PRESUPPOSITION SATISFACTION IN ATTITUDE CONTEXTS AND MODAL SUBORDINATION*

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1 Introduction

Heim's theory of presupposition—which we call the *satisfaction theory*, following Bart Geurts—is couched in the framework of *File Change Semantics*, a dynamic semantics developed in her renowned dissertation (Heim, 1982). Despite its succinct presentation in the nine pages of Heim (1983), the satisfaction theory of presupposition has had an immense impact on the field in several important respects.

First, it dissolved the then fervently debated question of whether presupposition should be conceived of as a purely pragmatic phenomenon, or should partly be dealt with by semantics. This question is only meaningful with a particular division of labor between semantics and pragmatics, and the dissolution came about when Heim's File Change Semantics tore down the conventional semantics-pragmatics divide, which resulted in a major shift in the focus of theoretical research on presuppositions in the decades to follow.

Second, the satisfaction theory as a theory of presupposition projection was unprecedented in its concreteness, comprehensiveness and applicability. For instance, almost no theory of presupposition projection before it could deal with presuppositions of quantified sentences as successfully (with a notable exception of Cooper 1983). The generality and versatility of the satisfaction theory made it a rigorous and at the same time practically workable framework for analyzing various presuppositional phenomena.

While the original formulation of the satisfaction theory given in Heim (1983) certainly raised both empirical and conceptual issues later on, its most important contribution is perhaps that these issues eventually led to further refinements of the theory (e.g. Beaver 2001, Schlenker 2009, Rothschild 2011), as well as to the development of alternative frameworks (e.g. Van der Sandt 1992, Beaver and Krahmer 2001, Schlenker 2008, 2011a).

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One important piece of work that broadened the empirical coverage of the satisfaction theory is Heim (1992), which tackles the issue of presuppositions triggered in attitude contexts. This article has been recognized as one of the major cornerstones on this topic, as well as a standard reference for the semantics of bouletic predicates and *de re* attitudes. However, in the same paper, Heim herself pointed out an empirical shortcoming of her satisfaction theoretic account, which, to the best of our knowledge, has not been given a formal treatment to this day. It is one of the goals of the present paper to fill in this gap. Specifically, we will follow Heim's (1992) own suggestions and further refinements by Roberts (1997), and formulate an extension of Heim's satisfaction theory that incorporates anaphora to possible worlds, or *modal subordination*. While one can find a number of formal treatments of modal subordination in the contemporary dynamic semantic literature (e.g. Kibble 1995, Frank and Kamp 1997, Geurts 1999, Stone 1999, Brasoveanu 2007, 2010a,b), they are not straightforwardly compatible with Heim's satisfaction theory of presupposition. In the present paper, we will develop a direct extension of Heim's dynamic semantics with the original spirit of the satisfaction theory, and demonstrate that it solves the empirical problem that Heim identified.

In addition to the empirical problem, some criticisms against Heim (1992) were raised by Bart Geurts in two related works, Geurts (1998) and Geurts (1999), both of which stemmed from his 1995 dissertation (as the essential parts of the two works are identical, we will hereafter only refer to Geurts 1999). The latter half of the present paper is devoted to revisiting Geurts' criticisms in defense of Heim's satisfaction theory, in light of recent developments in the area of the pragmatics of presuppositions.

Before embarking on the discussion, it is instructive to compare the current state in the literature of the problem of presuppositions in attitude contexts with that of the so-called *proviso problem*, which is another argument that Bart Geurts raised against Heim's satisfaction theory in his dissertation and subsequently published works, Geurts (1996) and Geurts (1999). The proviso problem is certainly problematic for the satisfaction theory (and its kin) and it has been so recognized by many, but rather than convincing its proponents to give up on this framework, it has spawned a number of interesting works that have provided novel theoretical views of the issue that are compatible with the satisfaction theory (e.g. Beaver 2001, Lassiter 2012, Pérez-Carballo 2009, Schlenker 2011b, Singh 2007, 2008). Compared to the proviso problem, the problem of presuppositions in attitude contexts has been less lively discussed since Bart Geurts' work (but see Roberts 1997). Through the present paper, we hope to contribute to the theoretical debate by directing more attention to the problem of presuppositions in attitude contexts and other modal contexts. Thus, it is not our purpose here to evaluate alternative frameworks, which is left for another occasion.

The organization of the present chapter is as follows. Section 2 provides the theoretical background by quickly reviewing the basic assumptions of the satisfaction theory of presupposition. Section 3 introduces the two main issues that presuppositions in attitude contexts give rise to. Heim's analyses of these problems are discussed in great detail in the following two sections, together with our technical solution to its major empirical shortcoming, and discussion of Geurts' criticisms.

2 The Satisfaction Theory of Presupposition

Let us first review the basics of the satisfaction theory (for more in-depth expositions, see Beaver 2001, Kadmon 2001, as well as Heim 1983). As mentioned in the introduction, the satisfaction theory is formulated in File Change Semantics. File Change Semantics, and other frameworks of dynamic semantics in general, aim at formally modeling the dynamics of information exchange in linguistic conversations by analyzing utterances as functions over information states. Following Heim (1992), we tentatively assume that information states are sets of possible worlds (We will enrich them in Section 4.2 with sequences of possible worlds).[1] These sets of possible worlds are meant to represent the conversational participants' mutually shared beliefs (or 'presuppositions' in a pragmatic sense) at a particular point in a conversation (Stalnaker 1973, 1974, 1978; see Stalnaker 1998, 2002 for further refinements). Following Stalnaker, we call such sets of possible worlds *context sets*, or sometimes simply *contexts*.

In this setting, an assertion of a declarative sentence can be conceived of as an update of the current context set, where the update amounts to shrinking the context set by sifting out those possible worlds where what is asserted is false. To illustrate, a simple sentence like 'It is raining' is given the following analysis.

(1) $[\![\textbf{it is raining}]\!] = \lambda c.\ \{w \in c \mid \text{it is raining in } w\}$

This is a function that takes a set of possible worlds c and returns the biggest subset of it that only contains possible worlds where it is raining. Heim called such functions over contexts *Context Change Potentials (CCPs)*.

What is distinctive about this system is that it captures the dynamics of information flow in a conversation. In order to see this, suppose that before the utterance of 'It is raining', the context set contained possible worlds where it is raining and worlds where it is not raining, representing a state of ignorance with respect to this information. After the utterance, a context set emerges that only contains only possible worlds where it is raining, which represents the state of the conversation where all the discourse participants commonly believe what had just been asserted.

Notice that the classical static truth-conditional semantics is subsumed by this framework, as truth-conditions can be defined in terms of CCPs, as illustrated by (2).

(2) $\text{`It is raining' is} \begin{cases} \text{true in } w_0 & \text{if } [\![\textbf{it is raining}]\!](\{w_0\}) = \{w_0\} \\ \text{false in } w_0 & \text{if } [\![\textbf{it is raining}]\!](\{w_0\}) = \varnothing \end{cases}$

In this dynamic semantic setup, Heim proposes to model presuppositions as pre-conditions for the updates by CCPs to succeed. It should be remarked that this is a direct embodiment of Frege's view of presupposition, which was later defended and popularized by Strawson (1950, 1952), which contends that presuppositions are conditions for utterances to make sense (which is not the only view of presuppositions advocated in the literature; see Beaver and Geurts 2011 for an overview). Heim formalizes this idea by making CCPs partial functions, as illustrated by the

[1] Heim (1982, 1983) and other versions of dynamic semantics such as Kamp and Reyle (1993) and Groenendijk and Stokhof (1991) assume information states to be sets of sequences of individuals (or assignments) or sets of pairs consisting of a sequence of individual and a possible world. This is because their main concern is anaphoric relations between various noun phrases. Although we will not be concerned with anaphora in the domain of individuals in the present paper, it is quite easy to implement it in our formal system, especially given that the core mechanism we will employ to account for anaphora in the modal domain is essentially the same mechanism that Heim (1982) and other authors employ to account for anaphora in the individual domain.

following example containing the presupposition trigger 'stop' (We grossly simplify the temporal meaning for the ease of exposition).

(3) a. $c \in \text{dom}([\![\textbf{it stopped raining}]\!])$ iff for all $w \in c$, it was raining in w

b. Whenever defined, $[\![\textbf{it stopped raining}]\!](c) = \{\, w \in c \mid \text{it is no longer raining in } w \,\}$

Generally, when $c \in \text{dom}([\![\,\phi\,]\!])$, we say *c satisfies* the presupposition of ϕ.

The most important feature of the satisfaction theory of presupposition consists in its treatment of complex sentences containing simpler sentences with presuppositions (Karttunen 1974 and Stalnaker 1978 are important precursors). Specifically, it is assumed that complex sentences update the context set with the CCPs denoted by their component sentences in a stepwise fashion specified in the lexical semantics of the embedding operator(s). By way of illustration, consider the conjunctive sentence 'ϕ and ψ'. It is assumed that the lexical semantics of 'and' says that this complex sentence first updates the input context c with $[\![\,\phi\,]\!]$, and after that, a second update is performed with $[\![\,\psi\,]\!]$ on the context resulting from the first update, i.e. $[\![\,\phi\,]\!](c)$. Notice importantly, the context that $[\![\,\psi\,]\!]$ updates is different from the initial context c.[2] We will refer to the context that a given CCP is used to update as its *local context*, and the context that the entire sentence takes as its *global context*. In the example at hand, the global context is also the local context for the first conjunct ϕ, while the local context for the second conjunct ψ is $[\![\,\phi\,]\!](c)$.

Importantly, it is a natural consequence of this analysis of 'and' that the presupposition of the second conjunct ψ in 'ϕ and ψ' is evaluated against its local context $[\![\,\phi\,]\!](c)$, rather than against the global context c.[3] Thus, the meaning of the conjunctive sentence can be analyzed as follows.

(4) a. $c \in \text{dom}([\![\,\phi \textbf{ and } \psi\,]\!])$ iff $c \in \text{dom}([\![\,\phi\,]\!])$ and $[\![\,\phi\,]\!](c) \in \text{dom}([\![\,\psi\,]\!])$

b. Whenever defined, $[\![\,\phi \textbf{ and } \psi\,]\!](c) = [\![\,\psi\,]\!]([\![\,\phi\,]\!](c))$

Consequently the conjunctive sentence 'ϕ and ψ' does not always presuppose what ψ alone presupposes. That is, even when the global context c does not satisfy the presupposition of ψ *per se*, $[\![\,\phi \textbf{ and } \psi\,]\!]$ may be able to update c, if ψ's local context $[\![\,\phi\,]\!](c)$ satisfies ϕ's presupposition. In such cases, we say the presupposition of ψ is *filtered* by ϕ. Concretely, the following conjunctive sentence can update a global context that does not satisfy the presupposition of the second conjunct.

(5) It was raining in the morning, and it stopped raining in the afternoon.

In this example, the presupposition triggered by 'stopped' is filtered by the first conjunct. By contrast, the conjunctive sentence 'ϕ and ψ' always presupposes whatever ϕ presupposes, as the local context for ϕ is identical to the global context.

For the sake of readability, we will henceforth adopt Heim's notation for CCPs, instead of the grandiose two-line notation like (4). For any atomic sentence S, if $c \in \text{dom}([\![S]\!])$ then $c + S = [\![S]\!](c)$; if $c \notin \text{dom}([\![S]\!])$, then $c + S$ is undefined. For a non-atomic sentence ϕ, $c + \phi$ is calculated by looking at the definition of the embedding operator(s), and it is crucially assumed that $c + \phi$ is

[2]This is only the case if the update with $[\![\,\phi\,]\!]$ is not trivial in c, i.e. $[\![\,\phi\,]\!](c) \neq c$. This is obviously not a logical necessity, but for natural language pragmatics, it is reasonable to require each utterance to be non-trivial. See Stalnaker (1973, 1974, 1978) for discussion.

[3]There are several recent attempts to derive projection properties of various connectives, including the asymmetric nature of 'and', from more general principles, rather than merely describing them in the lexical entries (see especially Schlenker 2008, 2009 and Rothschild 2011). Although this is certainly an important issue, we are not directly concerned with it in the present paper.

only defined if the presupposition of each atomic sentence in ϕ is satisfied in its local context. To illustrate, in the case of 'and', it is specified in its lexical entry that the update proceeds as follows.

(6) $c + (\phi \textbf{ and } \psi) = (c + \phi) + \psi$

This notation makes it clear that the presupposition of a complex sentence depends on the presupposition of its atomic components and at the same time also nicely visualizes what their local contexts are.

Other sentential connectives such as 'not', 'if' and 'or', as well as quantificational expressions can be given analyses in this framework, as Heim (1983) demonstrates. Although proper analyses of these operators are perhaps more contentious than the analysis of 'and' we have just reviewed (see Beaver 2001, Rothschild 2011 and Schlenker 2008, 2009 among others), it is an important achievement of the satisfaction theory that it offers a systematic way of analyzing the presuppositions of structurally complex sentences in terms of the syntax and semantics of their parts, whereby offering a framework to tackle the compositional problem of presupposition, better known as the *projection problem*.

3 Presuppositions in Attitude Contexts

Let us now turn to the main topic of the present paper, presuppositions in attitude contexts. For the most part, we will be concerned with sentences of the form 'Subj Pred that ϕ_p', where Pred is an attitude predicate and ϕ is the embedded sentence with a presupposition p, such as the following.

(7) a. David believes that it stopped raining.
b. David hopes that it stopped raining.

We will mostly focus on the belief predicate 'believe' and the bouletic predicate 'hope'. There are two major puzzles posed by sentences like (7): (i) accommodation of two-sided inferences and (ii) presupposition filtering. The rest of the section introduces these puzzles, and the subsequent sections will discuss them in turn.

The gist of the first problem of accommodation of two-sided inferences is as follows. When presented with the sentences in (7) without an elaborate context, one tends to understand them as having two inferences, (a) that David believes that it was raining, and (b) that it was actually raining. Let us call the former an i-inference, and the latter an e-inference. It should be kept in mind that for (7b) the i-inference is not that David *hopes* that it was raining, but David *believes* so, despite the fact that the attitude verb is *hope*. This is one of the characteristic features of presuppositions in attitude contexts that distinguish them from other types of inference including scalar implicatures.

As noticed by Geurts (1999), both i- and e-inferences project like presuppositions, e.g. they project out from the scope of operators like 'if' and 'not'.[4]

(8) a. If David believes/hopes that it stopped raining, he'll be disappointed.
b. David doesn't believe/hope that it stopped raining.

This observation suggests that both of these inferences are presuppositional in nature. How should they be accounted for by a theory of presupposition projection?

[4] (8b) is arguably ambiguous due to Neg-Raising, but the same two-sided inferences obtain under both readings.

Inspired by Lauri Karttunen's unpublished work, Heim (1992) claims that sentences like (7) have the i-inference as their conventional presupposition, and the e-inference is derived via pragmatic reasoning based on the i-inference (which we will review in detail later). Heim's idea was, however, criticized by Geurts (1999) on several grounds. One of the goals of the present paper is to address Geurts' objections against Heim's idea in light of recent developments in the pragmatics of presuppositions, and we will conclude that Geurts' criticisms are indefensible.

Before grappling with the first problem (which will be deterred until Section 5), however, we will first discuss the second major puzzle about presuppositions in attitude contexts, which has to do with the ways in which they get filtered. We focus on the following paradigm.[5]

(9) a. David believes that it was raining in the morning, and he (also) believes that it stopped in the afternoon. (*believe-believe*)

b. David believes that it was raining in the morning, and he hopes that it stopped in the afternoon. (*believe-hope*)

c. ?#David hopes that it was raining in the morning, and he believes that it stopped in the afternoon. (*#hope-believe*)

d. David hopes that it was raining in the morning, and he (also) hopes that it stopped in the afternoon. (*hope-hope*)

As we will see in the next section, Heim's theory can deal with the first three sentences, including the anomaly of (9d), but cannot explain the filtering effect in the fourth sentence, as pointed out by Heim (1992) herself. Simply put, this is due to the following reasons. According to Heim, both 'a believes ϕ_p' and 'a hope ϕ_p' has the i-inference that a believes p as its presupposition. This straightforwardly accounts for the felicity of (9a) and (9b), because the first conjunct entails it. Although the explanation of the infelicity of (9c) is a bit more convoluted, it is essentially due to the fact that the first conjunct containing *hope* cannot filter the presupposition that a believes p, due to the lack of entailment (i.e. 'David hopes that it was raining in the morning' does not entail that David believes so). However, by the same token, (9d) should be as bad as (9c), but it is not.

This is a major shortcoming of the satisfaction theory, especially given that an alternative approach advocated by Geurts (1999) accounts for all of these sentences. However, Heim (1992) hints at a possible way of accounting for (9d) that makes use of the mechanism of modal subordination, which Roberts (1997) later elaborated. In the next section, we will offer an extension of Heim's satisfaction theory, following Heim and Roberts' ideas.

[5] As Heim (1992) and Roberts (1997) remark, the judgments on (9c) might not be very crisp (and hence '?#'), although it is certainly worse than the other examples. Both Heim and Roberts raise some examples of the same kind that are more or less acceptable, at least for some speakers. Below is one due to Roberts, which involves *want*, rather than *hope* (% indicating speaker variation; her original judgment is #).

(i) %John wants Mary to come, although he believes that Susan is going to come too. (Roberts, 1997:227)

Roberts remarks that for some speakers, an interpretation analogous to (ii) is available.

(ii) John wants Mary to come, although he believes that if she does, Susan is going to come too.

We will come back to this in Section 4.3.

4 Presupposition Filtering and Modal Subordination

The main goal of this section is to amend Heim's (1992) theory so as to account for the filtering effects observed in *hope-hope* sequences like (9d). The most important modification is the assumption that 'a hopes ϕ_p' does not always presuppose that a believes p, like Heim assumes, but rather, it presupposes that p is satisfied in some contextually salient set of worlds compatible with a's beliefs. Thus, the presupposition Heim ascribes to it is a special case of this where all the belief worlds are taken into account. This idea itself is similar to how Geurts (1999) analyses the present phenomenon in a different framework, but unlike him, we will crucially stick to the satisfaction theory of presupposition. As repeatedly mentioned above, the core mechanism to be proposed is anaphora in the modal domain which enables modal subordination. While this idea itself is mentioned by Heim (1992) and Roberts (1997), and modal subordination has been extensively studied in various types of dynamic semantics (Roberts, 1987, 1989, Kibble, 1995, Frank and Kamp, 1997, Geurts, 1999, Stone, 1999, Brasoveanu, 2007, 2010a,b), no formal system directly compatible with the satisfaction theory of presuppositions has been offered. We will introduce our technical modification, after reviewing Heim's take on the issue.

4.1 Attitude Predicates in the Satisfaction Theory

How should attitude predicates be analyzed in File Change Semantics? Heim (1992) analyzes 'believe' as in (10), which is essentially a dynamicization of the standard Hintikka semantics. In what follows, we write $\mathrm{Dox}(d,w)$ to mean the set of David's doxastic alternatives in w, i.e. possible worlds compatible with what David believes to be true in w.

(10) $c + (\textbf{David believes } \phi) = \{\, w \in c \mid \mathrm{Dox}(d,w) + \phi = \mathrm{Dox}(d,w) \,\}$

Generally, for any set of possible worlds c, $c + \phi = c$ is the case, whenever the content of ϕ is true in all the possible worlds in c. Thus the CCP denoted by the sentence 'David believes that it is raining' only passes those possible worlds w in c where it is raining in all the possible worlds in $\mathrm{Dox}(d,w)$, i.e. David believes in w that it is raining.

With this meaning, we can readily see what will happen when ϕ has a non-trivial presupposition. The update of c with 'David believes ϕ' succeeds just in case the local context of ϕ, namely $\mathrm{Dox}(d,w)$, satisfies the presupposition of ϕ. More concretely, the following example is predicted to have a presupposition that David believes that it was raining.

(11) David believes that it stopped raining.

Thus, 'David believes that ϕ' has the presupposition that David believes the presupposition of ϕ to be true, which is the i-inference.

Under this analysis, the filtering effects in *believe-believe* sequences observed in examples like the following are straightforwardly accounted for.

(12) David believes that it was raining in the morning, and he (also) believes that it stopped in the afternoon.

As explained in Section 2, the update with a conjunctive sentence proceeds sequentially by first updating the global context with the first conjunct and then updating the resulting context with the second conjunct. In the present case, no matter what the global context is, the update with the first conjunct yields a context that consists of possible worlds where David believes that it was raining in the morning (if no possible worlds were left, the conversation would be inconsistent). This new set of possible worlds acts as the local context for the second conjunct. Consequently the presupposition of the second conjunct that David believes that it was raining is bound to be satisfied, and hence the presupposition gets filtered out.

Heim also gives an analysis of bouletic predicates like 'hope' (she mostly discusses 'want' but the semantic differences between 'hope' and 'want', if any, are immaterial for our purposes). Unlike in the case of 'believe' she departs from the Hintikka semantics.[6] The core idea (attributed to Stalnaker 1984) is that the sentence 'David hopes ϕ' expresses a conditional comparison between two classes of possible worlds compatible with David's beliefs. Specifically, Heim proposes that 'Davie hopes ϕ' means that David will be in a more desirable situation if ϕ is the case than if ϕ is not the case. Adopting Stalnaker's (1968) analysis of conditionals (Lewis 1973 also proposes a similar idea), Heim proposes the following analysis of 'hope'.

(13) $c + (\textbf{David hopes } \phi)$
$$= \left\{ w \in c \;\middle|\; \begin{array}{l} \text{for every } w' \in \mathrm{Dox}(d,w), \\ \mathrm{Sim}_{w'}(\mathrm{Dox}(d,w) + \phi) <_{d,w} \mathrm{Sim}_{w'}(\mathrm{Dox}(d,w) - (\mathrm{Dox}(d,w) + \phi)) \end{array} \right\}$$

The logical constants that appear here are defined as follows.

(14) a. $\mathrm{Sim}_w(c) = \{ w' \in c \mid w' \text{ is maximally similar to } w \text{ in } c \}$
b. $X <_{d,w} Y$ iff for each $x \in X$ and for each $y \in Y$, x is more desirable for David in w than y

In (13), the left-hand side of $<_{d,w}$ is the set of possible worlds maximally similar to David's doxastic alternatives in w where ϕ holds, and the right-hand side is the set of possible worlds maximally similar to David's doxastic alternatives where ϕ does not hold. It is expressed in the second line of (13) that each of the former worlds is preferred to any of the latter worlds.

Importantly, the local context for the embedded sentence ϕ is $\mathrm{Dox}(d,w)$ for each $w \in c$, which means 'David hopes ϕ' has a presupposition that David believes the presupposition of ϕ is true (rather than David hopes so), which is the desired i-inference.

This straightforwardly explains the filtering effects in *believe-hope* sequences like (15).

(15) David believes that it was raining in the morning, and he hopes that it stopped in the afternoon.

Just as in the case of *believe-believe* sequences, the second conjunct presupposes that David believes that it was raining, which is entailed by the first conjunct. Thus, together with the analysis of 'and' reviewed in Section 2, the filtering effects are accounted for.

Moreover, Heim's analysis of 'hope' also gives a natural account of the infelicity of *hope-believe* sequences like the following.

(16) ?#David hopes that it was raining in the morning, and he believes that it stopped in the afternoon.

As before, the second conjunct presupposes that David believes it was raining, but this time, the first conjunct does not entail this. Moreover, it is reasonable to assume that it is part of the meaning of the first conjunct that David does not know whether it was raining in the morning. Let us

[6] However, this move is not uncontested. See von Fintel (1999), Villalta (2008), Crnič (2011:Appendix), Rubinstein (2012:Ch.3) for critical discussions of Heim's analysis.

analyze this inference that the complement clause is not believed to be true or false as part of the presupposition triggered by 'hope' itself.[7]

(17) $c + (\textbf{David hopes that } \phi)$ is defined only if in each $w \in c$, $\mathrm{Dox}(d,w) + \phi \neq \varnothing$ and $\mathrm{Dox}(d,w) + \phi \neq \mathrm{Dox}(d,w)$.

Then, the presupposition of the second conjunct of (16)—that David believes that it was raining before noon—is incompatible with the presupposition of the first conjunct—that David does not know whether it was raining in the morning. Hence the infelicity.

As mentioned at the end of the previous section, one shortcoming of Heim's analysis, however, is that it cannot explain presupposition filtering in *hope-hope* sequences, as Heim herself points out.

(18) David hopes that it was raining in the morning, and he (also) hopes that it stopped in the afternoon.

According to Heim, the second conjunct again presupposes that David believes that it was raining before noon, but this is not entailed by the first conjunct, and furthermore, just as in the previous case of *hope-believe* sequences, this presupposition is incompatible with the presupposition of the first conjunct. Thus, an infelicity is predicted, contrary to fact. In what follows, we will propose to solve this problem by enriching the underlying dynamic semantics to enable anaphora in the modal domain.

4.2 Enriching the Satisfaction Theory with Anaphora in the Modal Domain

We have just seen that Heim's analysis explains the filtering effects in *believe-believe* and *believe-hope* sequences as well as the infelicity of *hope-believe* sequences, but *hope-hope* sequences remain a problem. What we will demonstrate here is that Heim's theory can be tweaked so as to deal with this problem, while keeping the central tenet of the satisfaction theory intact.

Simply put, the idea is to allow *hope* to refer to a contextually salient set of possible worlds as its modal base. Concretely, in the case of the *hope-hope* sequence (18), the first conjunct introduces the subset of David's doxastic alternatives where the expressed desire is true, and *hope* in the second sentence takes this set of possible worlds as the base of the comparison. Consequently, the presupposition of the second sentence is satisfied if it was raining in the morning *in these possible worlds*, rather than in all of David's doxastic alternatives. Then, the filtering effects are expected. In order to enable such anaphora to previously introduced possible worlds, we need to enrich the underlying dynamic semantics.

The keystone of the proposal is the assumption that contexts $(c, c', c'' \dots)$ are sets of *sequences* of possible worlds $(i, j, k, \dots)$, rather than simply sets of possible worlds (see Van den Berg 1996, Nouwen 2003, Brasoveanu 2007, 2010a,b for related ideas). This will allow us to register possible worlds that are introduced as the discourse proceeds, which will be important in accounting for the filtering effects in *hope-hope* sequences. To make full use of these sequences of possible worlds, we introduce discourse markers for possible worlds $(\omega_0, \omega_1, \omega_2, \dots)$, which are simply projection

[7] The inference in question is more likely to be a so-called *antipresupposition*, perhaps generated in competition with the version of the sentence with *glad*. See Percus (2006), Sauerland (2008) and Chemla (2008) among others for discussion along these lines. Related matters are taken up in Section 5. For our purposes here, the exact nature of this inference does not matter.

functions, i.e. ω_n is that function that picks out the nth coordinate from any sequence (if there is one). We also assume that each clause in the object language bears a discourse marker, indicating which possible worlds the clause is about.[8] This is illustrated by the following simple sentence.

(19) $c + [_{\omega_0}$ **It is raining** $] = \{\, i \in c \mid \text{it is raining in } \omega_0 i \,\}$

This CCP removes those sequences i from c such that it is not raining in $\omega_0 i$, i.e. the 0th coordinate of i, which we assume to be a possible world in the context set of the current conversation. Using $\omega_0 c$ as a shorthand for $\{\, \omega_0 i \mid i \in c \,\}$, therefore, $\omega_0 c$ is the context set.

When a sentence involves an attitude predicate (or any other intensional operator), a different discourse marker will appear, as in (20). We assume that the superscript on *believe* and the subscript on its complement clause are always identical, as ensured by syntax.[9] As a notational convention, a superscript always represents a new discourse marker, and a subscript an old one.

(20) $c + [_{\omega_0}$ **David believes**$^{\omega_1}$ $[_{\omega_1}\ \phi\ ]]$
$= \{\, j \mid \exists i \in c\colon\ i[\omega_1]j \wedge \omega_1 j \in \text{Dox}(d, \omega_0 j) \,\} + [_{\omega_1}\ \phi\ ]$

Here $i[\omega_1]j$ means that the sequences i and j are different at most in the values of $\omega_1 i$ and $\omega_1 j$ (*random assignment*). According to (20) the matrix clause alone introduces a new discourse marker ω_1 that designates one of David's doxastic alternatives in some $w \in \omega_0 c$. The subsequent update by the embedded clause eliminates those sequences j from the intermediate context such that it is not raining in $\omega_1 j$.

Notice importantly that in the resulting context c' we can recover $\text{Dox}(d, \omega_0 i)$ for any $i \in c'$ by taking $\omega_1 \{\, j \in c' \mid \omega_0 i = \omega_0 j \,\}$. This is because each sequence j contains one possible world compatible with David's beliefs in $\omega_0 j$, so by collecting the sequences that agree with j in the 0th position, we exhaust David's doxastic alternatives in $\omega_0 j$. This means that c' stores David's doxastic alternatives in each $w \in \omega_0 c'$. We will capitalize on this fact when we analyze the meaning of 'hope' later.

As in Heim's original theory, presuppositions are conceived of as pre-conditions for successful updates, as illustrated by (21).

(21) a. $c + [_{\omega_0}$ **It stopped raining** $]$ is defined only if for all $w \in \omega_0 c$, it was raining in w.
b. Whenever defined, $c + [_{\omega_0}$ **It stopped raining** $] = \{\, i \in c \mid \text{it is no longer raining in } \omega_0 i \,\}$

Notice that the set of worlds that must satisfy the presupposition is dependent on which discourse marker the clause has. Consider, for instance, the following belief report.

(22) $c + [_{\omega_0}$ **David believes**$^{\omega_1}$ $[_{\omega_1}$ **it stopped raining** $]]$
$= \{\, j \mid \exists i \in c\colon\ i[\omega_1]j \wedge \omega_1 j \in \text{Dox}(d, \omega_0 j) \,\} + [_{\omega_1}$ **it stopped raining** $]$

For the sake of exposition, let us call the set on the left-hand side of + in the second line c'. Then, the update with the embedded sentence is defined just in case for all $w \in \omega_1 c'$, it was raining in w. Since we know that for any $j \in c'$, $\omega_1 j$ is a member of $Dox(d, \omega_0 j)$, this amounts to the

[8] We are making the simplest assumption here that all clause-mate items are evaluated against the same discourse marker, but the theory is in principle compatible with more complex possibilities where different items in the same clause may refer to different discourse markers, which might be useful for analyzing *de re* readings. See Groenendijk and Stokhof (1984), Percus (2000) and Keshet (2008) for related discussion.

[9] If different indices were used, the CCP of the sentence would be independent of the meaning of the attitude predicate, which is clearly undesirable.

presupposition that for each $j \in c'$, David believes in $\omega_0 j$ that it was raining. Thus, we derive the same presupposition as Heim does.

Despite the superficial differences, the analysis so far is not different from Heim (1992) in any essential respects, and just like Heim, we can account for presupposition filtering in *believe-believe* sequences. Consider (23), for instance.

(23) $c + [_{\omega_0}$ **David believes**$^{\omega_1}$ $[_{\omega_1}$ **that it was raining in the morning** $]]$
$+[_{\omega_0}$ **David believes**$^{\omega_2}$ $[_{\omega_2}$ **that it stopped raining in the afternoon** $]]$

After processing the first sentence, we obtain c' such that in all $w \in \omega_0 c'$ David believes in w that it was raining in the morning. The matrix clause of the second sentence introduces another discourse marker ω_2 that holds possible doxastic alternatives for David *according to* c', so in all of these doxastic alternatives it was raining in the morning. Now, the update by the embedded clause of the second sentence is performed, whose presupposition requires that for all i in its input context it was raining in $\omega_2 i$, which is satisfied due to the meaning of the first sentence. Consequently, the presupposition gets filtered. Notice that in the final context c'' after the second sentence is processed, $\omega_1 j = \omega_2 j$ for any $j \in c''$, with both ω_1 and ω_2 representing David's doxastic alternatives.

The innovative aspect of our analysis consists in the semantics of bouletic predicates. Following Heim (1992), they are analyzed as expressing a conditional comparison between two kinds of worlds—the worlds maximally similar to the doxastic alternatives where the embedded clause holds and those where it does not hold—such that the attitude holder prefers each of the former worlds to any of the latter worlds. What is different from Heim is that the doxastic alternatives that serve as the base of this comparison are denoted by a discourse marker. In (24), it is represented as a subscript on *hopes*.

(24) $c + [_{\omega_0}$ **David hopes**$^{\omega_2}_{\omega_1}$ $[_{\omega_1}\ \phi\ ]] =$

$$\left\{ j \;\middle|\; \begin{array}{l} \exists i \in c \quad \forall w' \in \omega_1 \{ k \in c \mid \omega_0 i = \omega_0 k \} : \\ \qquad\qquad \mathrm{Sim}_{w'}(\omega_1(\{ k \in (c + [_{\omega_1}\ \phi\ ]) \mid \omega_0 i = \omega_0 k \})) \\ \qquad\qquad\qquad <_{d,\omega_0 i} \quad \mathrm{Sim}_{w'}(\omega_1(\{ k \in (c - (c + [_{\omega_1}\ \phi\ ])) \mid \omega_0 i = \omega_0 k \})) \\ \wedge i[\omega_2] j \wedge \omega_2 j \in \omega_1(\{ k \in (c + [_{\omega_1}\ \phi\ ]) \mid \omega_0 i = \omega_0 k \}) \end{array} \right\}$$

The base of the comparison here is $\omega_1 \{ k \in c \mid \omega_0 i = \omega_0 k \}$. Recall from above that for ω_1 that was introduced by *believe*, $\omega_1 \{ k \in c \mid \omega_0 i = \omega_0 k \}$ will be David's doxastic alternatives in $\omega_0 i$. if so, (24) will derive the same results as Heim. Specifically, the left-hand side of $<_{d,\omega_0 i}$ will be the worlds maximally similar to David's doxastic alternatives where ϕ holds, and the right-hand side the worlds maximally similar to David's doxastic alternatives where ϕ does not hold. In addition to this, the final line of (24) stores one of the possible worlds where ϕ holds in the 2nd position of j. This is going to be a key piece in our analysis of *hope-hope* sequences.

Notice that in order to ensure this intended interpretation, we need to constrain the possible values of ω_1 so that they will come out as David's doxastic alternatives and nothing else. This restriction can be conceived of as part of the presupposition of 'hope' itself:

(25) $c + [_{\omega_0}$ **David hopes**$^{\omega_2}_{\omega_1}$ $[_{\omega_1}\ \phi\ ]]$ is defined only if for all $i \in c$,

a. $\omega_1 i \in \mathrm{Dox}(d, \omega_0 i)$, and

b. $\{ k \mid \omega_0 i = \omega_0 k \} + [_{\omega_1}\ \phi] \neq \varnothing$ and $\{ k \mid \omega_0 i = \omega_0 k \} + [_{\omega_1}\ \phi] \neq \{ k \mid \omega_0 i = \omega_0 k \}$

The first condition (25a) ensures that ω_1 is a doxastic alternative for David in $\omega_0 i$. The second condition ensures non-triviality of the comparison, as before. It is important that ω_1 need not represent the entire set of David's doxastic alternatives and can be a proper subset of it. This will be crucial in accounting for presupposition filtering in *hope-hope* sequences, as we will see shortly.

With this semantics of 'hope', we can account for presupposition filtering in *believe-hope* sequences, just as well as Heim does.

(26) $c+[_{\omega_0}$ **David believes**$^{\omega_1}$ $[_{\omega_1}$ **that it was raining in the morning** $]]$
$+[_{\omega_0}$ **David hopes**$^{\omega_2}_{\omega_1}$ $[_{\omega_1}$ **that it stopped raining in the afternoon** $]]$

In this case ω_1 will hold the entire set of David's doxastic alternatives (at each $i \in c$), so what is going on is exactly the same as in Heim's original explanation. That is, the presupposition of the embedded clause of the second sentence is checked against David's doxastic alternatives where it was raining in the morning, which is to say that the presupposition is that David believes that it was raining in the morning. This presupposition is satisfied by the meaning of the first sentence, hence the filtering.

We can also explain the failure of presupposition filtering in *hope-believe* sequences. The essence of our explanation is the same as Heim's. To illustrate, consider (27).

(27) $c+[_{\omega_0}$ **David hopes**$^{\omega^2}_{\omega_1}$ $[_{\omega_1}$ **that it was raining in the morning** $]]$
$+[_{\omega_0}$ **David believes**$^{\omega_3}$ $[_{\omega_3}$ **that it stopped raining in the afternoon** $]]$

According to the meaning of 'believe', the presupposition of the embedded clause of the second sentence must be satisfied in the entire set of David's doxastic alternatives. Since the update with the 'hope'-sentence does not constrain this set, the presupposition cannot be filtered. In addition, the presupposition of 'hope' demands that ω_1 represent the set of David's doxastic alternatives (or a subset of it), and that there be at least one possible world in this set where it was not raining in the morning. This means that the presupposition of the second sentence is not going to be satisfied, whenever the presupposition of the first sentence is satisfied, which explains the infelicity.

Unlike Heim, furthermore, our analysis can deal with the filtering effects observed in *hope-hope* sequences. What is crucial is that the final line of the meaning of 'hope' in (24) above registers in ω_2 the doxastic alternatives where ϕ holds. Using this, we can analyze the *hope-hope* sequence in question as follows, where the modal base for the second 'hope' is introduced by the first 'hope', i.e. ω_2.

(28) $c+[_{\omega_0}$ **David hopes**$^{\omega_2}_{\omega_1}$ $[_{\omega_1}$ **it was raining in the morning**$]]$
$+[_{\omega_0}$ **David hopes**$^{\omega_3}_{\omega_2}$ $[_{\omega_2}$ **it stopped raining in the afternoon**$]]$

Assuming that the update with the first sentence is successful, the intermediate context c' is guaranteed to consist only of those sequences i such that $\omega_2 i \in \mathrm{Dox}(d, \omega_0 i)$—which means that ω_2 can function as the modal base of the second 'hope'—and furthermore in each $\omega_2 i$, it was raining in the morning, as ensured by the meaning of *hope*. Since the presupposition of the embedded clause of the second sentence is evaluated against these worlds, the presupposition gets filtered out, as desired.

Notice that it is not necessary that the second 'hope' refers to the possible worlds introduced by the first 'hope', and in principle, it could refer to the entire set of David's doxastic alternatives (which would be infelicitous just as under Heim's account), or some other (contextually salient) subset of it. These alternative parses are not relevant in accounting for presupposition filtering in *hope-hope* sequences, but it should be noted that allowing such possibilities is empirically welcome. In order to see this, consider the following example (cf. Crnič 2011).

(29) John hopes that Mary is single. He also hopes that Mary has a perfect family.

These two sentences can express John's conflicting desires, without ascribing him inconsistent beliefs. How is this possible? It should be clear that the modal base for the second *hope* cannot be John's doxastic alternatives in which Mary is single, unlike in the previous case. Rather, the two *hopes* need to be about different sets of possibilities, or else the two sentence would be inconsistent according to our semantics. See von Fintel (1999), Villalta (2008), Crnič (2011:Appendix), and Rubinstein (2012:Ch.3) for related discussions.

4.3 Modal Subordination and the Satisfaction Theory

We have just solved the major empirical shortcoming of the satisfaction theory, by enriching Heim's version with a new mechanism. As we repeatedly remarked above, this solution was suggested by Heim (1992) herself and countenanced by Roberts (1997), although they presented no formal implementation. The core machinery consists in a mechanism of anaphora in the modal domain which enables modal subordination. Modal subordination itself is a very general phenomenon observed with a number of modal and temporal operators besides attitude predicates, and is essentially independent from presuppositions, although often illustrated with presuppositions or pronominal anaphora. Our version of the satisfaction theory, therefore, can be conceived of as a theory of modal subordination as well. Here, we will demonstrate its applicability to modal subordination with non-attitude modals, drawing on data from Heim (1992) and Roberts (1997), although certain aspects of the analyses need to be rudimentary at this moment.

Heim (1992) raises the following example to make the point that something like anaphora to sets of possible worlds seems to be necessary anyway.

(30) If Mary comes, we'll have a quorum. If Susan comes too, we'll have a majority.
(Heim 1992:200; originally attributed to Carl Pollard p.c. to Irene Heim)

The problem of this example is that the presupposition triggered by *too* to the effect that some other salient person comes should not be satisfied, given the assumption that the local context for the antecedent of the second sentence is the context that results from the update with the first sentence (see Heim 1983). If so, it is reasonable to assume that it includes both possible worlds where Mary will come and where Mary won't. However, the example is acceptable and the presupposition seems to be filtered out.

Our extension of the satisfaction theory is applicable to (30) as well. Specifically, adopting the Stalnakerian analysis of conditionals (Stalnaker, 1968, Lewis, 1973), 'if' can be given the following meaning (see Brasoveanu 2007, 2010b and Stone 1999 for related ideas).

(31) $c + [_{\omega_0}\, \mathbf{if}^{\omega_2}_{\omega_1}\, [_{\omega_1}\, \phi\,], [_{\omega_2}\, \psi\,]] =$
$$\{\, j \mid \exists i\colon\ i[\omega_2]j \wedge \omega_2 j \in \mathrm{Sim}_{\omega_0 j}(\omega_1 \{\, k \in (c + [_{\omega_1}\, \phi\,]) \mid \omega_0 j = \omega_0 k \,\})\,\} + [_{\omega_2}\, \psi\,]$$

According to this semantics, the main function of 'if' is to introduce the worlds among ω_1 that are maximally similar to ω_0 where ϕ is true, and store them in ω_2. Notice that the presupposition triggered by ϕ needs to be satisfied by $\omega_1 c$. If $\omega_1 c = \omega_0 c$, the presupposition of the antecedent looks as if it projected out (just as in Heim's 1983 analysis). In more complex cases like (30), on the other hand, ω_1 can be some other possible worlds introduced by another ‘if’. Specifically, we analyze the sentences in (30) as follows.

(32) a. $[_{\omega_0}$ **If**$^{\omega_1}_{\omega_0}$ $[_{\omega_0}$ **Mary comes** $]$, $[_{\omega_1}$ **we'll have a quorum** $]]$
b. $[_{\omega_0}$ **If**$^{\omega_2}_{\omega_1}$ $[_{\omega_1}$ **Susan comes too** $]$, $[_{\omega_2}$ **we'll have a majority** $]]$

The antecedent of the second sentence is evaluated against ω_1, which holds possible worlds where Mary comes that are maximally close to the modal base of the first ‘if’. Clearly, in these worlds, the presupposition triggered by *too* is satisfied.

Roberts discusses a number of more examples of modal subordination, some of which are highly complex. In particular, the following examples involve different types of modals. In both cases, the relevant presupposition is a factive presupposition.

(33) a. Maxine should become a carpenter. Her friends would discover she could build things, and she's be very popular on weekends.
b. Mary is considering getting her Ph.D. in linguistics. She wouldn't regret attending graduate school. (Roberts, 1997:219)

We could in principle analyze these cases in an analogous fashion with the same idea: we let the first modal introduce possible worlds that serve as the modal base for the second modal. For reasons of space, we will refrain from giving explicit formulations here.

Roberts moreover points out further complications of the present phenomenon. One set of her examples involve deontic modals, so let us first discuss how to analyze such non-attitude modals in the present framework.

Following Kratzer (1977, 1981, 1991) among others, we analyze non-attitude modals as involving a modal base and an ordering source. Specifically, ‘it is premitted that ϕ’ roughly means that there is a possible world w among the circumstantially accessible possible worlds—which constitute the modal base—such that ϕ is true in w and that w is one of the best worlds among the modal base with respect to the relevant requirements determined by a contextually salient ordering source. In the following representation, we assume that the ordering source $\preccurlyeq$ is implicitly supplied. Crucially, the modal base is denoted by a discourse marker, e.g. ω_1 in (34).

(34) $c + [_{\omega_0}$ **it is permitted**$^{\omega_2}_{\omega_1}$ $[_{\omega_1}\ \phi\ ]] =$

$$\left\{ j \,\middle|\, \begin{array}{l} \exists i \in c: \\ \mathrm{Best}(\omega_1 \{ k \in c \mid \omega_0 i = \omega_0 k \}, \preccurlyeq_{\omega_0 i}) \cap \omega_1 \{ k \in (c + [_{\omega_1}\ \phi\ ]) \mid \omega_0 i = \omega_0 k \} \neq \varnothing \wedge \\ i[\omega_2] j \wedge \omega_2 j \in \mathrm{Best}(\omega_1 \{ k \in c \mid \omega_0 i = \omega_0 k \}, \preccurlyeq_{\omega_0 i}) \cap \omega_1 \{ k \in (c + [_{\omega_1}\ \phi\ ]) \mid \omega_0 i = \omega_0 k \} \end{array} \right\}$$

Here, $w' \preccurlyeq_w w''$ is intended to mean that the relevant requirements in w are satisfied in w' at least as well as in w'', and $\mathrm{Best}(W, \preccurlyeq_w)$ picks out those possible worlds in W that best comply with the requirements in w according to $\preccurlyeq_w$, i.e. for all $w' \in \mathrm{Best}(W, \preccurlyeq_w)$, $w' \preccurlyeq_w w''$ for each $w'' \in W$. The second line of (34) requires there to be at least one possible world among these best worlds in which ϕ is true, which encapsulates the existential quantificational force of the possibility modal, and ω_2 is used to store these worlds. Furthermore, in order to ensure the intended interpretation, the possible values of ω_1 need to be confined to circumstantially accessible possible worlds, which can be seen as part of the presupposition that ‘permitted’ itself triggers.

(35) $c + [_{\omega_0}$ **it is permitted**$^{\omega_2}_{\omega_1}$ $[_{\omega_1}\ \phi\ ]]$ is defined only if
for all $i \in c$, $\omega_1 i$ is circumstantially accessible from $\omega_0 i$.

Necessity modals can be given an analogous meaning, except that this time all the best worlds according to the ordering source are asserted to be possible worlds where the content of ϕ is true. Thus, the only crucial difference from 'permitted' is the universal quantificational force.

(36) $c + [_{\omega_0}$ **it is required**$^{\omega_2}_{\omega_1}$ $[_{\omega_1}\ \phi\ ]] =$

$$\left\{ j \;\middle|\; \begin{array}{l} \exists i \in c: \\ \mathrm{Best}(\omega_1\,\{k \in c \mid \omega_0 i = \omega_0 k\}, \leqslant_{\omega_0 i}) \subseteq \omega_1\,\{k \in (c + [_{\omega_1}\ \phi\ ]) \mid \omega_0 i = \omega_0 k\} \wedge \\ i[\omega_2]j \wedge \omega_2 j \in \mathrm{Best}(\omega_1\,\{k \in c \mid \omega_0 i = \omega_0 k\}, \leqslant_{\omega_0 i}) \end{array} \right\}$$

As the reader can easily verify, filtering effects of *permit-permit* sequences and *require-require* sequences are expected from these meanings. This expectation is borne out, as shown in (37).

(37) a. You are permitted to go to Paris this month, and you are (also) permitted to go there again next month.

b. You are required to go to Paris this month, and you are (also) permitted to go there again next month.

Let us now turn to the complications that Roberts points out. They have to do with mixed cases where one clause contains *permitted* and the other clause contains *required*. First, observe the following contrast. The pronoun *its* is intended to be anaphoric to *a bear*.

(38) a. You are required to find a bear and permitted to take its picture.

b. #You are permitted to find a bear and required to take its picture. (Roberts, 1997:218)

For the sake of argument, we assume that pronominal anaphora works in the same way as presuppositions (see Heim 1982, Van der Sandt 1992, Geurts 1999 for this idea). Thus, what this contrast shows is that *require-permit* sequences show filtering effects, while *permit-require* sequences do not. Notice that this is not what we expect, since according to our semantics, *require* in (38b) should be able to take the worlds where the hearer finds a bear as its modal base, just as the second occurrence of *required* in (37b) takes the worlds where the hearer goes to Paris this month. This should enable the anaphora.

Interestingly, Roberts points out that not all examples of this form are infelicitous. Below is one example of her examples illustrating this.

(39) You are now permitted to write a dissertation, but required to finish it by the end of next year. (Roberts, 1997:231)

In this example, *it* can be anaphoric to *a dissertation*, unlike in (38b), which complies with the predictions of our semantics.

With Roberts, we take these examples to be indicating that there are pragmatic factors in modal subordination that govern which possible worlds can serve as the modal base of which modal, and not all possibilities made available by semantics are always attested. Although the nature of these pragmatic factors is still ill-understood, this is not at all a far-fetched assumption, given that it is widely accepted that pronominal anaphora is restricted by a whole lot of pragmatic factors. Thus, our formal theory is a hypothesis about what is permitted by grammar, but clearly needs to be supplemented with pragmatics to capture what is actually attested. Needless to say, this is impossible to achieve at this moment, and calls for further investigations.

Before moving on, it should be mentioned that among the modal operators we have seen so far, *believe* is special in that it does not take a modal base. On this view, then, modal subordination with *believe* should be unattested, and presupposition filtering should be solely due to entailment (as in Heim's account). We are not aware of conclusive data to adjudicate this prediction (but see the discussion in fn.5), but if it turns out to be false, the meaning of *believe* given in (20) should be revised to include a modal base, as in (40).

(40) $c + [_{\omega_0}$ **David believes**$^{\omega_2}_{\omega_1}$ $[_{\omega_2}\ \phi\ ]]$
$= \{\, j \mid \exists i \in c\colon\ i[\omega_2]j \wedge \omega_2 j \in \omega_1 \{\, k \in c \mid \omega_0 i = \omega_0 k \,\}\,\} + [_{\omega_2}\ \phi\ ]$

However, one ramification of this revision is that we lose our account of the infelicity of *hope-believe* sequences. That is, if *believe* can take the worlds introduced by *hope* as its modal base, then filtering effects should be observed. This brings us back to the same semantics vs. pragmatics dilemma that we have just discussed. That is, one could hypothesize that the particular example we looked at was made unacceptable by pragmatics and look for one where the pragmatic restrictions are somehow lifted. In the absence of good understanding of the pragmatics involved, we cannot address this important issue here. Instead, we leave the discussion with Heim's characterization of the conundrum: "Once this mechanism [for modal subordination] is invoked, of course, the question arises to what extent it could also have been employed to yield some of the predictions that I took pains to make follow directly from the CCP definitions" (Heim, 1992:200f).

5 Accommodation of Two-Sided Inferences, Pragmatic Reasoning, and Antipresuppositions

As we saw in the previous section, the satisfaction theory, as well as our extension of it, only derives the i-inference as a presupposition for sentences like (41).

(41) John believes that it stopped raining.

What about the e-inference observed in neutral contexts that it was actually raining? Heim claims that the e-inference arises due to pragmatic properties of presupposition accommodation together with reasoning about naturalness, as summarized in the following passage.[10]

> So when we hear [(41)] out of the blue, we know two things: first, as a matter of the semantics of this sentence, we know that it requires the presupposition that John believes that it was raining. Second, we know that the speaker takes this to be uncontroversial and unsurprising. Now why would it be unsurprising that John has such a belief? The most natural guess is that it would be unsurprising because it was in fact raining and John was in an appropriate position to find out. Of course, these are not the only possible conditions under which someone might form a belief that it was raining; but they are the most *normal* conditions. Therefore, if accommodation is generally accompanied by a suggestion of unsurprisingness, then it is not so puzzling that these are the conditions which we spontaneously imagine to obtain. (Heim 1992:212; emphasis in original)

[10]The original idea is attributed to Lauri Karttunen's unpublished work. See Sharvit (1998) for the role of the same pragmatic reasoning in *de re* attitudes. Heim (1992) also suggests a different possibility of deriving the e-inference as a *de re* reading and demonstrates how such an analysis works for certain presupposition triggers, but as Geurts (1999) and Sharvit (1998) argue, this approach seems to fail to apply generally to all presuppositions. For reasons of space, we will not discuss this alternative in this paper.

Thus, according to Heim, the e-inference is not a presupposition of the sentence but arises via pragmatic reasoning. Geurts (1999) expresses objections against Heim's explanation in the following passage, however.

> [Heim's argument] takes the wrong direction, in that it attempts to draw conclusions about the speaker's beliefs on the basis of the beliefs that he ascribes to a third party, instead of the other way round. Although the notion is notoriously hard to make precise, it is generally accepted that in construing the beliefs of others we operate on a principle of charity: we try to avoid the conclusion that other people's beliefs are contradictory, we credit them with knowledge that we take to be uncontroversial or commonly available, and so on. It is only natural to assume that the same principle underlies our speaking of other people's beliefs. Putting the point without any of the necessary nuances: if a person *a*'s doxastic context is the subject of a conversation, the interlocutors will tend to assume that *a* believes what they believe. [...] Heim's argument, however, proceeds in the opposite direction, which is not nearly as plausible: in general, if I describe someone as believing that ϕ, I intend to at least remain uncommitted concerning the truth of ϕ. What is more, if someone describes a person as believing (rather than knowing) that ϕ, his description may often be taken to imply that he doubts that ϕ is true or is even convinced that it is false. In short: if a speaker reports on the beliefs of a person *a* there may be a tendency to ascribe to *a* beliefs that the speaker is taking for granted, but it is *a priori* unlikely that the hearer will ascribe a certain belief to the speaker because the speaker ascribes it to *a*.
> (Geurts, 1999:166)

In addition to this general doubt about the logic of Heim's explanation, Geurts furthermore raises an empirical counter-argument using the following sentence.[11]

(42) Fred knows that John believes that it was raining. (Geurts, 1999:165)

This examples has a factive presupposition triggered by 'know' to the effect that John believes it was raining. Notice that this is the same presupposition as what the satisfaction theory assigns to (41) above. Thus, if the pragmatic reasoning that Heim resorts to applies to (42) as well, (42) should also suggest that it was in fact raining, but this prediction is evidently wrong. In what follows, we will address both of these criticisms in defense of Heim's account of the e-inference.[12]

Firstly, as Geurts remarks in the above quote, by asserting 'John believes ϕ', one tends to connote that ϕ might be false, or sometimes even is in fact false. However, this fact is not directly relevant to Heim's account of the e-inference, as what she is talking about is the speaker's acting

[11] Notice that the logic behind this counter-argument is similar to the proviso problem.

[12] Geurts (1999) raises another objection adducing the following sentence.

(i) Wilma is polishing her stethoscopes. (Geurts, 1999:165)

This sentence has a presupposition that Wilma owns stethoscopes. If one were to accommodate this presupposition, the most natural context would be one where Wilma was a doctor, and indeed one could naturally conclude this. Therefore, for Heim (1992), the inference to that Wilma is a doctor should be of the same nature as the e-inference of (41). Geurts remarks, however, that these two inferences seem to be different in nature, because it is easier to cancel the inference of (i) than the e-inference of (41). While he might be right about this observation, however, we don't think this argument is very convincing, as there are many independent factors that are different between the two examples. To settle this issue, a more careful investigation, potentially involving controlled experiments, is called for.

as if it is unsurprising that a believes ϕ, rather than asserting that a believes that ϕ, and a crucial difference lies between these two, namely the logic of presupposition accommodation. We argue that when this is taken into consideration, Heim's explanation of the e-inference is not as farfetched as Geurts' quote above might suggest.

Before discussing the logic of accommodation behind Heim's account, it is instructive to be more precise about the inference that Geurts mentions, because this is pertinent to both of his criticisms. This inference from an assertion of 'John believes ϕ' to ϕ's non-truth (or falsity) is given a pragmatic analysis by Percus (2006) and others (e.g. Chemla 2008, Sauerland 2008, Singh 2011; see also Heim 1991). Following Percus, we call it an *antipresupposition*. The idea is roughly the following. An assertion of 'John believes ϕ' invokes an alternative sentence 'John knows ϕ', which conveys basically the same meaning but additionally has the factive presupposition that ϕ is true. Following Heim (1991), Percus postulates a pragmatic principle that favors the use of a sentence with more presuppositions to an alternative sentence with less presuppositions, *when everything else is equal*. Specifically, when two sentences ϕ and ψ assert the same thing and are both defined in the current context of utterance but ψ has more presuppositions, then ϕ cannot be felicitously used. Thus, the principle demands the use of 'John knows ϕ' instead of 'John believes ϕ', whenever the presupposition of the former is met, i.e. ϕ is true in the current context. Or conversely, 'John believes ϕ' can felicitously be asserted only if 'John knows ϕ' cannot be asserted, i.e. the context of utterance does not satisfy ϕ, which is the inference that Geurts is talking about.

The pragmatic principle in question is called *Maximize Presupposition*, which was originally proposed by Heim (1991) for the use of definite vs. indefinite noun phrases. Following Singh (2011), we state it in terms of CCPs as follows.[13]

(43) *Maximize Presupposition*
For any context c, $c+\phi$ is undefined if for some $\psi \in \mathrm{Alt}(\phi)$, the following are true:
  a. Both $c+\phi$ and $c+\psi$ are defined, and $c+\phi = c+\psi$.
  b. For some c', $c'+\phi$ is defined but $c'+\psi$ is not defined.

In the case at hand, ϕ is a sentence with 'believe' and ψ is the corresponding sentence with 'know'. We assume that 'know' means the same thing as 'believe' except that it has a factive presupposition.[14] More specifically, we assume the following meaning for 'know'.

(44) a. $c + [_{\omega_0}$ **David knows**$^{\omega_1}$ $[_{\omega_1}\ \phi\ ]]$ is defined only if
$\{\, j \mid \exists i \in c\colon\ i[\omega_1]j \wedge \omega_1 j = \omega_0 j\,\} + [_{\omega_1}\ \phi\ ] = \{\, j \mid \exists i \in c\colon\ i[\omega_1]j \wedge \omega_1 j = \omega_0 j\,\}$

[13] Noticing that Heim's original formulation of Maximize Presupposition suffers from the 'projection problem for antipresuppositions', Percus (2006) proposes some refinements of it. Singh (2011) points out that using CCPs and local contexts, the projection problem of antipresupposition can be dealt with naturally in tandem with the projection problem of normal presupposition.

[14] This is arguably an oversimplification (cf. the so-called 'Gettier problem'; Gettier 1963). Percus (2006) discusses potential issues arising from this assumption in a footnote where he suggests that such problems can be dealt with by adding more presuppositions to the lexical entry of 'know'. If he is right, the inference derived by Maximize Presupposition will then be weaker than what we derive here. Fortunately, this does not seem to be empirically problematic, but we will put this issue aside here, by tacitly focusing on those contexts where these extra presuppositions are satisfied.

b. Whenever defined,
$c + [_{\omega_0}$ **David knows**$^{\omega_1}$ $[_{\omega_1}\ \phi\ ]] = \{\, j \mid \exists i \in c\colon\ i[\omega_1]j \wedge \omega_1 j \in \mathrm{Dox}(d, \omega_0 j)\,\} + [_{\omega_1}\ \phi\ ]$
$(= c + [_{\omega_0}$ **David believes**$^{\omega_1}$ $[_{\omega_1}\ \phi\ ]])$

In words, the factive presupposition amounts to the requirement that the embedded clause be already true in each of the worlds in $\omega_0 c$. This is checked here with the sequences j that are just like the original sequences $i \in c$ except that $\omega_1 j$ is identical to $\omega_0 j$, which in turn is identical to $\omega_0 i$.

Thus, Maximize Presupposition derives the inference that Geurts mentions in the above passage for belief reports. However, it is important to realize that even if asserting that someone believes ϕ engenders an inference that ϕ is not (believed to be) true, this is not relevant to Heim's explanation of the e-inference. Rather, according to Heim, the sentence (41) *presupposes* that David believes that ϕ and the speaker expects the hearer(s) to accommodate this presupposition, and Maximize Presupposition simply has no role to play here.

Furthermore, Heim's explanation is not at all implausible, once the logic of presupposition accommodation is taken into consideration, contrary to Geurts' characterization that it "takes the wrong direction". Although presupposition accommodation is a notoriously recalcitrant issue widely debated in the current literature (see Stalnaker 2002, Simons 2003, Beaver and Zeevat 2007, von Fintel 2008) and it is of course impossible to elucidate every aspect of it here, it suffices to make some plausible assumptions about it for Heim's explanation to go through.

Here rare the details: Schematically, we have a sentence of the form 'John believes that ϕ_p' with a presupposition that John believes that p, which is the i-inference. Suppose that this sentence is uttered in a context that neither satisfies nor contradicts this presupposition. As a hearer, therefore, one needs to do something about this presupposition, namely accommodate it. What does it mean to accommodate a presupposition? Following the previous literature (see the works quoted above and references there in), we assume that presupposition accommodation is essentially context adjustment scaffolded by the mutually assumed principles of conversation and plausibility reasoning. More specifically, by uttering a sentence with a presupposition that is not satisfied in the context of utterance (and is not incompatible with it), the speaker makes her supposition clear that the presupposition should be uncontroversial and is ready to be accepted by the other conversational participants. Upon hearing such an utterance, the hearers in turn attempt to readjust the context so that it satisfies the presupposition, i.e. they accept the presupposition in question and also assume that all the other discourse participants also accepted it and that they all assume that the others assume that everybody accepted it, etc. We furthermore assume that the readjusted context should be the most natural one among the ones that satisfy the presupposition, as it is likely to be the one that the speaker has in mind (and expects the other conversational participants to be able to imagine).

Coming back to the example under discussion, the presupposition is that John believes that p, $B_j(p)$ for short. The context needs to be readjusted to satisfy this presupposition. Representing the situation where it is commonly believed that p by $CB(p)$, the accommodation results in the situation $CB(B_j(p))$. Notice now that logically, the resulting context must be either $CB(p) \wedge CB(B_j(p))$ or $\neg CB(p) \wedge CB(B_j(p))$. The crucial step in Heim's argument is that the hearer further reasons that the former kind of context is more natural for the cooperative and pragmatically competent speaker to have in mind than the latter kind of context, when they suggest that $B_j(p)$ is unsurprising and uncontroversial, and expect the other conversational participants to accommodate it. The reason for this is precisely because of the 'principle of charity' that Geurts himself mentions in the above quote. That is, if $CB(p)$ is the case, then one could naturally take for granted that $B_j(p)$, but if $\neg CB(p)$, then $B_j(p)$ should be surprising and probably worth asserting. As a result, the hearer draws the inference that $CB(p)$ as well, from the speaker's expectation that the current context is ready to accommodate $B_j(p)$.

Thus, it is incorrect to characterize this process as drawing the conclusion that $CB(p)$ from the speaker's uttering $B_j(p)$, as Geurts does, but rather, what the speaker does by uttering the sentence in question is reveal their assumption that the context is ready to accept $B_j(p)$ as uncontroversial, from which other discourse participants can conclude $CB(p)$. This explanation of the e-inference seems to be reasonable and plausible, given the auxiliary assumptions about how presupposition accommodation works.

Now, let us turn to Geurts' empirical counter-argument from (42), repeated below.

(42) Fred knows that John believes that it was raining.

We argue that this argument is missing one crucial ingredient, namely Maximize Presupposition, and once this principle is factored in, (42) is no longer problematic for Heim's account. Specifically, (42) invokes the following alternative sentence.

(45) Fred knows that John knows that it was raining.

This sentence has a presupposition that it was raining. Our version of the satisfaction theory derives this presupposition as follows. First, let us represent this sentence (46).

(46) $c + [_{\omega_0}$ **Fred knows**$^{\omega_1}$ $[_{\omega_1}$ **John knows**$^{\omega_2}$ $[_{\omega 2}$ **it was raining** $]]]$

The factive presupposition of the first 'knows' requires:

$$c_j + [_{\omega_1} \textbf{ John knows}^{\omega_2}\ [_{\omega 2} \textbf{ it was raining }]] = c_j \text{ where } c_j = \{\, j \mid \exists i \in c\colon\ i[\omega_1]j \wedge \omega_1 j = \omega_0 i \,\}$$

Furthermore, due to the factive presupposition of the second 'knows', this update is only defined if the following is the case:

$$c_k + [_{\omega 2} \textbf{ it was raining }] = c_k \text{ where } c_k = \{\, k \mid \exists j \in c_j\colon\ j[\omega_2]k \wedge \omega_2 k = \omega_1 j \,\}$$

Notice now that for any $i \in c$ there are $j \in c_j$ and $k \in c_k$ such that $\omega_2 k = \omega_1 k = \omega_1 j = \omega_0 j = \omega_0 i$. Thus, requiring that it was raining in all the worlds in $\omega_2 c_k$ is tantamount to requiring that it was raining in all the worlds in $\omega_0 c$. Consequently, (45) presupposes that it was in fact raining and that John believes/knows that it was raining.

Consider now Geurts' example in (42), analyzed as follows.

(47) $c + [_{\omega_0}$ **Fred knows**$^{\omega_1}$ $[_{\omega_1}$ **John believes**$^{\omega_2}$ $[_{\omega 2}$ **it was raining** $]]]$

Importantly, this has fewerer presuppositions than (46), i.e. its only presupposition is that in all the worlds in $\omega_0 c$ John believes that it was raining, and does not presuppose that it was in fact raining. Since the CCPs of these two sentences are identical whenever defined, Maximize Presupposition consequently derives from (47) the antipresuppositional inference that the presupposition of (46) is not satisfied in c. Since the presupposition of (47) must be satisfied in c for its own felicity, then it must be the case that it was not raining in some $w \in \omega_0 c$. Notice that this antipresupposition is in direct conflict with the e-inference. So if the speaker utters a sentence with this antipresupposition (which they are aware that the hearer(s) would draw using Maximize Presupposition), then the hearer(s) of course cannot infer that the speaker assumes that the e-inference is unsurprising. Thus, the e-inference can only be drawn from (41) and not from (42).

For these reasons, Geurts' criticisms are not detrimental to Heim's account of the e-inference. For the sake of completeness, let us examine some other sentences that Geurts discusses in favor of his alternative analysis. Consider first the following sentence.

(48) It is possible that Barney was tripped, and that he believes that it was Fred who tripped him. (Geurts, 1999:142)

This is a sentence of the form $\Diamond(p \wedge B_b(\phi_p))$. Assuming that $\Diamond$ is a presupposition hole (though widely accepted as a data point, this of course needs to be accounted for independently), the presupposition of the embedded sentence should become (part of) the presupposition of the entire sentence. What is the presupposition of the embedded sentence $(p \wedge B_b(\phi_p))$? According to the satisfaction theory, the second conjunct has a presupposition that Barney believes that p, and this presupposition needs to be satisfied in its local context, which is the context where p holds. Thus, the presupposition of $(p \wedge B_b(\phi_p))$ can be conceived of as a conditional presupposition that if p then Barney believes that p. Since this projects through $\Diamond$, the presupposition predicted for the entire sentence is: if Barney was tripped, then he believes that somebody tripped him. Geurts argues that this is not what is observed. Rather, the sentence seems to have no presupposition.

Again we do not think this is a problem for the satisfaction theory. Firstly, we observe that the sentence 'p' actually seems to be able to satisfy the presupposition that Barney believes that p. Concretely, one gets an impression that the following conjunctive sentence has no presupposition.

(49) Barney was tripped, and he believes that it was Fred who tripped him.

Yet, Geurts is right in that this is not what the satisfaction theory directly predicts and the predicted presupposition is in fact conditional, i.e. that if Barney was tripped, then he believes that he was tripped. Recall, however, that there is no reason why we shouldn't take into account pragmatic naturalness. In this particular case, it is especially natural for one to make an inference from 'Barney was tripped' to that Barney is aware that he was tripped, for reasons of naturalness, and this inference satisfies the presupposition of the second conjunct. In parlance of the satisfaction theory, one first updates the context with the first conjunct 'Barney was tripped' and eliminates certain worlds. In doing so, one could not only remove those worlds where Barney was not tripped but also ones where Barney is not aware that he was tripped, because these are highly unlikely situations. This accounts for our naive intuition about (49) and the lack of a substantial presupposition in (48).[15]

In essentially the same way, we can account for the lack of presuppositions in the following sentences, where the presupposition trigger in question is the possessive construction presupposing that Louise has a niece.

[15] Furthermore, recall the principle of charity, which Heim's account tacitly makes use of to derive the e-inference, as explained above, which dictates that if p is part of the common beliefs, one usually can take for granted that $B_b(p)$. Given this, one can furthermore account for (i) below, which is due to an anonymous reviewer.

(i) It is possible that Barney was tripped, and that Wilma believes that it was Fred who tripped him.

Here, in the local context of the second conjunct, one can accommodate that Wilma believes that Barney was tripped, because in that context this is commonly believed. We thank the reviewer for the reviewer. The same reviewer raised the same type of question regarding (50a) below, but our answer is essentially the same.

(50) a. If Louise has a niece, then she believes that her niece lives in Leeds.
b. If Louise believes that she has a niece, then she also believes that her niece lives in Leeds. (Geurts, 1999:138)

In both of these examples, the presupposition of the consequent that Louise believes that she has a niece seems to be filtered out by the antecedent. Geurts argues that while it has no problem with (50b), the satisfaction theory fails to explain the alleged presupposition filtering in (50a). For the sake of argument, let us assume that following (arguably simplistic) meaning of 'if' (Heim 1983).

(51) $c + (\textbf{if } \phi\textbf{, then } \psi) = c - ((c + \phi) - (c + \phi + \psi))$

According to this meaning, the local context for ψ is $c + \phi$, and hence ϕ should be able to filter out the presupposition of ψ. Therefore, the filtering effect (50b) is as expected. However, as Geurts claims, the presupposition filtering in (50a) cannot be explained by this. Rather, (50b) should have a conditional presupposition that if Louise has a niece, then she believes that she has a niece. But notice that this is the same problem as above, and we can give the same solution. That is, it is natural, if not logically necessary, to make an assumption that if Louise has a niece, then she is aware of it, especially given that no one has explicitly said otherwise. Thus, the update with the antecedent 'Louise has a niece' yields a context that satisfies the presupposition that she believes (or more appropriately knows) that she does, which in turn satisfies the presupposition of the consequent.

Finally, it should be clarified how the e-inference of 'hope' is accounted for under our modification of the satisfaction theory. Consider the following sentence.

(52) John hopes that it stopped raining.

It is observed that in a neutral context this sentence also gives rise to the e-inference that it was actually raining. For Heim, this is unsurprising, because this sentence has the i-inference as its presupposition, just like its 'believe' counterpart. However, recall that in our modification, the presupposition of this sentence could be weaker than what Heim predicts, and this assumption was crucial in explaining the filtering effect in *hope-hope* sequences. Specifically, the predicted presupposition is that it was raining in a salient subset of John's doxastic alternatives, which could be a proper subset. However, notice that in the case at hand, we are dealing with presupposition accommodation, and the situation does not contain any salient subset of John's doxastic alternatives. We suggest that in such a case, the modal base is by default resolved to the biggest possible set, i.e. the entire set of John's doxastic alternatives. As a result, the sentence yields the i-inference that John believes that it was raining, which is intuitively the correct result, and which in turn gives rise to the e-inference via Heim's logic.

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