alternative concept in (11), after some preliminary definitions:

(8) (SUBSTITUTE CONCEPT) C' is a substitute concept for C, if C' and C are direct subordinates of some concept C''.

For instance, *rose* and *tulip* are substitutes, because they are both directly subordinate to the concept *flower*. Note that, according to this definition, every concept is a substitute of itself.

(9) (SALIENT CONCEPT) A salient concept (at a certain point in a discourse) is a concept which is the reference of a word that occurred in the preceding discourse, or a concept of which an instance has been introduced in the preceding discourse.

So, if the word 'bicycle' has been used in the preceding discourse,[57] then the concept *bicycle* becomes salient.

Note that according to (9), if the preceding discourse contains the noun phrase 'a bicycle' or 'the bicycle', not only the concept *bicycle* is taken to be salient, but also the concept *vehicle*. This is due to the fact that by uttering 'a bicycle' or 'the bicycle', the speaker introduced an instance of the concept *vehicle*.

(10) (COMPLEMENTARY CONCEPT) C' is a complementary concept for C, if C' is the concept that is formed by substracting C from its directly superordinate concept.

For example, the complementary concept of *rose* is the concept that encompasses all flowers that are not roses.

(11) (ALTERNATIVE CONCEPT) C' is an alternative concept to C *if* C' is a salient substitute concept for C. If there is no salient substitute concept, then C' is the complementary concept of C.

In (II) of (AAA), the full alternative assertion is computed. (II.A) is applied if the accented word was not part of a presuppositional expression, as in 'A mán walks in the park'. The alternative assertion predicted for this example can be paraphrased as 'It is not the case that a 'non-woman' walks in the park'.

(II.B) applies to accented words that are part of a presupposition trigger. In that case, the computation of the alternative assertion is more complicated. Consider 'The animals hadn't been fed. The cáts were hungry'. In this case, the *unresolved* alternative assertion is: 'for all x in some set c of non-cats, it is not the case that hungry(x)'. Here the alternative concept for *cats* is *'non-cat'*. c has to be filled with (a discourse referent of) a set of non-cats that are salient in the utterance context.

In both (II.A) and (II.B), separate clauses are used for alternative assertions involving '$\neg$' or the weaker 'The speaker doesn't know whether' and 'It is not relevant to the point that the speaker is trying to make whether'. Whereas in the case of a weak alternative assertion involving, we can basically let 'The speaker doesn't know whether' or 'It is not relevant to the point that the speaker is making whether' take wide scope, this is not always possible in the case of $\neg$. The alternative assertion for an actual assertion of the form $\Phi \to \Psi$ is $\Phi \to \neg\Psi$, instead of $\neg(\Phi \to \Psi)$.

In (Grice, 1989:80) it is observed that denial of an actual assertion can have the same effect: 'Sometimes the denial of a conditional is naturally taken as a way of propounding a counterconditional, the consequent of which is the negation of the consequent of the original conditional. If A says " If he proposes to her, she will refuse him" and B says "That's not the case", B would quite naturally be taken to mean "If he proposes to her, she will not refuse him" (in context meaning, perhaps, "If he proposes, she will accept him")'.

Now consider the following variant of Grice's example: 'John may propose to Sue or Mary. If he proposes to Sue, shé will be happy'. The alternative assertion that we predict is: 'If he proposes to Sue, Mary won't be happy'. Letting the negation take wide scope produces the intuitively incorrect 'It is not the case that if he proposes to Sue, Mary will be happy'. This would have the counter intuitive implication that 'John proposed to Sue'.

In the description of the algorithm, we employ the following notational conventions:

(12) (NOTATIONAL CONVENTIONS)

a. A sub DRS K *contains* a condition C IFF C is a member of Con_K or an (embedded) presuppositional DRS B is member of Con_K and Con_B contains C.

b. A presuppositional DRS B is an *embedded member* of Con_K IFF B is a member of Con_K or B is a member of a presuppositional DRS B' which is an embedded member of Con_K.

c. $\vec{x}$ STANDS FOR $x_1, \ldots x_n$.

d. In $\text{P}\dagger(\vec{x})$, the dagger INDICATES THAT the concept P is the meaning of an accented word.

e. K := K′[E := E′] MEANS THAT we henceforth refer with K to the DRS that is obtained by replacing the discourse referent, condition or DRS E in K′ with E′.

f. * STANDS FOR a dummy condition, which has no semantic import.

g. Δ stands for '$\neg$' or 'For the current purpose of the conversation it is not relevant whether'.

(13) (AAA) ALTERNATIVE ASSERTION ALGORITHM

INPUT The content of the actual assertion is represented as a proto DRS K_{in}. A sub DRS K_{sub} of K_{in} contains a condition $\text{P}\dagger(\vec{y})$.

(I) $\text{K}_{in'}$:= K_{in} [$\text{P}\dagger(\vec{y})$:= $\mathcal{P}(\vec{y})$], where $\mathcal{P}$ stands for an *alternative* concept to P. $\text{K}_{sub'}$ is the sub DRS of $\text{K}_{in'}$ which contains $\mathcal{P}(\vec{y})$.

(II.A) $\mathcal{P}\dagger(\vec{y})$ does not occur inside a presuppositional DRS:

- FOR $\Delta = \neg$:
  - IF ∃C such that $\text{K}_{sub'}$ is the sub DRS of C, where C is part of C ⇒ D THEN K_{alt}:= $\text{K}_{in'}$ AND ∀C such that $\text{K}_{sub'}$ is the sub DRS of C, where C is part of C ⇒ D DO K_{alt} := K_{alt}[(C ⇒ D) := (C ⇒ ΔD)]
  - ELSE K_{alt} := $\text{K}_{in'}$[$\text{K}_{sub'}$:= [| Δ $\text{K}_{sub'}$]].
- For $\Delta \neq \neg$: K_{alt} := [| $\Delta K_{in'}$].

(II.B) $\mathcal{P}\dagger(\vec{x})$ occurs inside a presuppositional DRS B:

1. B′ := B[$\vec{y}$:=$\vec{\alpha}$]
2. $\text{K}_{in''}$:= $\text{K}_{in'}$ where B is replaced with a dummy condition *, and all occurrences of $\vec{y}$ with the singular discourse referents $\vec{x}$. $\text{K}_{sub''}$ is the sub DRS of $\text{K}_{in''}$ which contains *.

3. - FOR $\Delta = \neg$:
     -
     - IF ∃C such that $\text{K}_{sub'}$ is the sub DRS of C, where C is part of C ⇒ D THEN K_{alt}:= $\text{K}_{in'}$ AND ∀C such that $\text{K}_{sub'}$ is the sub DRS of C, where C is part of C ⇒ D DO K_{alt} := K_{alt}[(C ⇒ D) := [$\vec{x}$ | $\vec{x} \in \vec{\alpha}$] ⇒ (C ⇒ [|ΔD])], where B′ is added to the directly superordinate DRS of [$\vec{x}$ | $\vec{x} \in \vec{\alpha}$].
     - ELSE K_{alt} := $\text{K}_{in''}$ [$\text{K}_{sub''}$:= ([|[$\vec{x}$ | $\vec{x} \in \vec{\alpha}$] ⇒ Δ $\text{K}_{sub''}$)]], where B′ is added to $\text{K}_{in''}$ if $\text{K}_{in''}$ = $\text{K}_{sub''}$ and else B′ is added to the directly superordinate DRS of $\text{K}_{sub''}$.
   - For $\Delta \neq \neg$: K_{alt} := [| [$\vec{x}$ | $\vec{x} \in \vec{\alpha}$] ⇒ Δ$\text{K}_{in''}$], where B′ is added to $\text{K}_{in''}$ if $\text{K}_{in''}$ = $\text{K}_{sub''}$ and else B′ is added to the directly superordinate DRS of $\text{K}_{sub''}$.

OUTPUT K_{out} := K_{alt} (the alternative assertion)

The procedure that we have described has to be carried out for each accented condition in the proto-DRS of the actual assertion. Thus, if an assertion contains n accents, we obtain n alternative assertions in addition to the actual assertion.

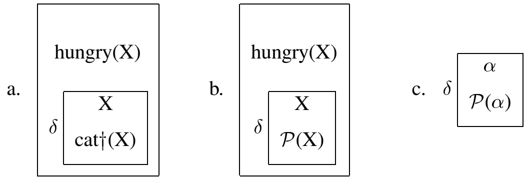
Let us illustrate how (AAA) works by computing the alternative assertions of a simple example. Subsequently, we will look into all of the subclauses of (AAA). So, consider:

(14) The cáts were hungry.

The actual assertion we associate with this sentence corresponds to the assertion that would have been triggered by its unaccented version. It can be found in (15.a). There, the dagger marks concepts that are the meaning of accented words in the utterance. In (15.b), the result of step (I) is depicted. Basically, the descriptive material 'cat' is replaced with the alternative concept $\mathcal{P}$ to the concept of 'cat'.

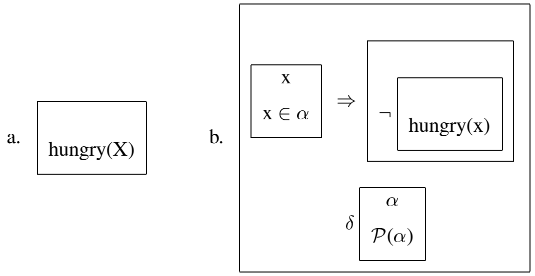
In (15.c), the effect of step 1. of (II.B) is visualized: a presuppositional DRS B′ is constructed from the presuppositional DRS B in (15.b): the plural discourse referent X in the presuppositional DRS B is replaced with the neutral discourse referent α. Thus, the alternative presupposition in the alternative assertion may later on get bound to a plural or a singular discourse referent.

(15)



In step 2. of (II.B), the presuppositional DRS is removed from (15.b); see (16.a). Furthermore, the plural discourse referent X is replaced with the singular discourse referent x. Finally, in the ELSE clause of step 3. (for $\Delta = \neg$), we construct the denial of (16.a). To obtain a DRS in which the denial of being hungry distributes over the individuals in the alternative α, we use an implicative condition. This gives us a reading where each of the individuals (x) in α is not hungry.

(16)



Below, we provide examples of all the situations that the clauses in (AAA) cover. The a.-sentences stand for the actual assertion, the b.-sentences for (a paraphrase of) the alternative assertion and in c. we indicate which clauses have been applied. For the purpose of the examples, we assume that $\Delta = \neg$. Note that in these examples all presuppositions have been resolved, whereas up till now we have only given a recipe for computing the unresolved representation of the alternative assertion. These are, however, difficult to paraphrase. The resolution process that we leave implicit for the moment is discussed in the next section. (In all examples, if we speak of the *n*'th clause we refer to the *n*'th clause of the clauses for the condition that $\Delta = \neg$)

(17) a. (A man came in). A wóman greeted him.

b. It is not the case that a man greeted him.

c. (II.A), the second clause of 3. We assume that 'man' is the alternative for 'woman'.

(18) a. (A dog came in). If a cát$_1$ sees the dog, it$_1$ will run away.

b. If a dog$_1$ sees the dog, it$_1$ will not run away.

c. The first clause of (II.A). We assume that 'dog' is the alternative for 'cat'.

(19) a. If Fred robbed the bank, then hé should be prosecuted.

b. If Fred robbed the bank, then no one other than Fred should be prosecuted.

c. The second clause of 3. in (II.B). We assume that concept that is the reference of 'he' is *masculine and very salient*. The alternative concept is therefore *not masculine or not very salient*.

(20) a. If a cat runs into a dog, then the dóg will attack.

b. If a cat runs into a dog, then the cat won't attack.

c. The second clause of 3. in (II.B).

(21) a. If Fréd gave you the money, then we are in trouble.

b. For everybody but Fred, if he/she gave you the money, then we are not in trouble.

c. The first clause of 3. in (II.B).

(22) a. Fred didn't rob the bank or hé should be prosecuted.

b. If Fred robbed the bank, then no one other than Fred should be prosecuted.

c. The second clause of 3. in (II.B). We assume that 'Φ or Ψ' is translated into 'if not Φ then Ψ', and double negations are cancelled. See chapter 3, section 3.2.

(23) a. There is a red and a green button. Fred pushed the gréen button, or we are in trouble.

b. If Fred did not push the red button, then we are not in trouble

c. The first clause of 3. in (II.B). An alternative paraphrase, obtained via contraposition, is 'If we are in trouble, then Fred pushed the red button'.

(24) a. John entertained the guests. Théy enjoyed it.

b. John didn't enjoy it.

c. The second clause of 3. in (II.B). We have added this example to illustrate the purpose of using a neutral discourse referents for the alternative presupposition. In this case the actual presupposition associated with 'Théy' is bound to a plural object, whereas the alternative is bound to the singular object denoted by the name 'John'.[58]

Resolution of actual and alternative assertions

Both the presuppositions in the actual and the alternative assertion(s) need to be resolved. We assume that resolution is conducted according to Van der Sandt's resolution algorithm. According to that algorithm the DRS for a new sentence is constructed in two stages. First a (proto) DRS (see section 1.1) is constructed which still contains the presuppositional DRS's. This proto DRS is then merged with the main DRS.

In a second stage, the presuppositional DRS's are resolved in the context provided by the main DRS. If everything goes well, this yields a proper DRS. In particular, the result of the resolution algorithm should meet certain acceptability conditions (Van der Sandt, 1992:367, see (15) on page 7) pertaining to the informativity and consistency of the resulting DRS.

Our scenario differs marginally from this one in case a sentence carries one or more accents. Such a sentence is associated with more than one proto DRS. Firstly, there is the proto-DRS which is computed as if there were no accent present, and secondly there are the other DRSs that can be obtained via the recipe in (AAA). All proto DRSs are merged with the main DRS. From there on, the resolution algorithm can do its work.

The third ingredient of our proposal concerns the resolution of the alternative presuppositions. We propose that their resolution is subject to the following condition:

(MAC) MARKED ACCESSIBILITY CONDITION
Take as the referent for the alternative presupposition a referent whose accessibility is equal to or greater than the accessibility of the referent of the actual presupposition.

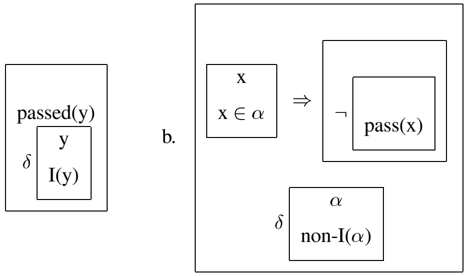
The idea behind (MAC) is that accenting an expression puts it in opposition to its unaccented (unmarked) variant. An accent which marks an expression signals that the meaning of the expression is also marked. For an anaphoric expression, marking can be used to guide the hearer to the marked (less accessible) referent. This is realized by the fact that in accordance with (MAC) the alternative presupposition can pick up the more accessible referent which would, if the accent were absent, be assigned to the actual presupposition.

We are now at a point where we can reanalyse the examples (1) and (2). Let us first look at (2), here repeated as (25).

(25) George: How did it go?
Mats: Well, I′ passed.

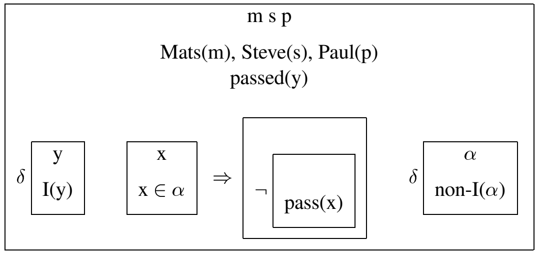
The actual and alternative assertion associated with Mats' utterance are:

(26) a. b.



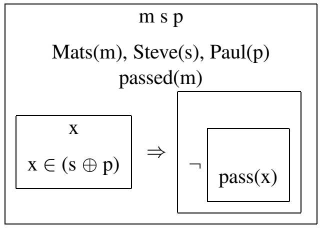
Note that the alternative concept for 'I' in this case is 'non-I'. Both proto DRSs are added to the main DRS. Let us assume that in this DRS the individuals Mats, Steve and Paul are each represented by a discourse referent.

(27)



We will now demonstrate how the resolution algorithm, when applied to this main DRS, yields the following proper DRS.

(28)



We will not go into the matter of how y resolves to m, but let us just assume that it does. The question then becomes what is a suitable and accessible antecedent for α. We could take (any summation of) m, p and/or s. But, in line with the (MAX) condition we seek the 'largest' antecedent. The 'largest' antecedent that can be constructed is $m \oplus p \oplus s$. However, this resolution is not admissible: *non-I* would not apply to all the members of this set.

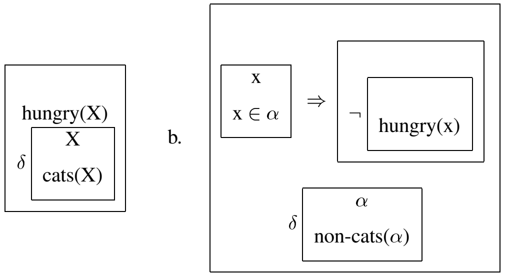
So, we have to seek the second largest antecedent for α that does yield an admissible resolution. The antecedent meeting this constraint is $s \oplus p$. Thus we obtain the DRS in (28). Note that this new main DRS entails that Mats passed and that Paul and Steve did not pass, i.e., the result is in line with our intuitions. Now consider Van Deemter (1994a)'s example of a non-identity anaphor that is induced by means of an accent:

(29) a. John fed the animals. The cats were hungry.

b. John fed the animals. The cáts were hungry.

The discourse in (29.a) suggests an identity reading for the noun phrase 'The cats'. This result is predicted by simply applying the standard Van der Sandtian resolution algorithm. For the second sentence of (29.b), we obtain two proto DRSs:

(30) a.



Both of these proto DRS are added to the main DRS. We now need to find an antecedent for X and α. The first sentence of (29.b) introduced some set of animals Y into the main DRS. So we might want to bind both X and α to Y. However, this will yield an inconsistent DRS, since we know that the animals in X are cats and those in α are non-cats. The first admissible resolution that we want to discuss, is the one which best suits the rationale behind the (MAC) conditions. The condition says that the alternative presupposition should pick up a referent that is equally or more accessible than the actual presupposition.

So, let us assume that α picks up the animals Y from the main context. Now there is nothing left for X, so an antecedent for X has to be *accommodated* (we assume that an accommodated entity has a low accessibility). Note that (MAC) rules out the reverse scenario where the actual presupposition is bound and the alternative presupposition is accommodated. There is, however, another option. X and α can pick up antecedents of equal accessibility. Thus we get the subset reading: both X and α pick up a subset of Y (constructed using PART, see page 88): $\alpha \subset Y$ and $X \subset Y$. Furthermore, the (MAX) conditions ensures that α and X fully consume Y: $(\alpha \oplus X) = Y$.

We have shown how our modified resolution algorithm in combination with the recipe for computing alternative assertions and the conditions on resolution (MAX, MAC and acceptability, in particular, consistency) give us the appropriate readings for (25) and (29).

5.3 Further Applications

In this section, we provide an informal discussion of some further data that are within the scope of our proposal.

Deaccenting and Nuclear Stress

The notion of *nuclear stress* is defined as follows: ‘It is a general rule of English that, in any major phrase, one word receives more stress than any of the others. This word is the rightmost non-anaphoric word of the rightmost constituent in the phrase’ (Levelt, 1995:176).[59]

Firstly, there is the issue why an anaphoric word (where we assume that Levelt means by anaphoric that the word is part of an expression that is co-referent with a linguistic antecedent) cannot receive the nuclear stress. The word that receives the nuclear stress is not anaphoric in Levelt’s sense (i.e., its most suitable linguistic antecedent), because nuclear stress accent would induce a non-identity anaphor (in this respect the predictions of our proposal are in line with those of Van Deemter, 1994a), i.e., the expression takes as its antecedent an object that is different from the most suitable and salient object that fits the expression, as in (the point is that there is no accent on the cats/them, wheras there is an accent on féed):

(31) The cats were hungry. John forgot to féed the cats/them.

Thus, in (31), the cats/them is deaccented and the accent moves one position to the left. Van Deemter (1994a) points out that also words which introduce a concept that was already introduced earlier on do not receive an accent:

(32) If Susan owns a car, she must be rich. Well anyway, you don’t neéd a car in New York City. (from Van Deemter, 1994a:20)

Van Deemter uses the notion of concept–givenness to explain examples such as (32). An occurrence of a word is concept-given if the reference of the word subsumes the reference of a word that occurred earlier on in the discourse.

Our proposal covers these cases, because it predicts that an accent on car would have led to an inconsistent reading of (32): if the accent were placed on *car* in (32), this would lead to an alternative assertion with the content that ‘It is not the case that you don’t need a car in New York’, because in this example the alternative concept to *car* is *car* (cf. definition 11.). Note that we also predict the deaccenting of ‘vehicle’ in:

(33) Juans owns a bicycle. You absolutely néed a vehicle if you work at Stanford. (Based on Van Deemter, 1994a:20)

The available alternative concept for *vehicle* is *vehicle* in this case. The introduction of a bicycle makes the concept *vehicle* salient, because bicycles are vehicles. Note that deaccenting doesn’t occur if we swap ‘bicycle’ and ‘vehicle’:

(34) Juans owns a vehicle. ⋆ You absolutely néed a vehicle if you work at Stanford. (Based on Van Deemter, 1994a:20)

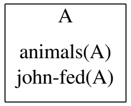
Quantifiers, Indefinites and Verbs

In (25) and (29) definite noun phrases were accented. Our proposal accent on words with a descriptive content, names and pronouns. Logical words (such as the quantifiers) are not dealt with. We do, however, deal with accented noun phrases that contain an unaccented generalized quantifier, as in:

(35) John fed the animals. Most pánthers were hungry.

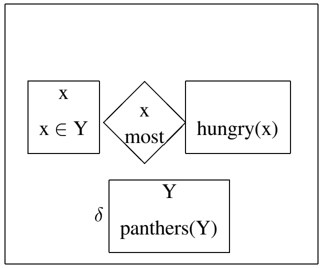
After processing the first sentence of this discourse we obtain the following DRS:

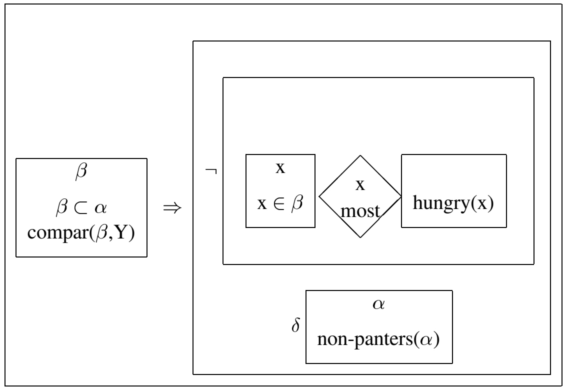
(36)



The second sentence gives rise to the addition of the following actual and alternative assertion (the representations are based on work on the representation of noun phrases in Krahmer and Van Deemter, 1997, but see also this book, section 3.2):

(37)



(38) 

The duplex condition in (37) represents the actual assertion associated with 'Most pánthers were hungry'. It states that most elements of Y are hungry, where Y is the set of panthers. The duplex condition in (38) corresponds with the alternative assertion. It states that for all parts β of α (the set of alternatives) that are comparable to the set of panthers Y, it holds that it is not the case that most individuals in β are hungry.

The new ingredient in this representation is the predicate 'compar'. We assume that, for instance, usually lions are comparable to panthers. So if this sentence is uttered in a situation where there is a salient set of lions, which is included in α (the set of *all* alternatives), then we can infer that it is not the case that most of these lions are hungry. If we resolve the presuppositional DRS's in (37) and (38), one reading that we come across is the subsectional reading where $\alpha \subset A$, $Y \subset A$, and $A = (\alpha \oplus Y)$. The other resolution, is the one where the panthers Y are accommodated, and the alternatives α are equated with the set of animals A (that is, on this reading all animals are non-panthers).

Let us now turn to accents on indefinites. For instance, consider:

(39) A: John saw a priest.
B: No, he saw a wóman.

The alternative assertion associated with B's utterance can be translated into English as 'John did not see a $\mathcal{P}$'. In this case, the salient concept available for $\mathcal{P}$ is the concept of *man* which was made salient by A. A introduced a priest, and priests are known to be men. Therefore, the concept *man* is a salient substitute for

the concept *woman*. Thus, we arrive at: 'John did not see a man' as corresponding to A's alternative assertion.[60]

Finally, let us examine an example of an accent on a verb. Consider (40), where the b. sentence is the alternative assertion belonging to the second sentence in a.:

(40) a. John swims. Peter rúns.
b. It is not the case that Peter swims.

In general, in case a verb is accented, the corresponding concept in the DRS is replaced with the alternative concept. In this case, the alternative for the concept of 'run' is the concept of 'swim'.

Corrections

Accents are often used in corrections:

(41) A: George won the elections.
B: No, Bíll won them.

Note that the alternative assertion that we predict for B's utterance is 'George did not win the elections' (assuming that the alternative presupposition triggered by the accent on 'Bill' takes *George* as an antecedent). Thus the alternative assertion explicates the meaning of 'No' in B's utterance.

It is beyond the scope of this chapter, to deal with more types of correction in detail. See Van Leusen (1997) for an extensive overview of different kinds of correction illustrated with constructed and real-life data. Interestingly, Van Leusen proposes that corrections basically *are* anaphors. Her proposal entails that 'corrections are anaphors that are not sensitive to scoping domains that normally function as barriers to anaphora resolution' (Van Leusen, 1997:22). At this point her proposal differs from the one we set forth in this chapter: according to our proposal anaphors involved in accenting are governed by the standard notion of accessibility. This difference in approach can be illustrated with the following example:

(42) A: John didn't give Mary a bunch of roses.
B: No, he gave her a bunch of súnflowers.
(Van Leusen, 1997:22)

The corrected proposition that *John gave Mary a bunch of roses* is within the scope of a negation. Note that B's utterance functions as a confirmation by correction (B confirms that *John didn't give Mary a bunch of roses*). If the correction functions as an anaphor to the proposition within the scope of the negation, then it must be assumed that corrections are not normal anaphors such as personal pronouns which do not allow for such antecedents (e.g., $\star$ 'John didn't give Mary a bunch of roses. She liked them').

Let us now analyse this example in terms of its alternative assertion. The accent on 'sunflowers' gives rises to the following alternative assertion:

(43)
$$\boxed{\begin{array}{c} x\ y \\ \text{John}(x) \\ \text{Mary}(y) \\ \neg\ \boxed{\begin{array}{c} \text{U,V} \\ \text{give}(x,y,U) \\ \text{bunch}(U),\ \text{of}(U,V) \\ \mathcal{P}(V) \end{array}} \end{array}}$$

In words, *John didn't give Mary a bunch of* $\mathcal{P}$. Now, $\mathcal{P}$ has to be instantiated with a suitable alternative concept to *sunflowers*. In this case, *rose* has just been mentioned, which makes it a salient concept at this point of the discourse and therefore the best candidate antecedent. Thus the resolved alternative assertion is: John didn't give Mary a bunch of roses. Thus, the confirmation of A's utterance corresponds to the alternative assertion of B's utterance. In other words, we furnished an explanation of (42) that does not require the use of 'abnormal' anaphors.

Multiple Accents

In the following discourse, there are assertions which carry more than one accent at once:

(44) The pánthers were hungrier than the púmas. (and) The púmas were hungrier than the chéetahs.

Note that if we interpret the sentences as standing in direct contrast with each other, then only trivial alternative assertions are predicted:

(45) a. The panthers were not hungrier than the cheetahs. (cancelled)

b. The pumas were not hungrier than the pumas. (trivial)

But now consider a situation where the alternatives for panthers, pumas and cheetahs are explicitly introduced in a preceding sentence:

(46) The animals hadn't been fed. The pánthers were hungrier than the púmas. (and) The púmas were hungrier than the chéetahs.

We obtain the following implicatures, after processing the first sentence:

(47) a. The non-panthers were not hungrier than the pumas.

b. The panthers were not hungrier than the non-pumas.

The information provided by the second sentence in combination with the earlier computed alternative assertions gives rise to inconsistencies, and thus causes the hearer to reconsider the alternative assertions of the first sentence. The recomputed alternative assertion is found below in a. (it is the recomputation of 47.b) and the newly computed alternative assertion on the basis of the second sentence can be found in b. Thus the entire discourse give rise to the following two alternative assertions:

(48) a. The panthers were not hungrier than the animals other than the pumas and the cheetahs.

b. The pumas were not hungrier than the animals other than the cheetahs.

Or in other words: *the panthers were only hungrier than the pumas and the cheetahs, and the pumas were only hungrier than the cheetahs*. Clearly, the computation of alternative assertions is not monotonic. But this comes as no surprise given the fact that implicatures in general are thought to be cancellable.

Collective Predication

Consider:

(49) The logícians meet on Mónday. The semánticists meet on Túesday.

We predict the following alternative assertions: *The logicians do not meet on Tuesday* and *The semanticists do not meet on Monday*. Let us write out the first of these alternative assertions (note that we have not strictly followed (AAA). Rather, we have employed some innovations that we introduced in connection with example (35)):

(50)
$$\boxed{\begin{array}{c} X\ Y\ t \\ \text{semanticists(X), logicians(Y), Tuesday(t)} \\ \boxed{\begin{array}{c} \beta \\ \beta \subset X \\ \text{comparable}(\beta,Y) \end{array}} \Rightarrow \boxed{\neg \boxed{\text{meet-on}(\beta,t)}} \end{array}}$$

We now assume that the β that satisfies comparability with the set of logicians is the set of semanticists X as a whole. This is influenced by the fact that the predicate applied to β is a *collective predicate*. Thus, we obtain the alternative assertion that the semanticists as a group did not meet on Tuesday. Of course, this does not logically preclude individual semanticists from partaking in the meeting of the logicians as well (i.e., there might be individuals that are both semanticist and logician).[61]

Note that in our account, whether there is overlap or not between the set of semanticists and that of logicians is not stipulated: it is governed by the acceptability conditions on the resolved representation of the actual and the alternative assertion. The only thing that follows via the alternative assertions is that the set of semanticists is *not* equal to the set of logicians. Note that this information has the status of a *cancellable* implicature. For instance, suppose it later on becomes known that all semanticists are logicians. That means that we can infer (on the basis of the explicit assertions) that these semanticists also meet on Monday. Thus the alternative assertion that *the semanticsts do not meet on Monday is cancelled*.

Questions and Answers

Accents have been mentioned in connection with *answers* to *questions*. Consider:

(51) A: Who walks in the park?
B: Jóhn (walks in the park).

Let us assume that the noun phrase 'Who' in *A*'s utterance presupposes a context set *C* from which the answer should select a subset of individuals, i.e., those individuals that walk in the park. The elliptical assertion made by *B* corresponds to 'John walks in the park' and the alternative assertion is 'The other people do not walk in the park'. Basically, we get a subset reading where 'John' and 'The other people' consume *C*. Note that the alternative assertion which is triggered by the accent corresponds to an exhaustive reading (relative to the context set) for the answer to the question.

Here we want to point out that accents do not always give rise to exhaustive readings of answers. In particular, multiple accents do not give rise to an exhaustive readings. For instance, from 'Jóhn bought a súitcase' one cannot infer that nobody else bought something (neither does our algorithm predict this: the algorithm predicts the following alternative assertions *John bought nothing else but a suitcase* and *Nobody else but John bought a suitcase*). So consider the following question–answer pair:

(52) A: Who bought what?
B: Jóhn bought a súitcase.

B's answer may receive an exhaustive interpretation (i.e., *nobody else (in the context set) but John bought something*). This is, however, not due to the accenting. In chapter 4 we discuss how exhaustive answers are computed (see, in particular, section 4.4).

5.4 Alternative Proposals

In this section, we present a number of alternatives to our proposal and show in what respects they are different form the proposal put forward in this chapter.

Grice on Stress

In his 'Further Notes on Logic and Conversation', Grice dedicates a section to stress (Grice, 1989:50–53). He considers stress to be a conventional device for highlighting, or making prominent, a particular word. He then points out that stress 'is one of the elements which help to generate implicatures'. He discerns three contexts in which stress plays a role.

(1) *Replies to wh-questions and corrections*. He claims that the effect of stress is to '(...) to make perspicuous elements which complete open sentences for which questions (in effect) demand completion (...)'[62] or to make perspicuous elements 'in respect of which what B is prepared to assert (or otherwise) and what B has asserted differ' as in:

(53) A: Jones paid the bill
B: Jónes didn't pay the bill; Smíth paid it

(2) Sentences such as the one uttered by B in (53) without the antecedent utterance by A. In that case, Grice claims that 'we are inclined to say that the implicature

is that someone thinks or might think that Jones did pay the bill'. B's utterance should be relevant to something or other. If the speaker implicates that somebody thinks or might think that Jones did pay the bill, then his utterance can be constructed by the interpreter as being relevant to that implicature.

(3) Grice considers situations where there is only the assertion of 'Jónes didn't pay the bill'. Again, it seems that the speaker acts as if somebody had asserted that 'Someone (other than Jones) didn't pay the bill'.

Grice generalizes his last claim as follows: 'In general, S($\acute{\alpha}$) is contrasted with the result of substituting some expression β for α, and commonly the speaker suggests that he would deny the substitute version, but there are other possibilities' (Grice, 1989:52). An example of the other possibilities that Grice refers to is that the speaker may implicate the weaker 'I do not confine myself to S(β)' instead of 'I deny that S(β)'.

The main tenet of Grice's proposal in (3) can be seen as the backbone of the proposal which we have put forward in this chapter. Whereas Grice speaks of a sentence that is contrasted with a variant of it under certain substitutions, we use the underlying actual and the alternative assertion.

Our contribution is that we work out a detailed account of how an alternative assertion affects the resolution of presuppositions in the actual assertion. This give us a handle to deal with the fact that accenting gives rise to non-identity anaphora.[63]

Accent and non-identity anaphora

Let us now compare our proposal with Van Deemter's non-identity account (Van Deemter, 1994a) and a related account presented in Hendriks & Dekker (1995). What we have shown is that the relation between non-identity anaphora and newness accents follows from general constraints on the processing of anaphoric material in unresolved alternative assertions. The alternative assertions account for the implicatures that accentuation induces.

These implicatures are beyond the scope of the non-identity theories. What makes our proposal particularly attractive is that it reveals the connections between the induction of implicatures and the non-identity readings.

Let us also point out that the non-identity theories as they are formulated in Van Deemter (1994a) and Hendriks & Dekker (1995) fail to account for a number of examples. Consider, for instance:

(54) The logicians and the semanticists went to the conference in Amsterdam. The semánticists enjoyed it.

In (54) a referent for the semanticists is introduced in the first sentence. This means that there is an identity anaphor between 'the semanticist' in the first sentence and 'The semánticists' in the second sentence. Thus it seems that the accent on 'The semánticists' cannot be interpreted as a non-identity anaphor

One can, however, argue that there is a non-identity anaphor despite the introduction of a discourse referent for 'the semanticists' in the first sentence, because 'The logicians and the semanticists' should be seen as introducing only one referent that is available for anaphoric reference.[64] Note that the fact that only one referent is introduced for anaphoric reference in (54) by means of the noun phrase 'The logicians and the semanticists' cannot be ascribed to the fact that the noun phrase contains a conjunction; compare:

(55) The teacher handed out the marks. Mary got an A. Peter got a B. Péter was very disappointed. '

Let us move to a related problem for the non-identity accounts.

(56) The logicians and the semanticists went to the conference in Amsterdam. The Dútch semanticists enjoyed it.

The problem is how a non-identity proposal can account for the fact that 'semanticists' receives no accent in the second sentence? One option is to invoke Van Deemter's (1994a) notion of concept givenness. The concept associated with 'semanticists' is introduced in the first sentence of (56). Van Deemter argues that in such cases if the concept is referred to later on by some expression, that expression should be deaccented. This may work well for (56). But then again, it would also lead to the undesirable prediction that semanticist should be deaccented in (54) as well. The solution to this problem is to assume that sometimes two or more concepts only supply one discourse referent. In (56), the concept *logician and the semanticist* may be available for identity anaphora on the level of concepts, whereas the concepts of which it is composed are not individually available for anaphoric reference.

These examples demonstrate that the proposals of Van Deemter (1994a) and Hendriks & Dekker (1995) need to be extended. What is more, their proposals do not account for the implicatures that the accents induce.

Contrast as contrariety

In Van Deemter (1994b) a treatment of contrastive accent that is separate from his proposal for newness accents is presented. Van Deemter defines contrast in terms of contrariety (a notion which dates back to Aristotle). Two propositions are each others contraries if it is impossible for them to be true at the same time.

Consider the following example from Van Deemter (1994b):

(57) Jóhn is married to Máry and Péter is married to Sálly.

Van Deemter proposes that contrast is licensed by contrariety between the conjuncts (possibly with substitutions of arbitrary variables for corresponding accented positions). Since there is no direct contrariety between 'a is married to *Mary*' and 'a is married to *Sally*', Van Deemter assumes that an implicature might be generated that the sentence is uttered in a monogamous society, thus obtaining a contrariety after all. We think, however, that even in a non-monogamous society we get the implicatures that John is not married to Sally and Peter is not married to Mary (which follow directly from our account). It is impossible to get these directly via Van Deemter's proposal: if there is no direct contrariety, he is always forced to assume that an interpreter 'accommodates' some 'rule' (i.e., 'monogamy': 'if a is married b and $c \neq b$, then a is not married to c') which enables the derivation of a contrariety. It is not clear what 'rule' an interpreter would need to come up with if she or he knows that the society in question tolerates polygamy.

The instructional view on accenting

Reinhart (1981) defines the *sentence topic* as that what the sentence is *about*. This idea was moulded into an instructional point of view in Vallduví (1992). Vallduví's equivalent of a sentence topic, the *link* of a sentence, is supposed to indicate *where* the new information that a speaker offers to a hearer should be recorded in the hearer's information state. The link is claimed to receive an L+H* accent. Vallduví suggests that locations for information storage can be identified with the file cards of Heim's file change semantics (Heim, 1982).

Vallduví bases his theory partly on evidence from Catalan in which links are grammatically marked, as opposed to the predominantly prosodic marking in spoken English. In this chapter, we are not concerned with any particular means for marking linkhood and simply assume that the linguistic expression corresponding with the link has been marked in some (possibly more than one) way with respect to the other expressions in the sentence.

Hendriks & Dekker (1995) point out some weaknesses in the instructional view expounded by Vallduví. They criticize, in particular, the use of locations in the form of file cards. They show that the same work can be done with a simple DRS extended with a condition which provides information about which discourse

referent a fictitious file clerk is working. Furthermore, they draw attention to the fact that it is not clear what happens with links involving quantifiers, negative or disjunctive information. Another observation of Hendriks and Dekker is that the rigid division of a sentence into a link, a tail and a focus commits Vallduví to the counterintuitive claim that pronouns belong to the focus (new information) put forward by a sentence.

Finally, note that there remains a strong similarity between non-identity accounts of accent as expounded by Van Deemter (1994) and Hendriks & Dekker (1995), and the instructional view on accenting. Signalling non-identity can be seen as an instruction to the hearer to switch to a non-identical referent before adding information on the discourse referent to the DRS.

The Background Presupposition Rule

Geurts and Van der Sandt (1997) present a new formulation of the so-called Background/Presupposition Rule (BPR) which goes back to Jackendoff (1972). In order to formulate this rule, we have to assume that a sentence is divided into two parts: a focus and a background. Consider:

(58) $[\text{Fred}]_F$ robbed the bank.

The idea is that 'Fred' is the focus and '. . . robbed the bank' the background of (58). The focus of a sentence can marked by means of an accent.

The BPR says that 'Whenever ϕ is backgrounded, the presupposition is triggered that $\phi*$ holds, where $\phi*$ is the existential instantiation of ϕ' (Geurts and Van der Sandt, 1997:37). Thus, *somebody robbed the bank* is triggered as a presupposition according to the BPR. The innovation of Geurts and Van der Sandt is that they show that interesting predictions can be made using only the rules for anaphora resolution as proposed in Van der Sandt (1992). They discuss, for instance:

(59) a. If Barney wasn't in town, then $[\text{Fred}]_F$ robbed the bank.
b. If anybody robbed the bank, then $[\text{Fred}]_F$ robbed the bank.

The idea is that the a. sentence presupposes that *somebody robbed the bank* whereas the b. sentence does not. This can be explained using Van der Sandt's account of anaphora resolution: in the case of the b. sentence the presupposition is bound to the antecedent of the implication. Therefore, it is not globally accommodated. In case of the a. sentence, the presupposition triggered by the BPR cannot be bound and therefore has to be globally accommodated. Thus, in that case, the presupposition survives.

As for the relation of the BPR to our proposal: the proposals appear to be complementary, i.e., account for different aspects of the same data. Note that the alternative assertions that we predict for (59.a/b) are, respectively, *If Barney wasn't in town, then nobody else but Fred robbed the bank* and *If anybody was in town, then nobody else but Fred robbed the bank*, respectively. These cannot be arrived at via the BPR. Furthermore, the BPR does not account for the observations concerning the relation between accent and non-identity anaphora.

5.5 Conclusions

Our proposal rests on the idea that an accent on an assertion induces a so-called alternative assertion. Roughly speaking, this idea corresponds with the proposal of Grice which says that accent on a subexpression α of a sentence $S(\alpha)$ triggers an implicature whose content is $\neg S(\beta)$, i.e., the denial of the sentence whose accented part α has been replaced by some alternative expression β.

We provided an algorithm for computing alternative assertions and subsequently worked out the role of alternative assertions in the resolution of presuppositions. We demonstrated that the presence of an alternative assertion can account for the so-called non-identity anaphora that have been associated with accents (Van Deemter, 1994a). Our account rests on the use of alternative assertions and some standard conditions, one less well-known condition and one new condition governing the resolution of presuppositions. Thus we showed that there is more unity in the data on accent than one might suspect at first sight, if one looks closely at the interaction between the derivation of an alternative assertion and presupposition resolution.

We showed that our proposal holds for accent on content words, names and pronouns. We refrained from dealing with accent on function words (such as 'the', 'or', etc.). This is a direction for future reseach. A further line of future research is the exact formulation of the notion of an alternative concept. This notion is in fact a psychological one. It should provide a model of how people actually organize the concepts which they use to understand the world.

Finally, we dealt with accents in different contexts: in corrections, confirmations, answers, etc. We did, however, restrict our attention to assertions. Accent on questions and commands is therefore a topic for further investigations.[65]

III

Conversation

6 Conversational Games

The heart of language is not "expression" of something antecedent, much less expression of antecedent thought. It is communication; the establishment of cooperation in an activity in which there are partners, and in which the activity of each is modified and regulated by partnership. (Dewey, 1925:179)

In his pathbreaking book 'Fallacies', Charles Leonard Hamblin introduces the notion of a system of *formal dialectics* (Hamblin, 1970). A dialectical system provides rules which 'may specify the form or content of what they [the conversational partners] say, relative to context and to what has occurred previously in the dialogue' (Hamblin, 1970:255).

Hamblin models the conversational context in terms of what he calls *commitment-stores*: 'We can conceive of a commitment-store physically as a sheet of paper with writing on it, or as a section of the store of a computer. As a dialogue proceeds items are periodically added and, in some circumstances, deleted.' (Hamblin, 1970:263). Hamblin stresses that the commitments which are added to or deleted from a commitment-store do not have to coincide with the beliefs of the dialogue partners: 'We do not necessarily believe everything we say; but our saying commits us whether we believe it or not.' (Hamblin, 1970:264).

The aim of this chapter is to model a number of naturally occurring conversational structures in terms of a conversational game. Hamblin's dialectical systems provide a good starting point for devising such a conversational game. We go beyond Hamblin's (1970) dialectical systems in the following respects. First, an account of imperatives and interrogatives in terms of commitments is provided for. Second, the issue of subconversation is addressed. An alternative is described to existing accounts which employ partial or more strict orders (lists, stacks) on conversation contributions in combination with destructive update rules on that order (e.g., Litman & Allen, 1987 and more recently Beun, 1994a; Ginzburg, 1995 and Piwek, 1995). Finally, we consider which predictions the proposed conversational game makes for the process of interpretation in conversation. In particular, the problem of presupposition resolution (see chapter 3) in conversations is addressed.

The conversational game that we are going to develop should account for structures that show up in naturally occurring conversations. For that purpose, we use the findings from discourse and conversation analysis (e.g., Coulthard, 1992; Stenström, 1994 and Sudnow, 1972). These fields have yielded structuralistic characterizations of conversation in combination with informal accounts of the context in which these structures come into being. The empirical orientation of these approaches made sure that a wealth of data has become available that is relatively untainted by premature theorizing. A less satisfactory aspect of the aforementioned approaches is that a multitude of utterance classifications has been generated which lack underlying organizing principles. In that respect, we attempt to make a contribution. The aim is to show that many of the structures and classifications posited by conversation and discourse analysts emerge from the rule-governed dynamics of the context.

This chapter is organized as follows. In section 6.1, we give a concise overview of the findings from conversation and discourse analysis. In section 6.2, the approach to modelling conversation in terms of rule-governed state changes is elaborated on by comparing conversations with the game of chess, i.e., a different type of activity that can be described in terms of rule-governed state changes. In section 6.3, we develop a dialectical system covering utterances in the three basic sentence types. In section 6.4, the coverage of the system is demonstrated by matching its output against the patterns which conversation and discourse analysts have reported on. Section 6.5 contains comparisons with alternative accounts. Finally, section 6.6 contains some remarks on the implications that the system that we have adopted has for presupposition resolution.

6.1 Conversation and Discourse Analysis

In Levinson (1983), Conversation Analysis (CA) and Discourse Analysis (DA) are presented as each others adversaries. Whereas DA is presented as applying notions from linguistics (such as rules and well-formed formula) to discourse on the basis of small collections of data, CA is depicted as being much more empirically oriented, shunning premature theorizing. The explicit analysis of discourses in terms of syntactic structure in combination with a rich system of categorizations of utterances is indeed characteristic for DA. However, like CA, DA has become an empirically oriented trade, cf., Coulthard (1992) and Stenström (1994).

Furthermore, CA itself, though it does not directly refer to notions from linguistics, on an informal level looks at the data through the same structuralist glasses that DA theorists employ. Although conversation analysts may not sperse their articles with abundant classifications of utterances, they nevertheless make use of such classifications. See, for instance, Schegloff (1972), who refers to question–answer and summons–answers sequences . The article also contains drawings of syntactic trees of discourse structures. In the next two sections, we describe some of the results from CA and DA, respectively, which we put to use as touchstones for the conversational game that we are to develop.

Conversation Analysis

Conversation Analysis (CA) was sparked of in the early 1960's by Sacks who was involved in Garfinkel's research in ethnomethodology. Ethnomethodology is directed at the participants' own, i.e., ethnic, methods of production and interpretation of everyday interaction. In order to uncover the structure of the activities of everyday life, Garfinkel used mainly tape and film as a starting point for analysis (see Garfinkel, 1972; Sudnow, 1972). Sacks concentrated on conversation, while pursuing this line of investigation (see, for instance, Sacks et al., 1974).

One of the best known observations reported by conversation analysts is that the basic building blocks of conversations are *pairs of utterances*, such as there are, for instance: a question followed by an answer, a command succeeded by a reply and an assertion followed by a signal of acceptance or rejection (the conversational fragments in 1. and 2. have been translated from Dutch):

(1) S: Is there only 1 flight from Lyon to Amsterdam on that day?
I: Yes.

(From Beun, 1987:68)

(2) A: Take the longest blue one that you have.
B: Yes. [does it]

(From Cremers, 1992:18)

(3) A: Bush is the president of the United States.
B: No, he isn't anymore.

(Fictitious dialogue fragment)

In each of these exchanges, the first utterance seems to require or set up an expectation, for the second utterance. To describe this phenomenon, the notion of

conditional relevance was introduced: 'When one utterance (A) is conditionally relevant on another (S), then the occurrence of S provides for the relevance of the occurrence of A' (Schegloff, 1972:76).

The examples suggest that utterance pairs consist of adjacent utterances. Together with the assumption that conversations are made up of such pairs, this would lead to the prediction that conversations are structured as sequences of pairs of utterances. Conversation analysts found that more complex structures occur, as exemplified by the dialogue fragment below.

(4) 1. A: Remove that blue one, too
2. B: That big blue one? (pointing gesture)
3. A: Yes.
4. B: Yes. (does it)

(Translation of a part of a Dutch dialogue – Cremers, 1992:85)

In this case, we have a pair $\langle 2., 3.\rangle$ which has been inserted into another utterance pair $\langle 1., 4.\rangle$. A sequence like this is called an *insertion* or *side sequence*.

Finally, we want to discuss a particular type of system which Sacks et al. (1978) put forward as the appropriate type of system to describe turn taking, but also for conversational phenomena in general. This type of system, the *locally managed system*, consists of rules which are thought to precisely describe local phenomena and at the same time leave room for global variation. For instance, the rules for turn taking, as proposed in Sacks et al. (1978), determine the conditions under which a turn can be passed from one participant to another, without constraining, amongst other things, the number of participants and the length of a turn.

However, there is no locally managed system to account for the structure of conversations in terms of the arrangement of utterance pairs. The informal accounts of conversation analysts are most easily formalised as a *grammar* for conversations. For instance, the following grammar captures some of the structural regularities which conversation analysts talk about.

(5) A grammar for conversations

(R1)	Conversation	$\rightarrow$ Subconversation
(R2)	Conversation	$\rightarrow$ Subconversation, Conversation
(R3)	Subconversation	$\rightarrow$ Pair
(R4)	Subconversation	$\rightarrow$ first(Pair), Conversation, second(Pair)
(R5)	Pair	= $\langle$Question, Response$\rangle$ | $\langle$Command, Compliance/Defiance$\rangle$ | $\langle$Assertion, Acceptance/Rejection$\rangle$

first(⟨X, Y⟩) $=_{df}$ X
second(⟨X, Y⟩) $=_{df}$ Y

A grammar like this is a long way from a locally managed system: the grammar describes the structure of conversations from the perspective of an external observer. It does not lay bare the relation between these structures and the local (situated) actions of conversational participants.

Furthermore, it does not address the relation between the location of an utterance pair and its conversational function: in conversational fragment 4, the pair ⟨2., 3.⟩ occurs because A has difficulties in interpreting the referring expression 'that blue one' in utterance 1. The functional aspects are lost because the grammar specifies the structure independent of the context in which this structure emerges.

Discourse Analysis

A good overview of many of the findings from DA can be found in Stenström (1994) (see also Coulthard, 1992 for a representative collection of papers by discourse analysts). This section uses the descriptions of conversation from Stenström (1994). Stenström's descriptions are based on naturally occurring spoken conversations from the Lond-Lund Corpus of English conversations (see Svartvik and Quirk (eds) 1980, Svartvik (ed.) 1990).

In DA, a conversation is analysed in terms of a hierarchy of levels. The levels that are usually discerned are: the *transaction*, *exchange*, *turn*, *move* and *act* level. In this chapter, we focus on the exchange level. Our aim is to provide an underlying context change model for the exchange patterns observed by, amongst others, DA analysts. The *exchange* is typically realized as what conversation analysts have called an adjacency pair. It is considered to be 'the minimal interactive unit and involves the negotiation of a single piece of information' (Stenström, 1994:48). An exchange may, however, consists of more than a pair of utterances. For instance, a question–answer sequence can be succeeded by an *evaluating follow up move* which rounds off the exchange:

(6) A: and do you teach?
B: No, I don't, because I'm not English at all.
A: I see.
(Based on Stenström, 1994:49)

When a conversation contains several exchanges, these are organized according to certain *patterns*. Stenström discusses the patterns involved in stating and questioning exchanges. She discerns two basic types of pattern involved in stating exchanges: exchanges consisting of statement–reply pairs and exchanges consisting of statement–acknowledgement pairs. The former pattern is called *chaining* and the latter *supporting*:

(7) *chaining*

$\boxed{\text{A: \textit{statement} B: \textit{reply}}}$ $\boxed{\text{A: \textit{statement} B: \textit{reply}}}$ *etc.*

supporting

$\boxed{\text{A: \textit{stat.} B: \textit{ack.} A: \textit{stat.} B: \textit{ack.} A: \textit{stat.} B: \textit{ack.}}}$ *etc.*

The boxes indicate the boundaries of an exchange. In case of supporting it is *A* who dominates the conversation, *B* only contributing acknowledgements, and is thus the main contributor of an extended exchange. For questioning exchanges, DA analysts found that the following patterns are most frequent (see Stenström, 1994):

(8) *chaining*

$\boxed{\text{A: \textit{question} B: \textit{answer}}}$ $\boxed{\text{A: \textit{question} B: \textit{answer}}}$ *etc.*

embedding

$\boxed{\text{A: } \textit{question}_1 \boxed{\text{B: } \textit{question}_2 \text{ A: } \textit{answer}_2.} \text{ B: } \textit{answer}_1}$

coupling

$\boxed{\text{A: } \textit{question}_1 \text{ B: (} \textit{answer}_1} \boxed{\textit{question}_2 \text{) A: } \textit{answer}_2}$

elliptical coupling

$\boxed{\text{A: } \textit{question}_1 \text{ B:}} \boxed{\textit{question}_2 \text{ A: } \textit{answer}_2}$

Embeddings are called *side* or *insertion sequences* by conversation analysts. We have already seen examples of chaining and embedding (see 1, 2, 3 and 4). Coupling can be seen as a form of chaining where the initiative goes from one participant to the other. Particularly interesting is eliptical coupling. There, the adjacency pair initiated with the first question seems to be incomplete. Consider:

(9) A: Do you know what they got?
B: What?

A: They didn't get replies from most people.
(Based on Stenström, 1994:53)

This pattern illustrates the importance of context. Although *A*'s question is not directly addressed, it is addressed with respect to the implicit assumption that a question is normally only posed if the questioner does not know the answer. So, when *B* asks 'What (did they get)', *A infers* that *B* does not know what they got, and therefore considers the original question to be answered. Thus adjancency pairs turn out to be only the *reflex of the dynamics of the underlying context in conversation*.

6.2 Stores and Rules

A conversational game consists of two components: a *conversational store* whose contents change during the conversation and a set of *conversational rules* which govern the timing and content of utterances and the way the utterances affect the conversational store. The analysis of conversations in terms of rule-governed state changes has been likened to descriptions of the game of chess (see, for instance, Bunt & Van Katwijk, 1979; Clark, 1996): in chess, a state corresponds to a particular distribution of the chess pieces on the board and the rules of chess regulate when and how which pieces can be moved. There are, however, also some fundamental differences between chess and conversations.

First, in a normal chess game the conversational state is physically present and visible to the players. Moves are realized by direct physical actions on the store (i.e., the chess board). In a conversation, the participants only act *as if* there is a publicly accessible conversational state. In fact, there are only the subjective mental representations that each of the participants has of the current conversational state. Consequently, in a dialogue, moves are indirect: an utterance is in the first place a physical event; it has to be *interpreted* by the addressee as constituting a certain move on the level of the dialogue game. Since interpretation is not always perfect, the representation which the participants have of the conversational state may diverge. However, if such a divergence is detected, the dialogue itself provides means for repair (e.g., clarificatory subdialogues, which are dealt with below).

Second, due to the fact that the dialogue participants only have a subjective representation of the conversational state, the distinction between moves which are in line with the rules and those that violate the rules is blurred. An utterance which might at first sight violate the conversational rules with respect to the representation that the interpreter has at that moment of the conversational state, may become legimate if the interpreter changes his or her subjective representation of the conversational state.

In chapter 3, we modelled several examples which illustrate this phenomenon and which are known under the term *accommodation* (Lewis, 1979); given certain circumstances, the presuppositions of an utterances can be added to the conversational store, if they were not yet part of that store. The notion of implicature which was introduced in Grice (1975) subsumes accommodation: what Grice calls the implicature is that piece of information that has to be added to the conversational store such that the current utterance is in line with Grice's maxims of conversation. Consider:

(10) A: Smith doesn't seem to have a girlfriend these days.
B: He has been paying a lot of visits to New York lately.
(From Grice, 1975:51)

Grice points out that *B*'s utterance can become relevant to the addressee if the addressee assumes that the speaker believes that Smith has, or may have, a girlfriend in New York. In other words, the aforementioned assumption is necessary to maintain the view that *B* is acting in accordance with the maxim of relation (i.e., *be relevant*). Generally, we might discern two options that are open to an interpreter when faced with an utterance which does not cohere with the conversational rules: (1) The utterance is considered to be unintelligible and this fact is communicated to the speaker; (2) The representation of the conversational store is adjusted, such that the utterance becomes intelligible. Here we can again make the following division: (2a) the interpretation of the utterance itself is adjusted; or (2b) the representation of the context relative to which the utterance is interpreted is adjusted.

A third difference lies in the fact that the content of conversational states is representational, i.e., it is *about* states of affairs in the 'real' world. For instance, if we agree that the Earth is closer to the sun than Pluto, then we believe our public commitment to be about the sun, the planets Earth and Pluto and the distances between these objects. A position on a chess board is not meant to reflect a state of affairs that is external to the chess game.

Fourth, conversations and chess games differ in that the rules of conversation in general, as opposed to the rules of chess, do not comprise rules which determine when a game has been lost or won. Rather the rules should be understood as delimiting the space within which communication can take place. Breaking the rules undermines communication, but obeying the rules is not a watertight guarantee that communication succeeds: if conversational participants start out with different representations of the game state this may give rise to miscommunication despite of the fact that the participants act in accordance with the conversational rules. In other words, compliance with the rules is a necessary but not a sufficient condition for communication.

For communication to be successful, the conversational partners should also have sufficiently similar representations of the game state at the outset of the conversation. Here, the words 'sufficiently similar' indicate that we are dealing with a relative notion. The purposes of the conversational participants are relevant: for some purposes approximate understanding is sufficient, whereas in other situations, exact understanding is required.

We pointed out that the conversational rules do not characterize when a conversational game has been won or lost. One can, however, add rules which specify when a conversation has been lost or won; thus obtaining specific conversational games, such as games of information transfer taking place at, for instance, an information desk. A game of information transfer is won if a particular piece of information (e.g., the departure time of a train) has been transferred from the information provider to the information seeker. In this case, both parties either lose or win the game (it is a game of coordination, as opposed to a game of conflict in which a party wins precisely then when the other party loses). If the game is lost, this does, however, not mean that communication broke down.

Suppose, for instance, that the information seeker does not succeed in making clear to the provider what information he exactly wants. In that case, the conversation may eventually be closed by the provider by saying: 'I am sorry, I don't understand what you want, I cannot help you'. In that case, though communication failed at a certain level, at higher level the participants can reach an agreement about the fact that they failed to communicate on the lower level. This way, communication is sustained on the higher level.

6.3 A Conversational Game

A conversational game consists of a conversational store and a set of conversational rules. The conversational store is an annotated commitment-store. Below, we explain what the annotations pertain to. The conversational rules come in two categories: rules which, given a conversational state, impose a preference order on possible utterances, and rules for updating the conversational store in the face of new information.

The Conversational Store

The primary component of the conversational store is the commitment-store. Roughly speaking, it contains the commitments which are assumed to be public at a given stage of the conversation. Before we going into the technical details let us discuss our reasons for adopting commitments to model conversation. Basically, commitments provide the tool for modelling the picture of conversation outlined in the quote from Dewey (1925) at the beginning of this chapter, but see also Malinowski (1923).

Establishment of cooperation, which is where the heart of language resides according to Dewey, can be thought of as being attained via the establishment of public commitments: if two conversational partners share a commitment to a particular line of action, they can each do their part in this action. For instance, if *A* proposes to *B* to go to the cinema (*A:* 'let's go to the movies'), and *B* accepts that proposal (*B:* 'ok'), then *A* and *B* have established a public commitment *to go to the cinema* which is expected to guide the actions of each of them.

Communicative actions give rise to commitments. Commitments, in turn, lead to expectations. These expectations can be directed towards different sorts of actions. Firstly, there are expectations with respect to *A*'s communicative actions: *A* is not expected to contradict information he is committed to. Secondly, commitments lead to the following expectations concerning non-communicative actions: (1) if according to *A*'s commitments some action α by *A* will occur, then *A* is expected to carry out α, and (2) if according to *A*'s commitments some event e is bound to happen or some state s is bound to hold, then *A* will not undertake any actions that prevent e or s from occurring. This holds for all of *A*'s actions, except for communicative actions aimed at changing *A*'s public commitments. This provision is needed to make sure that the conversational partners are allowed to change their mind.

Formally, a conversational store is a tuple $\langle \Gamma, A \rangle$, consisting of a commitment-store and an annotation. The annotation will be used to store information about the temporal order in which commitments were added to the commitment-store and the source of the commitments. The commitment-store itself will be identified with a type-theoretical context. For modelling a conversation between two individuals, say A and B, we need two conversational stores: one associated with each individual. Such a conversational store represents the subjective view of that individual on the current state of the conversation.

Formally, the annotation is a set of feature-value pairs. For our system we employ two features: $temp\_ord$ and $source$. The value of $temp\_ord$ is a partially ordered set whose members are the (proof) objects introduced in Γ. This poset has a supremum, which is the most recently introduced object. Due to the partial order, the temporal relation between some objects may be unknown. This seems a psychologically more realistic assumption than simply imposing a linear order on the set of objects. The second feature, $source$, consists of pairs of a source of information and a set of objects. For the moment, we distinguish only two sources: information obtained via communication versus information obtained via observation. For these two sources the features $commun.$ and $observ.$ are used, respectively.

The type-theoretical context that we are going to use will be framed in an extension of the modal PTS that is described in Borghuis (1994). A modal PTS is a PTS extended with deduction rules for entering and exiting subcontexts. These subcontexts can, for instance, be thought of as representing the commitments of a certain individual. Assume that C_A and C_B are proposition forming operators, which are to be interpreted as X *is committed to* $\ldots$ (where $X \in \{A, B\}$). In this chapter, we omit the full technical details of the system and refer to Borghuis (1994). The central rules are:

(11) C–import: IF $a : C_X p$ is derivable in a context Γ, THEN $k^\vee \cdot a : p$ is derivable in an X-context subordinate to Γ.

In words, if there is a proof (a) that some individual is committed to some proposition, then there is a proof ($k^\vee \cdot a$) for that proposition in the subcontext which contains the commitments of the individual.

(12) C–export: IF $a : p$ is derivable in an X-context subordinate to some context Γ, THEN $k^\wedge \cdot a : C_X p$ is derivable in Γ.

In words, if we can prove in the (commitment) subcontext of some individual that some proposition holds, then we can prove in the context that is superordinate to the aforementioned context that the individual is committed to the proposition in question.

Our extension of Borghuis's system is threefold: firstly, we assume that also Σ-types are available, secondly, we assume that there are two modal operators C_A and C_B, one for each interlocutor (Borghuis' (1994:27) original system has only one operator), and thirdly, we extend the system of Borghuis (1994) by adding an axiom and a rule, following Zeevat (1997). These ensure that the context Γ can be interpreted as containing the public commitments of the interlocutors.

(13) AXIOM $ax1 : [p : prop, q : C_A p, r : C_B p] \Rightarrow p$

In words, if it is a public commitment that A and B are committed to some proposition p, then p is a public commitment. Conversely, if p is a public commitment, then it is a public commitment that *A* and *B* are committed to p:

(14) IF $\Gamma \vdash a : p$ THEN $\Gamma \vdash r_A a : C_A p$ and $\Gamma \vdash r_B a : C_B p$.

The Conversational Rules

There are two main categories of conversational rules: *update* rules and *reaction* rules. We start off by introducing a general update rule and an implicit update rule. Subsequently, two reaction rules are proposed. Finally, three so-called content rules are put forward. The content rules are subservient to the general update rule.

Update Rules

In this chapter, the three basic sentence types are dealt with. Each of them is associated with a particular type of update of the conversational store. There is, however, a general pattern underlying these updates which is captured by the following rule:

(15) (GENERAL UPDATE RULE) IF X produces utterance u with content Φ, THEN update Γ with $C_X\Phi$.

In words, an interlocutor becomes publicly committed to the content of what he or she said. Each of the three different sentence types gives rise to a different content. For example, the content of a declarative sentence is equal to its propositional content. Interrogatives and imperatives are addressed when we introduce the content rules.

A conversational partner can take on a commitment by means of an appropriate utterance. Commitments can also be taken on by remaining silent. In particular, our hypothesis is that conversational partners assume the following: a conversational partner takes on the public commitments of an *expert* on issues concerning the expert's field of expertise without the need for explicit confirmation that such commitments have been taken on. We assume that the same holds for people who are considered to be an *authority* on some issue. Henceforth, we use the word 'expert' to refer to both experts and authorities. The formal representation of this implicit update rule is:

(16) (IMPLICIT UPDATE RULE)
IF $C_X\Phi$ is new information on Γ and there exists a substitution S such that $\Gamma \vdash Q : conv\_partners \cdot X \cdot Y, S : expert(X, \Phi)[S]$
THEN update Γ with a fresh proof for $C_Y \cdot P[S]$.

In words, if on Γ the information that X is committed to Φ is new, and furthermore X and Y are conversational partners and X is an expert with respect to Φ^{66}, then Γ should be updated with the information that Y is committed to P as well.

This rule should not be understood as implying that the addressee of an expert has to accept everything that the expert says. Such an addressee, say *A*, can cancel the commitment to a proposition Φ that it has implicitly taken on by explicitly asserting its denial. We assume that in such a situation the most recently introduced commitment of *A* is maintained:

(17) RECENCY HEURISTIC In case of conflicting public commitments, maintain those public commitments that have been introduced into Γ most recently.

Let us consider a plausible alternative to this recency heuristic to demonstrate the generality of the heuristic. The alternative rule is: 'the commitments that a person takes on explicitly are "stronger" than the commitments he takes on implicitly'. This rule works for situations in which an implicitly taken on commitment is cancelled by means of an assertion.

The limitations of such a rule show up when we consider the exchanges that take place in a classroom situation. Consider a situation in which a pupil asserts Φ and subsequently the teacher asserts $\neg\Phi$. After that exchange, $\neg\Phi$ has become a public commitment. This is not vindicated by the alternative rule.

The recency heuristic does support the conclusion that the aforementioned exchange gives rise to the public commitment $\neg\Phi$: on the basis of the general update rule we have $\Gamma \vdash C_{teacher}\neg\Phi$, and on the basis of the implicit update rule and the recency heuristic we have $\Gamma \vdash C_{pupil}\neg\Phi$. This adds up to: $\Gamma \vdash \neg\Phi$ (by rule 13) .

Reaction Rules

(18) EVALUATE There is a preference to react to the most recently introduced commitment $C_X\Phi$ on Γ (where X is the other conversational partner) for which it is not the case that $\Gamma \vdash \Phi$ or $\Gamma \vdash C_Y\neg\Phi$.

Note that the condition that the issue is still under discussion (i.e., it is not the case that $\Gamma \vdash \Phi$ or $\Gamma \vdash C_Y\neg\Phi$), means that sometimes it will be legitimate to react to a commitment that is not the most recent one that was introduced, but rather the most recent one that is still under discussion. In fact, such a reaction often occurs after a subconversation has been closed. In that case, a reaction is produced to an utterance that does not immediately precede the utterance that is to be produced.

Subconversations require an additional reaction rule. At the beginning of a subconversation, a new commitment is introduced which does not directly pertain to the issues that are still open. It is intended to remove certain obstacles that prevent a reaction in line with the evaluate rule. For instance, a certain commitment cannot be reacted to, because more information is needed to determine what reaction is in line with the evaluate rule would be appropriate (examples of such situations are dealt with in section 6.4).

(19) POSTPONE A speaker may postpone reacting according to the evaluate rule in order to remove an obstacle which prevents it from reacting in line with the evaluate rule.

Content Rules

The general update rule (15) specifies how the context is to be updated given an utterance u with some content Φ. In this section, we address the problem of assigning a content to an utterance. We propose that the three different sentence types (declarative, imperative and interrogative) give rise to three different types of content, provided that we concentrate on utterances that consist of non-elliptical sentences with default intonation.

By default intonation we mean that the intonation agrees with the sentence type, e.g., we do not consider declarative sentences with a final rise, that is, a question intonation. We refer to section 6.6 and chapter 7 for some remarks on elliptical utterances. Finally, we do not consider any gestures that might influence the content type that is associated with an utterance.

For utterances with a declarative sentence type, the content is equal to the propositional content of the sentence:

(20) (CONTENT RULE DECLARATIVES) IF utterance *u* consists of a declarative sentence S, THEN the content of u is the propositional content p of S.

Thus, if a dialogue partner *A* utters a declarative sentence with the propositional content Φ, then the public commitments Γ are update with $C_A\Phi$ (by rule 15). On the basis of the content of Γ, some more fine-grained distinctions can be made between different utterances involving declarative sentences.

Consider a situation in which person *A* utters a declarative sentence with content Φ to addressee *B*. Three situation can be discerned concerning the relation between the newly introduced commitment $C_A\Phi$ and the public commitments of B.

(21) *B* did not yet have a public position with respect to the proposition Φ:
not $\Gamma \vdash C_B\Phi$ and not $\Gamma \vdash C_B\neg\Phi$ (*initiation other*)
B is committed to the negation of Φ:
$\Gamma \vdash C_B\neg\Phi$ (*rejection*)
B is committed to Φ:
$\Gamma \vdash C_B\Phi$ (*confirmation*)

Similarly, three situation can be discerned concerning the relation between the newly introduced commitment $C_A\Phi$ and the public commitments of A immediately before the utterance:

(22) not $\Gamma \vdash C_A\Phi$ and not $\Gamma \vdash C_A\neg\Phi$ (*initiation self*)
$\Gamma \vdash C_A\Phi$ (*repetition*)
$\Gamma \vdash C_A\neg\Phi$ (*retraction*)

Following Zeevat (1997), an *assertion* can now be defined as a self and other initiation: the commitment that is introduced by the assertion and its negation should be a commitment of neither the addressee nor the speaker. Thus, according to our definition of assertions they should not involve a rejection, confirmation, repetition or retraction.

Let us round off our discussion of declaratives with a simple example:

(23) 1. A: It rains.
2. B: Yes, it does.

For now, it makes no difference whether we look at *A*'s or *B*'s representation of Γ. Utterance 1. leads to the addition of C_A (it rains) to Γ. Utterance 2., gives rise to an update with C_B (it rains). On the basis of (13) we now have that $\Gamma \vdash$ (it rains). In other words, this small exchange has given rise to a public commitment of A and B to the effect that it rains.

Imperatives are somewhat more complicated than declaratives. The propositional content of an imperative sentence is highly context dependent: both the time and the actor of the action that is introduced by means of the imperative sentence have to be inferred. The time is equal to the immediate future, unless the imperative sentence contains an explicit reference to a time, as in 'Answer the questions on the next page, after you have read the instructions'. The actor of the action is to be identified with the addressee(s) of the utterance. Thus we arrive at a propositional content Φ. The utterance content is obtained by embedding the propositional content into the operator C_X, where X is the addressee (the result is $C_X\Phi$).

(24) (CONTENT RULE IMPERATIVES) IF utterance *u* is addressed at dialogue partner X and consists of an imperative sentence S with propositional content Φ, THEN the content of u is $C_X\Phi$.

From this rule and the general update rule (15) it follows that an imperative utterance by A with propositional content Φ and addressee B leads to an update of Γ with $C_AC_B\Phi$. In other words, the speaker puts the proposition $C_B\Phi$ up for discussion by means of the imperative utterance.

Consider the following fictitious exchange, and assume that it was conducted by telephone:

(25) 1. A: Take a long blue block.
2. B: Ok

With 1., *A* introduces $C_AC_B\alpha$ into Γ (where α abbreviates 'B will take a long blue block'). In 2., *B* utters 'Ok'. It is analysed as *B* echoing the content of *A*'s utterance. Thus, Γ is updated with $C_B\alpha$.

Note that at this point no explicit agreement with respect to the proposition (B will take a long blue block) has as yet been reached: we have $\Gamma \vdash C_AC_B\alpha$ and $\Gamma \vdash C_B\alpha$, but *not* : $\Gamma \vdash C_A\alpha$.

However, since we can assume *B* to be an expert concerning her own actions (in particular, with respect to the other dialogue partner who has no visual information about the actions that *B* performs since the conversation is by telephone), we may apply the rule for implicit updates in (16) to the content of 2. Thus we have that $\Gamma \vdash C_A\alpha$. Using (13), we finally arrive at: $\Gamma \vdash \alpha$.

The implicit update rule only works if the addressee of the command is thought to be an expert on the proposition he or she introduced. Sometimes, however, the expertise is located with the issuer of the command. In that case, after the reaction to the command, an evaluative follow-up may be required (the conversational fragment has been translated from Dutch):

(26) A: Remove the uppermost of the two green cubes.
B: [does it].
A: 'OK'
A: Remove . . .
(From Cremers, 1993:9)

The setting for this exchange (an exchange which exemplifies a pattern that occurred frequently in the conversations that were collected) was as follows: *A* and *B* can communicate with typed input via computer keyboards and share a visually perceptible workspace in which *B* can manipulate blocks and *A* may only point at those blocks. *A* was the expert on where the blocks should be put. Here, the issuer of the imperative often does not rely on the implicit update rule, but rather provides an explicit acknowledgement (e.g., 'ok'). We assume that a mutually perceptible action ('[does it]' in 26) in response to a request also counts as the introduction of a commitment, i.e., that the person who carried out the action is committed to having carried out the requested action.

Note that from our analysis of imperatives and declaratives it follows that you can express any imperative content using a declarative, but not vice versa. Similarly, you can express any interrogative content using an imperative, but not vice versa.

(27) (CONTENT RULE INTERROGATIVES) IF utterance *u* consists of an interrogative sentence S, THEN the content of u is $C_B will\_be\_answered(q)$, where q is the semantic content of interrogative sentence S.

Consider:

(28) 1. A: Who is the King of France?
2. B: Louis the XIV.

After 1., the speaker has gone public on being committed to the addressee being committed to the question 'Who is the King of France?' being answered. A dialogue partner considers a question to be answered if it is committed to some proposition Φ and it is committed to Φ being a semantic answer to the question (see chapter 4). Formally, Γ contains the following rule:

(29) $[X : person, q : question, a : C_X(\Phi), b : sem\_answer(\Phi, q)] \Rightarrow C_X answered(q)$.

Note that the rule does not require a linguistic answer: whether a dialogue partner considers a question to be answered depends on the commitments of the dialogue partner. These can come about by means of symbolic communication, but could also arise out of observation. For instance, if *A* asks *B* 'Will the glass break if you drop it?', *A* can answer the question by dropping the glass.

6.4 Applications

In this section, we discuss the patterns observed by discourse and conversation analysts in the light of the conversational game that we have presented in the previous section.

Chaining

We have shown how the parts of a pair in a chain can be related via the evaluate rule (18). In case of a statement-reply pair, the pair might give rise to public agreement or disagreement concerning a certain proposition. In case of a question-answer pair things are more complicated. Sometimes agreement can be established implicitly, in case the implicit update rule is applicable, and sometimes it has to be established explicitly, for instance, when a teacher confirms the answer of a pupil.

Embedding

Consider the following conversation which was translated from Dutch:

(30) 1. A: Harry has the British nationality.
2. B: why so?
3. A: he was born on Bermuda
4. B: that doesn't mean anything

(Fictitious, Springorum, 1982:94)

In utterance 1., A. makes an assertion. B should react in line with the evaluate rule (18). There is, however, an obstacle which prevents *B* from doing so: *B* first wants to see the evidence on the basis of which *A* asserted 1. In line with the postpone rule (19), *B* asks a question in order to find out what evidence *A* has.

After 2., *B* has made public his commitment that *A* is committed to answering the question *why Harry has the British nationality*. *B* provides an answer, i.e., *Harry has the British nationality because he was born on Bermuda*. Implicitly, thereby *B* also asserts that the question is answered. This can be inferred on the basis of rule (29). However, *B* subsequently asserts that *A* has not provided a proper answer.

Note that he does not attack the proposition that *Harry was born on the Bermuda's*, but rather the proposition inferred via rule (29), which said that 3. contains the answer to B's question. In this case, at the end of the conversation the proposition *Harry has the British nationality* is still under discussion. Alternatively, B might have said 'Ok' in the fourth turn. Thereby, he would have accepted not only the answer to his why-question, but at the same time the assertion made by A. in turn 1.

Similar structures with slightly different content are dealt with in Beun (1994a).There, however, an explicit goal list is used to model the subconversation. See also Springorum (1982), who analyses such conversations using tree structures.

(31) 1. A: Where is John?
2. B: Is there a red Volvo on the driveway?
3. A: Yes.
4. B: Then he is at home.
(Fictitious)

Particularly interesting is the fourth turn in the conversation. In line with Dekker (1997), we assume that the 'then' indicates that B makes an assertion which is partly justified by a commitment introduced by A (i.e., that *there is a red Volvo on the driveway*).

We account for the structure as follows. After utterance 1., the following proposition has been introduced into Γ: $C_A C_B$ will_be_answered(Where is John?). *B*, however, uses the postpone rule instead of the evaluate rule, which would force *B* to say whether he is going to answer the question. *B* adds a new commitment on to Γ: $C_B C_A$ will_be_answered(Is there a red Volvo on the driveway?). *A* provides an answer, and thereby also becomes committed to having provided an answer.

At this point the most recently introduced commitment that is under discussion is: 'There is a red Volvo on the driveway'. The second most recent one is that '*A*'s question will be answered'. In this case, *B* does not react explicitly to the most recent commitment under discussion, but the to second most recent one. By saying 'Then he is at home', *B* asserts 'If there is a red Volvo on the driveway, then John is at home'. This counts as an indirect answer to the question in 1. (see chapter 4). And thus *B* has become committed to answering *A*'s question. Note that although *B* does not react to the most recently introduced commitment in 3., *B*'s utterance in 4. 'makes use' of this commitment.

Coupling

The third pattern that can be distinguished is coupling. Consider:

(32) 1. A: Who did it?
2. B: John. Didn't Peter tell you.
3. A: No, he didn't. (Fictitious)

In fact, there is nothing special to such a structure in terms of the conversational rules. Rather, the exchange is interesting from the perspective of who has the initiative in a conversation. In this case, the initiative is taken over in 2. by B.

Elliptical Coupling

Consider again:

(33) 1. A: Do you know what they got?
2. B: What?
3. A: They didn't get replies from most people.
(Based on Stenström, 1994:53)

To account for this discourse we need an additional rule to be added to Γ. The rule should say something like:

(34) Normally if somebody asks a question, he or she doesn't know the answer to it.

So when in 2., B asks 'What did they get?', she implicates that she doesn't know what they got. But this automatically answers A's original question. Furthermore, since everyone can be considered to be an expert on what he knows and doesn't know, the implicit update rule is applicable, Thus, the answering of the question in 1. is no longer under discussion after 2.

Dialogue Control Utterances

Bunt (1989) discerns a particular class of utterances and termed them Dialogue Control Utterances (DCUs). These are utterances that are about the conversation itself, and are used to manage different aspects of it such as turn-taking, opening/closing and feedback. Here we propose a distinction between those utterances about the conversation that can and those that cannot be assigned a commitment-store update on the basis of the imperative, interrogative or declarative sentence type of the utterance and the semantic content of the words that make up the sentence.

The update associated with the question for clarification 'What do you mean by that?' (the speaker becomes committed to the hearer being committed to the question being answered) is determined by the sentence type and the semantic content of the words that make up the sentence. The second class consists of utterances which are realized by certain lexical items such as 'Hello'.

We nevertheless think that it is beneficial to analyse such DCUs in terms of commitments. Particularly, because they occur in the same patterns as the other utterances. For instance, greetings typically take the form of an adjacency pair (see Stenström, 1994:140–148).

'Hello' might stand for the commitment that *the speaker and the addressee acknowledge each others presence*. If a speaker produces 'Hello', the proposition that *the speaker and the addressee acknowledge each others presence* is put up for discussion. If the other person now responds with 'Hello' (in line with rule 18, which says that a recently introduced commitment should be reacted to), then an agreement has been reached, since both partners are now committed to the proposition that *the speaker and the addressee acknowledge each others presence*.

6.5 Comparisons

In this section, we compare our model of conversational structure in terms of an underlying conversational game with other analyses of utterance meaning and conversational structure.

The 'I want' theory of imperatives

Particularly, in computational approaches to imperatives it has been proposed that 'do α' can be equated with the assertion of 'I want you to do α' or 'The speaker goal is that the addressee does α' (cf. Cohen et al., 1990). But now consider imperatives in a situation where person *B* gives *advice* to person *A*:

(35) A: Where is the station?
B: Turn to the right at the crossroads and then keep walking straight on.

Can we really say that it is *A*'s goal that *B* 'turns to the right at the crossroads and then keep walking straight on?' Here a paraphrase in terms of commitments seems more appropriate. *B* becomes committed to *A* being committed to *going to the right and then walking straight on*. What *B* really wants *A* is not an issue in this conversation.

Imperatives can be used in many different situations each of which adds something extra to the basic meaning in terms of commitments that we have supplied. For instance, in a situation where the imperative is uttered by somebody who has some form of authority, although the imperative is used to put a commitment of the addressee up for discussion, there is no real opportunity for discussion. The addressee is expected to simply accept the commitment, as oppposed to situations where the imperative is used to convey an advice or encouragement (e.g., 'Go ahead').

There are some uses of imperatives which appear to be at odds with our analysis in terms of commitments. These are greetings (e.g., 'Be welcome') and blessings (e.g., 'Go in peace', 'Have a nice day'). For instance, if *A* says 'Have a nice day' to *B*, *A* obviously does not become committed to *B* being committed to having a nice day.

It seems that in a situation like that, the speaker *A* acts *as if* he also addresses the 'the gods' or 'nature', and presents a commitment to them or it. That is, 'Have a nice day' means that the speaker is committed to the gods or nature being

committed to the addressee having a nice day. An addressee would arrive at this interpretation on the basis of the fact that the event which the imperative introduces is not under the control of the addressee (e.g., having a nice day, going in peace, being wellcome), whereas the event is within the powers of the gods (at least according to mythology and religion) or nature.

Varieties of Adjacency Pairs

In Clark & Schaefer (1989), we find on page 158 a great diversity of adjaceny pairs ranging from question-answer, offer-acceptance/rejection to greetings and farewell. Though the multiplicity of categories can be justified in terms of fine nuances in meaning, it obsures the underlying regularity. Clark & Schaefer describe this regularity in terms of pairs of presentations and acceptances, which are used to provide tree like structures for conversations. They note that the trees they propose 'are often revised on route' (Clark & Schaefer, 1989). However, no rules are specified for such revisions. Our conversational game on the other hand, also provides a model for the underlying patterns of conversation, but in a dynamic fashion. This system explicitly specifies how the context changes as the conversation proceeds.

Furthermore, Clark & Schaefer (1989) do not deal with the intricacies of the different sentence types and their update potentials. We provided an explicit model for that purpose. Finally, Clark & Schaefer's model is primarily directed at how partners negotiate mutual understanding of an utterance. In our dialectical system, we have abstracted over issues of interpretation. The focus is on the establishment of agreement/disagreement presupposing that understanding has already been achieved.

Dynamic Interpretation Theory

Bunt (1998) describes Dynamic Interpretation Theory (DIT), which has been develloped in a series of papers going back to Bunt (1989). In DIT, utterances other than DCU's are treated as context changes to the representations that the interlocutors have of each others propositional attitudes, such as their beliefs and desires. Bunt associates with an utterance its semantic content and its communicative function. The communicative function is computed on the basis of observable features of the communicative behaviour of the interlocutors. It defines a specific way of changing the context.

Bunt argues that the communicative function of an utterance is computed without access to contextual information other than the observable features of the communicative behaviour of the interlocutors. Here, we would like to point out that this might limit the applicability of DIT as opposed to the framework that is proposed in this chapter. Consider an utterance of a yes/no question with propositional content Φ. According to Bunt (1998), the context change associated which such a question is: *Speaker wants to know whether* Φ. Although this update seems appropriate for information dialogues[67], it does not apply to classroom situations. In such situations, we would prefer to say that the update effected by the question is that: *Speaker wants to know whether Hearer knows whether* Φ.

DIT seems to be tailored explicitly to information dialogues. By using a direct mapping from utterance features to the communicative function, there is no room for fundamentally different updates by utterances that share the same observable features (DIT does, however, allow for different inferences on the basis of the same update, because the context in which the inferences are drawn may be different).

Bunt (1998) points out that in natural communication there are social obligations (see also Allwood, 1994) which tell the interlocutors what to do and what to leave out. These obligations are based on general rules for the modes of conduct in a particular culture. For instance, these rules govern greetings. In particular, an initial greeting puts a what is known in DIT as a *reactive pressure* on the addressee to return the greeting. In this chapter, we described an underlying model for such reactive pressures. This model accounts for the patterns that are exhibited by greetings in terms of a rule which demands of interlocutors that they react to recently introduced commitments.

Non-incremental Updating and Subconversations

In Litman & Allen (1987), subconversations are modelled using a stack. A speaker always addresses the top item of the stack and sometimes items can be removed from the stack: i.e., when a question and its answer are together on the stack. The stack is a non-incremental device, since items are added and sometimes again *removed* from it. Items are on the stack as long as they have not yet been fully resolved in the conversation. Proposals in a similar vein have been made in, amongst others, Beun (1994a), who uses a goal list to which goals can be added and from which they can be removed again in the course of a conversation, Ginzburg (1995), who proposes a structure called QUD (Questions under Discussion), which can be updated and downdated with question, and Piwek (1995) and Kievit & Piwek (1995), who describe a stack structure for dealing with questions for clarification in the DENK dialogue system (Bunt et al., 1998).

In this chapter, we have demonstrated that an *incremental account* of subconversations is possible. Instead of using a stack, we used the public commitments-store Γ, together with an annotation for the time of introduction of the commitments. A certain proposition P was no longer an issue as soon as agreement or disagreement had been reached on Γ, i.e., $\Gamma \vdash C_A P$ and $\Gamma \vdash C_B P$ or $\Gamma \vdash C_A P$ and $\Gamma \vdash \neg C_B P$.

We think that the incremental account's main advantage is that it is more perspicuous. Stack operations become increasingly more complicated if one wants to account for the flexibility of actual conversations: sometimes people address issues that are not on top or the stack. Note that conversation (31) cannot be modelled in terms of a strict stack, since 1. which is below 3. on the stack is addressed at a point when 3. is still under discussion.

In Ginzburg (1995), the stack is for that purpose replaced with a partial order on the set of question under discussion. However, it still remains necessary to do the bookkeeping concerning which elements are added to and *removed from* this partial order. In our account, issues automatically fade out (due to the logic of Γ), when an agreement has been reached.

Finally, by representing information that is still under discussion on the public commitment-store, there are no technical impediments to drawing inferences that combine information which is still under discussion and information which is public. For instance, if only interlocutor *A* is committed to some proposition Φ, then we say that that proposition is under discussion. In terms of a stack-based account, we might say that the proposition is still on the stack. But now suppose that it is public information for *A* and *B* that $\Phi \rightarrow \Psi$. On our commitment-store we can now infer that *A* is committed to Ψ as well. In other words, Ψ is also under discussion. There is no way to model this by means of the stack. Where should we put Ψ on the stack?

6.6 Presuppositions in Conversation

A presupposition of an utterance limits the range of contexts in which the utterance can be felicitously uttered. For instance, 'The King of France is bald' makes only sense in a context in which it holds that there is a King of France. In chapter 3, we assumed that the context can be equated with what the interpreter of the utterance assumes to be the common ground of the interlocutors. On the basis of our analysis of declaratives, imperatives and interrogatives, we propose some refinements to this view.

In chapter 3, the notation Φ_π is used as an underspecified representation of the meaning of a declarative sentence S. Φ stands for the propositional content of S, and π for a presupposition which has not yet been resolved. For instance, 'The king of France is bald' is represented as: $bald \cdot X_{[X:entity, P:King\_of\_France \cdot X]}$. If the context contains an individual, say a, which satisfies the presupposition, i.e., it holds for a that $[a : entity, p : King\_of\_France \cdot a]$, then the presupposition can be resolved. This means that the presuppositional annotation is removed, yielding the proposition $bald \cdot a$. Finally, the context can be updated with this piece of new information (of course, provided that the interpreter accepts the information).

This account of presuppositions ties in nicely with the basic ideas underlying Pure Type Systems (PTS). In PTS, a type can only be used in a PTS context, if all its parts have already been introduced in that same context. Thus, $bald \cdot X$ cannot be added to the context, because X is not part of the context. The capital X is used to indicate that X has to be replaced by an expression from the context. The annotation ($[X : entity, P : King\_of\_France \cdot X]$) constrains the range of admissible replacements for X. In our example, a can function as a filler for X.

The account we have given does not take into account the specific update of the context that a declarative sentence gives rise to in a conversational game. According to the rules (15) and (20), the utterance by *A* of some sentence S with propositional content Φ gives rise an update of the public commitments Γ with $p : C_A\Phi$, that is, it becomes a public commitment that *A* is committed to Φ.

Thus, the context is not updated with Φ, but rather with $C_A\Phi$. In this case, the update is no longer conditional on whether the addressee accepts Φ. The embedding of Φ under C_A also affects the type-theoretical constraints of well formedness on Φ. Due to the embedding, these are no longer relative to Γ, but rather to the subordinate context of Γ which contains *A*'s commitments.

Any presuppositions of the utterance should be satisfied with respect to those commitments of *A* to which *A* is publicly committed. For our example this means that 'The King of France is bald' is predicted to make sense if the speaker of the utterance is publicly committed to there being a King of France. This is weaker than the usual constraint (as proposed in Stalnaker, 1974) which says that a presupposition should be satisfied by the common ground of the interlocutors.

There are many situations in which neither the speaker nor the addressee assume that the presuppositions are satisfied with respect to their common ground. During, for instance, an interrogation or examination the person that is interrogated or examinated may be left in the dark about whether the information he or she provides is accepted. Since what is said does not become common ground, any presupposition that draws on what has been said cannot be satisfied with respect to the common ground.

For imperatives different constraints on presupposition satisfaction hold, because their content is different from that of declaratives: the action that is to be performed is always under the scope of two commitment operators. The prediction is that a presupposition of an imperative must be satisfied under what the speaker is committed to that the addressee is committed to.

For instance, there are situations in which it is not unreasonable for *A* to issue

the following request to *B*: 'Show me the ghost which lives in the cupboard', even if *A* is committed to the proposition that there are no ghosts. A situation in which *A* might issue this request is one in which *A* believes that *B* thinks that there is a ghost in the cupboard. Alternatively, it would be unreasonable for *A* to tell *B* to show him the ghost that lives in the cupboard, if *A* believes that *B* believes that there are no ghosts.

These predictions concerning the behaviour of presuppositions follow directly from the content that we have assigned to imperatives. Similar predictions are made for what Searle (1969) calls the *prepatory conditions* of requests (such as, 'the speaker believes the hearer to be able to do the action'). In our model, such preconditions turn out to follow from the assumption that the update that is achieved with an imperative should yield a consistent output context (the consistency requirement goes back to Stalnaker, 1978).

If we have in our context that a certain person is committed to being unable to do some action, then we cannot add to that person's commitments the information that it will perform the action. Addition of that information to its commitments would lead to inconsistency; one cannot be committed to some course of actions which one considers to be impossible.

This treatment of prepatory conditions is possible due to our formalization of imperatives in terms of commitments. This formalization makes it possible to reason about the information conveyed with the imperative against the background of the other commitments of a dialogue partner. Thus, reasoning about the impact of conversational moves is nicely integrated with the general reasoning that an agent performs with the information he has about reality.

Searle's prepatory conditions can thus be modelled in our conversational game. There is, however, a small difference between Searle's interpretation of prepatory conditions and ours. For Searle, 'the speaker believes the hearer to be able to do the action' is a prepatory condition. Our alternative is that 'it is not the case that the speaker believes that the hearer believes that the hearer is unable to do the action'.

As in the case of ordinary presuppositions, we take into account what would be a reasonable move for the speaker towards the hearer. A difference between preconditions and presuppositions is that for a presupposition to be satisfied, positive evidence is required which satisfies the presupposition, whereas a precondition only requires the absence of the information that the precondition does not hold in the appropriate subordinate context. For instance, it is reasonable for a tourist to ask for directions, even if it is not the case that she believes that the addressee believes that he can provide an answer. Alternatively, it would be unreasonable for the tourist to perform the same request if she believes that the addressee believes that he cannot provide the answer.

Finally, let us consider the behaviour of presuppositions in questions:

(36) 1. A: John is unreasonable.
2. B: Why?

Here, *B* need not necessarily have accepted what *A* asserted after having posed the why-question: the whole point of *B*'s question may be to postpone a judgement and gather further evidence for assessing the information put forward by *A*. However, why-questions of the form 'Why P?'are standardly said to presuppose 'P'.

According to our account the presupposition needs to be satisfied with respect to what *B* thinks that *A* is committed to. In other words, *B* can ask *A* a question whose presuppositions *B* is not committed to. It is sufficient that *A* is committed to them in order to be able to answer the question. After all, the answer will normally be in the form of a declarative, and it and its presupposition pertains to *A*'s public commitments, not the ones of the questioner.

6.7 Conclusions

In this chapter, we provide a conversational game which covers some of the regularities which conversation and discourse analysts have found in conversations. The system incorporates update rules for declaratives, imperatives and interrogatives. It provides an explicit model of how dialogue partners negotiate their public commitments. It is demonstrated that the model has wide applicability, from telephone conversations to classroom situations.

A novel method for dealing with subconversations is introduced. The models from the literature for subconversations employ some sort of list, stack or partial order which keeps track of the location in the subdialogue (e.g., Litman & Allen, 1987 and more recently Beun, 1994a; Ginzburg, 1995 and Piwek, 1995[68]). Elements are added and subsequently removed from such a structure in the course of a subconversation. We provide a strictly incremental model which allows only for the addition of information. Such a model is more transparant than the traditional ones and allows for more flexible interactions between information that is introduced in a subconversation and other background information.

The conversational game that is introduced is shown to generate the naturally occurring patterns that have been found by discourse and conversation analysts.

Finally, we point out some differences between the satisfaction of presuppositions of declaratives on the one hand and that of interrogatives and imperatives on

the other hand. Furthermore, we noted that our presuppositions are weaker than those proposed by Stalnaker (1974) and the prepatory conditions of Searle (1969).

There is ample room for extensions to the conversational game that has been proposed. The issue of interpretation in conversation requires further examination. For instance, it would be interesting to find out how Clark's model of the negotiation of meaning in conversation (Clark, 1996) fits in with the conversational game that we proposed. Furthermore, our proposal relies on the representation of actions, events and times in the context Γ; we did, however, not provide the axioms for reasoning about such entities. We need to integrate our framework with an existing account or propose a new framework which is specifically tailored to the reasoning about time, actions and events of ordinary language users.

7 Conveyed Meaning

In the previous chapter, we dealt with the literal meaning of utterances. The literal meaning is a proposition with which the public commitments of the interlocutors have to be updated as a result of the utterance. It is based on the semantic content of the words that occur in the utterance and its sentence type. In particular, there is a direct mapping between the sentence type of an utterance and its type of literal meaning. We distinguished these different types of meaning on the basis of the sort of commitments that they introduce.

The reaction rules that we proposed in the previous chapter indicate the range of conversational moves that are available to an interlocutor given the public commitments of the interlocutors, and in particular the most recently introduced commitments. There are, however, examples of naturally occurring conversations which are beyond the reaction rules that we have proposed. Consider:

(1) A: Can you pass me the salt?
B: Here you are [does it].

The literal meaning of *A*'s utterance is that *A* asks *B* the question whether *B* can pass the salt. In terms of the conversational game that we introduced in the previous chapter, Γ —which contains the public commitments of the interlocutors— is updated with $C_A C_B will\_be\_answered(q)$ (where q stands for the semantic content of 'Can you pass me the salt'). In words, the speaker is committed to the hearer being committed to the question getting answered.

The problem that this example poses is that the literal meaning does not account for the occurrence of *A*'s utterance in this exchange. *B*'s reply is more appropriate after a request to pass the salt. This has led many researchers to the conclusion that the *conveyed meaning* of *A*'s utterance is the request 'Pass me the salt'.

In (1), one type of speech act (a question) is used to perform another type of speech act (a request). Generally speaking, the term *indirect speech act* is used if

the speech act that is associated with the literal meaning does not coincide with the type of speech act that is associated with the conveyed meaning. Indirect speech acts are a particular type of conveyed meaning.

In this chapter, we present an extension to the conversational game that was provided in chapter 6. This new system covers a subclass of what are know as conveyed meanings. This subclass consists of conveyed meanings that rely on *conventions* about the use of natural language expressions. By a convention we mean a rule that is are part of the common ground of a community. In particular, many indirect speech acts can modelled as being based on conventions. Informally, the conventions that we talk about are of the form 'Normally if somebody introduces the commitment Φ, she or he also means to introduce the commitment Ψ'.

In section 7.1, we first address the controversy which surrounds the notion of literal meaning. In section 7.2, we describe the data concerning conveyed meanings that we will addresss with our dialectical system. In section 7.3, we specify the dialectical system. In section 7.4, we test the system against the data. Section 7.5 contains comparisons with alternative approaches that have been advocated in the literature.

7.1 In Defense of Literal Meaning

In this chapter, the notion 'literal meaning' is used as a theoretical device for modelling certain patterns that show up in naturally occurring conversations. The adoption of this notion should be evaluated on the basis of the predictions that it allows us to make about naturally occurring conversations. In the sections that follow, these predictions are presented.

There is a practical motivation for using the notion of a 'literal meaning'. Most work in formal semantics (see Van Benthem & ter Meulen, 1997) presupposes the notion of literal meaning. The meanings that standard formal semantics theories assign to utterances do not cover conveyed meanings. This means that we can build upon the work that has been done in formal semantics. This work has yielded formal systems for associating literal meanings with utterances. In Kievit (forthcoming), a description of an algorithm for computing literal meanings that fits in very well with our proposal can be found. Kievit's algorithm was also develloped as part of the DENK project.

The distinction between conveyed and literal meaning is the backbone of Grice's theory of implicatures (Grice, 1975). For Grice, the literal meaning is *what has been said* and the conveyed meaning *what has been implicated*. Clark (1996:143) claims that Grice's distinction is build upon the following three assumptions:

(2) a. The literal meaning of an utterance is logically prior to its conveyed meaning.
b. There is a fundamental difference between the way literal and conveyed meanings are computed.
c. For every utterance type, the literal meaning is well defined.

Clark (1996:143–146) presents some common objections to these three assumptions. Let us try to find out whether these objections survive closer scrutiny. Clark uses one of Grice's own example (Grice, 1975) to formulate an alleged objection to (2.a). Consider:

(3) A: I am out of petrol.
B: There is a garage around the corner.

According to Grice, speakers are supposed to conform to what he calls the maxims of conversation. One of these maxims is *be relevant* (the maxim of relation). Grice observes that *B*'s utterance would be irrelevant if the garage *B* is talking about sells no petrol or is closed. Assuming that interlocutors are normally cooperative, *A* may therefore take *B* to implicate/convey that the garage *B* is talking about sells petrol and is open.

Clark points out that in british English 'garage' is ambiguous between *parking structure* and *service station*. That means that there are two potential literal meanings that can be associated with *B*'s utterance (the assumption is that a meaning cannot be ambiguous; this assumption is contestable, but let us assume that it is true for the sake of the argument). Clark's point is that which of the literal meanings is the actual literal meaning can only be determined after it has been worked out what *B* was implicating. According to Clark, the implicature is that 'B's remark was relevant to A's being out of petrol' (Clark, 1996:144).

Firstly, let us emphasize that this is *not* the implicature that Grice assigns to *B's* utterance, but rather an instantiation of the maxim *be relevant* (on the basis of *A*'s utterance). According to Grice, *the garage B is talking about sells petrol and it is open* are two of the implicatures that are generated. Let us see whether the objection also hold for these implicatures. Do we need the implicature that the garage sells petrol in order to arrive at the conclusion that it is a service station and if so, does this validate the conclusion that the conveyed meaning is logically prior to the literal meaning?

First, the disambiguation of *the garage* need not be based on some sort of implicature. It could simply be the case that the mention earlier on of 'petrol' activates the concept *service station*. This in turn might cause the addressee to link 'garage' with the concept *service station* instead of *parking structure*. Thus the disambiguation does not require the computation of an implicature.

Secondly, even if the disambiguation cannot be accomplished in the aforementioned way, that does not mean that we need an implicature to arrive at the disambiguation. Rather, it will be the maxim of relation itself which enforces the disambiguation. Whereas one reading, which assigns *parking structure* to 'garage', is not relevant, the other reading, which assigns *service station* to 'garage',is relevant (in the context of *A*'s utterance), because service stations do normally sell petrol.

Thus, we should distinguish the generation of an implicature from the use of a maxim to select a particular literal meaning. In the latter case, it is inappropriate to say that the literal meaning follows from some implicature.

The second assumption says that there are fundamental differences between the computation of conveyed and literal meaning, we agree with Clark that this assumption cannot be maintained. We already pointed out that the maxims can play a role in the determination of literal meaning as well as the conveyed meaning.

Finally, the third assumption says that the literal meaning should be well defined for every utterance type. Clark's counterexamples to this assumption are utterances such as 'Two pints of Guinness', 'hello', 'well', 'ah', and gestures. From the fact that there is no proper paraphrase for the literal meanings that are associated with such utterances, Clark infers that such a literal meaning does not exist. From our point of view, this argument does not touch the heart of the matter. There might very well be commitments associated with an utterance of 'hello' (as pointed out in the previous chapter), for which the only word in our vocabulary is 'hello'. In other words, the fact that there is no full sentential paraphrase of the literal meaning of an utterance, does not mean that such a literal meaning does not exist.

7.2 Some Observations

Conveyed meanings are examined in this section by looking at the follow-ups that they normally give rise to. Furthermore, the contexts in which conveyed meanings can occur are examined.

Reactions In this section, we mainly focus on conveyed meanings that are invoked through the use of a modal (such as, 'can', 'may', 'should', 'will', etc.). In our examples, we use 'can' as a representative for the whole class.

(4) a. A: Can you pass me the salt?

b. B: Yes, (I can)
B: No, (I can't)
B: Yes, (here you are) [does it]
B: here you are [does it]
B: [does it]
B: No, I won't.
B: *Yes, I won't
B: Yes, but I won't

These examples illustrate that reactions to literal meaning, conveyed meaning and both are possible. Interestingly, the combination 'Yes, I won't' sounds odd, whereas 'Yes, but I won't' is ok. Now, 'but' is typically used to indicate contrast with what one expected. The answer 'yes' appears to invoke an expectation towards complying with the implicit request. In other words, the reaction to the conveyed meaning depends upon the reaction to the literal meaning. Literal and conveyed meaning are not simply two separate independent speech acts. Note that the answer to the conveyed meaning might also consist solely of the requested action.

Offers

(5) a. A: Who is going to do the dishes today?

b. B: I can do it.
B: John can do it.

c. A: Can I help you?

Not only questions can give rise to indirect interpretations. Declaratives can also be used indirectly. For instance, B can propose to do the dishes by saying 'I can do it'. The examples in (4) and (5) suggest that there might be a general principle governing the conveyed meanings of utterances in general that contain a modal, such as in'Can you/I α, 'I/You/... can do α'.

Conditionals

(6) a. A: If you see John, you can tell him that he is fired.
B: Ok.

b. A: Can you tell John that he is fired, if you see him?
B: Ok.

c. A: I can help you, if you keep it a secret.
B: Thanks

The phrase containing a modal can occur in a conditional. Also, such a configuration gives rise to a conveyed meaning. For instance, in (6.a), B commits herself to telling John that he is fired, if she sees him. Accounts which attempt to establish a direct relation between, for instance, a question whether the addressee can do something and the request to do that action, do not cover such examples. A special rule would be required to relate conditional question to conditional requests.

7.3 The Conversational Game

A conversational game consists of a conversational store and a set of conversational rules. In this section we extend the system that was proposed in chapter 6. The extension will be a proper extension: we add additional stores and rules, leaving the previously introduced rules and store intact.

The conversational store

In chapter 6, the conversational store was defined as consisting of a commitment-store and an annotation. The annotation contained information pertaining to the time of introduction of the commitments on the commitment-store and the source of the commitments (observation or communication). Now, we propose to add a third component: the (public) conveyed commitments-store (Δ). It contains rules relating newly introduced commitments to commitments that a cooperative agent will take on by convention. Where do the rules on Δ come from? These rules can be seen as hypotheses that conversational partners have devised to bridge the gap between the literal content of an utterance and its possible follow-ups. This relation may also be rationally motivated, as we shall see in section 7.5.

Δ is formalized as a type-theoretical context, and has the same axioms as Γ for the logic of the commitment-operators C_A and C_B. It is a *global* context (cf. Bunt 1998), i.e., it does not change as a result of a conversation.

Given some explicitly introduced commitment, Δ indicates what other commitments follow from it on the basis of conventions of use for the former commitment. For instance, if some commitment β has just been introduced by participant A, then β is not only added to Γ, but it is also checked what the effect would be of adding β to Δ.

(7) (CONVEYED COMMITMENT)
γ is a conveyed commitment with respect to a newly introduced commitment β on Γ if $\exists b$ such that:

1. $\Delta, a : \beta \vdash b : \gamma$, and
2. a is a subproof of b.

The first condition says that the conveyed commitment should follow from Δ extended with the newly introduced commitment. The second condition makes sure that only expected commitments that depend on the newly introduced commitment are taken into account.

So, what rules does Δ contain? Here we discuss one rule which will be shown to cover most of the examples from the previous section:

(8) $r : [\alpha : action, x : person, p : can(do \cdot x \cdot \alpha)] \Rightarrow (do \cdot x \cdot \alpha)$

In words, if some agent x can do some action α, then the agent will do that action. Now consider a situation where an agent x says 'I can help you', i.e., $a : can(do \cdot x \cdot \alpha)$. In that case, the conveyed commitment is that 'the speaker will help the addressee'. The proof-object is $r \cdot \alpha \cdot x \cdot a$. Note that the proof for the newly introduced commitment (a) is part of the proof for the commitment that the speaker will help the addressee.

The conversational rules

We have described how conveyed commitments are induced. Now, we have to say something about how they influence the behaviour of the conversational partners. For that purpose we propose the following new update rule:

(9) CONVEYED COMMITMENTS UPDATE RULE If a new commitment β is introduced onto Γ, then also add those conveyed commitments associated with β (on the basis of Δ) to Γ which do not render Γ inconsistent.

The conveyed commitment can thus introduce an additional issue on which agreement has to be reached. Let us examine what predictions this approach yields with respect to the prototypical example of an indirect speech act:

(10) A: Can you pass me the salt?
B: Yes. [does it]

First, it should be noted that we do not assign any additional meaning to *A*'s utterance: it counts simply as a question. Only *B*'s answer carries a conveyed meaning. If *B* answers *A*'s question positively (that is with 'Yes', which can be paraphrased as 'I can pass you the salt'), then *B* introduces the following commitment onto Γ: C_B (B can pass the salt). The rule in (8) gives us the following conveyed commitment: C_B (*B* will pass the salt). Thus, a positive answer automatically burdens *B*

with a commitment to passing the salt. That is, unless Γ is rendered inconsistent by adding this commitment. In the following exchange the update of Γ with the conveyed commitment is blocked:

(11) A: Can you pass me the salt?
B: Yes, but I won't.

Γ is always first updated with the explicitly introduced commitments. In this case, the commitments that *B can pass the salt* and that *B will not pass the salt*. Only after that an attempt is made to add the conveyed committed that *B will pass the salt* (on the basis of rule (8) and the newly introduced commitment that *B can pass the salt*). In this case, the conveyed commitment can not be added after the explicitly introduced commitments have been added, since that would lead to an inconsistent Γ.

7.4 Evaluation

In this section, we explain how our proposal accounts for the other examples from section 7.2. We first consider the possible reactions to the question'Can you pass me the salt?'.

(12) B: Yes, (I can)
B: No, (I can't)

B might choose to react strictly to the literal content. In case, of a 'Yes' answer this, however, seems to be rather uncooperative. Except, of course, when Γ blocked addition of the conveyed commitment:

(13) A: I am not going to show you where the treasure is hidden.
B: You can't, because you don't know where it is.
A: I can.
B: No, You can't.
A: Yes, I can.

Note that a reaction to the conveyed commitment subsumes an answer to the literal content:

(14) A: Can you pass me the salt?
B: [does it].

In this case, *B*, by passing the salt, also implicitly answers the question whether he can pass the salt. And thus the question of *A* is answered.

Offers are amenable to a similar account:

(15) 1. A: Who is going to do the dishes today?
2. B: I can do it.
3. A: Ok.

In 2., *B* invokes the conveyed commitment that *B* will do the dishes. *B* becomes committed to doing the dishes. In 3., *A* says also to be committed to *B* doing the dishes. Thus a public commitment (amongst *A* and *B*) is obtained that *B* will do the dishes.

(16) 1. A: Can I offer you something to drink?
2. B: Yes, a beer please.
3. A: Sorry, we ran out of beer.

In 2., *B* is committed to *A* offering him a beer. In 3., *A* denies being committed to offering a beer implicitly by stating that there is no more beer available. Because *A* is an expert with respect to what he offers, *B* has to take over this commitment.

Let us finally examine the effect of modals in conditionals, such as:

(17) A: If you see John, you can tell him that he is fired.
B: Ok.

In this case, *B* accepts the entire conditional that *A* introduced. Now, if *B* ends up in a situation where he becomes committed to seeing John, then in virtue of the rule in (8), *B* becomes committed to telling John that he is fired. This case is, however, deviant from all the other ones that we discussed, because the commitment is private, i.e., the conveyed commitment does not become part of Γ. After all, *B* does not have to be there when *A* sees John. *B* should nevertheless feel committed, because if *A* later on asks him whether he saw John, and he then is truthful and says 'yes', then it does become a public commitment that *B* told John that he is fired.

7.5 Comparisons

In this section, we compare our approach to conveyed meanings with a number of proposals from the literature.

Idiom theories

According to idiom theories of indirect speech acts, 'Can you VP?', 'Would you VP?', and so on, are simply lexical alternatives for 'I request you to VP'. Levinson (1983) points out that the idea that 'Can you pass me the salt?' is ambiguous between its literal and its indirect reading is not in accord with the fact that an addressee of this utterance can react to both the literal and the indirect meaning (e.g., 'Yes, of course. Here you are'). If an utterance is really ambiguous between two readings, one cannot react to both readings at once, unless one wants to make a pun. Furthermore, idiom theory presents us with a new problem, namely that of specifying a pragmatic theory which explains how an addressee comes to select one reading as the primary one in the current context.

Inference theories

The most influential inference theory of indirect speech acts was proposed in Searle (1975). Searle starts from the idea that 'In cases where these sentences [such as 'Can you VP?'] are uttered as requests, they still have their literal meaning and are uttered with and as having that literal meaning' (Searle, 1975:70).

Searle notes that in case of an indirect speech act, the addressee has to somehow 'see' that the utterance is used to convey more than strictly its literal meaning. Searle provides no systematic account of how this is to be done. He acknowledges that sometimes it can be inferred from the fact that the literal meaning on its own is defective in context. For instance, if someone asks 'Can you pass me the salt?' at a dinner table, then this utterance is defective as a question, because in dinner table situations we normally do not have a theoretical interest in someone's salt passing abilities.

Following Grice (1975) we might say that as a question the utterance violates the maxim *be relevant*. However, in case somebody asks 'Can you recommend me a good movie?', the questioner is definitely interested in whether the other person can do so. To conclude, Searle refrains from seriously addressing the question of how an interpreter actually chooses for a particular interpretation.

Searle's analysis of indirect speech act interpretation consists of two parts. First the addressee has to somehow find out that the literal meaning is in some way irrelevant given the context. Second, starting from there, a conveyed meaning has to be inferred. Searle proposes that Speech Act Theory provides the means to relate the literal meaning systematically to an indirect reading.

The idea is that, for instance, in case of 'Can you open the door?' the literal meaning coincides with questioning a prepatory condition of the request expressed by 'Open the door'. Searle concedes that the inference chain between literal meaning and indirect meaning is not something that an interpreter normally produces step by step when interpreting ‘Can you pass me the salt?’.

Searle’s theory provides a rational reconstruction of indirect speech act interpretation. It does not model the underlying mechanisms involved in actual interpretation. Our model deals with to the problem of actual processing; it does not provide a rational justification of the conclusions that hearers draw. It does, however, address the issue of how to determine whether an utterance does or does not have a conveyed meaning: certain literal meanings are by default associated with certain additional commitments (e.g., a commitment to being able to do something will via the conversational rules in Δ lead to a commitment to actually to it). However, in certain contexts these defaults are cancelled. Thus, instead of explaining why the meaning of an utterance sometimes supersedes the literal meaning, we explain why the utterance meaning sometimes does not supersede the literal meaning. In this respect, our proposal is more constructive than that of Searle.

The use of default rules to model indirect speech acts has also been advocated in Perrault (1990) and Beun (1994b). The application of default rules there is, however, different for the one proposed in this paper. Perrault and Beun use default rules to reason *about* the behaviour of dialogue agents from a third person perspective. In this paper, default rules are put forward to model part of the internal processing states of a dialogue agent.

We wish to stress that Searle’s approach to indirect speech acts, which provides a justification for the relation between literal and indirect meaning, and our proposal which indicates how an interpreter arrives at an indirect interpretation are complementary. For instance, the rules of thumb that we suggest might be sufficient to arrive at the conveyed meaning, more creative uses of language will, however, require genuine reasoning about what the other person intends to convey.

The same criticism regarding the application of relevance applies to the theory that Gordon & Lakoff (1975) put forward. Their work is, however, in spirit more akin to that of ours. They use so-called conversational postulates to relate the literal to the indirect meaning of an utterance. For instance, there is a postulate which states that *If a asks b ‘can you VP’ and a does not intend to convey the question can you VP and b assumes this, then a has requested b to VP*. Again we think there is a problem concerning the application of such rules. It is not clear in which situations the antecedent of the rule satisfied. Furthermore, as we already pointed out, these rules do not apply to conveyed meaning that are triggered by embedded modals.

7.6 Conclusions

In this chapter, we have dealt with conveyed meanings as being associated to literal meanings through what one may call conventional rules of thumb relating certain commitments to other commitments. We do not wish to deny that more unfamiliar indirect speech acts require more flexible ways of arriving at an indirect meaning (see, e.g., Power, 1979).

We critized the existing inference approaches for being founded on an unclear notion of relevance. This notion of relevance is employed to determine whether there is more to an utterance than its literal meaning. We proposed an alternative strategy, which say that the rules of thumb for deriving conveyed meaning should be applied unless, they give rise to an inconsistent public commitment-store.

Finally, we showed that on the basis of one rule for the modal ‘can’ we could explain a whole variety of data, including offers, and the occurrence of the modal in conditionals.

Summary and Conclusions

The study of conversation is notoriously difficult, because naturally occurring conversations take place against the rich background of virtually every aspect of human existence. A theory of conversations will therefore inevitably have its shortcomings. For instance, in this book the focus is entirely on *information exchange* in conversations. No attention is paid to the atmosphere in which a conversation is conducted (e.g., hostile or friendly), ethical considerations (honesty, truthfulness), etc.

There is still an abundant background that needs to be taken into account, even if we narrow down our attention to information exchange in conversations. Utterances depend on the context for their interpretation and also change the context. In this respect, conversations are very similar to common board games such as chess. Utterances bear a likeness to the moves in such a game; a move in chess changes the context (i.e., the distribution of the chess pieces on the board) and is at the same time dependent on the context for its interpretation. A move of a particular piece from, say, square A1 to A3, will in some contexts be interpreted as beating another piece, in other contexts as checkmate, etc.

We have exploited the aforementioned resemblance by modelling conversation as a conversational game. In order to specify a conversational game, we needed to say what its contexts, i.e., conversational states, are and what the rules are that govern the interpretation of moves and the update of the conversational states.

We assume that an important principle governing conversational games is the quest for a consistent conversational state. This hypothesis legitimizes the use of a formal system of logic to model conversational states. Consistency is one of the basic notions of logic. The particular formal system that we chose to employ is Pure Type Systems (PTS).

PTS was chosen for several reasons. Most important are the following three. Firstly, it can be seen as a higher-order generalization of Discourse Representation Theory (DRT). DRT has proven to be very succesful for modelling anaphora. Anaphora play a key role in information exchange by means of natural language.

Secondly, a PTS allows a formalization of conversational states that can be processed by a computer. We already pointed out that a computationally feasible theory allows for enhanced experimental testing of the theory. Thirdly, in PTS proofs for propositions are explicitly represented. These proofs can employed for consistency maintenance of contexts. In particular, they can be used to locate the information that gave rise to an inconsistency.

PTS is introduced in part I. We exploit the similarities between DRT and PTS to explain the basic notions of PTS. Subsequently, we extend PTS with a framework for reasoning about normal objects. In particular, the extension allows for derivation of a conclusion about an object on the basis of the assumption that the object is a normal object of its kind. We demonstrate that the extension covers several forms of default reasoning. The underlying motivation for our attention to this subject is the fact that in daily life jumping to conclusions on the basis of the assumption that everything is normal is the rule rather than the exception.

In part II, the formal tools that have been introduced in part I are applied to three different areas in the study of conversation: presupposition, answerhood and accent. We demonstrate that these apparently different phenomena can be modelled along similar lines. The notion of an informational gap plays a key role.

The chapter on presuppositions provides a deductive framework for modelling the influence of world knowledge on presuppositions. We address the projection of presuppositions in conditionals and disjunctions, and supply an account of the so-called bridging examples. We report on a small observational study which supports our hypothesis that the quest for consistency might sometimes provide a good explanation for phenomena in the realm of presupposition resolution that have been linked to such intractable notions as ‘relevance’.

Our account of answerhood provides a proof-theoretic characterization of a variety of answers (indirect answers, negative answers, preventive answers, etc.). We show that our approach brings together the theories that start from the idea that answerhood should be explicated in terms of the possibility to *unify* a question and its answer and those theories that deal with the *dynamic* and *contextual side* of answerhood.

In the chapter on accents, we provide an account of accents which covers both contrastive accent (e.g., ‘The children were taken to the circus. The smáll children enjoyed it’ implicates that *it is not the case that the ‘non-small’ children enjoyed it*) and newness accent.

In part III, we examine longer stretches of conversation. The aim is to explain the patterns that such stretches exhibit in terms of an underlying model of changes to the conversational state. We propose some simple rules for updating the conversational state in the course of a conversation. We show that our system can be used to model a range of conversational structures that have been reported by conversation and discourse analyst. In particular, our account provides an incremental account of subdialogues, as opposed to the mainly non-incremental accounts from the literature and deals with the satisfaction of presuppositions in conversations.

Finally, the problem of conveyed meanings is addressed. The conveyed meaning of an utterance is the information that is communicated by means of the utterance without being literally said. We defend the distinction between literal and conveyed meaning and account for the relation between conveyed meaning, in particular the conveyed meaning which is associated with so-called indirect speech acts, and literal meaning in terms of a system of defeasible rules of thumb. We show that a simple system of such rules can account for a wide range of conveyed meanings.

In short, in this dissertation a number of problems concerning the meaning and use of utterances in conversations are addressed in detail. We show that the proposals that we put forward improve on the current state of the art in the literature. At the same time, we have tried to reveal to some extent the unity which underlies the different topics that are addressed.

Summary in Dutch

‘Wat is een conversatie?’, dat is de vraag die in dit proefschrift centraal staat. Het antwoord dat we formuleren gaat uit van de eenvoudige gedachte dat het voeren van een conversatie gelijkenis vertoont met het spelen van een spel. Een conversationeel spel kan worden gekarakteriseerd in termen van de toestanden van het spel en de dynamiek van deze toestanden. De bijdrage van dit proefschrift bestaat uit een nadere specificatie van de notie van toestand en toestandsverandering in conversaties. Het proefschrift valt uiteen in drie delen.

In deel I (Logic) worden de formele methoden beschreven die we gebruiken voor de modellering van toestanden en toestandsveranderingen in conversaties. Met name de (Constructieve) Typen Theorie wordt hierbij gebruikt. We beschrijven dit formalisme, dat zijn nut al heeft bewezen bij het formaliseren van wiskundig redeneren, en geven aan hoe het kan worden gebruikt bij de modellering van alledaags redeneren. Redeneren speelt een belangrijke rol bij het modelleren van conversaties: conversatiedeelnemers leggen door middel van redereneerstappen relaties tussen een uiting, de daaraan voorafgaande uitingen en achtergrondkennis.

In deel II (Information) bespreken we wat de mechanismen zijn die informatieuitwisseling in een conversatie op gang brengen. We gaan hierbij uit van het idee dat zogenaamde ‘informationele gaten’ (in de informatietoestanden van de conversatiedeelnemers) een cruciale rol spelen bij het verloop van een conversatie. We modelleren de notie van een ‘informationeel gat’ met behulp van de Typen Theorie. We tonen de verklarende kracht van deze benadering aan door drie belangrijke fenomenen uit de natuurlijke taal semantiek en pragmatiek te verantwoorden: presupposities, de vraag-antwoord relatie en zinsaccentuering.

In deel III (Conversation) werken we uit hoe ons model van toestandsverandering in conversaties een functionele verklaring geeft voor de door empirisch onderzoek aan het licht gebrachte structurele eigenschappen van conversaties. We laten zien dat het toestandsbegrip bovendien helpt bij het overbruggen van de vaak voorkomende kloof tussen de functie en de inhoud van een uiting. Illustratief voor deze kloof is de uiting ‘Kun je me even helpen?’. Terwijl deze uiting

is geformuleerd als een vraag wordt zij gebruikt om een verzoek te doen.

Kortom, in dit proefschrift worden een aantal problemen aangaande de betekenis en het gebruik van uitingen in conversaties (in het bijzonder presupposities, de vraag-antwoord relatie, zinsaccentuering, de relatie tussen conversationele structuur en contextverandering, en indirecte taalhandelingen) in detail behandeld. We laten zien dat de voorgestelde oplossingen een stap voorwaarts zijn ten opzichte van de in de literatuur bekende oplossingen. Tegelijkertijd is getracht een algemeen model voor conversaties te scheppen waarbinnen de resultaten van de afzonderlijke onderzoekingen een plaats hebben.

Notes

1. We infer from *I have control over opening the door* and *it is not the case that I have control over opening the door* and *I believe that I will open the door*, that *it is not the case that I believe that I will open the door*.
2. In fact, the utterance meaning is ambiguous between this reading, which involves denial of control, and a reading which involves denial of belief. Since the latter reading is anomalous, i.e., the utterance meaning is inconsistent, the hearer will opt for the first reading. This choice is based on the assumption that speakers strive for a consistent conversational state.
3. DENK is a Dutch abbreviation for *Dialogue Handling and Knowledge Transfer*.
4. Grice (1975) himself points out that this maxim seems to be in a league of its own: 'Indeed, it might be felt that the importance of at least the first maxim of Quality is such that it should not be included in a scheme of the kind we are constructing; other maxims come into operation only on the assumption that this maxim of Quality is satisfied.' (Grice, 1975:46)
5. HPSG stands for Head-Driven Phrase Structure Grammar. See Pollard & Sag (1994).
6. For function objects, the object stands for a regularity. For instance, a function from persons to their fathers, represents the regularity that every persons has a father.
7. Note that we do not exclude information which is subjective according to the agent's subjective point of view. For instance, an agent may have information concerning his own feelings, which he considers to be particular to himself and therefore not part of an external reality that is accessible to other agents. It would, however, be impossible to communicate such information.
8. Consider the set of all possible strings consisting of four letters. Clearly, in everday conversation four letter words will have a higher probability than four letter non-words. The formula for calculating the amount of information of a message says that the amount of information conveyed by a non-word is higher than that conveyed by a word (the lower p_N, the higher $log_2 \frac{1}{p_N}$ is). Here, information theory predicts that a meaningless message conveys more information than a meaningful message.
9. The construction rules that are provided in Kamp & Reyle (1993) are not compositional: the interpretation of a sentence is not built up from the interpretations of its syntactical parts. See, however, for instance Muskens (1996) for a compositional formulation of the construction rules.
10. This DRS is presented in the usual 'pictorial' fashion. Elsewhere in this book we also use a linear notation which we trust to be self-explanatory. E.g., in this linear notation the current DRS looks as follows:$[x, y \mid John(x), vehicle(y), drive(x, y)]$.
11. In Krahmer (1998), Van der Sandt's theory is combined with a version of DRT with a partial interpretation. In this way, DRSs which contain unresolved presuppositions can also be interpreted.
12. Classical Predicate Logic, which is known to be undecidable, can be embedded into PTS (the Curry-Howard-De Bruijn isomorphism).
13. See, for instance, Pelletier and Asher (1997) and Thomason (1997) for an overview of nonmonotonic logics. These articles focus in particular on applications of nonmonotonic logics in linguistics

and formal semantics.

14. We speak of the most basic form because the antecedent of the scheme we propose contains only one normality assumption. In practice there may be more such assumptions, especially when quanfication over situations is taken into account. For instance, *turtles lay eggs* does not mean that turtles which are normal with respect to laying eggs, lay eggs all of the time. They do it only in situations which are normal with respect to laying eggs.
15. Frege's argument has not remained undisputed. In fact, Bertrand Russell put forward a theory of definite descriptions which treats the presuppositions of an assertion as an integral part of the propositional content of that assertion (Russell, 1905).
16. The only situations in which it will remain necessary to tinker with the structure of an utterance involve the examples that have been advanced in favour of a Russellian account of presupposition (e.g., 'The King of France is not bald, since there is no King of France').
17. In Krahmer (1995), Van der Sandt's theory is combined with a version of DRT with a partial interpretation. In this way, DRS's which contain unresolved presuppositions can also be interpreted, and it is shown that this has several advantages.
18. Recall that this abbreviates:

$$\Pi x : entity.(\Pi y : chihuahua \cdot x.(\Pi z : enters \cdot x.(snarl \cdot Y_{[Y:entity, P:dog \cdot Y]}))).$$

To be complete, let us give the *syntactic* definition of proto types. For that we need the definition of a proper type, which goes as follows:

$$T :== V \mid type \mid prop \mid \Box \mid (\Pi V : T.T) \mid (\lambda V : T.T) \mid (T \cdot T).$$

A proto type T' can be obtained by substituting gaps (G) for one or more of the types which constitute some proper type T. The result is a Type with Gaps (TG). Furthermore, an annotation has to be attached to T (with gaps) for specifying the types of the gaps. A TG with one or more annotations (A) is a Proto Type (PT).

$$\begin{array}{lll} TG & :== & G \mid V \mid type \mid prop \mid \Box \mid (\Pi V : TG.TG) \mid (\lambda V : TG.TG) \mid \\ & & (TG \cdot TG) \\ A & :== & TG : TG \mid A \otimes A \\ PT & :== & TG \mid PT_A \mid (\Pi V : PT.PT) \mid (\lambda V : PT.PT) \mid (PT \cdot PT) \end{array}$$

The symbol $\otimes$ is used for the concatenation of sequences. Notice that the definition permits annotation of expressions which are already annotated. This is required for representing embedded presuppositions. Consider, for instance, *The man's cat purrs*. This sentence contains the presuppositions 'there is a man' and 'there is a cat which is owned by him'. Notice that the second presupposition depends on the first presupposition: the description of the second presupposition contains the presupposition trigger 'the man'. This means that the second presupposition can only be resolved after the first presupposition has been resolved. This is guaranteed by the way the algorithm processes the following representation of the sentence:

$$((purr \cdot X)_{[X:entity, P:cat \cdot X, Q:own Y \cdot X]})_{[Y:entity, R:man Y]}$$

The structure of this proto expression is $(\Phi_{\pi_2})_{\pi_1}$. Since the algorithm scans for structures of the form (Φ_π) it will first resolve π_1, yielding some substitution S and then proceed with $(\Phi_{\pi_2})[S]$. The substitution S assigns an appropriate man from the context to the gap Y in π_2.

19. In general: $\Gamma \vdash_\Delta C_1, \ldots, C_n$ abbreviates $\Gamma \vdash C_1, \ldots, \Gamma \vdash C_n$.
20. Interestingly, Zeevat (1992) compares the Van der Sandtian resolution of a presupposition with answering a 'query' in PROLOG, requiring the instantiation of a variable.
21. The $\cdot$ (representing function application) is left-associative, thus $f \cdot x \cdot y$ should be read as $(f \cdot x) \cdot y$.
22. This proto type contains some simplifications: the meaning of some parts of the sentence has not been analysed to the fullest detail: we stipulate that *"Spiff's weight is higher than it would be on*

earth" corresponds to $weight\_higher{\cdot}sp$. Additionally, some presuppositions are already resolved: *"Spiff"* to the variable sp and *"planet X"* to plx.

23. In fact, this requires us to add add to Γ the appropriate axioms ensuring that these plural individuals respect the proper relations between parts and wholes. See, for instance, Link (1983) for such an axiomatic system, which has been used within the framework of DRT by Kamp & Reyle (1993). By the way, this use of plural individuals in DRT is sketched in chapter 5.
24. For practical purposes it might be more convenient to use Σ-types from the very beginning. However, for expository reasons, we have refrained from using Σ-types. In particular, they obscure the parallels between PTS and DRT.
25. Assume that $u \to \bot$.
    From $u \to \bot$ and (i) it follows by contraposition and MP that $p \to \bot$.
    From (iii) and $p \to \bot$ it follows by MP that q
    From $u \to \bot$ and (ii) if follows by contraposition and MP that $q \to \bot$
    From $q \to \bot$ and q it follows by MP that $\bot$
    Withdrawal of the assumption gives us: $(u \to \bot) \to \bot$
    Using double negation we conclude from $(u \to \bot) \to \bot$ that u. (qed)
26. Quotes are taken from the reprint in Clark (1977).
27. Where does bridging fit in with Van der Sandt's preference hierarchy? We suggest the following preferences: *1.a* Binding to a non-inferred antecedent is preferred to accommodation, and *1.b* Binding to a non-inferred antecedent is preferred to binding to an inferred antecedent. Whether binding to an implied antecedent is preferred over accommodation or vice versa cannot be stated in a general way: this again depends on the 'plausibility'.
28. It has been observed that binding a pronominal anaphor to an implied antecedent is generally impossible. This follows from our present approach: the descriptive content of a pronoun is *so* small, that there will in general be many inferred objects meeting what little descriptive content there is, thus resulting in an 'unresolvable ambiguity'. Notice that this approach does not preclude that sometimes a pronoun *can* refer back to a inferred antecedent, as in 'Oh, I was on a bus and he didn't stop at the right stop' (Brown & Yule (1983)) and 'Did you hear that John finally is going to get married? She must be very rich'. In these cases, one implied antecedent seems to be more prominent than all others.
29. Notice that it can happen that both the effort and the plausibility conditions put together fail in selecting one most preferred proof- object. In that case an unresolvable ambiguity results; no determinate bridge can be constructed. The following provides an illustration of this: ?? *If John buys a car and a motorbike, he'll check the engine first*. There are two potential antecedents for the presupposition triggered by the engine which are indistinguishable under both the effort and the plausibility condition. As a result, the sentence is odd (marked by the double question mark).
30. A somewhat comparable approach is advocated in Poesio (1994). Poesio shows how shifts in the focus of attention influence the interpretation of definite descriptions.
31. $\Gamma - C$ gives those introductions which are present in Γ but not in C, i.e., have been added to the global context Γ since the beginning of resolution.
32. $V : \Phi'$ is temporarily added ('assumed') to the context in order to resolve any presuppositions in Ψ.
33. We have decided to code the preferences (binding over accommodation, etc.) into the algorithm itself. This choice is not forced upon us, it is just more efficient than calculating all possible resolutions, and order them afterwards. The move does, however, mean that we have to allow for backtracking.
34. Since χ may consist of a number of introductions $a_1 : b_1, \ldots, a_n : b_n$ we use an abbreviation here. For instance: $g : ([x : entity, p : car \cdot x] \Rightarrow [a_1 : entity, a_2 : engine \cdot a1])$ is an abbreviation of $g_1 : ([x : entity, p : car{\cdot}x] \Rightarrow entity)$ and $g_2 : ([x : entity, p : car{\cdot}x] \Rightarrow (engine{\cdot}g_1{\cdot}x{\cdot}p))$. In general: if $\Delta = [c_1 : d_1, \ldots, c_n : d_n]$, then $f : \Delta \Rightarrow [a_1 : b_1, \ldots, a_n : b_n]$ is an abbreviation for $f_1 : \Delta \Rightarrow (b_1)$,

$f_2 : \Delta \Rightarrow (b_2[a_1 := \Delta' f_1]), \ldots$, and $f_n : \Delta \Rightarrow (b_n[a_1 := \Delta' f_1, \ldots, a_{n-1} := \Delta' f_{n-1}])$, where $\Delta' = \lambda x(x \cdot c_1 \cdot \ldots \cdot c_n)$.

35. In section 4.3, a description of G&S's approach is given.
36. *How* and *why*-questions do not occur on this list, although they do belong to the class of wh-questions. *How* and *why*-questions are not dealt with, because they bring with them a host of problems which are beyond the scope of this chapter. For instance, *How*-questions require reasoning about actions, i.e., changes in the world itself, whereas *Why*-questions require an understanding of how reasoning about causation works (see, e.g., Bromberger, 1992).
37. Our work is related to that of Ahn (1994). He sketches the use of gaps to represent wh-questions in PTS. His work is different from ours in that he does not give a (formal) definition of the various notions of answerhood that are discussed in this chapter.
38. *Weak exhaustivity* is obtained by omitting condition (2).
39. Tijn Borghuis pointed out to me that in the early seventies N.G. De Bruijn proposed a distinction between proofs which is based on the same idea, namely that the identity of some proofs matters whereas that of other does not, and called it *proof irrelevance*; see De Bruijn (1980).
40. We assume that equal means β-equality. If two terms are β-equal, then they reduce to the same normal form.
41. In detail, we have a context $\Gamma = \ldots, j : person, p : walk \cdot j$ which is extended with $q : quickly \cdot walk \cdot j$. We assume 'quickly' is a function from propositions to propositions ($quickly : prop \to prop$) and that the introduction $f : [x : person, r : quickly \cdot walk \cdot x] \Rightarrow walk \cdot x$ (if somebody walks quickly, then he walks) is part of the context. In the extended context, we can obtain the substitution $[X := j, P := f \cdot j \cdot q]$ of (2). This substitution differs, however, not from $[X := j, P := p]$ (the substitution which we could obtain without extending the context with the information from the new assertion) with respect to the assignment to the marked gap X.
42. The substitution in question is $[F := \lambda x : prop.x, Q := f \cdot p, G := r]$, where r is a proof of the fact that $\lambda x : prop.x$ is equal to $\lambda x : prop.x$.
43. Note that our informal exposition of conditional answers correctly predicts that also *if ϕ then ψ* counts as a conditional answer to *whether ϕ*: addition of the antecedent of the conditional (i.e., ϕ) to Γ yields an answer to *whether ϕ*. Furthermore, it is easy to see that disjunctions such as *ϕ or ψ* count as conditional answers, provided that such a disjunction translates into *if not ϕ then ψ* or *if not ψ then ϕ*. Tautological answers such as *if ϕ then ϕ* are, correctly, ruled out by the informativity condition on assertions.
44. In the definition below, $\otimes$ is defined as follows to prevent the construction of illegal contexts: $\Gamma \otimes (A_1 : B_1, A_2 : B_2, \ldots, A_n : B_n) :=$ (i) $\Gamma, A_1 : B_1 \otimes (A_2 : B_2, \ldots, A_n : B_n)$ if atomic(A_1) & $\neg(\Gamma \vdash A_1 : B_1)$ (ii) $\Gamma \otimes (A_2 : B_2, \ldots, A_n : B_n)$ if $\Gamma \vdash A_1 : B_1$ (iii) $(\Gamma, A_1 : B_1 \otimes (A_2 : B_2, \ldots, A_n : B_n))[A_1 := x]$ (where x is a fresh variable with respect to Γ) else. In words: only add new information to the context, and if the new information is $A : B$ where A is not atomic, then replace A with a fresh variable. Remember that the context may only contain introductions of variables, not of composite objects.
45. Compare it with the following equivalence for propositional logic: $\Gamma, p \vdash q \Leftrightarrow \Gamma \vdash p \to q$.
46. We use $\Sigma(A_1 : B_1, \ldots, A_n : B_n)$ as an abbreviation for $\langle A_1, \langle \ldots \langle A_{n-1}, A_n \rangle \ldots \rangle : (\Sigma x_1 : B_1 . \ldots (\Sigma x_{n-1} : B_{n-1} . B_n) \ldots)$. This is necessary because $([X] \Rightarrow Q[S])$ is not a well-formed PTS expression. So, let us fully write out $p : ([X] \Rightarrow \Sigma(Q[S]))$, assuming that $Q[S] = (A_1 : B_1, \ldots, A_n : B_n)$ and $X = (C_1 : D_1, \ldots, C_n : D_n)$. The result is: $\lambda(C_1 : D_1.(\ldots \lambda C_n : D_n.\langle A_1, \langle \ldots \langle A_{n-1}, A_n \rangle \ldots \rangle) \ldots) : ([C_1 : D_1, \ldots, C_n : D_n] \Rightarrow (\Sigma x_1 : B_1 . \ldots (\Sigma x_{n-1} : B_{n-1} . B_n) \ldots))$.
47. We have $p : \phi \vdash (\lambda q : \phi \to \psi . q \cdot p) : (\phi \to \psi) \to \psi$. This follows (using PTS's abstraction rule, which is closely related to arrow introduction in propositional logic) from $p : \phi, q : \phi \to \psi \vdash q \cdot p : \psi$.

48. Note that G&S's notion of indirect answers does not cover preventive answers: the latter do *not* induce a new question.
49. Note that this definition actually subsumes negative answerhood, and can therefore be seen as a generalization of it.
50. To examine these issues in more detail, it seems interesting to look at questions within the more wider context of dialogues, and particularly their role in sub-dialogues. See, for instance, Beun (1994) for a framework in which such research could be carried out. Another interesting perspective is the one offered in Ginzburg (1995). Ginzburg proposes a notion of answerhood which is relativized with respect to the goals of the questioner. Thus an answer should not only resolve the question semantically, but also help the questioner achieve his or her goals.
51. At the Munich Workshop on the 'Formal Semantics and Pragmatics of Dialogue' (March 10-12, 1997) Jeroen Groenendijk presented recent work on 'Questions in Dynamic Semantics' which aims at 'remodelling the 'static' partition view of questions in update semantics'.
52. We take (pitch) accent (also referred to as *intonational focus*) to be the highlighting of an expression by prosodic means. See also section 5.2.
53. Van Deemter's approach employs standard DRT. In this respect, it differs from, for instance, Vallduví (1992). Vallduví uses Heim's (1982) file cards instead of Kamp's DRSs to account for the meaning of accent. The former contains more structure. Hendriks & Dekker (1995) show that such additional structure is superfluous.
54. In Kamp & Reyle (1993), the model theory for the DRSs that contain such new types of referents is based on the models which Link (1983) provides for count nouns. The idea is that the denotation of an NP which contains a count noun can be uniquely subdivided into atomic parts (as opposed to the denotata of mass nouns). Formally, the domain for NPs is structured by a part-whole relation which satisfies the axioms of upper semilattices (Kamp & Reyle, 1993:398–406).
55. Intuitively, in case of unit accentuation on 'The mayor of Óxford', the individual denoted by this noun phrase is contrasted with all contextually salient individuals that do not fit the description of the noun phrase. These 'alternative individuals' are picked up by what we call the alternative presupposition (see the next section). This alternative presupposition is formalized in the framework of DRT. It is computed on the basis of the actual presupposition. For instance, in this case the actual presupposition is $\delta[x \mid mayor\_of(x,y), \delta[y \mid oxford(y)]]$ and the alternative presupposition is $\delta[x \mid \neg[y \mid mayor\_of(x,y), oxford(y)]]$.
56. By 'unresolved', we mean that the anaphoric references that occur in the alternative assertion have not yet been bound to their antecedents.
57. There is a difficulty in determining exactly what the preceding discourse is. For our purpose, we define it as the preceding sentence. It is, however, conceivable that it covers more than the preceding sentence. This issue should be resolved on the basis of empirical data.
58. We assume that the concept that is the reference of 'They' is *plural and very salient*. The alternative concept is *not plural or not very salient*.
59. Levelt's claim that it is the rightmost non-anaphoric word of the rightmost constituent in the phrase that receives more stress than the other words in the sentence is probably not entirely accurate. In particular, the claim that it is the rightmost word may have to be modified, because the syntactic structure of a sentence seems to influence the position of the nuclear stress. See, e.g., Baart (1987) and Dirksen (1992). For the purpose of this chapter, we neglect more complicated formulations of the definition of nuclear stress, since they do not affect the proposal that we put forward for accent interpretation.
60. A further interesting fact that we will not delve into is the fact that 'a wóman' (39) can be constructed as coreferential with the priest that is introduced in A's actual assertion: A and B might understand each other as talking about the same person that John saw, despite their disagreement about its gender. See Dekker (1997), for an account along Gricean lines. In connection with this, note that

the following example can be interpreted in two different ways:

A: Someone likes Mary.
B: No, someone likes *Sue*.

If the indefinite employed by B is intended to be about the same individual as the indefinite employed by A, then the alternative assertion is: *It is not the case that the person A is talking about likes Mary*. If the indefinite of B is *not* linked to the person introduced by A, then the alternative assertion comes out as: *Nobody likes Mary*.

61. Kees van Deemter (personal communication) put forward example (49) as a counterexample to the approach to accenting proposed in Piwek (1997). In Piwek (1997), the inducement of alternative presuppositions by accents was taken as basic in combination with a constraint that said that the referents of the alternative and actual presupposition should not overlap. Clearly this was too strong.
62. See chapter 4 of this book for an explanation of the relation between questions and open sentences.
63. Grice's proposal seems to also provide a useful starting point for building practical systems for the generation of accent. For instance, in Theune (1997) a proposal concerning the generation of accents is set forward which we think to be akin to the Grice's proposal: '(...) two sentences which express the same type of data structure (and therefore express similar information) should be regarded as contrastive. Contrastive accent should be assigned to those parts of the second sentence that express values which differ from those in the data structure expressed by the first sentence' (Theune, 1997:185). The approach advocated by Theune (1997) has been successfully implemented in a data-to-speech generation system (see Klabbers, 1997).
64. Van Deemter and Hendriks (personal communication) tend towards this solution.
65. Consider, for example: 'Who knows an ánswer?'. Also here we would expect an 'alternative assertion' to be conveyed. This alternative assertion might be that *the speaker is not asking the addressee (or, e.g., not interested in) who knows something else than an answer*
66. This last condition is violated if P contains expression that have been introduced X's subordinate context, but not in Y's.
67. Bunt (1989) defines information dialogues as 'dialogues with the sole purpose of transferring (obtaining, providing) certain factual information'.
68. The stack-based proposal that was proposed in Piwek (1995) has been implemented in the DENK prototype (see Bunt et al., 1998).

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Curriculum Vitae

Paul Piwek was born on the 25th of june 1971 in Venlo. From 1983 until 1989, he attended the 'Blariacum College' in Venlo (VWO A and B). Subsequently, he studied Computational Linguistics and Philosophy at Tilburg University. He graduated (cum laude) in Computational Linguistics in August 1993. His master's thesis is titled 'a partial Discourse Representation Theory for neutral perception reports'. It was supervised by dr. R. Muskens. During his third year in Tilburg he was an assistant at the Computational Linguistics group of prof.dr. H. Bunt. In the fourth year, he did a traineeship at the University of Stuttgart in the group of prof.dr. H. Kamp. The daily supervision of the traineeship was by dr. T. Zimmermann. From August 1993 until August 1994, he studied Philosophy of Language and Cognitive Sciences at the University of Amsterdam. He received a postgraduate degree (cum laude) in August 1994. The thesis for this degree was on 'Events in a compositional Discourse Representation Theory'. The thesis was supervised by prof.dr. R. Bartsch. In april 1994, he joined the IPO (Center for Research on User-System Interaction) in Eindhoven, where he carried out a PhD. project which led up to this book. Since may 1 1998, Paul Piwek is working as a Research Fellow at the Information Technology Research Institute in Brighton.

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