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PLANS IN THE COMMON GROUND:
TOWARD A GENERATIVE ACCOUNT OF CONVERSATIONAL IMPLICATURE

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

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* * * * *

The Ohio State University
1994

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To
Alice L. Welker
and
Kathryn L. Welker

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INTRODUCTION

0.0. Introduction

The focus of this dissertion is the development of a general framework which can serve as the basis for a formal pragmatic (as opposed to computational or processing) theory of one variety of pragmatic data: conversational implicature. From a larger perspective, this framework may also be seen as contributing toward a theory of conversational competence: a theory of the rules and mechanisms necessary to model what people know that allows them to use language in conversation. A fully developed theory of conversational competence will account for a variety of pragmatic data, such as conversational implicature, indirect speech acts, accommodation of linguistic presuppositions, and processing/ disambiguation. In this dissertation, I will primarily be concerned with its capacity to account for conversational implicature only, and will not attempt to show how the framework can be used to account for other kinds of data as well.

0.1. Conversational Implicature

Conversational implicature is one of a number of linguistic phenomena initially discussed and categorized by Grice (1975), in order to delineate what kind of data must be accounted for in a semantic theory and what kind could be addressed as a part of pragmatics. Conversational implicatures are aspects of meaning that are communicated by an utterance in a conversational context, although they are not part of the literal meaning of the utterance. Two examples of conversational implicature that are commonly cited in the literature are the following (Grice 1975):

(1) A is standing by an obviously immobilized car and is approached by B; the following exchange takes place:
A: I am out of petrol.
B: There is a garage round the corner.
Implicature: B thinks, or thinks it possible, that the garage is open, and has petrol to sell. (p. 32)

(2) A is planning with B an itinerary for a holiday in France. Both know that A wants to see his friend C, if to do so would not involve too great a prolongation of his journey:
A: Where does C live?
B: Somewhere in the South of France.
(Gloss: There is no reason to suppose that B is opting out; his answer is, as he well knows, less informative than is required to meet A's needs. This infringement of the first maxim of Quantity can be explained only by the supposition that B is aware that to be more informative would be to say something that infringed the second maxim of Quality. "Don't say what you lack adequate evidence for," so B implicates that he does not know in which town C lives.) (pp. 32–33)

Clearly, the implicatures that Grice notes in these examples are not part of the literal meaning or entailed by the utterances in question; one can imagine alternative contexts in which these implicatures do not arise. In the first example, imagine a guest saying to his host, "I need to get my car fixed tomorrow." In such a case, the conversational implicatures would be that the garage is likely to be open tomorrow—and that it does repair work. In the second example, a response "In the South of France" would not carry the identified implicature in a context in which the specific location was not important—such as at a faculty meeting, where one person casually asks where a missing colleague is.

Grice's work was of tremendous importance in restricting the data that needed to be accounted for in semantics, thus supporting the development of formal semantic theories. Grice proposed a Cooperative Principle with associated Maxims of Conversation which he used to explain how implicatures arise during conversation, as illustrated in the examples above (Grice 1975). In Grice's approach, implicatures were seen as arising in three different ways: when a speaker obeyed a maxim, violated one maxim in order to obey another, or deliberately "flouted" a maxim. Grice's approach was highly informal, but his maxims may be taken as providing a loose taxonomy of various kinds of implicature.

Formal accounts of conversational implicature have been developed, most notably Horn (1972), Gazdar (1979), Atlas and Levinson (1981), Horn (1985), Hirschberg (1985), Levinson (1987), McCafferty (1987), and Ginzburg (1990). However, each of these accounts addresses only a portion of the full range of data that falls into this category. The most promising formal accounts fall into a category that McCafferty (1987) has called "the plan-based approach to natural language understanding." These accounts, inspired by a programmatic account in Thomason (1990), include a representation of the plans of

interlocutors, and link these plans to specific utterances in specific contexts. In particular, Thomason (1990) proposed bringing together representations of plans and a representation of the conversational record, which contains the information that interlocutors take to be "public" or shared by all of them. Plan- and goal-based approaches have been explored for implicatures that arise via Grice's maxim of Relevance in McCafferty (1987) and for implicatures that arise via Grice's maxims of Quantity/Quality in Ginzburg (1990). Plan-based approaches are in keeping with Grice's original account, which included the following Cooperative Principle (Grice 1975, p. 26):

(3) *The Cooperative Principle:*
Make your contribution such as is required, at the stage at which it occurs, by the accepted purpose or direction of the talk exchange in which you are engaged.

The framework developed in this dissertation is also a plan-based approach. In it, I provide a more explicit version of Grice's cooperative principle, which includes a formalized "purpose of the exchange" in terms of the plans and goals of interlocutors. I begin with the hypothesis that conversational implicatures are identified within a conversational context in which the plans of the speaker are recognized by all interlocutors. In this account, the actual generation of a conversational implicature will take place on the assumption that when a speaker contributes to a conversation, he or she is obeying a requirement that the contribution furthers the conversational goals as well as or better than any other contribution she could have supplied. At this point, I am using the term *conversational goals* loosely, to denote propositions in the common ground (the common ground being a set of propositions that are taken for granted by all conversational participants) which correspond to the goals or plans of one or more of the interlocutors, which each conversational contribution must further. If necessary, in order to make a speaker's contribution satisfy the requirement, the hearer will add propositions to the common ground that combine with what was actually said to further the conversational goals in question. The propositions added may be conversational implicatures, accommodated information that satisfies presuppositions, or propositions identifying the (indirect) speech act being performed. Here, I will be concerned only with the propositions that represent conversational implicatures associated with the utterance.

For this account to work and be explicit, it must include a representation of utterance context that includes representations of the mutually recognized plans of interlocutors (that is, plans that are believed by all interlocutors to be mutually recognized). In constructing these representations, I have drawn on recent work in Discourse Representation Theory/File Change Semantics, which provides a formal representation of utterance context, and recent work in planning theory, which provides a formal account of plans and their role in communication.

In the approach I am taking, implicatures arise in the following way: in order to satisfy a Revised Cooperative Principle, which requires that a speaker's contribution is *maximally goal/plan furthering*, the hearer will infer additional propositions of two types: 1) propositions that make the utterance goal/plan furthering ("base" implicatures) and 2) propositions concerning the "maximality" of the contribution, which are based on the assumption that it was not possible for the speaker to have contributed any other utterance that would be *more* goal/plan furthering (I am calling these "comparative" implicatures, because they generally involve comparing what was said with what might have been said). The kind of implicatures that will arise in this second category will include propositions concerning the speaker's willingness and ability (as well as other constraints on possibility) to have said something else that would have furthered the conversational goals more. Two principles will be involved in this process: a Revised Cooperative Principle, and a Principle of Cooperative Inferencing.

A range of disparate examples fall into the category of conversational implicature. The account developed in this dissertation will deal with the kinds of examples that have been addressed by previous accounts, as well as new examples. The examples mentioned previously suggest the range of data I will be concerned with. Each includes implicatures in both categories (base and comparative). I will briefly sketch how these two examples would be accounted for in the framework I am proposing. Although these examples have been discussed in the past, only some of the implicatures I will describe have been discussed in conjunction with them. I believe there are two reasons that only a subset of the implicatures associated with these examples has been recognized in the past: first, the context of utterance considered in evaluating implicatures has been minimized as much as possible in previous discussions of many of these examples (and implicatures are highly dependent on the context of utterance), and second, some of the implicatures are more

obvious or striking than others. In the following discussion, I will describe the context of utterance, and will informally suggest the conversational goals that lead to the generation of implicatures.

(1) A is standing by an obviously immobilized car and is approached by B; the following exchange takes place:
A: I am out of petrol.
B: There is a garage round the corner.
Implicature: B thinks, or thinks it possible, that the garage is open, and has petrol to sell.

This example was given by Grice to show how an implicature could arise via the assumption that an interlocutor is obeying the Maxim of Relevance. Under the approach taken here, the conversational goals after A's utterance include furthering a plan for A to get gas immediately. The implicature noted by Grice is a base implicature, necessary simply for B's utterance to further A's plan of getting gas. The conversational goals in this example focus on the development of a real-world (or "domain") plan. It is important to note that B's contribution serves to suggest a plan for A to get gas at the gas station B has mentioned.

A comparative implicature for this example—one that is based on the assumption that B has provided the most plan-furthering response possible—would be the following: "The gas station B has suggested is the closest station at which A could get gas." Since the conversational plan is to develop the best possible plan for A to get gas, if there is a closer gas station, then (ceteris paribus) B's contribution should suggest a plan to get gas at the closer station. If A assumes that it would be possible for B to mention such a station if it did exist (e.g., that B would be willing and able to mention it)—and in this situation there is no reason not to assume this)—A can assume that the station B did mention is the closest. (Note: What constitutes the "best plan" is actually quite complex, and these examples are somewhat simplified for brevity and clarity.)

(2) A is planning with B an itinerary for a holiday in France. Both know that A wants to see his friend C, if to do so would not involve too great a prolongation of his journey:
A: Where does C live?
B: Somewhere in the South of France.
[*Implicature:*]...B implicates that he does not know in which town C lives.

In this example, the conversational goals include A's goal of visiting C. This goal would involve a plan to go to where C lives. For A to develop and execute such a plan, A must know where to go. Any information about C's whereabouts will be of interest to A, but the more detailed the information, the better it will further A's conversational goals. The base implicature that B believes that C is in the South of France is thus due to the fact that the information that B is providing would not be helpful if it is not true. The implicature noted by Grice—that B does not know in which town C lives—arises by comparing what B did say to alternative utterances that both interlocutors are aware that B might have said. In this case, such an alternative utterance would be one providing the name of a town. Because this utterance would have furthered the conversational goals better than the one provided, and because B did not provide this utterance, A can assume that there was some reason that B did not provide this utterance. In this situation, the most likely reason for not providing the more detailed information was that B did not know it.

0.2. Approach

The account developed in this dissertation will include (and integrate) at least the following elements: 1) a representation of utterance context, which includes a representation of the "contextualized" literal meaning of utterances, and 2) a way of identifying and representing the "public" (i.e., mutually known or recognized) plans of interlocutors.

Each of these elements is independently motivated, in that it has been used to explain other kinds of linguistic phenomena.

0.2.1. A Representation of Context

A representation of the common ground for an utterance was first discussed by Stalnaker (1978):

> Roughly speaking, the presuppositions of a speaker are the propositions whose truth he takes for granted as part of the background of the conversation. A proposition is presupposed if the speaker is disposed to act as if he assumes or believes that the proposition is true, and as if he assumes or believes that his audience assumes or believes that it is true as well. Presuppositions are what is taken by the speaker to be the COMMON GROUND of the participants in the conversation, what is treated as their COMMON KNOWLEDGE or MUTUAL KNOWLEDGE. The propositions presupposed in the intended sense need not really be common or mutual knowledge; the speaker need not even believe them.

> He may presuppose any proposition that he finds it convenient to assume for the purpose of the conversation, provided he is prepared to assume that his audience will assume it along with him. (p. 321)

The notion of mutual knowledge—despite problems with formally defining it—is an important part of conversational communication. Thomason (1990) describes what takes place in conversation as the participants "working together to build a shared data structure ... working on a common project that is in plain view" (p. 339). This shared data structure is the evolving common ground of the conversation. The difficulty is that the common ground is not in plain view, and interlocutors may make assumptions about it that turn out to be wrong (leading to what Stalnaker calls a "defective context"). Despite its problems, the notion of an idealized common ground will be an important basis for this account. The representation of the common ground will contain information taken to be mutually believed, including the mutually recognized plans of interlocutors and a record of the conversation (what has been said, by whom, etc.). The steps by which a conversational context is "worked on" or developed by interlocutors will be explicitly characterized, as part of a plan which connects each utterance to the larger conversational plan.

Utterance context has been used in accounting for a variety of problems in semantic analysis. As Kamp (1981) and Heim (1982) have shown, utterance context plays a significant role in accounting for anaphora involving unbound pronouns. Utterance context has also been used in accounts of phenomena such as verb tense (Partee 1984), presupposition projection (Heim 1981, 1991), and modal subordination (Roberts 1989). Context of utterance is clearly important for the generation of conversational implicatures; all accounts of such implicatures refer (at least minimally) to the conversational context.

For the purposes of this account, I will use discourse representation theory (DRT) as the basis for developing a representation of both the conversational context.

0.2.2. Plans and their Role in Communication

Work in artificial intelligence has led to study and formalization of the role of plans in cooperative communication (Allen and Perrault 1981, Litman and Allen 1990, Pollack 1986). Particular emphasis has been given to the role of plans in cooperative question answering. At least two types of plans seem to be important for communication: speaker plans (plans that connect an utterance with a goal; e.g., a plan to communicate a need for

gas, so as to find out where a gas station is located, so as to execute a domain plan to get gas) and domain plans (real-world plans that an interlocutor is attempting to further through the conversation: e.g., going to the gas station so as to get gas). (In fact, a speaker plan is also a domain plan, but it is a special type of domain plan which includes an utterance action.) As mentioned previously, plans have also been used in accounts of indirect speech acts, and Ginzburg (1989) uses a formal representation of goals in his situation semantics-based account of informativeness. Thomason (1990) suggests that the principle "Adjust the conversational record to eliminate obstacles to the detected plans of your interlocutor" could be called the cooperative principle (p. 344).

In fact, indirect references to plans can be found in many accounts of implicature. Informally, we may think of a plan as consisting of a series of acts that, if accomplished, together result in the attainment of a goal. Having a plan may be thought of as being in a certain (mental) relation to such a series of acts. This relation has been described as including at least having the intention to do the acts in the plan, believing that the acts can be executed, and believing that if they are executed the goal of the plan will be attained. Notions related to plans that have been referred to in the literature on conversational implicature include intention and purpose. *Purpose* is defined in Webster's Ninth Collegiate Dictionary as "something set up as an object or end to be attained: INTENTION." I will take it as referring to the *goal* of an interlocutor. Grice's cooperative principle refers to purpose: "Make your conversational contribution such as is required, at the stage at which it occurs, by the accepted purpose or direction of the talk exchange in which you are engaged." In addition, his maxims of Quantity refer to informativeness specifically as it relates to "the current purposes of the exchange." (In fact, the second Maxim of Quantity, "Do not make your contribution more informative than is required," seems to exist only to block implicatures that do not concern the plan of the conversation.) The notion of speaker's intention is also an important part of Grice's account of conversational implicature, since it is the hearer's belief that the speaker intended to communicate the implicature via the maxims that allows the implicature to arise. Plans and plan inferencing rules make it possible to formalize what Grice referred to as "the purpose of the exchange," as well as speaker intentions.

A variety of formal systems for representing plans have been developed (e.g., Fikes and Nilsson 1971, Sacerdoti 1977, Pollack 1986, Litman and Allen 1990); the system I will use will be primarily based on Pollack (1986), and will be adapted to the DRT framework.

In addition to representations of the common ground of a conversation and the public plans it includes, this account will include two principles that together generate conversational implicature. These principles are a Revised Cooperative Principle and a Principle of Cooperative Inferencing.

The Revised Cooperative Principle I will propose may be informally described as follows:

(4) *The Revised Cooperative Principle (informal definition)*
Provide an utterance that:
(a) brings the common ground closer to the conversational goals
(b) is better than any other utterance you could have provided in terms of making the conversational goals in true in the common ground

The first clause of the Revised Cooperative Principle constrains the speaker's plan that may be inferred based on the utterance, in that this goal of this plan must be to address the conversational goals (the conversational goals being a set of propositions that characterize the current goal of one or both of the interlocutors). Once this plan has been inferred and added to the common ground, "base implicatures"—propositions related to the plan that has been added—have been generated.

The second clause of the cooperative principle leads to what I call "comparative implicatures"—implicatures that arise by comparing the utterance that was provided with other utterances that could have been provided. In characterizing the conversational goals that may lead to or block implicatures, I identify and discuss three types of goal sets. In developing a formal definition of the cooperative principle, I build on work by Kratzer (1981) and Heim (1992).

The Principle of Cooperative Inferencing, which works together with the Revised Cooperative Principle, is as follows:

(5) *Principle of Cooperative Inferencing*
Given an update of the common ground combined with mutually recognized inferencing rules and background knowledge, assume that all inferences that it is mutually recognized can be drawn are part of the speaker's intended meaning.

This principle will provide a basis for determining specifically what implicatures will arise, based on what is taken to be mutually recognizable.

0.2.3. Goals and Unique Features of this Approach

Pragmatics is concerned with the kind of meaning that is dependent on context, and with how language is used in context. Work that has a bearing on these issues is currently being done in a variety of fields, each of which has a different ultimate aim and a different set of beginning assumptions. For example, much work is currently being done in the field of computer science to better understand and computationally model natural language communication. In addition, work in psychology (and psycholinguistics) is being done to understand and model how language is psychologically processed—and in using language people make assessments about what it is appropriate to assume other people may be able to achieve in processing, and these assessments play a role in the way they use language and in the kinds of pragmatic meaning that both interlocutors take to be associated with what has been said.

As mentioned previously, the framework developed in this dissertation is intended to contribute to a theory of conversational competence, which will include conversational implicature along with other kinds of pragmatic data such as indirect speech acts and accommodation of linguistic presupposition. Conversational competence is slightly outside of the focus of traditional linguistics, which is generally concerned with developing theories of linguistic competence—modeling what people must know[1] in order to produce and understand language in isolation from a context. In working toward the development of a formal theory of conversational competence, I have borrowed from related work in

[1] Although a competence theory of any kind attempts to model what people know in order to achieve a particular result, the way this knowledge is modeled does not necessarily involve representations corresponding to actual cognition or conceptual representations. The goal is to come up with a set of rules or mechanisms that lead to the same result as the mental processes that people really engage in. Whether the set of rules or mechanisms relates in any way to the actual mental processes is not necessarily important.

computer science and psycholinguistics. However, the assumptions and aims that drive my work are different from those of computer science or psychology. I have attempted to remain within the linguistic tradition in this account, rather than adopting the goals of the related fields from which I have borrowed. I have also attempted to develop a framework which is consistent with other work currently being undertaken in the area of formal pragmatics and context-change semantics.

Traditionally, accounts of pragmatic data have been informal in nature. However, as linguistic phenomena in which semantics and pragmatics are closely intertwined are increasingly being studied, and as the interaction between semantics and pragmatics is therefore being more carefully considered, the emphasis has shifted to formal accounts of both semantic and pragmatic data. A new focus on context and on meaning as the "context change potential" of a linguistic unit—the total change that it can make in the linguistic context to which it is added—makes the integration of pragmatics and semantics even more important. Formal accounts of some kinds of pragmatic data have been pursued, both in linguistics (Geis (to appear) on speech acts, Heim (1991) on presupposition) and in related fields such as computer science (Perrault and Allen (1980) on speech acts). Formal accounts of some kinds of conversational implicature have also been developed. However, there is not yet a single formal account providing general principles or mechanisms that address the full range of conversational implicature.

The account I am developing draws from work on the formal representation of utterance context and plans. A significant difference of this approach from previous ones is that it brings these representations of utterance context and plans together in a single framework. This is appropriate, considering that in all of the linguistic areas I have described, it is only the mutually recognized or "public" plans of interlocutors that are important—the plans that each interlocutor recognizes, believes the other interlocutors to recognize, and believes the other interlocutors to recognize that he and they all recognize. This quality of public plans will be addressed by locating them within the common ground.

I see the most significant feature of the framework I will develop as being the explicit way in which the relatively small number of formally defined mechanisms within it work together to make predictions that are borne out by linguistic data. The explicitness of the approach is especially significant in the treatment of conversational implicature, an area in which linguists have been looking for a more explanatory account for some time.

0.3. Overview of the Dissertation

In Chapter I, I review many of the leading accounts of implicature that have been proposed. I use Grice's Maxims of Conversation as an underlying structure for this section, since many of the accounts that have been proposed have focused on implicatures that arise from one or another of the different maxims. In this chapter, I will show that while each of these accounts has contributed to our understanding of implicature, none of them alone is entirely adequate. The section will conclude with an overview of accounts that fall into a category that McCafferty (1987) has called "the plan-based approach to natural language understanding."

In Chapter II, I describe and develop the technical preliminaries on which the account I will propose will be built. In order to capture the fact that implicatures arise based on information that is "mutually recognized" (that is, taken by each interlocutor to be recognized by all interlocutors), I follow Stalnaker (1979), Heim (1982), Thomason (1990) and others in assuming that throughout a conversation, interlocutors are contributing to a common ground that they take to be shared. I will use Discourse Representation Theory (DRT)—a dynamic (context-change) semantic theory that has already been used as a level of representation that includes both semantic and pragmatic information (Kadmon 1990, Roberts 1989)—to represent the common ground.

Like other plan-based approaches, a central idea behind the account I develop is that interlocutors' goals and plans play a crucial role in how conversational implicatures arise. Recent work in artificial intelligence and planning theory has led to computational accounts of plans and how plans are inferred; I borrow from these accounts to develop a formalism for plans and formal plan inferencing rules that operate within the discourse representation structures (DRSes) which are used to represent linguistic contexts in DRT. In keeping with the fact that conversational implicatures arise based on information that interlocutors take to be mutually recognized, I will assume that the information used to infer plans, the plan inferencing rules themselves, and the plans that are inferred are all located in the common ground. All of this is a part of a larger process in which conversational implicatures are "generated" through the cooperative addition of plans to the common ground.

In Chapter III, I describe a general framework that leads to the generation of conversational implicature. Grice's cooperative principle and maxims of conversation were intended to characterize rational, cooperative behavior in such a way that non-literal, non-conventional meanings associated with an utterance in a conversational context could be explained. In this chapter, I provide a new version of the cooperative principle (the Revised Cooperative Principle) which more explicitly characterizes what it means to be cooperative in a conversation. The Revised Cooperative Principle generates two kinds of implicatures: base implicatures and comparative implicatures. It is part of a larger process of interpreting the total meaning of an utterance, which includes "decoding" the utterance to determine its literal meaning, checking to be sure any presuppositions associated with the utterance are satisfied, accommodating or querying any unsatisfied presuppositions, identifying base implicatures associated with the utterance, and finally identifying comparative implicatures. The Revised Cooperative Principle, a Principle of Cooperative Inferencing (which works with the Revised Cooperative Principle to support more specific inferences) and the overall process through which implicatures arise are described in this chapter.

In Chapter IV, I discuss a single example in detail, and then provide less formal discussions of a collection of other examples to illustrate how the system developed here predicts the different implicatures that will be generated in different contexts. In addition, I compare this framework to previous accounts of each type of implicature.

CHAPTER I
CONVERSATIONAL IMPLICATURE: LITERATURE REVIEW

1.0. Introduction

According to Gazdar (1979), "An implicature is a proposition that is implied by the utterance of a sentence in a context even though that proposition is not a part of nor an entailment of what was actually said" (p. 38). The kinds of implicatures that may occur are extremely varied, both in terms of how they seem to arise and in terms of the kind of information they contribute to the context of utterance.

The accounts of conversational implicature described in this section begin with an overview of Grice's ground-breaking, informal account of the Cooperative Principle and Maxims of Conversation. Next, each of Grice's Maxims of Conversation (with associated implicatures) is discussed in detail, with Grice's own discussion first and subsequent accounts described afterward. Finally, frameworks that offer alternatives to Grice's overall approach are discussed.

Through the discussion of different kinds of implicature and the various accounts of implicature that have been proposed, several themes will emerge. One of these concerns a distinction between two distinct types of implicature, which I will term *base implicatures* and *comparative implicatures*. Base implicatures arise solely on the assumption that the speaker is providing a helpful or "plan-furthering" response. Comparative implicatures arise by comparing what the speaker said to alternatives which would be more "plan-furthering," and drawing inferences as to why the speaker did not provide one of these alternatives.

Another pair of themes is implicit in the discussion in the previous paragraph. Conversational implicatures are closely connected to what Grice called "the purpose of the exchange," which involves the plans and goals of interlocutors. In addition, implicatures often involve an inferencing process that applies to information that is taken to be recognized by all of the interlocutors in the conversation (and taken by each of them to be recognized by each of them). Both the purpose of the exchange and the information used for inferencing are part of the conversational context within which conversational

implicatures arise; this context thus plays a crucial role in determining what implicatures will arise.

1.1. Grice's Cooperative Principle and Maxims of Conversation

Conversational implicature was first discussed by Grice (1975, 1978),[1] who was concerned with using pragmatic principles to explain phenomena that linguists had believed needed to be treated semantically. Using a theory of conversational implicature to "factor out" part of the conveyed meaning of utterances reduced the burden on semantics, as well as making a principled distinction between two kinds of meaning. For example, philosophers had discussed the difference between the meaning of logical connectives (e.g., $\wedge$ and $\vee$) and their natural language counterparts; for example, *and* often (but not always) has an additional "temporal" quality (as seen in *John pulled off his pants and jumped into bed*), while sentences containing *or* often seem to entail that the speaker does not know which of the two conjuncts is true (e.g., in most contexts, it would be odd for someone to say *John is in the kitchen or the bathroom* when he knows that John is in the kitchen). By showing that these additional meanings can be accounted for using basic principles of conversation, rather than having to be treated as part of the conventional meaning of the connectives, Grice made it possible to develop a simplified semantic account of the natural language words.

1.1.1. Grice's General Approach

Grice saw conversational implicature as part of a theory of rational, cooperative behavior of which language use is only a part. In Grice (1975) he states, "... one of my avowed aims is to see talking as a special case of purposive, indeed rational, behavior..." (p. 28). In considering how rationality and cooperativity might play a role in our use of language in conversation, Grice states:

> Our talk exchanges do not normally consist of a succession of disconnected remarks, and would not be rational if they did. They are characteristically, to some degree at least, cooperative efforts; and each participant recognizes in them, to some extent, a common purpose or set of purposes, or at least a mutually accepted direction. (p. 26)

[1] The dates shown here are the dates these articles were originally printed. Much of Grice's work has been reprinted in a new collection; page numbers cited throughout this section reference that collection rather than the originally printed articles.

Grice develops the idea that rationality and cooperativity underlie conversational behavior by identifying three characteristics of cooperative transactions: 1) participants have a common goal (for example, "each party should, for the time being, identify himself with the transitory conversational interests of the other"), 2) interlocutor's contributions should be "dovetailed" and 3) both parties must agree to terminate the exchange.

Grice summed up the cooperativity that characterizes conversations in the following principle:

(1) *The Cooperative Principle:*
Make your contribution such as is required, at the stage at which it occurs, by the accepted purpose or direction of the talk exchange in which you are engaged.

The cooperative principle focuses on the *purpose* or direction of a conversation. According to Grice, in order to obey the Cooperative Principle, speakers follow the Maxims of Conversation described below (p. 45-46).

(2) *The maxim of Quality:*
Try to make your contribution one that is true; specifically:
1. Do not say what you believe to be false.
2. Do not say that for which you lack evidence.

The maxim of Quantity:
1. Make your contribution as informative as is required (for the current purposes of the exchange).
2. Do not make your contribution more informative than is required.

The maxim of Relation:
Be relevant.

The maxim of Manner:
1. Avoid obscurity of expression.
2. Avoid ambiguity.
3. Be brief. (Avoid unnecessary prolixity.)
4. Be orderly.

Grice noted that this list of maxims was not total, but he considered the ones he had identified to be primary (p. 28):

> There are, of course, all sorts of other maxims (aesthetic, social, or moral in character), such as "Be polite," that are also normally observed by participants in talk exchanges, and these may also generate nonconventional implicatures. The conversational maxims, however, and the conversational implicatures

connected with them, are specially connected (I hope) with the particular purposes that talk ... is adapted to serve and is primarily employed to serve."

Given the Cooperative Principle and the Maxims of Conversation, Grice proposed the following process through which implicatures arise (paraphrased from Grice 1975, pp. 30–31):

(3) S's saying that *p* conversationally implicates *q* iff:
- (i) S is presumed to be observing the conversational maxims, or at least the Cooperative Principle
- (ii) the supposition that S is aware that, or thinks that, *q* is required in order to make his saying *p* consistent with this presumption
- (iii) S thinks (and would expect the hearer H to think that S thinks) that it is within the competence of H to work out, or grasp intuitively, that the supposition mentioned in (ii) is required

As Levinson (1983) points out, there is a relationship between Grice's approach to implicature and his theory of meaning-nn (non-natural meaning). Natural meaning is seen in examples such as *Those spots mean measles*, in which the significance of a stimulus is directly inferable from the stimulus itself, combined with background knowledge. In the case of non-natural meaning—seen in examples such as *Those three rings on the bell (of the bus) mean that the bus is full*—the belief that the meaning is intentionally conveyed is required in order for the meaning to be conveyed at all.[2]

Grice originally proposed the following definition for meaning-nn (paraphrased from Grice (1957), p. 220):

(4) "S meant something by uttering *x*" is true iff, for some audience A, S uttered *x* intending:
- (i) A to produce a particular response *r*
- (ii) A to think (recognize) that S intends (i)
- (iii) A to fulfill (i) on the basis of his fulfillment of (ii)

The response *r* referred to in the definition means the development of a belief (in the case of an assertion) or an intention (in the case of a request or command).

2 To see this, imagine that a gorilla has taken over the bus and is driving it haphazardly all over the city. If the gorilla rang the bell three times, even a person who knew that three rings conventionally meant that the bus was full would probably not believe that the three rings produced by the gorilla meant that the bus was full—because the recognition of the *intention* to communicate this would be missing.

This definition is intended to capture the generalization that communicative actions are crucially intentional. However, this original definition of meaning-nn, while it captured the basic intuition that the hearer's recognition of the speaker's intention is a crucial part of the communicative act, was subject to criticism and counterexamples. As a result, the definition was later revised to incorporate the idea that S's intention had to be mutually known—that is, both interlocutors had to recognize that the clause in (ii) was known by each of them, and that each of them knew it was known by the other. The following modification of the definition incorporates the requirement that the communicative intention must be mutually recognized[3]—that is, that both interlocutors recognize the intention, and that they both recognize that they both recognize the intention.

(5) "S meant something by uttering *x*" is true iff, for some audience A, S uttered *x* intending:
- (i) A to produce a particular response *r*
- (ii) S and A to mutually recognize that S intends (i)
- (iii) S and A to mutually recognize that S intends A to fulfill (i) on the basis of his fulfillment of (ii)

Returning to the definition of *conversationally implicates* in (3), we may see that the conversationally implicated material *q* is part of the total meaning-nn associated with *p*: If S intends to obey the cooperative principle and the maxims (to paraphrase clause (i)), then S must intend to convey *q*. The mutual recognition that S intends *q* arises, on Grice's account, from the utterance of *p* combined with the assumptions that 1) S is obeying the cooperative principle and maxims and 2) it is mutually recognized that H can "work out" (or infer) that *q* is required.

Conversational implicature as part of the intended meaning of an utterance and the two assumptions above will be discussed further later in this section, as well as in the framework I will develop.

3 As I will discuss in Chapter II, mutual knowledge seems to be too strong a requirement. A notion of mutual recognition or mutual supposition is more satisfactory.

1.1.2. Calculating Implicatures through the Maxims

Grice distinguished between three ways in which the maxims are used to create implicatures in conversation: a speaker may obey a maxim, violate a maxim in order to obey another, or flout a maxim.[4] Grice offered the following examples to illustrate these three means of creating an implicature (Grice 1975, p. 32).

> (6) A is standing by an obviously immobilized car and is approached by B; the following exchange takes place:
> A: I am out of petrol.
> B: There is a garage round the corner.
> (Gloss: B would be infringing the maxim "Be relevant" unless he thinks, or thinks it possible, that the garage is open, and has petrol to sell; so he implicates that the garage is, or at least may be open, etc.) (p. 32)

Here, because B is assumed to be obeying the Maxim of Relation, implicatures arise to make B's statement relevant to A's purpose (of getting gas).

> (7) A is planning with B an itinerary for a holiday in France. Both know that A wants to see his friend C, if to do so would not involve too great a prolongation of his journey:
> A: Where does C live?
> B: Somewhere in the South of France.
> (Gloss: There is no reason to suppose that B is opting out; his answer is, as he well knows, less informative than is required to meet A's needs. This infringement of the first maxim of Quantity can be explained only by the supposition that B is aware that to be more informative would be to say something that infringed the second maxim of Quality. "Don't say what you lack adequate evidence for," so B implicates that he does not know in which town C lives.) (pp. 32–33)

In this case, because B has violated a maxim, the inference arises that he could provide no more specific information (which would have allowed B to obey the maxim).

> (8) A is writing a testimonial who is a candidate for a philosophy job, and his letter reads as follows:
> "Dear Sir, Mr. X's command of English is excellent, and his attendance at tutorials has been regular. Yours, etc."
> (Gloss: A cannot be opting out, since if he wished to be uncooperative, why write at all? He cannot be unable, through ignorance, to say more, since the man is his pupil; moreover, he knows that more information than this is wanted. He must, therefore, be wishing to impart information that he is reluctant to write down. This supposition is tenable only if he thinks Mr. X is no good at philosophy. This, then, is what he is implicating.) (p. 33)

[4] Interestingly, the majority of Grice's examples fall into the last of these categories. Grice also noted that an interlocutor may "opt out" of obeying the cooperative principle; in such cases, no implicatures arise.

According to Grice, by violating the first maxim of Quantity (Make your contribution as informative as is required), B has caused an implicature to arise.

In fact, it has been noted (e.g., Hirschberg 1986) that most cases of implicature can be explained as being in one of the first two categories: obeying a maxim, or violating one maxim in order to obey another. Instances of "maxim clash"—where a speaker is not able to obey all of the maxims, and so must choose which one to obey and which one to violate—are significant, since it suggests that the maxims may need to be weighted with respect to one another (Hamish 1976). It is often possible to explain examples that Grice would have considered to be flouting in some other way. For instance, the example in (8) may be explained in the following way: A is obeying the maxim of Quality, by providing information that he believes to be true and for which he has adequate evidence. The purpose of a testimonial is to provide information concerning the subject of the letter; although such letters are concerned with both positive and negative information, in our society there tends to be a focus on conveying positive information (and somewhat of a prohibition against providing negative information, especially against one's own student) (Chierchia and McConnell-Ginet (1990), Roberts (p.c.)). The first maxim of Quantity requires that A say as much as he can, with the purpose of conveying information about Mr. X. Now, on the assumption that A is obeying this maxim, the reader may infer that there is nothing else of a positive nature that A can write about Mr. X. In fact, I would say this is what is most likely to be inferred, and that the negative effect of the letter is what has been called "damning with faint praise" (Hamish 1976). Here, the speaker is obeying the maxim of Quality rather than the maxim of Quantity (as in the example in (7)).

Most of the accounts of conversational implicature that follow, and the one I will develop, have focused on implicatures in Grice's first two categories: ones that arise either on the assumption that the hearer is obeying a maxim, or ones that arise on the assumption that the speaker is violating a maxim in order to obey another (that is, the speaker is obeying the cooperative principle and maxims to the best of his ability). In the first case, the implicature arises merely based on the actual utterance provided. In the second case, the implicature arises from comparing what was said with a more satisfactory utterance (in terms of the purposes of the conversation), and then inferring a reason that the more

satisfactory utterance wasn't provided. For example, in (7) above, A infers that B could not provide a more informative (and thus more satisfactory) answer without violating the second maxim of Quantity—thus the implicature arises that B does not know exactly where C lives. Similarly, in the flouting example, a more positive testimonial can be inferred not to be true, since if it were, A should have provided it. I see this distinction in how implicatures are created as a crucial one, and it will play a central role in the account I will develop.

1.1.3. Generalized and Particularized Conversational Implicature

In addition to characterizing different ways of using the maxims to create implicatures, Grice identified two different kinds of conversational implicature: particularized conversational implicature (implicatures that are specific to a particular context of utterance) and generalized conversational implicature, where "the use of a certain form of words would normally (in the absence of special circumstances) carry such-and-such an implicature or type of implicature" (p. 37). The examples discussed in the previous section were all examples of particularized conversational implicature. Grice offers the following example of generalized conversational implicature:

(9) Anyone who uses a sentence of the form *X is meeting a woman this evening* would normally implicate that the person to be met was someone other than X's wife, mother, sister, or perhaps even close platonic friend. . . . (p. 37)

Grice identifies the first maxim of Quantity as being responsible for this implicature; the reasoning is described in the following section. The important thing to note here is that in generalized conversational implicature, the implicature that arises is associated with the use of a specific form (in this case a noun phrase with an indefinite article), rather than being dependent upon a particular situation.

Much early work on conversational implicature focused on generalized implicatures, for at least two reasons. First, early work in linguistics tended to focus on language independently of context. Second, generalized implicatures, because of their relatively context-independent nature, were sometimes difficult to distinguish from conventional implicatures (discussed in the next section). Following Grice's program, generalized implicatures were treated as a separate class from particularized implicatures in terms of the way in which they arose: they were seen as being associated with specific

linguistic forms (as described by Grice), and unless contextual factors intervened or the speaker "opted out" of obeying the cooperative principle (i.e., deliberately chose not to be cooperative), they would be expected to arise when those forms were used in conversation. Particularized implicatures, on the other hand, are seen as being calculated based on the conversational context. The general patterns through which particularized and generalized implicatures arise were thus considered to be different.

In fact, it is not clear that—at least in cases such as the one described in (9)—there is such a dramatic difference between the two types of implicature (Roberts, class notes). When conversational implicatures were primarily discussed and analyzed with very minimal contextual background, generalized implicatures seemed much stronger and more obvious than particularized ones. However, context can often make a difference in what implicatures arise even when forms that are associated with these "generalized" implicatures are used. For example, consider the following (constructed) context:

(10) A and B are fraternity members, who are discussing the new recruits into the fraternity. One part of the initiation process is that new recruits are prohibited from having any social contact with women during their week of initiation.
A: How are the new recruits making it through initiation week?
B: Well, X had dinner with a woman last night, but Y and Z are still doing fine.

In such a context, in which only the fact that the person being met is a woman relevant to the purpose of the exchange, implicatures concerning X's relationship with this woman do not arise. (Instead, an implicature will arise to the effect that B thinks X is not making it through initiation week very well.) On an account such as the one in Gazdar (1979)—to be discussed later in this chapter—the implicature that the woman is not X's mother, wife, etc. would arise and then have to be canceled due to the context. However, there is no evidence that this implicature would arise in this context at all.

Grice himself noted that there are cases involving the use of the form *an X* in which no implicatures arise ("I have been sitting in a car all morning") and cases in which a "reverse" implicature arises ("I broke a finger yesterday") (p. 38). However, he does not give a detailed account of why the difference in implicature should occur. I will return to this in section 1.2.2 (The First Maxim of Quantity).

Although I have suggested that there is no reason to treat implicatures like the one described by Grice as generalized instead of particularized, there may be other cases in which implicatures are tied to specific forms (e.g., the generic present tense). (However, even in some of these examples it is possible to find conversational contexts in which these implicatures do not arise.) I will be more concerned with particularized implicatures in the account I am developing.

1.1.4. Implicature and Other Varieties of Meaning

Grice's account of conversational implicature was part of a larger program of categorizing and distinguishing between a variety of pragmatic phenomena. In particular, Grice was concerned with distinguishing between literal meaning, conventional implicatures, conversational implicatures (generalized and particularized) and nonconversational, nonconventional implicatures. These distinctions are shown in the chart below (from Neale (1992), p. 524), with the addition of the generalized/particularized distinction):

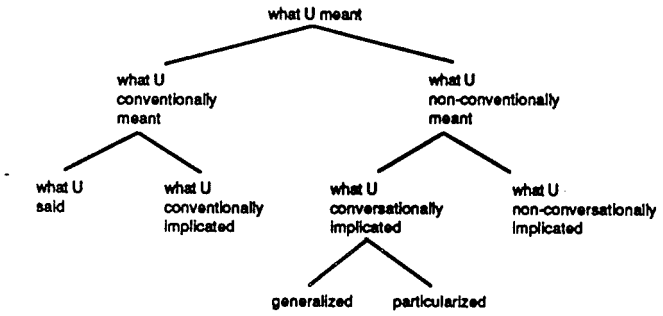

Figure 1: Varieties of Utterer's Meaning

In order to help identify whether an element of meaning was conversationally implicated, as opposed to being part of the literal meaning ("what U said") or a conventional implicature associated with the utterance, Grice devised a number of tests. These tests follow from the fact that conversational implicatures arise from the requirement that utterances in a conversation should be cooperative, rather than being linked to the form of the utterance in

some way (except for the Manner maxims, which make reference to the form of utterances). Problems with these tests have been noted (e.g., Sadock 1978); I mention them here primarily to delineate the nature of conversational implicature.

Cancellability (or defeasibility)

Because inferences arise from the assumption that the speaker is obeying the cooperative principle, it follows that generalized implicatures may be canceled in specific instances in which the speaker is presumed not to be cooperative (e.g., is "opting out"). According to Grice, an implicature can be canceled either explicitly "by the addition of a clause that states or implies that the speaker has opted out" or contextually "by being used in a context that makes it clear that the speaker is opting out." (p. 39) An example of this might be: "X is meeting a woman tonight—I can't say who." Court cases are typical contexts in which it is not always assumed that the speaker is being cooperative.

Non-detachability

Because implicatures arise from the literal meaning of an utterance (as Grice would put it, from what has been "said"), it follows that a conversational implicature cannot be detached from the meaning of an utterance regardless of what form is used to convey that meaning. (Implicatures that arise via the Maxim of Manner are an exception to this, since—unlike the other maxims, which concern the content of what is said—the Manner Maxims concern the form of what is said.)

Non-conventionality

The conventional meaning of an utterance is an input to the process of calculating the conversational implicatures that arise from it—that is, conversational implicatures are calculated after the literal meaning of the utterance has been determined. For this reason, the implicatures themselves cannot be part of the conventional meaning.

Non-literalness

Conversational implicatures are not part of the literal meaning of what has been said, and hence may be false when what has literally been said is true. This is why conversational implicature may be used to mislead.

Calculability
It should be possible to calculate a conversational implicature based on the assumption that the speaker is obeying the cooperative principle.

The characteristics of conversational implicature described above should follow from any account of implicature. In Grice's account, these characteristics follow from the fact that implicatures arise due to the assumptions that 1) implicatures are calculated from the literal meaning of what was said, so cannot be a part of that literal meaning, and 2) implicatures arise based on the assumption that the speaker is obeying the cooperative principle and the maxims of conversation.

1.1.5. Conclusion

For the most part, later theorists have adopted Grice's Cooperative Principle and general program for calculating implicatures (but see e.g. Sperber and Wilson (1988), Thomason (1990), described in later sections). Most of the revisionary work that has been done has focused on the Maxims of Conversation. Although the maxims were a tremendously important starting point in drawing a distinction between semantics and pragmatics, there are still a number of problems with them from a formal perspective. First, they are not principled in any way: they are simply a collection of rules with little independent motivation. Second, they are vague, requiring a great deal of supplementation in order to identify the implicatures that should arise in a given context (e.g., the first maxim of Quantity requires knowledge of how informative a contribution needs to be relative to the purposes of the exchange, yet provides no criteria for determining what those purposes are or how they influence informativeness). This implicit information must be supplied by the individual using the maxims to calculate implicatures. Third, as will be discussed in later accounts, although Grice identified implicatures according to the individual maxims, cases in which maxims "clash" or interact in some way are relatively common. To account for the implicatures that arise in these cases, there must be some "weighting" of the maxims (cf. Harnish 1976) or some other procedure for determining which maxims will win out. In particular, as pointed out in Atlas and Levinson (1981) (to be discussed) the quantity maxims are contradictory, and no information is provided about how to resolve the contradiction. Finally, in Grice's framework, implicatures could arise via the maxims in three different ways: on the assumption that a speaker was obeying a maxim, on the assumption that a speaker was violating a maxim to obey another, and on the assumption

that a speaker was flouting a maxim but obeying the Cooperative Principle. In some cases, the pattern of implicature is remarkably similar, even when different strategies were supposedly involved.

Several valuable elements of Grice's account, which will be seen in later accounts, are the following: 1) the primacy of "the purpose of the exchange," however this may be characterized, 2) the fact that implicatures arise via an inferencing process of some type, and 3) the fact that the speaker's obeying the cooperative principle as well as the working out of the implicated information must be mutually recognized (although Grice himself did not put it in these terms).

1.2. Formalization of the Maxims

In this section, I will review the examples Grice provides in which implicatures arise, organized according to the maxims which he claims gives rise to them. For each of the maxims, Grice gives a non-linguistic example to support the idea that the maxims are fundamentally the result of constraints on rational, cooperative behavior (as opposed to being primarily linguistic in nature). For many (but not all) of the maxims, Grice also gives a linguistic example of how implicatures arise based on the maxim. After describing Grice's approach to each maxim, I will describe more recent accounts of the maxim.

1.2.1. The Maxims of Quality

Grice does not provide an example for the first maxim of Quality ("Do not say what you believe to be false"). For the second maxim of Quality ("Do not say that for which you lack evidence") he provides the following example, in which the first maxim of Quantity clashes with the second Quality maxim, and the Quality maxim wins (repeated from the previous section).

(7) A is planning with B an itinerary for a holiday in France. Both know that A wants to see his friend C, if to do so would not involve too great a prolongation of his journey:
A: Where does C live?
B: Somewhere in the South of France.
(Gloss: There is no reason to suppose that B is opting out; his answer is, as he well knows, less informative than is required to meet A's needs. This infringement of the first maxim of Quantity can be explained only by the supposition that B is aware that to be more informative would be to say something that infringed the second maxim of Quality. "Don't say what you lack adequate evidence for," so B implicates that he does not know in which town C lives.)

The Quality implicature here is that B *does* have adequate evidence that C lives somewhere in the South of France, even if he doesn't know exactly where. (The implicature described in Grice's gloss also involves the first maxim of Quantity).

Gazdar (1979) provides a formal definition of the maxim of Quality, pointing out that Grice's requirements are similar to the ones that have been discussed in the philosophical literature with respect to the definition of knowledge as justified true belief. He then gives the following informal definition of a single Quality maxim, which incorporates this notion of knowledge:

(15) QUALITY': Say only that which you know (p. 46).

He then provides the following corresponding formal definition (p. 46):

(16) Utterance of ϕ by a speaker s implicates Kϕ (where for Kϕ read *s knows that* ϕ).

Rather than treating the quality maxims as maxims of conversation, Gazdar notes that Quality only applies to utterances that are assertions. He therefore defines them as one of the felicity conditions for assertion of an utterance.

(17) For any declarative sentence ϕ, assertion of ϕ commits the speaker to Kϕ. (p. 48)

Treating the maxim of Quality as a felicity condition (specifically, the sincerity condition) on assertion builds it into speech act theory, so that it does not have to be treated independently in a theory of implicature.

Harnish (1976) points out that the maxim of Quality is important to cooperation: "... truly groundless information has at least a good a chance of being wrong as right, and as such would probably not be helpful—thereby violating the [cooperative principle]" (p. 343). Lewis's (1969) theory of convention also has bearing on this issue. According to Lewis, the truthful use of a language is a convention (in a specialized sense that he defines). Truthfulness in his framework is the basis on which language has meaning at all.

These varied perspectives on the maxim of Quantity all see Quality as primary over the other maxims.

1.2.2. The First Maxim of Quantity

Grice gives the following example of an implicature that arises due to the First Maxim of Quantity (Make your contribution as informative as is required (for the current purposes of the exchange)) (also discussed in the previous section).[5]

(11) When someone, by using the form of expression *an X*, implicates that the X does not belong to or is not otherwise closely connected with some identifiable person, the implicature is present because the speaker has failed to be specific in a way in which he might have been expected to be specific, with the consequence that it is likely to be assumed that he is not in a position to be specific. (p. 38)

In describing how the maxim of Quantity guides rational behavior, Grice gives the following example:

(12) If you are assisting me to mend a car, I expect your contribution to be neither more nor less is required. If, for example, at a particular stage I need four screws, I expect you to hand me four, rather than two or six. (p. 28)

If the assistant offered two screws, he or she would be violating the first maxim of quantity. This is similar to the pattern in the South of France example in (7), in which by violating the first maxim of Quantity, B implicates that he does not know in which town C lives.

Other examples that are commonly cited in the literature include the following:

(13) A: Mary has three children.
Implicature: Mary has no more than three children.

(14) Some of the guests left early.
Implicature: Not all of the guests left early.

The reasoning process involved in arriving at the implicatures described in these examples is characteristic of all of the implicatures that arise from the first maxim of Quantity. This process involves comparing what the speaker did say to alternative utterances that are informationally stronger relative to the purposes of the exchange, and

[5] It is important to note that in formulating the maxim, Grice relativizes the quantity of information to the purpose of the talk exchange—thus building in a reference to something like the Maxim of Relevance. As we will see, most accounts of this submaxim have ignored this important point.

inferring that for some reason the speaker could not have provided the informationally stronger statement. The hearer's general inference pattern looks like this (adapted from Levinson (1983), p. 135):

(18) Inference pattern underlying (weak) Quantity 1 implicatures:
a) The speaker said *p*.
b) There is an alternative utterance *q*, informationally stronger than *p* (relative to the current purpose of the conversation), which the speaker might have provided.
c) Quantity 1 would require the speaker to provide *q* if she were in a position to do so, so there must be some reason that the speaker could not have said *q*.

This is the part of the inference pattern that is found in all implicatures that arise via Quantity 1.[6] However, what is mutually recognized by both the speaker and hearer (i.e., is in the conversational background) about what the speaker is likely to know and why she might not have made the stronger statement will determine the specific implicatures that actually arise.

Many Quantity 1 implicatures that arise due to the inference patterns in (18) fall into a subcategory that has been termed "scalar implicature" (since in these cases a "scale" of values ordered according to some relation can be seen as contributing to the implicatures that arise—e.g., the implicature in (13) is based on a scale of numerals; values higher on the scale than *three* are implicated to be false). Not all of the implicatures that arise based on the first maxim of Quantity are scalar implicatures; Grice's South of France example and his "X is meeting a woman" example do not straightforwardly lend themselves to a scalar account. However, the scalar implicature subcategory has received the most attention in formal accounts of this maxim, since in these examples it is possible to use the notion of a scale as part of the formalization.

"Strong" Quantity 1 implicatures like the ones in (13) and (14) above, in which the speaker's not having said the stronger statement leads to the specific implicature that the stronger statement is not true, involve what Gazdar (1979) has termed "epistemic modification." Epistemic modification occurs when it is mutually believed that the speaker is in a position to know whether the stronger statement is true, and when the stronger statement is relevant to the current purpose of the conversation. The first maxim of Quality

6 Note that this inference pattern suggests that the first maxim of Quantity is actually being violated, rather than being obeyed.

comes into play, dictating that the speaker should not say what she believes to be false. Epistemic modification thus involves the following additional steps in reasoning:

(19) Inference pattern leading to epistemic modification:
d) The speaker is in a position to know whether *q* is true or false.
e) If the speaker knows that *q* is false, then the speaker would be violating the Maxim of Quality if she said *q*. This would be a reason for the speaker not to have provided *q*.[7]
f) Therefore, the speaker must know that *q* is false.

It is interesting to note that this inference pattern is responsible for the implicature in Grice's South of France example, repeated below:

(7) A is planning with B an itinerary for a holiday in France. Both know that A wants to see his friend C, if to do so would not involve too great a prolongation of his journey:
A: Where does C live?
B: Somewhere in the South of France.
(Gloss: There is no reason to suppose that B is opting out; his answer is, as he well knows, less informative than is required to meet A's needs. This infringement of the first maxim of Quantity can be explained only by the supposition that B is aware that to be more informative would be to say something that infringed the second maxim of Quality. "Don't say what you lack adequate evidence for," so B implicates that he does not know in which town C lives.)

Although there are cases in which epistemic modification takes place, Hirschberg (1986) points out that implicatures to the effect that stronger statements *q* are false do not always arise; whether or not the stronger implicature arises seems to depend on what the speaker's knowledge is taken to be and assumptions about other reasons the speaker might not have provided a more informative response. The following is an example where only a weaker implicature to the effect that the speaker does not believe that the higher value holds: $\neg Bp$ (as opposed to believing that the higher value does not hold: $B \neg p$):

(20) Context: A and B are discussing a party that A attended the night before.
A: It was boring, so I left early. Some other people did too.

7 Again, note that this suggests that the Maxim of Quality may be weighted more highly than Quantity 1.

Unlike the example in (14), in this case no implicature arises from the use of the quantifier *some* to the effect that higher quantifiers on the quantifier scale (e.g., *all*) are false. Only the implicature that A does not have the belief that *all of the people left early* arises. The reason that only the weaker implicature arises is that it is mutually recognized that A is not in a position to know whether all of the people left early, since A left early and is likely not to be aware of the full set of people who did. The reasoning pattern here would differ from the one described previously in that steps (d) through (f) would be replaced by the following:

(d') The speaker could not have said q because she was not in a position to know whether q is true or false.

This leads to the weaker implicature.

As discussed in the previous section, most early accounts of Quantity 1 implicatures have treated them as generalized implicatures rather than particularized ones. The role of context has for the most part been ignored or minimized, despite the fact that Grice's original formulation of the maxim specifically relativized these implicatures to the purposes of the exchange. The importance of this relativization can be seen in the following example:

(21) A: I'm having a dinner party and I need four more chairs.
B: John has four chairs.

In this example, a scalar implicature to the effect that A needs no more than four chairs arises. However, no scalar implicature arises based on B's utterance, despite the fact that saying "John has five chairs" would be—independent of the context—informationally stronger. This example points out the fact that Quantity 1 implicatures are "bounded" by the purpose of the conversation. It also suggests that, staying within Grice's original classification, the Maxim of Relevance may be more important than Quantity 1.

An important point about scalar implicatures is that they relate to a more general notion of strength of information, or informativeness. In fact, scales can be seen as rankings of values or sentences in terms of their informativeness. An account of informativeness which addresses implicatures that arise via the first maxim of Quantity in general (which include scalar implicatures) is Ginzburg (1990); this more overarching account is discussed in a later section. Notable accounts of scalar implicature are described in more detail in the remainder of this section.

1.2.2.1. Horn (1972)

Horn (1972) developed the first formal account of the implicatures that arise due to the first maxim of Quantity. His account focused on the type of implicature that arises when a value on a "quantitative scale" has been asserted; namely, an implicature that the speaker could not have asserted a higher value on the scale. The following is typical of Horn's examples:

(22) That's (at least) the 734th time I've told you not to slam the door (and it may even be the $\left\{\begin{array}{l}\text{735th}\\ \text{\#733rd}\end{array}\right\}$).

In this example, Horn points out the fact that there is a scalar implicature based on the number 734 to the effect that a higher number on the scale (e.g., 735) could not be asserted; however, this implicature can be suspended with a phrase such as the one in parentheses ("may even be..."). This is in contrast to information that is entailed by what has been said (all values lower on the scale); when a suspension clause is filled in with one of these values, the result is an anomalous sentence.

Horn also pointed out that the quantitative scales on which such implicatures are based are dependent on contextual factors—in a golf game, achieving a lower score entails that it is possible to achieve a higher one, so the scale is reversed. The implicature pattern is shown in the following example:

(23) Arnie is capable of breaking 70 on this course, if not $\left\{\begin{array}{l}\text{65}\\ \text{\#75}\end{array}\right\}$.

Quantitative scales may be based on entailment, with higher values on the scale entailing the lower values on the scale (as in the previous example), or may be based on less obvious relations. For example, saying that someone is pretty implicates that she is not beautiful; however, it is not clear that *beautiful* entails *pretty*. Horn notes that scales can be identified by constructions that suspend implicature of the higher values, such as those shown in (22) and (23). He gives examples of a variety of types of scales which can give rise to implicatures, including adjective scales (*beautiful* if not *pretty*, *warm* if not *hot*), temporal scales (*midnight* if not *earlier*, *sick* if not *dying*), and quantificational scales (*some* if not *all*).

Having given a range of examples of implicatures that arise based on quantitative scales, Horn provides the following formalization of scalar implicatures (p. 112):

(24) We shall assume that on quantitative scales with defined end-points the negation of this end-point (or strongest element) must be inferred by the listener from the stipulation of any weaker element on that scale, while the negation of non-terminal elements may be inferred from the stipulation of relatively weaker elements....

More schematically, given a quantitative scale of n elements p_1, p_2, ..., p_n and a speaker uttering a statement S which contains an element p_i on this scale, then
(i) the listener can infer $\sim S(p_i/p_j)$ for all p_j, p_i $(j \neq n)$[8]
(ii) the listener must infer $\sim S(p_i/p_n)$
(iii) if $p_k > p_j > p_i$, then $\sim S(p_i/p_j) \supset \sim S(p_i/p_k)$
(where S(a/b) denotes the result of substituting b for all occurrences of a in S [and a>b means that a is ordered before or higher than b])

A schematic application of this rule is as follows. Take a scale with elements p_1, p_2, ..., p_5, as shown below.

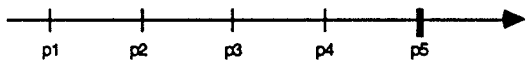

Figure 2: Schematic Scale

Suppose that $S(p_2)$ is asserted. Then, according to Horn's rule (adapted from Horn's own explanation):

(i) the listener can infer $\sim S(p_3)$ and $\sim S(p_4)$

(ii) the listener must infer $\sim S(p_5)$

(iii) if one value is ranked more highly on the scale than another ($p_k > p_j$ means that p_k is ranked above p_j), then inferring the negation of the higher value is more likely to be justified then inferring the negation of the lower value, even if both are ranked above the asserted value. Thus, the inference of $\sim S(p_4)$ is more justified than the inference of $\sim S(p_3)$.[9]

8 This definition assumes that the ordering of the elements on the scale is $p_k > p_j > p_i$ (i.e., p_k is ordered higher than p_j, which is ordered higher than p_i).

9 This interpretation of clause (iii), which is paraphrased from Horn's discussion, seems to require that the $\supset$ symbol means something like "is less likely to be inferred."

More specifically, Horn gives the following example: "If we are told by someone that some of his best friends are Zoroastrians, it is safer for us to conclude that it is not the case that *most* of them are than that not *many* are. We must draw the inference that not *all* are, i.e. that at least some are not Zoroastrians" (p. 112). The following diagram of the relevant scale will aid in relating the definition to the example.

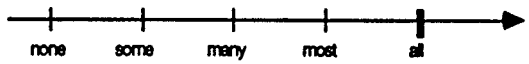

Figure 3: Quantifier Scale

In fact, it is not clear that the strength of implicatures that Horn formalizes is really a function of position on the scale; contextual salience and (as Hirschberg (1986) points out) speaker knowledge play a significant role in determining what implicatures will arise.

Horn's account of scalar implicatures was a landmark account, in that it was one of the first attempts to formalize conversational implicature. However, it has a number of defects, including the fact that the quantitative scales (later called "Horn scales") which give rise to these implicatures are defined relatively informally. These scales are also assumed to have an independent existence (e.g., Horn's definition states "given a quantitative scale..."), rather than being contextually determined (although Horn's golf game example, in which the order of the elements on a numerical scale is reversed, indicates an awareness of the importance of context). As formalized by Horn, the maxim leads to implicatures independently of the purpose of the conversation, which will result in the listener being licensed to infer implicatures that do not actually arise (e.g., in the example in the previous section, the hearer would be licensed to infer "John doesn't have five chairs," since *five* is higher on the quantitative scale than *four*—even though whether John has five chairs is not obviously relevant to the purpose of the exchange, and the implicature does not actually arise). Also, as mentioned previously, the inferences that Horn's rule licenses are too strong: in many cases it is not the negation of the higher values on the scale that is inferred, but merely the speaker's inability to make a stronger statement.

1.2.2.2. Gazdar (1979)

Gazdar (1979) provides a formal definition of the first maxim of Quantity. His general program is to generate for each sentence the set of potential quantity implicatures, then allow contextual cancellation in certain circumstances. If contextual cancellation does not take place, the full set of quantity implicatures is taken to apply. Gazdar also discusses the place of implicature in a larger semantic/pragmatic theory, stating:

(25) It is both in the spirit of Grice's program and in the interests of economy to read these nonconventional inferences from the semantic representation. (p.56)

Gazdar argues that reading implicatures from the lexical items associated with the sentence would be treating them as conventional implicatures, while reading implicatures from the semantic interpretation of a sentence (the proposition it expressions) would be impossible.

In providing a formal definition of implicatures that arise via the first maxim of Quantity, Gazdar defines two functions that determine the potential quantity implicatures a sentence might have. The first of these is a refinement of Horn's formalization, focusing on the implicatures that arise for a sentence containing a scalar expression. Like Horn's definition, this function refers to a quantitative scale on which expression alternatives are ordered. The second definition focuses on what Gazdar calls "clausal quantity implicatures," seen in examples like the following (where the (a) utterance leads to the implicature in (b)) (p. 60):

(26) a. My sister is either in the bathroom or the kitchen.
b. I don't know that my sister is in the bathroom.

(27) a. If John sees me then he will tell Margaret.
b. I don't know that John will see me.

Like Horn, Gazdar assumes that the scales used for generating scalar implicatures are "given to us," although he cites work by Fauconnier (1975) as providing evidence that these scales are pragmatically rather than semantically based (p. 58). He mentions that Caton (1966) has suggested how one type of quantitative scale—entailment based—may be formed:

(28) Let Q be an n-tuple of expressions such that $Q = \langle \alpha_0, \alpha_1, \ldots \alpha_{n-1} \rangle$ where $n > 1$. Then if Q is a quantitative scale: $[\phi_{\alpha i}] \subset [\phi_{\alpha i+1}]$ where α_i and α_{i+1} are any pair of simple expression alternatives with respect to α_i, $\alpha_{i+1} \in Q$. (p. 58)

Only a subset of the scales that Horn refers to will match this definition; presumably other (non-entailment-based) scales will be defined in some other way.

Given a quantitative scale, Gazdar defines a function which takes a sentence as argument and returns a set of scalar quantity implicatures. (The precise formalism used by Gazdar is not essential for understanding his approach, so I will not include it here.) Like Horn's formalism, Gazdar's leads to implicatures to the effect that given a statement containing a scalar expression, all statements containing a higher expression on the scale are false. Unlike Horn, Gazdar's formalism makes no claim about sentences containing expressions higher on the scale being less likely than ones containing lower expressions, as long as both are above the stated expression on the scale.

In addition to the function which gives the scalar implicatures associated with an utterance, Gazdar defines a function which takes a compound sentence and returns a set of "clausal" implicatures like the one in (27b). According to his formal definition of this function, implicatures arise to the effect that any sub-part of the sentence (which is not entailed by the sentence, and whose negation is not entailed by the sentence) may or may not be true, for all the speaker knows. This is the implicature in (27b), where "John sees me" is the sub-part of the sentence in question.

Gazdar's work is especially valuable in terms of identifying a place for implicature generation within a larger semantic/pragmatic framework. The account of scalar implicature he develops improves on the formalism offered by Horn, and also accounts for implicatures that Horn's account does not include, but has several problematic features. First, it treats these implicatures as being created independently of context and then canceled if necessary. Cancellation mechanisms/motivations are not formalized or discussed in detail, nor is there a clear argument for why we would want to assume that an implicature arose and was canceled in a context in which there is no evidence that the implicature ever existed. (In fact, this runs counter to Grice's own approach, which included a guideline derived from Occam's Razor: "Senses are not to be multiplied beyond necessity" (p. 47).) Second, his account produces the strong implicatures that higher values on the scale are not true, which does not always apply. Third, it is not clear that the clausal

implicatures that Gazdar's account produces always arise, as shown in the following example (Chierchia and McConnell-Ginet (1990), p. 196):

(29) a. I am certain that Joan is smart.
b. I don't know whether Joan is smart.

Since *I am certain that Joan is smart* does not entail *Joan is smart*, Gazdar would predict the clausal implicature in (b), based on the utterance in (a); this implicature would then have to be contextually cancelled.

Finally, although Gazdar does attempt to account for more of the Quantity 1 implicatures than Horn does, he uses two separate mechanisms to do so. It would be ideal to capture all of these implicatures, which Grice saw as forming a kind of natural class, through a single mechanism. Ideally, this mechanism would derive other Quantity 1 implicatures, such as the South of France example, as well.

1.2.2.3. Hirschberg (1986)

Hirschberg (1986) provides a formal, computational, and comprehensive account of scalar implicature which includes the kinds of examples discussed by Horn, Gazdar and others and goes beyond them. Like previous accounts, she treats scalar implicatures as generalized implicatures; unlike them, the formalism she develops gives context a role in determining which implicatures will arise (rather than using it post facto to cancel implicatures). However, although she does discuss the role of context and at what point it would contribute to the determination of implicatures, she does not provide an explicit strategy for relating actual implicatures to a specific context of utterance (which would include the purpose of the exchange). Because her account is computational in nature (rather than being a linguistic or philosophical account), she focuses on developing a formal account of the data rather than capturing underlying generalizations concerning conversational implicature as a whole, and scalar implicatures in particular.

Hirschberg begins by developing a formal definition of conversational implicature to serve as a background for her account, taking Grice's account as a foundation. For the most part, this definition rewrites Grice's account in formal language; the exceptions are an amendment of Grice's definition of implicature and a careful consideration of which of the conditions on implicature need to be included. This definition is as follows (I will provide Hirschberg's translation of the formal definition immediately after it) (p. 38):

(30) CONVERSATIONAL-IMPLIC $(S,H,p_j,u_i,C_k) \leftrightarrow$
1. INTEND $(S,$ CAUSE (SAY (S,H,u_i,C_k), BEL$(H,p_j)))) \wedge$
2. BEL $(S,$ BMB[10] $(H,S,$ IS-COOP$(S,C_k,$ {QUALITY,QUANTITY, RELATION,MANNER}$)))) \wedge$
3. BMB$(S,H,$ LICENSE $(S,H,p_j,u_i,C_k,$MAXIMS$)) \wedge$
4. CANCELABLE$(u_i,p_j) \wedge$
5. (NONDETACHABLE$(u_i,p_j) \vee$ (MANNER $\in$ MAXIMS)) $\wedge$
6. REINFORCEABLE (u_i,C_k)

(31) A speaker S conversationally implicates to a hearer H a proposition p_j by uttering u_i in context C_k if and only if
1. S intends to convey p_j to H via u_i
2. S believes that it is mutually believed between S and H that S is being cooperative (i.e., obeying the maxims of cooperative conversation)
3. S believes that it is mutually believed between S and H that, given S's u_i in a context C_k, and given S's cooperativity (i.e., obedience to the maxims represented in MAXIMS), p_j 'follows'
4. p_j is cancellable
5. p_j is nondetachable except when it arises via the maxim of manner [i.e., those maxims involved in LICENSE in clause 3 do not include the Maxim of Manner]
6. p_j is reinforceable

The first three conditions in the above definition correspond generally to Grice's outline of what conversational implicature is. Hirschberg's amendment of this definition is the inclusion of mutual belief (as opposed to just hearer's belief) in clause 2 (cf. Grice's definition in (3)). Hirschberg's justification for this is as follows (p. 20):

> ... suppose you believe I am obeying the [cooperative principle] but I believe that you do not believe this. If, say, I believe you believe I am not observing the Maxim of Quality, then, when I assert p_i, I will not believe that I can implicate p_j, even though [the first condition] holds. So, under this condition, implicatures will be defined which S does not believe have been licensed by an utterance, violating Grice's belief in the primacy of speaker intention to meaning...

[10] Hirschberg's BMB operator stands for one-sided mutual belief: in this case, the speaker's belief that it is mutually believed that X.

The point here is the same one that arose in Grice's account of meaning-nn (cf. the definition in (4) and discussion)—it is the *mutual* belief or recognition of the speaker's intention that leads to the implicature.

Conditions 4–6 are ones that Hirschberg considers to be collectively necessary and sufficient to distinguish conversational implicature from other aspects of utterance interpretation (e.g., presupposition). The first two of these were discussed in section 1.1.4. Reinforceability was proposed by Sadock (1978) as an additional test for implicature.

In order to formalize speaker cooperativity, Hirschberg equates being cooperative with obeying the maxims of conversation:

(32) $\forall m_i \in M_j$ {OBEY(S, m_i, C_k) $\leftrightarrow$ IS-COOP(S, C_k, M_j)} (p. 14)

According to this definition, "S is being cooperative with respect to maxims M_j iff S is obeying each $m_i \in M_j$" (p. 14). OBEY(S, m_i, C_k) indicates that S is observing the maxim m_i in the context C_k. Hirschberg states, "Given this definition, we can specify Grice's notion of speaker cooperativity as just speaker obedience to the Maxims of Quality, Quantity, Relation, and Manner: IS-COOP(S, C_k, {QUALITY, QUANTITY, RELATION, MANNER})" (p. 14).

Hirschberg's general approach to formalization of the maxims involves taking Grice's maxims as given and defining, for each, what it means for a speaker to be obeying that maxim (OBEY(S, m_i, C_k)). The bulk of her work focuses on the first maxim of Quantity combined with the maxim of Quality; her approach involves identifying the scalar implicatures that will be licensed if the speaker is assumed to be obeying the two maxims. The formal definition she eventually provides connects to Condition 3 of her definition of conversational implicature, which concerns the licensing of implicatures given the assumption that the speaker is obeying a particular maxim.

In formalizing scalar implicature, Hirschberg uses the term "orderings" to denote the relationships that support scalar implicature (cf. Horn's term "scale") and the term "ordering metric" to refer to the principle according to which an ordering is defined (e.g., entailment is one ordering metric). Importantly, she notes that not all orderings that support scalar implicature are linear. She identifies the following subclasses of scalar implicature that are not treated by Horn, Gazdar and others (p. 57): 1) inferences based on an alternate value (rather than higher or lower) in a non-linear ordering being referenced and 2) inferences arising not just from a speaker's affirmation of some value (as in previous accounts) but also from a speaker's denial of or commitment to ignorance of some value. It is important to note that unlike previous accounts, Hirschberg does not license the stronger implicatures that the speaker knows that the other values are false (or true), but instead licenses the weaker implicatures that these values are false or unknown, or true or unknown. Additional strengthening, if it occurs, will be the result of the background information available to the speaker and the hearer.

In addition to the larger number of implicature patterns, Hirschberg considers a much broader range of examples and orderings that lead to implicatures. Some of the kinds of things that can be ordered that she discusses are: quantifiers; modals; logical connectives; numerals; ranked entities, states, actions and attributes; time; space; sets and whole/part relationships; type/subtype, instance-of, and generalization/specialization relationships; and entity/attribute relationships.

In the following discussion, diagrams are provided (adapted from Hirschberg) that illustrate the patterns of implicature Hirschberg's account focuses on licensing. These diagrams are supported with examples illustrating the different patterns of implicature; these examples also suggest the range of orderings that Hirschberg considers.

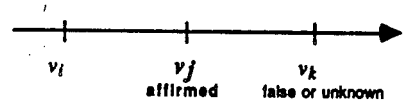

Figure 4: Affirmation of a Value (Linear Ordering)

If v_j is affirmed, the implicature is licensed that the speaker believes v_k is false or unknown. The following is an example of this, in which a whole/part relationship is the basis for the ordering:

(33) A: Did you manage to read that section I gave you?
B: I read the first couple of pages. (p. 57)

The implicature that B did not read the section (v_k) is licensed by the affirmation of a lower value, "the first couple of pages" (v_j).

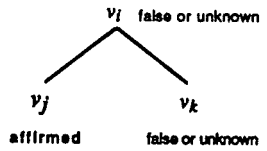

Figure 5: Affirmation of a Value (Alternate Values)

If v_j is affirmed, the implicatures are licensed that 1) v_i is false or unknown, and 2) that v_k is false or unknown. In the following example, which involves a type/subtype relationship, the implicature that v_k is false or unknown is clearly licensed, although the implicature that v_i is false or unknown is less evident:[11]

(34) A: So, Leo likes Bonkers?
B: She likes liver flavor. (p. 58)

By affirming that Leo likes liver flavor (v_j), B implicates that whether Leo likes any other flavor (v_k) is false or unknown.

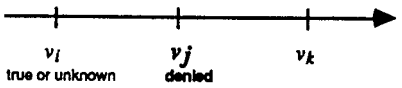

Figure 6: Denial of a Value (Linear Ordering)

[11] In fact, I am not certain that an implicature concerning the higher value should be licensed at all. It seems to arise based on the entailment relationship that holds between the higher value and lower values, which is determined by the relation that is the basis for ordering them. Furthermore, in this example, my intuition is that that the higher value is actually true or unknown: if one likes liver Bonkers, it seems to follow that one likes Bonkers.

If v_j is denied, the implicature is licensed that the lower value v_i is true or unknown. (This is the reverse of the implicature when a value is asserted.) An example of this, in which rankable attributes are ordered, is the following:

(35) A: Was he cute?
B: He wasn't stunning. (p. 59)

Here, B implies that "cute" (v_i) is true or unknown by denying the higher value "stunning" (v_j).

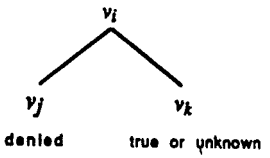

Figure 7: Denial of a Value (Alternate Values)

If v_j is denied, the implicature is licensed that v_k is true or unknown. The following example illustrates this pattern:

(36) A: Have you made fondue in this pot yet?
B: Not chocolate fondue. (p. 58)

By denying "chocolate fondue" (v_j), B affirms that she has made some other kind of fondue.

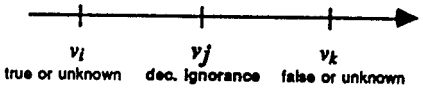

Figure 8: Declaring Ignorance of a Value (Linear Ordering)

If the speaker declares ignorance of v_j, two kinds of implicatures are licensed: 1) the implicature that v_i is true or unknown, and 2) the implicature that v_k is false or unknown. The first type of implicature is shown in the example below, which involves a temporal ordering on rankable states:

(37) A: Do you have information on [Kathy M. for maternity]...?
B: I don't think she's delivered yet.
A: Then she HAS been admitted.
B: Yes. (p. 63)

By denying "delivered," B scalar implicates that a lower value on the scale (of activities involved in the process of having a baby), "being admitted," is true or unknown. A requests confirmation of this implicature in the follow-up question.

An example of the other kind of implicature, in which a higher value is implicated to be false or unknown, is the following:

(38) A: Is it warm in Antarctica in the summer?
B: I don't know if it gets above freezing. (p. 63)

Here, B implicates that it is not warm in Antarctica ("warm" being higher on the scale than "above freezing").

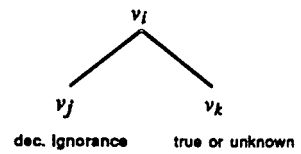

Figure 9: Declaring Ignorance of a Value (Alternate Values)

If the speaker declares ignorance of v_j, alternate values are implicated to be true or unknown. This pattern is shown in the following example.

(39) A: So, does Leo need shots this spring?
B: I'm not sure about rabies. (p. 64)

By declaring ignorance of whether Leo needs rabies shots, B implicates that B is sure about all the other kinds of shots.

To describe the patterns of implicature above, Hirschberg provides "conventions of scalar implicature." These conventions connect to Condition 3 of her definition of conversational implicature, by specifying which implicatures are licensed according to the maxim of Quantity. Specifically, Hirschberg provides the following formula (p. 65):

(40) (IS-COOP (S, C_h, {QUANTITY, QUALITY}) $\wedge$
SCALAR-IMP (S, H, u_i, p_j, C_h)) $\Rightarrow$
LICENSE (S, H, u_i, p_j, C_h, {QUANTITY, QUALITY})

So, if S is cooperative with respect to the maxims of quantity and quality, and if S scalar implicates p_j by uttering u_i to H in context C_h, then S licenses the implicature that p_j by uttering u_i to H in C_h.

The three conventions of scalar implicature are described below (p. 82). These conventions are defined not in terms of ordered values, but in terms of sentences that contain values that are ordered with respect to an ordering O. The ordering of the values according to O is extended to the sentences containing those values, as long as the values do not occur under the scope of negation.

(41) *Scalar implicature convention 1 (Affirmation)*
$\exists O$ (BMB (S, H, SALIENT (O, C_h)) $\wedge$
REALIZE (u_i, AFFIRM (S, e_i, BEL (S, p_i))) $\wedge$
(HIGHER-SENT (p_i, p_j, O) $\vee$ ALT-SENT (p_i, p_j, O)) $\Rightarrow$
SCALAR-IMP (S, H, u_i, $\neg$BEL (S, p_j), C_h)

This convention is the one that has been recognized by previous authors (e.g., Horn 1972, Gazdar 1979), although they have formalized it differently. The definition states that if there is some ordering O such that 1) S believes that it is mutually believed by the speaker and hearer that O is salient in the context C_h, and 2) the utterance u_i realizes the

proposition that S affirms[12] a value e_i by affirming S 's belief in a proposition p_i which contains e_i, and 3) if there is a sentence p_j that is higher than p_i with respect to the ordering O or alternate with respect to O, then the utterance of u_i licenses the scalar implicature (in the context C_h) that S does not believe it is the case that p_j is true. As Hirschberg discusses, this convention does not license the stronger implicature that the speaker believes it is not the case that p_j holds: additional contextual information would have to combine with the weaker implicature to give the stronger one (e.g., what the speaker is mutually believed to know). Unlike Horn, Hirschberg does not consider that the hearer has greater license to infer implicatures concerning values higher in the ordering than others, and in fact points out that there is no evidence to support such a claim. Strength of implicature depends on what is known about the speaker's knowledge.

As can be seen from this definition, Hirschberg considers context to play a significant role in determining what ordering is salient. For this reason, her account gets the right result for the example in (21), in which no scalar implicature arises. This example is repeated below for convenience:

(21) A: I'm having a dinner party and I need four more chairs.
B: John has four chairs.

Hirschberg's account would allow the ordering of numbers of chairs to be based on a relation such as "more helpful than," which could have *four* as its highest value. No implicatures would then be licensed about numbers higher than four, since those numbers would not be on the scale.

(42) *Scalar implicature convention 2 (Denial)*
$\exists O$ (BMB (S, H, SALIENT (O, C_h)) $\wedge$
REALIZE (u_i, DENIAL (S, e_i, BEL (S, $\neg p_i$))) $\wedge$
(LOWER-SENT (p_i, p_j, O) $\vee$ ALT-SENT (p_i, p_j, O))) $\Rightarrow$
SCALAR-IMP (S, H, u_i, $\neg$BEL (S, $\neg p_j$), C_h)

[12] Hirschberg gives the following definition of affirmation: "p_i represents an affirmation of a subexpression e_i iff p_i is of the form BEL (S, p_j) and p_j is simple with respect to e_i" (p. 74). A proposition is simple with respect to a subexpression as long as the subexpression does not occur under the scope of negation within the proposition. Her predicate AFFIRM is a relation between a speaker, a subexpression, and a proposition containing that subexpression.

This convention licenses implicatures based on the speaker's denial of a sentence containing some value in an ordering. The definition states that if there is some ordering O such that 1) S believes that it is mutually believed by the speaker and hearer that O is salient in the context C_h, and 2) the utterance u_i realizes the proposition that S denies[13] a value e_i through the proposition that S believes the proposition $\neg p_i$ which contains e_i, and 3) there is a sentence p_j that is lower than p_i with respect to the ordering O or alternate with respect to O, then the utterance of u_i licenses the scalar implicature (in the context C_h) that S does not believe it is the case that p_j is false.

(43) *Scalar implicature convention 3 (Declaring Ignorance)*
$\exists O$ (BMB (S, H, SALIENT (O, C_h)) $\wedge$
REALIZE (u_i, IGN (S, e_i, $\neg$BEL (S, p_i))) $\Rightarrow$
((LOWER-SENT (p_i, p_j, O) $\Rightarrow$
SCALAR-IMP (S, H, u_i, $\neg$BEL (S, $\neg p_j$), C_i))
$\vee$
(HIGHER-SENT (p_i, p_j, O) $\Rightarrow$
SCALAR-IMP (S, H, u_i, $\neg$BEL (S, p_j), C_i))
$\vee$
ALT-SENT (p_i, p_j, O) $\Rightarrow$
SCALAR-IMP (S, H, u_i, BEL (S, p_j), C_i))))

This convention licenses implicatures based on the speaker's assertion of ignorance of a sentence containing some value in an ordering. The definition states that if there is some ordering O such that 1) S believes it is mutually believed by the speaker and hearer that O is salient in the context C_h, and 2) the utterance u_i realizes the proposition that S declares ignorance of[14] a value e_i through the proposition that S does not believe the proposition p_i which contains e_i, then 3) if a sentence p_j is lower than p_i with respect to the ordering O, then the utterance of u_i licenses the scalar implicature (in the context C_i) that S does not believe it is the case that p_j is false, or 4) if p_j is a higher sentence with respect to O, then the utterance of u_i licenses the scalar implicature (in the context C_i) that S does not believe it is the case that p_j is true, or 5) if p_j is an alternate sentence with

[13] Hirschberg gives the following definition of denial: "p_i represents an denial of a subexpression e_i iff p_i is of the form BEL (S, $\neg p_j$) and p_j is simple with respect to e_i" (p. 74).
[14] Hirschberg gives the following definition of declaring ignorance of a value: "p_i represents an assertion of ignorance of a subexpression e_i iff p_i is of the form $\neg$BEL (S, p_j) and p_j is simple with respect to e_i" (p. 74).

respect to O, then the utterance of u_i licenses the scalar implicature (in the context C_i) that S believes that p_j is true.

In order for the conventions above to be useful, the kinds of ordering that support scalar implicatures must be defined in such a way as to provide a formal notion of what it means for a value or predicate to rank higher, lower or alternate on the scale. Comparing the kinds of relations that support scalar implicatures with those that do not, Hirschberg claims that any ordering of elements that can be formally characterized as a partially ordered set (poset) will support scalar implicature. Given two elements ordered in a poset, it is possible to determine whether one is higher or lower than another, or whether the two are alternates with respect to some higher or lower value. Using posets to determine whether a relation can support scalar implicatures identifies entailment as one such relation, and includes other orderings as well. Hirschberg points out that some relations do not support scalar implicature; these relations also do not impose the ordering necessary to create a poset.

An important point to note about Hirschberg's three conventions is that while for the most part they seem to give the right results, they do not explain why these patterns of implicature seem to arise. For example, affirmation of a value in a linear ordering leads to the implicature that higher values are false or unknown, while denial of a value in a linear ordering leads to the implicature that lower values are true or unknown. A pattern may be noted by looking at the following scales.

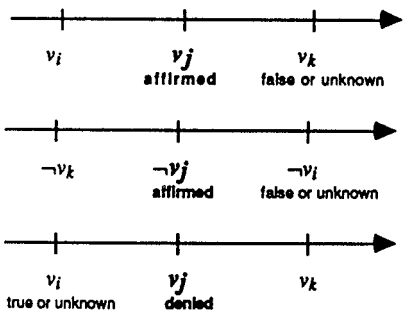

Figure 10: Comparison of Implicature Patterns

The first scale shows the affirmation of a value on a scale. Now, when all of the values on the scale are negated, the ordering is reversed (e.g., a scale of numerals 1, 2, 3 would be reversed to $\neg 3, \neg 2, \neg 1$: in this case, the ordering metric is entailment, and it is easy to see that the ordering would have to be reversed for this metric). Affirming a negative value on such a scale is equivalent to denying the positive value: this is shown in the second scale. According to the rule for affirmation of a value, higher values on the scale are considered false or unknown. Thus, the implicature is licensed that $\neg v_i$ is false or unknown, which is equivalent to the implicature that v_i is true or unknown (shown in the third scale, which is Hirschberg's scale for denial of a value). Thus, once the reversal of the scale takes place, a single rule can account for both affirmation and denial of a value in a linear ordering. In addition, the examples involving alternate values could be accounted for with this rule if we translate them into linear orderings. This could be done as shown in the following diagram.

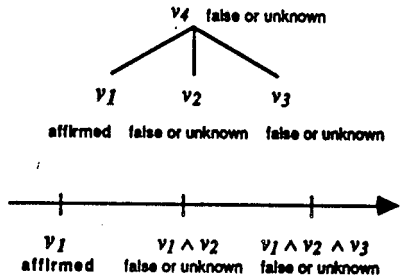

Figure 11: Alternate Values Converted to Linear Ordering

The linear ordering at the bottom of Figure 11 is entailment-based; by affirming a lower value on the scale, a speaker will implicate that higher values (which affirm additional alternate values) are false or unknown. The highest value on the scale, which includes each of the alternate values, would be equivalent to v_4. Once the alternate value ordering has been rewritten as a linear ordering, the generalization concerning denial discussed above will apply to these examples as well.

Without going into detail for each of Hirschberg's rules (and in fact, declaring ignorance of a value is not as straightforwardly accounted for), I would like to suggest that the patterns above indicate that there is a general principle underlying all of these implicatures, presumably relating to strength of information.

In summary, Hirschberg's account goes beyond previous accounts of scalar implicature, both in terms of the patterns of implicature considered and the range of relations that can support these implicatures. Her identification of posets as the basis for determining whether a relation can support scalar implicatures is also superior to previous approaches, which only identified entailment as one such relation and used suspendability as an informal metric for identifying these relations. In the scalar implicature category she identifies and accounts for implicatures that had not been previously noted; however, her account does not include all of the implicatures that have been argued to derive from the first maxim of Quantity (e.g., clausal implicatures, the South of France example). Hirschberg builds in the role of context in the licensing of implicatures, which allows her to make correct predictions where others have not. However, although Hirschberg does indicate where context would play a role, she does not consider how it would play that role (e.g., how one might determine what relation was salient in the context). In addition, her formalizations of what it means to be cooperative and of conversational implicature in general, while they do offer some added insights (e.g., the speaker's belief that it must be mutually believed that an implicature is licensed), for the most part seem to rewriting of Grice's theory in formal language; furthermore, her treatment of cooperativity as merely obeying the maxims seems to miss a generalization concerning the importance of cooperation to rational behavior (these are important issues for a linguistic or philosophical account, though possibly not for a computational one). Finally, her account provides a disjunction of conditions which, while they generally give the right results, seem to miss a generalization concerning an underlying principle about why these patterns of implicature arise.

1.2.3. The Second Maxim of Quantity

Grice provides one linguistic example of the second maxim of Quantity ("Do not make your contribution more informative than is required"). Strictly speaking this maxim is inherently vague, since Grice does not explicitly specify what must be considered in determining how informative a contribution is "required" to be—required in view of what?

Despite the technical vagueness of the maxim, Grice's intention was almost certainly to use the second maxim of Quantity to consider a contribution's informativeness in terms of the purposes of the exchange—just as in the first maxim of Quantity, which it immediately follows ("Make your contribution as informative as necessary (for the purposes of the exchange)"). This interpretation is supported by Grice's brief parenthetical commentary on this maxim:

> (44) (The second maxim is disputable; it might be said that to be overinformative is not a transgression of the Cooperative Principle but merely a waste of time. However, it might be answered that such overinformativeness may be confusing in that it is liable to raise side issues; and there may also be an indirect effect, in that the hearers may be misled as a result of thinking that there is some particular *point* in the provision of the excess of information. However this may be, there is perhaps a different reason for doubt about the admission of this second maxim, namely, that its effect will be secured by a later maxim, which concerns relevance.) (pp. 26–27.)

Grice provided a real-world example relating to the maxim of Quantity as a whole (repeated for convenience):

> (12) If you are assisting me to mend a car, I expect your contribution to be neither more nor less is required. If, for example, at a particular stage I need four screws, I expect you to hand me four, rather than two or six.

The part of this that is relevant here is the expectation that the interlocutor would not provide six screws. This can be extended to linguistic examples, as described in the next section.

The similarity that Grice points out between the second maxim of Quantity and the maxim of Relation ("Be relevant") is obvious. However, it's worth noting that in fact the two are not identical: As interpreted by Grice, Relation only adjures the speaker to provide a response that is relevant to the purposes of the exchange, while the second maxim of Quantity could be interpreted as requiring that the speaker not provide information that goes *beyond* the purposes of the exchange.

1.2.3.1. Implicatures on the Gricean Interpretation

Grice provides one linguistic example of how an implicature might arise based on the second maxim of Quantity. As in the case of the implicatures that arise based on the first maxim of Quantity, it is the infringement of the maxim that leads to the implicature:

(45) A wants to know whether *p*, and B volunteers not only the information that *p* , but information to the effect that it is certain that *p*, and that the evidence for its being the case is that *p* is so-and-so and such-and-such.

B's volubility may be undesigned, and if it is so regarded by A it may raise in A's mind a doubt as to whether B is as certain as he says he is ("Methinks the lady doth protest too much"). But if it is thought of as designed, it would be an oblique way of conveying that it is to some degree controversial whether or not *p*. (pp. 33–34)

I find this example somewhat unconvincing: my intuition says that B would not be trying to imply that *p* is controversial, but rather that in a situation where *p* is controversial A might be more likely to be interested in knowing the evidence on which B is making the claim. In other words, the context in which such information would be required in one in which *p* is controversial. Now, if B takes it to be mutually believed that *p* is controversial, and in fact A does not realize that *p* is controversial, A might be able to infer that *p* is controversial from B's response. I would consider this to be accommodation (cf. Heim 1982) of information that B presupposes is the mutually recognized (i.e., in the common ground), rather than B's conscious creation of an implicature.

Apart from the example above, it does seem to be the case that implicatures can arise based on the second maxim of Quantity. Consider the following example:

(46) A: I'm having a dinner party and I need four more chairs.
B: John has six chairs.

Now, B's response would violate the second maxim of Quantity, since only the information that John has four chairs is required, given the purposes of the exchange (the primary purpose being to find a way for A to get four chairs). However, the admonition that a speaker be cooperative is so strong that, rather than merely interpreting B's response as uncooperative, A is likely to try to find a reason for B's having provided the additional information. In other cases we have seen in which a maxim is violated, the reason for the violation has been the speaker's need to obey another maxim of conversation (e.g., the South of France example, scalar implicature examples). However, no other maxim seems to be coming into play here, so A will have to look for a different reason for B to provide more information than seems necessary. My intuition is that the additional information is used to reinforce the likelihood that John will loan the chairs—in other words, to provide evidence that the plan B is suggesting is a good one for A to adopt. This relies on an assumption on B's part that John's having *more* than four chairs would make John more

likely to loan A the four chairs. So the implicature arises here that John is especially likely to loan the chairs.[15]

The only formalization of the second maxim of Quantity in keeping with the interpretation described above is found in Ginzburg (1990), which is discussed in a later section. However, as we will see, Ginzburg does not discuss *implicatures* that arise based on the second maxim of Quantity; rather, he discusses how it is used to judge the cooperativity or informativeness of a response. To my knowledge, there are no formal accounts of implicatures due to the second maxim of Quantity on the Gricean interpretation.

1.2.3.2. Enrichments (Atlas and Levinson (1981))

Levinson (1987) has suggested that a different class of implicatures, which is introduced and developed in Atlas and Levinson (1981), may be licensed by the second maxim of Quantity. I will refer to this class of implicatures as "enrichments" (from Levinson 1987) to distinguish them from implicatures that arise via the first maxim of Quantity and the implicatures based on the second maxim of Quantity discussed in the previous section. Enrichments are based on an interpretation of the second maxim of Quantity that goes something like this: "Do not make your contribution more informative than is required (in view of what you take to be mutually believed)."

Enrichments arise through a process that is the reverse of the process involved in the licensing of scalar implicatures. With scalar implicatures, the hearer compares what has been said (*p*) with an informationally stronger proposition (*q*); the implicature arises based on that comparison that the speaker could not have said the stronger proposition (*q*). With enrichments, the pattern is exactly the opposite: based on what has been said (*p*), the implicature arises that the speaker really meant an informationally stronger proposition (*q*). (I term this type of implicature "enrichment" because intuitively, the weaker proposition *p* is "enriched" (or strengthened) to the more informative proposition *q*.) The majority of the work that has been done on enrichments is found in Atlas and Levinson (1981) and Levinson (1987). The account in Sperber and Wilson (1988), discussed in a later section, is also similar to this approach in some respects.

To help distinguish enrichments from scalar implicatures, I would suggest a reasoning pattern that underlies their licensing based on Quantity 2; this reasoning pattern may be compared to the one for scalar implicatures. This pattern is related to the account in

[15] Depending on how definite the need for just four chairs is, this response might also be interpreted as suggesting that John could loan all six chairs. Contextual factors would determine which implicature arises here.

Atlas and Levinson, although it differs somewhat for reasons I will mention during the discussion of their account. The general reasoning pattern that underlies enrichments based on Quantity 2 can be described in the following way:

(46) Reasoning pattern for enrichments:
a) The speaker said *p*.
b) Information necessary to infer a stronger proposition *q* is mutually recognized by the speaker and hearer, and accessible to both of them.
c) Because the speaker knows that the information necessary to derive *q* from *p* is already mutually recognized and does not need to be stated, according to Quantity 2 (Say no more than you must), he should not provide this information himself.[16]
d) Therefore, the speaker must have meant the hearer to enrich his statement *p* to the more informative statement *q*.

To develop a formal account of enrichments, a significant challenge is to explicitly characterize what mutually believed information is accessible to be used in the enrichment process (referred to in step (3) of the reasoning process); this is what Atlas and Levinson's account attempts to do.

One of the special concerns with this type of implicature is that given an utterance, the hearer has to be able to determine which of the two maxims of Quantity should apply: given a proposition *p*, how can a hearer determine whether to infer 1) that a stronger implicature *q* is false or unknown (scalar implicature) or 2) that *q* is true (enrichment)? Examples of "maxim clash" will be discussed in more detail in a later section.

In their account, Atlas and Levinson (1981) give (among others) the following examples of enrichments, where the (a) sentence represents what has been said and the (b) sentence represents the enrichment based on the (a) sentence:[17]

(47) a. Kurt went to the store and bought some wine.
b. Kurt went to the store in order to buy some wine.

(48) a. The baby cried and the mother picked it up.
b. The baby cried and the mother of the baby picked it up.

16 This step is necessary to make the process of enrichment relate to the second maxim of Quantity; however, it is possible to characterize the process of enrichment without this step. How this can be done will be discussed further in Chapters III and IV.

17 Many of the examples given by Atlas and Levinson actually turn out to be instances of presupposition or other pragmatic phenomena.

Atlas and Levinson suggest that the way to account for these examples is to extend Grice's maxims by adding a Principle of Informativeness, along with two maxims and conventions that guide an interlocutor in obeying the principle and the maxims. These are the following:

(49) *Maxims of Relativity*
1. Do not say what you believe to be highly noncontroversial, that is, to be entailed by the presumptions of the common ground.
2. Take what you hear to be lowly noncontroversial, that is, consistent with the presumptions of the common ground.

Conventions of Noncontroversiality (among which are)
1. *Convention of Intension (Common Knowledge):* The obtaining of stereotypical relations among individuals is noncontroversial.
2. *Convention of Extension (Exportation) :* If A is "about" t, then
a. If [*t*] is a singular term, [$\exists t\ (x = t)$] is noncontroversial
b. If [*t*] denotes a set, [$\exists t\ (x \in t)$] is noncontroversial
c. If [*t*] denotes a state of affairs or a proposition, [*t* is actual] and [*t* is true] are noncontroversial.

Principle of Informativeness
Suppose a speaker *S* addresses a sentence *A* to a hearer *H* in a context *K*. If *H* has *n* COMPETING interpretations $A^{u1}, A^{u2}, \ldots, A^{un}$ of *A* in the context *K* with information contents $INF(A^{u1})$, $INF(A^{u2})$, ..., $INF(A^{un})$, and G_A is the set of propositions that are noncontroversial in *K*, then the "best" interpretation A^{u*} of *A* for *H* is the most informative proposition among the competing interpretations that is consistent with the common ground.
Let A^{u*} be A^{uj} for the least *j*, $1 \leq j \leq n$, such that $INF(A^{uj} + G_A) = \max INF(A^{ui} + G_A)$, $1 \leq i \leq n$.
The sentence *A* will tend to convey the pragmatic content PRON(*A*) to the hearer *H*: $PRON(A) = INF(A^{u*} + G_{A^{u*}})$ where $G_{A^{u*}}$ is the set of propositions that are noncontroversial in the context and that are "about" what A^{u*} is "about."

The first Maxim of Relativity is a speaker's maxim relating to what is mutually believed, and the second Maxim of Relativity as providing a maxim for hearers. The Conventions of Noncontroversiality provide more specific information about what it means for a proposition (or components of the proposition) to be noncontroversial. The first of these—the Convention of Intension or Common Knowledge—is fairly straightforward, assuming that we have a formal notion of what it means for relations to be "stereotypical"

(the intuition, of course, is fairly clear). The second convention—the Convention of Extension—is somewhat more complicated, and in fact depends upon a notion of "aboutness" which is not well developed in Atlas and Levinson's account. This convention is paraphrased in Levinson (1987) as follows: "the existence or actuality of what a sentence is 'about' is noncontroversial..." (p. 66).

Given the maxims and conventions, the Principle of Informativeness licenses a hearer to enrich the content of what has been said by adding noncontroversial information, thus supporting what Atlas and Levinson call "inference to the best interpretation, the understanding that best 'fits' both the shared background presumptions in the context and the communicative intentions attributable to the speaker in light of 'what he has said' " (p. 42). To give an example of how these additional factors lead to implicature (via the Maxim of Relativity and the first Convention of Noncontroversiality), Atlas and Levinson say, "If a predicate Q is semantically nonspecific with respect to predicates P_i, $1 \leq i \leq n$, but for some j, $1 \leq j \leq n$, P_j is stereotypical of Q s, then in saying [Qt] a speaker will convey [P_jt] ..." (p. 41). This process is shown in the following example:

(50) a. John was reading a book.
b. John was reading a non-dictionary.

In stereotypical situations involving the reading of a book, the book is not a dictionary.

Atlas and Levinson point out that the Principle of Informativeness may clash with the first maxim of quantity. The following examples illustrate situations in which a clash occurs, with the same linguistic form (an indefinite description) being used in both utterances (p. 49):

(51) a. John is meeting a woman this evening.
b. The person to be met is someone other than John's wife, mother, sister, or perhaps even a close platonic friend.

(52) a. I broke a finger yesterday.
b. The finger is mine.

In (51), the first maxim of Quantity results in the implicature in (51b). An argument from first maxim of Quantity could be made for (52) as well, which would lead to the scalar implicature that the speaker is not in a position to say that the broken finger is hers. However, in fact the implicature that does occur here is an enrichment rather than a scalar

implicature; Atlas and Levinson explain this as being due to the principle of informativeness:

> Once again the explanation of the inference lies in what speakers take as stereotypical or conventional behavior. The use of the indefinite description *a finger* leaves it open whose finger was broken, but the speaker's breaking someone else's finger would be regrettable if unintentional and contrary to our social norms if intentional. As noted in the second maxim of Relativity, we are loathe to interpret the utterance so as to impute an abnormal or unnatural act unless there are specific indications to that effect. (p. 49)

It is not clear how "specific indications to that effect" would be addressed in this account.

Additionally, Atlas and Levinson suggest that in cases where no scale can be established, an enrichment will occur rather than a scalar implicature. An example of this is the implicature in (47b), repeated below:

(47) a. Kurt went to the store and bought some wine.
b. Kurt went to the store in order to buy some wine.

Atlas and Levinson claim that a scalar implicature does not arise because *and* and *in order to* are not ordered on a scale (the relevant scale, they say, would be *and* and *or*).

In some respects, Atlas and Levinson's general approach seems basically correct: examples show that speakers do seem to take for granted certain "noncontroversial" information, which is then used by hearers to enrich the content of what has been said. However, their characterization of what information is noncontroversial via the Conventions of Noncontroversiality suffers from several deficiencies. First, the second Convention of Noncontroversiality relies on a notion of "aboutness" which they do not define (and which they do not explicate clearly in their examples). Second, they rely on the notion of default or stereotypical information to identify presumptions that are in the common ground. This notion is vague, and is also not context-specific enough. In fact, a more general notion of "consistent with what is mutually known"—and accessible in a particular context—would seem more appropriate. To illustrate this, consider the following example:

(53) Context: A and B are pirates.
A: How did the battle go?
B: Arr, I broke two arms, a leg, and a finger.

Here, it is not clear that the finger mentioned belonged to the pirate (in fact, it seems much more likely that it was someone else's). Stereotypically, it might still be the case that in most situations where someone breaks a finger it is that person's own finger—but the situation being discussed here is different from most situations, and has its own set of assumptions. To account for the difference in implicatures, it is important to relativize "stereotypical"—or simply "expected"—information to the situation it is a part of, and to the information shared by a specific speaker and hearer. Finally, it is likely that accessibility of information and difficulty of processing should also be considered in order to determine when information can be filled in by the hearer (and left unsaid by the speaker).

1.2.3.3. Conclusion

In summary, we have seen two interpretations of Quantity 2, and considered two different kinds of implicatures that are licensed by these interpretations. Both types of implicature seem to be valid, although they seem very different in character.

Quantity 2 implicatures on the Gricean interpretation involve a comparison between what was said and what "should" have been said, and implicatures arise based on this comparison. These implicatures involve finding a reason that more information was given than might have been expected.

The process which leads to enrichments can be described using a comparison, as I have done, but in fact the enrichment process suggested by Atlas and Levinson does not require comparing the weaker statement provided with an informationally stronger one. Instead, principles are used to strengthen the statement before any comparison is made. This sort of implicature depends upon a notion of mutual belief or common ground, with a concomitant notion of processing an utterance within a common ground, that is not reflected in Grice's approach to implicature. The importance of this notion will be seen in discussion of later accounts (Ginzburg 1989, Sperber and Wilson 1988).

1.2.4. The Maxim of Relation (Be relevant)

Grice provides two examples in which implicatures arise based on the assumption that the speaker is obeying this maxim. The first was discussed in the first part of this chapter, and is repeated below:

(54) A is standing by an obviously immobilized car and is approached by B; the following exchange takes place:
A: I am out of petrol.
B: There's a garage around the corner.
(Gloss: B would be infringing the maxim "Be relevant" unless he thinks, or thinks it possible, that the garage is open, and has petrol to sell; so he implicates that the garage is, or at least may be open, etc.) (p. 32)

This example clearly involves a plan to get gas, and the implicatures that arise are concerned with actions in this plan and conditions required in order for someone to perform those actions (e.g., in order to get gas at a station, the station must have gas, must be open, etc.). The second example is the following:

(55) A: Smith doesn't seem to have a girlfriend these days.
B: He has been paying a lot of visits to New York lately.
B implicates that Smith has, or may have, a girlfriend in New York.

Here, the implicature that arises is due to the need to be relevant to the topic of conversation: determining whether or not Smith has a girlfriend.

Most early theorists ignored the maxim of Relation due to the fact that it is difficult to formalize without formalizing contextual information (Gazdar 1979). More recent, plan-based accounts of implicature (e.g., Thomason 1990, McCafferty 1987) have paid more attention to this maxim. These accounts will be discussed in the final section of this chapter. Relevance theory, developed by Sperber and Wilson (1986), attempts to reduce all of the maxims to just the maxim of Relevance; however, they do not consider the kinds of examples that Grice discussed in this category.

1.2.5. The Maxims of Manner

The only examples Grice explicitly gives for the maxims of Manner are ones in which they are flouted (although he does discuss a piece of data in which an implicature can be attributed to an interlocutor obeying a Manner maxim). One example involves the flouting of the maxim "Be brief" (Grice 1975):

(56)(a) Miss X sang "Home Sweet Home."
(b) Miss X produced a series of sounds that corresponded closely with the score of "Home Sweet Home."
(Gloss: Why has [the reviewer] selected that rigamarole [in (b)] in place of the concise and nearly synonymous *sang* ? Presumably, to indicate some striking difference between Miss X's performance and those to which the word singing is usually applied. The most obvious supposition is that Miss X's performance suffered from some hideous defect. The reviewer knows that this supposition is what is likely to spring to mind, so that is what he is implicating.) (p.37)

As I mentioned in the beginning of this chapter, most of Grice's flouting examples can be reinterpreted as violating a maxim in order to obey another maxim. In this case, it could be argued that the word *sing* implies a certain level of musicality, and that the reviewer believed that ascribing this level of musicality to the performer would violate the first maxim of Quality. By using a longer and more precise form, he was able to avoid this—thus creating the implicature that Miss X's performance couldn't be called "singing."

Another example, in which an implicature arises based on the assumption that an interlocutor is obeying the Manner maxim "Be orderly," can be discerned from Grice's overall discussion of implicature. This is the "temporal succession" implicature that is often associated with the use of the word *and*, as seen in the following example (Grice 1989):

(57) He got into bed and took off his trousers. (p. 8)

Harnish (1976) suggests the following as more specific versions of the maxim of Manner (p. 359):

(58) *Super Submaxim*
Be representational; in so far as possible, make your sayings "mirror" the world.

He then suggested the following submaxims, one of which relates to Grice's maxim "Be orderly":

(59) *Submaxim of Time*
In so far as possible, make the order of saying reflect the order of events.

To my knowledge, there are no other accounts of implicature that focus on the maxims of Manner. The accounts in Horn (1985), Levinson (1987), and Sperber and Wilson (1986) touch on these maxims, and they will be discussed in these sections.

1.3. Reformulating the Maxims

In this section, accounts which reformulate or provide a total account of the maxims (rather than focusing on just one, or treating them independently of one another) will be discussed. In many of these accounts, interactions between the maxims are considered as well.

1.3.1. Harnish (1976)

Harnish (1976) provides a discussion of the Gricean system as a whole, and in particular considers how the different maxims relate to one another. Although his system is not significantly different from the Gricean one, he goes beyond Grice in considering how the different maxims might be weighted with respect to one another, and how a clash in the maxims might be resolved.

Harnish proposes two principles which apply in the case of maxim clash (when a speaker cannot be assumed to be obeying all of the maxims), both of which are principles guiding the hearer's interpretation of what has been said. First, he suggests the Principle of Charity, which goes as follows (p. 344):

(60) *Principle of Charity*
Other things being equal, construe the speaker's remark so as to violate as few maxims as possible.

He also suggests the following Weighted Principle of Charity, for pairs of maxims (p. 344).

(61) *Weighted Principle of Charity* (for pairs of maxims)
Other things being equal, construe the speaker's remark so that it is consistent with the maxim of higher weight.
or
If the speaker has infringed one or another of a pair of maxims, other things being equal, assume that he has chosen to infringe the lowest valued maxim.

The second of these principles requires that there is a weighting or ordering on the maxims. Harnish points out that Grice's example of maxim clash, repeated below, assumes that the maxim of Quality is weighted higher than the maxim of Quantity.

(7) A is planning with B an itinerary for a holiday in France. Both know that A wants to see his friend C, if to do so would not involve too great a prolongation of his journey:
A: Where does C live?
B: Somewhere in the South of France.
(Gloss: There is no reason to suppose that B is opting out; his answer is, as he well knows, less informative than is required to meet A's needs. This infringement of the first maxim of Quantity can be explained only by the supposition that B is aware that to be more informative would be to say something that infringed the second maxim of Quality. "Don't say what you lack adequate evidence for," so B implicates that he does not know in which town C lives.) (pp. 32–33)

Harnish gives the following rationale for the weighting of these two maxims: "If it can be assumed that the speaker S is observing at least the [cooperative principle], then S will pick quality over quantity if only because truly groundless information has at least a good a chance of being wrong as right, and as such would probably not be helpful—thereby violating the [cooperative principle]" (p. 343). He further suggests that "... relevance is at the top, controlling most of the others" (p. 341).

Harnish's discussion is firmly situated in the Gricean framework. The value of his observations is primarily in highlighting some of the less obvious issues within that framework, such as the need to weight or order the maxims with respect to one another.

1.3.2. Horn (1985)

Building on the work by Grice, his own and Gazdar's work on formalizing the first maxim of Quantity, and Atlas and Levinson's Principle of Informativeness, Horn (1985) reformulates the maxims of conversation to create a more principled system. Horn's Q and R principles are intended to replace all of the maxims of conversation except the maxim of Quality. They correspond to two forces identified by Zipf as influencing language: the "Principle of Least Effort" (speaker's economy) and the "Force of Diversification" (auditor's economy). As stated by Horn (including a quote from Zipf), "Given *m* meanings, the speaker's economy will tend toward 'a vocabulary of one word which will refer to all the *m* distinct meanings', while the hearer's economy will tend toward 'a vocabulary of *m* different words with one distinct meaning for each word' " (p. 11). These

two forces have been seen by Zipf and others as the forces that drive language change. Horn's Q principle corresponds to the Force of Diversification (auditor's economy) and the R principle to the Principle of Least Effort (speaker's economy). The two principles are given below (p. 13):

(63) The Q principle (hearer-based):
Make your contribution sufficient (cf. Quantity 1);
say as much as you can (given R).
Lower-bounding principle, inducing upper-bounding implicata

(64) The R principle (speaker-based):
Make your contribution necessary (cf. Relation, Quantity2, Manner);
say no more than you must (given Q).
Upper-bounding principle, inducing lower-bounding implicata.

As with Grice's maxims of conversation, implicatures arise based on the hearer's belief that the speaker is obeying the maxims. Although Horn's two principles are superficially quite simple, the way implicatures arise based on them is rather more complex.

The Q principle replaces Grice's first Quantity implicature. Simply put, the Q principle says that given a speaker's statement *p*, the recipient may infer "at most *p*" (since if the speaker could have said more, she would have). In cases involving scalar predicates, the mechanics of this involve establishing a "Horn scale," an entailment-based ranking of the different possible utterances, and then inferring that values higher on this scale than the one affirmed do not hold. The implicatures that arise based on this principle are "comparative" in the sense described in the introduction to this chapter.

The R-principle is the opposite of the Q-principle: given a speaker's statement *p*, the recipient may infer something more than *p*. This principle replaces the second Quantity maxim, the maxim of Relation, and the Manner maxims. Horn gives indirect speech acts as a classic example of this sort of implicature (e.g., "Can you pass the salt?" taking on the additional meaning that the speaker is requesting that the hearer pass the salt). This principle is intended to cover the examples that were discussed by Atlas and Levinson (1981) as deriving from the Principle of Informativeness, as well as ones deriving from Relation and the Manner maxims.

It is clear from the description of the effect of these two principles that they may "clash"—how does a hearer know whether the Q principle or the R principle is being obeyed in any particular instance? Horn notes the problem of principle clash in examples like the following (p. 19):

(65) Implicature based on the Q principle:
I slept on a boat yesterday. →
The boat was not mine.

(66) Implicature based on the R principle:
I lost a book yesterday. →
The book was mine.

In (65), the Q principle leads to the implicature that it is not the case that any more specific information could be given. The scale established would be one in which the more specific information "The boat was mine" is higher than the more general information expressed by the actual utterance. The Q principle then generates the implicature that this more specific information is not the case. In the example in (66), the R principle generates the implicature that the utterer meant more than what was actually said (in particular, a "stereotypical relation" is assumed to hold between the book and the speaker); this probably has to do with presuppositions associated with the verb *lose* (one typically possesses the things one loses) (Roberts, p.c.). Although Horn does note that the two principles may clash, he does not provide any guidelines for reconciling them in this paper.[18]

In addition to being silent on the question of principle clash, Horn's Q and R principles make wrong predictions in some cases. For example, it is possible to identify a scalar predicate without the generation of a Q-based implicature. Let's return to the example in (21):

(21) A: I'm having a dinner party and I need four more chairs.
B: John has four chairs.

Here, a scale could be identified based on the numeral determiner in B's response (since when a scale can be identified, the Q principle applies). This would lead to the implicature that B has no more than four chairs. This prediction is clearly incorrect, since no

[18] Horn later augments his system with a resolution schema from Levinson (1987), discussed in the next section.

implicature of this sort is generated. Instead (remaining within Horn's framework) something like the R implicature would apply, to give the implicature that B is offering to loan A the chairs. If some way were provided of determining that the Q implicature does not hold in this case (even though its application is licensed by the presence of a scale), the R-based implicature might be a result of amplifying the content up to what is judged to be the speaker's point—but here again, there is no information given that might give a clue as to how the speaker's point would be identified. The incorrect prediction here may be related to another problem with Horn's system, discussed in Levinson (1987), which is that it is not entirely clear how the R-principle would lead to the kinds of implicatures Grice discusses as being due to the maxim of relevance.

The major advantage this system has over Grice's maxims of conversation is that the two principles Horn suggests are independently motivated, both through Zipf's generalization with respect to language change and in a number of other cases Horn surveys. In addition, a distinction is made between the two kinds of inferencing patterns that lead to implicature ("base" vs. "comparative," to use the terms introduced at the beginning of this chapter). However, although the two principles look fairly simple, it turns out that to really make this work, a lot of other information has to be supplied about things like what constitutes saying "no more than you must," and how one would judge what the speaker's intended point is. These are key pieces of information for identifying which implicatures arise, and they are completely unaddressed by this system (although possibly augmenting this account with the formal account developed by Atlas and Levinson (1981) would at least partially address this problem).

1.3.3. Levinson (1987)

Levinson (1987) takes the work in Atlas and Levinson (1981) and Horn (1985) as the basis for another reformulation of the Gricean system, which actually turns out to be a formalization of Grice's original maxims. He includes Horn's Q-principle, but breaks Horn's R-Principle into the I-Principle described in Atlas and Levinson (1981) and a Gricean maxim of Relevance. He also assumes that at least some of the maxims of Manner (which he calls the M principle) will be required, although he does not discuss this point in detail. The Q and R principles, with Levinson's labels, are described below, along with how they influence the speaker and addressee.

(67) *Q-Principle*
Hearer-oriented: "Make your contribution sufficient"

Speaker's maxim: Make your contribution as informative as is required for the current purposes of the exchange". Specifically: don't provide a statement that is informationally weaker than your knowledge of the world allows, unless providing a stronger statement would contravene the I principle.

Recipient's corollary: Take it that the speaker made the strongest statement consistent with what s/he knows, and therefore that:
(a) if the speaker asserted A(W), and <S,W> form a HORN SCALE, then one can infer K~(A(S)) i.e. "the speaker knows that the stronger statement would be false"
(b) if the speaker asserted A(W) and A(W) fails to entail an embedded proposition q, which a stronger statement A(S) would entail, and S & W are "about" the same semantic relations (form a contrast set), then one can infer: ~Kq, i.e. Pq, P ~q (i.e. The speaker doesn't know that q obtains, or equivalently, it is epistemically possible that q or that not-q obtains) (pp. 67–68)

The two clauses in the Recipient's corollary to the Q-principle include the scalar implicatures first formalized by Horn (1972) (clause a) and the clausal implicatures formalized by Gazdar (1979). Other kinds of implicature that arise via the first maxim of Quantity (e.g., the South of France example) are addressed by the introductory portion of the Q-principle. Levinson begins to address the issue of maxim clash in this principle, by eliminating stronger statements that would result from the application of the I-principle from consideration. Thus, the proposition in (47a), if uttered, would not be compared with the proposition in (47b).

(47) a. Kurt went to the store and bought some wine.
b. Kurt went to the store in order to buy some wine.

A simpler solution to this part of the maxim clash problem would be to apply the I-principle first, so that the proposition to which the Q-principle applies (e.g., (47a) is already strengthened (e.g., to 44b).[19] This would make it unnecessary to refer to the I-principle in the definition of the Q-principle.

19 Ordering the two principles with respect to one another is reminiscent of the ordered rules used in phonological analysis.

(68) *I-Principle*
Speaker-oriented: "Say no more than your hearer needs, given Q"

Speaker's Maxim: The maxim of minimization
"Say as little as necessary" i.e. produce the minimal linguistic clues sufficient to achieve your communicational ends, bearing Q in mind.

Recipient's corollary: Enrichment Rule
"Amplify the informational content of the speaker's utterance, by finding a more *specific* interpretation, up to what you judge to be the speaker's m-intended point. Specifically:
(a) Assume that stereotypical relations obtain between referents or events, *unless* (i) this is inconsistent with what is taken for granted, or (ii) the speaker has broken the maxim of Minimization, by choosing a prolix expression
(b) Assume the existence or actuality of what a sentence is "about", if that is consistent with what is taken for granted
(c) Assume referential parsimony—avoid interpretations that multiply entities in the domain of reference; specifically, prefer coreferential readings of reduced NPs (pronouns or zeros). (p. 68)

Levinson's I-principle is quite similar to the one proposed in Atlas and Levinson (1981), with the addition of the clauses (i) and (ii) in clause (a), and clause (c). Clause (a.i) addresses the fact that other contextual information ("what is taken for granted") may take precedence over stereotypical information (as in the pirate example). Clause (a.ii) includes implicatures like the one discussed in Grice's example of flouting a manner maxim; on this account, stereotypical associations with the word *sing* would be prevented because the speaker chose the prolix expression *produced a series of notes that corresponded with the score of* instead. Clause (c) relates to another issue that Levinson discusses in this paper.

Levinson suggests the following resolution schema for cases in which the two principles clash:

(69) Revised resolution schema:
(i) genuine Q-implicatures from tight Horn scales and similar contrast sets of equally brief, equally lexicalized linguistic expressions 'about' the same semantic relations, take precedence over I-implicatures.
(ii) In all other cases, the I-principle induces stereotypical specific interpretations, *unless:*
(iii) there are two (or more) available expressions coextensive in meaning, one of which is unmarked in form and the other marked in form. In that case, the unmarked form carries the I-implicatures as per usual, but the marked form Q/M-implicates the nonapplicability of the pertinent I-implicatures. (p. 71)

The resolution schema given in (69) is somewhat redundant, including some of the information in the recipient's corollaries of the two maxims. Clause (iii) is intended to account for the following pattern (p. 70):

(70) a. "John could solve the problem"
b. John solved the problem (I-implicature)
c. "John had the ability to solve the problem"
d. It's possible that John didn't solve the problem (Q-implicature)

Levinson notes that Horn's R-Principle ("Say no more than you must") involves two kinds of minimization, one involving the content of what is said and one involving the form of what is said. These are summed up as follows (p. 72):

(71) *Minimization1:* semantically general expressions preferred to semantically specific ones;
Minimization2: "shorter" expressions (with less units of speech production) preferred to "longer" expressions.

He then notes a correlation between inferential patterns associated with minimal forms of both types: 1) expressions which are semantically minimal lead to enrichments with stereotypical information (e.g., the temporal enrichment associated with *and*), as do expressions which are minimal in form (e.g., *John stopped the car* normally implies that the car was stopped in the usual—stereotypical—way) and 2) when an informationally stronger expression is not used, it may be inferred that (for some reason) the expression could not be used; this is also the case when a briefer expression is not used (e.g., *John caused the car to stop* implies that the car was stopped in an unusual way).

While Levinson agrees with Horn that there are two principles or maxims that govern how much information a speaker should provide, he suggests that Grice's second maxim of Quantity (his informativeness, Horn's R-principle) and the maxim of Relevance cannot be conflated as Horn proposes. He ultimately concludes that Grice's original maxims, made more formal with the above definitions, look better than anything else that has been proposed to date.

The difficulties with this account are essentially some of the same difficulties that were associated with those accounts. In particular, no way of identifying the speaker's intended point is provided (i.e., Levinson does not attempt to formalize the maxim of Relevance and the contextual information it would need to refer to). Although the resolution schema he proposes accounts for many of the cases of implicature clash, it does so in a

somewhat cumbersome, stipulatory way. In particular, the inferential pattern associated with the two kinds of minimization is addressed in two different places, rather than through a general comparative principle (as Horn attempted to do in his Q-principle). Finally, Levinson is agnostic about whether Manner implicatures can be conflated with the Q or R principle.

Despite the problems mentioned above, in this account Levinson neatly brings together the accounts in Atlas and Levinson (1981) and Horn (1985), and if we consider some of the general properties of implicature discussed in the introduction to this chapter, we can see that this framework captures many of them. First, there is a general distinction between comparative implicatures (via the Q-principle) and base implicatures (via the R-principle). Second, there is a general inferencing process which, in combination with some sort of maxim of Relevance (which Levinson does not attempt to describe), leads to the base implicatures associated with an utterance. This account touches on most of the main issues involved in conversational implicature, leaving the issue of Relevance the most undefined.

1.4. Reductionists (Sperber and Wilson 1988)

Sperber and Wilson (1988) reduce the maxims of conversation even further than Horn, to just a single one: relevance. They provide a definition of relevance, and derive all instances of meaning—both implicature and "explicature" (their name for the propositional content of an utterance)—from the cognitive process through which a hearer determines an utterance's "relevance" in their technical sense. Their account focuses primarily on the inferential and contextual aspects of conversational implicature mentioned in the introduction to this chapter, as opposed to cooperativity with respect to the purposes of the exchange. While previous accounts had accepted Grice's general framework (including the cooperative principle and the general strategy for working out implicatures), Sperber and Wilson's account describes an entirely new one.

A difficulty with recapitulating Relevance Theory is that Sperber and Wilson provide definitions of new terms that replace traditional, familiar ones, then use their new definitions in further definitions. This makes it difficult to understand many of their ideas without glosses for the terms in their definitions, or (as in the presentation in Sperber and Wilson (1988)) without a step-by-step explanation of each of the concepts. In this section, I will try to generally explain how Sperber and Wilson's approach works, connecting unfamiliar terminology to traditional notions when possible. I will go into greater detail in

explaining the parts of their theory that build on (as opposed to reinterpreting) existing theories. To explain how the approach works, I will begin with what happens when an individual utters something.

When an individual U utters p, it is, in Sperber and Wilson's terminology, an act of *ostensive-inferential communication*. Their definition of ostensive-inferential communication is as follows[20]:

(72) *Ostensive inferential communication:* the communicator produces a stimulus which makes it mutually manifest[21] to communicator and audience that the communicator intends, by means of this stimulus, to make manifest or more manifest to the audience a set of assumptions {I}. (p. 63)

Based on the ostensive-inferential production of p, a hearer H can infer that a speaker S intends to make a set of assumptions {I} mutually manifest. H can also assume that {I} includes the assumption that S has this informative intention (that is, H can assume that S intends to make mutually manifest the assumption that S intends to make {I} mutually manifest).

Over and above these assumptions, H can assume that *p* is *optimally relevant* (in the sense mentioned in the Principle of Relevance, below):

(73) *Principle of relevance*
Every act of ostensive communication communicates the presumption of its own optimal relevance. (p. 158)

The presumption of *p*'s optimal relevance may be thought of as also being included in {I}[22]. This presumption of relevance drives the remainder of the inferencing process; as Sperber and Wilson put it, "The very act of communication creates expectations which it then exploits" (p. 37). The presumption of optimal relevance is described in more detail below:

[20] This definition replaces clauses (1) and (2) of Grice's definition of meaning-nn.

[21] For the purposes of this discussion, the term "mutually manifest" (and the term "manifest") in the above definition may be taken to mean "mutually known" ("known") or "mutually recognized." Sperber and Wilson argue against the notion of mutual knowledge, but their approach may be understood without a detailed explanation of this notion. Their notion of "mutual manifestness" will be revisited in Chapter II.

[22] This corresponds roughly to clause (3) in Grice's (revised) definition of meaning-nn.

(74) *Presumption of optimal relevance*
(a) The set of assumptions {I} which the communicator intends to make manifest to the addressee is relevant enough to make it worth the addressee's while to process the ostensive stimulus.
(b) The ostensive stimulus is the most relevant one the communicator could have used to communicate {I}. (p. 158)

An individual determines how relevant a stimulus is according to the following two-part definition of relevance of a phenomenon ("phenomenon" being a term which subsumes "utterance"):

(75) *Relevance of a phenomenon (comparative)*[23]
Extent condition 1: a phenomenon is relevant to an individual to the extent that the contextual effects achieved when it is optimally processed are large.
Extent condition 2: a phenomenon is relevant to an individual to the extent that the effort required to process it optimally is small. (p. 153)

Relevance of a phenomenon as defined by Sperber and Wilson is explicitly a relation between an utterance (phenomenon) and an individual, and implicitly involves a context as well. This is due to the definition of optimal processing, which is a relation between an utterance and a context:

(76) *Optimal processing of an assumption:*
Achieving maximal relevance involves selecting the best possible context in which to process an assumption: that is, the context enabling the best possible balance of effort against effect to be achieved. When such a balance is achieved, we will say that the assumption has been *optimally processed.* (p. 144)

In order to evaluate the relevance of an utterance, it is first necessary to process it optimally within a context. This is a feature of Sperber and Wilson's theory that is significantly different from previous approaches; for them, the processing of an utterance crucially involves the construction of a local context within which the effects of the utterance are evaluated. That is, rather than determining the contribution of the utterance to a local

[23] Although this definition includes the term "comparative," it is not connected to comparative implicatures like those which arise due to Horn's Q-principle. In fact, as I'll discuss later, it is difficult to see how Sperber and Wilson's theory accounts for most Quantity 1 implicatures.

context that is accepted as given, the local context is enriched in ways that facilitate the processing of the utterance within it.[24]

The requirements on relevance stated in (75) are thus requirements on the construction of the local context in which it is to be interpreted as well: within the constructed context it must have significant effects (that is, it must contribute to the context in a significant way), and constructing a context in which the utterance is relevant (and then processing the utterance within that context) must not require too much effort. The greater an effect the utterance has on a context, the more relevant that utterance is—and the less effort required to process it in a context, the more relevant it is. The context in which a perfect balance is reached between contextual effects and processing effort is the context in which the utterance is optimally relevant.

Optimal processing, like relevance, involves determining an utterance's contextual effects. The process through which contextual effects arise is a cognitive one, and involves two steps: the construction of a context, and the application of deductive rules to the contents of that context to develop new assumptions or to change the strength of existing assumptions. The new assumptions and/or the change in strength of existing assumptions are the contextual effects of the utterance (e.g., the change in the context). The cognitive elements that Sperber and Wilson suggest underlie this process are (conceptual) memory and a deductive device.

In Sperber and Wilson's theory, concepts in a person's memory include up to three kinds of information: logical (identifying "deductive rules" concerning the concept, for concepts corresponding to lexical entries of words like *and*), encyclopedic (containing descriptive information about the concept) and/or lexical (the natural language word or phrase that expresses the object). When confronted with an utterance, the hearer begins with the existing context, then adds to it assumptions from previous deductive processes, encyclopedic information about concepts in the context or in the new assumption, and/or information about the immediate environment. The deductive device then operates on the information in the context to develop new assumptions. Sperber and Wilson describe the deductive device as follows:

[24] Although superficially this seems quite different from accounts in which an utterance is processed in a previous context, in fact it can be interpreted similarly. The local context may be defined as the part of the total context which contains accessible information (such as the previous utterance and inferences drawn from it), to which information from the larger context may be added.

> The device we envisage is an automaton with a memory and the ability to read, write and erase logical forms, compare their formal properties, store them in memory, and access the deductive rules contained in the logical entries for concepts. Deductions proceed as follows. A set of assumptions which will constitute the axioms, or initial theses, of the deduction are placed in the memory of the device. It reads each of these assumptions, accesses the logical entries of each of its constituent concepts, applies any rule whose structural description is satisfied by that assumption, and writes the resulting assumption down in its memory as a derived thesis. Where a rule provides descriptions of two input assumptions, the device checks to see whether it has in memory an appropriate pair of assumptions; if so, it writes the output assumption down in its memory as a derived thesis. The process applies to all initial and derived theses until no further deductions are possible. (pp. 94–95)

Sperber and Wilson constrain the operation of the deductive device (so that, for example, it doesn't apply recursively to its output in an infinite loop, as would be licensed by the rules of conjunction or addition) by restricting it to certain kinds of deductive rules, ones that lead to *non-trivial logical implications*.[25]

> (77) *Non-trivial logical implication:* A set of assumptions {P} logically and non-trivially implies an assumption Q if and only if, when {P} is the set of initial theses in a derivation involving only elimination rules, Q belongs to the set of final theses. (p. 97)

After the deductive device has operated on the assumptions in the constructed context, the result will be a set of assumptions {I}—the very set referred to in the definition of ostensive inferential communication, the one that the speaker intends to communicate by producing *p*.

To briefly encapsulate the above discussion, the general idea is this:

1) if a speaker S ostensively produces *p*, then (by the principle of relevance) the assumption that *p* is optimally relevant will be communicated
2) in order for *p* to be optimally relevant:
   a) *p* will make mutually manifest a set of assumptions {I} which is relevant enough to make it worth a hearer H's effort to process the stimulus

[25] The difference between trivial and non-trivial logical implications, and between the type of rules Sperber and Wilson don't and do allow, can be intuitively seen by comparing the "introduction" rule of conjunction (which would allow the deductive device to take the assumption corresponding to "It's raining" as input and give the assumption corresponding to "It's raining or the sun is shining" as output—obviously a trivial implication in the sense that it does not contribute to the context in a meaningful way) and the "elimination" rule of modus ponens (which would allow the deductive device to take the assumptions corresponding to "If it's raining we'll watch a movie" and "It's raining" to arrive at the assumption corresponding to "We'll watch a movie"—obviously non-trivial).

b) *p* will be the most relevant stimulus S could have used to communicate {I}

3) in order for *p* to be the most relevant stimulus S could have used, if *p* is processed in the context in which its effects and the effort to process it are in the best possible balance (i.e., if *p* is optimally processed), then the balance of effects and effort that results from processing *p* to get the set {I} is better than could have been achieved by any other stimulus.

Probably the most significant problem with relevance theory is the definition of optimal processing of an assumption (and the determination of which of two possible utterances is more relevant), which does not lead to predictions about what the set {I} will be (and hence about what implicatures will arise in a given situation). Specifically, the problem here is the indeterminacy of the definition of the best possible context, which is stated to be "the context enabling the best possible balance of effort against effect to be achieved" (p. 144). The question is, how is the best possible balance to be determined? I consider this to be the weakest point of Sperber and Wilson's approach, because their answer to this question seems to lead to a theory that is unfalsifiable. They state:

> A rational communicator, who intends to make the presumption of relevance manifest to the addressee, must expect the processing of the stimulus to confirm it [the presumption of relevance]. . . . To recognize the communicator's informative intention, the addressee must discover for which set {I} the communicator had reason to think that it would confirm the presumption of relevance. (p. 165)

Sperber and Wilson then discuss two different ways in which the addressee might choose the right hypothesis about the contents of {I}. One strategy is to enumerate all possible hypotheses, evaluate them, and then select one, while the other is to develop a single hypothesis, test it, and select it if it seems correct. They then point out that (and this must be due to the fact that the effort involved in constructing a context and processing the assumptions in it is greater if it is the second, or third, or tenth context that has been constructed, since effort is cumulative) ". . . the order in which hypotheses are tested affects their relevance. As a result, the principle of relevance does not generally warrant the selection of more than one interpretation for a single ostensive stimulus" (p. 167). More specifically:

> An addressee who is using [the item-by-item testing strategy], and who wants to maximise cognitive efficiency, will test hypotheses in order of accessibility. Suppose he arrives at a hypothesis which is consistent with the principle of relevance. Should he stop there, or go on and test the next hypothesis on the ground that it might be consistent with the principle of relevance too? It is easy to show that he should stop there. Suppose he does go on, and finds another hypothesis which verifies the first part of the presumption of relevance: the putative set {I} is relevant enough. In these circumstances, the second part of the presumption of relevance is almost invariably falsified. If it was at all possible, the communicator should have used a stimulus which would have saved the addressee the effort of first accessing two hypotheses consistent with the principle of relevance, and then having to choose between them. (p. 168)

So, because he is assuming that the communicator provided an optimally relevant stimulus, the hearer will assume that the set {I} that is being communicated is the first set that occurred to him (i.e., his first hypothesis). But how does the hearer arrive at an initial hypothesis? Sperber and Wilson state:

> A coded stimulus gives immediate access to a highly determinate set of concepts: the code itself determines which concepts are activated, and moreover assembles them into a logical form which can be directly used as an assumption schema. The context provides ways of completing these assumption schemas into full hypotheses.
>
> Once an initial set of hypotheses has been recovered, the addressee can add to it by assuming that the set {I} includes further assumptions contextually inferable from those already recovered . . . The important point is that, given the cognitive environment, given the initial context, and given the stimulus, some hypotheses are more accessible than others, and this means that they require less processing effort. (p. 167)

This provides some suggestions about how the initial hypothesis is established, but does not actually *predict* what the initial hypothesis will be (other than, circularly, that it will be the most relevant one!). Sperber and Wilson admit that there are unanswered questions (e.g., how the assumption schemas are filled out, and—crucially—what the order of accessibility of hypotheses is), but state that these questions apply to cognitive psychology as a whole. Still, these questions are a problem in that they limit the theory's ability to make predictions.

Finally, we may consider how Sperber and Wilson would treat the kinds of implicatures discussed in other accounts. Unfortunately, they do not discuss the same examples that have been discussed in these accounts, which makes comparison difficult. Generally, the kinds of examples we have seen so far have been categorized according to

the Gricean maxims as belonging to three categories: Quantity 1 implicatures, enrichment implicatures (in which informational content is made more precise) and relevance implicatures.

The enrichment implicatures that have been seen as arising via Atlas and Levinson's Principle of Informativeness would most likely be treated by Sperber and Wilson as what they call "explicatures"—developments of the logical form of the proposition *p*. Sperber and Wilson state that there are three subtasks involved in the identification of the logical form of a proposition (starting with the logical form arrived at by decoding the utterance): disambiguation, reference assignment and enrichment. Of these, I will discuss disambiguation and enrichment as being representative of or similar to the kinds of implicature have been treated as arising via the Principle of Informativeness.

Examples of disambiguation are similar to examples like (78) below, in which it is considered likely that the book in question is not a dictionary. The example described by Sperber and Wilson in this category is the following:

(78) The child left the straw in the glass.

The question is, how do we determine that the meaning of *straw* in this sentence is a "drinking tube" and not a "cereal stalk"? Sperber and Wilson state:

> A child drinking from a glass with a straw is a stereotypical event which we assume, as do most other people working on the organisation of memory, is recorded in the form of a single chunk, stored at a single location in memory and accessed as a single unit. Such a chunk constitutes a highly accessible encyclopaedic context in which the drinking-tube interpretation of ([78]) can be processed at minimal cost. (p. 186)

This discussion is reminiscent of Atlas and Levinson's Conventions of Noncontroversiality (and Levinson's Recipient's corollary to the I-principle), which consider stereotypical relations among individuals to be noncontroversial and therefore to be usable in determining the best interpretation of an utterance. In comparing the two approaches, we may note the following: 1) Atlas and Levinson's Conventions of Noncontroversiality are more formally stated, and 2) Sperber and Wilson's account follows from their claim about how memory is organized, making it more explanatory than the Conventions of Noncontroversiality, which are basically just stipulated.

Some implicatures that have been seen as arising via the Gricean maxim of relevance can be treated straightforwardly using relevance theory. Here is an example that gives rise to what Sperber and Wilson call implicatures (p. 194):

(79) Peter: Would you drive a Mercedes?
Mary: I wouldn't drive ANY expensive car.

Two implicatures immediately arise based on this, which illustrate the two kinds of implicatures Sperber and Wilson describe: implicated premises and implicated conclusions. The implicated premise here is *A Mercedes is an expensive car*, and the implicated conclusion is *Mary wouldn't drive a Mercedes*. The deductive rule involved is modus ponens, and the form of the deduction goes like this:

(80) Form of the deduction to implicated premises and conclusions
I wouldn't drive ANY expensive car. ($P \rightarrow Q$)
A Mercedes is an expensive car. (P)
I wouldn't drive a Mercedes. (Q)

This is one of the strongest areas of Sperber and Wilson's work, since they have identified a distinction between implicatures that is connected with principles of deduction (which are built into their framework). This is one area that is pretty clear-cut: given the fact that there is a cognitive deductive device that identifies the premises and conclusions of statements, it is unproblematic to see what those premises and conclusions would be.

In addition to these implicatures, which the listener could be fairly certain were intended by the speaker, other implicatures could arise if the listener enriches the context with further assumptions. In fact, the hearer would have to assume that the set {I} that the speaker intended to convey includes more than just the two implicatures above, since those implicatures could have been conveyed by an easier-to-process response (e.g., "No"). In describing how further implicatures could be arrived at, Sperber and Wilson suggest that the context could be enriched with the assumption in (81), allowing the implicated conclusion in (82) to be deduced (again through modus ponens).

(81) People who refuse to drive expensive cars disapprove of displays of wealth.

(82) Mary disapproves of displays of wealth.

This illustrates an interesting feature of Sperber and Wilson's theory, which is that there is essentially no cut-off on what can be taken as implicated by the speaker (implicatures that are speaker-backed and therefore clearly intended to belong to the set {I} discussed in the definition of ostensive inferential communication above) and the assumptions that are derived because of the hearer's uninvited enrichment of the context (and that are thus the hearer's responsibility).[26]

Sperber and Wilson do not discuss "plan-based" relevance implicatures like the one in Grice's gas station example; I assume these would be accounted for by bringing into the context assumptions about how people achieve goals such as getting gas (i.e., information about goals and plans to achieve them), then drawing inferences based on them. However, Sperber and Wilson do not discuss plans as part of the inference process at all.

Sperber and Wilson do not discuss examples of implicatures due to the first maxim of Quantity. In fact, their theory does not always seem to be able to handle these implicatures, especially if it is not reinforced with a maxim of Quality (which they argue is not necessary). Consider the following example:

(83) Context: A and B are discussing a mutual friend, Mary, who B knows has three children.
A: How many children does Mary have?
B: Two.

Now, according to Sperber and Wilson, all that is necessary here is that B's utterance makes some set of assumptions manifest to the audience which is relevant enough to make it worth the addressee's while to process the utterance. The first question here is, what does it mean for the set of assumptions to be relevant enough? In this case, it should provide information pertaining to A's question (presumably there would be an open proposition of some sort in the memory of the deductive device corresponding to the question, so that the only contextual effects the utterance would have would relate to the question). So, processing the stimulus leads to the addition of the assumption that Julie has two children.

[26] This seems to be a problem, since Sperber and Wilson first characterize communication in terms of the hearer's search for the contents of the set {I} that the speaker has in mind, but then say that not only does the hearer go beyond this set {I}, it is even unclear at what point {I} has been left behind.

But in this context there is an additional (scalar) implicature that Mary has exactly three children, or only three children. In traditional approaches, this implicature arises via a comparison of what was said with what could have been said, and (based on the first maxim of Quantity combined with the maxim of Quality) the hearer infers that if the speaker did not offer a more informative proposition, she was not in a position to do so. We might try to use the principle of relevance in this way as well—intuitively, if the speaker knows that Mary has three children but did not say so, she is not providing the most relevant answer. However, as written by Sperber and Wilson, the principle of relevance (and the embedded presumption of optimal relevance) has nothing to say about this. There is *no* requirement that the set of assumptions associated with the utterance provided by the speaker be more relevant than any other any other set of assumptions she could have provided. The only requirement on the set of assumptions communicated is that it be "relevant enough" for the hearer to process it—it doesn't have to be the set of assumptions that would be most relevant to the hearer. (The requirement of optimal relevance merely states that the *stimulus* be the most relevant one relative to the set of assumptions that the speaker intends to communicate.) To apply the definition to the above example, knowing that Mary has two children will lead to some cognitive effects with very little processing. So, it should be relevant enough for the hearer to process, regardless of whether Mary actually has three children. The second part of the presumption of optimal relevance requires that the stimulus provided be the most relevant one for communicating the set of assumptions that it communicates. There is no consideration here of other sets of assumptions that might be communicated. So A can't infer that if B were in a position to communicate something of greater interest to A, B would have. There is an inherent lack of cooperativity here that Sperber and Wilson in fact consider to be a positive feature of their theory:

> Achieving optimal relevance, then, is less demanding than obeying the Gricean maxims. In particular, it is possible to be 'optimally relevant' without being 'as informative as required' by the current purposes of the exchange (Grice's first maxim of quantity): for instance by keeping secret something that would be relevant for the audience to know. It seems to us to be a matter of common experience that the degree of co-operation described by Grice is not automatically expected of communicators. People who don't give us all the information we wish they would, and don't answer our questions as well as they could, are no doubt much to blame, but not for violating principles of communication. (p. 162)

On Sperber and Wilson's account, it does seem to be the case that something like the scalar effect can arise in specific situations, with the correct context. Consider the following example (Roberts, class notes), in which Sperber and Wilson would predict that no scalar implicature arises:

(84) Context: If all the cookies are gone, then A must bake more.
B (to A): #John ate some of the cookies.

In this case, B's utterance, rather than inducing a scalar implicature, is actually anomalous. (A's response would most likely be "So?") This is because in the context given, B's utterance is not relevant enough to be worth processing by A (it has no contextual effects). The following example, with a different context, shows when this utterance could be relevant:

(85) Context: If John ate some of the cookies, A will punish him.
B (to A): John ate some of the cookies.

In this situation, the utterance is relevant (since it has contextual effects), and in fact Sperber and Wilson's account correctly predicts that no scalar implicature arises.

Generally, although Relevance theory does predict at least one situation in which a scalar implicature does not arise, I don't see any way to predict that a scalar implicature will occur.

Advantages of this theory over Grice's maxims are that it directly addresses the role of context and the inferencing process that are involved in conversational implicature, and attempts to find independent motivation for the one maxim it contains. However, the independent motivation it relies on—theories of human cognition—is for the most part highly speculative at this stage. The whole discussion of how the context is enriched hinges on how information is stored by people and how they access it and use it in creating new contexts. Sperber and Wilson assume some basic rules that are part of the deductive device in the human mind, but even these are speculative. Thus, it is very difficult to use Relevance theory to make predictions about what implicatures would arise, and it is very tempting to use information about what implicatures arise as the basis for development of the theory of cognition—which is supposed to be independently motivated. So, until more is known about human cognition, it's just not possible to make the kind of predictions one would like to see from a theory of this sort. There are a couple of instances (mentioned

above) in which the theory seems to make some clear predictions, especially when implicatures arise as inferences drawn by the deductive device applied to the constructed context. In other cases, much of the discussion is just as vague as the discussion provided by Grice (1975) and Horn (1985).

Perhaps most importantly, Relevance theory makes wrong predictions or no predictions with respect to some key examples of implicature. Probably the most noteworthy of these is the Quantity 1 implicatures. Nowhere do Sperber and Wilson themselves discuss Quantity 1 implicatures, and it is not clear how a hearer would know to enrich the context so that the Quantity 1 implicature is inferred. It seems likely that Sperber and Wilson would handle this by making it an "explicature" (altering the actual propositional form), and for scalar implicatures this would almost have to involve something like Horn's scales being present in the human mind somehow (along with the deductive device and encyclopedic entries). Thus, accounting for the scalar implicatures would probably involve making claims about cognition in order to get the facts about implicatures right—which as mentioned above is circular reasoning. At any rate, the theory as it stands is inferior to Grice on this account.

Finally, in extending the notion of relevance, Sperber and Wilson have left behind the original focus of the maxim of Relation. Their account does not give a special status to "the purpose of the exchange," to use Grice's phrase, which plays a crucial role in determining what implicatures will arise. This point is brought out in Ginzburg (1990), a plan-based account of informativeness discussed in the next section.

1.5. Plan-based Theories of Implicature

Beginning with an account by Thomason (1990), a number of plan-based accounts of implicature have been developed. The value of these accounts is two-fold. First, they allow for a formalization of the notion of "the purpose of the exchange" which is so central to Grice's own description of the maxims. This is most obviously significant for the maxim of Relation, which has been impossible to characterize without formalizing this notion, but it is also critical for the maxims of Quantity, which should be "bounded" or constrained by the purpose of the exchange. Second, since plans crucially rely on the notion of intention, they are consistent with implicatures as instances of meaning-nn—meaning that arises through the recognition of the speaker's intention to convey that meaning.

The account in Thomason (1990) identifies the general principles that guide most of the other accounts. However, the way these principles are realized in these accounts is quite different.

1.5.1. Thomason (1990)

Thomason (1990) is a programmatic approach that focuses on both conversational implicature and accommodation of presupposition, seeing them both as instances of a more general process of accommodation. Thomason suggests bringing together the conversational record, which contains information that is public, with plans of interlocutors. He then proposes a principle of accommodation which leads to both conversational implicatures and accommodation of presupposition.

In Thomason's approach, there is "a public, evolving representation of the state of a conversation: the conversational record" (p. 335). This representation contains information that is public, in the sense that it is mutually recognized (or, as Thomason puts it, "can be supposed to be available to all the conversational participants" (p. 335)). In addition to information about what has been said, the conversational record contains a structure that determines the *presumptions* it contains: "the things that are supposed, or established, at a given stage of the conversation." This structure is updated throughout the conversation. Thomason suggests the following picture of how the conversational record is altered by assertion (p. 338):

Figure 12: Effect of Assertion on the Conversational Record

He points out, however, that this simple picture does not take into account "the strategic planning of speech acts" (p. 338).

Thomason points out an important difference between Grice's approach and Thomason's own view of the conversational record and its role in communication: on Grice's view, "the participants of a conversation are attempting to work on each other" (i.e., get each other to adopt certain beliefs and intentions) (p. 339), while on Thomason's

view, the participants in a conversation "are working together to build a shared data structure" (p. 339). The attitudes that interlocutors take toward this shared data structure may vary: Thomason considers that the propositions contained in it are presumed rather than believed. In certain contexts, however, interlocutors may believe what is contained in the conversational record as well.

Having informally characterized the conversational record, Thomason brings together the conversational record with representations of interlocutor's mutually recognized plans. He points out the importance of intention in Grice's work, especially in his definition of meaning-nn (as paraphrased by Thomason, "a speaker S means *p* if S intends the hearer (1) to believe *p* and (2) to do so partly in virtue of the recognition of intention (1)" (p. 342)). Relating this to plan recognition, Thomason says, "To come to believe *p* partly in virtue of recognizing intention *i* is to come to believe *p* by recognizing a plan that involves *i*" (p. 342). He provides the following revised definition of meaning-nn:

(86) To mean *p* is to intentionally reveal an intention to make *p* asserted through the hearer's recognition of the status of an intention or plan of the speaker's. (p. 345)

The final piece in Thomason's approach is the bringing together of two kinds of pragmatic data: accommodation of presuppositions and conversational implicature. He does this by describing a notion of obstacle elimination which consists of the following steps:

(87) 1. recognizing the plan of your interlocutor
2. detecting obstacles to the plan in the form of certain false preconditions of subgoals belonging to the plan
3. adopting the goal of making these preconditions true
4. forming a plan to carry this out
5. acting on this plan
(p. 343)

Thomason then describes the principle behind accommodation (which he offers as an alternative to Grice's cooperative principle) in terms of obstacle elimination:

(88) Adjust the conversational record to eliminate obstacles to the detected plans of your interlocutor. (p. 344)

Finally, Thomason identifies two kinds of implicature based on accommodation: 1) accommodated revision of the background presumptions, leading to "background implicatures" (accommodated presuppositions) and 2) accommodated revision of the input .

proposition, leading to "assertional implicatures" (conversational implicatures). He sees cooperation in conversation as relating to "a mutual plan of the conversation" (p. 355), which would involve discourse goals such as the goal of providing an answer to a question. Given these ideas, Thomason suggests that:

> ...we should replace the maxims with a general theory of group planning of public data structures, with special application to conversational planning. This theory should then yield many principles, more specific than the maxims, and deriving from the idea that what a speaker means should fit in and cohere with the conversational plan, and with the reconstructed plans of our conversational partners. (p. 356)

In addition to the general account described here, Thomason sketches how some examples of conversational implicature might be treated. Since these are sketches rather than full accounts, I will not go into them here. A crucial point in these examples, however, is the fact that in many cases plans are involved in calculating the implicature. Extensive work has been done in the field of artificial intelligence in the area of formalizing plans and developing rules through which one individual can infer the plan of another individual. In this work, plans are defined as collections or sequences of actions which, when performed, achieve a goal. In addition, the mental attitude of "having a plan" may be defined as having certain beliefs and intentions concerning the actions that make up a plan. (Plan formalism and rules for inferring plans will be discussed in more detail in Chapter II.) Thomason distinguishes between two kinds of plans: discourse plans (which primarily involve modifying the conversational record) and domain plans (which primarily involve real-world activities). The general procedure Thomason proposes is that a proposition corresponding to what is asserted is added to the conversational record. Plan recognition takes place (via the application of plan inferencing rules), and then an answer is provided which eliminates obstacles to the plan.

Thomason's programmatic approach has served as inspiration to more formal and complete accounts of implicature. His idea of using plans, which are formal in nature (especially as developed by those in the artificial intelligence), to formalize "the purpose of the exchange"—and thus determine what implicatures will arise—has the potential to offer a much more constrained and explicit account of implicature than the one developed by Grice. His notion of the evolving conversational record as the basis for the creation of implicature is well motivated by Grice's own work and observations. I will adopt most of

the general ideas in this account in my own work, with the exception of Thomason's version of the cooperative principle.

1.5.2. McCafferty (1987)

McCafferty (1987) develops a plan-based theory of implicature that focuses on implicatures that arise via the maxim of Relation (i.e., relevance implicatures). Specifically, McCafferty considers the two relevance examples offered by Grice (the Smith dating example and the out of gas example). He modifies the context for these examples, showing how the account he has developed leads to different implicatures in each of the different contexts.

McCafferty's general approach is as follows. Given an utterance in a context, the hearer attempts to infer the speaker's plan. A discourse plan—in Thomason's sense, a plan which primarily involves modifying the conversational record—that links the speaker's utterance with the speaker's goal will be inferred; inferring this plan may or may not require inferring a domain plan—which primarily involves real-world activities—as well.

The plan inferencing formalism that McCafferty assumes relies on plan inferencing rules of the standard type (e.g., Allen 1983, etc.), which refer to preconditions and effects of actions (discussed in detail in Chapter II). McCafferty assumes that information about the way actions are linked to one another via preconditions and effects is represented in a "planning net":

> (89) Planning net: The representations of a set of actions can be combined into a semantic net. They form a directed labeled graph. The nodes are events and states (the actions, their preconditions, etc.). The directed labels give the relationships; the labels will be "precondition," "body," and "effect." (p. 39)

The planning net contains all of the actions related to some action. To take one of McCafferty's examples, suppose Willa picks up a Michelin Guide (describing different restaurants in town). A planning net associated with this action might include two different possible goals: one of eating at the restaurant, one of robbing the restaurant. The net will include actions like going to the restaurant, sitting down at a table, pulling out a gun, etc. These actions may be linked with one or more of the goals in the planning net.

Plan inferencing rules are used to find a path through the planning net that results in a single plan that is consistent with the observed action and information about the probable goal. McCafferty develops a set of rules that include plan inferencing rules as well as

general principles governing speaker behavior which may also guide him in inferring the plan.

Unlike Thomason, McCafferty does not assume that a conversational record plays a role in the plan inferencing/implicature creation process. Instead of being mutually recognized or "public," McCafferty's plans are more consistent with the Gricean approach, in which the speaker's intention is to "work on" or create some response from the hearer (in the form of beliefs and intentions that the hearer adopts).

To see in more detail how McCafferty's approach works, we may consider one of his examples. As mentioned above, McCafferty considers various contexts for the utterances in question and accounts for differences in the implicatures that arise. I will review the version of the Smith dating example that is most like Grice's example.

(90) A: Has Smith been dating anyone?
B: He's been flying to New York every week-end.
...A and B mutually know that Smith goes to New York on the weekends either to attend to business or to date. Other things being equal, they consider the two explanations to be equally likely. Suppose as well that his doing business in New York does not imply anything about whether he is dating someone. (p.68)

McCafferty's account begins with B's response to A's question. B's discourse goal is taken to be to answer A's question, based on the following rule (p. 123):

(91) If a speaker asks a question ϕ, and ϕ's semantic interpretation is the set of answers G, then the speaker might be intending to make knowing which answers in G are the true answers a conversational goal.

The action of utterance has been observed. A must now infer a plan that links the action of utterance with the action of answering the question.

To infer the plan, A may first consider a domain planning net, which contains actions and goals related to Smith's flying to New York every week-end. This planning net would look as follows:

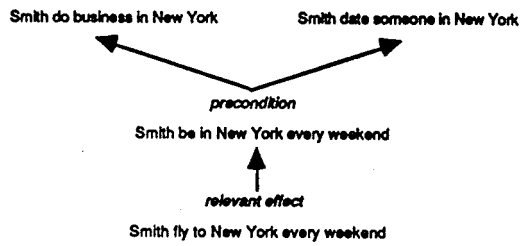

Figure 13: Planning Net for Smith's Domain Plan

Plan inferencing will refer to this plan, and will require the following rules.

(92) If a speaker utters a declarative sentence ϕ, and p is the semantic interpretation of ϕ (in the context), then the speaker (by default) intends[27] that the hearer believe p. (p. 70)

(93) If a speaker intends that a hearer believe p, and knowing p allows the hearer to reconstruct a [domain] plan—or at least makes that plan as likely as any other; then the speaker might be intending that the hearer conjecture this plan. (p. 80)

(94) If a speaker intends that a hearer recognize a plan; then the speaker might be intending that the hearer believe that one of the events of the plan holds. (p. 71).

Using these rules, the hearer can find a path through the planning net for possible speaker plans associated with B's utterance in (90). This "discourse" planning net describes the actions and goals in the speaker plans that might possibly be related to the action of utterance. By relying on the rules above, A can determine that the B's discourse or speaker plan was the following:

[27] Although McCafferty initially formulates his rules by referring only to speaker intention, he later notes that in fact "Gricean" intentions are what are relevant here: speaker's intentions that are recognized by the hearer. In fact, as has been discussed in previous sections, it is the mutual recognition of intention that is required for implicatures to be generated.

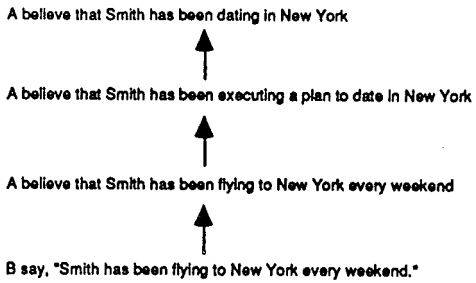

Figure 13: B's Speaker Plan

The linkage between the first (bottom) and second actions in the plan arises via the rule in (92). The link between the second and third actions arises via the rule in (93), with the plan that A is able to reconstruct being a plan in which Smith flies to New York every week-end in order to date someone. The line between the third and fourth actions arises via the rule in (94), with the event in question being Smith's action of dating someone in New York.

In addition to the dating example, McCafferty provides an account of the gas station example. The account is similar to that of the dating example, with the addition of several rules that concern a speaker's suggesting that the hearer adopt a particular plan (e.g., an action is suggested that is part of the plan, the speaker's belief that the plan is feasible, etc.).

Finally, McCafferty develops a view of conversation that includes a conversational context, conversational goals ("goals that the participants have for the conversation"), and domain plans. This part of his account is more general, and reflects more of the insights in Thomason (1990) concerning the building of a set of shared presumptions. In this section, McCafferty shows how goals and plans can be introduced and developed through a conversation. As in other parts of his account, the rules used here are still quite specific in nature. Although he assumes certain overarching conversational principles (such as the existence of conversational goals, domain goals, domain plans, etc.), he does not formalize them. In addition, he establishes no formal connection between conversational goals (which might include a goal of constructing a plan to see a movie, to use one of

McCafferty's examples) and domain plans (which might include specifying an initial plan of seeing a movie to a more detailed domain plan of seeing a Bogart film). (If a domain plan to see a movie is specified to seeing a Bogart film, intuitively the conversational goal is now to construct a plan to see a Bogart film as well.) In McCafferty's account, these two kinds of things are formally independent of one another.

McCafferty's account represents one of the first attempts to develop a truly formal account of implicatures that arise via the maxim of relevance. The rules he proposes in combination with the representation of plans and planning nets allow implicatures to be explicitly calculated. The role of context is included in his account as well. In addition, McCafferty distinguishes between domain goals and conversational goals, locating both of these in the common ground of the conversation.

McCafferty's approach is limited by the representation of plans that he is using. In addition, the rules he provides are of several different kinds: some seem quite related to traditional plan inferencing rules, while others are specific to particular lexical items. Although he assumes that an interlocutor's response must address the conversational goals, he provides no overarching requirement (cf. Grice's cooperative principle) that would ensure this. His account of what it means to answer a question is also quite informal. Finally, it is not clear how his account could be extended to other kinds of implicatures besides relevance implicatures.

1.5.3. Ginzburg (1990)

Ginzburg (1990) offers a situation-semantics account of informativeness which he then extends to a maxim of quantity/relevance. Ginzburg's account is of special interest because of his emphasis on goal-fulfillingness as a primary contributor to the informativeness of an utterance, and his bringing together the maxims of Relevance and Quantity.

Basically, Ginzburg provides a way to order utterances in terms of their degree of informativeness. His approach is designed to account for the generalization that the informativeness of an utterance is dependent on what is already in the context, as well as how the information provided (in combination with what is in the context) relates to the goal. Specifically, there are three different kinds of circumstances in which two utterances can be ordered with respect to a goal: 1) when one utterance is goal-fulfilling and another is not, 2) when both utterances are goal-fulfilling, and 3) when neither utterance is entirely goal-fulfilling. To account for this, Ginzburg's ordering takes into account the interaction between the utterance and the context (in other words, how the context is "updated" by the

utterance) as well as the goal that the utterance is intended to fulfill. Ginzburg provides three examples to illustrate the three kinds of circumstances above, which I will discuss one at a time:

(95) Three kids, Tom, Dick and Harriet, are playing outside, one of whom, *Dick*, does not know the name of the president.
Tom to *Dick*: My dad is the President, so you do what I say.
Dick to *Harriet*: Who is he?
Harriet to *Dick*:
(a) He's called Tom Smith.
(b) His dad isn't the President. (pp. 2–3)

This example illustrates a situation in which only one of the utterances is goal fulfilling, and highlights the way context or what is known interacts with the proposition expressed by the utterance to influence the utterance's informativeness. Dick's goal in this situation is generally to find out whether he has to obey Tom (assuming he would have to obey the President's son), and specifically to find out whether Tom is the president's son. Given the fact that Dick does not know who the president is, the response in (a) will not fulfill his goal of finding out whether the Tom is the president's son. (The only way the (a) response would be goal-fulfilling would be if Dick knew the president's name and also assumed that if Tom had the same surname it would follow that he was the president's son.) The (b) response, on the other hand, is goal-fulfilling.

(96) Adam is searching for Betty's house, knowing only that he is in the right neighborhood. He encounters Carla and asks for directions... we assume that the house sought is the one house in the neighborhood possessing a Rococo ceiling, while it, together with a few others, is also equipped with a metal door.
Carla: (a) It has a metal door.
(b) It has a Rococo ceiling.

The two responses in (a) and (b) differ in informativeness depending on the context. Ginzburg describes two contexts: if there is a power outage and utter darkness, it will be impossible for Adam to locate the house by looking in windows to find a Rococo ceiling. So (a) will be more informative, even though it does not limit the possibilities as much as the (b) utterance. If there is not a power outage, however, (b) will be more informative since it reduces the candidate houses to just a single one.

(97) Adam is searching for a friend's house, in conditions of darkness and desolation. Utterance alternatives:
(a) It's the tallest building on campus.
(b) It's the tallest building on Palm Drive.

In Ginzburg's account, the crucial feature of this example is the fact that more information is provided in the (a) utterance than is necessary for Adam to achieve his goal, given a plan that involves walking around and looking for the tallest building. Ginzburg also uses this example to highlight the importance of the plan or scheme through which the goal will be fulfilled—since the (a) utterance will require Adam to walk all over campus comparing buildings, while the (b) utterance only requires Adam to walk down Palm Drive. Although Ginzburg notes the importance of the plan here, as we will see his account does not actually build a comparison of plans into determining informativeness.

Ginzburg incorporates context into his informativeness ordering by ordering not utterances themselves, but the updated epistemic/mental states that result from adding them to the previous epistemic state. He is uncommitted as to what these epistemic states are, saying that they might be the mutually recognized information often called "the common ground," or they might be something else (e.g., the hearer's belief state, or what the speaker believes the hearer's beliefs to be). By ordering epistemic states rather than utterances, he captures the generalization that the informativeness of an utterance depends on what is known (and, if we assume that the epistemic state is the common ground, mutually known).

Goal-fulfillingness is incorporated in a somewhat more complex way, and may best be understood as part of the definition of informativeness. Informativeness of an utterance u is defined relative to an epistemic state e, a goal g, and a scheme Sch. Ginzburg states that schemes are similar to plans in AI, but gives only informal examples of them. Importantly, in his formalism, only one scheme can be involved in the determination of an utterance's informativeness.

An utterance's informativeness is represented with an ordered pair whose first member comes from the set {0, 1} and whose second member identifies the update associated with the utterance (relative to an epistemic state, a goal and a scheme). The numeral that is the first member of the pair indicates whether the update is goal fulfilling (1 if it is, 0 if it isn't). Ginzburg summarizes this with the following definition (p. 14).

(98) $...\text{Inf}_{e,g,\text{Sch}}(u) = \langle 1, \text{Update } (e, u)_{\text{Sch}} \rangle$ if u is goal fulfilling
$\langle 0, \text{Update } (e, u)_{\text{Sch}} \rangle$ otherwise

Next, a set which includes all pairs of the type above is defined, as follows:

(99) Let INF (e, g, Sch) $=_{def}$ {0, 1} x {z | ∃u such that z= Update (e, u)$_{Sch}$}

Finally, an ordering $>_{inf}$ on the set of INF (e, g, Sch) is defined, which depends on several other orderings. I will give Ginzburg's definition (p. 14) below, then explain each of its clauses individually.

(100) We define the informativeness ordering on INF (e, g, Sch) as follows:
<i, s> $>_{inf}$ <j, t> iff one of the following:
1. i > j
2. i = j = 1 and t $>_{epistemic}$ s[28]
3. i = j = 0 and s $>_{g}$ t

In the definition above, i and j range over the set {0, 1} and s and t range over the set of updates (consistent with the definition of INF (e, g, Sch) as a set of numeral-update pairs).

Clause (1) of the definition states that the informativeness of one update is ordered before the informativeness of another update if its first (numerical) element is greater than the first element of the other. Since there are only two possible values for this first element, 0 and 1, this clause boils down to i = 1 and j = 0—in other words, the update in the first is goal-fulfilling and the second one is not. So according to this clause, a goal-fulfilling update is more informative than a non-goal-fulfilling one. Ginzburg terms this clause the goal-fulfilling principle. It addresses the first example, in which a response that Tom is not the president's son is more informative than giving his name.

Clause (2) applies when both updates are goal-fulfilling. In this case, the informativeness of one utterance will be ordered before the other if the epistemic state represented by its update is epistemically ordered after the other epistemic state. (Intuitively, this amounts to the idea that an interlocutor shouldn't give more information than is necessary to fulfill the goal—the second maxim of Quantity). The epistemic ordering of one state before another depends (at least partially) on the anchoring of the parameters in that state,[29] in several ways. If an epistemic state has no unanchored parameters it will be epistemically ordered before a state that does have unanchored parameters. The fewer objects a parameter is anchored to, the greater the epistemic ordering

[28] Note: Ginzburg actually writes s $>_{epistemic}$ t; however, I believe this to be a typographical error based on his description of the meaning of this clause.
[29] Anchoring of parameters is something like supplying values for arguments of a predicate.

of a state containing it (so that if the set of things a parameter is anchored to in one epistemic state is a subset of the set of things it is anchored to in another state, the first state will be ordered before the second). Ginzburg calls this the upwards monotonicity principle. He cites it as applying in the example in (97), where knowing that it's the tallest house is on Palm Drive is more informative than knowing it's the tallest building on campus given a scheme of walking around and comparing the heights of buildings—even though saying it's the tallest building on campus is more informative in an absolute sense.

Clause (3) applies when neither update is goal-fulfilling. In this case, the informativeness of one utterance will be ordered before another if the epistemic state represented by its update is more goal fulfilling than that of the other. Ginzburg calls this the downwards monotonicity principle. This clause applies to the second example in the case where darkness prevails: knowing that the house has a Rococo ceiling cannot help fulfill the goal when it is impossible to see inside, while knowing that the house has a metal door is partially goal-fulfilling if the plan is to walk from house to house touching the doors.

Ginzburg's account of informativeness successfully builds in the crucial role of context in contributing to the informativeness of an utterance, in that he orders not utterances, but the updates that result from adding them to the existing context. His focus on goal fulfillingness is crucial, as he shows in his examples. However, the way in which he formalizes goal fulfillingness misses the significant role that plans (or schemes, in his terminology) play in determining the goal fulfillingness of an utterance/update. The problem is as follows.

Ginzburg's definitions allow for only a single scheme, and in fact informativeness varies depending on the scheme. There is no mechanism for ranking utterance-scheme combinations: one scheme has to be taken as given and used as the basis for the ordering. Yet it might be intuitively obvious that one utterance is more informative than another, because the scheme associated with it is preferable to the scheme associated with the other. This is illustrated with the following example:

(101) Suppose that Alan is planning a party and needs four more chairs to accommodate all the people who are attending. The following facts are known to Alan and Carla: Betty lives next door to Alan, Carla lives across town, and Alan has very little money. Alan tells Carla he needs four chairs for his party; Carla has the following utterance options:
a) Betty has four chairs.
b) I have four chairs.
c) Kmart has chairs on sale this week.

Underlying each of the utterances in (101) is a plan: in (a), it's a plan to borrow four chairs from Betty; in (b), it's a plan to borrow four chairs from Carla; and in (c) it's a plan to buy four chairs. These plans can be ordered in terms of Alan's preference for carrying them out: the first will involve the least difficulty, the second somewhat more (in terms of transporting the chairs), and the third is especially undesirable considering Alan's financial situation. All of the utterances are goal fulfilling.

Using Ginzburg's framework, each of the utterances in (101) can only be evaluated according to a single scheme. In most of his examples Ginzburg treats schemes as being contextually determined; it might be possible to distinguish the first two schemes (which involve borrowing) from the third (which involves buying) based on contextual salience (e.g., Alan might have a scheme in mind of borrowing the chairs), but it is unlikely that the first two could be distinguished from one another (unless Alan had one of the two schemes in mind already, which might or might not be the case). More importantly, there is a clear ordering between the utterances in terms of how they fulfill the goal, even though all three are goal fulfilling. Ginzburg provides no way to order utterances that are goal-fulfilling except in terms of providing too much information (downwards monotonicity).

Ginzburg might say that the ordering on the utterances in (101) does not have to do with informativeness, but has instead to do with something like helpfulness. However, the ordering on such utterances plays the same role with respect to implicature that Ginzburg's informativeness ordering plays. Ginzburg relates informativeness to implicature with the following maxim of quantity/quality:

(102) If $u_1, u_2, \ldots, u_n$ are the alternatives for a speaker in discourse situation Ds, and if u_j is maximal in $Inf(e, u, g)_{Sch}$, then u_j should be uttered. (p. 19)

Given a "(precluding) constraint that a non-true utterance should not be chosen," (p. 19; cf. Grice's maxim of Quality) the idea is that if the speaker does not provide the maximally

informative utterance relative to a given goal and scheme, then the speaker can be assumed not to know that it is true. In combination with the definition of informativeness, this maxim can account for the basic type of Quantity 1 and scalar implicatures, even ones that are goal dependent—the first account that I am aware of to do so. However, it could not account for an implicature that would arise from the utterance of (101c) to the effect that Carla is not able or willing to suggest a plan that involves Alan borrowing the chairs from her—yet if such a plan is clearly preferable to one in which Alan must buy the chairs, this implicature would in fact arise. What's more, the mechanism that would cause it to arise seems to be the same as in Ginzburg's maxim of quantity/quality in conjunction with some sort of quality maxim—but one that compares plans as well as goal-fulfillingness.

To summarize, Ginzburg's account captures the idea that informativeness of an utterance is relativized to a goal and a context, by ordering different updates of an epistemic state in terms of the goal-fulfillingness of the updates. The ordering he develops makes it possible to formally account for the full range of weak implicatures due to the first maxim of Quantity. The limitation of the scalar accounts of these implicatures was that scales could be used only when sentences were being compared that were the same except for a single expression in a sentence, this expression then being compared to others on a scale. Ordering the updates associated with utterances makes it possible to compare such sentences, as in the scalar accounts, and also to compare other kinds of goal-fulfilling updates. Thus, in Ginzburg's account, scalar implicatures would be a subset of the Quantity 1 implicatures, all of which would arise based on an ordering.

A problem with Ginzburg's account is that his notion of goal-furtheringness is not related to plans in any way, which keeps him from being able to account for some differences in informativeness that might arise. In addition, although he uses his account of informativeness to develop a maxim of Quantity/Relevance that can lead to a weak form of implicatures due to the first maxim of Quantity (as in Hirschberg 1986), he does not identify specific implicatures associated with uttering a "non-maximal" utterance (e.g., the implicature in (97c) that Carla would not be willing to loan the chairs herself, "strong" scalar implicatures, etc.).

1.6. Conclusion

This chapter has provided an overview of the kinds of data that have been termed conversational implicature, and the various accounts that have been proposed of this data. The theory I will develop in the next three chapters will extend to all of these categories, focusing in particular on the kinds of implicature identified by Grice. Before moving on, I'll review this data, and summarize the accounts that have been provided to date.

1.6.1. Review of the Data

As mentioned in the introduction to this chapter, it is possible to distinguish between two general classes of implicature: base implicatures, which arise just from the utterance alone (combined with an assumption of cooperativity), and comparative implicatures, which arise when what was said is compared to alternatives which, if they had been provided, would have been more cooperative.

Base implicatures include Grice's Relevance implicatures (e.g., "There's a station around the corner" implicating that the station is open and has gas to sell) and Quality implicatures (that the speaker believes that what has been said is true, and has adequate evidence for saying it). In addition, the enrichments discussed by Atlas and Levinson (1981), Levinson (1987), and Sperber and Wilson (1988) are included in this class. This category also includes implicatures that arise based on Grice's Manner maxim "Be orderly" (e.g., "John pulled his pants off and jumped into bed."). Some of these implicatures are somewhat different from most of the implicatures originally identified by Grice in that they are not always crucially connected to what Grice termed "the purpose of the exchange" (although they can be); they seem instead to involve a process of inferencing based on mutually recognized information, some of it stereotypical or encyclopedic in nature.

Comparative implicatures especially include the Quantity 1 implicatures, which arise on the assumption that the speaker has provided the best utterance she could. Scalar implicatures (e.g., "Mary has three chairs" leads to the implicature that she does not have four) are a sub-category of this type. The Quantity 2 implicatures (e.g., "John has six chairs" implicating that he would be especially willing to loan four in a context in which a need for four chairs has been expressed) also fall into this category. In addition, comparison may be made with respect to utterance form, as seen in the implicatures that arise when a "prolix" form is used (e.g., "Miss X produced a series of sounds that corresponded closely with the score of "Home Sweet Home" implicating that her performance was not good enough to warrant the use of the word "sing," and examples

like *John had the ability to solve the problem*). In both cases, a weak implicature arises to the effect that the speaker could not have provided the preferred alternative; strong implicatures as to why the preferred alternative could not be provided then arise based on contextual information.

1.6.2. Summary of Previous Accounts

In this summary the various accounts of implicature that have been proposed, I am mostly concerned with identifying the aspects of those accounts that have the most significance for the account I will eventually propose. For this reason, I will not touch on every account, but instead will focus on specific ones. After reviewing Grice's account, I will review other accounts of implicature in terms of the two classes of implicature discussed in the previous section.

The original framework proposed by Grice for explaining conversational implicature focused on furthering the "purpose of the exchange," and identified specific maxims that speakers could be assumed to follow as a way of doing this. Although Grice himself did not explicitly suggest a weighting of the maxims with respect to one another, the fact that the purpose of the exchange appears in two of them (Relevance and Quantity) as well as in the Cooperative Principle itself suggests that he considered it to be primary. As has been noted (e.g., Harnish (1976), and cf. Lewis (1969)), the maxim of Quality is also essential, since if the speaker is not following it, there is no way of guaranteeing that the information he is providing is helpful (its helpfulness will depend on whether it happens to be true). In addition to maxims relating to the purposes of the exchange, Grice also identified maxims which seem to be related to the processing of the actual form of what was said. Grice's account, while it extended over a wide range of data, was highly informal. Of the kinds of data that are now considered to be conversational implicature, the only kind he did not identify were the category of enrichments and Quantity 2. Both base and comparative implicatures were included in Grice's account, although he himself did not identify them in this way. For the most part, comparative implicatures arose through violation or flouting of one of Grice's maxims, on the assumption that the speaker was obeying some other maxim or the Cooperative Principle in general.

Within the category of base implicatures, enrichments have been discussed primarily by Atlas and Levinson (1981), Levinson (1987), and Sperber and Wilson (1988). In Levinson (1987), these implicatures arise through a modified version of the I-Principle originally proposed in Atlas and Levinson (1981); for Sperber and Wilson, they

arise—together with Relevance implicatures—through a single maxim of Relevance. In both accounts, enrichments arise through a process of inferencing to a mutually recognized set of assumptions (although Sperber and Wilson do not strictly require mutual recognition). The inferencing rules used in this process are more carefully delineated in Sperber and Wilson, but how information is used in the inferencing process is still somewhat speculative on their account. What information is available for inferencing is more simply described in Levinson (1987), but the complexity that Sperber and Wilson attempt to capture may be necessary for a full account of the inferencing that occurs. At any rate, these implicatures arise based on the information that is taken to be mutually recognized (and accessible to both speaker and hearer) along with inferencing rules that can be applied to that information to lead to the addition of new inferred information. This makes context of critical importance in determining what implicatures will actually arise based on an utterance.

Accounts of Relevance implicatures, another type of base implicature, have been developed by Sperber and Wilson (1988), Thomason (1990) and McCafferty (1987). Sperber and Wilson's account addresses some of the inferencing that seems to underlie this type of implicature, but does not include a representation of "the purpose of the exchange" that is so crucial for many of the examples in this category. The plan-based account of McCafferty (1987), which uses representations of plans and goals to formalize the purpose of the exchange and refers to information contained in the linguistic context, provides a more satisfactory account of these implicatures. However, McCafferty's account is limited to Relevance implicatures, and does not provide an overarching cooperative principle of any kind. The programmatic approach of Thomason (1990) sketches a much more comprehensive picture, but without the details required in a full account. Thomason's approach involves a conversational record which includes the (mutually recognized) plans of interlocutors, as well as a new version of the cooperative principle phrased in terms of plans.

To date, comparative implicatures due to the maxim of Quantity have been best addressed by Ginzburg (1990). Ginzburg defines orderings on informativeness that are—as Grice originally intended—bounded by the purpose of the exchange. Most other accounts of implicatures due to the first maxim of Quantity have focused on specific subcategories of these implicatures (scalar and clausal), and these have been treated independently of one another (Gazdar 1979, Levinson 1987); Ginzburg's account includes these and others through a single mechanism. However, Ginzburg's focus is on accounting

for informativeness, not implicature, and further inferencing would have to take place to extend his informativeness ordering to determine the specific implicatures that would arise. In addition, Ginzburg's orderings only compare utterances with respect to goals, not plans. The data that Ginzburg discusses, and the patterns associated with Quantity 1 implicatures that he notes, are not as extensive as those discussed by Hirschberg (1986); I am assuming that the general pattern of informativeness I discussed at the end of the discussion of her approach would fall out of Ginzburg's orderings.

Finally, comparative implicatures involving the form of utterances (e.g., Grice's flouting example, etc.) have been discussed by Horn (1985) and Levinson (1987). Levinson accounts for these by blocking inferences based on stereotypical information when prolix (longer) forms are used. This seems to miss the generalization that the same inferencing pattern is used for both this type of implicature and the ones that are concerned with semantic content (e.g., Quantity implicatures).

1.6.3. Summary

Previous work has shown that a fully adequate theory of conversational implicature must include the following elements: 1) a representation of the mutually recognized conversational context, 2) a formalization of "the purpose of the exchange," 3) a cooperative principle governing the behavior of interlocutors with respect to the purpose of the exchange, which will lead to the base and comparative implicatures described above, and 4) inferencing rules and constraints on how those rules apply to information in the context. In Chapter II, I will discuss technical preliminaries necessary for the first two of these elements. In Chapter III, I will propose a theory that includes the third and fourth of these elements.

CHAPTER II
TECHNICAL PRELIMINARIES

2.0. Introduction

In Chapter I, I concluded by identifying four critical elements of a theory of conversational implicature. In this chapter, I will describe the technical preliminaries necessary to formally represent the first two of these elements: a representation of the mutually recognized conversational context (or common ground) and plans and plan-inferencing rules necessary to characterize the purpose of the exchange. The account of implicature I will develop brings together a representation of the conversational context of utterance with a representation of the "public" or mutually recognized plans of interlocutors in a conversation. In Chapter III, I will develop a theoretical framework which includes the other elements in theory.

In representing the context of utterance—or the common ground for the conversation—I will make use of Discourse Representation Theory (DRT), a dynamic (context-change) semantic theory that has already been used as a level of representation that includes both semantic and pragmatic information (Kadmon 1987 (diss.), 1990, Roberts 1987 (diss.), 1989). I will discuss the general idea of the common ground and its structure, then provide a description of an intensional version of Discourse Representation Theory from Roberts (1989) which I will use to formalize the common ground.

In representing plans that are located in the common ground, and in referring to principles that guide interlocutors in inferring these plans based on the utterances of others, I will borrow from work on planning in the field of artificial intelligence. I will begin by discussing generalizations from the philosophy of mind and action about what it means to have a plan (Bratman 1987), and then review different approaches that have been taken to formalizing plans and plan inferencing rules.

Finally, I will adapt plan and plan inferencing formalism developed in Pollack (1986) to the DRT framework, in order to represent public or mutually recognized plans—plans in the common ground. In doing this, I will identify lexical entailments associated with the propositional attitudes *plan* (i.e., have a plan) and *intend*.

2.1. A Representation of the Common Ground

As the basis for developing an algorithm for identifying the way plans and plan inferencing/recognition principles lead to the generation of implicatures in context, plans may be thought of as being located in a structure intended to be a formal representation of the common ground. By *common ground*, I mean the information (in the form of a conjunction of propositions) that interlocutors in a conversation treat as mutually recognized or mutually supposed. This information serves as the larger context in which a record of the conversation is embedded. The total common ground must include and differentiate between multiple levels of context, including the context of prior discourse (the conversational record), the local or accessible context (also described as "working memory" (Walker 1993)), and the larger context which contains all of the information mutually recognized to be shared by the interlocutors.

I will use formalism developed in discourse representation theory (DRT) to represent the common ground. The conversational record will be the subset of propositions in the common ground which involve a SAY relation: that is, propositions about propositions having been "said" by interlocutors, as well as the propositions that are added to the common ground on the basis of those utterances, will be treated as being closely connected to the conversational record. These propositions, which have been asserted by interlocutors, have a special status in that there is especially strong motivation for an interlocutor's believing them to be mutually supposed, and they can be referred to differently in conversation (e.g., differences between linguistic and deictic anaphora). They may also be distinguished from their pragmatic implications, since studies have shown that literal meaning of what is said has a faster "decay rate" than the general change caused in the common ground, although what was literally said is not lost immediately (and may available for several conversational turns).

2.1.1. Philosophical Background

The notion of common ground is intuitively familiar to linguists and nonlinguists alike. Thomason (1990) refers to it as being like a salad that is added to by the interlocutors in a conversation cooperatively and publicly. However, unlike a salad, the common ground of a conversation is tacit and intangible. In fact, although interlocutors behave as though there is a common ground and each of them knows what it is, it is clear from miscommunications that an interlocutor may be mistaken about what is in the common ground.

The idea that the common ground is the set of propositions that are mutually known has been discussed by a number of linguists and philosophers. The problem with this definition of the common ground is that defining what it means for something to be mutually known is subject to a problem of infinite regression, as seen in the following definition given in Clark and Marshall (1981: 17), and cited as originally due to Schiffer (1972):

(1) A and B mutually know that *p* =def.
  (1) A knows that *p*.
  (1') B knows that *p*.
  (2) A knows that B knows that *p*.
  (2') B knows that A knows that *p*.
  (3) A knows that B knows that A knows that *p*.
  (3') B knows that A knows that B knows that *p*.
  et cetera ad infinitum.

The importance of the infinite recursion of this definition is that, if at any point in the reasoning process the mutual knowledge requirement breaks down, the proposition in question can no longer be considered part of the common ground. This is shown in the following example from Clark and Marshall:

> On Wednesday morning Ann and Bob read the early edition of the newspaper, and they discuss the fact that it says that A Day at the Races is showing that night at the Roxy. When the late edition arrives, Bob reads the movie section, notes that the film has been corrected to Monkey Business, and circles it with his read pen. Later, Ann picks up the late edition, notes the correction, and recognizes Bob's circle around it. She also realizes that Bob has no way of knowing that she has seen the late edition. Later that day Ann sees Bob and asks, 'Have you ever seen the movie showing at the Roxy tonight?' (p. 13)

In this example, all of the clauses in the definition in (1) are satisfied up to clause (2'), yet *p* (the proposition that Monkey Business is showing at the Roxy) is not mutually known. Suppose Bob sees Ann looking at the paper with his red circle on it, but Ann does not see him see her. Then clauses (2') and (3')—Bob knows that Ann knows that Monkey Business is playing at the Roxy, and Bob knows that Ann knows that Bob knows that Monkey Business is playing at the Roxy—would also be true, but clause (3) would not be true—Ann does not know that Bob knows that Ann knows that Monkey Business is playing at the Roxy. The proposition that Monkey Business is playing at the Roxy would

still not be mutually known in this situation. If at any point there is a breakdown in the regression, the proposition will not be mutually known.

Clark and Marshall point out that this infinitely recursive definition makes it almost impossible for an interlocutor to determine that some proposition *p* is mutually known, because in order to do so each clause in the definition would have to be checked—and since there are an infinite number of clauses, this would mean an infinite amount of time spent checking. Yet interlocutors seem to be able to decide in a matter of seconds that something is mutually known.

One of the earliest approaches to this problem is found in Lewis (1969). Lewis makes use of the notion of common knowledge, defined as follows (p. 56):

(2) Let us say that it is common knowledge in a population *P* that *X* if and only if some state of affairs *A* holds such that:
  (1) Everyone in *P* has reason to believe that *A* holds.
  (2) *A* indicates to everyone in *P* that everyone in P has reason to believe that *A* holds.
  (3) *A* indicates to everyone in *P* that *X*.

This definition avoids the problem of infinite regress, because the mutual knowledge of a proposition *X* can be assumed based on the assumption that some other proposition or set of propositions holds. Clark and Marshall have used this definition to develop a new definition of mutual knowledge, in which the kinds of states of affairs (e.g., a state of affairs in which *X* is directly observable by members of *P*, etc.) that can qualify as *A* in this definition are explored. Although this issue requires further study, I will take it that the basic notion is solid enough that it is reasonable to use something like mutual knowledge as the basis for defining the common ground. However, I will assume throughout that the propositional attitude of "mutual recognition" or "mutual supposition," the terms I will use most frequently, are more appropriate than mutual knowledge, which has been claimed to be too strong (Sperber and Wilson 1988).[1]

The view of the common ground I am assuming is shown in Figure 15.

[1] Thomason (1993) suggests that the public common ground that is created in the course of a conversation may consist of suppositions rather than beliefs (or knowledge); he says that a supposition is "like a belief, but may be temporary, ad hoc, and not taken seriously by the supposer" (p. 3). Furthermore, he adds, "Letting supposition replace belief in the theory of speech acts provides a single, well-motivated solution to swarms of objections and counterexamples that have been proposed in the philosophical and computational literature" (p. 4). I take mutual recognition to be similar in nature to mutual supposition, and I will use these terms interchangeably.

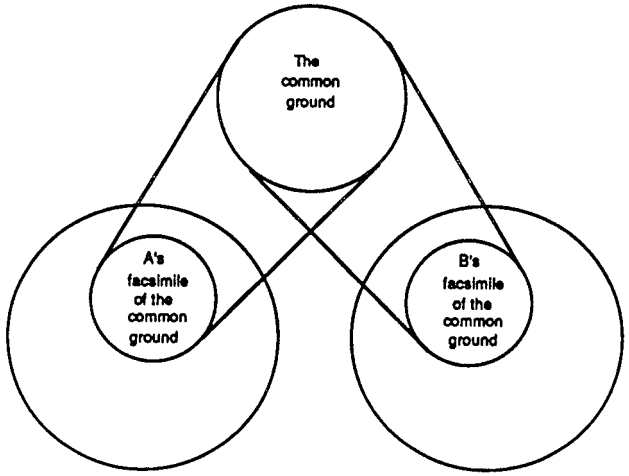

Figure 15: The Common Ground

The idea behind this diagram is that each interlocutor has a mental representation or facsimile of what he or she believes the common ground to be. Although an interlocutor's facsimile may not be identical to the "real" common ground (the actual set of propositions that are mutually recognized or supposed) each interlocutor intends for his or her facsimile to be as close as possible, and behaves as though it is identical unless evidence to the contrary arises.

This notion of common ground is essential for a number of reasons. First, not all plans (or information that only one interlocutor believes) are relevant to an account of implicature: only those plans that are taken to be "public"—that is, contained in the common ground and so mutually supposed by all conversational participants—seem to play a role. For example, the utterance "John has four chairs" might be taken to implicate that John would be willing to loan those chairs, but only in a context in which there is a public plan to figure out a way for one of the interlocutors to get four chairs. In a situation in

which an interlocutor *secretly* needs to get four chairs and asks another interlocutor how many chairs John has, the response that John has four would carry with it no implicatures that the responder believes John might loan them. Although, as I have pointed out, the actual common ground is most likely somewhat different from what interlocutors believe it to be, I will use a single common ground as the basis for formalization, in accordance with the fiction that interlocutors' facsimiles of it are correct (Roberts, p.c.).

2.1.2. The Contents of the Common Ground

As mentioned above, the common ground contains a set of propositions that are mutually recognized by the participants in a conversation, and this set of propositions also contains the states-of-affairs that are used in conjunction with a schema like the one proposed by Lewis (1969) to determine that other propositions are in the common ground. Heim (1982) was the first to provide a representation of the common ground of this sort. The set of propositions in the common ground may include propositions about the physical surroundings of interlocutors (for example, the proposition that the sun is shining if you and I are outside and can both see that the sun is shining), less direct propositions that each of us consider to be mutually recognized (perhaps based on our mutual experiences, perhaps based on our shared cultural background, etc.), and propositions that represent our mutually recognized (or public) plans. It is this last set that is most important for this framework, since in this framework it is public plans that are most important for the conventional and conversational implicatures that are generated for utterances within the common ground.

The common ground contains plans and goals that in a sense define the common ground and regulate how it is modified in a conversation. These include, for example, the plan to create a facsimile of the common ground and then to behave as though this facsimile is the real common ground, and the plan to use what is in the common ground as the basis for communication (e.g., using particular rules or conventions that belong to a common language). These plans and goals are always supposed to be followed by all participants in a conversation. One of the goals in this category that will become especially important is the goal for every utterance added to the common ground to be cooperative, in sense to be described later.

For the purposes of this account, I will distinguish between three kinds of information located in the common ground at any point in a conversation. This includes the literal meaning of what has been said, the information that is readily accessible (in the sense

that it is immediately available to supply discourse referents as antecedents for pronouns and other definites, as well as to be input to inferencing processes), and the larger set of propositions that are mutually recognized by interlocutors. I assume that there is some organizational structure to the larger set of propositions (e.g., linked data structures). This division of the common ground is shown diagrammatically in Figure 16: Structure of the Common Ground.

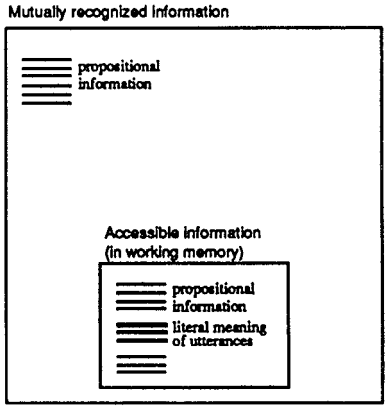

Figure 16: Structure of the Common Ground

I will assume that inferencing rules are also located in the common ground, if they are assumed to be mutually recognized.

2.1.3. Discourse Representation Theory

The semantic theory that will form the basis for this account of conversational implicature is Discourse Representation Theory (DRT). Features of DRT that make it appropriate are the following: 1) the semantic structures it is used to build (Discourse Representation Structures) can easily be interpreted as partial representations of the "common ground" of the conversation (cf. Heim 1982), 2) it allows multiple utterances to be added and

interpreted in sequence, 3) it easily supports representation of other information besides the semantic representation of utterances (e.g. background information and "pragmatic" information/bits of meaning), and provides mechanisms for determining which parts of that information are "accessible" to interlocutors at any point in the conversation.

In DRT, construction rules are provided which take a syntactic structure for a sentence and use it to build a representation of the meaning of that sentence. I will not describe these rules in detail; for more information, see Kamp and Reyle (1992).

As pointed out in Roberts (1989), propositional attitudes are fundamentally modal in nature, and modals require an intensional approach. I will modify the intensional version of DRT found in Roberts (1989) for my work.

Syntax

DRL, the language of discourse representation structures (DRSes), is based on a set VAR of variables, a set of n -place predicates (for all n), and the relation symbols $\neg$, $\vee$, $\Rightarrow$, and <...>. DRL is the set of all DRSes, where DRSes are defined as follows:

(3) Definition of a DRS
A DRS K is a pair $\langle X_K, C_K \rangle$, where X_K, the local domain of K, is a finite set of variables and C_K, the set of conditions in K, is a finite set of conditions.

Conditions are all and only the following:

(4) DRS conditions
1. If P is an n -place predicate and $x_{i_1}, \ldots, x_{i_n}$ are variables, then $P(x_{i_1}, \ldots, x_{i_n})$ is a(n atomic) condition.
2. If K_i is a DRS, then $\neg K_i$ is a condition.
3. If K_i and K_j are DRSes, then $K_i \vee K_j$ is a condition.
4. If K_i and K_j are DRSes, then $K_i \Rightarrow K_j$ is a condition.

The following syntactic notions may be defined on (occurrences of) DRSes:

(5) Definition of accessibility
$\leq$, is accessible from, is the smallest partial order on DRSes such that for any DRS K, if $\neg K \in K, K_i \Rightarrow K_j \in C_K$, or $\langle K_i, \ldots, K_j \rangle \in C_K$ then $K \leq K_i$ and $K_i \leq K_j$, and if $K_i \vee K_j \in C_K$, then $K \leq K_i$ and $K \leq K_j$

The accessible domain of K_i, A_{K_i}, is the set of all variables in (local) domains of DRSes accessible from K_i : $A_{K_i} = \cup_{K \leq K_i} X_K$.

We then impose the following condition on DRSes:

(6) No free variables:
If x occurs in an atomic condition in C_K, then $x \in A_K$.

Semantics
A model M for DRL is a structure $\langle W, A, \iota \rangle$, where W is a set of possible worlds, A is a nonempty set of individuals, and ι is the interpretation function mapping pairs of an n-place predicate and a world into *pow* (A^n).

An assignment function, f, is a total function from VAR to A.

Given two assignment functions, f and g, g varies from f at most with respect to X, $g\ \langle X \rangle\ f$, iff $\forall y\ [\neg (y \in X) \rightarrow g(y) = f(y)]$.

The truth of a DRS with respect to a world and an assignment function is defined recursively, as follows:

(7) *Truth of a DRS*
For all worlds w, u, v, w', u', assignment functions f, g, h, models M, DRSes K, K_i, K_j, sets of conditions C, n -place predicates P, and variables x :

1. $\langle w, f \rangle \models_M K$ iff $\forall c \in C_K\ (\langle w, f \rangle \Vdash_M c)$

2. (a) $\langle w, f \rangle \Vdash_M P(x_{i_1}, \ldots, x_{i_n})$ iff $\langle f(x_{i_1}), \ldots, f(x_{i_n}) \rangle \in \iota\ (P)(w)$

(b) $\langle w, f \rangle \Vdash_M (\neg K_i)$ iff $\neg \exists g\ [g\ \langle X_{K_i} \rangle f\ \&\ \langle w, g \rangle \Vdash_M K_i]$

(c) $\langle w, f \rangle \Vdash_M (K_i \vee K_j)$ iff $[\exists g\ [f\ \langle X_{K_i} \rangle g\ \&\ \langle w, g \rangle \Vdash_M K_i] \vee \exists g\ [g\ \langle X_{K_j} \rangle f\ \&\ \langle w, g \rangle \Vdash_M K_j]]$

(d) $\langle w, f \rangle \Vdash_M (K_i \Rightarrow K_j)$ iff $\forall g\ (g\ \langle X_{K_i} \rangle f\ \&\ \langle w, g \rangle \Vdash_M K_i) \rightarrow \exists h\ (h\ \langle X_{K_j} \rangle g\ \&\ \langle w, h \rangle \Vdash_M K_j)]$

Additional semantic rules will be developed later in this section, for new conditions that are developed as a part of this account. The full set of rules appears in the Appendix.

2.2. A Representation for Plans

Intuitively, a plan is a collection of actions through which an agent intends to achieve some goal. Planning has received a great deal of attention in the field of artificial intelligence, where it has played a role in two kinds of activities: 1) it has been used to allow computational systems to formulate and carry out procedures for accomplishing complex tasks, and 2) it has been used to enable such systems to recognize the plans of human beings in order to interact with them in a cooperative way. In this section, I will review two approaches to plans and plan inferencing within artificial intelligence. The first, which Pollack (1986, p. 33) calls the *data-structure view of plans*, sees plans as being abstract structures made up of actions between which certain relations hold (e.g., one action causing the next, or enabling the next). I describe this view because it underlies many of the planning systems currently used. The second, the *mental phenomenon view of plans*, focuses on the state of mind of the agent who has such a plan, paying special attention to the agent's beliefs and intentions concerning actions within the plan. This view is especially useful for the account I am developing.

The data-structure view of plans predates the mental phenomenon view of plans within the field of AI. In early AI work, in which computational systems synthesized plans

in order to carry out tasks, an agent's mental attitudes toward the actions in a plan did not need to be explicitly represented (since the only mental attitudes relevant at this point were those of the computational system, which were implicitly represented in the planning system itself). The focus of the work was on putting actions together to create plans, which could then be executed to perform some task. As might be expected, the form of the representations developed for plan synthesis was strongly influenced by the structures used in artificial intelligence as a whole, as will be discussed later.

As work in AI moved into the area of plan recognition, in which computational systems attempted to infer the plans of other agents, the mental attitudes of agents toward the actions in their plans (and the relations between those actions) became more important. In order to infer another agent's plan, a system had to be able to consider the agent's beliefs and intentions as they related to a possible plan. Systems for plan recognition/inferencing were developed that built on the existing plan synthesis systems. These systems included operators representing beliefs about agent attitudes (belief and desire/intention) toward the actions in their plans and/or the relations between those actions. The strategies that had been developed for plan synthesis were then adapted to be used for inferring plans as well. One system within this category, described in Pollack (1986), is designed to incorporate generalizations about plans and intentions from the philosophy of mind and action. The planning formalism and rules that will be used in the account developed in the remainder of this work, which are described in section 2.3., will be adapted from this account.

In the following sections, I will review each of the two approaches to planning (data-structure and mental representation), and describe a planning system built on each one. I will also review other planning literature that is relevant to the representations of plans in DRT.

2.2.1. The Data-Structure View of Plans

2.2.1.1 General AI Problem-Solving Structures

Most of the systems used for planning and plan recognition, which reflect the data-structure view of plans, have a structure that is derived from the structures used for AI problem-solving in general. Problem-solving in AI has been conceived of as a process involving the development of a plan for solving a problem and then the execution of that plan in order to solve the problem. This process was concerned with planning in an implicit sense: what was important was not the existence of the plan *as a plan* (in the way we think of an agent

having a plan), but only the ability to execute the sequence of actions included in the plan in order to solve a problem. Only later, when such sequences of actions were considered independently of their execution, were they seen as being plans. Before beginning a discussion of planning and plan recognition systems, I will describe the general structures used in AI problem-solving.

According to Rich and Knight (1991, p. 35), in order to describe and solve a problem in AI, the following must take place:

- definition of a state space, in which states are represented by nodes
- specification of initial states within the space state, from which the problem-solving process may begin, and goal states, which would be acceptable solutions to the problem
- specification of a set of rules/operators (for clarity, I will henceforth refer to these only as operators) that describe possible changes in state (or transitions from one state to another)

The elements described above are combined with a control strategy and a knowledge base to form a *production system*, which facilitates a *search process*. A search process may be thought of as a movement through the state space that begins with an initial state and, through the sequential application of operators, moves through states in the space until a goal state is reached (and the problem is solved). The operators themselves then form a chain linking the initial state with the goal state. The search process may work forward from the initial state to the goal state ("forward chaining," as just described), may start with the goal state and work backward from the goal state ("backward chaining"), or may work from both directions until a complete chain of rules has been formed.

Three of the elements of a production system deserve special discussion:

- states
- rules/operators
- control strategy

States

A state is a node representing a particular situation or state of the world at any given time. Each node or state represents a configuration of all of the objects in the relevant domain (that is, a way the world might be with respect to those objects). In linguistic semantics terms, we may think of a state as being the set of propositions which are all true at that state.

Operators

An operator may be thought of as a function that applies to a state to give a new state (i.e., moves from one node to another). Operators are often seen as representing events or actions which change the current state to a new state through their occurrence.

The operators that are part of a production system have a two-part structure: one part of the operator identifies the state(s) to which the operator may apply (usually by referring to some characteristic of the state: e.g., a proposition that must be true in that state), and another part describes the change in state that will occur if the operator is applied (which will result in a new state). The first part of the operator is called its *preconditions*, and the second part its *effects*. During the search process, an operator may be applied to any state that matches its preconditions. The effects part of the operator alters that state to determine a new, unique state to which another operator may then apply. As described above, the result of the process is a chain of operators that link a beginning state and a goal state.

Looking at this from the perspective of linguistic semantics, an operator creates a transition from one state to another by changing the propositional information that corresponds to the states. If the propositions that are true at a given state match the preconditions of an operator, then that operator can apply to that state. The effects of the operator result in the addition of new propositions or the deletion of existing propositions. The new state will differ from the previous one only with respect to the propositions identified in the effects portion of the operator.

As an example of how an operator can apply to one state to produce another, we might think of the kind of operators used to move a piece in a chess game (Rich and Knight 1991, p. 30). The preconditions of each operator would identify the characteristics of the board that are relevant to the application of the operator, and the effects would identify the changes to be made in the board. An example of one such operator would be the following (p. 31):

(8)	Preconditions:	White pawn at Square (file e, rank 2)
		Square (file e, rank 3) is empty
		Square (file e, rank 4) is empty
	Effects:	White pawn at Square (file e, rank 4)

The following diagram illustrates how an operator can create a transition from one state to another by altering the propositional information that characterizes them:

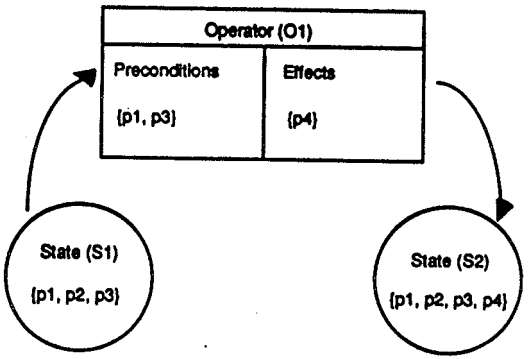

Figure 17: State Transitions

Control strategy

Often, the preconditions satisfy two or more operators, but no more than one operator can be used at a given time. Therefore, control strategy is used to guide the application of the rules. It will determine which operator should apply if two or more operators are applicable, as well as the order in which operators should be applied. Heuristics are often incorporated into the control strategy, for ranking the plans that would result from applying certain operators and using this ranking to choose between them.

2.2.2.2. STRIPS, NOAH and their Derivatives

Much of the work in planning today relies on representations derived from the NOAH system (Sacerdoti 1977) and its predecessor STRIPS (Fikes and Nilsson 1971). In these approaches, plans are composed using a search process like the one described above. Each action in a plan is treated as an operator, with a two-part structure that specifies the preconditions for the operator and its effects. In addition to representing an action, an operator in a plan may also represent a proposition, in which case it is interpreted as any action that would achieve that proposition (Pollack 1986). The plan itself is represented via

a plan graph, with nodes that correspond to operators in the plan, which connects an initial state with a goal state.

The general strategy in planning systems is as follows: at the beginning of the planning process, a beginning state and a goal state are identified. The system has access to a library of operators like those described in the previous section, which are used for plan synthesis. Similar to the operators described above, each operator usually has a minimum of three parts:

- a header, which gives the name of the operator
- a preconditions list, which states all of the propositions that must be true for the operator to apply
- an effects list, which states all of the propositions that will be true once the operator has applied (the effects list is sometimes divided into two lists: an add list, containing all of the propositions which will be added once the operator has applied, and a delete list, identifying all of the propositions which will be removed from the description of the current state)

In addition, an operator may have a list of constraints (which describes restrictions on the operator) and a body (a set of subactions or subgoals that together result in the performance of the action) (Pollack 1986). Pollack gives the following as an example of a typical operator in such systems (p. 18):

(9)
Header:	PICKUP (x)
Precondition:	ONTABLE (x) & HANDEMPTY & CLEAR (x)
Effect list:	¬ ONTABLE (x) & ¬ HANDEMPTY & HOLDING (x)

As is suggested by the uninstantiated parameters in the operator above, the operators in a system's operator library may represent action schemas (in which different values may be instantiated) rather than specific actions. "CLEAR (x)" means that nothing is on top of x. The operators and representations of propositional information in this particular system (e.g. PICKUP (x), ONTABLE (x) and HANDEMPTY) differ from traditional linguistic representations in that they leave implicit the agent argument. Systems vary in terms of how the agent argument is treated; in others (e.g., STRIPS) the agent argument is specified.

Plan construction

Rules referring to the relations between operators that can license their connection to one another as part of a plan are used for plan construction. Three relations are typically used to create a plan graph connecting two nodes α and β (p. 21):

(10) *α causes β*: β is on the effects list of α
α is-a-precondition-of β: α is on the preconditions list of β
α is-a-way-to β: α is part of the body of β

These relations refer to information about the operators α and β that is encoded in the operator library (i.e., identification of what is contained in their preconditions list, effects list, or body). When a relation is used to link one node to another within a plan graph, there is said to be an arc between those two nodes, which may be labeled with the relation that licensed the connection.

Plan inferencing

In order for a system to infer the plan of another agent, it must be able to reason about that agent's plan construction process. This means reasoning about the agent's beliefs and desires/intentions with respect to the actions in the plan and the way they are linked together. Unlike plan construction rules, plan inferencing rules must refer to the agent's attitudes toward the actions in his or her plan.

The plan inferencing process generally begins with an observed action and/or an expected goal action, and applies plan inferencing rules until a likely plan has been arrived at that would contain the action and/or goal in its body. The rules used in plan inferencing incorporate the inferring agent's beliefs about the planning agent's beliefs and/or desires.

2.2.2.3. A Cooperative Question-Answering System Built on the Data-Structure View: Allen & Perrault (1980)

Plan inferencing systems have been developed to account for a variety of linguistic data in the past, including responses to sentence fragments, cooperative question answering, and indirect speech acts (Allen 1983). One of the earliest of these systems was developed in work by Allen & Perrault, which appears in Allen & Perrault (1980), Perrault & Allen (1980), and Allen (1983). The system developed and applied in these works includes plan construction rules that refer to the relations between actions described above, as well as a

number of more specific rules. In addition, it includes plan inferencing rules that are the inverses of the rules used for plan construction (because the plan inferencing rules are used to reason backwards about what plan the planning agent is likely to have constructed). When used for cooperative question-answering, the system will take as input an observed action (a linguistic speech act, generally a request for information) which is inferred based on an interlocutor's question. The system will then apply plan inferencing rules (along with heuristics which form the control strategy constraining the search) to connect this action to other actions until a complete plan has been inferred. The system then uses the inferred plan to answer the question cooperatively, which may mean providing additional information that the user has not specifically requested. For example, given a question "What time does the train to Toronto leave?" the system might respond, "4:00 at gate 11."

The following is an example of an operator in Allen and Perrault (1980, p. 451):

(11) Header: BOARD (agent, train, station)
Precondition: AT (agent, the x : DEPART.LOC (train, x),
the x : DEPART.TIME (train, x))
Effect list: ONBOARD (agent, train)

The header for the operator identifies the action and its parameters (the kinds of arguments it takes). In the example above, the parameters for the BOARD action are "agent," "train," and "station." The precondition is that the agent be at the departure location for the train at the departure time. The effect of the action is that the agent is on board the train. Unlike earlier approaches, the agent is explicitly identified in the representations of actions and propositional information.

Also unlike the early approaches to planning, in this system the rules for plan construction include a representation of the planning agent's attitudes toward the acts in his/her plan. Allen and Perrault (1980) provide several such rules (p. 446), one of which is the following:

(12) Action-Precondition Rule
$XW(ACT) = c \rightarrow XW(P)$ if P is a precondition of ACT[2]
"... if X wants to execute ACT, X must first ensure that its preconditions are true."

[2] The "= c" notation indicates that this rule is used for plan construction rather than inferencing. An *i* replaces the *c* in plan inferencing rules.

In other words, if X wants to execute ACT, X may also want P to be true.

This rule could be used to add a step to a plan that results in making the preconditions true. For example, if an agent is developing a plan to board a particular train, the agent can check the preconditions of the BOARD act and note that she must be at the departure location at the departure time. The agent can then add a step to her plan that represents this propositional information (i.e., AT (A, the x: DEPART.LOC (train, x), the x : DEPART.TIME (train, x))—with appropriate parameter instantiations). This is backward chaining, applying the inferencing rules backward from the goal act. (Note that the AT operator represents a state rather than an action; it would be interpreted as the action of achieving this state.) One partial plan (in the form of a plan graph) involving these two operators would be the following[3] (Note: In this—and most—planning formalism, the plan is described with the goal action at the top and sub-actions below):

(13) BOARD (A, train1, Toronto)
|
|
AT (A, the x : DEPART.LOC (train1, x),
the x : DEPART.TIME (train1, x))[4]

Another rule that Allen and Perrault use for plan construction is the following:

(14) Effect-Action Rule
$XW(E) = c \rightarrow XW(ACT)$ if E is an effect of ACT
If X wants to achieve E, then X may want to execute ACT.

In other words, if X wants to achieve the effect of some action, then X wants to execute that action.

When the operators in an operator library are used to construct a plan, the result is a directed graph whose nodes are propositions or actions (i.e., operators as described above). The operators are connected via arcs that identify the relationships between the nodes—the relationships that were the basis for the rules used to connect the nodes as part

[3] Operators are referred to by header only.
[4] Note that the AT operator is propositional in form; as previously mentioned, this operator may be interpreted as an action that would achieve this proposition.

of a plan. For example, an *enable* arc links nodes when one is a precondition to the other, and an *effect* arc links nodes where one is in the effect list of the other.

The rules just described were used for plan construction. The rules for plan inferencing are the inverses of the plan construction rules, since they are used to reason about an agent's probable plan—the result of the plan construction process. For example, the plan inferencing rule corresponding to the Action-Precondition Rule described above would be the following:

(15) Precondition-Action Rule
SBAW(P) = $i \rightarrow$ SBAW(ACT) if P is a precondition of action ACT
". . . if [S believes that] A wants to achieve some goal P, then [S believes that] A may want to execute an action ACT enabled by P." (p. 446)

In other words, if the inferring agent S believes that the planning agent A wants to achieve P, and P is a precondition of ACT, then the inferring agent may conclude that A may want to execute ACT.

A variety of other rules have been used for plan inferencing in addition to the one above. The following rule is similar to the Precondition-Action Rule in that it refers to part of the basic information about operators that allows them to be linked (i.e., the effect list).

(16) Action-Effect Rule
SBAW(ACT) = $i \rightarrow$ SBAW(E) if E is an effect of ACT
"If [S believes that] A wants to execute an action, then [S believes that] A wants the effects of that action." (p. 446)

Another of Allen and Perrault's rules is the Body-Action Rule. This rule takes advantage of the fact that an operator (action) may be defined as having a body consisting of other operators (actions) (cf. the earlier list of what an operator may consist of).

(17) Body-Action Rule
SBAW(B) = $i \rightarrow$ SBAW(ACT) if B is part of the body of ACT
". . . if [S believes that]A wants to execute an action B that is part of the execution of another action ACT, [then S believes that] A may want to execute ACT." (p. 446)

Commentary

The system developed by Allen and Perrault was an important contribution to work on planning in AI and linguistics in that it provided an explicit system that could actually predict what kind of information would be given as part of a cooperative response. However, systems like this one can be criticized on a number of levels. First, the relations between acts that are encoded in the operator library of these systems may be adequate for plan construction, but they do not reflect intuitive understandings about how acts are related in human plans. Their definitions are determined by the structure of operators in computational systems, rather than being motivated by real-world examples of human planning. The relations that may hold between actions in plans have been studied as part of the philosophy of action (e.g., Goldman 1970), and the generalizations that have come out of this work should be reflected in a representation of plans and the relations between the actions they contain (if one of the goals is to reflect how humans plan and infer plans). Second, there is ambiguity in the relations as they are defined: it is often possible to characterize the relation between two acts two different ways. For example, in some cases both the Body-Action Rule and the Precondition-Action Rule may be used to describe the relation between two acts. As noted by Pollack (1986), if an act is part of the body of another act, the relationship between them may often be inferred based on either of the two rules. Ideally, a plan inferencing system would specify the relationships between acts in a plan more precisely. Finally, the representation of agent attitudes using the operator W (for want) is simplistic, and does not reflect philosophical theories concerning the attitudes of agents toward their plans (Bratman 1987).

2.2.2. Mental Representation View of Plans

2.2.2.1. Generalizations from the Philosophy of Mind and Action

Unlike the data-structure view of plans, the mental representation view of plans has arisen from work in the philosophy of mind and action. Under this view, plans are seen as complex mental attitudes concerning a sequence of actions and the relations that hold between them. In the philosophy of mind, there has been a special concern with identifying the specific mental attitudes that an agent has toward the acts in his/her plan—e.g., belief, desire, and/or intention—and the relations between the acts in a plan (Bratman 1987, Davidson 1980). The kinds of relations that can logically hold between acts—e.g., generation and enablement—have been studied in the philosophy of action (Goldman 1970), and are continuing to be studied by researchers in AI who are concerned with a

more precise specification of what it means to have a plan (Balkanski 1993, Di Eugenio 1993).

The original proponent of the mental representation view of plans, Pollack (1986, 1990) points out that in data-structure-oriented systems like the one described previously, what it means for an agent to have a plan is defined in terms of the structure of a plan (that is, in terms of the relations that hold between the acts in it) combined with simple agent attitudes of belief and desire. Given a constructed plan, the agent is taken to "want" each of the acts in the plan, and to "want" the appropriate relations to hold between those acts. The acts and the relations between them are determined by the plan inferencing rules (which are focused on the structure of the plan itself). As a result, Pollack states, "... Allen, and his followers, analyze the state of having a plan only in terms of the structure of its object" (p. 81).

Pollack is especially concerned with the inadequacy of the data-structure view from the perspective of a certain kind of data in cooperative question-answering: systems like the one described previously are not able to infer invalid plans (plans in which the planning agent's beliefs are deemed by the inferring agent to be incorrect). However, it is also possible to criticize such systems from another perspective, in that they do not appropriately capture generalizations about what it means for an agent to have a plan. Pollack states:

> (18) For me to have a plan to do β, which consists in the doing of some collection of acts π, it is not necessary that the performance of π actually lead to the performance of β. What is necessary is that I believe its performance will do so. This insight is at the core of a view of plans as mental phenomena; on this view, plans "exist"—that is, gain their status as plans—by virtue of the beliefs of the person whose plans they are. (p. 83)

To capture this important insight, it is necessary that agent attitudes such as belief play a crucial role in the definition of having a plan.

In addition to beliefs about the acts in their plans (and relations between them), agents must also have certain intentions concerning the acts in those plans. Bratman (1987) has argued that there is a significant difference between desire (which is used in traditional systems) and intention: intention is conduct controlling, while desire is only a potential influencer of conduct (p. 16). In his work, which situates plans and intentions within the larger domain of practical reasoning, he points out that it is the conduct-controlling aspect

of intention that allows plans to be used for coordinating actions between people, as well as for guiding an agent's further planning.

In defining what it means for an agent to have a plan, then, it is necessary to characterize the agent's mental states in terms of the attitudes of belief and intention. Pollack (1986) provides a preliminary formalization of having a plan that refers to these agent attitudes, as follows (p. 44):

> (19) (P0) An agent G has a plan to do β, that consists in doing some set of acts π, provided that
> 1. G believes that he can execute each act in π.
> 2. G believes that executing the acts in π will entail the performance of β.
> 3. G believes that each act in π plays a role in his plan.
> 4. G intends to execute each act in π.
> 5. G intends to execute π as a way of doing β.
> 6. G intends each act in π to play a role in his plan.

This definition leaves the specific relations that may hold between acts undetermined. However, it appears that two kinds of relations, at least, may hold between the acts in a plan. The first, which has been extensively discussed by Goldman (1970), is *generation*. The generation relation holds between two acts when the first act automatically causes (or generates) the second act under certain conditions. For example, my action of turning the rightmost knob on my stove will generate my action of turning on the right back burner, as long as certain conditions hold (the gas is turned on, the pilot light is lit, etc.). The second act follows from the first, with no additional work on my part. The second relation, which has not been studied in as much detail, is *enablement*. The enablement relation holds between two acts when one act leads to conditions in which the second act may be performed. For example, my action of lifting the lid on a pot of boiling water enables my action of adding salt. The first action plays an important role in setting up the requisite conditions for the second, but something else must be done as well.

In her work in developing plan inferencing system for cooperative question answering (a research project similar to Allen and Perrault 1980), Pollack provides a formal definition of the generation relation. Formalization of the enablement relation has been undertaken by Balkanski (1993) and Di Eugenio (1993), described in later sections.

2.2.2.2. A Cooperative Question-Answering System Built on the Mental Representation View: Pollack 1986 (SPIRIT)

In contrast with Allen and Perrault (1980), in which the plan representations and synthesis/inferencing rules are derived from a data structure approach, Pollack (1986) has developed a formalism and general approach to plans that takes seriously the notion that a plan is a complex mental attitude toward a series of actions. Her formalism incorporates the work by Bratman (1987) concerning the nature of plans and intentions, as well as work by Goldman (1970) concerning relations that may hold between actions in a plan. I will later develop a DRT-based formalism for plans that is adapted from Pollack's system.

As in Allen and Perrault (1980), the goal of Pollack's framework is the development of a computer program that is able to infer the domain plan that underlies some query. This system, SPIRIT (a System for Plan Inference that Reasons about Invalidities Too), is able to infer both valid and invalid plans. The input to the plan inferencing process is a representation of a query which includes a goal act and a queried act (e.g., one of Pollack's examples: "I want to talk to Kathy, so I need to call the hospital"). The formal system Pollack develops provides a representation of plans in terms of speaker belief and intention, and provides plan inferencing principles that take plausible plans (i.e., plans the inferrer believes it is plausible that his or her interlocutor has) involving one or more acts and expand these plans by adding additional acts. Once the inferrer has developed a plausible plan that connects the queried act with the goal act, the inferrer may take this plan to be the plan underlying the query. In this way, the system is able to provide a response to the question that goes beyond the question asked to address the plan that underlies the question.

In order to define what it means for an individual to "have a plan," Pollack builds on an action formalism developed in Allen (1984). Pollack describes the two kinds of relations that may hold between the acts in plans, generation and enablement. She provides a definition of generation, and leaves the definition of enablement for future work.

Formal definition of generation

To formalize the notion of generation, Pollack defines a GEN (generate) predicate. This predicate is defined in terms of a second notion, that of conditional generation (CGEN). Pollack's definition of the CGEN predicate is as follows (p. 58):

(20) (C1) CGEN (α, β, C)$=_{def}$

(i) $[\forall Q_1 \forall t_1 [[\text{HOLDS } (C, t_1) \ \& \ \text{OCCURS}(\alpha, Q_1, t_1)] \rightarrow \text{OCCURS}(\beta, Q_1, t_1)$ &

(ii) $\exists Q_2 \exists t_2$ [OCCURS (α, Q_2, t_2) & $\neg$ OCCURS (β, Q_2, t_2)] &

(iii) $\exists Q_3 \exists t_3$ [HOLDS (C, t_3) & $\neg$ OCCURS (β, Q_3, t_3)]]

The HOLDS and OCCURS predicates are ones that were originally developed by Allen. In Pollack's revision of Allen's framework, each of these is a relation that combines with other things to form a proposition. The predicate HOLDS is a two-place relation between propositions and time intervals: HOLDS(ρ ,t) can be read as "Proposition ρ holds through time interval t." The predicate OCCURS is a three-place relation between act-types[5], agents, and time intervals[6]: OCCURS (α,Q,t) can be read as "Agent Q performs α in time interval t" (or: "α occurs performed by Q at t").

The definition in (17) says that for an action α to conditionally generate an action β under condition C, it must be the case that:

(i) for all agents and times, if C holds and α occurs performed by Q, then β must also occur,

(ii) there is some combination of agents and times such that it is possible that α might occur when β does not occur and

(iii) there is some combination of agents and times such that C holds but β does not occur.

Pollack then defines the GEN predicate in terms of this predicate (p. 60):

(21) (G4) GEN (α, β, Q, t) = $\exists$C (CGEN (α, β, C) & HOLDS (C, t))

The idea behind this definition is that for one act to generate another, it must conditionally generate it under some condition that holds at the time the action is performed.

Using the GEN predicate, Pollack provides a definition of *simple plan* (a plan containing acts which are all related to one another via the generation relation). This definition is motivated by work by Bratman (1987) and others.

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[5] An act-type is defined by Pollack as a type of action that can be performed by an agent at a time.

[6] Here Pollack has revised Allen's system, in which OCCURS is a two-place relation between events and time intervals, so that the agent is represented as a separate argument rather than embedded in the event.

(22) (P1) SIMPLE-PLAN (Q, α_n, [$\alpha_1, \ldots, \alpha_{n-1}$], t_2, t_1) =def
(i) BEL (Q, EXEC (α_i, Q, t_2), t_1) for i = 1, . . . , n-1 &
(ii) BEL (Q, GEN (α_i, α_{i+1}, Q, t_2) for i = 1, . . . , n-1 &
(iii) INT (Q, α_i, t_2, t_1) for i = 1, . . . , n-1 &
(iv) INT (Q, by (α_i, α_{i+1}, t_2, t_1) for i = 1, . . . , n-1

SIMPLE-PLAN (Q, α_n, [$\alpha_1, \ldots, \alpha_{n-1}$], t_2, t_1) should be read "agent Q has a simple plan at time t_1 to do α_n at time t_2, α_n being a plan which consists of doing the set of (simultaneous) acts {$\alpha_1, \ldots, \alpha_{n-1}$} at time t_2" (Pollack 1986: 78). It is important to note the fact that the acts in the plan (including the goal act) are act-types (similar to *properties*, in the linguistic sense) rather than propositions. The agent of each of the acts is defined to be the individual who has the plan. In all of the representations of plans that follow, it should be kept in mind that in Pollack's system, plans involve sequences of act-types rather than sequences of propositions. These act-types correspond to operators in traditional systems.

Clause (i) of this definition says that the agent Q believes each sub-act in the plan is executable, in a specific sense. Briefly, if an agent believes that an act is executable, then the agent believes 1) that she can carry out that act and 2) that either the act is a *basic act* (discussed in a later section) or there is some other basic act (or series of basic acts) that generates the act.

Clause (ii) says that the agent believes that each sub-act in the plan will generate the following act. If i has a value between 1 and n-2, clause (ii) requires that Q believes that each act will generate the next and that each of his acts plays a role in his plan, and if i has the value n-1, Q believes his acts will entail his goal.[7]

Clause (iii) says that Q intends to do each sub-act in his plan, and clause (iv) says that Q intends by doing each act to do the next act.

As mentioned above, the plan inferencing process in Pollack's system does not apply directly to plans. Instead, it is a process that applies to what Pollack calls an EPLAN' (plausible explanatory plan). The EPLAN' predicate builds on another predicate, the EPLAN (explanatory plan) predicate.

[7] The definition of SIMPLE-PLAN given by Pollack is not entirely sufficient for this paper, in that many plans involve not just the GEN relation, but also the ENABLE relation. Later I will discuss a definition of PLAN that includes acts that are linked with the ENABLE relation as well as the GEN relation.

The EPLAN predicate describes the "explanatory plan" that an inferring agent believes links the planning agent's utterance with the goal the planning agent is trying to achieve. This predicate is like the predicate SIMPLE-PLAN except that 1) it makes each part of the definition subject to an interlocutor R's beliefs about the elements of a plan held by another interlocutor and 2) it contains an additional clause that states that inferring agent believes that the planning agent believes that the conditions necessary for each sub-act in the plan to take place are met. The first difference follows straightforwardly from the fact that an explanatory plan represents one agent's reasoning about another agent's plan. The second difference arises due to the plan inferencing process, which relies on both action relations between acts in a plan and also on beliefs about the conditions that hold to support the conditional relationship. It is important to note that the additional clause identifies information that is in some sense an inherent part of having a plan, whether or not it is explicitly called out.

The EPLAN' (plausible EPLAN) predicate is like the EPLAN predicate except that it concerns EPLANs that the inferrer takes to be plausible rather than actual ones. All of the plan inferencing axioms (which allow a more complex plan to be inferred from a simpler one) apply to EPLAN's (i.e. plausible EPLANs). The result of the plan inferencing process is a plausible EPLAN. The actual definition of any agent R believing any other agent Q to have a plausible eplan appears in (23) below (p. 131)[8]:

(23) (P1) BEL(R, EPLAN'(Q, α_n, [$\alpha_1, \ldots, \alpha_{n-1}$], t_2, t_1) =def
(i) BEL(R,BEL' (Q, EXEC (α_i, Q, t_2), t_1) for i = 1, . . . , n-1 &
(ii) BEL(R,BEL' (Q, GEN (α_i, α_{i+1}, Q, t_2) for i = 1, . . . , n-1 &
(iii) BEL(R, INT' (Q, α_i, t_2, t_1) for i = 1, . . . , n-1 &
(iv) BEL(R, INT' (Q, by (α_i, α_{i+1}, t_2, t_1) for i = 1, . . . , n-1 &
(v) BEL(R,BEL' (Q, ρ_i, t_1),t_1) for i=1,...,n-1
where each ρ_i is CGEN (α_i, α_{i+1},C_i) & HOLDS (C_i,t_2)

The predicates BEL' and INT' in this definition are plausible belief and plausible intention. In Pollack's system, the plan inferencing process begins with a query that is represented with a sentence of the following form: QUERY(Q,ø,α,β,t_2,t_0), which is "read as asserting that Q's query ø at time t_0 asks how to do α in order to do β at performance

[8] The definition of EPLAN is identical to this, except that the beliefs and intentions in it are not marked as plausible beliefs and intentions.

time t_2" (p. 123). The process ends when the inferrer R, given some query ø, has been able to prove "a theorem of the form: $\exists\alpha_1 ... \exists\alpha_{n-1} \exists\beta \exists\rho_1 ... \exists\rho_{n-1}$ [BEL (R, UNDERLYING EPLAN(ø,Q,β,α_n, [α_1,...,α_{n-1}],[ρ_1,...,ρ_{n-1}],t_2,t_1),t_1)" (126). In other words, R has found a plausible eplan that links the speaker's queried act with the goal act, and believes it to be the underlying EPLAN.

The plan inferencing process includes axioms that allow simple plausible eplans to be expanded to more complex ones. Before the process can begin, the act-types in the query must be translated into eplan act-types. This is done straightforwardly with the following axiom (p. 130):

(24) Q1 BEL(R,QUERY(Q,ø,α,β,t_2,t_0),t_1) →
BEL(R,EPLAN(Q,α,[],[],t_2,t_0),t_1) &
BEL(R,EPLAN(Q,β,[],[],t_2,t_0),t_1)

This axiom says that if Q has a query which has the initial act α and the goal act β, then Q has an eplan to do α and an eplan to do β. (For example, if Q says, "I want to talk to Kathy, so I need the number for the hospital," the initial action is getting the number for the hospital and the goal action is talking to Kathy.) The empty square brackets in the two eplans in the consequent of the conditional indicate that there are no sub-acts (the first empty square brackets) and hence no CGEN relationships (the second empty square brackets) in the EPLAN. Plan inferencing rules will be applied to link the two "mini" EPLANs (each of which is a partial plan) through a series of sub-acts. Next, Pollack provides axioms deriving plausible belief (BEL') and plausible intention (INT') from belief and intention, and plausible eplans from eplans (pp. 130-131):

(25) Q2 BEL(R,BEL(Q,ρ,t_2],t_1) →
BEL(R,BEL'(Q,ρ,t_2],t_1)

(26) Q3 BEL(R,INT(Q,α,t_2,t_0),t_1) →
BEL(R,INT'(Q,α,t_2,t_0),t_1)

(27) Q4 BEL(R,EPLAN(Q, α_n, [α_1,...,α_{n-1}],[ρ_1,...,ρ_{n-1}],t_2,t_1),t_1) →
BEL(R,EPLAN'(Q, α_n, [α_1,...,α_{n-1}],[ρ_1,...,ρ_{n-1}],t_2,t_1),t_1)

The axioms given above serve the purpose of transferring all of the information provided by a query into the kind of information that can be used for inferring plausible eplans (plausible belief and intention, rather than "actual" belief and intention). As mentioned previously, all of Pollack's inferencing rules apply to plausible explanatory plans. Pollack provides a number of plan inferencing axioms that an interlocutor can use to expand a plausible eplan into a larger plausible eplan. These plan inferencing axioms are taken to apply under the condition that the inferrer has no reason to believe that they would not apply. Two of the most important axioms she provides are the following:

(28) (PI1) BEL (R, EPLAN' (Q, α_n, [α_1,...,α_{n-1}],[ρ_1,...,ρ_{n-1}],t_2,t_1),t_1) &
BEL (R, CGEN(α_n,γ,C), t_1)
→
BEL(R, EPLAN'(Q,γ,[α_1,...,α_n],[ρ_1,...,ρ_{n-1}],t_2,t_1),t_1)
where ρ_n=CGEN(α_n,γ,C) & HOLDS(C,t_2)

"This rule says that if R's belief that Q has some plausible eplan includes a belief that Q plausibly intends to do an act of α_n, and R also believes that act-type α_n conditionally generates some γ under condition C then R can (nonmonotonically) infer that Q plausibly has the additional intention of doing α_n in order to do γ. The plausibility of Q's having this intention depends upon his also having the supporting belief that α_n conditionally generates γ under some condition C, which (Q believes) will hold at performance time" (p.134). In other words, this axiom supports "forward chaining" from the observed act toward the goal act.

(29) (PI2) BEL (R, EPLAN' (Q, α_n, [α_1,...,α_{n-1}],[ρ_1,...,ρ_n],t_2,t_1),t_1) &
BEL (R, CGEN(γ,α_1,C), t_1)
→
BEL(R, EPLAN'(Q,α_n,[γ,α_1,...,α_n],[ρ_0,ρ_1,...,ρ_n],t_2,t_1),t_1)
where ρ_0=CGEN(γ,α_n,C) & HOLDS(C,t_2)

"Axiom PI2 says that if R's belief that Q has some plausible eplan includes a belief that Q plausibly intends to do an act of α_1, and R also believes that some γ conditionally generates act-type α_1 under condition C, then R can infer that Q plausibly intends to do an act of γ in order to do α_1, and plausibly believes that the supporting conditional generation

relation holds and that its generation-enabling condition C will hold at the intended performance time" (p. 135). In other words, this axiom supports "backward chaining" from the goal act toward the observed act.

The axioms PI1 and PI2 replace traditional plan inferencing rules that refer to the relations between acts in terms of the preconditions, effects and body of operators. The result of applying these axioms (and others that Pollack has defined) is the creation of a plan graph in the traditional sense, whose nodes correspond to the acts in the plan. The knowledge that the system relies on in applying the axioms is encoded in two knowledge bases: a domain knowledge base, which reflects the system's beliefs about the domain, and a user model, which reflects the system's beliefs about what the user believes to be true.

Commentary

Pollack's formalism provides a principled definition of what it means to "have a plan" with respect to agent attitudes (that is, her definition takes into account insights from the philosophy of mind and action), as well as a characterization of the generation relation. However, this formalism must be extended to include a definition of the enable relation, as well as a more generalized definition of the PLAN predicate (one that will allow either generation or enablement as the relation between a pair of acts within the plan).

2.2.2.3. Other Action Relations

As mentioned in the previous section, Pollack's definition of SIMPLE-PLAN takes into account only the action relation of generation. To create a richer notion of plan, it is necessary to include all of the relations that may hold between actions. As mentioned above, one of these action relations that has been identified is enablement (Pollack 1986, Balkanski 1993, Di Eugenio 1993). Other action relations have been noted as well (Balkanski 1993, Di Eugenio 1993). This is an area in which work is currently taking place; for the purposes of this dissertation I will discuss only the current definitions of enablement.

Enablement is the relation that holds between two acts when one act leads to conditions in which the second may be performed. Balkanski (1993) provides the following definition for conditional enablement (paraphrased in Di Eugenio 1993, p. 73):

(30) α enables β if and only if
1. the time of α is prior to the time of β ,
2. there are a set of conditions, C, such that one of the conditions in C, C_i, holds as a result of the performance of α, and either
   (a) there is a third action γ, and γ conditionally generates β under C ; or
   (b) C are the executability conditions on β.

Clauses (a) and (b) in this definition identify two different types of enablement. The first involves the performance of an additional (unspecified action); the second is more consistent with the intuitive definition of enablement given above—the first act leads to conditions in which the second may be performed.

This definition can be modified to be parallel to Pollack's account of generation, which involves two steps: first, the notion of conditional generation is defined (α conditionally generates β under condition C) and then generation is defined in terms of this notion (α conditionally generates β under C, and C holds). To modify the definition of enablement to be parallel to this, I suggest something like the following (based on an early definition by Balkanski, Di Eugenio technical note):

(31) CENABLES $(\alpha, \beta, C_1) =_{def} \exists C_2$
(i) CGEN $(\alpha$, ACHIEVE $(C_2), C_1)$ &
(ii) [CEXEC $(\beta, C_2) \vee \exists \gamma$ CGEN $(\gamma, \beta, C_2)]$

According to this definition, an act α conditionally enables an act β if
i. α generates achieving the set of conditions C_2 under conditions C_1, and
ii. either: (a) C_2 has to hold for β to be executable—CEXEC (β, C_2)
or: (b) there is a third action γ that conditionally generates β under C2.

Clause (ii.a.) in this definition corresponds to clause (2b) in the definition in (30), and clause (ii.b) corresponds to clause (2a). Given this definition for conditional enablement, it is possible to define enablement in terms of it. The following definition of enablement is analogous to Pollack's definition of generation:

(32) ENABLES $(\alpha, \beta, t) = \exists C$ (CENABLES (α, β, C) & HOLDS (C, t))

According to this definition, α enables β at time t iff there is some condition C under which α CENABLES β, and C holds at time t.

Di Eugenio has noted problems with Balkanski's definitions, and has developed a version that is appropriate to her own work. For the purposes of the account developed here, I believe Balkanski's definition to be adequate. However, I assume that this definition could be replaced by whatever is finally agreed upon by those who are doing research in this area.

2.2.3. Conclusion

The mental representation view of plans as developed in Pollack (1986), and with the additional action relation of enablement, provides a basis for developing a formalism of plans that interlocutors in a conversation take to be mutually recognized (i.e., plans in the common ground). The appropriateness of this view, as opposed to the data structure view, derives from the fact that when a plan is mutually recognized, it is the planning agent's beliefs and intentions that are mutually recognized. In the next section, I will build on Bratman's (1987) philosophical approach to plans and intention, and the formal account in Pollack (1986), to develop an account of plans and plan inferencing rules within the DRT framework. This will allow the representation of mutually recognized plans within the common ground.

2.3. Plans in DRT

In this section, I will adapt the plan formalism developed by Pollack (1986) to the Discourse Representation Theory framework, and extend it to include plans whose actions are linked through enablement as well as generation. The general approach I will take is to treat *plan* as a propositional attitude, but one that is complex (following Pollack (1986, 1990) and Bratman (1987)). The complexity of the attitude *plan* comes from the fact that it is defined in terms of at least one other attitude (namely, *intend*), combined with the fact that its object argument, unlike a proposition, has an internal structure that must be referred to in the definition of *plan* (i.e., an ordered set of propositions characterizing the actions that make up the plan). I will define the attitude *plan* using lexical entailments that specify the complex structure of its object argument and that identify the planning agent's intentions towards the actions that make up the plan. I will also provide lexical entailments for the attitude *intend* that contribute to the total meaning of *plan* (as in Pollack's definition of SIMPLE-PLAN). Once the complex propositional attitude *plan* has been defined, it will be

possible to refer to it as though it were a simple propositional attitude (like *believe* or *want*), and also to identify beliefs and intentions that an agent who has a plan must have.

In developing a representation for plans in DRT, I will build on treatments of propositional attitude verbs by Asher (1986) and Heim (1992). My goal here is not to contribute to the literature on propositional attitudes, but rather to explicate how such a theory would be connected to the account I am developing here. I have chosen the accounts in Asher (1986) and Heim (1992) because they provide tools that can be used for characterizing propositional attitudes within DRT, and not because I think either of these accounts has the final word on how propositional attitudes should be treated. When a fully adequate theory of propositional attitudes is developed, it should be possible to reinterpret my treatment of *intend* and *plan* in terms of that theory.

In addition to the lexical entailments which constrain the meaning of *plan*, I will also provide plan inferencing rules which can apply to a DRT representation of a plan. Like Pollack's plan inferencing rules, these will refer to action relations and will allow plans to be inferred through forward and backward chaining. The plan inferencing rules I will develop will allow plans to be inferred which have actions linked through the action relations of generation (as in Pollack's definition) and enablement.

2.3.1. Propositional Attitudes

Although a variety of accounts of propositional attitudes have been proposed by linguists and philosophers over the years, none is entirely problem-free. Given the lack of a definitive treatment, I will take two approaches to propositional attitudes as a starting point. The first, Heim (1992), includes an adaptation of the traditional approach to propositional attitudes (cf. Hintikka 1969) to context change semantics. The second, Asher (1986), is valuable in that it provides a DRT representation of sentences containing propositional attitude verbs.

2.3.1.1. Intend *and* Plan *as Propositional Attitudes*

As defined and discussed in much of the literature in the philosophy of mind and action (Davidson 1980, Bratman 1987) and in the literature in artificial intelligence (e.g. Pollack 1986, 1990, Cohen and Levesque 1990), *intend* is different from many other propositional attitude verbs in that it has often been defined as taking an action as argument rather than a

proposition.[9] Attitudes toward an action have been termed by Davidson "pro-attitudes" (Davidson 1980), and intention has traditionally been treated as being of this type. AI formalism of plans has sometimes treated individual acts in plans (these individual acts collectively forming the object of the verb) as properties, and sometimes as propositions.

In order to develop a treatment of *intend* (and *plan*) that is consistent with the treatment of other propositional attitude verbs, I will assume that *intend* takes a propositional argument. I consider this view to be supported by the fact that *intend* and *plan* can both appear in syntactic/semantic patterns in which other propositional attitude verbs are found.[10]

2.3.2. Propositional Attitudes in Context-Change Semantics (Heim 1992)

Propositional attitudes have been semantically characterized as relations between an individual and a set of worlds (Hintikka 1969); this is the approach used in Heim (1992). I will use only the basic definitions of propositional attitudes provided by Heim, which are based on the approach to propositional attitudes found in Hintikka (1969), ignoring the more complicated issues she is concerned with in her account.

In Heim (1992), the meaning of the propositional attitude *believe* is defined in terms of an accessibility function: i.e., a function from worlds to sets of worlds. For any individual α, the function Dox_α identifies at each world *w* the set of worlds that characterize α's beliefs at that world. Heim formally defines this function as follows (p. 187):

(33) Doxastic accessibility:
For any $w \in W$,
$\text{Dox}_\alpha(w) = \{w' \in W: w' \text{ conforms to what } \alpha \text{ believes in } w\}$

[9] Much of the discussion here is also relevant to the verb *plan*; however, for simplicity I will refer only to *intend* throughout the discussion.

[10] The following collection of sentences show several syntactic and semantic patterns in which the verb *intend* may appear. The verb *plan* may appear in the first and third of these patterns (and possibly the fourth).

a. I intend to go.
b. I intend you to go.
c. I intend for you to go.
d. I intend that you will be there.

Prototypical propositional attitude verbs, such as *expect* and *want*, can appear in many of these patterns as well.

According to this definition, when the function Dox_α is applied to a world w, it gives the set of worlds in W in which the propositions that α (in w) believes to be true are true. Given this definition, Heim provides the following definition for *believe* (p. 188):

(34) General belief rule:
For any c, $c + \alpha$ *believes* $\varphi = \{w \in c: \text{Dox}_\alpha(w) + \varphi = \text{Dox}_\alpha(w)\}$

The + symbol in this definition refers to the process through which the context (which in this case is α's beliefs) is modified when a new proposition is added; basically, the original set of worlds is intersected with the new set of worlds corresponding to the proposition being added to give a new set of worlds (which will, of course, be smaller than or identical to the original set of worlds). This definition says that when the set of worlds w' in which α's beliefs are true is intersected with the set of worlds in which the propositionφ is true, the result is the original set of worlds. Intuitively, what this means is that the proposition φ is true in all of α's belief-worlds—the set identified by $\text{Dox}_\alpha(w)$. For brevity, Heim restates this rule as follows:

(35) General belief rule (revised):
For any c, $c + \alpha$ *believes* $\varphi = \{w \in c: \text{Dox}_\alpha(w) + \varphi = \text{same}\}$

Heim also provides a definition of the verb *want* which is similar in form to her definition for *believe*.[11] Heim's simple definition for *want* makes use of the notion of buletic accessibility; an accessibility function Bul_α is defined which identifies the set of worlds in which what α wants is true. This accessibility function is as follows:

(36) Buletic accessibility:
For any $w \in W$,
$\text{Bul}_\alpha(w) = \{w' \in W: w' \text{ conforms to what } \alpha \text{ wants in } w\}$

The definition for *want* then builds on this accessibility function in just the same way that the definition for *believe* built on the doxastic accessibility function (p. 192):

[11] She actually provides two definitions for *want*, one of them parallel to the definition of *believe* and one of them more complex. Although the more complex definition, which relates the desired proposition to the real world, is more satisfactory, for my purposes her simpler definition will be adequate.

(37) General desire rule:
For any context c,
$c + \alpha$ *wants* φ = {w ∈ c: $Bul_\alpha(w) + \varphi$ = same}

A definition along these lines for the propositional attitude *intend* is quite simple to imagine. Minimally, an accessibility function must be defined to identify the set of worlds in which what a intends has come to pass. This function might be defined as follows:

(38) Intentional accessibility:
For any w ∈ W,
$Int_\alpha(w)$ = {w' ∈ W: w' conforms to what α intends in w}

The meaning of *intend* may then be characterized in terms of this accessibility function, as in the following definition:

(39) General intention rule:
For any context c,
$c + \alpha$ *intends* φ = {w ∈ c: $Int_\alpha(w) + \varphi$ = same}

Of course, this definition does not capture other parts of the meaning of *intend*, such as the idea that α will take some action, or beliefs concerning what is intended. These elements of meaning are addressed in the lexical semantics for *intend*, which I will discuss in section 2.3.2.1. However, the definition in (38) does characterize the general form of the relation that holds between the propositional attitude verb and its arguments, and the semantic elements that are essential for its model theoretic interpretation.

2.3.1.3. Propositional attitudes in DRT (Asher 1986)

Recent treatments of propositional attitudes in DRT (Asher 1986, Kamp 1990) have been developed in response to problems with standard treatments of propositional attitudes. DRT accounts are representational in nature: they postulate an intermediate level of representation (the DRS) that contributes to the meaning of the object of the propositional attitude, giving a more "fine-grained" representation of the meaning of the proposition. Consider the following example:

(40) John believes that he owns a cello.

In the standard approach described above, the meaning of the sentence would be the set of worlds (a proposition) in which John stands in the *believe* relation to the set of worlds (proposition) associated with the sentence *he owns a cello*. In DRT approaches, the object of the propositional attitude would not be the set of worlds associated with the sentence *he owns a cello*, but the DRS for that sentence. In the notation in Asher (1986), the DRS for the sentence in (1) would look as follows.

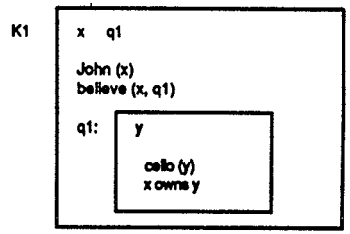

Figure 18: DRS for "John believes that he owns a cello."

As described above, the object of the propositional attitude verb *believe* is represented with a DRS, which John is asserted to stand in the *believe* relation to. This DRS in turn can be associated with a set of worlds, or proposition. In Asher's account, the crucial aspect in evaluating the truth of a DRS such as that in Figure 16 would be to compare the representation in p_1 to the total cognitive state that characterizes John's beliefs. As Asher puts it, "The report will be true or false depending on whether the characterization matches the content and ultimately the structure of a belief of the subject" (p. 134).

Extending Asher's representation of propositional attitudes to *intend*, a DRS that represents the sentence *John intends to buy a cello* would look as follows:

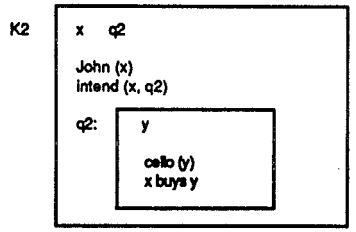

Figure 19: DRS for "John intends to buy a cello."

As the reader may note, the only difference in form between this DRS and the one in (2) are the wording changes. The meaning of *intend* would change the satisfaction conditions (i.e., the world-assignment pairs that would verify the condition) for the condition "intend (x1, p2)", and hence the satisfaction conditions for the entire DRS.

Given the representational approach described above, all that remains is to characterize the relationship between the propositional attitude and the proposition described in the DRS. Asher (1986) does not describe the meaning of *believe* itself; his account instead focuses on how the meaning of a particular belief (such as the one depicted in p_1) must be related to the believer's total cognitive state. I will not build on this aspect of Asher's account, but will instead use the representation of propositional attitudes and their objects in conjunction with a traditional semantic interpretation of the propositional attitude (i.e., as a relation between an individual and the set of worlds characterized by the DRS).

2.3.1.4. A modified DRT approach to propositional attitudes

In (2e) below, I have replaced Asher's verification conditions for a condition of the form "$q_i : K_\alpha$" (where K_α represents the DRS associated with q_i) with a simplified version that reflects the standard "set of worlds" approach. The following verification condition will be added to the semantic rules in section 2.1.4, for a condition of the form $q : K$:

(41) *Verification rule for a condition of the form* $q : K$

2. (e) $\langle w, f \rangle \Vdash_M (q : K)$ iff $\forall w' \in W$ [$w' \in f(q) \leftrightarrow \langle w', f \rangle \models_M K$]

According to this definition, a condition of the form $q : K$ is verified by a world-assignment function pair $\langle w, f \rangle$ if and only if for all worlds w' in W, w' is a member of the set of worlds assigned to q by the assignment function f if and only if the world-assignment function pair $\langle w', f \rangle$ will verify the DRS K. In other worlds, the set of worlds that f assigns as the interpretation of q is the same set which may combine with the assignment function f to verify the DRS K. Hence, K is a representation of the proposition denoted by q.

Before moving on, it is useful to consider how the verification condition in (e) combines with a propositional attitude verb, as shown in the DRS in Figure 18. To consider how a condition such as [*intend* (x_1, q_1)] would be verified, we may consider the verification rule for a condition of this type, repeated below:

(42) *Verification rule for a condition of the form* $P(x_{i_1}, \ldots, x_{i_n})$

2. (a) $\langle w, f \rangle \Vdash_M P(x_{i_1}, \ldots, x_{i_n})$ iff $\langle f(x_{i_1}), \ldots, f(x_{i_n}) \rangle \in \iota(P)(w)$

Applying this rule to the condition [*intend* (x_1, q_1)], we get the following:

(43) $\langle w, f \rangle \Vdash_M$ *intend* (x_1, q_1) iff $\langle f(x_1), f(q_1) \rangle \in \iota$ (*intend*)(w)

The interpretation function ι maps *intend* into a set of ordered pairs of individuals and sets of worlds. If the ordered pair that the assignment function f assigns to x_1 and q_1 at w is in the set of ordered pairs for *intend*, then the world-assignment function pair will verify the condition.

The rule (2e) in (40) serves to further constrain the nature of q_1. Given an additional condition of the form $q_1 : K_1$, the set of worlds that can be assigned to q_1 is further constrained: now, it not only has to be a set of worlds that x_1 stands in the intend relation to, it also has to be the same set of worlds that (together with f) verify K_1 at w.

2.3.2. Defining the Attitudes *Intend* and *Plan*

Now that we have a means for representing and characterizing the meaning of sentences containing propositional attitude verbs in DRT, we may consider the specific meanings associated with the lexical items *intend* and *plan*. I will characterize the meanings of *intend* and *plan* by identifying specific lexical entailments of these words.

I will begin by considering the propositional attitude of intention, since previous accounts of the meaning of the attitude *plan*, or "having a plan" as described in Pollack (1986), have been developed in terms of this attitude.

The remainder of this sub-section has two parts. First, I will develop lexical entailments characterizing the meaning of *intend*. I will then develop lexical entailments characterizing the meaning of *plan* that refer to the attitude *intend*.

2.3.2.1. A Definition of Intend

Intention to act, and what it means to act intentionally, has been discussed extensively in the philosophy of mind and action. The traditional model of intention holds that intention to act can be defined in terms of belief and desire: an agent's desires in combination with what he believes about his ability to act and the results of his actions lead to the agent's development of an intention to act. As work has progressed in the area of planning, however, the limitations of this approach have become clear. Bratman (1987) points out that intention has a conduct-controlling quality which does not follow from the desire-belief model, and argues that intention should be treated as a primitive attitude rather than a derived one. Unlike desire, intentions control an agent's future actions. This means that they can serve as inputs to an agent's practical reasoning about further intentions (serving as a "background framework that helps to focus deliberation" (p. 34)), as well as helping to coordinate activities between agents. An account that reduces intention to a combination of desire and belief cannot account for these conduct-controlling aspects of intention. I will follow Pollack (1986, 1990), Cohen and Levesque (1990) and others in adopting Bratman's view of intention as a primitive attitude.

Based on Bratman's philosophical criteria, Cohen and Levesque (1990) have developed a formal account which includes two meanings for *intend*. This account is framed within a larger formal theory of rational action, which is beyond the scope of this work. In identifying the entailments associated with *intend* I have benefited from this work, although the definitions provided here are different from Cohen and Levesque's in many ways.

In his work, Bratman focuses on defining intending to act, rather than intending for a proposition to hold. Therefore, although I will borrow from his account, the entailments identified here will be slightly different from the ones that play a role in his theory. Bratman identifies the following key characteristics of intention, which I will attempt to capture: 1) intention is future-oriented, focusing on an agent's attitude toward future actions, 2)

intention to achieve a proposition requires that the agent believe it is possible to achieve that proposition (but not that the agent will necessarily achieve the proposition)[12], and 3) intentions control the actions of the intending agent until they are achieved; i.e. the agent is committed to doing the action. In addition to the attributes of intention identified by Bratman, we may note two additional characteristics of intention: 4) one generally has some control over what one intends (this is related to the characteristic in (2)), and 5) intention to achieve a proposition entails that the agent desires to achieve that proposition. I will briefly discuss each of these characteristics in turn, then provide three formal entailments which are intended to capture all of them.

Future-oriented nature of intention

Bratman discusses future-oriented intention extensively in his work. In terms of practical reasoning, future-oriented intention plays an important role in helping people coordinate their own activities to achieve their goals, and also to coordinate their activities with those of others. Thus, the propositional object of *intend* is something whose truth is specific to some future time, even if that future time is quite immediate (e.g., I may intend to close the door and then do so directly).

Belief in possibility

There has been debate about how strongly committed an agent is to the belief that what she intends will actually come to pass; Bratman has argued that claiming that she must believe that she will certainly achieve what she intends to is too strong. However, it would be irrational for an agent to intend to do something which she believes is *not* possible. This is the weak sense of possibility. However, in the normal case, an agent will believe that she *can* accomplish what she intends (not just that it is possible). This is the level of belief that is formalized by Pollack.

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[12]This is the entailment of intention that Pollack (1986) builds into her definition of what it means to have a plan. Formalizing it seperately—as part of the meaning of *intend*—will simplify the definition of *plan* provided later in this chapter. However, Pollack has taken a stronger view than that of Bratman. I will provide lexical entailments that address both the weak sense of possibility that Bratman requires and also the stronger requirement that Pollack has used.

Rational commitment to action

Bratman has pointed out that one of the features of intention that allows it to play a role in practical reasoning is that the agent (and others) are able to form certain beliefs based on the knowledge of the agent's intention. In particular, if an agent intends *p*, then this intention gives others reason to believe that in fact the agent will achieve *p*. (Although, as mentioned previously, requiring that the agent believe absolutely that she will accomplish *p* may be too strong.) Bratman describes this by saying that plans resist reconsideration. One aspect of the agent's commitment to the intended action or proposition is that the agent will continue to have the intention to achieve the action/proposition until one of the following two situations comes to pass: 1) either the action or proposition is achieved or 2) the planning agent comes to believe that it is impossible to achieve the intended action/proposition. In either event, a rational agent will drop the intention. However, it also seems to be the case that if an agent loses the desire to achieve the intended action, the intention will be dropped. This might happen due to a change in other beliefs and intentions held by the agent. To maintain the rationality of intention, conditions under which an agent might change her desires would have to be constrained. (This would prevent an agent from having a plan one minute and whimsically abandoning it the next, which would be irrational.)

Control

Bratman did not focus on this aspect of intention, possibly because his account is concerned with intention as a relation between an individual and an action. However, when we consider intention as a relation between an individual and a proposition, it becomes obvious that we must explicitly require that the intending agent must have some control over what is intended; in the case of intention to act, being the agent of the action necessarily requires that the agent has some control (since she is actually performing the action in question).

The importance of requiring that the agent have some control over the intended proposition or action may be seen from the oddity of examples like the following:

(44) John intends for the sun to rise tomorrow.

The reason for the strangeness of this example seems to be that John has no control over whether the sun rises tomorrow. In contrast, I might say to a child, "I intend for you to be in bed by nine." The naturalness of this seems to arise from the fact that I may have some

control over whether the child is in bed by nine (being in a position of authority, for example, which would mean that an action of ordering the child to do something could have a causal effect on the child's behavior).

Desire

When an individual has an intention to achieve a proposition, the impetus for adopting that intention is generally a desire to achieve the proposition.

Entailments capturing these aspects of intention

Before describing my own entailments for *intend*, I will briefly review the definition of SIMPLE-PLAN in Pollack (1986), from which one of these entailments will be adapted.

(20) (P1) SIMPLE-PLAN (Q, α_n, [$\alpha_1, \ldots, \alpha_{n-1}$], t_2, t_1) $=_{def}$
(i) BEL (Q, EXEC (α_i, Q, t_2), t_1) for i = 1, . . . , n-1 &
(ii) BEL (Q, GEN (α_i, α_{i+1}, Q, t_2) for i = 1, . . . , n-1 &
(iii) INT (Q, α_i, t_2, t_1) for i = 1, . . . , n-1 &
(iv) INT (Q, by (α_i, α_{i+1}, t_2, t_1) for i = 1, . . . , n-1

Pollack pointed out that clauses (i) and (ii) of this definition should follow from the definition of *intend* combined with clauses (iii) and (iv) of the definition.

Clause (i) of this definition says that the agent Q believes at t_1 that each sub-act in the plan is executable at t_2. Pollack provides the following definition of executable (p. 72):

(45) Definition [of executability]
EXEC (β, G, t) $=_{def}$
(i) [BASIC (β, G, t) $\wedge$ SC (β, G, t)] $\vee$
(ii) $\exists\alpha_1 \ldots \exists\alpha_n$ [BASIC (α_1, G, t) $\wedge \ldots \wedge$ (BASIC (α_n, G, t) $\wedge$
SC (α_1, G, t) $\wedge \ldots \wedge$ SC (α_n, G, t) $\wedge$ GEN (α_1; ...; α_n, β, G, t)]

BASIC (β, G, t) is read: β is in the set of actions that are basic for agent G at time t. According to this definition, if an agent believes an act is executable, then the agent believes that either 1) the act is a basic act and the agent stands in "standard conditions" to it (standard conditions being the conditions under which the act is executable) or 2) there is some other basic act or series of basic acts that generates the act, and the agent stands in standard conditions to that basic act or series of basic acts. According to Pollack, a basic act

is one which can be performed at will, and which cannot be performed *by* doing some other action (p. 67); she notes that the set of basic actions has traditionally been considered to be the same as the set of bodily actions (e.g., moving an arm in a particular way, etc.). However, Pollack points out when executability is considered within some domain of action, we typically do not "reason 'all the way down' to the level of bodily actions" (p. 68); instead, we stipulate some particular set of act-types as basic. Once a set of act-types is stipulated as basic, reasoning about sub-acts that might generate those acts is not allowed. One way to think about this is that the set of basic acts is the starting point for planning and reasoning about plans, and this set includes all the acts that may be the initial act in some plan.

Pollack describes the role of the standard conditions for a specific act-type as follows: "An agent is in the standard conditions with respect to act-type α at time t if there are no external forces that prevent him from doing α at t" (p. 69). She notes that internal conditions, which identify when a basic act is in a particular agent's repertoire, may also determine whether an agent is able to execute a particular action.

We may now consider how clause (i) of the definition of SIMPLE-PLAN in conjunction with the definition of executability relates to the aspects of the meaning of *intend* described previously. Three aspects of the meaning of *intend* are addressed by this clause: the agent's belief in the possibility that the action she intends may come to pass, the agent's belief that she has some control over bringing about this action, and the future-oriented aspect of intention.

I will suggest two entailments for intend that are similar to the one in clause (i) of the definition of SIMPLE-PLAN, with respect to these three aspects of the meaning of *intend*. The first one is the following:

(46) *General belief entailment of* intend
$\forall x \, \forall q \, \forall t$ [intend (x, q, t) $\rightarrow$
[believe $(x, \Diamond \exists t' \; [t < t' \wedge$ cause $(x,$ hold $(q, t'))])]]$

This says that if an agent x intends q at time t, then the agent believes that there is some time t' later than t such that x is able to cause q to hold at the later time t'.[13] This very general entailment captures three of the aspects of intention discussed above: the future-oriented nature of intention, the agent's belief in the possibility of the intended proposition/action occurring, and the agent's belief that she has some control over the achievement of the intended proposition/action (by having the ability to cause the proposition to hold). In addition, this entailment captures part of the commitment characteristic of intention: if a time comes at which x no longer believes it is possible for her to achieve the intended proposition, the consequent of the conditional will be false and it will no longer be possible for x to hold the intention. This entailment stipulates that the agent believes it is possible she will cause the intended proposition to hold, without specifying the specific basis for this belief. This is the weak sense of belief in possibility that Bratman's account requires. A stronger sense, consistent with the normal interpretation of intention (and Pollack's formalism) will be discussed at the end of this section.

The remaining elements of the meaning of *intend* that have yet to be formally captured are the "persistence" aspect (one maintains an intention until the thing intended has been achieved or until one decides it can no longer be achieved) and desire. The following entailment captures the characteristic that if x intends q, then x wants or desires q.

(47) *Desire entailment of* intend
$\forall x \, \forall q$ [intend $(x, q) \rightarrow$ want (x, q)]

The persistence entailment is rather more complicated. The general idea behind it is that as long as the other entailments described above remain true—that is, the agent continues to believe it is possible to achieve the thing intended and continues to want to achieve the thing intended—then until the intended proposition is achieved, the agent will maintain the intention.

[13] The "holds" predicate used in this definition is borrowed from Allen (1984) (I am using this formalism for consistency with Pollack (1986), whose account of plans I am adapting to this framework.). "Holds (p, t)" is true iff proposition p holds throughout time interval t (i.e., p is true at time t).

(48) *Persistence entailment of* intend

$\forall x\ \forall q\ \forall t$ [intend (x, q, t) $\rightarrow$
$\forall t'$ [$t < t'$ $\wedge \neg$ hold (q, t') $\wedge\ \forall t''$ [$t < t'' < t' \rightarrow$ intend (x, q, t'')] $\rightarrow$
[intend (x, q, t') $\leftrightarrow$
[believe $(x, \Diamond\ \exists t''$ [$t' < t''$ $\wedge$ cause $(x$, hold (q, t''))]) $\wedge$ want (x, q, t')]]]]

This says that if x intends q at time t, then for all times t' later than t, such that q does not hold and x has intended q at all times t'' between t and t', then x will intend q at t' if and only if x (still) believes that it is possible that x can cause q to hold at some future time t'', and x still wants q at t'. If at any time it becomes true that x does not believe it is possible that x can cause q to hold, or x stops wanting q, then at that time x will no longer intend q. As mentioned previously, to ensure that this entailment is consistent with Bratman's account of intention as a rational attitude, there would have to be some constraints on an agent's changing her desires (as they relate to intention).

Specific Belief Entailment of Intend

In addition to the general belief entailment developed earlier (repeated below for convenience), I will also develop a specific entailment for *intend* that addresses the agent's belief that he or she can cause the intended action to hold.

(46) *General belief entailment of* intend

$\forall x\ \forall q\ \forall t$ [intend (x, q, t) $\rightarrow$
[believe $(x, \Diamond\ \exists t'$ [$t < t'$ $\wedge$ cause $(x$, hold (q, t'))])]]

The reason for developing a specific belief entailment is that the specific definitions provided here will play a role later in the entailments I will provide for *plan*. These in turn will contribute to the plan inferencing rules. I identify this more specific entailment here (rather than in the definition of *plan*) for two reasons: first, it is an entailment of *intend* (rather than *plan*), and second, it provides a somewhat stronger entailment with respect to the possibility of the agent's causing the intended action. In particular, the general belief entailment in (46) requires only that the agent believe it is possible that she can cause the intended action to hold, while intuitively a stronger entailment seems to be required in most cases: specifically, that the agent believes she has the ability to cause the action to hold.

To develop a more specific entailment that the agent believes she has the ability to cause the intended action to hold at some future time, along the lines of the one proposed by Pollack, I will define new terms, achievable and conditionally achievable, which subsume part of Pollack's definition of executable. I will also define a simplified definition of executable (which does not include the parts I have assigned to conditionally achievable). The lexical entailment below corresponds to clause (i) of Pollack's definition of SIMPLE-PLAN:

(49) *Specific belief entailment of* intend

$\forall x\ \forall q\ \forall t$ [intend (x, q, t) $\rightarrow$
[believe $(x, \exists t'\ \exists C_l$ [$t < t'$ $\wedge$ cond-ach (q, x, C_l, t') $\wedge$ hold (C_l, t')])]]

Rather than use Pollack's definition of executable, I have chosen to use a new concept, conditionally achievable (abbreviated as "cond-ach"). I find it more intuitive to reserve "executable" for the performance of a basic action; achievable seems more appropriate when an action is done by doing other actions. I will replace Pollack's definition of executability with a new one, which includes only the first clause of Pollack's original definition (the second clause being addressed by the definition of conditionally achievable).

Pollack's definition of executability is repeated below:

(45) Definition [of executability]
EXEC $(\beta, G, t) =_{def}$
(i) [BASIC $(\beta, G, t) \wedge$ SC (β, G, t)] $\vee$
(ii) $\exists \alpha_1 \ldots \exists \alpha_n$ [BASIC $(\alpha_1, G, t) \wedge \ldots \wedge$ (BASIC $(\alpha_n, G, t) \wedge$
SC $(\alpha_1, G, t) \wedge \ldots \wedge$ SC $(\alpha_n, G, t) \wedge$ GEN $(\alpha_1; \ldots; \alpha_n, \beta, G, t)$]

Clause (i) of this definition says that an action is executable if it is a basic action and the agent stands in standard conditions to the action. Clause (ii) says that an action is executable if there is a set of basic actions that are executable by the agent and that together generate the action.

The simplified definition of executable that I will assume includes only the first clause of the definition in (45). Clause (ii) of Pollack's definition of executability will be included in the definitions of achievable and conditionally achievable. I will begin with the definition of conditionally achievable. "Cond-ach (q, x, C_l, t)" is read, "q is conditionally achievable by x under condition c at time t.

(50) *Definition of conditionally achievable*
$\forall q_1\ \forall x\ \forall C_i\ \forall t$ [cond-ach $(q_1, x, C_i, t) =_{def}$
i) basic $(q_1) \wedge$ exec $(q_1, x, t) \vee$
ii) $\exists q_0$ [cond-gen $(q_0, q_1, C_i, t) \wedge$ achievable $(q_0, x, t) \vee$
ii) $\exists q_0$ [cond-enable $(q_0, q_1, C_i, t) \wedge$ achievable (q_0, x, t)]]]

This definition says that an action q_1 is conditionally achievable by an agent x under a set of conditions C_i at a time t if and only if either 1) that action is basic, and the action is executable at t, 2) there is another action q_0 which conditionally generates q_1 under C_i at t, and q_0 is achievable, or 3) there is another action q_0 which conditionally enables q_1 under C_i at t, and q_0 is achievable. To be sure that an action is achievable, this definition could be applied recursively until a basic action is identified. This definition relaxes the constraint that each plan must begin with a basic action—instead, the initial action in each plan must be believed to be "traceable" to a basic action.

The achievable predicate used in the definition—like the generate and enable predicates—is defined in terms of conditional achievability in the following way:

(51) *Definition of achievable*
$\forall p\ \forall t$ [achievable (p, t) iff $\exists C$[cond-ach (p, C, t) $\wedge$ holds (C)]].

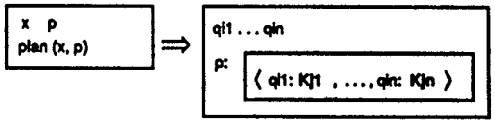
This specific belief entailment in (49) will permit significant inferences to be drawn during the plan inferencing process.

2.3.2.3. *A Definition of* Plan

Now that we have characterized the meaning of *intend* via lexical entailments, we can develop entailments characterizing the meaning of *plan*. Technically, I will treat *plan* identically to *intend* (and other propositional attitude verbs), as a relation between an individual and a proposition. However, the propositional object of *plan* itself contains an ordered set of propositions—and the agent's attitudes toward those propositions, and the way in which those propositions must be related to one another, must be specified.

The structure of the propositional argument of *plan* is described in the following DRT entailment. This entailment will constrain the construction of a DRS containing a plan.

(52) *Propositional argument structure entailment of* plan



The boldface K_{j_1} and K_{j_n} represent actual DRSes that would be associated with the labels q_{i_1} through q_{i_n}. This entailment describes the argument of *plan* as a DRS (i.e., a proposition) which contains an ordered set of labeled propositions. This entailment will ensure that whenever a condition of the form *"plan (x, p)"* is entered into a DRS, another condition of the form *"p: K"* (where *K* contains a condition of the form "$\langle q_{i_1}: K_{j_1}, \ldots, q_{i_n}: K_{j_n} \rangle$") will be entered as well. As a result, whenever the proposition that an agent has a plan has been added, the DRS will contain at least the following:

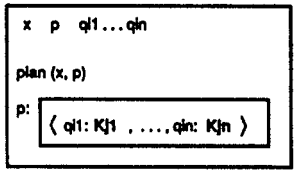


Figure 20: Schematic Representation of a DRS Containing a Plan

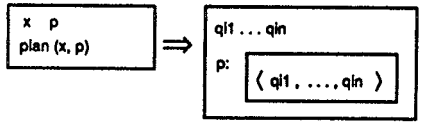
The semantic interpretation of the ordered set of propositions contained within the sub-DRS associated with *p* in Figure 19 is shown below.

(53) *Verification rules (for ordered set of conditions)*
(f) $\langle w, f \rangle \Vdash_M (\langle q_{i_1}: K_{j_1}, q_{i_2}: K_{j_2}, \ldots, q_{i_n}: K_{j_n} \rangle)$ iff
(i) $\exists g\ [g\ \langle X_{K_{j_1}} \rangle f\ \&\ \langle w, g \rangle \models_M K_{j_1}]\ \&$
(ii) $\langle w, g \rangle \models_M \langle K_{j_2}, \ldots, K_{j_n} \rangle$
(g) $\langle w, f \rangle \Vdash_M (\langle K_j \rangle)$ iff $\exists g\ [g\ \langle X_{K_j} \rangle f\ \&\ \langle w, g \rangle \models_M K_j]$

According to (53f), a world-assignment function pair $\langle w, f \rangle$ will verify a condition of the form $\langle q_{i_1} : K_{j_1}, q_{i_2} : K_{j_2}, \ldots, q_{i_n} : K_{j_n} \rangle$ if and only if (i) there is an assignment function g just like f except that new values may be assigned to the variables in the domain of the first DRS in the ordered set of DRSes, and g verifies the first DRS in the ordered set, and (ii) g also verifies the ordered set of DRSes consisting of all of the remaining DRSes in the set. This first clause is applied recursively until an ordered set consisting only of a single DRS remains. Then the verification condition in (53g) applies. The verification conditions in (53f) and (53g) together ensure that through the verification process, the values assigned to variables for each of the domains of the ordered sub-DRSes in the plan will remain fixed; that is, if a value is assigned to a variable in q_{i_1}, that value will still be assigned when the assignment function that was used to verify q_{i_1} is extended to a new assignment function for verifying q_{i_2}. Hence, there is a linear anaphoric accessibility relation between the sub-DRSes in the plan.

To make rules referring to DRSes containing plans easier to read, I will omit the boldface DRS indication. However, this is a notational convenience only; in an actual DRS containing a plan, the DRS associated with each q label would be shown. I do this only to make the rules more compact and easier to read. Using this abbreviatory convention, the rule in (52) would appear as follows:

(54) *Propositional argument structure entailment of* plan (abbreviated form)



This rule would be expanded to the rule in (52).

Next, the attitudes that the agent must have toward the ordered set of propositions that represent the actions in the plan must be characterized—in particular, the agent's intentions toward each of the actions. Since the entailments describing the meaning of *intend* include entailments concerning the agent's beliefs about what she intends (specifically, the entailment in (47)), this part of the meaning of *plan* will not have to be explicitly characterized. That is, if the meaning of *intend* has been properly characterized,

the agent's beliefs (as described in clauses (i) and (ii) of Pollack's definition of SIMPLE-PLAN) will be entailed by the agent's intentions.

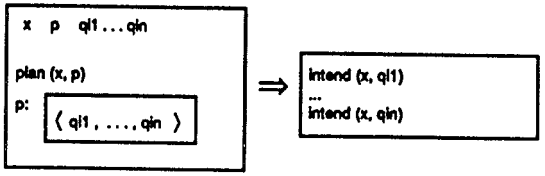
The lexical entailment for *plan* that I will propose differs from Pollack's definition of SIMPLE-PLAN in that only the two clauses concerning intention are specified, although the belief entailments that follow from the meaning of *intend* may be identified. In addition, in accordance with the discussion in the previous section, the objects of *intend* will be treated as propositions rather than properties. Finally, a more general term which is compatible with the relations of generation and enablement is used ("*as-a-way-to*" instead of "*by*").[14]

Pollack's commonsense definition of "having a plan" shown in (19) is relevant to the more general entailments for *plan* (instead of the ones that refer only to the action relation of generation). This definition is repeated below.

(19) (P0) An agent G has a plan to do β, that consists in doing some set of acts π, provided that
1. G believes that he can execute each act in π.
2. G believes that executing the acts in π will entail the performance of β.
3. G believes that each act in π plays a role in his plan.
4. G intends to execute each act in π.
5. G intends to execute π as a way of doing β.
6. G intends each act in π to play a role in his plan.

Clause (4) of this definition is quite straightforwardly captured with the following entailment:

(55) *Preliminary intention entailment of* plan

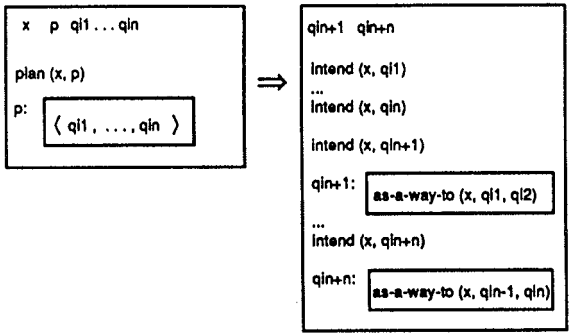


14 The specific terminology was borrowed from Pollack (1990), but the general approach is derived from Grosz and Sidner (1990), where the general term *contribute* (serving a similar function) is described.

This entailment says that if x has a plan p consisting of a series of actions, then x intends to achieve each of the actions in the plan.

Clauses (5) and (6) may be captured by using the predicate *as-a-way-to* (x, q_i, q_{i+1}), which is modified from a predicate which takes an pair of acts as its argument (as in Pollack's system) to one which takes two propositions (corresponding to actions in the plan) as arguments. "*As-a-way-to* (x, q_i, q_{i+1})" would be read, "x achieves q_i as a way to achieve q_{i+1}." To get the full intention entailment of plan, we may require that for each pair of actions in the plan, this proposition is true. The final entailment is shown below:

(56) *Intention entailment of* plan



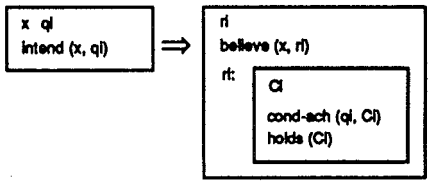
This entailment says that if an individual x plans p, then x intends to achieve each subproposition contained in p and intends to achieve each subproposition as a way of achieving the subproposition that is ordered after it. This entailment captures the characteristics of "having a plan" that are described in clauses (4–6) of the definition in (19).

As mentioned previously, the belief entailments in clauses (1–3) do not need to be specified as part of the meaning of *plan*, since they follow from the meaning of *intend*. In order for an individual to adopt the intentions shown in the right-hand box in (55), the individual must have the beliefs specified in the belief entailment of *intend*. The specific belief entailment for *intend* is repeated below:

(49) *Specific belief entailment of* intend
$\forall x\, \forall q\, \forall t$ [intend (x, q, t) →
[believe (x , $\exists t'$ $\exists C_l$ [t <t' ∧ cond-ach (q, C_l , t') ∧ hold (C_l , t')]]]]

The DRT version of this entailment is the following (with the time argument suppressed):

(57) *Specific belief entailment of* intend (DRT version)



In order for an agent to believe that an action is conditionally achievable, the agent must have a specific belief to the effect that the action is basic and executable, or that some other achievable action generates or enables it. Whichever belief is appropriate must be present for each action. In order to satisfy the entailment that each action is achieved as a way to achieve the subsequent one, each pair of actions in the plan must be related via the generation or enablement relation. Thus, whenever a DRS contains a plan, it must also contain the agent's beliefs and intentions concerning the propositions/actions in that plan. This is the information specified in Pollack's definition of explanatory plan (EPLAN), which is necessary for plan inferencing rules.

2.3.3. Plan Inferencing Rules

The entailments of *plan* that together specify the complex nature of its propositional argument (i.e., a proposition that contains an ordered set of propositions) and the attitudes of the agent of the plan toward those attitudes (primarily intention, which itself entails/presupposes belief) are closely connected to the way in which a plan is constructed. For this reason, the plan inferencing rules I will suggest are related to the rules identifying the lexical entailments of *plan* and *intend*. As mentioned earlier in this chapter, the rules used to infer a plan are generally adapted from the rules used to construct it, the only difference being that inference rules allow reasoning about the agent's beliefs and intentions, while the construction rules work directly with those beliefs and intentions.

The forward and backward chaining inferencing rules I will suggest are developed from those proposed in Pollack (1986). However, the dynamic semantic framework used here makes it possible to organize the information that is associated with a plan in a different way than she does, and one which is consistent with how this information is inferred. In particular, since the plans that I am concerned with are public plans—plans that are located in the common ground—all of the information necessary for the plan inferencing rules to apply is located in the common ground as well. (Only information that is mutually recognized can be used in the plan inferencing process, since only plans that are mutually recognized play a role in conversational implicature.) Furthermore, the beliefs may be those just of the planning agent, or may be shared (mutually recognized/supposed) beliefs.

The assumption that the plan inferencing rules and information used for inferencing are mutually recognized is different from many traditional plan inferencing systems, which refer separately to the beliefs of the planning agent and the beliefs of the inferring agent. In such a system, the information that I am assuming exists in the common ground would be assumed to exist in the planning agent's and the inferring agent's "total cognitive states" (in the sense of Asher 1986). The plan inferencing rules in Pollack (1986) are of this type.

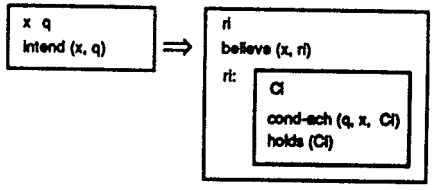
The plan inferencing rules proposed by Pollack operate on what she calls a plausible explanatory plan. In Pollack's framework, a plan consists of a sequence of acts along with entailments specifying the planning agent's beliefs and intentions concerning the sequence of acts. An explanatory plan contains all of the information in the plan, with the addition of the inferring agent's beliefs about the planning agent's beliefs about the way in which the acts in the plan are linked (specifically, that each act conditionally generates the next under a set of conditions, and that the set of conditions associated with the conditional generation relation for each act holds). Pollack's definition of plausible explanatory plan (which is identical to explanatory plan except that each of the propositional attitudes is plausible rather than actual) is repeated below:

(20) (P1) BEL(R, EPLAN'(Q, α_n, [$\alpha_1, \ldots, \alpha_{n-1}$], t_2, t_1) =$_{def}$
(i) BEL(R,BEL' (Q, EXEC (α_i, Q, t_2), t_1) for i = 1, . . . , n-1 &
(ii) BEL(R,BEL' (Q, GEN (α_i, α_{i+1}, Q, t_2) for i = 1, . . . , n-1 &
(iii) BEL(R, INT' (Q, α_i, t_2, t_1) for i = 1, . . . , n-1 &
(iv) BEL(R, INT' (Q, by (α_i, α_{i+1}, t_2, t_1) for i = 1, . . . , n-1 &
(v) BEL(R,BEL' (Q, ρ_i, t_1),t_1) for i=1,...,n-1
where each ρ_i is CGEN (α_i, α_{i+1},C_i) & HOLDS (C_i,t_2)

The action relation linking each pair of actions (which in a simple-plan is always generation) and the specific set of conditions under which the action relation holds are crucial in order for plan inferencing to take place, since plan inferencing rules allow two actions to be linked depending upon whether the agent has the requisite beliefs concerning the action relation that links them and the conditions under which one action leads to another.

It is important to note that although Pollack only called out the planning agent's beliefs about the specific link between acts in the definition of explanatory plan (and not in the definition of simple plan), in fact whenever someone has a plan, she will have those specific beliefs about the action relation that links the acts and the set of conditions under which the linking holds—since these specific beliefs are necessary to license the more general beliefs that are entailed by the definition of *intend*. In the account developed here, this follows from the fact that there is a lexical entailment for *intend* that requires that if an agent intends an action, then the agent beliefs that that action is conditionally achievable (reinterpreted below in DRL, with the time argument suppressed):

(58) *Specific belief entailment of* intend (DRT version)



Furthermore, if an agent believes that an action is conditionally achievable under a set of conditions C_i, the definition of conditionally achievable (repeated below) will ensure that the agent believes that either 1) the action is basic and executable, 2) another action q_0 conditionally generates that action under C_i, and q_0 is achievable, or 3) another action q_0 conditionally enables that action under C_i, and q_0 is achievable.

(50) *Definition of conditionally achievable*
$\forall q_1 \forall x \ \forall C_i \ \forall t$ [cond-ach $(q_1, x, C_i, t) =_{def}$
i) basic $(q_1) \wedge$ exec $(q_1, x, t) \vee$
ii) $\exists q_0$ [cond-gen $(q_0, q_1, C_i, t) \wedge$ achievable $(q_0, x, t) \vee$
ii) $\exists q_0$ [cond-enable $(q_0, q_1, C_i, t) \wedge$ achievable (q_0, x, t)]]]

(51) *Definition of achievable*
$\forall p \ \forall t$ [achievable (p, t) iff $\exists C$[cond-ach $(p, C, t) \wedge$ holds (C)]].

To be certain that an action q_i is achievable, it will be necessary to reason down to a basic action; both clauses (ii) and (iii) of the definition refer to another action which must be achievable, and the only way to determine if that action is achievable is to determine whether the action is a basic action that is executable, or to find another action that generates or enables the action under a set of conditions that holds. In practice, inferencing all the way down is not always necessary; planning and inferring agents may take for granted an agent's ability to perform certain non-basic actions.

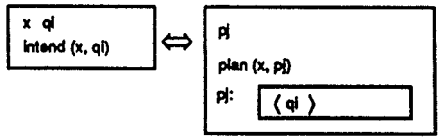
The plan inferencing rules used here are different from Pollack's in that they do not refer to plausible explanatory plans, but instead refer to plausible beliefs that are associated with an agent's plan. These beliefs, which are entailed by the agent's intending to do the actions in the plan, are similar in some respects to linguistic presuppositions: believing that an agent has a plan presupposes or assumes that the agent has the requisite beliefs concerning the actions in the plan, due to the fact that these beliefs are required for the agent to have the necessary intentions. Rather than defining an explanatory plan that identifies these beliefs, we may consider that these beliefs are located in the common ground along with the plan, and may be used as input to the plan inferencing rules. The beliefs may be located in the common ground as propositions that are believed by the planning agent or as propositions that are mutually recognized; mutually recognized propositions are necessarily believed or supposed by the planning agent as well, assuming that the planning agent is one of the interlocutors in the conversation. Once a plan has been accepted, it may be assumed

that all relevant beliefs associated with the plan are accepted as well (since otherwise the plan should have been rejected as being incompatible with one of the interlocutor's own beliefs).

Like Pollack's rules, the rules developed here take a partial plan and expand it through forward or backward chaining. The inputs to the plan inferencing rules are: 1) partial plans, 2) beliefs about linkages between actions, and 3) beliefs about the conditions under which actions are linked to one another. As discussed earlier, the plans that are significant for conversational implicature are public plans—plans that are mutually recognized by all interlocutors. The fact that these plans are mutually recognizable may be modeled by including them in the common ground along with other propositions that are mutually recognizable. In addition to the plans themselves being included in the common ground, the information necessary to infer those plans must be mutually recognized—and hence located in the common ground—as well. The public plans that play a role in generating implicature are usually inferred on the basis of an utterance of one of the interlocutor's; they can only be mutually recognized plans if the information necessary to infer them is mutually recognized as well.

Like Pollack, I will assume that when an intention has been recognized, it may be inferred that the intending agent has a "mini-plan" consisting just of the single intended action. This is described in the following axiom:

(59) *Mini-plan axiom*



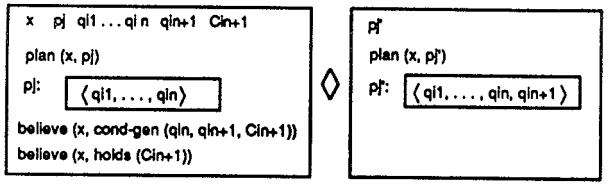
This rule will allow the plan inferencing process to begin once an intended action has been inferred.

The plan inferencing process used here will include four plan inferencing rules which will allow forward and backward plan inferencing. These rules are quite similar to Pollack's forward and backward chaining rules; however, in addition to the two forward and backward chaining rules that support inferencing based on the generation relation, there

are forward and backward chaining rules that involve enablement as well. I have not distinguished between plans and plausible plans in this account.

The first rule allows forward chaining based on the generation relation. The rule is as follows:

(60) *Forward-chaining inference rule: conditional generation*



This rule takes a plan containing some number of actions n, the agent's belief that a conditional generation relation holds between the highest action in the plan and another action under a set of conditions C_{n+1}, and the agent's belief that the set of conditions C_{n+1} holds, and gives the possible inference that the agent has an expanded plan which includes the new action. Making this inference rule involve possibility rather than strict entailment addresses the fact that other factors may plan a role in whether this inference rule is taken to apply—in particular, whether it is likely that the planning agent intends to do q_{n+1}.[15]

The belief that the conditional generation relation holds between the highest action in the plan and the new action may occur via stored action schemas[16] of the form shown below, which would be located within an individual's "total cognitive state," to use Asher's terminology (i.e., each action schema would represent a belief of the individual x whose plan is being inferred), or within the common ground itself:

15 One of the examples in Bratman (1986) relates to this issue. Suppose x intends to bomb a building, knowing that as a result of this schoolchildren will be killed. However, the killing of the schoolchildren is only incidental for x; in fact, x would prefer that the schoolchildren were not killed (they just happen to be in the wrong place at the wrong time). X's goal is to blow up the building. This action generates the killing of the schoolchildren; however, we would still not want to say that x had a *plan* to kill the schoolchildren.

16 An action schema identifies two types of actions that are related via conditional generation or econditional nablement, and the conditions that must hold for the two actions to be related. These are not specific actions, in that the argument variables in them are left unspecified. A schema of any sort leaves argument variables unspecified.

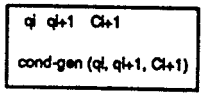


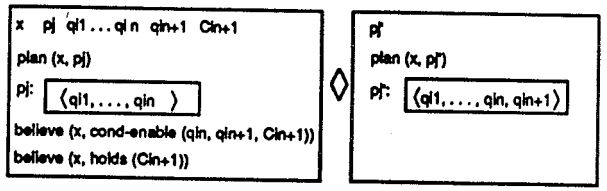
Figure 21: Form of a Conditional-Generation Action Schema

A particular action schema would include general descriptions of each of the actions and the conditions under which the first action generates the second.

When the forward chaining rule in (60) is used to infer a new plan, the common ground in which that plan is located will include the beliefs shown in the left-hand box concerning the relationship between the new action added to the plan and the action that immediately precedes it, as well as the belief that the specific condition specified in the conditional generation relation holds (i.e., the last two entries in the left-hand DRS).

The forward chaining conditional enablement inference rule is like the conditional generation one, except that the relation specified is enablement rather than generation.

(61) *Forward-chaining inference rule: conditional enablement*



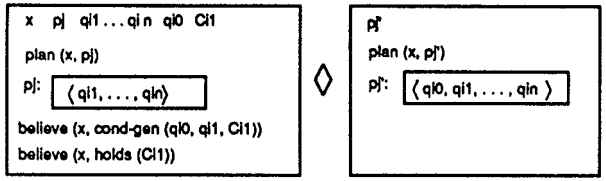
When this rule is used to infer a new plan, the common ground will include the last two beliefs shown in the left-hand box, along with the representation of the new plan.

The two plan inferencing rules that have just been discussed can be used alone or together to infer a plan; when both rules are used, the plan will contain both action relations. However, whenever a plan is inferred (or even constructed, since the same rules used to infer a plan could be used to construct one), it must be the case that for each pair of actions q_i and q_{i+1} in the plan, the agent believes that either a conditional generation or a conditional enablement relation holds between the actions, and that the required conditions

hold. This is because the only way to infer or to construct a plan is to use the rules in (59) and (60) (or their backward chaining counterparts, which, as we will see, have the same belief requirements).

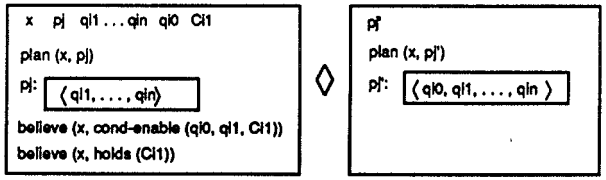
The backward-chaining rule for conditional generation is just like the forward chaining rule except that, instead of building onto the end of the plan, the rule builds onto the beginning of it. The rule is as follows:

(62) *Backward chaining inference rule: conditional generation*



The conditional enablement rule is different from the conditional generation one only with respect to the action relation:

(63) *Backward chaining inference rule: conditional enablement*



2.3.4. Conclusion

In this chapter, I have introduced and described the notions of *common ground* and *plan*, which are two significant elements of an account of conversational implicature. I have provided formal definitions and representations of these which incorporate appropriate philosophical generalizations, using mechanisms from formal semantics. The plan inferencing rules and entailments of *plan* and *intend* described in this chapter support the

inferring of a public plan. The overall inferencing process using these rules and entailments will be shown in detail through the discussion of examples in Chapters III and IV.

In Chapter III, I will bring the elements described in this chapter together with two principles which capture the remaining elements of an overall account of conversational implicature.

CHAPTER III
GENERAL FRAMEWORK

3.0. Introduction

As I discussed at the end of Chapter I, a theory of conversational implicature must include a representation of the common ground, a formalization of the purpose of the exchange, a cooperative principle which governs interlocutors' behavior with respect to the purpose of the exchange (and leads to the generation of implicature), and inferencing rules and constraints on how they apply to contextual information to create new inferences. The first two of these elements were discussed in Chapter II. In this chapter, I will discuss the second two of these elements. I will propose a Revised Cooperative Principle, which will replace Grice's Cooperative Principle and which will lead to the generation of base and comparative implicatures, and a Principle of Cooperative Inferencing, which will be related to Levinson's I-principle and Sperber and Wilson's deductive rules and deductive device. To formalize the purpose of the exchange, I will make use of the plan formalism and inferencing rules developed in Chapter II. In addition, I will propose that there are three kinds of goal sets (sets of propositions that characterize the goals of interlocutors) that lead to implicatures; one of these goal sets, which I will call the *accepted goal set*, represents the primary purpose of the exchange. This goal set contains a plan of one or more of the speakers. The Revised Cooperative Principle and the Principle of Cooperative Inferencing, in combination with the three goal sets, will lead to the generation of the full set of conversational implicatures. No additional maxims of conversation are required in this account.

The account proposed in this section is a framework rather than a fully detailed theory of implicature. Several areas must be refined before this account is entirely predictive. However, the structure of the framework and the elements in it provide a more comprehensive and less stipulatory account of implicature than any previous accounts, and do allow predictions in many key examples. In developing this account I have borrowed from insights in previous work. The framework developed here is in the spirit of plan-based accounts of implicature (e.g., Thomason (1990), McCafferty (1987), and Ginzburg (1990)), and also includes an inferencing process similar to the one proposed in Sperber

and Wilson (1988). The uniqueness of this particular framework is the integration of the various elements that contribute to implicature within a single framework.

I will follow Thomason in assuming the existence of a common ground, which contains the information interlocutors take to be mutually recognized. My conception of the common ground is described in Chapter II, section 1. As discussed there, I will use Discourse Representation Theory (DRT) as the basis for formalizing the common ground, since DRT is a context-change semantic theory that allows a variety of kinds of information to be represented. This makes it possible to see how utterances lead to progressive changes in the common ground, and how goals and plans that are represented there play a role in the generation of conversational implicatures. Unlike Thomason, I will couch the cooperative principle in terms of furthering a goal (via a plan), rather than accommodation. I will also provide a more detailed definition of the cooperative principle.

I will follow McCafferty in using representations of plans as a crucial part of the generation of implicature, and in assuming that there are speaker plans, domain plans, and something that corresponds to a conversational goal/plan (in my account, the accepted goal set).

I will follow Ginzburg in making an ordering on the updates associated with utterances central to my account. Unlike Ginzburg, I will assume that the updates in question are updates of the common ground, rather than of an unspecified epistemic state; also, I will identify three different kinds of goal sets that are used to order utterances and associated updates: the accepted goal set (which includes transactional goals), the interactional goal set, and a goal set including processing and "contextualization" goals. These goal sets are associated with the basic elements involved in conversation: a purpose, people, and an utterance in a context. To formalize the orderings on updates, I will build on Kratzer's (1981) work on modality.

In addition to the plan-based accounts of implicature described above, the account developed here will also build on work by Sperber and Wilson (1988) and others in assuming that a general inferencing process (driven by what I will call the Principle of Cooperative Inferencing) applies to the utterance and to specific mutually recognized information to create specific inferences. The plan inferencing process is one part of this general inferencing process.

3.1. Overview of the Framework

Grice's Cooperative Principle and Maxims of Conversation were intended to characterize rational, cooperative behavior in such a way that non-literal, non-conventional meanings associated with an utterance in a conversational context could be explained. As Grice realized, cooperativity, and the rules used to formalize it, is an extra-linguistic phenomenon; it is of interest to linguists because of the profound effect it has on language use and meaning.

In this section, I will provide a new version of the Cooperative Principle (the *Revised Cooperative Principle*) which more explicitly characterizes what it means to be cooperative in a conversation. The Revised Cooperative Principle leads to the two kinds of implicatures noted at the end of Chapter I, base implicatures and comparative implicatures. It is part of a larger process of interpreting the total meaning of an utterance, which includes "decoding" the utterance to determine its literal meaning, checking to be sure any presuppositions associated with the utterance are satisfied, accommodating or querying any unsatisfied presuppositions, identifying base implicatures associated with the utterance, and finally identifying comparative implicatures. The interpretation process I will describe is necessary for theoretical and practical reasons: base implicatures must be determined before comparative ones to get the right result, and no inferencing can happen until there is a semantic representation to use as the initial input. An account of the psychological processing involved in the generation of implicatures would be quite a bit more complicated than the simplified process I will describe. The Revised Cooperative Principle, a Principle of Cooperative Inferencing (which works with the Revised Cooperative Principle to support more specific inferences) and the overall process through which implicatures arise are described in this section.

A conversation may be modeled as an iterative modification of the common ground. Interlocutors modify the common ground by adding new propositions corresponding to observed information (e.g., real-world information, interlocutors' utterances, etc.), adding inferences that may be drawn based on those propositions and other information that is in the common ground, etc. Each time information is added to the common ground, a new "update" of the common ground is created. The generation of conversational implicatures is a part of this iterative modification of the common ground.

The two principles which govern the generation of conversational implicatures in this account are the Revised Cooperative Principle (RCP) and the Principle of Cooperative Inferencing (PoCI). The Revised Cooperative Principle has two parts, corresponding to the

two general types of implicature (base and comparative). The informal version of the Revised Cooperative Principle is as follows:

(1) *The Revised Cooperative Principle (informal definition)*
Provide an utterance/update that:
(a) brings the common ground closer to the accepted goal set
(b) is better than any other mutually recognized utterance/update that you could have provided in terms of making the goals in each of three goal sets (the accepted goal set, the processing/contextualization goal set and the interactional goal set) true in the common ground

The RCP places two basic requirements on an utterance: 1) that it lead to an update that is more similar to the accepted goal set—which includes a goal of one of the interlocutors and a *speaker plan* to achieve that goal, possibly together with other propositions—than the original common ground (this amounts to a requirement that the utterance is goal/plan furthering) and 2) that the update is ordered equal to or before any other update that the speaker could have provided—the accepted goal set, the processing/contextualization goal set or the interactional goal set. Clause (a) will lead to the generation of base implicatures, while clause (b) may lead to comparative implicatures with respect to each of the goal sets. Intuitively, the RCP ensures that any utterance is maximally plan/goal furthering: it furthers a goal, and does so to the best of the interlocutor's ability.

The PoCI works in conjunction with the RCP to generate implicatures. This principle is as follows:

(2) *Principle of Cooperative Inferencing*
Given an update of the common ground combined with mutually recognized inferencing rules and background knowledge, assume that all mutually recognizable inferences are part of the speaker's intended meaning.

This principle is reminiscent of the enrichment process described in Atlas and Levinson (1981), Horn's R-principle (Horn 1985), and Sperber and Wilson's Principle of Relevance (Sperber and Wilson 1988). Once an utterance has been produced, enrichments of the basic meaning of the utterance will result from the application of this principle. If there are any alternative utterances that are mutually recognized to be better than the one provided with respect to one of the goal sets, this principle leads to implicatures concerning the specific reason that an interlocutor could not provide this utterance. The Principle of Cooperative Inferencing will be discussed further in a later section.

Given these two principles, it is now possible to sketch how they interact to generate conversational implicatures. Again, I am outlining an interpretation process that applies to an utterance; the steps in this process must be ordered with respect to each other to arrive at the right set of conversational implicatures.

I assume that when an utterance is produced, an initial inferencing process applies, governed by the Principle of Cooperative Inferencing. This principle requires that all inferences that it is mutually recognized can be drawn based on the new utterance/update should be assumed to be part of the speaker's intended meaning; it will apply iteratively throughout the interpretation process (i.e., whenever a new proposition is added to the common ground, inferences will be drawn based on the PoCI). The inferencing process includes a plan inferencing process (involving the plan inferencing rules developed in Chapter II), which results in the inference of a plan (the *speaker plan*) which connects the action of utterance to a goal that the speaker is trying to achieve through that action of utterance. In addition, general inferencing takes place based on the utterance, information that is accessible (i.e., in the "working memory" portion of the common ground), and possibly other information in the common ground that is associated with the propositional content of what has been said (such as encyclopedic entries associated with lexical items, as described by Sperber and Wilson (1988)).

The initial inferencing (which includes the inferencing of the speaker plan) is constrained by the first clause of the Revised Cooperative Principle, which will require that the intended update associated with the response provided furthers what I have called the accepted goal set. The accepted goal set is a set of propositions which contains a goal of at least one of the interlocutors, as well as the propositions which make up the speaker plan to achieve that goal through the conversational interaction. The propositions contained in the accepted goal set are typically ones that have been introduced by a prior utterance. The result of the initial inferencing process is an update of the common ground which includes previous information (e.g., previous utterances, the accepted goal set before the utterance, etc.), the new utterance, the speaker plan associated with the utterance, other propositional information that has been inferred on the basis of the utterance, and possibly a revised version of the accepted goal set. The new propositions that have been added represent the literal meaning of the utterance and the "base" implicatures associated with it. These base implicatures include enrichments (which are largely the result of the Principle of Cooperative Inferencing) and relevance implicatures (which are directly connected to the speaker plan that is inferred based on the assumption that the speaker is obeying the RCP).

Comparative implicatures arise through a secondary inferencing process, which begins by comparing the update of the common ground that is associated with the utterance to other mutually recognized utterance/update alternatives, with respect to the accepted goal set (containing plan-related goals), the contextualization/processing goal set (containing goals relating to ease of processing or "contextualizing" the utterance), and the interactional goal set (containing goals relating to maintaining the "face" of interlocutors). If an alternative utterance/update that is better with respect to one of the goal sets is mutually recognized, a weak implicature to the effect that the speaker could not have provided that utterance/update arises (e.g., "weak" scalar implicatures fall into this category). Then the Principle of Cooperative Inferencing will apply to derive specific reasons that the better update wasn't provided (e.g., "strong" scalar implicatures, cf. Gazdar's (1979) "epistemic modification"). Comparative implicatures that arise based on these two principles include scalar implicatures, other Quantity 1 implicatures, Quantity 2 implicatures, and implicatures that arise when a prolix form is used (e.g., Grice's example of flouting of a Manner maxim).

The specific type of comparative implicature that arises will depend on which goal set is the basis for the comparison, as well as on the contents of the specific accepted goal set. The RCP generates the plan-based implicatures in each of these categories; inference-based implicatures (enrichments and strong comparative implicatures) arise via the Principle of Cooperative Inferencing. The following diagram summarizes the primary categories of conversational implicature that result from the interaction of the RCP and the Principle of Cooperative Inferencing, and (in the case of comparative implicatures) the different goal sets they are associated with:

	Accepted goal set	Processing goal set	Interactional goal set
Base implicatures (RCP clause a)	Relevance Quality Enrichments Manner (orderly)		
Comparative implicatures (RCP clause b)	Scalar Other quantity 1	Flouting manner/ use of prolix form Quantity 2	(Not addressed by previous accounts)

Figure 22: Categories of implicature

Two kinds of plans play a role in the account developed here: speaker plans and domain plans. A speaker plan connects the action of utterance with a goal of the speaker via a series of sub-actions; that is, the action of utterance is the first action in a plan to achieve some goal. A domain plan is a more complex plan involving other, real-world (i.e., extra-conversational) actions.[1] In Grice's gas station example, the speaker plan associated with the second utterance includes (among other actions) an initial utterance action of saying "There's a garage around the corner," an intermediate action of proposing a domain plan in which the first interlocutor goes to that station and fills up, and a final action of helping the interlocutor find a way to get gas. The domain plan consists of the actions required to get gas: finding a station, going to the station, purchasing the gas, etc. Speaker plans often involve developing and executing domain plans, and they are frequently involved in achieving one of the early steps in such a plan (e.g., in the domain plan to get gas there may be an early action of finding a gas station; this action is furthered through the speaker plan associated with communicating a need for gas).

As mentioned previously, the accepted goal set at any given time may contain a speaker plan of one of the interlocutors. This speaker plan is accepted by both interlocutors as the plan that both are trying to further. The cooperativity of subsequent utterances is evaluated in terms of this goal set and the speaker plan it contains. For example, in the Gricean relevance example, when the second interlocutor says that there is a garage around the corner, he is responding to the accepted goal set established by the first interlocutor's utterance, which includes the goal of getting gas and a plan for achieving that goal by indicating a need for gas. Inferences are drawn on the assumption that the second interlocutor's utterance is intended to further this goal set. In two-turn conversations like this example, the general pattern appears to be that an accepted goal set is introduced by the first utterance and furthered through the next utterance. In multiple turn conversations, the accepted goal set may govern the utterances of both interlocutors until it is closed, and may also be modified by those utterances.

At this point, I will go through the various elements of the framework in greater detail. I will begin by discussing how the common ground is updated, identifying specific updates that have theoretical significance for an account of implicature and the plan inferencing process that occurs during the updating of the common ground. Next, I will discuss the three goal sets referred to in the RCP, with brief descriptions of how each of

[1] Speaker plans are actually a subset of the class of domain plans, but for simplicity I have used the two terms to differentiate between the two types of plans.

them may lead to implicature. Then I will review work by Kratzer (1981) and Heim (1992) showing how an ordering on propositions and sets of propositions can be formally defined in terms of another set of propositions. This type of formal ordering is then used in a formal definition of the RCP, which uses the goal sets as the basis for ordering the updates of the common ground. In clause (a) of the RCP, there is a requirement that an update of the common ground is ordered higher than the original common ground with respect to the accepted goal set (which amounts to a requirement that at least one of the propositions in that set has been made true). In clause (b), there is a requirement that the update provided is ordered as high or higher than any other mutually recognized update that could have been provided with respect to each of the goal sets (which amounts to a requirement that if a proposition in one of the goal sets is true in an alternative update, it must also be true in the update provided). The Principle of Cooperative Influencing is then described in somewhat more detail. The chapter concludes with a discussion of what happens when an utterance is added to the common ground.

3.2. Updating the Common Ground, including Implicature Generation

Conversing may be thought of as an ongoing process of modifying the common ground. I will model this ongoing modification as an iterative process in which interlocutors take turns creating new updated versions of the common ground (updates) and accepting or rejecting the new updates that are created. Acceptance of a common ground is normally indicated by building on what was added without question (Stalnaker 1978, Thomason 1990). When a common ground O_i is modified, a new common ground O_{i+1} is created. This new common ground may be an *actual* common ground (i.e., all of the propositions it contains are mutually recognized by the interlocutors in the conversation) or it may be a *provisional* common ground. A provisional common ground is one which contains propositions that are not necessarily recognized or accepted by all of the interlocutors in the conversation. I will use the notation O_i' to represent a provisional common ground.

Figure 23 shows the process of updating the common ground (represented as a set of propositions which corresponds to a set of worlds)[2]:

[2] If this were a model of utterance processing, the top portion of this diagram would be oversimplified, since after an utterance is initially processed it may be reanalyzed based on additional information. However, for the purposes of the account I am developing, this simplification is not problematic.

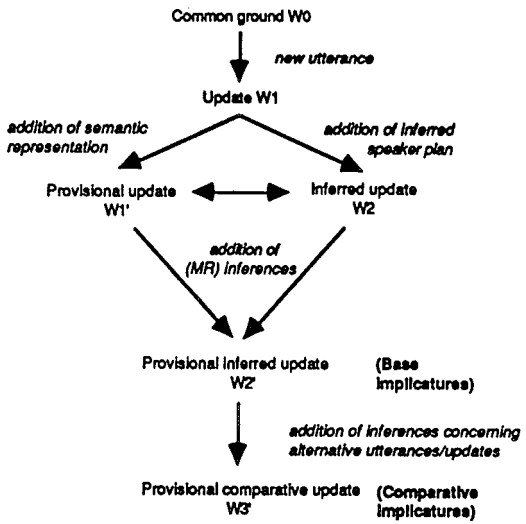


Figure 23: Updates of the Common Ground

When an interlocutor produces an utterance in a conversation, the common ground W_0 is updated. The new update W_1 includes the propositions that 1) the interlocutor has produced this utterance, 2) the interlocutor has "said" the literal meaning associated with the utterance (in the Gricean sense of "say"), and 3) the interlocutor has created a new update (W_1') which contains all of the information in the current common ground along with the semantic representation of what was said (that is, the interlocutor has created an update of the common ground which includes the meaning of the utterance as part of its propositional content). These three propositions are mutually recognized by all of the interlocutors, since they are "common knowledge" in the sense described by Clark and Marshall (1981)—the initial act of utterance has been directly observed by all of the interlocutors, and each interlocutor has evidence to the effect that it has been directly observed by the others (physical copresence, etc.); furthermore, there is a mutually recognized plan (discussed later in more detail) according to which the action of utterance leads to the other two

propositions. As a result, this update of the common ground is actual, rather than provisional. At this point, two updates of the original common ground W_0 are salient in the conversation: an actual common ground W_1, which includes the previous context along with the three propositions described above, and a provisional common ground W_1', which includes everything in the actual common ground along with the semantic representation of what was said.

The reason for distinguishing between the new provisional update and the new actual update is that the new proposition associated with the semantic representation of what has been said is not necessarily accepted by all of the interlocutors. Until this update of the common ground has been accepted, it will remain provisional.

Based on what the interlocutor has "said," a plan linking the act of utterance with the interlocutor's goal will be inferred using mutually recognized plan inferencing rules and linkages between actions in plans. This inferencing is part of the general inferencing that takes place due to the Principle of Cooperative Inferencing—it involves mutually recognized inferencing rules and applies only to mutually recognized information—and is constrained by the Revised Cooperative Principle: the goal of the plan that is inferred must relate in some way to the accepted goal set (and/or must introduce a new goal set). The goal of this plan is the *speaker goal*, and the plan linking the utterance to the goal is the *speaker plan*.

Once the speaker plan has been inferred, an updated common ground will be created by adding this plan to the previous common ground. I call this an *inferred* update of the common ground (W_2 in the diagram).

Next, the semantic representation of what was said will be added to the inferred update of the common ground, creating a new provisional update that includes the speaker's plan as well as the meaning of what was said. In addition, the effect of the utterance in terms of the previous goal and plan will be added at this point (e.g., a domain plan associated with the speaker's goal may be added or an existing domain plan may be modified, and parts of the speaker plan or domain plan may actually be executed by the changes that take place in the common ground). Enrichments are also added at this time. The contents of this update (W_2') will comprise the literal meaning and "base" implicatures associated with what was said.

At this point, the Revised Cooperative Principle will come into play again, requiring that the update provided was the best one that could have been provided (in a sense to be explicitly described later). The provisional inferred update W2' will be compared to other

updates that would better further the accepted plan/goal. In the final inferencing step, mutually recognizable inferences will be drawn about why the speaker did not provide the more "plan-furthering" update, and these will be added to the common ground (these propositions represent strong comparative implicatures). The result will be the update W_3'.

The general pattern through which the Revised Cooperative Principle and the Principle of Cooperative Inferencing interact may be summarized as follows: 1) the first clause of the Revised Cooperative Principle guides the initial inferencing process that generates the base implicatures; during this part of the process, the RCP leads to traditional relevance and quantity implicatures while the PoCI leads to enrichments; then 2) the second clause of the RCP leads to the comparison of the update associated with the utterance to alternative utterances/updates (weak comparative implicatures); finally, 3) the PoCI applies to generate specific implicatures as to why the better alternatives were not provided (strong comparative implicatures.

In the next several sections, the different elements of the framework informally discussed above will be described in more detail. These elements include: the three goal sets used for comparing utterance alternatives, a formal ordering on updates of the common ground with respect to a goal set, a formal definition of the Cooperative Principle which makes reference to the three goal sets and the formal ordering based on them, and a characterization of the mechanisms involved in the Principle of Cooperative Inferencing. Finally, the general process will be reviewed in greater detail for a generic utterance.

3.3. Goal sets

In order to evaluate the cooperativity of an utterance according to the RCP, the provisional inferred update of the common ground associated with that utterance is first compared to the original common ground with respect to the accepted goal set. Then, the update is compared to alternative updates that are mutually recognized to be alternatives to the update provided with respect to three goal sets: the accepted goal set, the processing/ contextualization goal set, and the interactional goal set. I will assume that the three goal sets may be modeled as sets of propositions; this will allow updates of the common ground to be formally ordered according to how many of the propositions in these goal sets are true in them (as described in sections 3.4. and 3.5.). In the remainder of this section, I will describe the contents of each type of goal set and give an example from Grice (1975) of how implicatures arise based on it. At the end of this section, I will discuss interactions between the goal sets.

The choice of the three goal sets mentioned above may seem ad hoc; however, I believe it is actually motivated by the nature of the communicative situation itself. Any normal linguistic communication involves a general purpose or goal (which may be transactional or discourse-based), the people who are engaged in the communication, and a natural language utterance—all of which are embedded within an existing context. The general purpose or goal corresponds to the accepted goal set, the specific interaction between the people at a social level is addressed by the interactional goal set, and the decoding and interpreting of the utterance within the linguistic context is governed by the processing/contextualization goal set.

3.3.1. The Accepted Goal Set

The accepted goal set includes the speaker's plan—the plan linking the action of utterance to the speaker's ultimate goal—and may include a propositions from a domain plan connected to the speaker plan.

In the account I am developing, an interlocutor's utterance is associated with a goal, which I have called the speaker goal. This goal may involve achieving some effect in the real world (e.g., may be primarily transactional), and/or it may involve changing the attitudes of one's interlocutor(s).[3] A plan may be inferred that links the speaker's utterance action to the achievement of this goal (the speaker plan). In the account developed here, the speaker plan is the only strictly "conversational"[4] plan involved in the communicative process.

The speaker goal and the speaker plan which links the utterance to the speaker goal are included in the goal set associated with an interlocutor's utterance. The goal set is a set of propositions associated with the interlocutor's goal (which may be correlated with the set of worlds in which those propositions are true). One of these propositions is the goal proposition itself. Other propositions which characterize the goal set are the actions in the plan to achieve the goal, as well as the conditions that must hold for the appropriate action

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[3] Grosz and Sidner (1986) identify three components that contribute to the structure of discourse: the structure of the sequence of utterances (which they term linguistic structure), an intentional structure, and an attentional state. Their intentional structure corresponds in some respects to a domain plan in my account. Importantly, their intentional structure includes discourse intentions which may involve a task-oriented plan or a rhetorical plan. I will assume that the domain plans in this account may be task-oriented ones or rhetorical ones. (Note: This account is not addressing the same phenomena as that of Grosz and Sidner, and I am making no claims about its empirical equivalence.)

[4] McCafferty (1987) identified two kinds of goals: domain goals and conversational goals. In addition, he had speaker plans which addressed these goals. In the account developed here, speaker plans may contain conversational goals (e.g., McCafferty's conversational goal of constructing a plan to see a movie, or a conversational goal of getting the answer to a question).

relations to hold between the actions in the plan. Other entailments of the goal action are also included in this set.

As an example, we may consider the goal set that is associated with the first utterance in one of Grice's relevance examples (Grice 1975), repeated below:

(3) A is standing by an obviously immobilized car and is approached by B; the following exchange takes place:
A: I am out of petrol.
B: There is a garage round the corner.
(Gloss: B would be infringing the maxim "Be relevant" unless he thinks, or thinks it possible, that the garage is open, and has petrol to sell; so he implicates that the garage is, or at least may be open, etc.)
(p. 32)

The goal set which A's utterance introduces includes the goal action of A's getting gas: that is, the proposition *get (A, gas)*), propositions to the effect that A wants to develop and then execute a domain plan which will result in getting the gas, a partial domain plan that consists of only the goal of getting gas, and meta-goals[5] concerning the domain plan to be developed: specifically, that A have to walk a minimum of distance, spend a minimum amount of money for the gas, etc. Once the update of the common ground associated with A's utterance has been accepted, the goal set associated with that utterance becomes the accepted goal set.[6] If B is being cooperative, clause A of the RCP will require that B's utterance relates to the accepted goal set associated with A's utterance. As a result, base implicatures relating B's utterance to the development of a domain plan for A to get gas arise—specifically, these implicatures include B's belief that the conditions hold that are necessary for actions in the plan to be performed (i.e., A won't be able to get gas at the station unless the station is open and has gas to sell).

As an example of how the accepted goal set may lead to a comparative implicature, we may consider Grice's South of France example, repeated from Chapter I (Grice 1975).

[5] The goal set may include meta-goals which apply to any domain plans, such as taking a minimum amount of time, achieving two goals with a single action, etc.—especially when a domain plan has not yet been developed.
[6] Modification of the accepted goal set through a conversation is quite complicated. A's goal set becomes the accepted goal set partly because there is no accepted goal set prior to A's utterance. If there had been, A's utterance would have had to relate to that goal set (possibly modifying it).

(4) A is planning with B an itinerary for a holiday in France. Both know that A wants to see his friend C, if to do so would not involve too great a prolongation of his journey:
A: Where does C live?
B: Somewhere in the South of France.
(Gloss: There is no reason to suppose that B is opting out; his answer is, as he well knows, less informative than is required to meet A's needs. This infringement of the first maxim of Quantity can be explained only by the supposition that B is aware that to be more informative would be to say something that infringed the second maxim of Quality. "Don't say what you lack adequate evidence for," so B implicates that he does not know in which town C lives.) (pp. 32–33)

Unlike base implicatures, comparative implicatures are negative in nature: they arise when the update provided is *not* ordered as high as another (alternative) update. The accepted goal set introduced by A's utterance includes the propositions that A has the goal of visiting C, that A wants to know where C lives so that A can decide whether to develop a plan to visit A, etc. According to this set, an utterance/update providing more specific information about where C lives would be better than the one provided. Because B did not provide this utterance, it is mutually recognized that B could not provide it. In this case, the reason inferred that B wasn't able to provide a more specific utterance is that B did not have enough information to do so.

Speakers' goals are introduced and furthered throughout a conversation. Domain goals are introduced in a variety of ways, either overtly ("I want to find a gas station") or more indirectly ("I am out of petrol"). Indirect communication of a goal takes place by providing information that will allow the speaker's domain plan to achieve the goal to be inferred. This may involve providing information that can be considered in conjunction with background information to allow the goal to be inferred, or may involve mentioning a condition on a plan to achieve the goal. Goal inference will be discussed in greater detail through discussion of specific examples. Once the goal has been inferred, it can be used as part of the plan inferencing process (which involves the plan inferencing rules discussed in Chapter II).

Generally, an utterance takes place in a conversational context (common ground) in which a specific goal is salient or accepted; this goal is often a goal or action in an interlocutor's previously inferred speaker plan.[7] In the gas station example, A has a

[7] In some cases, a goal set may be associated with a specific situation; e.g., before any words are spoken, a customer approaching a clerk at a store knows that the clerk has a goal of helping him obtain what he wants (within the domain of what the store has to offer).

speaker plan that involves enlisting B's help in developing (and possibly executing) a plan for A to get gas. A response when this is the most recently added plan in the common ground should in some way further the construction of a plan to get gas or should further the speaker goal in some other way (e.g., by saying, "There are two stations near-by. One is slightly closer, but gas is more expensive there. Which do you want directions to?"). The accepted goal set may include a domain goal, an answer to a question, or a discourse topic (and these may overlap). When a domain goal has been identified, the salient goal will be the achievement of that domain goal. When a question has been asked, the salient goal for the responder will be to provide an utterance that "answers" that question. An accepted goal set will remain in force, guiding the responses of both interlocutors, unless it is explicitly "closed" (and the topic is changed or the conversation is concluded). Many of the goal sets that lead to implicature have to do with real-world goals; however, it is also quite common for propositions in the goal set to involve entertaining someone, giving someone interesting information, etc. A goal of providing new information may be formally connected to the reduction of the context set that is associated with the common ground (cf. Stalnaker 1978).

The requirement that an utterance must address or further the accepted goal set serves to constrain the utterances that may cooperatively be provided, and also provides a basis for ranking or ordering utterances (and associated updates). For example, a question constrains the kind of information that can be appropriately provided in answer to it (e.g., providing information that suggests whether or not Smith is dating anyone these days). The introduction of a topic for discussion constrains the utterances that can be added to the conversation, at least until the topic is closed. When a domain goal has been introduced, an interlocutor must provide an utterance that furthers that goal (e.g., helping someone find out where to get gas). Base implicatures arise on the assumption that the utterance provided in response to the accepted goal set furthers that goal set.

Some plan-based accounts have assumed that there is a conversational goal which persists until it has been satisfied. In the account I will provide, a new speaker goal may be inferred with each utterance act. However, the goals and plans that are associated with utterances must "dovetail" (to use Grice's phrasing) as required by the new cooperative principle I provide—that is, each speaker plan associated with an utterance must somehow further the accepted goal set, and is likely to do in a way that relates to the immediately

preceding utterance.[8] Furthermore, there is likely to be a domain plan to which specific utterances relate; this domain plan may impose a structure on the conversation as a whole. (This occurs when various aspects of the plan need to be filled out or specified through the conversation.)

The first clause of the RCP requires that an utterance must lead to an update which is closer to the accepted goal set than the previous update of the common ground. As will be discussed in sections 3.4 and 3.5, an update will further a goal set if it makes some of the propositions in the goal set true. The best utterance is one that leads to an update in which the goal itself is true. An utterance which leads to an update in which only an action in a plan to achieve the goal is true is goal-furthering to a lesser extent (since such an utterance will generally make fewer propositions in the accepted goal set true). An utterance in which a condition on the action relation between two actions in a plan to achieve the goal is true is also goal-furthering. All of this follows from the fact that if an interlocutor has a plan to achieve a goal (which is included in the accepted goal set), then making some part of that plan true (either actions or conditions) brings the interlocutor closer to the goal.

3.3.2. The Processing/Contextualization Goal Set

This goal set contains propositions concerning the ease of processing of an utterance. Ease of processing includes: parsing (e.g., syntactic complexity), decoding (e.g., ambiguity), embedding the semantic representation of the utterance into the representation of the context (e.g., reference assignment), and doing the additional inferencing necessary to arrive at the speaker's intended meaning.

As an example of how an implicature may arise by comparing the utterance/update provided with alternatives with respect to this goal set, we may consider one of Grice's flouting examples (Grice 1975):

> (5) (a) Miss X sang "Home Sweet Home."
> (b) Miss X produced a series of sounds that corresponded closely with the score of "Home Sweet Home."
> (Gloss: Why has [the reviewer] selected that rigamarole [in (b)] in place of the concise and nearly synonymous *sang* ? Presumably, to indicate some striking difference between Miss X's performance and those to which the word singing is usually applied. The most obvious supposition is that Miss X's performance suffered from some hideous defect. The reviewer knows that this supposition is what is likely to spring to mind, so that is what he is implicating.) (p.37)

[8] As mentioned previously, although I do not go into detail on this, I assume that this set may be modified through a conversation. How exactly this modification takes place is an area for further work.

Here, the utterance in (b) may be compared with the much briefer and less syntactically complex one in (a). When ordered according to the processing/contextualization goal set, which includes a proposition something like Grice's Manner maxim "Be brief" (or, more likely, an injunction to minimize syntactic complexity (Boland, p.c.)) the update associated with the (a) utterance is ordered before the update associated with the (b) utterance. Since this utterance/update was not provided, it is mutually recognized that the speaker could not have provided it. In this case, the reason that can be inferred for not providing it is that the speaker does not want to suggest that Miss X's performance deserved to be called "singing."

I am not making specific claims about the full set of propositions contained in this goal set, since much remains to be learned about how language is processed—and, more importantly for this account, what is mutually supposed about how language is processed. I will assume, however, that this set at least includes propositions to the effect that 1) the utterance provided is as brief and syntactically simple as possible and 2) a minimum of inferencing is required to see how the utterance furthers the accepted goal set (i.e., satisfies clause (a) of the RCP).[9] I take it that both of these propositions are at least intuitively motivated.

3.3.3. The Interactional Goal Set

In this category, I will include the politeness goals identified by Brown and Levinson (1987). According to Brown and Levinson's theory, one of the things that conversationalists do is try to maintain one another's "face." Brown and Levinson identify two kinds of face, positive and negative. They define positive face as "the want of every member that his wants be desirable to at least some others" and negative face as "the want of every 'competent adult member' that his actions be unimpeded by others" (p. 62). An individual's face is maintained largely through the actions of others, so "it will in general be to the mutual interest of two [individuals] to maintain each other's face" (p. 60). Certain acts are by their very nature face threatening; these actions may be "redressed" to preserve face.

Brown and Levinson categorize "face-threatening acts" (FTAs) according to whether these acts threaten the speaker's face or the hearer's face, and according to whether they threaten positive or negative face. For example, an FTA that threatens the hearer's positive face would be disapproval or criticism of the hearer (which suggests that the hearer's wants are not being reinforced), while an FTA that threatens the hearer's negative face would be an order or request (which impedes the hearer's actions). An FTA that threatens the speaker's positive face would be an apology (which suggests that the hearer's wants are valued more highly than the speaker's), and one that threatens the speaker's negative face would be giving an excuse (which suggests that the speaker has to account for his actions to someone else, and therefore his actions are not unimpeded by others). Brown and Levinson then go on to identify strategies for "redressing" FTAs, by using indirect speech acts, etc.

I will assume the interactional goal set includes propositions to the effect that each interlocutor will attempt to maintain the positive and negative face of all interlocutors. Although this requirement may seem strong, it is the basis for implicatures concerning the politeness of interlocutors: when an interlocutor violates one of these requirements for no apparent reason, implicatures arise to explain why (e.g., the matter was too urgent to waste words, they were angry, etc.).

Grice did not give any examples involving interactional goals, although he did mention that his system could be augmented by adding maxims governing politeness.

3.3.4. Interactions between the Goal Sets

As mentioned in the above discussions, each of the three goal sets I've identified may lead to conversational implicature. However, it is also important to point out that these goal sets may interact with each other: when an interlocutor provides an update that does not satisfy clause (b) of the RCP with respect to one of the goal sets, it may be because she is choosing to satisfy another goal set instead. In this case, there will probably be implicatures to the effect that 1) the interlocutor was satisfying the other goal set and 2) the other goal set was more important. Implicatures of this kind arose in Grice's singing example (where the accepted goal set is interpreted as including a proposition concerning giving a truthful report of the concert)—the reviewer considered it more important to give a truthful report (and possibly to amuse the reader) than to use a brief/syntactically simple expression.

It may be the case that there is already a contextual assumption about which goal sets are most important in any given conversation. Generally, it's probably more important to provide an utterance that "maximally furthers" the accepted goal set than either of the others. However, in some situations one of the other two might be more important, such as

9 Of course, these two principles may be in conflict with each other (cf. Levinson 1987, Sperber and Wilson 1988). I don't have much to say about how this particular conflict can be resolved at this point.

occasions in which people are taking special care not to offend one another or when things must be done in a hurry (so especially brief expressions are used).

3.4. Ordering Utterances/Updates with Respect to a Goal Set

In order to formally characterize what it means to order one update of the common ground before or after another with respect to a goal set, I will borrow from Kratzer's (1981) work on modality. Kratzer has argued that to characterize the meaning of a modal expression, it is necessary to identify the sort of conversational background (the modal base) which serves as the domain of the modal (the set of worlds or situations over which it ranges), and then to use another conversational background as the basis for ordering the set of worlds that correspond to the modal base (ordering source). The conversational background that is the basis for ordering the set of worlds corresponding to the modal base is a set of propositions. In Kratzer's approach, this set of propositions is used to induce an ordering on worlds: a world *w* is ordered before a world *w'* if more of the propositions in the ordering source are true in *w* than *w'*.

Kratzer describes a variety of different kinds of conversational backgrounds, such as a realistic conversational background (which assigns to each world the set of propositions that are true in that world), an epistemic conversational background (which assigns to each world the set of propositions that are established knowledge to one or more people in that world), a stereotypical conversational background (which assigns to each world the set of propositions that are in the normal course of events in that world), a deontic conversational background (which assigns to each world the set of propositions that are commanded in that world), etc. When a modal expression is used, one conversational background serves as the modal base; another conversational background then serves as an ordering source on the worlds in the modal base. For example, in the sentence, *John must be at the store*, the modal base is an epistemic one ("in view of what is known, John must be at the store") and the ordering source is the stereotypical conversational background ("in view of the way things usually are").

A conversational background can serve as an ordering source on a set of worlds by acting as an "ideal" to which the worlds in the set are compared. The formal way that this is defined is the following (where $\leq_A$ is an ordering induced by a set of propositions A, and W is a set of worlds (those in the intersection of the modal base) (p. 47):

(6) The Ordering $\leq_A$:
For all worlds w and $z \in W$:
$w \leq_A z$ if and only if $\{p: p \in A \text{ and } z \in p\} \subseteq \{p: p \in A \text{ and } w \in p\}$

Given a set of worlds W, a world *w* is ordered before a world *z* according to the set of propositions A[10] if and only if the set of propositions in A that have *z* as a member (i.e., in which *z* is true) is a subset of the set of propositions in A that have *w* as a member (i.e., in which *w* is true). Or, to look at it another way, *w* is a member of as many or more of the propositions in A than z is—thus, as many or more of the propositions in A are true in *w* as in *z*.

Kratzer's notion of an ordering source is quite relevant to considering how an utterance and the update of the common ground that results from that utterance further the goal set. The set of propositions used as the basis for the ordering will be ones contained in one of the three goal sets (depending on which one is being considered at the time).

In this framework, rather than using the ordering source to induce an ordering on a single set of worlds, the ordering source will instead be used to compare and rank whole sets of worlds (the sets of worlds which are associated with updates of the common ground). To do this, it is necessary to extend the ordering on single worlds to an ordering on sets of worlds. This is done in the following definition (borrowed from Heim 1992).

(7) For any $w \in W$, $X \subseteq W$, $Y \subseteq W$,
$X \leq_A Y$ iff $w' \leq_A w''$ for all $w' \in X$, $w'' \in Y$.

According to this definition, a set of worlds X is ordered before or equal to another set of worlds Y with respect to a set of propositions A iff all worlds in X are ordered before or equal to the worlds in Y with respect to A. This means that as many or more of the propositions in A are true in the worlds in X than are true in the worlds in Y.

3.5. Formal Definition of the Cooperative Principle

At this point, we may bring together the three goal sets and the ordering scheme described in the previous section to formalize the Cooperative Principle. Consider our preliminary definition of the cooperative principle, repeated below:

[10] Note the direction of the arrow used here; it is different from the notation used in, for example, Horn (1972) and Ginzburg (1990).

(1) *The Revised Cooperative Principle (informal definition)*
Provide an utterance/update that:
(a) brings the common ground closer to the accepted goal set
(b) is better than any other mutually recognized utterance/update that you could have provided in terms of making the goals in each of three goal sets (the accepted goal set, the processing/contextualization goal set and the interactional goal set) true in the common ground

In formally defining the Revised Cooperative Principle, it will be necessary to use two kinds of ordering. One, like the ordering described in the previous section, is a partial order—identifying sets of worlds that are ordered either before or equal to one another. This ordering is applicable to clause (b) of the RCP, in which it is required that all alternative utterance/updates be as good or better than the one provided. The definition of this type of ordering, which was given in the previous section, is summarized below (with G standing for one of the three sets of goals):

(8) (a) For all worlds w and $z \in W$:
$w \leq_G z$ if and only if $\{p: p \in G \text{ and } z \in p\} \subseteq \{p: p \in G \text{ and } w \in p\}$
(b) For any $w \in W$, $X \subseteq W$, $Y \subseteq W$:
$X \leq_G Y$ iff $w' \leq_G w''$ for all $w' \in X$, $w'' \in Y$.

In addition, a total ordering is necessary for comparing the update of the common ground to the previous common ground—in this case, the requirement is that the update of the common ground must be *better than* the previous common ground in terms of the accepted goal set. The definition of this ordering is identical to the previous one, except that it is no longer possible for worlds to be equal to one another in terms of the goal set: the worlds in the set that is ordered before the other set must all be ones in which more propositions are true. The definition is as follows (A stands for the set of propositions in the accepted goal set):

(9) a. For any $w \in W$, $X \subseteq W$, $Y \subseteq W$,
$X <_A Y$ iff $w' <_A w''$ for all $w' \in X$, $w'' \in Y$.
b. For all worlds w and $z \in W$:
$w <_A z$ if and only if $\{p: p \in A \text{ and } z \in p\} \subset \{p: p \in A \text{ and } w \in p\}$

As discussed in the previous section, there are three goal sets that must be considered in comparing different updates. The general principle is that the update associated with the provided utterance must further the accepted goal set A to some extent, and must further one of the three goal sets better than any other update that the speaker could have provided. Each of the goal sets may be used as an ordering source to compare the various sets of worlds that correspond to the relevant updates of the common ground. I will use the notation $\leq_A$ to refer to the ordering based on the accepted goal set, $\leq_I$ to refer to one based on the interactional goal set, and $\leq_C$ to refer to one based on the processing/contextualization goal set.

With this background, it is now possible to formally define the cooperative principle:

(10) *The Revised Cooperative Principle (RCP)*
Given an existing common ground W_0 and an accepted goal set S, provide an utterance u such that :
(a) for all W_2' such that W_2' is a provisional inferred update of the common ground associated with u, $W_2' <_A W_0$ and
(b) for all W_2'' such that W_2'' is a mutually recognizable provisional inferred update associated with some alternative utterance you could provide, for all goal sets G (G = A, C, I): $W_2' \leq_G W_2''$

Clause (a) of this definition states that a provisional inferred update must be ordered before the original common ground with respect to the goal state A. According to the definition in (10), one set of worlds is ordered before another set with respect to a set of propositions A iff each world in the first set is ordered before each world in the second set; one world is ordered before another with respect to a set of propositions A iff the set of propositions that are true in that world are a superset of the propositions in A that are true in the lower ordered world. In other words, more of the propositions in A will be true in the higher ordered world. Thus, more of the propositions in A (the propositions that characterize the goal state) must be true in W_2' than in W_1.[11] Clause (b) of the definition states that any alternative update the speaker could have provided must be ordered equal to or below the provided update with respect to each of the three goal sets. This means that no propositions in the goal set in question can be true in the alternative update if they is not are not true in

11 For the purposes of this dissertation, ordering according to number of propositions will be adequate. However, Kratzer (1989) notes that ordering according to number of propositions alone may be too simplistic, since information seems to be grouped or "lumped" in some ways. The point here is that a formal ordering can be defined, which can be used to order updates of the common ground with respect to a set of propositions which characterize the plans and goals of interlocutors.

the update provided as well. If this clause is violated, a reason for the violation will be inferred.

The general pattern is shown in the following diagram:

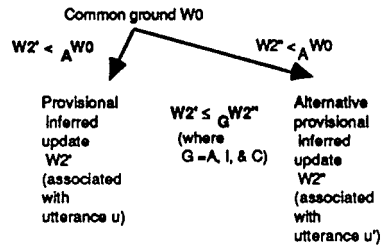


Figure 24: Orderings on Updates

The primary ordering requirements are shown in bold in the diagram. Given an utterance *u* associated with a provisional inferred update W_2', the cooperative principle requires that W_2' be ordered before W_0 with respect to the accepted goal set. This will mean that at least one of the propositions in this goal set that was not true prior to the utterance must be true after it. Now, any alternative utterances u' that the speaker could have provided which also further the accepted speaker's goal set (i.e., W_2" $<_S W_0$) must meet the requirement that they are ordered after the utterance that the speaker did provide with respect to at least one of the three goal sets.

At this point, it will be helpful to consider in more detail how the RCP leads to the generation of implicature. Based on the first clause of the RCP, a speaker plan will be inferred that links the utterance provided to a goal action that makes at least one of the actions in the accepted goal set true. The result of the inferencing process will be the provisional inferred update W2', which will include the base implicatures which are associated with the plan inferred. Next, the comparative part of the principle will apply if there is an apparent violation: that is, if there is an alternative utterance associated with an alternative provisional inferred update W2" such that the provided utterance is not ordered before this update with respect to at least one of the goal sets, implicatures will arise. In

most cases, these will include an implicature that the speaker could not have provided the alternative utterance/update along with mutually recognized reasons why the speaker could not have provided this utterance/update (e.g., the speaker believed the utterance/update was false, etc.). This is the mechanism that leads to scalar implicatures, some of the floutings discussed by Grice, and some other examples that will be discussed in the next chapter.

When there is a mutually recognized update that is superior to the update provided with respect to one of the goal sets, the reasons that may be inferred for why the speaker did not provide that update generally fall into three categories: 1) inferences concerning the alternative update and (usually) the speaker's epistemic state (i.e., that the speaker did not know that the utterance/update was true), 2) inferences concerning other goal sets that are furthered by the utterance (e.g., an inference that it was more important to be brief than to be polite, etc.), and 3) inferences concerning the goal set that was not furthered (e.g., a reanalysis of what the contents of that goal set are). A fourth possibility is that a breakdown has occurred and the interlocutor did not recognize that the superior alternative was a mutually recognized one; this amounts to a breakdown in what is in the common ground.

The following example of a Quantity 2 implicature shows how a goal set may be reanalyzed in order to satisfy clause (b) of the RCP:

(11) A: I need four chairs.
B: John has five chairs.

In this case, the utterance provided ("John has five chairs") is ordered equal to the alternative utterance "John has four chairs" with respect to the accepted goal set—either utterance supports the inference to a plan to borrow four chairs from John—and the interactional goal set. However, the utterance alternative "John has four chairs" is ordered before "John has five chairs" in terms of ease of processing—one must do an additional inference step to arrive at the entailment that John has four chairs. It's not possible to reason that the speaker couldn't have said "John has four chairs" (as in the scalar implicature examples), since if John has five chairs it entails that he has four chairs—so "John has four chairs" must be an option for the speaker. In this context, what happens is that the accepted goal set—which had previously included a proposition to the effect that the source of the chairs has four of them (a condition on being able to get the chairs from the source)—now includes a proposition to the effect that the source of the chairs has more

than four, and so would be more likely to loan the four that are needed.[12] This example will be discussed in greater detail in the next section.

3.6. The Principle of Cooperative Inferencing

The Principle of Cooperative Inferencing, repeated below, is a part of the overall process through which implicatures are generated.

(2) *Principle of Cooperative Inferencing*
Given an update of the common ground combined with mutually recognized inferencing rules and background knowledge, assume that all mutually recognizable inferences are part of the speaker's intended meaning.

I assume that this inferencing is similar to the contextualization of an utterance described by Sperber and Wilson, in which the new utterance is added to the currently accessible context, this context is enriched with the required information from other locations in the common ground (e.g., long-term memory, etc.), and inference rules leading to what Sperber and Wilson called non-trivial logical implications are applied.

The definition in (2) is obviously quite vague (especially in comparison to the formal version of the RCP). What is needed to make it more explicit is a theory of what inferences are mutually recognizable, which includes specifying the inferencing rules that may apply and what background knowledge is accessible at any point in a conversation. At present, I am not proposing such a theory. However, I will sketch some of the ideas that have been discussed by others to constrain the application of this principle.

3.6.1. Inference rules

Inference rules explicitly used by Sperber and Wilson as part of their "deductive device" (which operated on information present in the local context to derive implicatures) include *modus ponens*, and *modus tollendo ponens*. Other rules that it has been suggested may play a role in inferencing (Walker 1993, Cohen 1987) include *modus tollens* and *modus ponendo tollens*. These rules appear below (each rule begins with the major premise, then the minor premise, and finally the conclusion):

[12] Alternatively, an implicature to the effect that A could borrow five chairs from John might arise, depending on how definite A was about the number of chairs needed. In this case as well, a modification of the accepted speaker goal set takes place, this time to include the proposition that A wants five chairs.

(12) *Modus Ponens*
$P \rightarrow Q$
P
Q

(13) *Modus Tollens*
$P \rightarrow Q$
$\neg Q$
P

(14) *Modus Tollendo Ponens*
$P \vee \neg Q$
Q
P

(15) *Modus Ponendo Tollens*
$P \vee Q$
Q
$\neg P$

The plan inferencing rules used in this dissertation are special cases of the rule of *modus ponens*; these rules have complex propositions in the antecedent of the major premise rather than a simple one.

The general inferencing rules apply to accessible information to derive new inferences. In some cases they may play a role in making information accessible. For example, using the rule of modus ponens, if someone adds the minor premise and conclusion to the common ground, it causes the major premise to be mutually recognized. This is seen in the following example (Walker 1993, p. 152):

(15) Context: Interlocutors are trying to decide on an Indian restaurant for eating lunch.
A: Listen to Ramesh. He's Indian.

The major premise, that people of a certain nationality know more about things of that nationality, is added to the common ground to support the inference.

Sperber and Wilson have also discussed examples in which premises and conclusions are added to the common ground to support inferencing. They discuss examples in which both premises and conclusions are conversationally implicated.

3.6.2. Accessible Information and Mutually Recognizable Inferences

Given an input proposition and the wealth of information available in the common ground, an almost unlimited number of inferences can be drawn. However, not all of these inferences are part of the implicated meaning associated with an utterance. According to the Principle of Cooperative Inferencing I suggest, the inferences that are actually conversational implicatures are inferences that it is mutually recognized can be drawn.[13] This leaves us with the question of what distinguishes the mutually recognizable subset of inferences from the total set of inferences.

In the inferencing process suggested by Sperber and Wilson (1988), the deductive device operates on the current local context (which is roughly equivalent to a short-term memory store) once that context has been enriched with the addition of encyclopedic information associated with lexical items in the proposition in question (p. 139). However, Sperber and Wilson do not give much additional information about how or when the addition of encyclopedic information is licensed.

I will assume that it is mutually recognizable that all information located in short-term memory is available for inferencing; all resulting inferences are mutually recognized.

Like Sperber and Wilson, I will assume that it is mutually recognizable that some encyclopedic information is available for inferencing; like them, I am not certain precisely what information this is (except that it includes encyclopedic information associated with specific lexical items).

Since it is mutually recognized that interlocutors are obeying the RCP, I assume all inferences necessary to satisfy the RCP are mutually recognizable. This means that information in the larger common ground that is required in order for inferences to be drawn that satisfy the RCP can be accessed (i.e., brought into the local context or "working memory").

13 In this respect, the account I am suggesting diverges from Sperber and Wilson's. Sperber and Wilson do not have a clear cut-off between inferences they call "speaker backed" and ones that the hearer draws without being sure that they were implicated. In the account I am suggesting, only speaker-backed inferences are actually implicatures. The line between propositions that are mutually recognized and those that are not is still fuzzy, though—even in actual conversations. There are often cases when one is not certain whether a certain inference was intended, and so whether to take it as implicated. However, even in these cases it seems to be the assumption of the speaker's intention to make the proposition mutually recognized that determines whether a proposition is implicated, or merely inferable.

Once the Principle of Cooperative Inferencing has caused information from the larger common ground to be added to the immediately accessible portion of it, the information added and any inferences drawn based on the new information and the existing information are part of the set of conversational implicatures.

3.7. Overview of the Process for a Generic Utterance

Now that I've described the general framework involved in the generation of conversational implicature, I discuss in greater detail how it applies to a generic utterance.

The steps in the update process were depicted diagrammatically in Figure 23, repeated below:

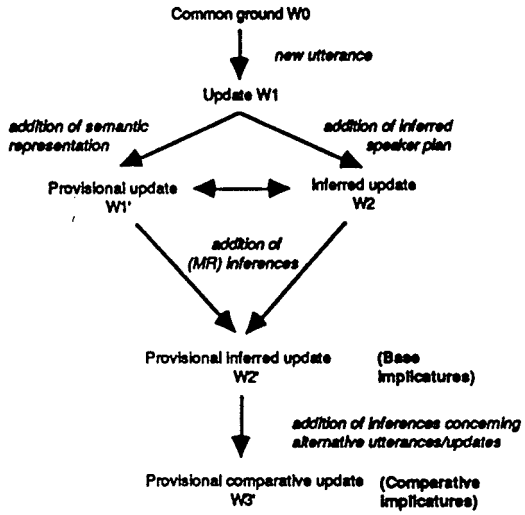


Figure 25: Updates of the Common Ground

The process begins with a common ground W_0 which may include an accepted goal set. An interlocutor *x* provides a new utterance, which leads to an update of the common ground W_1. This update includes the fact that *x* has uttered *u*, along with the fact that *x* has "said" the literal meaning of *u*. In addition, the proposition that *x* has created a new provisional update of the common ground which includes the semantic representation of *u* is added. All of this information is mutually recognized. Although this information is added immediately and automatically when a new utterance is added, in this account it is the result of an initial plan inferencing activity.

The information above is added to the common ground based on the mutually recognized assumption that it is *x*'s ***intention*** for this information to be added—and in fact, that these three propositions are actions in a public (mutually recognized) plan which are connected to one another via the action relations described previously. This public plan is inferred using the mutually recognized plan inferencing rules and knowledge about relations between actions discussed in Chapter II. By considering in detail the part of the total utterance plan that these three actions comprise, we will see that it is imperative that the appropriate action relations and conditions be mutually recognized for the plan to have the proper effect on the common ground.

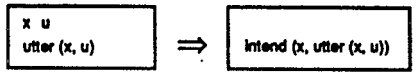
The plan inferencing process used to infer the first three steps in the speaker plan is a part of the more general inferencing process that takes place due to the Principle of Cooperative Inferencing. According to this principle, all inferences that it is mutually recognized can be drawn will be added to the common ground. In order to apply the RCP to the update associated with an interlocutor's utterance, it is necessary to infer the interlocutor's speaker plan—since it is mutually recognized that the RCP will be applied to the utterance/update, and that to do this, it is necessary to infer the speaker plan. It is thus mutually recognized that inferences necessary to identify a speaker plan will be drawn.

The first step in an interlocutor's altering the common ground is the production of some utterance *u*. When an interlocutor *x* utters *u*, the fact of utterance is normally mutually recognized. The motivation for this mutual belief is the physical evidence of A's production of utterance *u* combined with assumptions about interlocutors' attention, rationality, physical ability to hear, etc. With the addition of the proposition that *u* has been uttered, an update of the common ground O is created which contains all of the information in O combined with the fact of *x*'s utterance of *u*. Since the proposition that *x* has uttered *u* is mutually supposed, the new update that is created meets the criteria for being an actual

common ground rather than a provisional one. The action of utterance is the first step in an interlocutor's plan to alter the common ground.

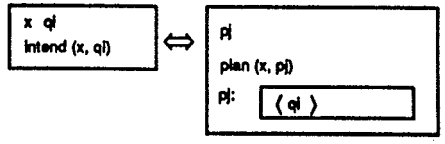
Based on the observed action of utterance, an inference is drawn that this action is intentional. Not all actions that an agent observes are intentional actions that can be used as the basis for beginning the plan inferencing process. For example, an individual might, while walking, step on an uneven place in the sidewalk and stumble. This would in most cases not be an intentional act that is a part of a plan (or at least not part of a plan that is meant to be recognized). Because the first action is a communicative action, it may be inferred that it is the agent intends to do that action. In view of this, I will include the following entailment in the full set of plan inferencing rules:

(17) *Intentionality of utterance action entailment*



This entailment would apply to a specific utterance *u* to give the inference that the speaker *x* intended to utter *u*. Given this entailment, which is mutually recognized (i.e., located in the common ground), it is now possible for the plan inferencing rules discussed in Chapter II to apply. The first rule that will apply is the Mini-plan axiom, repeated below:

(18) *Mini-plan axiom*



According to this rule, if an individual intends to do an action, it is possible to infer that the individual has a plan to do that action.

At this point, the two rules above have combined with the initial utterance action to create a mini-plan consisting just of that utterance action. A common ground containing this plan would look as follows:

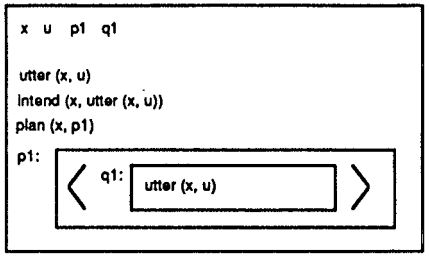


Figure 26: Common Ground Containing Mini-plan

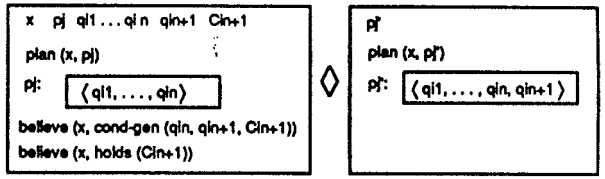
At this point, the common ground contains: 1) the supposition that *x* has uttered *u* (based on the mutual observation of this action), 2) the supposition that *x* intended to utter *u* (based on the "intentionality of utterance action" rule), and the supposition that *x* has a plan which contains just the single action of uttering *u* (based on the mini-plan axiom). All of these suppositions are mutually recognized, since they were performed in order to satisfy the RCP (which it is mutually recognized that the speaker is obeying). (Note: the common ground shown in Figure 24 is still schematic, in that specific characterizations for *x* and *u* have not been provided.) The belief necessary to license *x*'s intention to utter *u* is that *x* is capable of uttering *u*; this could also be added, but, since it follows from the production of the utterance, I will not add it to the common ground.

The next step in the plan to alter the common ground is adding the literal meaning of *u*, which I will call sem(*u*), into the common ground as having been "said" by the interlocutor. *Say (x, sem(u))* is read as "*x* says the semantic interpretation of *u*." I am using the word *say* here in the rather technical way that it has been used by Grice, to denote a speaker's expression of the literal meaning associated with some sentence. At this point the proposition expressed by sem(*u*) is not added directly to the common ground: only its having been said by the interlocutor is added. The new common ground created by this addition is still an actual one, because the fact that sem(*u*) has been said by *x* will be mutually recognized by everyone in the conversation—assuming the information necessary for the two acts to be linked in the plan is available in the common ground (e.g., is mutually supposed).[14] This information will be discussed shortly.

[14] Throughout this discussion, I am assuming for the sake of simplicity that the correct semantic representation is identified the first time. However, it is possible that misinterpretation would occur at this point, and the original semantic representation identified would have to be replaced with a new one. The recognition that the first semantic representation was incorrect might be prompted by plausibility factors, contextual factors (including its cooperativity), etc. Since this is not a theory of language processing, I will not be greatly concerned with these issues.

The plan inferencing rule that would be used by an interlocutor to infer a plan that links the first two actions above is the Forward-chaining inference rule. This rule is as follows (repeated from Chapter II):

(19) *Forward-chaining inference rule: conditional generation*



According to this rule (which is located in the common ground), if it is mutually recognized that an agent *x* has an plan which includes a final action q_{i_n}, and if it is mutually recognized that *x* believes that this action q_{i_n} conditionally enables another action $q_{i_{n+1}}$ under a condition $C_{i_{n+1}}$ which *x* believes holds, then it may be mutually recognized that *x* has the expanded plan which includes the previous plan with the new action $q_{i_{n+1}}$ (and the conditions $C_{i_{n+1}}$ on $q_{i_{n+1}}$) added to it.

Applying this rule to the utterance action, in order for this rule to apply it must be mutually recognized that the two actions are linked via conditional generation, and that it is mutually recognized that the requisite condition on the action relation holds. In this case, the condition which must hold is that the conventions of the language which allow the meaning of the utterance to be "decoded" are mutually recognized. As Pollack has described, the plausibility of this inference rule is dependent on how plausible it is that the condition *C* holds. To see that it is essential that it is mutually recognized that the two actions are linked, we may think of a situation in which two people mutually recognize that they do not speak the same language. In such a situation, if one person uttered something in her own language in the presence of the other person, she would expect the fact of utterance to be entered into the common ground, but not the semantic representation of what was uttered. Because she does not believe that the conventions necessary for the

relation between the two actions to be generated are mutually recognized (e.g., she does not believe that the necessary condition on the action relation holds), she will not form a plan in which these two actions are linked. Similarly, an interlocutor will generally not use vocabulary items which she does not take to be mutually recognized (cf. Grice's maxim of Manner: Avoid obscurity of expression).

Adding the new action to the plan, we get the following update of the common ground.

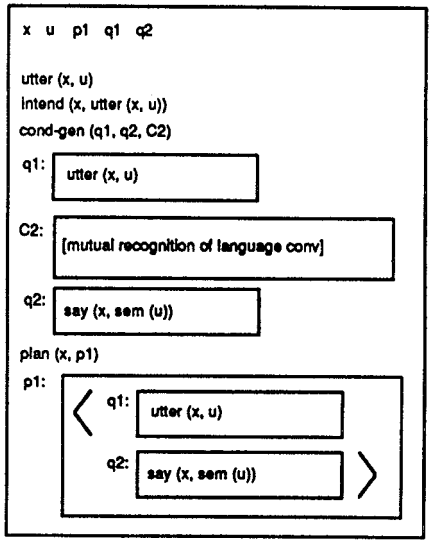


Figure 27: Common Ground Containing Speaker Plan with First Two Steps

Once the plan in Figure 24 has been inferred, the forward-chaining inference rule can be applied again to add another action to the end of the plan. In this case, the action added is the action of updating the common ground. "Update (x, O, sem (u), O') is read "*x* updates the common ground O by adding the semantic representation of *u* to create a new common ground O' "). As in the previous linkage, the relation between these two actions is conditional generation: the action of saying will conditionally generate the updating of the common ground under certain conditions. The condition *C* in this case is that all of the presuppositions associated with sem (u) must be satisfied in the common ground.[15]

The new version of the common ground with the expanded plan is shown below:

[15] This is the point at which accommodation might take place (cf. Stalnaker 1978, Thomason 1990). The issue of accommodation is quite relevant to the account developed here, since an interlocutor will only accommodate information if to do so would help to satisfy the accepted goal set. For example, accommodation when a definite NP is used is quite common. However, if someone asks, "Have you seen the letter?", accommodating the fact that there is a unique/familiar letter will not further the accepted goal set (which might—depending on the context—include a proposition of finding the letter). In such a case, accommodation would not take place, and the interlocutor would most likely say something like, "What letter?" I won't discuss accommodation further in this dissertation, but I hope the above discussion makes clear how it would fit into the account proposed here.

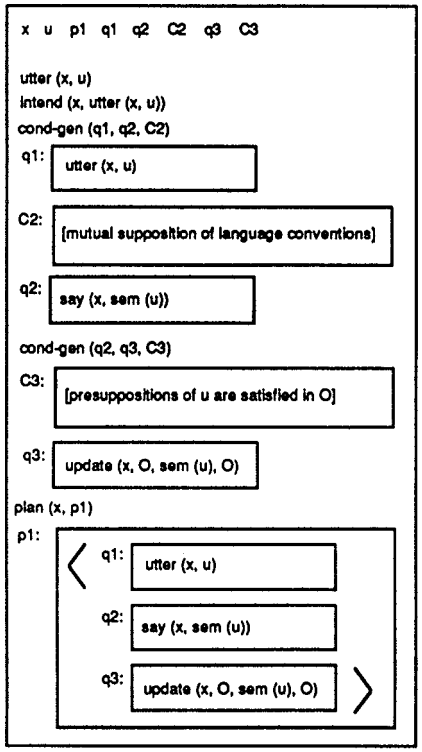


Figure 28: Common Ground Containing Speaker Plan with First Three Steps

A non-DRT theoretic way of representing plans is shown below. I employ it here because it is more space efficient.[16]

[16] In some cases, I will use the less formal representation of plans for reasons of space; however, it should be understood that this less formal representation may easily be translated into the DRT version.

(20)
| CEXEC, C1= x is physically able to produce u
utter (x, u)
| CGEN, C2= x & y are both cognizant of language conventions
say (x, sem (u))
| CGEN, C3= presuppositions are satisfied in O'
update (x, O, sem (u), O')

In addition to being entered into the common ground as a plan, the plan will also affect the common ground as described above, by causing all three of the actions to be added to the common ground. This follows from the definition of conditional generation: if an individual has a simple plan to do something and performs the first act in that plan, and all of the conditions on the conditional-generation relationships between the actions in the plan hold, then the individual has performed the plan. Thus, by producing an utterance under the appropriate conditions, an individual will cause the semantic representation of that utterance to be added to the common ground as having been "said" by that individual, and also the proposition that a new update of the common ground has been created. The new actual update of the common ground is W_1 in the diagram. In addition, a provisional update of the common ground W_1' is created in which the semantic representation of *u* has been added as a new proposition in the common ground. Both updates exist independently of one another at this point.

After the first three actions in the plan have been inferred, in most cases the plan inferencing process continues with the identification of the planning agent's utterance goal—the goal of the plan that is associated with the utterance.[17] This may be done using several different kinds of information. First, the change in the common ground that results from adding the semantic representation of *u* (i.e., the new update O') is considered. Second, if a goal has been entered into the common ground by another interlocutor's previous utterance, the goal of the new plan must be one that addresses this previously existing goal. Third, some basic inference rules may apply. Finally, other mutually

[17] In Pollack's framework, plan inferencing always begins with an observed action and a goal action, and results in a plan which links the two. In fact, it is possible to use plan inferencing rules to infer upward from an observed action until no further inferencing can take place, then assume that the final action inferred is the goal action. In the framework developed here, I will generally assume that it is mutually recognized that the hearer can use the information that is available in the context together with the speaker's utterance to infer the utterance goal, and then uses a plan inferencing process to link the observed action and the goal action. Part of my motivation for this is that in some cases the RCP constrains what the goal of this utterance plan can be, and inferring a plan strictly upwards could be a very inefficient process (as it might lead the inferring agent down wrong paths).

recognized information may be accessed, such as communicative interaction structures (which contain compiled information that governs standard interactions; Geis (in press)) that are linked to utterance form or content.

The identification of the utterance goal is important for the plan inferencing process I am using here, but is also important in that the hearer's recognition of the speaker's goal is generally a part of the plan. This is crucial when the goal of the plan must address an existing accepted goal set. Thus, an action is added to the first three in the plan to the effect that the speaker's goal is mutually recognized by the speaker and the hearer. The relation between the two actions in this case is enablement: the updating of the common ground creates a situation in which the mutual recognition of the utterance goal can take place.[18] The condition which must hold for the first action (updating) to enable the second (causing recognition of the speaker goal) is that the information necessary (e.g., previous goal, basic inference rules, communicative interaction structures (Geis, in press), etc.) to support the inferencing is mutually recognized. The new plan is as follows:

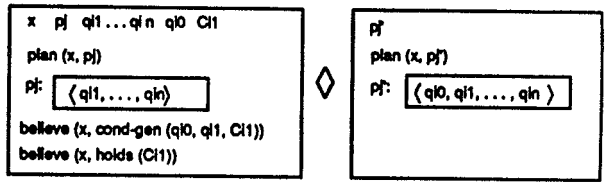
(21)
| CEXEC, C= x is physically able to produce u
utter (x, u)
| CGEN, C= x & y are both cognizant of language conventions
say (x, sem (u))
| CGEN, C= presuppositions are satisfied in O'
update (x, O, sem (u), O')
| CENABLE, C= MR of appropriate background information
cause (x, MR (x, y, speaker-goal (x, qi)))

As mentioned previously, an important characteristic of the speaker goal is that it is the last action or proposition in a plan that begins with A's utterance act. In this sense, it is quite different from other goals that A might be inferred to have which A is *not* trying to further through the utterance.

[18] I have broken the plan down to a level of detail that seems appropriate for explaining speaker intentions, mutually recognized beliefs, etc. It may be possible to break the plan down even further, including each inference step, the fact that the hearer's recognizing the goal is a step that, together with the speaker's recognition of the goal, generates the mutual recognition of the goal, etc. Including each of these steps is not necessary for the account of conversational implicature that I am developing, and would lead to a plan representation with a level of detail that would obscure the main points.

At this stage, the plan inferencing process begins to work backwards from the goal action. The backward-chaining inference rule, repeated below, is used to link sub-actions to the goal action of the plan.

(20) *Backward-chaining inference rule: conditional enablement*



At this point, utterance plans may vary significantly depending on the goal of the plan, etc. However, one more element is common to all utterance plans: the process of inferring actions through backward chaining will allow the end portion of the plan to be linked to the beginning portion of the plan through the action of the speaker's causing it to be mutually recognized that the speaker has the mutually recognized plan that the hearer has just inferred. The final plan appears as follows ("..." represents whatever specific actions link the beginning and end of the plan).

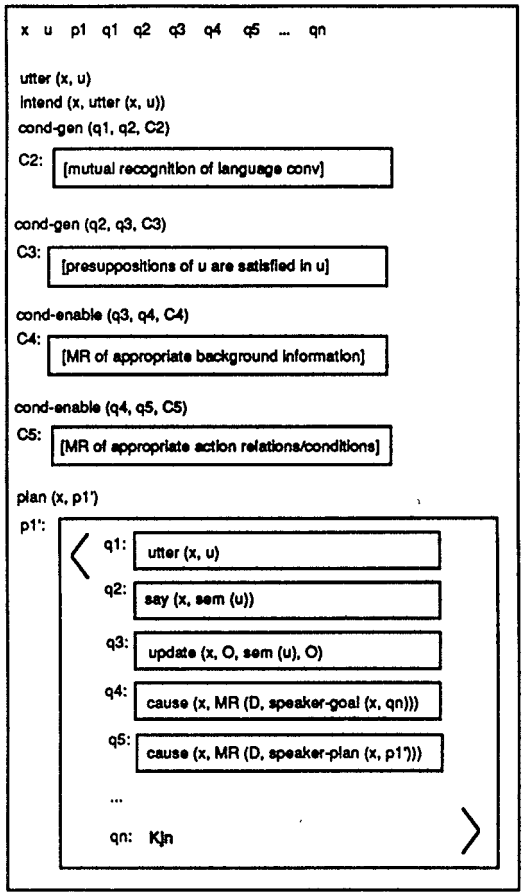


Figure 29: Speaker Plan Schema

As indicated in the plan above, the relation between the action of x's causing her goal to be mutually recognized and x's causing the utterance plan to be mutually recognized is that the appropriate action relations and conditions under which the action relations hold are mutually recognized. (If the speaker believes that one action in her plan generates another under certain conditions, but it is not mutually recognized that the hearer has this belief, it will not be possible for a mutually recognized plan to be inferred.)

Once the entire plan has been inferred, it is added to the common ground as being x's mutually recognized plan; this creates the inferred update W_2 shown in the diagram. As shown in the diagram, the hearer may go back and forth between the provisional update W_1' containing the semantic representation of what x said and the inferred update in W_2: if the provisional update of the common ground does not support the inferencing of a plan, this update may be changed and a new plan may be inferred.

When a consistent provisional update and inferred update have been mutually recognized, these two updates will be combined along with propositions[19] that follow from the inferred plan and any enrichments based on the Principle of Cooperative Inferencing into the provisional inferred update W_2' (e.g., introduction of the domain goal q_i, development of a plan, etc.). This update of the common ground contains the literal meaning of the utterance and the base implicatures that are associated with it. The base implicatures include the actions in the utterance plan, the conditions that hold between them, the propositions that have been added based on the plan, and enrichments. The cooperative principle requires that the update of the common ground W_2' is closer to the goal state than the original common ground. It is important to note that W_2' contains only information which is intended to be communicated: it includes the speaker's mutually recognized plan and propositions which are mutually recognized to follow from it. Additional (not mutually recognized) inferencing on the hearer's part is not included in this common ground, and is not an implicature.

I have shown the inferring of the speaker's plan as a step-by-step "building-block" type of process. However, it could also be modeled as a more automatic process in which a precompiled plan schema (like the final representation of the plan in Figure 27) is accessed and values are instantiated. In the next chapter, this way of building plans will be discussed.

[19] These propositions will be discussed in more detail for specific examples in the next section.

The final part of the process leads to comparative implicatures. According to the cooperative principle, it is mutually recognized that the speaker must have provided the most goal-furthering update possible. Based on this principle, it is in most cases mutually recognized that any mutually accessible alternative updates that are better than the one provided (in the sense that the one provided is not ordered before the alternative with respect to any of the three goal sets) could not have been provided by the speaker. This principle accounts for the "weak" scalar implicatures discussed by Hirschberg and Ginzburg to the effect that the speaker did not believe that any stronger utterance alternative (e.g., higher on the scale, more highly ranked according to an ordering) was true. The Principle of Cooperative Inferencing then applies to generate specific implicatures based on mutually recognized information (such as an implicature that the speaker knew that the more goal-furthering updates were not true—among other possibilities).

3.8. Conclusion

In this chapter, I have described the general framework of the account I am proposing. This framework includes two principles: the Revised Cooperative Principle and the Principle of Cooperative Inferencing. These principles interact with mutually recognized contextual information to generate two kinds of conversational implicature, base implicatures and comparative implicatures. Contextual information that is especially critical for the operation of the RCP includes plans (and the background information and rules necessary to infer them) and the three goal sets (the accepted goal set, the contextualization/processing goal set, and the interactional goal set). The PoCI applies to this information along with other accessible information that is taken to be mutually recognized.

The RCP is used to constrain and evaluate the cooperativity of a specific update of the common ground: namely, the update that results from the initial inferencing that takes place when an utterance is added to the common ground. Part of this initial inferencing is the inferring of a speaker plan associated with the utterance. The inferring of this plan is constrained by the RCP: the new update of the common ground which includes this plan (and other inferences) must satisfy clause (a) of the RCP if the speaker is being cooperative.

The RCP contains a formal ordering used to rank updates of the common ground with respect to a set of propositions. In each case, this set of propositions is one of the three goal sets. Clause (a) of the RCP requires that the new update of the common ground is ordered higher than the original common ground with respect to the accepted goal set

(this is a total order). This means that at least one of the propositions in the accepted goal set that was not true before must be true in the new update. Clause (b) of the RCP requires that the new update is ordered equal to or before any mutually recognized alternative updates that the speaker could have provided with respect to each of the three goal sets (a partial order). This means that any proposition in the goal set in question that is true in one of the mutually recognized alternatives must also be true in the update provided. If clause (b) is violated, it will be inferred that the speaker could not have provided one of the higher-ordered alternatives, and a reason for this inability will be inferred through the PoCI.

The update of the common ground that is compared to the original common ground (as required by clause (a) of the RCP) includes a speaker plan that is inferred based on the new utterance, mutually recognized contextual information, and the plan inferencing rules described in Chapter II. In the framework I have developed, this plan exists within a DRT representation of the common ground. Lexical entailments of the attitude *plan* (described in Chapter II) mean that if the proposition that the speaker has a plan is added to the common ground, certain of the speaker's beliefs and intentions with respect to the actions in the plan and the conditions between those actions are added as well. The plan inferencing rules (and other, more general inferencing rules) lead to an update of the common ground that includes quite a bit more information than just what was said. This information (with the exception of the literal meaning of the utterance) comprises the total set of base implicatures associated with the utterance.

In addition to being compared to the original common ground, this update is compared to alternative updates with respect to each of the goal sets (clause (b) of the RCP). If there is an update which would make more of the propositions in the any of the three goal sets true, it will be inferred that the speaker could not have provided this update. Inferencing rules may then be applied to mutually recognized, accessible information in the common ground to derive specific reasons that the speaker could not have provided the superior update. The new inferences just described comprise the total set of comparative implicatures associated with the utterance.

In Chapter IV, specific examples showing how this framework can lead to different kinds of implicature will be described. At the end of Chapter IV, this framework will be compared to previous accounts; its advantages and areas for future work will be discussed.

CHAPTER IV
SPECIFIC EXAMPLES

4.0. Introduction

In this chapter, I will illustrate how the framework developed here leads to the generation of the various kinds of implicature that have been discussed in the literature.

In order to show how the framework leads to progressive modification of the common ground throughout a conversation, I will begin by considering a single constructed example at a very fine level of detail. This example will include several types of implicature, and will show how implicatures are generated in the common ground and how they contribute to the interpretation of later utterances. In addition to discussing the example with the base context I am assuming, I will suggest how manipulating the context (i.e., what is mutually recognized by the interlocutors) can influence the implicatures that arise. I will also discuss a few alternative utterances at a crucial point in the example, and analyze the differences in implicatures. It should be clear from the extended discussion of this example that many more conversational implicatures arise based on an utterance in a real context than has been previously acknowledged in most accounts.

After going through the constructed example, I will provide sketches of how implicatures are generated in a variety of other examples that have been discussed in the literature. In this last section, I will compare previous accounts of implicature to the framework I am proposing. The chapter will end with a conclusion summarizing the strengths and weaknesses of the framework proposed in this dissertation, and areas for future work.

4.1 Constructed Example: Four Chairs

The constructed example I will discuss consists of a two-utterance dialogue, excerpted from a longer constructed discourse. The full discourse is as follows:

(1) Context: Ann and Bob are friends and co-workers. It is Monday morning; Ann stops by Bob's desk on the way to her own. Ann is planning on having a small dinner party on Friday, to which Bob has already been invited. John, a mutual friend and another co-worker, is also coming to the party. Greetings have been exchanged.
Ann: So how was your week-end?
Bob: Really good. We went to see a movie and I did some planting. Quite restful. How was yours?
Ann: It was okay. I'm still getting ready for this party on Friday.
Bob: How's it going?
Ann: Well, I've made just about all the arrangements, but I still need four chairs.
Bob: John has four chairs.

The part of this conversation I will formalize are the last two utterances, paraphrased as follows:

(2) a. Ann: I need four chairs.
b. Bob: John has four chairs.

As discussed in Chapter I, this is an example in which no scalar implicature arises, even though a numeral determiner (which often gives rise to scalar implicature) is involved. Intuitively, the reason that no scalar implicature arises is that any value higher than four would be provide more information than necessary, given the purpose of the exchange (for A to get four chairs). The two principles I have developed together with the representation of plans in the common ground will predict that no scalar implicatures will arise, and will generate several other implicatures associated with the utterance.

After discussing the example in its original form, I will note implicatures that would arise from different responses that Bob might give, namely: 1) "John has two chairs," in which a scalar implicature does arise, and 2) "John has five chairs," in which what I have called a Quantity 2 implicature arises. I will begin by analyzing the exchange in detail in a context in which it is mutually recognized that Ann just wants Bob to help her figure out a way to get four chairs.

In discussing the example, I will consider each of the two utterances in detail. For each utterance, I will begin with a detailed description of the plan inferencing and update process, and end with an analysis of the implicatures that arose via the process. I will not discuss in detail those aspects of the plans that were discussed in the previous chapter (e.g., the first three actions in the plan).

To review, the general plan inferencing and updating process I am assuming is as follows: 1) an utterance is produced; 2) initial inferencing takes place (which includes the inferring of the speaker plan associated with the utterance), which is constrained by the Revised Cooperative Principle (if there is an accepted goal set) and which results in the base implicatures associated with the utterance; 3) the update of the common ground is compared with alternative updates that also satisfy the first clause of the RCP, and comparative implicatures may arise; and 4) more specific inferences as to why any better updates were not provided are added. In addition, the accepted goal set may be changed due to the production of the utterance, resulting in a new goal set.

Although I discuss the process just described in a great level of detail, it is important to note that there are still outstanding issues not addressed by this framework, which limit the explicitness of this account. I will point these out as they become relevant.

4.1.1. Initial Utterance: "I need four chairs"

Before Ann's utterance of "I need four chairs," the common ground contains the information communicated in the previous discourse as well as other background knowledge that Ann and Bob take to be mutually known. The accepted goal set before the utterance includes the goal of Ann telling Bob about her party (since Bob has asked how it's going).

(2) a. Ann: I need four chairs.

4.1.1.1. Plan Inferencing and Updating

Once Ann's utterance has taken place, the fact of utterance is added to the common ground. As described in the previous chapter, this triggers the plan inferencing process. The preliminary explanatory speaker plan, consisting of the first three steps inferred, the action relations between them, and the conditions on those action relations, is shown in the following partial plan.. The specific inferencing pattern through which this partial plan is created was described in detail at the end of Chapter III.

Throughout this account, I will model the inferring of speaker plans as involving the action-by-action construction of the plan via plan inferencing rules. It would be quite possible to model this process using plan schemas—collections of actions which have uninstantiated arguments—for the parts of the plan that are always the same (e.g., the plan schema of the first four acts in a speaker plan shown at the end of Chapter III). However, since some of the actions in the plan must be added using the inferencing rules, it is simpler

to use the inferencing rules throughout. I will use plan schemas as part of the inferencing process when domain plans are inferred.

The steps involved throughout the plan inferencing process are constrained by the plan inferencing rules I identified in Chapter II, and I will refer to these rules in the plan inferencing process. However, as we will see, there are points in this process where there is some vagueness as to what the specific information is that these rules refer to. I do not consider it part of the obligation of this framework to provide this specific information—which would include a specification of primitive action types and their relationships to each other (which should probably be developed in the field cognitive or computer science, cf. Bolinger (1965)—but it would eventually be required to make this account fully explicit.

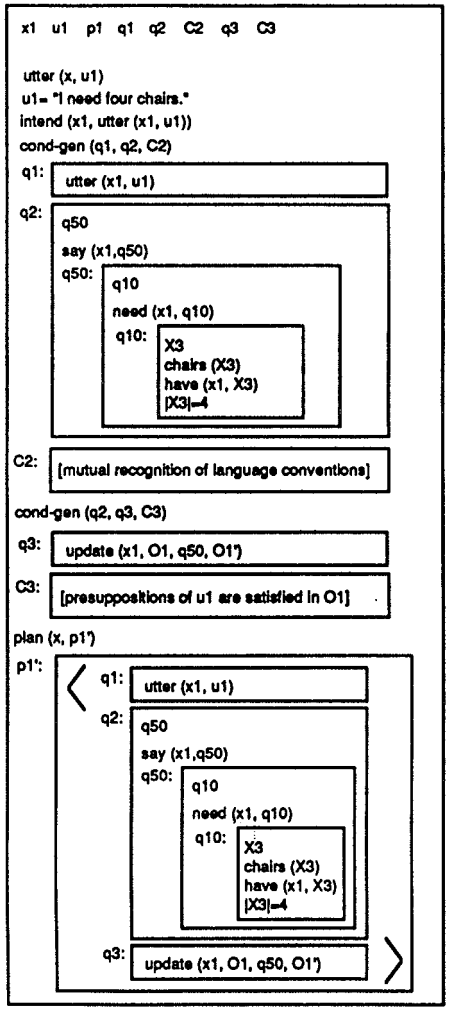


Figure 30: First Three Steps in Speaker Plan: "I need four chairs."

The DRS representation of the plan in Figure 23 is obviously quite large; however, all of this information must be included to get the semantic interpretation right.[1] In order to make the plans involved in this account easier to read, I will use the following pseudo-DRT notation to represent a plan like the one above in a DRS:

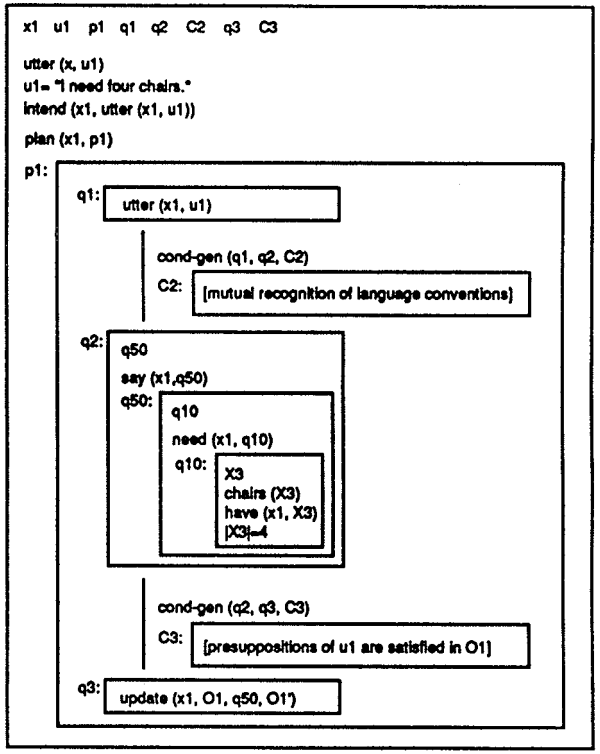


Figure 31: First Three Steps in Speaker Plan (Pseudo DRT-notation)

1 The DRT representation of the meaning of Ann's utterance is not syntactically correct, since in it, the second argument of *need* is a proposition (normally corresponding to a sentence) rather than an individual (which corresponds to a noun phrase, the syntactic argument of *need*). However, this representation is correct with respect to the opacity of the noun phrase argument of *need*. (How opacity is to be treated in DRT is still an open question.)

The relationship between the plan in Figure 30 and that in Figure 31 should be fairly clear. The primary difference between the two is that the action relations between each pair of actions is indicated between the two actions, as is the condition under which the action holds. From now on, I will use representation forms similar to that in Figure 28 for reasons of clarity and space (in addition to ones like those at the end of Chapter III).

After the fact of utterance and the inference of the first three steps in the plan, the first three steps in the plan are executed, creating the intended change in the common ground. The common ground will look as follows[2] (Note: the common ground will include much more information than is shown here; in particular, the partially inferred plan in Figure 31, things that have been said previously in the conversation, previously inferred plans, the accepted goal set, etc. I am omitting this information for reasons of space):[3]

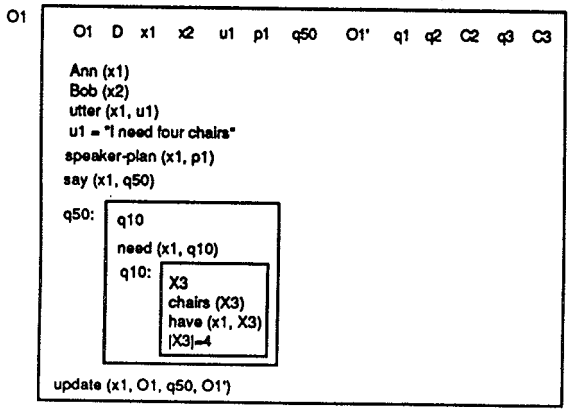


Figure 32: The Common Ground O_1

[2] The variables O_1 and O_1' in the universe of the DRS represent updates of the common ground. Given an update of the common ground, interlocutors are aware of it and of (fairly recent) previous updates. The variable D refers to the discourse situation, and could be described further as indicating who the interlocutors are, where the discourse takes place, etc. This variable is used in propositions of the form "MR (D, x)," which is read "x is mutually recognized in a discourse situation D."

[3] Note that the update includes the plan itself. I have included the reference to the plan, but have omitted the full description of it (shown previously) for reasons of space. (However, I have included the discourse referents for the actions in the plan.)

The common ground O_1 is associated with a set of worlds W_1; the position of this set of worlds in the overall inferencing/updating process is shown in the following diagram (repeated from Chapter III):

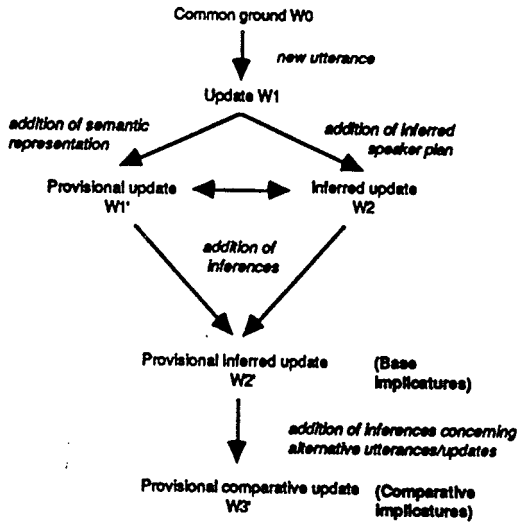


Figure 33: Updates of the Common Ground

The resulting update of the common ground also contains the proposition that Ann—represented by x_1—has created an update of O_1 by adding the semantic representation of q_1, creating a new common ground O_1' (associated with the set of worlds W_1' in the diagram above). O_1' is a provisional common ground, in the sense that it has been created by Ann but has not yet been accepted by Bob (so while the fact of its creation is mutually recognized, it has not yet been mutually recognized to be the current common ground—Bob could still reject it). The provisional common ground O_1' will look as follows:

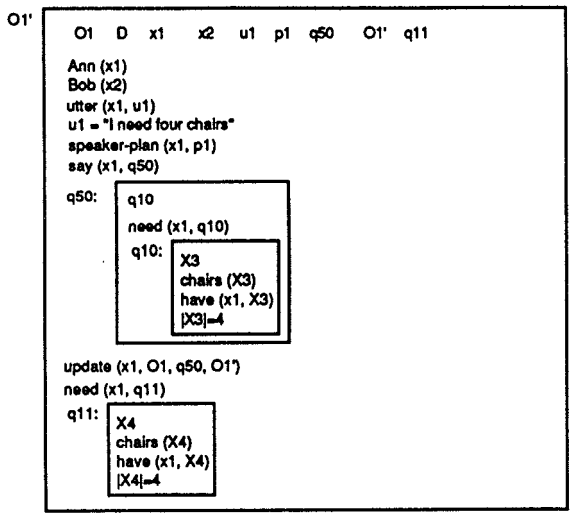


Figure 34: Provisional Update of the Common Ground O_1'

Next, background knowledge and default assumptions are used to identify the "ultimate" speaker goal associated with Ann's utterance—the goal Ann is trying to further through the utterance. The reasoning process I assume underlies this goes as follows: Ann has been discussing preparations for an event (in fact, this was the previous speaker goal, which Ann's utterance should address). Ann and Bob have a relationship in which they regularly help each other achieve their domain goals, so Ann can assume that Bob will be willing to help her achieve the goal of getting four chairs. In this situation, indicating a need leads to the inference that the person is trying to get the thing that is needed.[4] It is

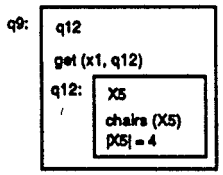
[4] It is important to note that there are situations in which indicating a need does not cause the goal of obtaining the thing that is mentioned to be introduced into the common ground as the speaker goal associated with an utterance. For instance, two co-workers (at the same hierarchical level in a company) might be discussing their jobs. Suppose one of them said, "I need a raise." The other could quite appropriately respond, "Me too"—rather than attempting to help the first coworker achieve the goal. Due largely to the fact that the co-worker is not in a position to help the first interlocutor achieve the goal, the original speaker would not have been taken to be communicating a speaker goal of getting a raise; the goal would have been more along the lines of complaining about his job.

important to note that Ann's having this goal is mutually recognized: Ann believes that the information necessary for Bob to infer that this is Ann's goal is mutually recognized, and also that Bob can infer that Ann believes this information to be mutually recognized.

The inferencing I have just described involves some hand-waving on my part. Although I have sketched an inferencing process, there would still need to be a formalization of specific rules to support this process, possibly including the communicative-interaction structures developed in Geis (in press). McCafferty (1987) attempts to characterize some of the detailed inferencing rules/information that would be required. While such a characterization is ultimately required for a fully explicit account, I take it that development of the specific rules required should be handled within some other discipline such as cognitive science. Still, without such an explicit system, this account is not fully predictive at this point.

The mutually recognized goal of getting four chairs is represented in DRT as follows:[5]

(3)



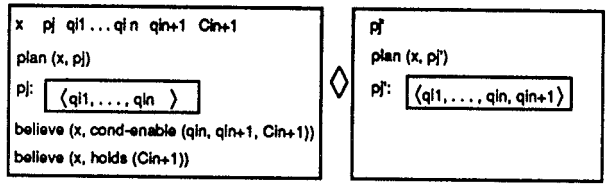
The special status of this goal as Ann's speaker goal—as opposed to just a domain goal that could be inferred based on Ann's utterance—may be seen by imagining a slightly different context for the exchange between Ann and Bob. Suppose Ann has been hired to plan a party for Bob, and is engaged in making the preparations for it. Bob is asking how Ann is progressing. In such a case, Ann's utterance of "I need four chairs" would be taken as merely providing information about how Ann is doing on preparing for the party, since Bob is not taking a helpful role toward Ann (and Ann is responding to a previous speaker goal of reporting to Bob). Now, in this case, Bob could infer from Ann's utterance that Ann has a goal of getting more chairs, but Ann is not trying to achieve or further this goal

[5] Note that the verb *get* also induces opacity in this context.

through her utterance to Bob. Although Bob could help Ann achieve her goal, that is not Bob's role in the overall activity. In a case like this, getting four chairs would not be a speaker goal, because it is not the ultimate goal that the speaker is trying to further through the utterance.

Having inferred this goal through a mutually recognized inferencing process, Bob is able to use the forward chaining conditional enablement plan inference rule to link this goal with the highest action in the plan so far (the update of the common ground). This inference rule, introduced in Chapter II, is repeated below:

(4) *Forward chaining inference rule: conditional enablement*



This rule takes a plan containing some number of actions n, the agent's belief that a conditional enablement relation holds between the highest action in the plan and another action under a set of conditions C_{n+1}, and the agent's belief that the set of conditions C_{n+1} holds, and gives the possible inference that the agent has an expanded plan which includes the new action. This rule is applied to the existing plan p_1. It requires that it be mutually recognized that Ann believes that the highest action in that plan, updating the common ground, will enable her ultimate goal to be mutually recognized (this mutual recognition of her goal being the fourth step in the plan) under a particular condition, which holds. The condition in question here is that Ann believes that Bob is willing and able to help her achieve her goal. The speaker plan resulting from the application of this inferencing rule includes the new fourth action shown below:

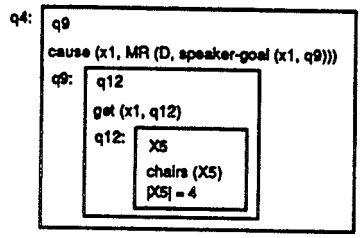


Figure 35: Fourth Step in Ann's Speaker Plan

The common ground containing this new plan is as follows (with the plan represented in the simpler notation):

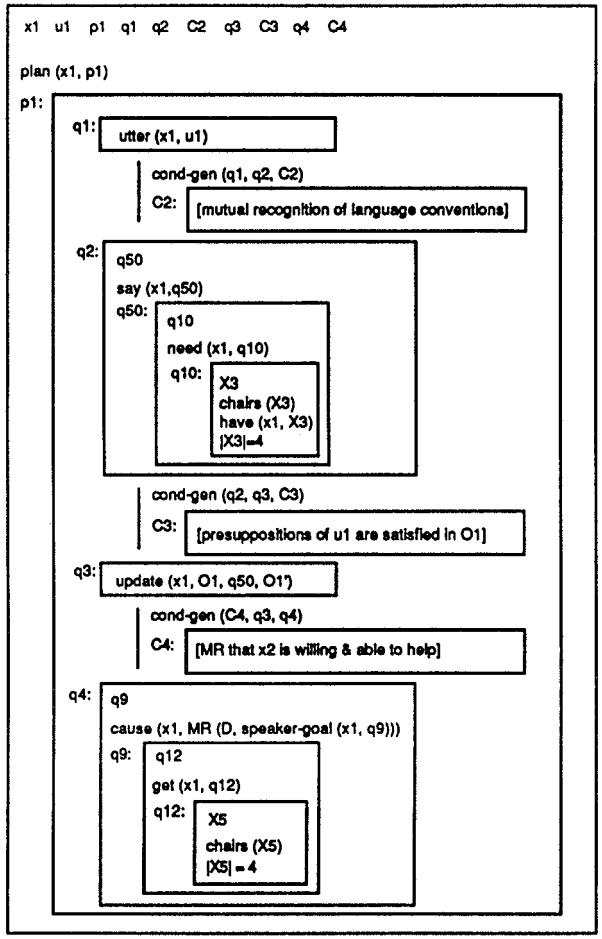


Figure 36: First Four Actions in Ann's Speaker Plan

The fourth action in the plan is executed, leading to the following intermediate update of the common ground, with the addition of the (now mutually recognized) speaker goal.[6]

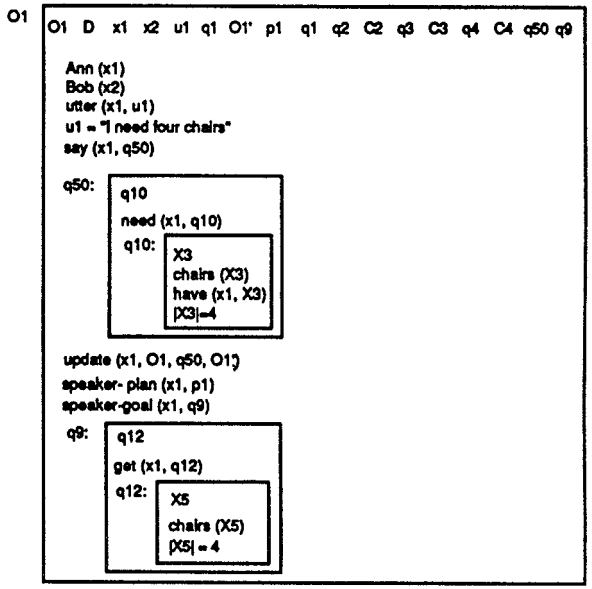


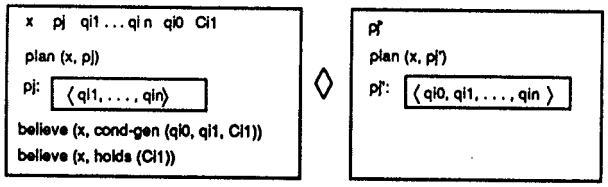
Figure 37: Update with Speaker Goal

Now that the goal of the plan has been identified, plan inferencing will work backward from the goal act using the backward-chaining inference rules until the portion of the plan being inferred can be linked to the beginning part of the plan. The first inferencing step in this process will allow Bob to infer that Ann's plan to achieve her goal involves

6 I insert the currently inferred version of the speaker plan at different places in the DRSes at different times. To explicitly characterize the inferential role it plays, different versions of it should be inserted throughout the DRS. This would be unnecessarily confusing and complicated to do, so I'm just including one version at a time, where it is most relevant.

executing a domain plan to get four chairs. This is based on a mutually recognized fact that executing a domain plan to achieve a domain goal will conditionally generate that domain goal, under the condition that the domain plan is well-formed. At this point, it is not clear what exactly the domain plan that will be executed is (except that it will have the goal action of getting four chairs). The backward chaining inference rule involved is the conditional generation rule, shown below:

(5) Backward-chaining plan inference rule: Conditional generation



The backward-chaining rule is similar to the forward-chaining one, except that it adds an action to the beginning of a plan rather than to the end of it. This rule takes the goal action of the plan and *x*'s belief that there is a conditional generation relation between executing a plan and making the goal of the plan true, and gives the following plan.

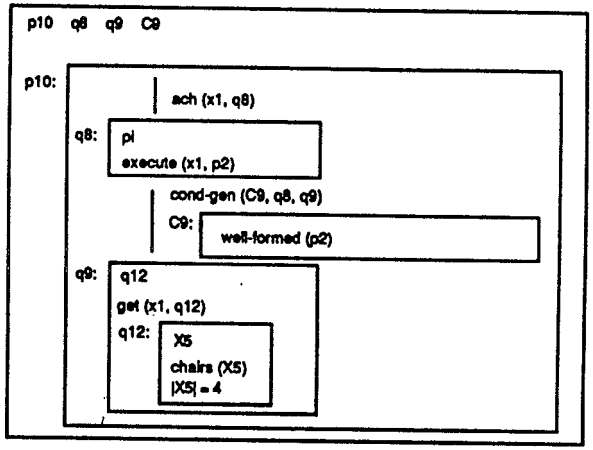


Figure 38: Last Two Actions in Ann's Speaker Plan

Note that in this plan there is no condition preceding the first action. This is because, for all actions except basic ones, conditions are associated with the action relation that holds between a pair of actions. The planning agent must believe that these conditions hold. When no preceding condition is present, the planning agent must believe at least that the action is achievable. (This can be inferred from the intention entailment of *plan* from Chapter II, combined with the belief entailment of *intend*.)

Next, a similar line of reasoning is used to add the next act to the plan. In this case, the action scheme involved links the action of executing a plan with the action of developing the plan, through the relation of enablement: developing a plan enables executing the plan, under the condition that no more development of the plan is required.[7]

The develop predicate is similar in character to the *update* predicate, in that it applies to a plan to give another plan. I am borrowing from Grosz and Sidner's (1990) notion of Shared Plan in treating the develop activity as a shared activity, one in which both or either interlocutor may participate. In fact, at this point Bob could infer that Ann's plan involves having this plan developed by Bob alone. Whether Ann intends for the development to be collaborative or for Bob alone to do the construction could depend upon Ann's personality and the relationship between the two. Postulating the collaborative action is more open-ended, since if just one of them engages in it, the collaborative action will still be fulfilled. The details of how a plan is developed will be discussed further in the analysis of Bob's response to Ann's utterance. To indicate that two agents *x* and *y* are co-developing a plan *p*, I use the following notation: *develop ({x, y}, p)*. The new plan looks like this:

[7] I am treating the develop predicate as an activity predicate rather than an accomplishment predicate: that is, it is possible to continually develop a plan, making it more and more explicit. When no more development can take place, then the plan is executable. "Develop ({x1, x2}, p2, p3)" is read: x1 and x2 develop p2, creating p3."

I have also simplified this plan by omitting sub-actions required to execute the plan. In particular, I will assume that a plan is executed by executing each of the actions contained in it; when all actions have been executed, the plan as a whole will be executed. "Execute (x, qi, pj)" is read" "x executes action qi in plan pj." Predicates of this form will play a role later in this account.

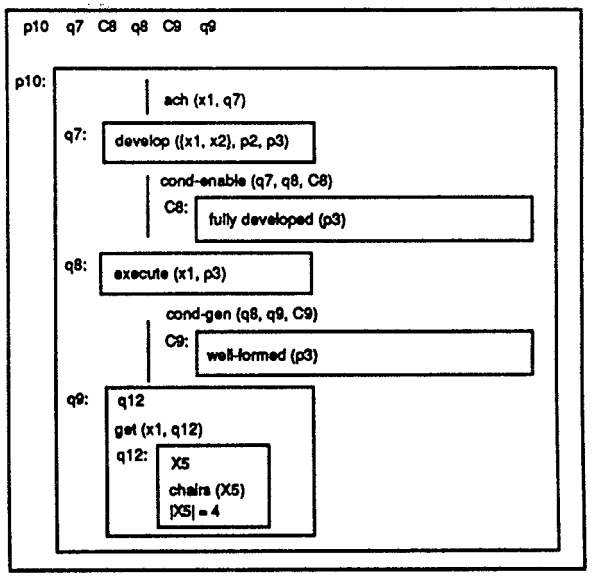


Figure 39: Last Three Actions in Ann's Speaker Plan

The next action that is added to the plan is a standard one in speech act theory: the action that A intends will cause B to help A develop the plan is B's adopting the intention to help A develop the plan.[8] The resulting plan as follows.

[8] Commenting on their definition of "request," Perrault and Allen (1980) state: "The intention of a request is to get the hearer to want to do the action, and this is accomplished by getting the hearer to believe that the speaker wants the hearer to do the action and then depending on the hearer to decide to do it" (p. 175). The definition above, like many others in the planning literature, characterizes this feature of requesting in terms of the mental state of the addressee—a mental state in which the addressee wants or adopts the goal of performing the action desired by the speaker. This focus on the addressee's mental state most likely derives from Grice, who defines meaning in terms of the audience's response to an utterance. More specifically, as Neale (1992) points out, Grice (1969) suggests that we should "represent the M-intended effect of imperative type utterances as being that the hearer should *intend* to do something (with of course the ulterior intention on the part of the speaker that the hearer should go on to do the act in question)" (p. 123). Grice's stated goal is to lead to "a simplified treatment of the M-intended effect, as being always the generation of some propositional attitude."

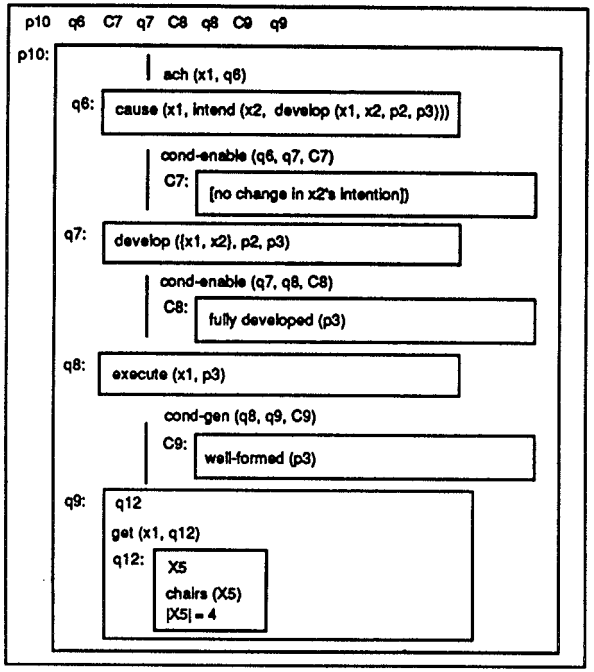


Figure 40: Last Four Actions in Ann's Speaker Plan

Next, plan inferencing will work backwards one more time, to add the action that x_1 causes x_1's speaker plan—the plan that is currently being inferred—to be mutually recognized. The mutual recognition of the plan as a whole is what will in turn enable x_1's causing x_2 to adopt the intention of developing the plan, under the condition that x_2 is able and willing to help develop the domain plan: the traditional felicity conditions on speech acts. This action is also linked to the end of the first part of the plan (the first four actions inferred previously) via the forward chaining conditional enablement rule: the mutual recognition of x_1's speaker goal enables the mutual recognition of x_1's total plan, under the condition that all of the inferencing rules and action schemes necessary to infer the plan are mutually recognized. The total plan is as follows:

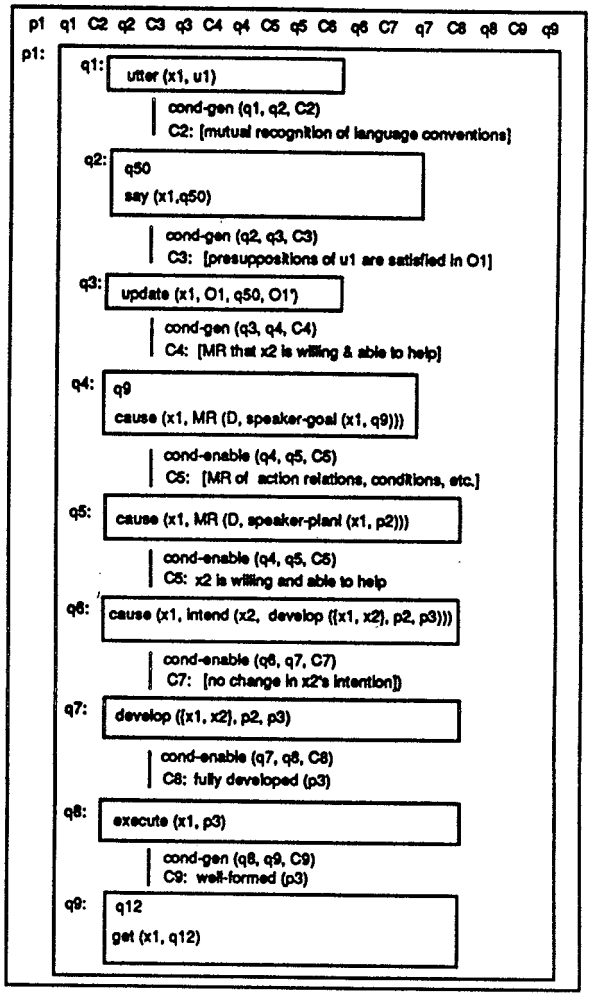


Figure 41: Ann's Complete Speaker Plan

Once the plan has been inferred, it is added to the common ground to create the inferred update O_2. The domain plan variables are added to the common ground before the full version of the inferred plan. In addition, the domain plan p_2 in its current form—which consists only of the goal action of getting four chairs—is added as well. The inferred update (which again includes only the reference marker to the speaker-plan) is shown below:

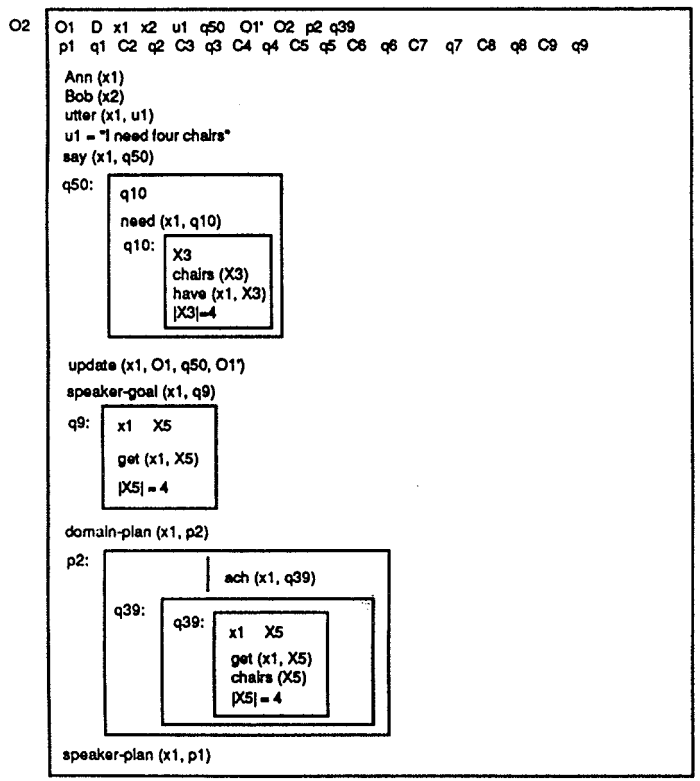


Figure 42: Inferred Update O_2

Finally, the inferred update of the common ground O_2 is combined with the provisional update of the common ground O_1' to create the provisional inferred update O_2'.

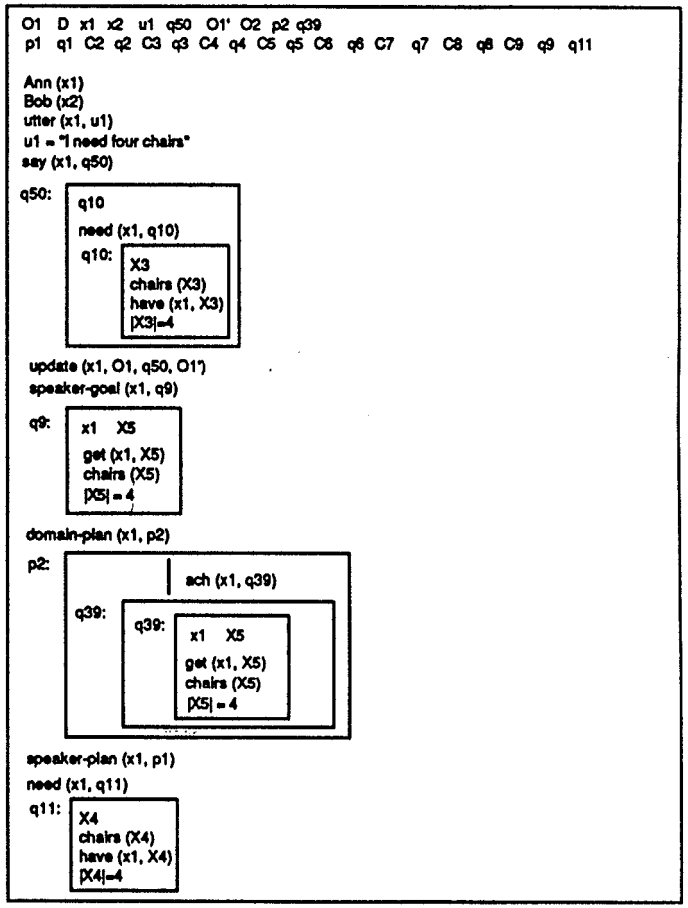


Figure 43: Provisional Inferred Update O_2'

4.1.1.2. Analysis of Implicatures

Prior to Ann's utterance, the accepted goal set included Ann telling Bob about how her preparations for the party were going. An additional goal of Bob helping her is presupposed by Ann's utterance and the conversational context. Ann's utterance addresses this goal set, then enters a new one as described in the plan inferencing process. At this point, the base implicatures associated with Ann's utterance consist of the plan that has been inferred along with the domain goal entered into the common ground. Informally, these implicatures include: 1) the implicature that Ann has a goal of getting four chairs for her dinner party and 2) the implicature that Ann wants Bob's help in figuring out how to get the chairs. The first of these implicatures may be considered an enrichment of the utterance (since "I need four chairs" could be interpreted more specifically in a variety of ways, including the type of chairs in question—four dining room chairs or folding chairs, vs. four armchairs for the living room—and the desired relation between the person and the chairs—permanent ownership, temporary possession, etc.).

The provisional inferred update of the common ground is next compared with the updates associated with alternative utterances with respect to the three goal sets discussed in the previous chapter: the speaker goal set, the interactional goal set, and the processing/contextualization goal set. According to the cooperative principle, the update associated with the utterance provided must be ordered before or equal to the update associated with any other utterance, according to at least one of these goal sets. Any utterance/update is ordered before the one provided can lead to comparative implicatures based on this part of the cooperative principle. The processing/contextualization and interactional goal sets are not relevant here, since there is not an alternative utterance/update which is mutually recognized to further these goal sets more than the one provided.

As mentioned previously, the accepted goal prior to Ann's utterance includes the goal of Ann telling about how her preparations for the party are going. It's not clear that one utterance would be superior to any other with regard to that goal. Since it is essentially Ann's goal, what she chooses to tell is at her discretion. However, the accepted goal set also includes the goal of Bob helping Ann achieve her goals. This goal will require that Ann provides information about her goals, which leads to a scalar implicature to the effect that Ann needs only four chairs.

4.1.2. Response Utterance: "John has four chairs"

Before Bob's utterance of "John has four chairs," the common ground contains all of the information described in the previous section. The accepted goal set now contains Ann's speaker plan, the domain plan p_2, and relevant meta-goals. I will now go through the inferencing process and analysis of implicatures associated with Bob's response.

(2) b. Bob: John has four chairs.

4.1.2.1. Plan Inferencing and Updating

In responding to A's utterance (rather than rejecting it), B accepts the provisional common ground. B's response is added to the new common ground in the same way that A's was: after the first three steps in the plan are inferred, the fact of utterance, the semantic representation of the utterance as having been "said," and the creation of a provisional update containing the semantic representation are entered first. The portion of the common ground associated with Bob's utterance looks like this (keeping previous discourse referents in the universe of the DRS):

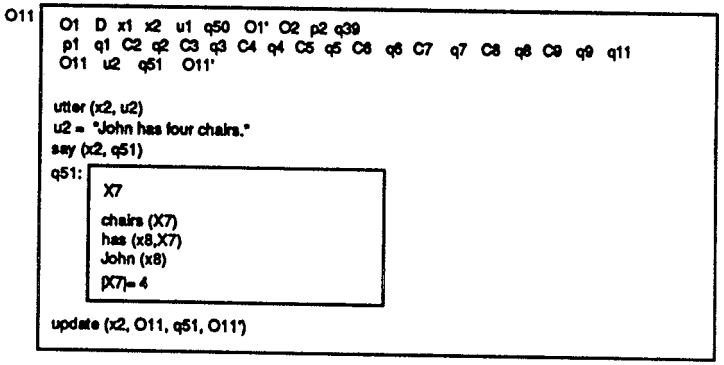


Figure 44: Update O_{11} Associated with Bob's Utterance

The semantic representation of Bob's utterance, shown in q_{51}, is added to the common ground as having been said by Bob. Now, given this update of the common ground, Ann must infer Bob's speaker goal and then connect this goal to Bob's utterance via a speaker plan. In order for Bob to be cooperative, the speaker plan associated with his response must cause a change in the common ground which furthers the accepted goal set in some way. (This guarantees that his cooperativity is intentional, rather than accidental.) The default assumption is that he intends to do it in the way intended by Ann: by helping her develop a plan to get the chairs.

The first three actions in the plan were inferred in the same way that the first three actions in Ann's plan were inferred. They are as follows:

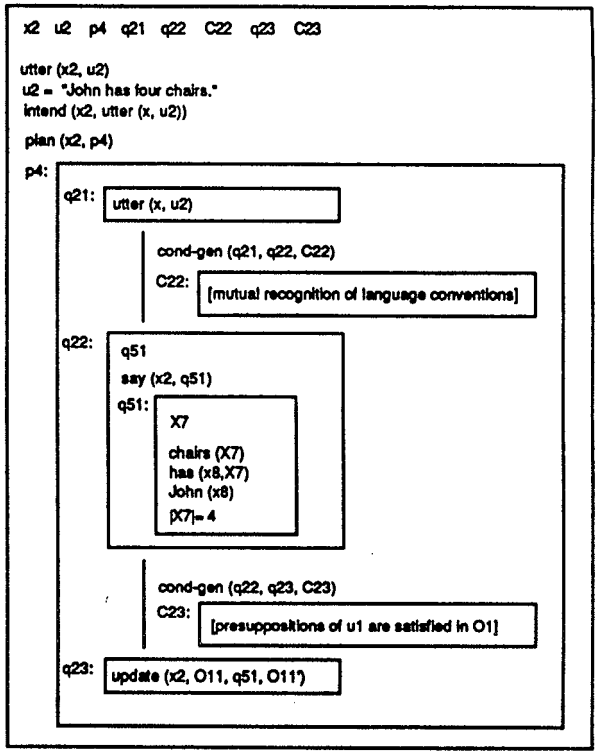


Figure 45: First Three Actions in Bob's Speaker Plan

Next, the inferred goal action is added to this sequence. In this case, the goal of Bob's plan may be inferred to be to help develop a plan to get four chairs. This goal may be inferred based on the fact that in order to be cooperative, Bob must be furthering the accepted goal set which includes Ann's speaker plan in some way: that is, he must be making one of the propositions in this goal set (and hence Ann's speaker plan) true. The new plan (inferred via the same pattern as Ann's plan) is as follows:

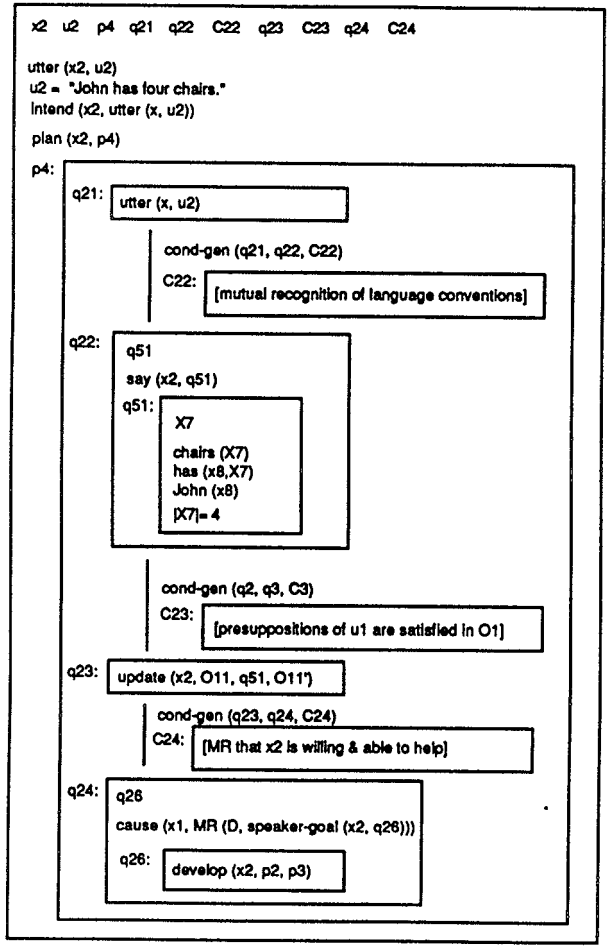


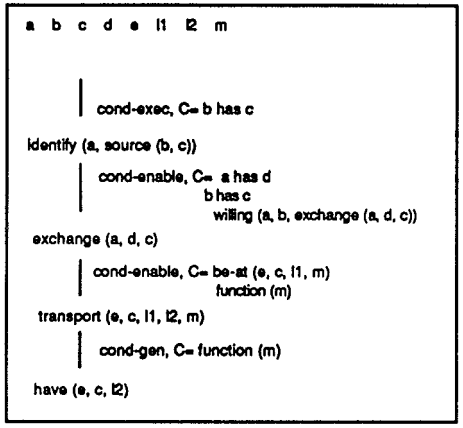
Figure 46: First Four Actions in Bob's Speaker Plan

Now that the speaker goal has been identified, the plan inferencing principles can work backward from the goal action to fill in the plan (as in the previous utterance). The next action inferred must be one that will either generate or enable Bob's development of the domain plan, which currently consists just of the goal action. Rather than constructing the domain plan from scratch, I will assume that various plan schemas are mutually recognized by Ann and Bob (i.e., are located in the common ground), and that Bob's utterance references one of these plan schemas (i.e., brings it from the larger common ground to the smaller working memory portion which is accessible for inferencing). The various plan schemas that would lead to the goal action of Ann's getting four chairs might involve one of three plan types or "schemas": buying the chairs, borrowing the chairs, or stealing the chairs. Which of these plan schemas Bob is suggesting will depend on a number of factors, including 1) the kind of plan Ann is likely to want to execute (cf. Ann's willingness) and 2) how John might fit into the plan (cf. Ann's ability to execute the plan). I will sketch each of the three plan schemas in turn. In each of the schemas, a is trying to obtain c from b. l1 and l2 refer to locations, d to an amount of exchange, e or f to an individual who undertakes to transport the thing obtained (possibly the same as a or b, possibly different), and m to a means of transportation. I am suppressing the time argument in these plan schemas for reasons of simplicity.

It is important to note the relationship between the domain plan and the speaker plan. Ann's speaker plan is in the accepted goal set, along with a domain plan consisting just of the goal action of getting four chairs. The domain plan which Bob develops through his speaker plan must further the accepted goal set, by realizing as many propositions in it as possible. Specifically, his speaker plan should lead to the development of a domain plan which, if executed, would make the goal of Ann's speaker plan true.

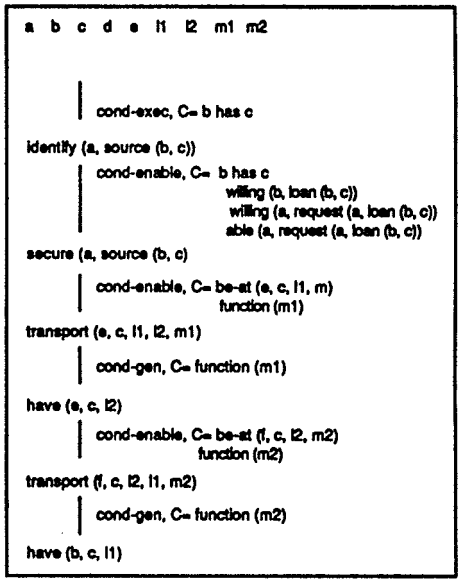
I will use a formalism similar to that of the previous plans for the plan schemas. However, due to the fact that it will not be necessary to refer to the actions in the schemas individually, I will omit the labeled boxes that surround them (and the ones that surround the conditions). I will indicate the action relation that applies to each pair of actions and the conditions required for the relation to hold.

(6) *Buying plan schema*



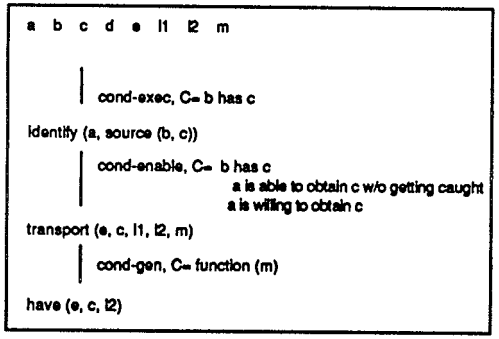
This schema requires that **b** (who is the source of **c**), has **c** and is willing to exchange it for some amount **d**. In addition, **a** must have the amount **d** that is required.

(7) *Borrowing plan schema*



This schema requires that the source **b** has **c** and is willing to loan it to **a**. In addition, **a** must be willing and able to request that **b** loan **c**.

(8) *Stealing plan schema*



This schema requires that **b** has **c**. In addition, **a** must be willing and able to obtain **c** illicitly.

Applying these schemas to the case of the four chairs, each of the plan schemas involves an initial step of identifying a source for the chairs, which in each case has the condition that the source must possess the chairs. However, the remaining conditions vary quite a bit from schema to schema. Bob has stated that John has four chairs, which is the condition on the executability of the initial action of each of the plan schemas. This fact, together with the Revised Cooperative Principle and the Principle of Cooperative Inferencing, will make these plan schemas available for inferencing (i.e., will cause them to be brought from the larger common ground to the smaller working memory portion of it). Now, to determine which of the plan schemas Bob might be suggesting, it is necessary to give John as the value for **b**, the four chairs as the value for **c**, and Ann as the value for **a** and then consider which of the conditions in each of the resulting plans are most likely to be consistent with what is mutually recognized.

In order for Ann to adopt the plan of buying the chairs from John, it would be necessary for Ann to believe that John is willing to exchange the chairs for some amount of money, and that she too is willing to exchange some amount of money for the chairs.

In order for Ann to adopt the plan of borrowing the chairs from John, she must believe that John is willing to loan her the chairs, and that she is willing and able to request John to loan her the chairs.

In order for Ann to adopt the plan of stealing the chairs, she must believe she can obtain the chairs without getting caught, and must be willing to obtain them in that way.

Given that it is mutually recognized that Ann and John are friends, it is fairly easy to eliminate a plan for Ann to steal the chairs from John.[9]

If it is mutually recognized that John sells things to people (e.g., John owns a pawn shop, or is planning to move soon and is selling his furniture), Ann might infer that Bob is suggesting that she buy the chairs from John. However, if this is not the case, it is more usual for friends to loan things to one another instead of selling them. Furthermore, people may generally be taken to be willing to request one another to loan things. Thus, the conditions on the borrowing plan schema are more consistent with what is mutually recognized than the other plan schemas, so Bob may be inferred to be suggesting a plan involving this schema rather than others.[10]

In order to fill out the remainder of the plan schema, it is necessary to use other mutually recognized contextual information. In particular, if it is mutually recognized that John has a truck, and John is generally a very helpful person, then the schema could be filled out with John bringing the chairs to the party and taking them home with him. This plan is depicted below. (I have written out the arguments in the plan rather than using variables, to make it easier to read. If this were a real DRT plan, appropriate values would appear in the universe of the DRS.)

---

9 To see that in some contexts an implicature to this effect could arise, however, consider a situation in which it is mutually recognized that Ann and John are enemies and that Ann has stolen things in the past, and Bob says: "John has four chairs, and he never locks his door at night." The additional part of Bob's utterance addresses Ann's ability to obtain the chairs without getting caught—a condition which is found only in the stealing plan schema. In this case, Bob would be taken to be suggesting a plan for Ann to steal the chairs.

10 Deciding which plan is most likely to be adopted is more complex than I have described it here, especially when choosing between plans that are more similar to one another than these. However, I hope the discussion I've provided suggests how the elements of the plan together with mutually recognized information can be input to such a decision process.

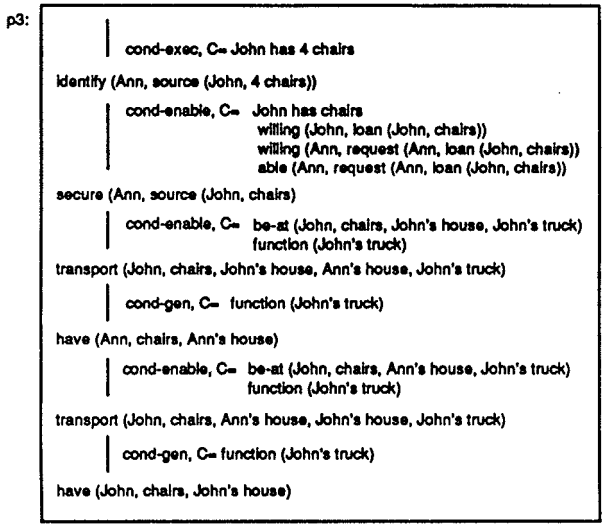


Figure 47: Domain Plan to Borrow Chairs from John

I will assume for the moment that this is the plan that Bob is suggesting.

Bob's speaker plan is as follows:[11]

11 I have omitted steps which concern accessing a plan schema, instantiating variables for the meta-variables in it, etc. These steps are highly technical and require claims about cognitive processing which are irrelevant here.

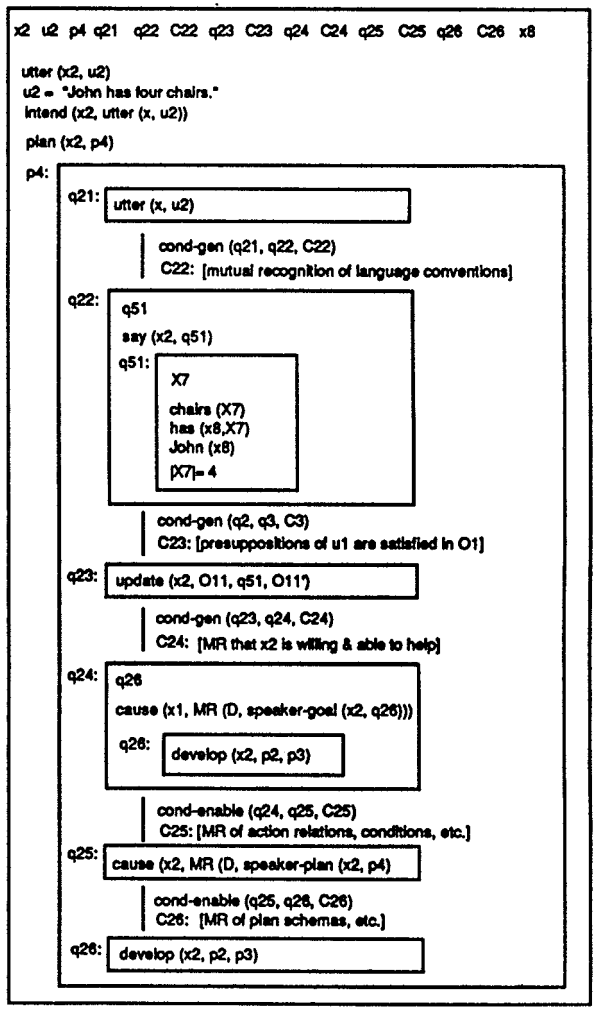


Figure 48: Bob's Complete Speaker Plan

The inferred update of the common ground will include Bob's speaker plan and the domain plan Bob has suggested. As in the previous example, the domain plan is entered into the common ground first.

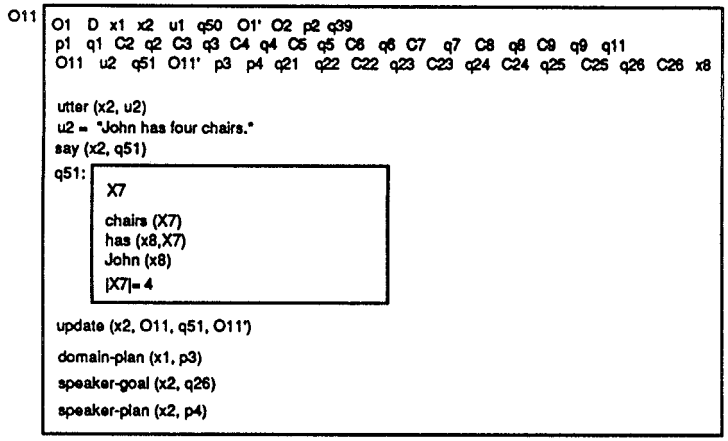


Figure 49: Inferred Update O_{12}

The provisional inferred update of the common ground associated with Bob's utterance will include the new domain plan, Bob's speaker plan, and the semantic representation of what was said (along with all of the information from previous utterances in the discourse). In addition, it includes additional inferences that may be drawn through the execution of parts of the domain and speaker plan. The portion of the common ground associated just with Bob's utterance is as follows:

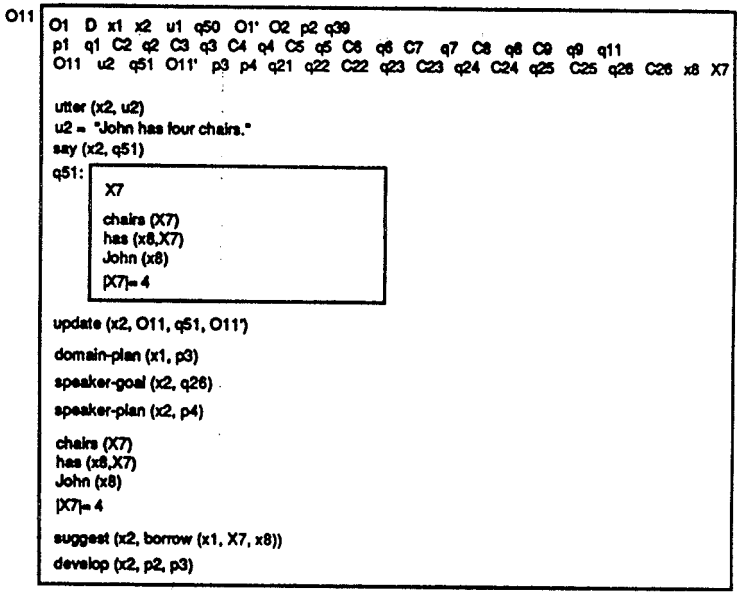


Figure 50: Inferred Provisional Update O_{12}'

This inferred provisional update will be used to determine the base and comparative implicatures associated with Bob's utterance.

4.1.2.2. Analysis of Implicatures

Intuitively, the implicatures resulting from Bob's utterance are: 1) that Bob believes John would be willing and able to loan the chairs (and more specifically would be able and willing to engage in all the actions included in the domain plan p_3)—this is what Grice would have called a relevance implicature, and 2) that Bob is not either able or willing to loan the chairs himself. As mentioned before, no scalar implicature arises. These implicatures are predicted by this framework, as I will discuss.

The base implicatures associated with Bob's utterance include the propositions in Bob's speaker plan, along with the propositions in the domain plan that Bob has suggested. Specifically, these include all of the conditions on the actions in the domain plan, which would have to hold for the plan to be executable. One of these conditions is that John is able and willing to loan the chairs (I have called out ability conditions independently in the plan; they include having the chairs, etc.). Another condition is that Ann is willing and able to request John to loan her the chairs; although this implicature might not be as readily apparent as the other, it does seem to be present.[12] Bob would not have suggested this plan if he did not believe these conditions to hold, since this plan must be executable if Ann is to use it to achieve her goal. In addition to developing the plan for Ann, it is important to note that Bob also executes one of the actions in the plan, the identification of a source for the chairs.

The comparative implicatures result from comparing the provisional inferred update to alternative utterance/updates that are mutually recognized to be superior to the one provided in terms of one of the three goal sets (accepted goal set, processing/ contextualization goal set, or interactional goal set). The interactional and processing/ contextualization goal sets are not relevant here, since there is no alternative utterance/ update which is mutually recognized to further one of these goal sets more than the one provided. However, even though in this context it is mutually recognized that Ann was only asking Bob for help in developing a plan (as opposed to indirectly asking Bob to loan her the chairs), there will still be an implicature that Bob could not loan Ann the chairs and bring them to the party. This implicature arises from comparing the update of the common ground that would result from the utterance of "I have four chairs"—and the inference that Bob could bring the chairs with him to the party—to the update that was provided in terms of the accepted goal set. In the update in which Bob brings the chairs, more of the

12 To see this, consider Bob suggesting to Ann that she borrow the chairs from her worst enemy.

propositions in the accepted goal set are true, since one of the actions in the plan has actually been executed (the action of securing a source for the chairs). Thus this update would be ordered higher than the other one, and according to the second clause of the Revised Cooperative Principle, there must then be some reason Bob did not provided it. Additional inferencing will suggest that the reason was that Bob either wasn't able to or wasn't willing to bring the chairs.

The reason that no scalar implicature arises here is that it is not mutually recognized that an update in which the proposition "John has five chairs" is added furthers the accepted goal set (or either of the other goal sets) any better than the one that was provided. So, since it is not ordered higher than the utterance/update provided, no comparative implicature arises.

To consider these implicatures a little more specifically, we may consider what propositions the accepted goal set contains before Bob's utterance:

(9) *Propositions in accepted goal set derived from speaker plan*

MR that x2 is willing to help x1 achieve her goal
cause (x1, MR (D, speaker-goal (x1, q9)))
MR of appropriate action schemes, conditions & rules
MR (D, speaker-plan (x1, p1)))
x2 is willing and able to help
intend (x2, develop ({x1, x2}, p2, p3)))
nothing happens to change B's intention
develop ({x1, x2}, p2, p3)
p3 is completely developed
execute (x1, p3)
  (where p3 is a domain plan which has "get (A, X5)" as its goal act)
p3 is well-formed
get (x1, X5)

In addition to the set of propositions above, which relate directly to the speaker plan, propositions deriving from the domain plan associated with the speaker plan may also be added. For example, all of the plan schemas that might be employed in developing a plan to get four chairs had the condition that the source of the chairs had four chairs. It will be necessary for this proposition to be true in order for Ann to execute a plan to get four

chairs from the source. I will therefore add this proposition to the set, creating the following total set of propositions:[13]

(10) *Propositions in accepted goal set (speaker and domain plan)*

MR that x2 is willing to help x1 achieve her goal
cause (x1, MR (D, speaker-goal (x1, q9)))
MR of appropriate action schemes, conditions & rules
MR (D, speaker-plan (x1, p1)))
x2 is willing and able to help
intend (x2, develop ({x1, x2}, p2, p3)))
nothing happens to change B's intention
develop ({x1, x2}, p2, p3)
p3 is completely developed
execute (x1, p3)
(where p3 is a domain plan which has "get (A, X5)" as its goal act)
p3 is well-formed
get (x1, X5)
source (z, X5) & have (z, X5)

The update that would have been associated with the utterance "I have four chairs" combined with the assumption that Bob could also bring the chairs would be the following:

13 If Ann had a more specific domain plan in mind, more propositions about that plan would be included. The reason only one proposition is included at this point is that a range of plan types might achieve Ann's goal, and the one proposition is a condition on the execution of all of them.

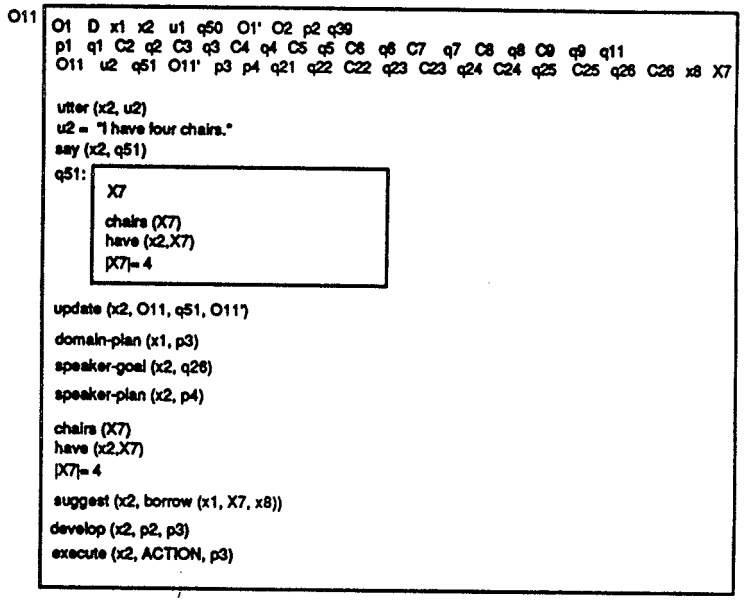


Figure 51: Provisional Inferred Update O_{12}" Associated with "I have four chairs"

This update would be ranked higher than the actual update, since more of the propositions associated with Ann's goal set are true in this update: in particular, Bob has executed one of the actions in the domain plan p_3 (in addition to just developing it). Because this update would be preferable, yet Bob did not provide it, it will be mutually recognized that Bob could not provide it for some reason. Mutually recognized reasons that Bob could not have provided the more preferred utterance/update (e.g., Bob doesn't have a truck so couldn't transport the chairs, Bob doesn't have four chairs, Bob isn't willing to loan the chairs) will be inferred due to the Principle of Cooperative Inferencing and added to the common ground: these are the comparative implicatures associated with Bob's response of "John has four chairs."

It is important to note that no scalar implicature arises in this example. This is because if such an implicature did arise, it would be the result of comparing the utterance/update that was provided to another utterance/update such as "John has five chairs." In this account, the fact that no scalar implicature arises follows from the fact that John having more than four chairs is not a proposition contained in the goal set: that is, as the goal set is currently defined, adding the proposition that John has five (or six, or seven, etc.) chairs does not bring the common ground any closer to the goal set than merely saying "John has four chairs."

4.1.3. Discussion of Different Responses (and their Implicatures)

At this point, we may consider other versions of this exchange, in which Bob's answer is different and see what implicatures arise in these versions.

4.1.3.1. Alternative 1: "John has two chairs."

Suppose Bob said, in response to Ann's statement, the following:

(11) John has two chairs.

Let's assume that the domain plan inferred based on this utterance is just like the previous except that John is only going to bring two chairs with him in his truck.

In this case, the implicatures associated with the utterance would be the following: 1) Bob believes that John would be willing and able to loan the chairs (and do everything else required), 2) John does not have four chairs (or three), and 3) Bob is not either able or willing to loan the chairs himself. Again, these implicatures are predicted by this account.

In this example, the plan inferencing works identically to the inferencing described previously; however, the cardinality of the set of chairs referred to throughout is *two* rather than *four*. The propositions in the accepted goal set are the same as before.

The base implicature that Bob believes John would be willing and able to loan the chairs arises, as in the last example, from Bob's suggestion of the plan.

The comparative implicatures that arise include the scalar implicature that John has no more than two chairs and the implicatures concerning Bob's ability and willingness to loan the chairs himself. The set of propositions in the inferred provisional update associated with the utterance "John has two chairs" may be compared to the updates for all utterances which would further the goal more than the utterance provided, in particular the following: 1) John has three chairs, 2) John has four chairs, 3) I have two/three/four chairs. Each of

the updates associated with each of these utterances would be ordered before the one provided with respect to the accepted goal set. The first two utterances would create updates that would bring Ann closer to her goal of having four chairs, since they are associated with domain plans that result in her having a larger number of chairs. The third utterance, as in the previous example, makes more of the propositions in the accepted goal set true. None of these utterances is preferable to the one provided in terms of the interactional or processing/contextualization goal sets, so the implicature arises that the speaker could not have provided these utterances. As before, mutually recognized reasons for the inability will be inferred. This is what leads to the scalar implicature that John has no more than two chairs (as well as the implicature that Bob could or would not provide the chairs himself).

4.1.3.2. Alternative 2: John has five chairs.

Suppose Bob said the following in response to Ann's statement:

(12) John has five chairs.

Intuitively, the implicature arises here that John is especially likely to be willing to loan the chairs,[14] along with the previously discussed base implicatures. I will treat this as a comparative implicature which involves the processing/contextualization goal set in addition to the accepted speaker goal set.

In this case, the utterance/update provided in (12) is ordered equal to the alternative utterance/update "John has four chairs" with respect to the accepted goal set—either utterance supports the inference to a plan to borrow four chairs from John—and the interactional goal set. However, "John has four chairs" is ordered before "John has five chairs" in terms of ease of processing—one must do an additional inference step to arrive at the entailment that John has four chairs (e.g., inferring that if one has five chairs, then one must have four chairs based on entailment). At this point, an inferencing process must take place to determine how the speaker could have been obeying the Revised Cooperative Principle.

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14 An alternative implicature is that John could loan all five chairs. Only one of these implicatures would be likely to arise, and context would determine which one. For simplicity, I will assume that the one described above is the implicature that would arise. This is especially likely if not everyone in John's household is attending the party (so it would be good if he could leave one of his chairs behind).

Unlike the other comparative implicatures we have seen so far, in this case it's not possible to reason that the speaker couldn't have said "John has four chairs," since if John has five chairs it entails that he has four chairs—so "John has four chairs" *must* be an option for the speaker.

If it is mutually recognized that the speaker is being cooperative, the only way to interpret the utterance provided as obeying the cooperative principle is to reassess the goal sets used for ordering the utterances (or decide that the utterance itself was misheard or misunderstood, which does not apply in this case). Only the accepted goal set can be modified, so this is the one that is reassessed. This goal set is repeated below:

(10) *Propositions in accepted goal set (speaker and domain plan)*

MR that x2 is willing to help x1 achieve her goal
cause (x1, MR (D, speaker-goal (x1, q9)))
MR of appropriate action schemes, conditions & rules
MR (D, speaker-plan (x1, p1)))
x2 is willing and able to help
intend (x2, develop ({x1, x2}, p2, p3)))
nothing happens to change B's intention
develop ({x1, x2}, p2, p3)
p3 is completely developed
execute (x1, p3)
(where p3 is a domain plan which has "get (A, X5)" as its goal act)
p3 is well-formed
get (x1, X5)
source (z, X5) & have (z, X5)

In this context, what happens is that the accepted goal set—which had previously included the proposition that the source of the chairs has four of them (a condition on being able to get the chairs from the source)—is modified so that the condition on being able to obtain the chairs from the source is *not* that the source has four chairs, but that the source has "ample" chairs. That is, the last proposition in the accepted goal set (which says that the source of what is needed has what is needed) is modified to a proposition to the effect that the source of what is needed has a large number of what is needed (the more, the better).[15] This new proposition is connected to a mutually recognized assumption that when someone has more than enough of something, he is more likely to be willing to loan some of it.

[15] This may also have to do with the FTAs identified by Brown and Levinson (1987); the request will be less onerous and less face-threatening if John has extra chairs, (Geis p.c.).

The inferencing process that results in the modification of the accepted goal set results in two implicatures: 1) the implicature that John is especially likely to loan the chairs, since he has extra (which arises due to the mutually recognized assumption described above), and 2) the scalar implicature that John has only five chairs.

The scalar implicature arises due to the change in the goal set: the utterance/update can be now compared to ones in which John has even more chairs—since these would be superior with respect to the new accepted goal set if they could be provided. Comparative implicatures concerning why the speaker couldn't have provided the preferable responses will then arise. It is important to note that this scalar implicature is associated with the change in the goal set, since it did *not* arise when the goal set only included the proposition that the source of the chairs had four of them.

4.1.4. Conclusion

In this section, I have provided a detailed discussion of how the framework developed in Chapter III generates several kinds of implicature: relevance implicatures (which arise due to the first clause of the Revised Cooperative Principle), quantity 1 implicatures, quantity 2 implicatures and other comparative implicatures. In addition, this framework does not generate quantity 1 or scalar implicatures inappropriately: as Grice intended, the requirement on "quantity" of information imposed by the second clause of the Cooperative Principle is formally restricted to the purposes of the exchange. The way implicatures are generated by the interaction of the RCP and PoCI via plan inferencing rules and the formalized purpose of the exchange (in the form of the accepted goal set) has been discussed; many varied implicatures are shown to result from these mechanisms.

4.2. Overview of Implicature Examples

In this section, I will briefly discuss how the account developed here would apply to the types of implicatures identified in Chapter I. Some of these types of implicature were discussed in the extended example; I will refer to these where appropriate. I will also compare the account provided here to previous accounts of the various kinds of implicature.

The diagram below, repeated from Chapter III, shows how the different kinds of implicature that have been discussed in the past are generated through the framework I am proposing:

	Accepted goal set	Processing goal set	Interactional goal set
Base implicatures (RCP clause a)	Relevance Quality Enrichments Manner (orderly)		
Comparative implicatures (RCP clause b)	Scalar Other quantity 1	Flouting manner/ use of prolix form Quantity 2	(Not addressed by previous accounts)

Figure 52: Categories of Implicature

This section will be organized according to the framework I have developed, with specific types of implicature as subsections. In addition to discussing the different types of implicature independently of one another, I will also compare how the framework developed here addresses the problem of maxim clash discussed by Atlas and Levinson (1981), Horn (1985) and Levinson (1987).

4.2.1. Base Implicatures

Base implicatures include relevance implicatures, quality implicatures, enrichments (cf. Atlas and Levinson 1987) and implicatures due to the Manner Maxim "Be orderly." On the account provided here, these implicatures arise before comparative implicatures, as part of the initial inferencing that takes place when an utterance is added to a common ground.

4.2.1.1. Relevance Implicatures

As mentioned in Chapter I, relevance implicatures are quite straightforwardly accounted for using a plan-based theory of implicature, since such theories allow the purpose of the exchange to be formalized. The base implicatures discussed in the previous example (e.g., that John would be willing and able to loan Ann four chairs) are an example of implicatures that Grice would have explained as arising due to the maxim of Relevance. Grice's own gas station example is easily accounted for as a base implicature (Grice 1975):

> (13) A is standing by an obviously immobilized car and is approached by B; the following exchange takes place:
> A: I am out of petrol.
> B: There is a garage round the corner.
> (Gloss: B would be infringing the maxim "Be relevant" unless he thinks, or thinks it possible, that the garage is open, and has petrol to sell; so he implicates that the garage is, or at least may be open, etc.)
> (p. 32)

Here, the accepted goal set that B must respond to includes the speaker goal of A's getting gas and a plan which links A's utterance to this goal through B's recognition that A has a need for gas, and so wants to get gas. Propositions representing a domain plan to get gas may also be included, such as the actions of going to a gas station, filling up the car, paying for the gas, etc. As in the previous example, A needs to find a source for the gas before the domain plan can be executed.

B's utterance provides information that identifies a source for gasoline, which can be used to develop A's domain plan for getting gas by specifying a source for the gasoline. The implicatures that Grice has identified are the conditions necessary for the gas station to serve as a source for the gasoline. Although the account I have just sketched is conceptually consistent with Grice, it differs dramatically in degree of formalization. In Grice's approach, the Cooperative Principle together with the Maxim of Relevance are responsible for the conversational implicatures; how they are responsible is left largely to the imagination of the person applying them to the example. The fact that so many people can

apply the Maxim of Relevance to an example and come up with the same set of implicatures that would arise based on it is due to their "conversational competence" as speakers of English, not the rigor of Grice's theory. There is no way in Grice's account to explicitly characterize the purpose of the exchange that both his Cooperative Principle and the maxim of Relation refer to, nor to specifically generate the implicatures that arise.

The account I've sketched of the implicatures in (13) is consistent with the account in McCafferty (1987), although the plan formalism differs somewhat. McCafferty's account includes three kinds of plans: speaker plans, conversational plans, and domain plans. McCafferty's speaker plans are similar to the speaker plan in this account in that they link an action of utterance with a speaker goal, although McCafferty's plans are much less detailed than the ones I am assuming. The two accounts differ in that McCafferty does not identify a set of inferencing rules which operate automatically to lead to the inferring of a speaker's plan; instead he provides a collection of rules at varying levels of generality which lead to specific implicatures. In his account, conversational implicatures arise due to the many rules he provides rather than any overarching principles.

To summarize, the present framework builds on both Grice's and McCafferty's accounts. Like Grice (1975), this framework provides general principles that lead to conversational implicatures like the one in (12); like McCafferty (1987), specific mechanisms are provided that may be used to generate implicature. The advantage of this framework is that the specific mechanisms used for generating implicature are based on general principles, rather than being part of an unstructured collection of rules.

Sperber and Wilson's account of relevance implicatures does not fall into the category of plan-based theories of implicature, but does provide some important generalizations. Sperber and Wilson do not discuss examples like Grice's, which involve real-world plans and goals of interlocutors. One of these is the following, repeated from Chapter I (Sperber and Wilson 1988, p. 194):

(14) Peter: Would you drive a Mercedes?
Mary: I wouldn't drive ANY expensive car.
Implicatures:
A Mercedes is an expensive car.
Mary wouldn't drive a Mercedes.

On Sperber and Wilson's account, the implicature arises partly due to the assumption that Mary is providing a response to Peter's question (the question corresponding to Grice's "purpose of the exchange"). The other element that is responsible for the implicature is

what Sperber and Wilson call the deductive device, which applies deductive rules to contextual information to derive implicatures. As mentioned in Chapter I, this is the strongest aspect of Sperber and Wilson's theory, and I have incorporated it into my own account through the Principle of Cooperative Inferencing. The difficulty with Sperber and Wilson's account is that there is no way to represent the purpose of the exchange. This is somewhat problematic in examples like the one they have suggested, since some way of indicating that the purpose of the exchange is for Mary to provide an answer to Peter's question must be provided. It is even more problematic in examples like Grice's own gas station example, since—as Ginzburg (1990) points out—Sperber and Wilson have no way of evaluating the relevance of utterances with respect to plans and goals of interlocutors.

4.2.1.2. Enrichments

Enrichments arise through the application of the Principle of Cooperative Inferencing, and in some contexts may be generated in part by the Revised Cooperative Principle. Inference rules apply to the semantic representation of the new utterance combined with mutually recognized accessible information (possibly stereotypical) to derive enrichment implicatures. The Revised Cooperative Principle plays a role in that the enrichment must be consistent with an update of the common ground which furthers the accepted goal set, and thus must be relevant.

Grice's example of implicatures in this category is the following (Grice 1989, p. 8):

(15) He got into bed and took off his trousers.

In Grice's account, the implicature in this example—that getting into bed preceded taking off his trousers—arises due to the assumption that the interlocutor is obeying the Manner maxim "Be orderly." Little additional information, and no formalism, is provided to explain further how this implicature arises.

An example of enrichments discussed by Atlas and Levinson (1981) is the following (p. 36):

(16) a. Kurt went to the store and bought some wine.
b. Kurt went to the store in order to buy some wine.

Here, the (a) utterance leads to the enrichment in (b).

In the account I am proposing, all of these examples would be the result of the Principle of Cooperative Inferencing. I assume that general deductive rules applied to mutually recognized contextual information would be responsible for generating the implicatures in these examples. The contextual information involved would include both stereotypical information and also information that is specific to a particular situation.

On Atlas and Levinson's account, the inference in (16b) arises due to one of their Conventions of Noncontroversiality—the Convention of Intension (Common Knowledge)—which states that stereotypical information is noncontroversial. Atlas and Levinson further state, "Temporal, causal, and teleological relations between events are stereotypical in our 'common sense' conceptual scheme" (p. 42). Thus, the conversational implicature in (16b) would be a result of this convention combined with the fact that there is a teleological relation between going to the store and buying some wine—stereotypically, people go to the store with the purpose of buying something there.

Atlas and Levinson's account is compatible with the framework I have suggested, and in fact includes a greater level of detail than this framework. However, their reference to "stereotypical information" leaves open the question of how to determine what information is stereotypical. In addition, as discussed in Chapter I, a more general notion of contextually salient information seems to be a more appropriate characterization of "common knowledge" than stereotypical information. Assuming a common ground which contains mutually accessible information (including the literal meaning of the utterance) to which basic deductive rules can apply provides the flexibility to account for examples in which nonstereotypical information is a part of the process of generating implicatures.

In addition, because Atlas and Levinson accept the original framework proposed by Grice (with the augmentation of Horn scales to predict when Quantity implicatures will arise), their account does not have the level of generality of this framework. This issue will be discussed in greater detail near the end of this section, when I review the way previous accounts have addressed the so-called "maxim clashes" between something like Atlas and Levinson's Principle of Informativeness and the first maxim of Quantity.

4.2.2. Comparative Implicatures

Comparative implicatures may arise via any of the three goal sets. The majority of comparative implicatures that have been previously discussed in the literature have arisen via the accepted goal set; however, implicatures arising via the processing/contextualization goal set have been discussed as well.

4.2.2.1. Quantity 1 Implicatures

Implicatures due to the first maxim of Quantity are generated by the second clause of the Revised Cooperative Principle. The way this works has been discussed in the previous example. In the framework developed here, Quantity 1 implicatures (and the sub-class of scalar implicatures) are a subset of the larger group of implicatures that involve a comparison of utterances/updates with respect to a goal set. What distinguishes Quantity 1 implicatures from other types of comparative implicatures is that the ordering involved in comparing the utterances/updates is the accepted goal set, often with a goal of providing information (so that informativeness becomes what is evaluated). The sub-class of *scalar implicatures* is further distinguished in that the form of the utterances being compared is identical except for the scalar element. In addition, a specific intonation pattern is often associated with scalar implicatures (Pierrehumbert 1980, Ward and Hirschberg 1985).

Although Grice discussed Quantity 1 implicatures as a general class, later work primarily focused on the sub-class of scalar implicatures—probably because of the fact that scalar implicatures were easier to formalize once the notion of a scale had been developed. Scalar implicatures are also easier to account for because when a scalar element[16] is used, it helps to identify the alternative utterances to which the utterance provided should be compared. Many accounts (e.g., Atlas and Levinson 1981, Horn 1985, Levinson 1987) seem to lose sight of the fact that scalar implicatures are only one type of Quantity 1 implicature, and that whatever general principle is responsible for Quantity 1 implicatures should contribute to scalar implicatures as well. The most comprehensive of the scalar accounts is Hirschberg (1986); I will briefly review and compare this account to the framework I have developed.

As Hirschberg has characterized scalar implicatures, they arise via a partially ordered set of expression alternatives, where the sentences containing the different expressions are identical. The ordering used in the present framework for comparing utterances/updates is also a partial order; however, rather than ordering expressions, the utterances (and updates associated with them) containing those expressions are themselves ordered. When utterances are identical except for a single element, this translates to an ordering on the expressions contained in those utterances. The more general approach of comparing utterances (rather than expressions within utterances) also allows other

[16] I am considering a scalar element to be an element that clearly "evokes" a scale, either by its meaning or because of the intonation applied to it.

alternative utterances/updates which are not similar in form to be compared. As seen in the extended example, this is essential.

Another advantage of this account over Hirschberg (1986) is that it provides a way to more explicitly characterize the orderings according to which utterances/updates are ordered (by formally characterizing the goal set(s) used to order the utterances/updates), rather than taking them as given or saying merely that they are determined by context.

Finally, ordering utterances/updates rather than the elements within them makes it possible to capture generalizations that are lost in Hirschberg's theory. In particular, Hirschberg identified affirmation and denial of a value as leading to two different patterns of implicature; however, these two patterns are clearly related. The generalization I noted in summarizing her account is that denial of a value seems to have the effect of reversing the original scale. When entire utterances (which may include negation) are compared, rather than comparing just the expressions in them, this very effect is achieved.

Another account of Quantity 1 implicatures that deserves comment in Ginzburg (1990). Like the framework I have developed, Ginzburg's account imposes an ordering on utterance/updates, rather than just ordering an element within the utterance provided. In this respect, his account is more general than Hirschberg's, and comparable to the account I have developed. However, Ginzburg's account does suffer from the fact that he focuses on goals rather than on plans, with the result that his ordering is not as specific as one that is based on something like the more detailed accepted goal set that I have proposed.

Finally, both Hirschberg and Ginzburg generate only "weak" quantity 1 implicatures (i.e., implicatures to the effect that a stronger statement couldn't have been made). To get the stronger implicature (e.g., that the interlocutor believed that a stronger statement wasn't true), it is necessary to apply something like the Principle of Cooperative Inferencing after the utterance/update has been compared to alternatives.

4.2.2.2. Quantity 2 Implicatures

As discussed in the detailed example, the theory developed here correctly predicts when Quantity 2 implicatures (such as the one associated with "John has five chairs") will arise. To my knowledge, there are no other accounts which predict that implicatures in this category will arise; however, Ginzburg does incorporate something like Grice's second maxim of Quantity in his account. This is the aspect of his informativeness ordering that states that an update s is ordered before an update t if both updates are goal furthering and if t contains more information than s—in other words, t provides more information than

necessary to achieve the goal. It would be possible to extend this to generating a Quantity 2 implicature along the lines of the one I have discussed, but again, Ginzburg does not incorporate into his framework the mechanisms necessary to derive the "strong" implicatures that arise. In my framework, the Quantity 2 implicature does not arise due to a requirement like Ginzburg's, but rather due to the requirement that no extra processing should be required beyond what is necessary to satisfy the accepted goal set (cf. Sperber and Wilson 1988). This indirectly translates to the requirement that extra information should not be provided.

4.2.2.3. Flouting Manner Implicature

Grice's example in which a Manner maxim (Be Brief) is flouted can be accounted for in this framework by using the processing/contextualization goal set to compare a long-winded response with a shorter one. The example is repeated below (Grice 1975):

> (17) (a) Miss X sang "Home Sweet Home."
> (b) Miss X produced a series of sounds that corresponded closely with the score of "Home Sweet Home."
> (Gloss: Why has [the reviewer] selected that rigamarole [in (b)] in place of the concise and nearly synonymous *sang* ? Presumably, to indicate some striking difference between Miss X's performance and those to which the word singing is usually applied. The most obvious supposition is that Miss X's performance suffered from some hideous defect. The reviewer knows that this supposition is what is likely to spring to mind, so that is what he is implicating.) (p.37)

Here, the utterance in (b) may be compared with the much briefer and less syntactically complex one in (a). When ordered according to the processing/contextualization goal set, which includes a proposition to the effect of Grice's Manner maxim "Be brief," the update associated with the (a) utterance is ordered before the update associated with the (b) utterance. Since this utterance/update was not provided, it is mutually recognized that the speaker could not have provided it. In this case, the reason that can be inferred for not providing it is that the speaker does not want to suggest that Miss X's performance deserved to be called "singing."

The advantage of this approach over Grice's is that the implicature arises through the same process that other implicatures do—comparing what was said to what might have been said—instead of through an entirely different one.

4.2.3. Maxim Clash

Another area in which the account developed here seems to capture generalizations is in the matter of maxim clash discussed in Chapter I. Maxim clash occurs when, given an utterance in a context, it might be possible to apply one of the Conventions of Noncontroversiality (associated with Atlas and Levinson's I-principle), or to apply the Maxim of Quantity—each of which leads to different results. The use of the indefinite article is one example of this, seen in the following examples (Atlas and Levinson 1981, p. 49):

(18) a. John is meeting a woman this evening.
b. The person to be met is someone other than John's wife, mother, sister, or perhaps even a close platonic friend.

(19) a. I broke a finger yesterday.
b. The finger is mine.

In the first example, the implicature in (b) arises via the first maxim of Quantity. In the second, the implicature arises via the I-Principle. In such cases, it is necessary to predict which principle will apply. Levinson (1987) offers the following revised resolution schema for instances of maxim clash (p. 71):

(20) *Revised resolution schema*
(i) genuine Q-implicatures from tight Horn scales and similar contrast sets of equally brief, equally lexicalized linguistic expressions 'about' the same semantic relations, take precedence over I-implicatures.
(ii) In all other cases, the I-principle induces stereotypical specific interpretations, unless:
(iii) there are two (or more) available expressions coextensive in meaning, one of which is unmarked in form and the other marked in form. In that case, the unmarked form carries the I-implicatures as per usual, but the marked form Q/M-implicates the nonapplicability of the pertinent I-implicatures.

This resolution schema is intended to account for the indefinite article examples described above as well as examples like the following (p. 70):

(21) John could solve the problem.
Implicature: John solved the problem.

(22) John had the ability to solve the problem.
Implicature: John didn't solve the problem.

Levinson's resolution schema works in combination with the recipient's corollaries to his Q- and I-Principles. However, even so Levinson actually misses one of the points captured in the earlier attempt at resolving maxim clash in Atlas and Levinson (1981): in the example in (19), it is necessary to "block" the Q-principle from applying to create the Q-implicature, "The finger was not mine." (Atlas and Levinson achieved this by stipulating that the interpretation arrived at via the first maxim of Quantity must be consistent with stereotypical information; if it is not, the Principle of Informativeness will apply instead.) Furthermore, this resolution schema misses an important generalization concerning comparative implicatures, which Levinson himself notes (p. 73):

> ... the classic scalar (and clausal) Quantity1 inferences are upper-bounding inferences: from the *absence* of an informationally stronger expression, one infers the *negation* of its applicability; in just the same way, the Q/M implicatures involved in the Hornian division of labour induce, from the *absence* of a briefer (unmarked) expression, the *negation* of the applicability of that shorter expression.

It should be obvious that the parallelism that Levinson described is not reflected in the resolution schema in (20).

In the framework developed in this dissertation, both scalar implicatures and the Q/M implicatures (e.g., in (18)) to which Levinson refers would arise via the second clause of the RCP (augmented with the Principle of Cooperative Inferencing). In the case of the scalar implicatures, the accepted goal set is the basis for determining what alternative utterances could not have been provided, which then leads to specific implicatures. In the case of the Q/M implicatures, the processing/contextualization goal set is the basis for the comparison. The basic mechanism in both cases is the same.

With respect to the clash between the Q and I implicatures, in this framework, enrichments are base implicatures, and hence are added to the common ground before the update of the common ground is compared with alternative updates. If an alternative update which is superior to the "enriched" update is mutually accessible, comparative implicatures may then arise. To see how this works in the case of an indefinite article, in the example in (18), the Principle of Cooperative Inferencing would first apply to the (a) utterance. In this context, there would not be enough information for any inferencing to take place to create a more specific interpretation—that is, for an enrichment to occur—so the update of the common ground including the literal meaning of the utterance would then be compared with alternative updates. If another update would better further the accepted goal set, which in

this case would probably include something like a goal of getting information about John, comparative implicatures to the effect that the speaker couldn't have provided the stronger statement (and implicatures about why) would arise.

In the broken finger example, during the initial inferencing process, the Principle of Cooperative Inferencing would apply to the utterance in combination with contextual "stereotypical" information in much the way that has been described in previous accounts. By the time the update containing the literal meaning of that utterance is compared with alternative updates, it already includes the more specific information that has been inferred (e.g., "The finger was mine."). Thus, this update will be equivalent to one in which this information is explicitly stated, so no comparative implicature will arise.

4.3. Conclusion

My goal in developing this framework has been to identify the different elements that work together to generate the full range of conversational implicatures, and to characterize them as formally as possible. As I have discussed in this chapter, this framework captures generalizations that have been missed by previous accounts. It includes a small number of mechanisms which interact to generate all of the quite disparate implicature types that have been identified, rather than just focusing on a subset or addressing different types of implicature independently from one another. In addition to accounting for each of the different kinds of implicature, the framework also accounts for instances of "maxim clash"—predicting which implicature will arise in a given context. Principles governing maxim clash do not have to be explicitly stated in this account; instead, they follows from the structure of the framework. Finally, most of the mechanisms in the theory—the Revised Cooperative Principle, the Principle of Cooperative Inferencing, and the three goal sets—have been characterized to a level of detail that makes predictions possible (the Principle of Cooperative Inferencing being the most least formal of the three).

Throughout this chapter, I have focused on the strengths of the framework developed here. However, there are a number of open questions and areas for future work, which must be addressed in developing a completely explicit and rigorous account. First, the Principle of Cooperative Inferencing has not been defined as formally as necessary for making strong predictions concerning inferencing to mutually recognizable conclusions. More detailed information about specific inferencing rules, and the information to which they would apply, is also necessary for this account to be fully predictive. In addition, the planning formalism, while it allows for explicit formalization of the purpose of the

exchange via the accepted goal set, is not entirely automatic—it is possible to come up with any number of different representations for a given plan. I assume that as work in planning theory continues, a more constrained way of characterizing different plans will be developed (e.g., a limited set of predicates used in plan representation, and constrained relationships between them). As Bolinger (1963) has pointed out, this is a computational issue rather than a linguistic one. I consider most of the information mentioned here to be required to make this account fully explicit, but outside of the scope of this project.

I have developed and explored this framework as it relates to conversational implicature. However—as mentioned in Chapter I—I also envision it as the basis for a more general theory of conversational competence, which would apply to phenomena such as recognition of indirect speech acts, predicting when accommodation of presupposition would occur, generally determining what an appropriate response is, etc. I leave these as areas for future work.

APPENDIX:
RULES IN THE FORMAL SYSTEM

A.1. DRT Syntax and Semantics

Syntax

DRL, the language of discourse representation structures (DRSes), is based on a set VAR of variables, a set of n -place predicates (for all n), and the relation symbols $\neg$, $\vee$, $\Rightarrow$, and <...>. DRL is the set of all DRSes, where DRSes are defined as follows:

(1) Definition of a DRS
A DRS K is a pair $\langle X_K, C_K \rangle$, where X_K, the local domain of K, is a finite set of variables and C_K, the set of conditions in K, is a finite set of conditions.

Conditions are all and only the following:

(2) DRS conditions
1. If P is an n -place predicate and $x_{i_1}, \ldots, x_{i_n}$ are variables, then $P(x_{i_1}, \ldots, x_{i_n})$ is a(n atomic) condition.
2. If K_i is a DRS, then $\neg K_i$ is a condition.
3. If K_i and K_j are DRSes, then $K_i \vee K_j$ is a condition.
4. If K_i and K_j are DRSes, then $K_i \Rightarrow K_j$ is a condition.

The following syntactic notions may be defined on (occurrences of) DRSes:

(3) Definition of accessibility
$\leq$, is accessible from, is the smallest partial order on DRSes such that for any DRS K, if $\neg K \in K, K_i \Rightarrow K_j \in C_K$, or $\langle K_i, \ldots, K_j \rangle \in C_K$ then $K \leq K_i$ and $K_i \leq K_j$, and if $K_i \vee K_j \in C_K$, then $K \leq K_i$ and $K \leq K_j$

The accessible domain of K_i, A_{K_i}, is the set of all variables in (local) domains of DRSes accessible from K_i : $A_{K_i} = \cup_{K \leq K_i} X_K$.

We then impose the following condition on DRSes:

(4) No free variables:
If x occurs in an atomic condition in C_K, then $x \in A_K$.

Semantics

A model M for DRL is a structure $\langle W, A, \iota \rangle$, where W is a set of possible worlds, A is a nonempty set of individuals, and ι is the interpretation function mapping pairs of an n-place predicate and a world into *pow* (A^n).

An assignment function, f, is a total function from VAR to A.

Given two assignment functions, f and g, g varies from f at most with respect to X, g $\langle X \rangle$ f, iff $\forall y$ $[\neg (y \in X) \rightarrow g(y) = f(y)]$.

The truth of a DRS with respect to a world and an assignment function is defined recursively, as follows:

(5) *Truth of a DRS*
For all worlds w, u, v, w', u', assignment functions f, g, h, models M, DRSes K, K_i, K_j, sets of conditions C, n -place predicates P, and variables x:

1. $\langle w, f \rangle \models_M K$ iff $\forall c \in C_K$ ($\langle w, f \rangle \Vdash_M c$)

2. (a) $\langle w, f \rangle \Vdash_M P(x_{i_1}, \ldots, x_{i_n})$ iff $\langle f(x_{i_1}), \ldots, f(x_{i_n}) \rangle \in \iota(P)(w)$

(b) $\langle w, f \rangle \Vdash_M (\neg K_i)$ iff $\neg \exists g$ [$g \langle X_{K_i} \rangle f$ & $\langle w, g \rangle \Vdash_M K_i$]

(c) $\langle w, f \rangle \Vdash_M (K_i \vee K_j)$ iff [$\exists g$ [$f \langle X_{K_i} \rangle g$ & $\langle w, g \rangle \Vdash_M K_i$] $\vee$
$\exists g$ [$g \langle X_{K_j} \rangle f$ & $\langle w, g \rangle \Vdash_M K_j$]]

(d) $\langle w, f \rangle \Vdash_M (K_i \Rightarrow K_j)$ iff $\forall g$ ($g \langle X_{K_i} \rangle f$ & $\langle w, g \rangle \Vdash_M K_i$)
$\rightarrow \exists h$ ($h \langle X_{K_j} \rangle g$ & $\langle w, h \rangle \Vdash_M K_j$)]

(e) $\langle w, f \rangle \Vdash_M (q : K)$ iff $\forall w' \in W$ [$w' \in f(q) \leftrightarrow \langle w', f \rangle \models_M K$]

(f) $\langle w, f \rangle \Vdash_M (\langle q_{i_1} : K_{j_1}, q_{i_2} : K_{j_2}, \ldots, q_{i_n} : K_{j_n} \rangle)$ iff

(i) $\exists g$ [$g \langle X_{K_{j_1}} \rangle f$ & $\langle w, g \rangle \models_M K_{j_1}$] &

(ii) $\langle w, g \rangle \models_M \langle K_{j_2}, \ldots, K_{j_n} \rangle$

(g) $\langle w, f \rangle \Vdash_M (\langle K_j \rangle)$ iff $\exists g$ [$g \langle X_{K_j} \rangle f$ & $\langle w, g \rangle \models_M K_j$]

A.2. Lexical Entailments and Inference Rules

(6) *General belief entailment of* intend
$\forall x \forall q \forall t$ [intend (x, q, t) $\rightarrow$
[believe $(x, \Diamond \exists t'$ [$t < t'$ $\wedge$ cause $(x,$ hold $(q, t'))$]]]]

(7) *Desire entailment of* intend
$\forall x \forall q$ [intend $(x, q) \rightarrow$ want (x, q)]

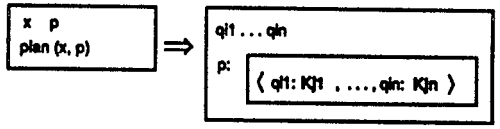
(8) *Persistence entailment of* intend
$\forall x \forall q \forall t$ [intend (x, q, t) $\rightarrow$
$\forall t'$ [$t < t'$ $\wedge \neg$ hold (q, t') $\wedge \forall t''$ [$t < t'' < t' \rightarrow$ intend (x, q, t'')] $\rightarrow$
[intend (x, q, t') $\leftrightarrow$
[believe $(x, \Diamond \exists t''$ [$t' < t''$ $\wedge$ cause $(x,$ hold $(q, t''))$]) $\wedge$ want (x, q, t')]]]]

(9) *Specific belief entailment of* intend
$\forall x \forall q \forall t$ [intend $(x, q, t) \rightarrow$
[believe $(x, \exists t'$ $\exists C_i$ [$t < t'$ $\wedge$ cond-ach (q, x, C_i, t') $\wedge$ hold (C_i, t')]]]]

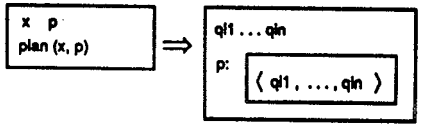
(10) *Definition of conditionally achievable*
$\forall q_1 \forall x$ $\forall C_i$ $\forall t$ [cond-ach $(q_1, x, C_i, t) =_{def}$
i) basic (q_1) $\wedge$ exec (q_1, x, t) $\vee$
ii) $\exists q_0$ [cond-gen (q_0, q_1, C_i, t) $\wedge$ achievable (q_0, x, t) $\vee$
ii) $\exists q_0$ [cond-enable (q_0, q_1, C_i, t) $\wedge$ achievable (q_0, x, t)]]]

(11) *Definition of achievable*
$\forall p \forall t$ [achievable (p, t) iff $\exists C$[cond-ach (p, C, t) $\wedge$ holds (C)]].

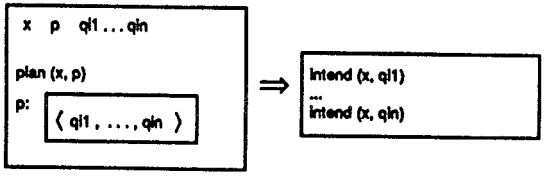
(12) *Propositional argument structure entailment of* plan



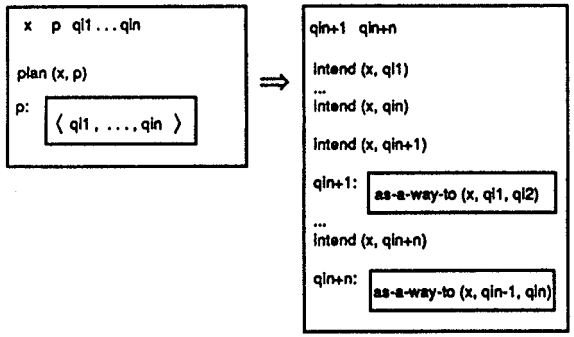
(13) *Propositional argument structure entailment of* plan (abbreviated form)



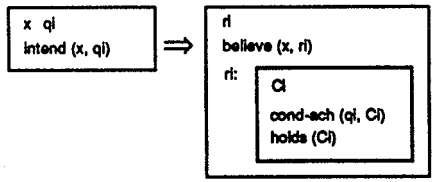
(14) *Preliminary intention entailment of* plan



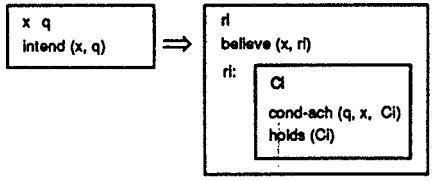
(15) *Intention entailment of* plan



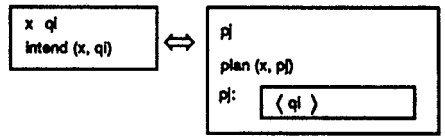
(16) *Specific belief entailment of* intend (DRT version)



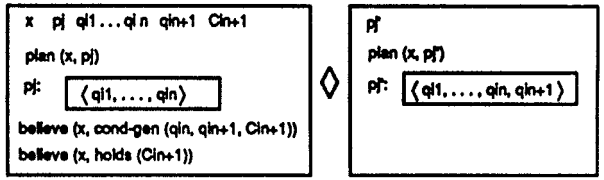
(17) *Specific belief entailment of* intend (DRT version)



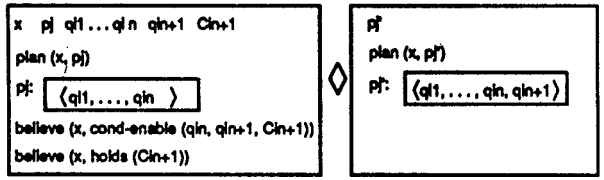
(18) *Mini-plan axiom*



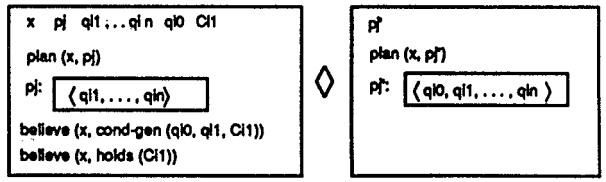
(19) *Forward-chaining inference rule: conditional generation*



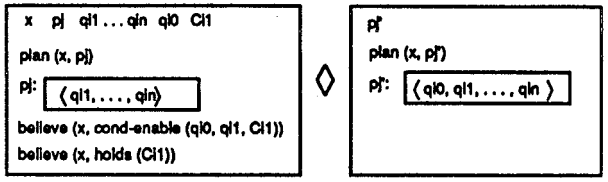
(20) *Forward-chaining inference rule: conditional enablement*



(21) *Backward chaining inference rule: conditional generation*



(22) *Backward chaining inference rule: conditional enablement*



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