Support for Update Semantics (House Version)

Paul Dekker

ILLC/Department of Philosophy
Faculty of Humanities
University of Amsterdam
dekker@hum.uva.nl

Abstract

In this paper classical systems of update semantics are studied from the wider perspective of information exchange. We present independent compositional statements of the content of, update with, and support for first order expressible sentences. It is shown that a proper update with the contents of supported utterances is safe, in the sense that it does not corrupt the information distributed over the interlocutors. The pragmatic outlook on update and support also allows us to escape from some of the objections that has been raised against first order analyses of natural languages connectives, notably that of conditionals as material implication. The adopted outlook furthermore provides inspiration for a plausible analysis of functional dependencies and of certain cases of what has been called quantificational and modal subordination.

1. Introduction

Dynamic Semantics (DS) is a branch of linguistics originating from the model-theoretic and referentially-based work of Montague and his followers. The characteristic feature of dynamic semantics is that it systematically takes into account certain pragmatic aspects of interpretation. In the original versions of dynamics semantics, the object of study is the (dynamic) logic of the effects which the utterance of indicative sentences may bring about in an utterance situation (Discourse Representation Theory, File Change Semantics, Dynamic Predicate Logic, Update Semantics); in other versions also the logic of the satisfaction-conditions and pre-conditions are systematically studied (Situation Semantics, Epistemic Semantics).

In this paper we adopt a more systematic outlook on the semantics and pragmatics of assertions in natural language, one that takes into account both update effects on the side of the hearer, as well as the information which a speaker can be said to be committed to in support for her assertions. The main inspiration for this paper comes from (Grice, 1975; Grice, 1978; Stalnaker, 1978; Stalnaker, 1998). Technically, it elaborates upon the work of (Kamp, 1981; Heim, 1982; Groenendijk and Stokhof, 1991; Veltman, 1996).

We will proceed as follows. In the next section we introduce crucial notions and issues (semantic as well as pragmatic) in the context of a simple fragment of natural language which has the expressive power of propositional logic. In section 3 we lift the discussion to the first order level, and show how the relatively trivial results and observations from the propositional logic can be preserved, in a non-trivial way, at the first order level. Section 4 discusses a conceptual issue which automatically arises at the first order level. Maybe surprisingly, this doesn't have to do with the dynamics of first order interpretation—which has been given a natural explanation in section 3—, but with the absence of it in certain contexts. The insights gained in this section constitute motivation for a natural extension of the empirical scope of the first order system with functional dependencies, which is sketched in section 5. In the concluding section we summarize the results.

2. The Exchange of Propositions

In this section we introduce the basic notions which this paper focuses on, that of the 'content of', 'update with' and 'support for' assertions. The concepts are introduced for a fragment of natural language which can be analyzed in terms of that of propositional logic.

2.1. Propositional Semantics

Let us assume we have a language of proposition logic built up from a set of proposition letters by means of negation and conjunction. Interpretation is stated relative to a model $M = \langle W, V \rangle$, consisting of a set of possible worlds W and an initial valuation function V, which assigns sets of worlds to proposition letters.

Satisfaction is defined relative to such a model M and a world $w \in W$:

Definition 1 (Propositional Satisfaction)

- $w \models_M p$ iff $w \in V(p)$
  $w \models_M \neg\phi$ iff $w, \not\models_M \phi$
  $w \models_M \phi \wedge \psi$ iff $w \models_M \phi$ and $w \models_M \psi$

Obviously, these are the standard satisfaction conditions.

In terms of the satisfaction conditions we can spell out the contents of our sentences as the sets of possible worlds in which the sentences are true:

Definition 2 (Propositional Contents)

- the content of ϕ in M, $[\![\phi]\!]_M$, is $\{w \mid w \models_M \phi\}$

It is completely straightforward to see that the contents of our sentences could as well have been spelled out independently and in a compositional fashion, for:

Observation 1 (Composition of Contents)

- $[\![\neg\phi]\!]_M = W \setminus [\![\phi]\!]_M$
  $[\![\phi \wedge \psi]\!]_M = [\![\phi]\!] \cap [\![\psi]\!]$

Clearly, this little propositional system has a classical, Boolean semantics.

2.2. Pragmatics of Assertion

Let us now see how our propositional system language can be used to characterize aspects of propositional information *exchange*. Agents are assumed to exchange information about the (actual state of the) world, and the information they have can be modeled by means of the sets of possible worlds which might be the actual one for as far as the agents know.

So what can we say that an agent a may pick up when somebody else asserts a particular sentence ϕ (and if a accepts the assertion)? Obviously, this is the update of the information t which he already had with the information which he gets:

Definition 3 (Propositional Updates)

- the update of t with ϕ in M, $[\![\phi]\!]_M(t)$, is $t \cap [\![\phi]\!]_M$

After accepting ϕ, an agent is taken to believe the world to be as he thought it was before the update, and also as it is said to be by the utterance of ϕ.

Let us now take a look at the other party in the game of information exchange, and see how the speaker's information relates, or must relate, to what she says to be the case. One of the main goals of the game of information exchange is that agents exchange true information, so one of the major principles is that the speaker's information state s support the contents of her utterances:

Definition 4 (Propositional Support)

- s supports ϕ in M, $s \models_M \phi$, iff $s \subseteq [\![\phi]\!]_M$

If one says that the actual world is a ϕ-world, then one ought not to conceive it possible that the actual world is not a ϕ-world.[1]

2.3. Coherent Information Exchange

The present propositional notions of content, update and support are closely and coherently related. Update and support can also be specified independently, and in a compositional fashion:

Observation 2 (Compositional Updates)

- $[\![\neg\phi]\!]_M(t) = t \setminus [\![\phi]\!]_M(t)$
  $[\![\phi \wedge \psi]\!]_M(t) = [\![\psi]\!]_M([\![\phi]\!]_M(t))$

Observation 3 (Compositional Support)

- $s \models_M \neg\phi$ if for no $\emptyset \subset s' \subseteq s$: $s' \models_M \phi$
  $s \models \phi \wedge \psi$ iff $s \models_M \phi$ and $s \models_M \psi$

This is appealing, because it shows that we can study the logic of update and support separately and in a formally transparent fashion, without having to worry about the implications of this for the philosophically well-motivated notion of linguistic content.

[1] This notion of support may serve to implement Grice's maxims of quality. It can also be used to specify Hamblin's notion of commitment: a speaker can be said to be committed to having the information supporting what she says.

It is also easily seen that the update with a supported assertion is safe. The information which an agent has after the update with a supported assertion is contained in the joint information which he and the speaker had before the assertion:

Observation 4 (Supported Updates)

- if $s \models_M \phi$ then $s \cap t \subseteq [\![\phi]\!]_M(t)$

This fact guarantees that a proper exchange of propositional information does not corrupt the information exchanged. Thus, if the interlocutors start out with correct information, and only exchange supported information, then each of the player's information after the exchange is correct, too. Surely, this is a key property of a sound system of information exchange.

2.4. Pragmatics of Conditionals

In this paper implication is, as usual, defined in terms of negation and conjunction: $\phi \rightarrow \psi =_{\text{df}} \neg(\phi \wedge \neg\psi)$. Thus:

Observation 5 (Implication satisfaction)

- $w \models_M \phi \rightarrow \psi$ iff, if $w \models_M \phi$ then $w \models_M \psi$

Several objections have been raised against such a material implication analysis of conditional sentences, one of these being that it is too weak. An implication is already satisfied by w if the antecedent clause is not satisfied. When we take pragmatic matters into account, however, such an objection loses its bite.

Consider the support a speaker may have. If it is true that if $s \models_M \phi$ then $s \models_M \psi$, it does not yet follow that $s \models_M \phi \rightarrow \psi$. More is required to make the latter point true, viz., that $\forall w \in s$: if $w \models_M \phi$ then $w \models_M \psi$. This is a stronger requirement with an intensional flavor. State s supports $\phi \rightarrow \psi$ if s has evidence for some trans-world dependency between ϕ and ψ.

This point can be appreciated further when we consider the following two related facts:

Observation 6 (Role Switches)

- $\sigma \models \neg\phi$ iff $[\![\phi]\!](\sigma) = \emptyset$
- $\sigma \models \phi \rightarrow \psi$ iff $[\![\phi]\!](\sigma) \models \psi$

Support for a negation $\neg\phi$ consists in evidence against an attempted *update with* ϕ. Similarly, support for an implication consists in support for the consequent which is functionally dependent on an update with the antecedent. Notice that this functional dependence should not be a trivial one. Grice's quantity maxims exclude evidence for $\neg\phi$ or ψ to support an utterance of $\phi \rightarrow \psi$.

When we consider a fragment of natural language which can be modeled by a language of propositional logic, the notions of content, update and support are seen to be coherently related. Content of, update with, and support for the utterance of a propositional sentence can be defined separately, and any one of these notions can be defined in terms of another. Besides, exchange of information can be defined in a safe way. What about a fragment of natural language with the expressive power of first order predicate

logic? The next section discusses what are appropriate notions of content, update and support when we are concerned with the utterance of sentences with indefinite elements (in particular pronouns, and indefinite noun phrases)?

3. First Order Exchange

In this section we sketch the semantics and pragmatics of a first order language, built upon three assumptions, relatively well-motivated in the philosophical literature (cf., e.g., (Stalnaker, 1998)). First, indefinite noun phrase (modeled by means of existentially quantified phrases) are generally used with referential intentions; second, anaphoric pronouns may refer back to the individual which a preceding indefinite was intended to refer to; third, both kinds of terms are linearly ordered in discourse. The set up of this section mirrors that of the previous one. We first specify a satisfaction semantics for a first order language (which includes pronouns), and then we develop suitable notions of content, update and support. (The observations, definitions and results of this section are extensively discussed in (Dekker, 2000).)

3.1. Satisfaction of First Order Assertions

Let us assume a language built up from variables, pronouns ($\mathtt{p}_1, \mathtt{p}_2, \ldots$) and relational constants by means of negation, existential quantification and conjunction. Variables are dealt with in the usual way by means of variable assignments and pronouns look back in the discourse for preceding antecedents. A pronoun $\mathtt{p}_i$ is interpreted as coreferential with the i-th existential found when going back in the discourse from the place where the pronoun occurs. Relative to a sequence e, a pronoun $\mathtt{p}_i$ selects the i-th individual e_i from that sequence, thus indicating that it is coreferential with the i-th potential antecedent in preceding discourse.

Formulas are interpreted relative to sequences of individuals satisfying both their existentials and pronouns. (For a start, we neglect 'worldly' information.) Given that existentials (associated with indefinites) are used with referential intentions, and since these occur in a linear order, the 'length' $n(\phi)$ of a formula ϕ is that the number of existential quantifiers in ϕ not in the scope of a negation. Satisfaction is defined, furthermore, relative to a first order model $M = \langle D, E\rangle$ consisting of a domain of individuals D and an interpretation E for the non-logical constants. It is defined as follows:

Definition 5 (First Order Satisfaction)

- $e \models_{M,g} Rt \ldots t'$ iff $\langle [t]_{g,e}, \ldots, [t']_{g,e}\rangle \in E(R)$
  $e \models_{M,g} \exists x\phi$ iff $e{-}1 \models_{M,g[x/e_1]} \phi$
  $e \models_{M,g} \neg\phi$ iff $\neg\exists c \in D^{n(\phi)}$: $ce \models_{M,g} \phi$
  $e \models_{M,g} \phi \wedge \psi$ iff $e \models_{M,g} \psi$ and $e{-}n(\psi) \models_{M,g} \phi$
  where $e{-}m$ is the sequence $e_{m+1}, e_{m+2}, \ldots$

This satisfaction semantics is dynamic in that it accounts for inter-sentential anaphoric binding. Due to its treatment of existentials, pronouns, and its dynamic notion of conjunction, the following two formulas are equivalent:

Observation 7 (Dynamic Conjunction)

- $\exists x(Dx \wedge \exists y(Py \wedge Fxy)) \wedge \exists z(Tz \wedge S\mathtt{p}_1\mathtt{p}_2 z) \Leftrightarrow$
  $\exists z\exists x(Dx \wedge \exists y(Py \wedge Fxy) \wedge (Tz \wedge Sx\mathtt{p}_1 z)) \Leftrightarrow$
  $\exists z\exists x\exists y(Dx \wedge Py \wedge Fxy \wedge Tz \wedge Sxyz)$

This mirrors the natural language equivalence between:

(1) A diver found a pearl. She sold it to a tourist.
(2) A diver sold a pearl she found to a tourist.

Our satisfaction semantics also accounts for a worn-out example like the famous 'donkey-sentence':

(3) If a farmer owns a donkey he beats it.
(4) Every farmer beats every donkey he owns.

since, e.g.,

Observation 8 (Dynamic Implication)

- $(\exists x\phi(x) \rightarrow \psi(\mathtt{p}_1)) \Leftrightarrow \forall x(\phi(x) \rightarrow \psi(x))$

The interested reader is referred to (Dekker, 2000) for a further exposition of this system.

3.2. First Order Contents and Updates

In the propositional system of section 2 formulas were defined to be satisfied by certain possible worlds, and in the first order system by certain sequences of individuals, in an extensional manner. The two definitions can be combined by resorting to intensional models $\mathcal{M} = \langle W, D, I\rangle$, which consist of a set of worlds W, a domain of individuals D, and an interpretation function I such that for all $w \in W$: $\mathcal{M}_w = \langle D, I_w\rangle$ is an (extensional) model:

Definition 6 (First Order Contents)

- $[\![\phi]\!]_{\mathcal{M},g} = \{we \mid e \models_{\mathcal{M}_w,g} \phi\}$

The first order contents of a formula ϕ are given by (Heim, 1982)'s satisfaction sets, sets of worlds and sequences of individuals which jointly satisfy the conditions imposed upon them by ϕ.

Although our first order notion conjunction from section 3.1 has been seen to be dynamic, it can be understood to derive from a (Boolean) form of intersection:

Observation 9 (Conjunction is Boolean)

- $[\![\phi \wedge \psi]\!]_{\mathcal{M},g} = [\![\psi]\!]_{\mathcal{M},g} \cap [+n(\psi)][\![\phi]\!]_{\mathcal{M},g}$

In this observation $[+n(\psi)]\tau$ indicates the *update* of the satisfaction set τ with the fact that $+n(\psi)$ more terms have been used after the satisfaction set $\tau = [\![\phi]\!]_{\mathcal{M},g}$ has been established, i.e., after the assertion of ϕ.

With the notion of conjoining contents at hand, first order updates can be specified as follows:

Definition 7 (First Order Updates)

- $[\![\phi]\!]_{\mathcal{M},g}(\tau) = [\![\phi]\!]_{\mathcal{M},g} \cap [+n(\phi)]\tau$

Under this definition, the update notion of conjunction turns out to be a form of composition:

Observation 10 (Conjunction as Composition)

- $[\![\phi \wedge \psi]\!]_{\mathcal{M},g}(\tau) = [\![\psi]\!]_{\mathcal{M},g}([\![\phi]\!]_{\mathcal{M},g}(\tau))$

Interestingly, the dynamics of conjunction (and that of interpretation more in general) thus can be seen to reside in the temporal order of updating with the successive conjuncts. Conversely, the dynamic notion of conjunction (composition) is seen to be based on an underlying (Boolean) notion of intersection.

Our notions of content and update are not merely derived notions, for

Observation 11 (First Order Compositionality)

- both the contents of and the dynamic update with a first order formula ϕ can be defined independently and compositionally

The definitions are given in (Dekker, 2000). As a matter of fact, it appears to be immaterial whether one adopts a classical or an update notion of meaning as the basic one if one sets out to deal with intersentential anaphoric relationships

3.3. Compositional Support and Coherence

Like we said in the introduction to this section, a speaker is assumed to use indefinites (and other terms, for that matter) with referential intentions. When we turn to the support for first order utterances, these intentions have to be dealt with explicitly.

Indefinite terms (like definite ones) are assumed to be supported by specific subjects in the speaker's state of information. These states of information which an agent a has about sequences of individuals are modeled by sets of worlds and sequences of individuals, viz., the worlds w which a thinks might be the actual one, with the sequences of individuals e as the individuals which she has information about (her subjects). A speaker's information state, thus, can also be modeled as a Heimian satisfaction set.

In order to indicate that a speaker has a certain subject in mind when uttering an indefinite or pronoun, we use links l which relate the terms she utters to the subjects of her information state. Given that the (uttered) terms are linearly ordered, these links can be specified as sequences of subjects of the speaker. Thus, e.g., a link ij for an utterance of a formula ϕ indicates that the last term in ϕ is supposed to be supported by the i-th subject of the speaker, and the one but last term by her j-th subject.

First order support can now be defined as follows:

Definition 8 (First Order Support)

- $\sigma \models_{\mathcal{M},g,l} \phi$ iff $\sigma \subseteq [l][\![\phi]\!]_{\mathcal{M},g}$

In this definition, $[l]\tau$ translates the information $\tau = [\![\phi]\!]_{\mathcal{M},g}$ has about $n(\phi)$ subjects into information about the corresponding subjects of σ (given by l), and that information is supposed to be supported by σ's subjects. (See (Dekker, 2000) for more discussion.)

Under the present definition, support for a dynamic conjunction corresponds to its dynamic satisfaction, for:

Observation 12 (First Order Conjunction Support)

- $\sigma \models_{\mathcal{M},g,l} \phi \wedge \psi$ iff $\sigma \models_{\mathcal{M},g,l} \psi$ and $\sigma \models_{\mathcal{M},g,l-n(\psi)} \phi$

The linking functions l can be seen to mediate between satisfying sequences of individuals and supporting subjects. Support for two anaphorically related terms actually consists in support for the two terms by one and the same subject so that

Observation 13 (Anaphoric Support)

- $\sigma \models_{\mathcal{M},g,l} \exists x\phi \wedge F\mathrm{p}_1$ iff $\sigma \models_{\mathcal{M},g,l} \exists x(\phi \wedge Fx)$

Like the notions of content and update, that of support can be stated independently:

Observation 14 (Compositional Support)

- the support for a first order formula ϕ can be defined independently and compositionally

(The definition is spelled out in (Dekker, 2000).) Actually, it turns out to be immaterial whether one adopts a support or another (satisfaction, update) notion of meaning as basic.

Now that we have defined (related) notions of first order update and support, we may turn back to the issue of safe information exchange, this time at the first order level. Its characterization is somewhat more involved:

Observation 15 (Supported First Order Updates)

- if $\sigma \models_{\mathcal{M},g,l} \phi$, then $(\sigma \cap [m]\tau) \subseteq [l'][\![\phi]\!]_{\mathcal{M},g}(\tau)$

provided that $l' = l \cup (m \circ -n(\phi))$ be a function

There is no room, here, to discuss the details of the side conditions, but, basically, it amounts to this. An update of τ with an utterance of ϕ is safe, if the utterance is supported by σ under a link l, and if pronouns unresolved in ϕ are justly matched with subjects in σ. Notice that if ϕ itself is resolved, that is, if ϕ contains no unresolved pronouns, the situation is entirely similar to that of the propositional setting. If ϕ is not resolved however, then the hearer should, of course, take care in resolving pronouns in the right way. We, again, refer to (Dekker, 2000) for further discussion.

3.4. Support for Dynamic Implications

In section 2.4 we have seen that the support for an implication consists in more than the simple truth or satisfaction of a material implication, even though it is eventually based on a material satisfaction analysis. Thus one argument against the material implication semantics of conditionals was made harmless. At the first order level, one more argument against this analysis is countered, as our notion of support also solves what has been known as "Peirce' Puzzle" (Read, 1992).

The following two formulas are equivalent in ordinary predicate logic:

(5) $\exists x(\phi(x) \leftarrow \psi(x))$
(6) $\exists x\phi(x) \leftarrow \forall x\psi(x)$

Peirce considered the following sentence:

(7) There is some married woman who will commit suicide in case her husband fails in business.

Although (7) is of the form (5), it seems to express a much stronger statement than (8), which is of the, deemed equivalent, form (6):

(8) Some married woman will commit suicide if all married men fail in business.

Peirce therefore proposes an alternative analysis, as to which (7) states that there is some married woman who under all possible courses of events would commit suicide if her husband would fail, again, with a stronger interpretation of the embedded conditional.

However, upon a material implication analysis of conditionals, the support (not satisfaction-) conditions of (7) are the same as those Peirce argues for. For (7), under an analysis as in (5), to be supported, the speaker must have a woman in mind such that upon all courses events which the speaker conceives possible, that woman commits suicide in case her husband fails. That is, again under Gricean assumptions, (7) requires a speaker to acknowledge a dependence between failure and suicide, relative to a woman which the speaker has in mind. (Likewise, (8) also expresses a dependence, but a different one, and not relative to some specific woman.)

4. Dynamics of Dialogue

4.1. Blocking Issues

Under the pragmatic perspective adopted in this paper, it is no mystery why indefinites and pronouns interact in the dynamic way they do. Like definite noun phrases, indefinites noun phrases are used with referential intentions, and anaphoric pronouns simply pick up the referents intended to be associated with their antecedents. This has been characterized using sequences of individuals in a Tarskian fashion. The dynamics of conjunction has been seen to reside in the (assumed) linear construction of discourse. Basically, conjunction is intersection, but dynamic conjunction in addition acknowledges the order of terms (the order of referential intentions) in a discourse. These principles are independently motivated on pragmatic grounds.

Thinking of it, it is not so much the dynamics of indefinite reference and anaphoric co-reference that is conceptually puzzling, but the lack of it when indefinites figure in certain constructions: under a negation, in the antecedent of conditionals, in the restriction of quantifiers, and also in interrogatives and imperatives. If, as we think, anaphoric potential derives from referential intentions, then why do these referential intentions vanish in these negative (and other) contexts?[2]

In this section we attribute the blocking effects of the mentioned constructions to their typical role in discourse and dialogue. As we will see in the next section, a proper acknowledgment of the typical role of these constructions in discourse and dialogue also gives us a natural handle on the type of dependencies which indefinites in these constructions do give rise to.

4.2. Negation as a Role Switcher

We think the blocking effects of negations and other constructions can be understood well when we take into account their typical role in actual dialogues and the thematic structure of such dialogues. A negation *Not S* may serve to answer the issue—raised explicitly or implicitly—whether *S* is true. For instance, consider an utterance of (9):

(9) Farly doesn't run a sushi bar.

Typically, such an utterance does not serve to state of Farly and of some sushi bar that the first doesn't run the last. It is much more likely that it states—possibly in answer to the question whether Farly runs a sushi bar—that he doesn't, that is, that there is no such bar which Farly runs.[3] Generally, then, a speaker need not have a particular sushi bar in mind when uttering (9), and the reason may be that, intuitively, the existence of such a sushi bar is not part of what the speaker claims to have evidence for. Rather, the existence of such a bar appears to be part of the issue which the speaker addresses—negatively in example (9)—, or even part of what the hearer might have claimed just before. So actually, when somebody utters (9), she is normally not coming up with a sushi bar herself, but she is claiming to have evidence against the existence of such a bar, were anybody else thinking of the possibility of there being one, or even of thinking of claiming there actually to be one.

As a matter of fact, this intuition is already implicitly spelled out in our definition of negation support. For it turns out that the first observation in (6) also holds for our first order system:

Observation 16 (First Order Role Switch)

- $\sigma \models \neg\phi$ iff $[\![\phi]\!](\sigma) = \bot$[4]

State σ supports $\neg\phi$ iff the update with ϕ is absurd, that is, iff σ has evidence against ϕ. Notice that the support for $\neg\phi$ can be thus, spelled out in terms of an update with ϕ, and that updates with indefinites do not presuppose referential intentions with the updater.[5]

4.3. Implication as a Double Role Switcher

The conception of negation as a role switching device has a further pay off when we consider the pragmatics of conditionals $\phi \rightarrow \psi$, which are defined in terms of negation (and conjunction). For instance, the evidence which a speaker may bring to bear upon her assertion of a conditional sentence can be seen to consist in her evidence for the consequent of the conditional, were she to accept anybody else's evidence for the antecedent.

Also this observation is implicitly accounted for, as, evidently, the second observation in (6) holds as well in our first order system:

[2] Surely this 'generalization' requires some qualification. Indefinite noun phrases can be used 'specifically' in all of the mentioned contexts—under a negation, in the restriction or scope of adnominal and adverbial quantifiers, etc. However, we think that the majority of indefinites in these contexts is not 'specific' in this sense.

[3] One has to be careful with these types of sentences, because alternative interpretations are easily made available by emphasizing, e.g., *Farly*, or *run*. We here assume the utterance to carry what may be called a 'neutral' intonation.

[4] We here assume ϕ to be resolved.

[5] The indicated role switch is of course reminiscent of the one adopted in systems of game-theoretical semantics (*GTS*, cf., e.g., (Hintikka and Sandu, 1997)). In *GTS*, the truth of ϕ is defined in terms of the existence of a winning strategy for a 'verifier'. A verifier is supposed to come up with evidence for ϕ and be able to supply witnesses for (indefinite) terms in ϕ. However, when it comes to a negation $\neg\phi$, the verifier gets the role of the 'falsifier' of ϕ, who has to refute any attempt to verify ϕ by somebody else.

Observation 17 (First Order Double Role Switch)

- $\sigma \models (\phi \rightarrow \psi)$ iff $\exists l$: $[\![\phi]\!](\sigma) \models_l \psi$[6]

Not only does this provide motivation for the often attested existential closure over the indefinites in the antecedent of a conditional, but it also suggests the speaker's evidence for the consequent clause to be functionally dependent on the possible witnesses for these indefinites. As we will see below, the functional type of support which the speaker can be required to have for indefinites in the consequent clause can be cashed out by subsequent pronouns, if these are also read functionally.

4.4. Background and Focus in Discourse

In the preceding discussion the typical impact of negations (and implications) has been spelled out in terms of the different roles of the speaker and a hearer. In *GTS*, these roles have been qualified as that of an (initial) verifier and that of an (initial) verifier, but we think the pragmatic division of labour at issue is more general than that.

Coherent discourses and dialogues generally consist of assertions which have an (explicit or implicit) 'background' or 'topic' part, and an (explicit) 'focus'.[7] Typically—that is, if context or intonation have no interfering effects—one could say that e.g., the contents of negated sentences, the antecedents of implications, and the restrictions on quantifiers constitute a background or topic, which the speaker is not automatically supposed to support, but which she is supposed to react upon. It is the focus part of her utterance which she can be required to have support for, possibly in functional dependence on such a background.

Given this it is no mystery that, by default, indefinites in the background part of an assertion do not introduce possible referents for pronouns used in subsequent utterances. Since the speaker need not be required to support that part of her utterance, these indefinites fall beyond her 'pragmatic jurisdiction' so to speak, and they are not assumed to be used with referential intentions. Indefinites in focus, however, do require speaker's support, and generally are associated with referential intentions. However, since the focus may be functionally dependent on a background, the referential intentions associated with indefinites in focus may be functional, too.

5. Functional Dependencies

In the preceding section we already indicated that support for, and satisfaction of, the consequent of an implication can be functionally dependent on that of its antecedent. However, so far, the possible witnesses of indefinites in the consequent, or, rather, the possible witness-*functions*, did not appear in the satisfying sequences or supporting states themselves. In this section we show that a more principled account of the dependencies is not only possible, but also desirable. We here restrict ourselves to stating the relevant satisfaction conditions. Corresponding notions of update and support can be obtained by suitable generalizations.

5.1. Transparent Universal Quantification

Consider the following well-known example:

(10) Harvey courts a girl at every convention. She usually comes to the banquet with him. (after Karttunen)

Surely this sentence may serve to state something about a particular girl which Harvey courts at every convention, but—knowing Harvey—it is probably not about one particular girl. Thus, (10) may serve to state that, at every convention, there is a girl Harvey courts, and which he takes to the banquet with him. Which girl that is is of course functionally dependent on which convention we consider, and this is where functional witnesses come in.

An utterance of the first sentence of (10) can be taken to involve a reference to possible functions g, which associate girls which Harvey courts with the conventions he visits. Therefore, the utterance of the second sentence can be taken to refer back to these and to state that for most c, if c is a convention which Harvey visits, then $g(c)$ accompanies Harvey to the banquet of c.

Such readings can be derived compositionally by combining the techniques from, e.g., (Jacobson, 1999) with the account of anaphoric relationships sketched in this paper. Consider the following notion of universal quantification:

Definition 9 (Transparent Universal Quantification)

- $wfe \models_g \forall x\phi$ iff $\forall d \in D$: $wf(d)e \models_{g[x/d]} \phi$ (with $f : D \rightarrow D^{n(\phi)}$)

This definition of universal quantification is transparent as it it doesn't invoke any existential closure over the indefinites in ϕ, their witnesses being given by the function f in the satisfying sequence, relative to the possible values of x. Upon this definition (and assuming an extension of our language with function variables), we can state the following equivalence:

Observation 18 (Dynamic Skolem Quantifiers)

- $\forall x \exists y \phi(x, y) \Leftrightarrow \exists f \forall y \phi(x, f(x))$

This Skolem equivalence is special, since it is dynamic: the witness function f is accessible for subsequent pronouns. For example (10) this means that the pronoun "she" can be associated with a suitable antecedent.

5.2. Transparent Implication

As has already been indicated, conditional sentences also license functional anaphoric dependencies. Consider:

(11) If a book is printed with Kluwer it has an index. It can always be found at the end. (after Heim)

Support for an utterance of the first sentence of (11) may consist of a witness function f, assigning indices to books printed with Kluwer. If the speaker has such a function in mind, then she may refer back to it with a pronoun when she subsequently utters the second sentence. The second

[6] The whole implication is assumed to be resolved.

[7] Cf., e.g., (Jackendoff, 1972; Karttunen and Peters, 1979; von Stechow, 1991; Rooth, 1992, Ch. 6) for a number of formally quite different analyses of this distinction, which we, however, think are really close in spirit to the one we have in mind. Notice that, when we use the term 'focus', we do not mean 'contrastive focus' here.

utterance then is assumed to be about books printed with Kluwer, too, and expresses that, always, if b is a book printed with Kluwer, then $f(b)$ can be found at the end of b.

The satisfaction of implications can be adjusted in the following principled, and pragmatically motivated way:

Definition 10 (Transparent Implication Satisfaction)

- $wfe \models (\phi \rightarrow \psi)$ iff $\forall c \in D^{n(\phi)}$: if $wce \models \phi$ then $wf(c)ce \models \psi$ (with $f : D^{n(\phi)} \rightarrow D^{n(\psi)}$)

Also with this definition, we escape existential closure over indefinites in the scope (consequent) of the implication. The indefinites are supposed to be satisfied by the values of the satisfying function f, relative to the possible values of the indefinites c in the antecedent.

That this notion of implication is really transparent can be seen from the following equivalence:

Observation 19 (Dynamics Skolem Implication)

- $(\exists x\phi(x) \rightarrow \exists y\psi(y)) \Leftrightarrow \exists f(\exists x\phi(x) \rightarrow \psi(f(\mathtt{p}_1)))$

Again, the witnesses supporting indefinites in the consequent are available for subsequent anaphoric pronouns, as long as these can be conceived to be functionally dependent upon possible witnesses for indefinites in the antecedent.

The interpretation of implications in our framework is a strong one (as it is in most systems of dynamic semantics) in the sense that it amounts to universal quantification over the possible value of indefinites in the antecedent clause. A sophisticated use of the witness functions f, however, allows us to generate weak and asymmetric readings as well, both in a transparent fashion.

5.3. Transparent Beliefs

Techniques similar to the ones discussed above can be used to approach the interpretation of indefinites in modal and belief contexts. Consider two typical examples of so-called modal subordination:

(12) Mary thinks there is a burglar in the house. She thinks he came in through the chimney.

(13) A wolf might come in. He would eat you first.

When asserting (12) the speaker can be taken to refer to what constitutes Mary's representation of possible witnesses of a possible burglar in her belief state; similarly, the witness for a wolf can be seen to be dependent on the possibilities in which a wolf comes in. In either case, the witness is available as a referent for a subsequent pronoun, if that pronoun can be interpreted as functionally dependent upon the same parameters, viz., Mary's belief state, or the possibility that a wolf comes in.

We here refrain from spelling out the exact details of a suitable definition of the satisfaction of these modal statements, as it involves some technical complications. We refer to (Dekker and van Rooy, 1998) for further discussion.

5.4. Specific Indefinites

A last issue which we want to touch upon here is the phenomenon of specific indefinites, cf., e.g., (Abusch, 1994; Reinhart, 1997; Kratzer, 1998). As we already said above, indefinites sometimes do escape from contexts which normally constitute a background, and which systematically forbid genuine quantifiers to be raised from there. Here are a couple of representative examples:

(14) If a certain linguist shows up, we are supposed to be particularly polite, but do you remember who? (Reinhart)

(15) Max did not consider the possibility that some politician is corrupt. (Kratzer)

(16) If three relatives of mine die, I will inherit a house. (Ruys)

(17) If each student improves into two subjects, then no-one will fail the exam. (Schlenker)

We will not discuss, here, how such indefinites exactly manage to escape these contexts. (Apparently, it has to do with information structure.) Rather, we are concerned with the pragmatic or semantic impact of the readings obtained.

As Kratzer observes, the specific readings of the above examples are quite a bit pragmatically infected, but we think they are infected more than has generally been acknowledged. For both upon a wide scope indefinite interpretation, and upon a choice function analysis, the above sentences seem to suffer from the same problem as the one addressed by Peirce. Consider, for instance, example (14). Upon both analyses the example can be seen to be satisfied as long as we can pick up any linguist who doesn't show up. Intuitively, this is not correct. Upon a specific interpretation, an assertion of (14) ought to be made with a particular linguist in mind, relative to whom our expected politeness is functionally dependent upon the possibility of her showing up. As the reader may remember from the discussion in section 3.4, no such problem will arise within our pragmatically oriented framework. Our notion of support requires the speaker to dispose of precisely that kind of information.

Conclusion

In this paper we have studied meaning and interpretation from a pragmatic point of view. We have sketched a systematic and coherent account of the content of, update with, and support for sentences of a first order logic. Our general perspective on information exchange has allowed us to deal with intersentential anaphoric binding, from all three perspectives.

We have shown that our notions of content, update and support each can be defined independently, and in terms of one another. We have also shown under which conditions first order information exchange is safe, crucially relying upon updates with supported assertions. We have argued that a pragmatic notion of support indeed undermines some of the objections which has been leveled against the semantic account of conditionals as material implications. The pragmatic outlook upon the use of indefinites has finally inspired a more principled analysis of the support of indefinites in background focus structures, one which enabled a straightforward extension of our empirical scope.

With regard to the last issue more has to be said though. In order for pronouns to be interpreted functionally, the background of the antecedent indefinites has to be recovered, and we have said nothing about how this can be achieved. The theses (Geurts, 1995; Frank, 1997; van

Rooy, 1997; Stone, 1998) provide some recent, dynamic, analyses of this type of reconstruction.

6. References

Dorit Abusch. 1994. The scope of indefinites. *Natural Language Semantics*, 2:83–135.

Paul Dekker and Robert van Rooy. 1998. Intentional identity and information exchange. In Jerry Seligman and Patrick Blackburn, editors, *Proceedings of ITALLC'98*, Chiayi, Taiwan. National Chung Cheng University.

Paul Dekker. 2000. Meaning and use of indefinite expressions. manuscript, University of Amsterdam, submitted for publication in the *Journal of Logic, Language and Computation*.

Anette Frank. 1997. *Context Dependence in Modal Constructions*. Ph.D. thesis, Universität Stuttgart, Stuttgart.

Bart Geurts. 1995. *Presupposing*. Ph.D. thesis, Universität Stuttgart, Stuttgart.

H.P. Grice. 1975. Logic and conversation. In P. Cole and J. Morgan, editors, *Syntax and Semantics, Vol III: Speech Acts*. Academic Press, New York.

H.P. Grice. 1978. Further notes on logic and conversation. In P. Cole, editor, *Syntax and Semantics, Vol IX: Radical Pragmatics*. Academic Press, New York.

Jeroen Groenendijk and Martin Stokhof. 1991. Dynamic predicate logic. *Linguistics and Philosophy*, 14(1):39–100.

Irene Heim. 1982. *The Semantics of Definite and Indefinite Noun Phrases*. Ph.D. thesis, University of Massachusetts, Amherst. published in 1988 by Garland, New York.

Jaakko Hintikka and Gabriel Sandu. 1997. Game-theoretical semantics. In Johan Benthem and Alice ter Meulen, editors, *Handbook of Logic and Language*, pages 361–410. Elsevier, Dordrecht.

Ray Jackendoff. 1972. *Semantic Interpretation in Generative Grammar*. MIT Press, Cambridge, Massachusetts.

Pauline Jacobson. 1999. Towards a variable-free semantics. *Linguistics and Philosophy*, 22:117–84.

Hans Kamp. 1981. A theory of truth and semantic representation. In Jeroen Groenendijk, Theo Janssen, and Martin Stokhof, editors, *Formal Methods in the Study of Language*. Mathematical Centre, Amsterdam. Reprinted in J. Groenendijk, T. Janssen, and M. Stokhof (eds.), *Truth, Interpretation and Information*. Foris, Dordrecht, 1984.

Lauri Karttunen and Stanley Peters. 1979. Conventional implicature. In Choon-Kyu Oh and David A. Dinneen, editors, *Syntax and Semantics 11 – Presupposition*, pages 1–56. Academic Press, New York.

Angelika Kratzer. 1998. Scope or pseudoscope? are there wide-scope indefinites? In Susan Rothstein, editor, *Events in Grammar*, pages 163–196. Kluwer, Dordrecht.

Stephen Read. 1992. Conditionals are not truth-functional: an argument from Peirce. *Analysis*, 52:5–12.

Tanya Reinhart. 1997. Quantifier scope: How labor is divided between qr and choice functions. *Linguistics and Philosophy*, 20:335–397.

Mats Rooth. 1992. A theory of focus interpretation. *Natural Language Semantics*, 1(1):75–116.

Robert Stalnaker. 1978. Assertion. In Peter Cole, editor, *Syntax and Semantics 9 – Pragmatics*, pages 315–332. Academic Press, New York.

Robert Stalnaker. 1998. On the representation of context. *Journal of Logic, Language and Information*, 7:3–19.

Matthew Stone. 1998. *Modality in Dialogue: Planning, Pragmatics and Computation*. Ph.D. thesis, IMS, University of Pennsylvania.

Robert van Rooy. 1997. *Attitudes and Changing Contexts*. Ph.D. thesis, IMS, Stuttgart.

Frank Veltman. 1996. Defaults in update semantics. *Journal of Philosophical Logic*, 25:221–261.

Arnim von Stechow. 1991. Focussing and background operators. In Werner Abraham, editor, *Discourse Particles*. John Benjamins, Amsterdam.