

Introductory notes on dynamic semantics*

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1 Introduction

‘Dynamic semantics’ gets used in various, not always compatible ways. On perhaps its most inclusive use, it applies to a range of semantic systems embracing a thesis we might call:

DISCOURSE PRIMACY. It is fundamentally entirely discourses that have truth-conditions (or more broadly, informational content). Individual sentences have truth-conditions in at best a derivative sense, insofar as they have some potential to impact the truth-conditions of a discourse.

This thesis breaks with a long semantic tradition—going back at least to Frege, and running through Montague, Davidson, Lewis and beyond—which revolves around the individual sentence, articulating the meaning of all linguistic expressions in terms of their contributions to the truth-conditions of the sentences in which they occur. By shifting the locus of truth-conditions in systematic theorizing to the discourse, DISCOURSE PRIMACY shifts the center of gravity in semantics. It recommends that we articulate the meaning of a sentence in terms of its potential to contribute to the truth-conditions, or informational content, of discourses in which it can occur. This idea was first developed by [Kamp \[1981\]](#) and (independently) by [Heim \[1982\]](#), in works that formed the starting point for subsequent theorizing in the dynamic tradition.

Exactly how to model a discourse is itself a theoretical question on which theorists working in the spirit of DISCOURSE PRIMACY may differ. But a common theme in the dynamic tradition is to model a discourse via aspects of the mental states of the agents in conversation. For instance, [Kamp \[1981\]](#) models a discourse via a certain kind of a structured representation (a *discourse representation structure*, or DRS), which (he postulates) is an abstract model of the kind of mental representation involved in linguistic processing and understanding. On his picture, it is fundamentally these structures that have truth-conditions. And in [Heim \[1982\]](#), the fundamental bearers of truth-conditions are the coordinated states of presupposition of the participants of the conversation. It is the content of these states that the meanings of sentences operate upon.

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Once we take the dynamic turn and accept DISCOURSE PRIMACY, we come to a fork in the road concerning how to articulate the meanings of sentences. One path accepts a thesis we can call DYNAMIC REPRESENTATION; the other, a thesis we can call DYNAMIC INTERPRETATION.

DYNAMIC REPRESENTATION. Sentences encode instructions for updating a certain kind of representation, and it is this representation, not sentences or other linguistic expressions, that is the primary object of compositional semantic interpretation.

DYNAMIC INTERPRETATION. The compositional semantic value of a sentence is an operation on a body of information.

Roughly, [Kamp \[1981\]](#) takes the first path, and [Heim \[1982\]](#) the second—though with important qualifications, to be described below. As noted, Kamp’s account centrally involves a certain intermediate layer of representation, a DRS. He supplies a systematic construction procedure for mapping a sentence or sequence of sentences to a DRS, and a systematic procedure for interpreting DRSs. The resulting system is not locally compositional in the usual sense, for it does not directly associate linguistic expressions with interpretations. For relevant discussion see [Groenendijk and Stokhof \[1991b\]](#), [Kamp and Reyle \[1993\]](#), [Muskens \[1996\]](#), [Muskens et al. \[2011\]](#), [van Eijck and Kamp \[2011\]](#). We don’t directly discuss DYNAMIC REPRESENTATION here. It is better treated against the larger context of Discourse Representation Theory (DRT), the family of approaches to semantic theorizing that followed in the footsteps of [Kamp \[1981\]](#). Many excellent introductions to DRT are available. See for instance [Kamp and Reyle \[1993\]](#), [Geurts and Beaver \[2007\]](#), [van Eijck and Kamp \[2011\]](#).

On a more restrictive use of ‘dynamic semantics’, it applies just to those accounts that embrace DYNAMIC INTERPRETATION. This restricted use is the one in play henceforth. These notes are about the import and upshot of DYNAMIC INTERPRETATION—for short, DYNAMIC. Our focus is on the idea that the compositional semantic value of a sentence is the sort of thing that updates a body of information (in some sense of ‘body of information’ to be formalized). We will spend most of our time reviewing ideas in the dynamic semantics of [Heim \[1982\]](#).

To get a handle on DYNAMIC, contrast it with its much more traditional cousin, STATIC:

STATIC. The compositional semantic value of a sentence is a truth-condition—a function from possible worlds to truth-values, or more generally, a function from indices (points in a model) to truth-values.

We can think of STATIC and DYNAMIC as alternative empirical hypotheses about what kind of thing the semantic value of a sentence is.

These two hypothesis occur at a very high level of abstraction. Bringing data to bear on the choice between them—and understanding what, substantively, is at issue in the choice between the two—is a subtle matter of continuing

investigation. This introduction will attempt to give an initial sense of the discussion in the literature on these questions.

We have two aims. First, we should like a basic sense of how, in principle, DYNAMIC could be incorporated into a theory which performs the sort of explanatory work traditionally expected from accounts assuming STATIC. This we tackle in §2. Second, we should like a sense of some of the specific linguistic phenomena that have been taken to recommend DYNAMIC over STATIC, and a sense of the dynamic systems devised for these phenomena. This is provided in §3-§5, which discuss anaphora, presupposition projection, and epistemic modals, respectively.

2 Dynamic semantic values

How, in principle, might dynamic semantic values be put to work in explaining the kind of phenomena we have always expected our semantic values to cover? That prompts the prior question: what is it we expect semantic values to explain? Theorists of course differ in exactly what work they expect this notion to perform, but let us focus on a few of the most usual supposed explananda.¹

First there is the *productivity* of language use: the empirical fact that competent speakers can understand and produce complex expressions that they have never before encountered. This is a typical motivation—perhaps the leading motivation—for embracing compositionality. The assumption of compositionality is a point of common ground between STATIC and DYNAMIC: typical defenders of each assume compositionality partly with an eye towards explaining the productivity of language use.

More illuminating differences between the sort of theory one gets out of DYNAMIC as opposed to STATIC emerge when we look at other explanatory demands typically placed on semantic values. Besides helping to explain productivity by being compositional, the semantic values of sentences are normally expected to do the following explanatory work:

- (i) The semantic values of sentences should play a central role in explaining how speakers *communicate*, and in particular, *transfer information*, by using the sentence.
- (ii) The semantic values of sentences should play a central role in explaining which sentences follow from which, and which sentences are incompatible with which.

These tasks will be approached in importantly different ways, depending on whether one embraces STATIC or DYNAMIC.

¹For more discussion of the explananda of semantics, see [Yalcin \[2013\]](#).

2.1 Communication

Take first (i). How, assuming *STATIC*, is meaning leveraged to communicate information? A familiar and traditional story is the following. By *STATIC*, sentences have truth-conditions. We take it these truth-conditions are, or determine, the item of informational content normally communicated in context by an assertion of the sentence. (Or anyway, a central component of that informational content). Building on Grice and Stalnaker, we take it communication takes place against a background of mutually shared presuppositions—a *common ground*—and that the characteristic pragmatic impact of an assertion is to add the informational content determined by the sentence uttered to the common ground of the conversation. Thus an assertion normally serves to update the common ground, as a function of the content of the sentence asserted in context. It is a feature of the pragmatics of assertion that the common ground is normally to be updated in this way. (See [Stalnaker \[1978\]](#).)

This story assumes *STATIC*, but note that according to it, an asserted sentence is nevertheless associated with a rule for updating the common ground—with a CCP. The idea that a sentence has a CCP is thus not proprietary to *DYNAMIC*. How then does *DYNAMIC* differ from *STATIC* in respect of (i)? The core difference is that on a dynamic view, the CCP of a complex sentence is determined *compositionally* from the semantic values of its parts. Ancillary pragmatic assumptions are not required. And correspondingly, the compositional contribution of an *embedded* sentence—the semantic ingredient the sentence contributes to the larger linguistic expressions in which it occurs—is itself taken to be a CCP. Thus the CCP of a conjunction, for instance, is a literally a function of the context change potentials of its parts. That is quite different than the static version of the story, where the context change potential of a sentence is only determined with the help of pragmatics, and applies only in connection with *unembedded*, asserted sentences.

When it comes to conversational update, the dynamic view rolls into the semantics what, on a static view, would be parceled to pragmatics. The compositional contribution of a sentence is just identified with an instruction for updating the informational context, or common ground, of a conversation.

2.2 Consequence

Turn next to (ii), the demand that the semantic values of sentences play a central role in explaining which sentences follow from, or are consequences of, which. On the typical static view, the story is straightforward: sentences have truth-conditions, and consequence is a matter of truth-preservation. An argument is valid, we can say, just in case if the premises are true, the conclusion must also be true.

Since a dynamic semantics does not generally associate sentences with truth-conditions, it cannot tell the same story. (It might try to tell the same story indirectly, by associating all declarative sentences with context-change potentials that determine, in some systematic way, truth-conditions. But this would

be a severe constraint, and one precluding many of the motivating applications for dynamic semantics in the literature.) To cover the entailments evidenced to us by the productions of competent speakers, and so perform the explanatory work required by (ii), dynamic semantic systems are typically equipped with alternative formalizations of consequence.

Central to most of these formalizations is the notion of a *fixed point* of a sentence. The fixed points of a sentence will be those states of information which, when operated on by the CCP of the sentence, return just that state of information back. Intuitively, the fixed points of a sentence will be those information states that already incorporate the informational update associated with the sentence. The fixed points of a sentence ϕ are said to *support* ϕ (or *accept* ϕ , or *incorporate* ϕ). If the CCP of ϕ is $[\phi]$, then

Def. Information state i **supports** ϕ iff $i[\phi] = i$.²

A common idea in many dynamic semantic systems is that the CCP of a propositionally factual declarative sentence will map information states into fixed points of the sentence. Thus, e.g., ‘It’s raining’ might map an information state i into a new information state i' incorporating the information that it is raining; since i' incorporates that information, updating i' with ‘It’s raining’ just returns i' back. (This would give some explanation why we generally don’t find it informative to say things twice: once our conversation is fixed point of a sentence, uttering the sentence will not—at least as a matter of the semantics of the sentence—alter the information that is common ground.)

Once we have the idea of a fixed point of a sentence, we can define consequence in terms of it. Here there are various options, of which I will just mention two of the most discussed (for additional discussion and further options, see for instance van Benthem [1996], Veltman [1996], Beaver [2001], Muskens et al. [2011] and references cited therein). First, consequence may be defined as follows:³

$\phi_1, \dots, \phi_n \models_1 \psi$, just in case every state of information which supports each of ϕ_1, \dots, ϕ_n also supports ψ .

On this analysis, consequence is the sort of thing that preserves support, rather than truth. The idea is that once a state of information is updated with the premises of a valid argument, it already incorporates the update associated with the conclusion. A second dynamic definition of consequence is:⁴

$\phi_1, \dots, \phi_n \models_2 \psi$, just in case every state of information which is a fixed point of $[\phi_1] \dots [\phi_n]$ also supports ψ .⁵

²Note the postfix notation, with arguments written to the left of their functions.

³See for instance ‘validity₃’ in Veltman [1996]; ‘reasonable inference’ in Stalnaker [1975]; ‘informational consequence’ in Yalcin [2007].

⁴See for instance the notion of entailment defined in Groenendijk and Stokhof [1991a]; ‘validity₂’ in Veltman [1996]; entailment as defined in the update logic of Beaver [2001]; and many other places.

⁵By $[\phi_1] \dots [\phi_n]$, we have in mind a CCP which is the composition of the component CCPs, one equivalent to the update of those sentences in the given order.

Here again consequence is the sort of thing that preserves support, but only for the premises taken together in the given order. Because changing the order of the premises could, in principle, invalidate an argument, this notion is more restrictive.

Which notion of consequence it makes sense to assume will depend on the particulars of the dynamic semantics one is considering. For example, on some systems (examples to appear below), a set of sentences will only have a well-defined update given a particular order for the sentences. In these contexts, it can make sense to adopt \models_2 rather than \models_1 . For now, our aim has merely been to show how consequence can be defined in a dynamic setting, so that we can see how dynamic semantic values might in principle be brought to bear on entailment data.

(Note that the above definitions of consequence are not proprietary to dynamic semantics. As we noted above, a theorist who prefers to associate sentences with static semantic values may nevertheless avail herself of the idea that sentences have CCPs; and therefore she may avail herself of any notion defined in terms of the CCPs of sentences, including the above notions of consequence.)

As the dynamic semanticist can provide a notion of entailment, so too she can provide for a notion of truth, in order to track/predict the truth-value judgments of speakers. There are various ways to do this. A typical strategy, pursued for example by Heim [1982], is to define truth first for information states, and then derivatively for sentences relative to information states. Truth for information states will usually be some version of the idea that a true (false) information state is one where the information incorporated in the state is (in)compatible with the way things actually are. (The exact definition will depend, of course, on how information states are modeled.) Truth for sentences can then be given relative to information states, as a function of their CCP. For example, Heim lays down the following constraints:

A sentence ϕ is **true relative to** i if i is true and $i[\phi]$ is true.

A sentence ϕ is **false relative to** i if i is true and $i[\phi]$ is false.

True sentence keep true contexts true; false sentences turn them false.

These constraints only supply some sufficient conditions for truth/falsity of sentences relative to true states. What of truth relative to false states? One reason Heim focuses on true states is the following:

Suppose an utterance has just occurred, and been believed, of the sentence:

- (i) There will be a concert₁ tonight.

But in fact, there will not be. This utterance of (i) was false, and so is the [context] that it has produced. Now suppose the next utterance is (ii):

- (ii) It₁ will start at eight.

Is the utterance of (ii) true or false, and what facts matter for the decision? There is no straightforward answer to this question. About the utterance of (i), and about the utterance of the whole text (i) + (ii), we would say they are false. But for (ii), the question is somehow inappropriate. (219)

So it is not obvious we want truth for sentences defined relative to every context. Still, as Heim notes, we do have judgments to the effect that some sentences are true or false in abstraction from the particular conversational context they update. See §3.2 of Heim [1982] for further discussion. See also Stokke [2012] for discussion of other systems and relevant definitions.

Another possibility would be to define truth for sentences *simpliciter* by quantifying over true information states. For instance:

A sentence ϕ is **true** iff $i[\phi]$ is true for every true i .

A sentence ϕ is **false** iff $i[\phi]$ is false for every true i .

These definitions would potentially make for truth value gaps. Whether they would be adequate to intuition depends on the particulars of the dynamic semantics one is considering.

The idea that the data of semantics largely concerns the truth-conditions of sentences is sometimes treated as a platitude. But in a context in which we are debating the virtues of STATIC versus DYNAMIC, we must acknowledge that this is really a theory-laden and question-begging way to describe the matter. The dynamic approach offers a rival characterization of the data of semantics: the data are, at the most general, data about the potential of a sentence to update or change a conversation. It is fundamentally these kinds of facts that judgments about consequence, compatibility, and truth track. On this approach, intuitions about the truth-conditions of sentences derive from the character of their CCPs.⁶

The indirect relation between sentences and truth-conditions is what makes it the case that talk of sentences expressing propositions often lacks clear sense in a dynamic setting. Similarly for the traditional distinction between a sentence's informational content and its force. The reason, again, is that the chief locus of information on a dynamic picture is not the sentence, but rather the conversational states the participants in the discourse. Sentence meanings are not themselves items of informational content, but are rather tools for manipulating a shared body of information.

⁶Lewis has written that “Semantics with no treatment of truth-conditions is not semantics” ([Lewis, 1970, 18]). What he meant to underscore in saying this was that a semantics should associate expressions with *interpretations* as opposed to mere translations. It is worth emphasizing that in this respect, dynamic semantics and truth-conditional semantics are on the same side of the fence: they are each card-carrying members of the interpretive, model-theoretic tradition in semantics.

2.3 A sample semantics: negation and conjunction

The preceding gives an abstract idea of how DYNAMIC might in principle be worked into a theory which explains the sort of things we expect a compositional semantics to explain. But a real sense for the dynamic approach can only come through working with concrete examples. For illustrative purposes, then, let us consider an example of a toy dynamic semantics, one defined an ordinary artificial propositional language L containing just negation and conjunction. We will soon turn to more complicated systems.

Def. A **model** \mathcal{M} for L is a pair $\langle W, I \rangle$ where W is a set of possible worlds, and I is an **interpretation function** mapping the propositional letters of L to sets of worlds.

Def. A **context** in \mathcal{M} is any subset of $W_{\mathcal{M}}$.

Def. For any \mathcal{M} , an **update function** $\cdot[\cdot]$ (for \mathcal{M}) is a function from wffs of \mathcal{L} to functions from contexts (in \mathcal{M}) to contexts (in \mathcal{M}) defined as follows, where α is any propositional letter, ϕ and ψ are any wffs, and c is any context set in \mathcal{M} :

$$\begin{aligned} c[\alpha] &= c \cap \mathcal{I}(\alpha) \\ c[\neg\phi] &= c - c[\phi] \\ c[\phi \wedge \psi] &= c[\phi][\psi] \end{aligned}$$

This simple semantics illustrates the way in which the CCP of a complex sentence may be defined in terms of the CCPs of its constituent parts. It also incorporates the idea of representing the informational common ground of a conversation via the set of possible worlds presupposed to be open by the interlocutors—in Stalnaker’s jargon, a *context set* (Stalnaker [1970, 1975, 1978]). The worlds left open by a context set are those compatible what is being presupposed in conversation. Information growth is a matter of eliminating possibilities. Sentences characteristically act to knock worlds out of context sets, thereby growing the amount of information taken for granted in the conversation.

This toy dynamic semantics determines a conversation system with two abstract properties worth noting. By ‘conversation system’, we mean:

Def. A **conversation system** is a triple $\langle C, S, \cdot[\cdot] \rangle$ where C is a set of contexts, S is a set of sentences, and $\cdot[\cdot] : S \times C \rightarrow C$.

(A dynamic semantics determines a conversation system, but not necessarily vice-versa: the conversation systems level of description abstracts from intra-sentential compositional structure. For more discussion of this notion, see Roth-schild and Yalcin [2012].) The two notable properties are *eliminativity* and *distributivity*:

Def. A conversation system $\langle C, S, \cdot[\cdot] \rangle$ is **eliminative** just in case $c[\phi] \subseteq c$, for all $c \in C$, $\phi \in S$.

Def. A conversation system $\langle C, S, \cdot[\cdot] \rangle$ is **distributive** just in case $c[\phi] = \bigcup_{i \in c} \{i\}[\phi]$, for all $c \in C$, $\phi \in S$.

(Note that as defined, these properties only make sense when the elements of the set of contexts are taken to be sets.) Distributivity says that the output context of any update just as well might be arrived at by updating on singletons in the prior context and aggregating the results. Eliminativity entails that this aggregate set will always be some subset of the original context.

These two features entail that our toy update function acts much like a sieve. If we run a bucket of flour through a sieve, the output is a new, smaller quantity of flour from that bucket. Which particles the sieve lets through is entirely a matter of the individual particles and their sizes. If we had sieved half of the bucket first and then the second half, we still would have gotten the same output flour.

If your dynamic semantics is eliminative and distributive, it means that at a certain level of abstraction, it admits of static reformulation (van Benthem [1986]). By ‘static’, we mean the following:

Def. A conversation system $\langle C, S, \cdot[\cdot] \rangle$ is **van Benthem static** just in case for some set W , there exists some proposition map $\llbracket \cdot \rrbracket : S \rightarrow \mathcal{P}(W)$, such that $c[\phi] = c \cap \llbracket \phi \rrbracket$ for all $c \in C$, $\phi \in S$.

A van Benthem static system is one where any sentence can be mapped to a set of points (intuitively, propositional truth-conditions), and update is just a matter of intersecting that set with the input context (thereby adding that truth-conditional information to the common ground, in the style of Stalnaker [1978]). Van Benthem showed that van Benthem staticness coincides with the property of satisfying both *eliminativity* and *distributivity*:

Theorem (van Benthem). A conversation system is van Benthem static iff it is eliminative and distributive.

The van Benthem static systems are supposed to fit the stereotype of the kind of CCPs a proponent of a static semantics would favor. Phenomena seeming to call for a departure from van Benthem staticness are then sometimes thought to motivate a dynamic semantics for that phenomena over a more traditional, static semantics. This is simplistic, however, since theorists who favor statically formulated semantics will typically appeal to varieties of context-sensitivity that would induce conversation systems which fail to be van Benthem static. In other words, you can give a semantics and pragmatics where sentential semantic values are truth-conditions, but where van Benthem staticness is violated (see Rothschild and Yalcin [2012] for more discussion). So the connection between the van Benthem staticness of a language and the proper shape of its compositional semantics is quite indirect.

Still, the failure of the eliminativity or distributivity properties, relative to some given fragment of language, is one way of beginning to approach the question whether the work done by a given conversation system can be reformulated in a manner incorporating a more traditional, static conception of meaning. If a system is van Benthem static, that certainly tells us something interesting about the sort of conversational dynamics possible in the corresponding language.⁷

An extensive discussion of these matters occurs in [Rothschild and Yalcin \[2012\]](#), who generalize van Benthem’s result. They work with a more abstract concept of staticness, one that does not require contexts to be sets:

Def. A conversation system is **static** just in case it is isomorphic to some van Benthem static system.

Using this notion of “static”,⁸ they prove the following representation theorem:

Theorem (static representability). A conversation system is static just in case it is idempotent and commutative.

where:

Def. A conversation system $\langle C, S, \cdot[\cdot] \rangle$ is **idempotent** just in case $c[\phi] = c[\phi][\phi]$, for all $c \in C$, $\phi \in S$.

Def. A conversation system $\langle C, S, \cdot[\cdot] \rangle$ is **commutative** just in case $c[\phi][\psi] = c[\psi][\phi]$, for all $c \in C$, $\phi \in S$.

for any context c . This result assumes nothing about the structure of contexts. It gives us another abstract angle on one kind of ‘very static’ conversation system. Failures of idempotence or commutativity in the conversation system of a language might then be considered a step towards “dynamicness”, in one technical sense. It also aligns with the idea, common in the dynamic semantics literature, that “robustly dynamic” linguistic phenomena are cases that seem to require order-sensitivity, hence violations of commutativity.

Now that we have a rough sense of how dynamic semantic explanations might proceed in principle, we can ask what might make explanations in this style desirable. As competing hypotheses about a certain class of semantic values, we should favor DYNAMIC over STATIC only if doing so makes for an overall more explanatory theory. Let us see, then, some cases where DYNAMIC gets put to work. We will review just three broad areas—our main objective being only to get acquainted with some early and well-known dynamic semantic accounts, and to achieve a rough and initial sense of some of the terrain. The three areas

⁷Eliminativity and distributivity are also useful properties for classifying dynamic systems. For example, dynamic predicate logic ([Groenendijk and Stokhof \[1991b\]](#)) is distributive but not eliminative, whereas Veltman’s update semantics for epistemic modals is eliminative but not distributive. See [Groenendijk and Stokhof \[1991a\]](#).

⁸Note we are talking here about staticness as a property of conversation systems, and not as a property of compositional semantic theories.

are: (i) intersentential and donkey anaphora, (ii) the problem of presupposition projection, and (iii) the semantics of epistemic modals. We proceed in that order.

3 Intersentential and donkey anaphora in FCS

3.1 Indefinites and their discontents

We are familiar with the idea of using the apparatus of quantification to model certain kinds of anaphoric reference in natural language. In particular we are familiar with the idea of giving semantics for

- (1) A car drove by and it honked.

in a manner which treats the pronoun *it* as a variable bound by an existential quantifier introduced by the indefinite *a car*, so that we may associate the sentence with truth-conditions along the lines of:

- (2) $\exists x(x \text{ is a car} \wedge x \text{ drove by} \wedge x \text{ honked})$

What to say, however, when we break (1) into two sentences?

- (3) A car drove by. It honked.

Naively, it would seem desirable to semantically associate this brief discourse with the same truth-conditions as (1) (cf. Geach [1962]). Yet this would apparently require the scope of the indefinite in the first sentence to reach across the sentence boundary so as to bind *it* in the second sentence—not an option, given ordinary variable binding is a strictly intrasentential affair.

Should we instead understand the semantic relation between *a car* and *it* in (3) on the model of coreference? That would call for the availability of a non-quantificational, referential interpretation of indefinite noun phrases. But this idea quickly runs into difficulties. For instance, it raises the question why the discourse:

- (4) Bob doesn't have a car. # It's black.

is defective (cf. Karttunen [1976]). If the indefinite and the pronoun were understood on the model of coreference, we should hear (4) as saying that a specific car, which Bob doesn't have, was black. We don't hear it that way.

So two obvious ways to construe the semantic relation between the indefinite and the pronoun in (3) face clear obstacles. This puzzle has an intrasentential analogue in the phenomenon of donkey anaphora (Geach [1962]). Consider:

- (5) Every farmer who owns a donkey beats it.

It is obvious that the indefinite in this sentence is not a referring expression. But nor can we straightforwardly understand the anaphoric pronoun *it* as bound by the indefinite, for the pronoun is not within the indefinite’s scope.

Moreover, if we wished to render the truth-conditions of the natural reading of (5) in the language of predicate logic, we would reach for the following:

$$(6) \forall x \forall y [(farmer(x) \wedge donkey(y) \wedge owns(x, y)) \supset beats(x, y)]$$

Somehow, the deeply embedded indefinite in (5) appears to really take wide scope over the whole sentence—and moreover express universal, rather than existential, quantification. It is hard to understand how these truth-conditions could be achieved compositionally from (5).

It was in large part to address these and related puzzles about intersentential and donkey anaphora that [Kamp \[1981\]](#) and [Heim \[1982\]](#) each proposed their dynamic semantic systems. Indeed, the semantics of anaphora is arguably the leading historical motivation for going dynamic (with presupposition projection coming in at a close second). We will focus on the *file change semantics* (FCS) developed in [Heim \[1982\]](#), but we emphasize that the overlap between Heim’s and Kamp’s accounts is quite substantial.

3.2 File change semantics

In its treatment of anaphora, FCS weaves together a number of distinct innovations. First, it treats definite and indefinite noun phrases (*the cat, a cat*) as semantically akin to open sentences (*x is a cat*), and not as introducing any quantificational force of their own. Complex noun phrases are treated as semantically akin to conjunctions of open sentences. (Thus *a big cat* has a logical form tantamount to $(x \text{ is big} \wedge x \text{ is a cat})$.) Second, following [Lewis \[1975\]](#), FCS incorporates the idea of unselective quantification, allowing quantifiers to bind (not just one but) all variables free in their scope. Third, it employs a novel representation of the discourse context, one which can be seen as enriching the Stalnakerian context sets used in our toy semantics above. Fourth, FCS embraces DYNAMIC.

These assumptions work in tandem to treat the data. I will try to bring out their separate contributions, with particular attention to the last assumption.

3.2.1 Open sentences and unselective quantification

Heim’s first two innovations can be put to work immediately on the classic donkey sentence (5). Given that indefinite noun phrases contribute open sentences, we take the underlying logical form for (5) to be:⁹

⁹Heim does not explicitly recursively define the class of logical forms that she uses to model the fragment of English she is concerned with, but the following approximates her assumptions, and would be adequate to her purposes. Let L contain countable indexed variables x_i and arbitrarily many n -place predicates G^n for arbitrary n . Then the grammar of L is:

$$t ::= x_i, \phi ::= G^n(t_1, \dots, t_n) \mid (\phi\phi) \mid (\neg\phi) \mid (\phi \wedge \phi) \mid \forall(\phi, \phi)$$

(5) Every farmer who owns a donkey beats it.

$$\forall(x_1 \text{ is a farmer} \wedge x_1 \text{ owns } x_2 \wedge x_2 \text{ is a donkey, } x_1 \text{ beats } x_2)$$

Now the challenge is to compositionally associate something with the syntax of (5) with the truth-conditions expressed by (6). How does one quantificational determiner do the work of the two quantifiers we apparently need?

This challenge is met by appeal to second innovation, the idea of unselective quantification. Unlike the more familiar selective quantifiers, an unselective quantifier does not serve to bind specific free variables; rather, it binds any and all variables free in its scope. The Lewisian semantics for the unselective universal quantifier \forall is:

$$\forall\phi \text{ is true iff } \phi \text{ is true under every admissible assignment of values to all variables free in } \phi^{10}$$

Heim requires a generalized, dyadic version of this idea, where the quantifier combines with two clauses (a *restrictor clause* and a *nuclear scope*). She requires:

$$\forall(\alpha, \beta) \text{ is true iff } \beta \text{ is true under every admissible assignment of values to all variables free in } \beta \text{ which satisfies } \alpha$$

Or equivalently,

$$\forall(\alpha, \beta) \text{ is true iff } \alpha \supset \beta \text{ is true under every admissible assignment of values to all variables free in } \alpha \supset \beta$$

This delivers the truth-conditions (6) for (5), our desired outcome.

This solution requires just the first two innovations mentioned above (namely, a nonquantificational analysis of indefinites and unselective quantification). But looking beyond (5), the idea that indefinite noun phrases are non-quantificational raises immediate questions. It is not an accident that indefinites have been traditionally associated with existential quantification. We certainly appear to get existential readings for indefinites in the default case, when they are not scoped under other operators (as in (1)); and we seem also to get existential readings in the intersentential case (as in (3)). Where does this existential force come from, if not from the semantics of the indefinite itself?

A *well-formed discourse* of L is then any sequence of wffs from L .

Heim calls open sentences of the form $G^n(x_1, \dots, x_n)$ *atomic propositions*, and the rest *molecular formulae*. Molecular formulae of the form $(\alpha\beta)$ are *cumulative*. Examples of atomics include 'she hit it', 'the cat'. Examples of cumulative moleculars include 'the cat napped', 'a big cat'. Note Heimian wffs do not all correspond to full sentences. All complex noun phrases are cumulative molecular formulae, for example. As indicated, in Heim's semantics, any cumulative molecular $(\alpha\beta)$ will be semantically equivalent to $(\alpha \wedge \beta)$. For this reason, I generally ignore the distinction between the two below, and confine discussion in the main text to the conjunctive form.

¹⁰Thus for example if ϕ contains two free variables x and y , the unselective $\forall\phi$ has the same truth-conditions as $\forall x\forall y\phi$.

3.2.2 Satisfaction sets

This is where the third innovation enters in. Heim introduces a novel model of the discourse context, and uses it to (inter alia) introduce a kind of ‘discourse level’ of existential quantification. Let me explain.

Recall that on the Stalnakerian pragmatic picture, the informational context (context set) is given by a set of possible worlds. Heim proposes to replace context sets with *satisfaction sets*, which are sets of *assignment worlds*:

Def. An **assignment world** is a pair of a possible world and a variable assignment.

Def. A **satisfaction set** is a set of assignment worlds.

Assignment worlds are the sorts of things we can evaluate *open* sentences with respect to. Heim’s idea is that (1) semantically determines a constraint on assignment worlds. Specifically, (1) is satisfied at an assignment world (f, w) just in case $f(x)$ is a car in w and $f(x)$ drove by in w and $f(x)$ honked in w . Likewise, the two sentences of (3) each semantically determine constraints on assignment worlds.

For Stalnaker, sentences semantically determine conditions on possible worlds, and the characteristic pragmatic effect of successfully asserting a sentence is to eliminate possible worlds incompatible with the corresponding truth-condition from the context set of the conversation. Heim’s picture of (1) is similar in that it determines a condition on assignment worlds, and its characteristic pragmatic effect will be (in part) to eliminate assignment worlds incompatible with the corresponding condition from the satisfaction set of the conversation. But Heim differs from Stalnaker in that she accepts DISCOURSE PRIMACY. Individual sentences do not receive any direct mapping into possible worlds truth-conditions in the semantics, and their effect on the discourse context cannot in general be characterized in terms of the addition of some possible worlds content. It is only the state of a conversation that gets associated with possible worlds truth-conditions. Sentences can serve to change the truth-conditions of a conversation, and can (sometimes) be understood as adding truth-conditional content to the conversational context; but as we will see, the way in which sentences do this is not generally deterministic. Because it is fundamentally discourse contexts that have truth-conditions, Heim will explain a range of truth value judgments about sentences indirectly, by appeal to their characteristic dynamic effects on the truth-conditions of a conversation.

Heim associates her satisfaction sets with possible worlds truth-conditions as follows:

Def. A satisfaction set s is **true** at w iff there exists some assignment f of values to variables such that $(f, w) \in s$.

Now it is not hard to see how this definition assists in predicting the felt existential force of (1). Imagine an informationally ‘null’ discourse context—a

satisfaction set which excludes no assignment worlds. Now update this satisfaction set with (1), by eliminating the assignment worlds which fail to satisfy the corresponding constraint. The resulting context is true, according to the definition above, just in case there exists some assignment f of values to variables such that $f(x)$ is a car in w and $f(x)$ drove by in w and $f(x)$ honked in w —just the existential reading we intuited for (1). And indeed, more generally, satisfaction of this existential truth-condition will be an aspect of the truth-conditions of any conversation that incorporates (1). On this approach, its existential force effectively derives from its context change potential, together with the way that truth is defined for discourse contexts.

This account of the existential reading of (1) appeals to its context-change potential, but it does not require DYNAMIC. The story so far is compatible with the idea that in the compositional semantics, (1) is assigned a static condition on assignment worlds. Still, one might wonder why Heim pursues this indirect route through context-change potential in order to explain its existential reading. Couldn't one take a more direct route? For example, why not introduce the existential quantification in a post-semantic definition of truth for individual sentences? That is, why not just say that generally, a sentence ϕ is true just in case there exists some assignment f of values to variables free in ϕ where the static condition on assignment worlds semantically associated with ϕ is satisfied?

This would indeed work for (1), but it would fail for (3). It would predict that the second sentence of (3) has the truth-conditions *something honked*, where that something is possibly different than the car that drove by—the intuitively incorrect result. To get the right result for (3) and for intersentential anaphora generally, Heim locates the existential force at the discourse level. In addition, she adopts the idea (following Stalnaker [1974]) that the discourse impact of the assertion of a conjunction is equivalent to that of consecutive assertion of the conjuncts. This entails that (3) has the same same context-change potential as (1), and hence that they should strike us as equivalent discourses—the desired result.

3.2.3 Domains and discourse referents

The story so far still leaves much unexplained. Notably, it fails to interact with negation correctly. Consider the first sentences of (4) above:

(4a) Bob doesn't have a car.

Sticking to Heim's first innovation, we treat this as equivalent to:

$\neg(\text{Bob has } x \text{ and } x \text{ is a car})$

Plainly we do not want to leave the free variables here to be existentially bound at the discourse level. On the preferred reading of the sentence, the existential force applies below the scope of the negation.

We could respond to this issue by supposing that negation in general is really interpreted in the semantics as equivalent to $\neg\exists$ —that is, as classical negation

together with an unselective existential quantifier scoped immediately under. But this would yield the wrong prediction for:

- (7) Bob has a car. It’s not black.

We don’t want to say that this discourse is true just in case Bob has a car and *nothing* is black. If negation somehow introduces existential quantification under its scope, that quantificational force should not bind the pronoun in (7). Similarly, consider:

- (8) Every farmer who owns a donkey doesn’t feed it.

$$\forall(x_1 \text{ is a farmer} \wedge x_1 \text{ owns } x_2 \wedge x_2 \text{ is a donkey}, \neg (x_1 \text{ feed } x_2))$$

Here we want the variables under the scope of negation to stay available for binding by the unselective universal quantifier outscoping it.

Evidently, we need more control over what is bound where. To solve these and other problems, Heim makes two moves beyond those already reviewed. First, she introduces additional structure into the representation of context, structure for tracking which variables are to be bound at the discourse level as opposed to somewhere else. She adds, beyond satisfaction sets, *domains*:

Def. A **domain** is a set of variables.¹¹

A conversational context is now a pair of a satisfaction set and a domain. The pair must satisfy the condition that if a variable is not in the domain, it is free relative to the satisfaction set, in the following sense:

Def. A variable is **free** in s iff for any two assignment functions f and f' that differ only in their assignment to x , and any world w : if $(f, w) \in s$, then $(f', w) \in s$.

Intuitively, the domain tracks the objects mentioned in the conversation. If we think of a conversation as generating “a file that consists of records of all the individuals, that is, events, objects, etc., mentioned in the text and, for each individual, records whatever is said about it” [Karttunen, 1976, 364], then the domain gives the set of file labels. In Karttunen’s jargon, it tracks the *discourse referents* of the conversation.¹² Variables not the domain are required to be free because we want any substantive constraint on the value of a variable to correspond to a file labeled with that variable. Summarizing, our conversational contexts are now *files*:

¹¹Officially, Heim takes a domain to be a set of numerals, each corresponding to possible variable index.

¹²The term ‘discourse referent’ is sometimes used to refer to linguistic expressions (viz., variables playing the discourse role just described), and sometimes applied to the kinds of things which are the semantic values of variables (viz., functions from assignments to individuals). Heim tends to employ the former use. Karttunen [1976] introduced the notion functionally, as follows: “Let us say that the appearance of an indefinite noun phrase establishes a ‘discourse referent’ just in case it justifies the occurrence of a coreferential pronoun or a definite noun phrase later in the text” (366).

Def. A **file** F is any pair of a satisfaction set s and a domain d which is such that if $x \notin d$, then x is free in s .

(Note that a variable may be in the domain of F , yet free in the satisfaction set of F .)

The second move Heim makes is to embrace DYNAMIC. Her semantics compositionally maps sentences directly into updates on files. We now review her semantics, and explain how it resolves the above problems with negation.

Since files are domain-satisfaction set pairs, Heim's dynamic semantics maps each sentence to a pair of updates, one on domains and one on satisfaction sets. While the update effect of a sentence on a satisfaction set is sometimes partly a function of its update effect on the corresponding domain, the reverse is not the case. Therefore we can recursively state the update effect of sentences on domains separately.¹³ As follows: for any domain d of any file F , and any variables x_i, \dots, x_n , predicates G , and sentences α, β .¹⁴

$$d + G(x_i, \dots, x_n) = \{d \cup x_i, \dots, x_n\}$$

$$d + (\alpha \wedge \beta) = d + \alpha + \beta$$

$$d + \neg\alpha = d$$

$$d + \forall(\alpha, \beta) = d$$

Thus, open sentences always ensure that the indices of the variables they contain are included in the domain. They either expand the domain, or leave it alone. A conjunction expands the domain whenever one of its conjuncts does. In contrast, negated and universally quantified statements never expand the domain. The latter assumption is incorporated to reflect the hypothesis that these sentences do not serve to establish new discourse referents. This hypothesis is suggested by (e.g.) (4) (repeated below) and (9):

(4) Bob doesn't have a car. # It's black.

(9) Every farmer who owns a donkey beats it. # It's in pain.

Now that we understand how the domain evolves, we can recursively state Heim's update rules for satisfaction sets. We first define the following relation between assignment functions, given a file F :

Def. $f' \sim_{d_F} f$ iff for all $v \in d_F$, $f(v) = f'(v)$.

Now for any satisfaction set s of any file F , and any variables x_i, \dots, x_n , predicates G with matching intensions \mathcal{G} , and sentences α, β , satisfaction sets update as follows:

¹³This way of describing Heim's view was suggested to me by Daniel Rothschild.

¹⁴Here I employ Heim's style of notation: '+' means 'updated with'. '+' expresses an update function which maps a domain (satisfaction set, file) and a wff to a domain (satisfaction set, file), depending on context.

$$\begin{aligned}
s + G(x_i, \dots, x_n) &= \{(f, w) \in s : \mathcal{G}(f(x_i) \dots f(x_n), w) = 1\} \\
s + (\alpha \wedge \beta) &= s + \alpha + \beta \\
s + \neg\alpha &= \{(f, w) \in s : \text{there is no } f' \sim_{d_F} f \text{ such that} \\
&\quad (f', w) \in s + \alpha\} \\
s + \forall(\alpha, \beta) &= \{(f, w) \in s : \text{for every } f' \sim_{d_F} f \text{ such that} \\
&\quad (f', w) \in s + \alpha, \text{ there is some } f'' \sim_{d_F + \alpha} f' \\
&\quad \text{such that } (f'', w) \in s + \alpha + \beta\}
\end{aligned}$$

The update of a file by a sentence is then simply the result of updating its domain and its satisfaction set:

$$F + \alpha = \langle s_F + \alpha, d_F + \alpha \rangle$$

Let us look at the way satisfaction sets are updated. Atomic open sentences eliminate assignment worlds, in the style described already in section 3.2.2 above. The update rule for conjunction encodes the Stalnakerian idea that conjunction is tantamount to consecutive assertion.¹⁵ Observe that no appeal to the domain of the file occurs for these updates. With negation and quantification, however, domains come into play. Negation effectively expresses classical negation over an unselective existential quantifier, but this quantifier is not permitted to bind variables that are already in the domain. This correctly predicts, for example, that (7) adds the information that Bob has a car which is not black to the conversational common ground.

The Heimian clause for the universal quantifier is rather more complex. To motivate it, we can start with the following simpler semantic idea:

$$\begin{aligned}
s + \forall(\alpha, \beta) &= \{(f, w) \in s : \text{for every } f' \sim_{d_F} f \text{ such that} \\
&\quad (f', w) \in s + \alpha, (f', w) \in s + \alpha + \beta\}
\end{aligned}$$

This is basically a dynamic version of the unselective universal quantification described above, where we use domains to understand what variables the quantifier should not bind. Heim [1983a] breaks it into three steps:

- Step 1. Tentatively update your initial file F with α . Call the result F' .
- Step 2. Tentatively update your initial file F with α followed by β . Call the result F'' .
- Step 3. Now for each $(f, w) \in s_F$, consider the set of assignment worlds (f', w) in F' which are such that f and f' agree on d_F (i.e., $f \sim_{d_F} f'$). Is every one of those assignment worlds also in F'' ? If so, keep (f, w) ; otherwise eliminate that assignment world from the satisfaction set.

¹⁵Note that as cumulative molecular formulae are semantically equivalent to conjunctions ($F + (\alpha\beta) = F + (\alpha \wedge \beta)$), we set explicit discussion of them aside.

It is easy to confirm that this semantics gets the desired result for the basic donkey sentence (5).¹⁶ It also gets the right result for our donkey sentence with negation in the nuclear scope, repeated:

- (8) Every farmer who own a donkey doesn't feed it.
 $\forall(x_1 \text{ is a farmer} \wedge x_1 \text{ owns } x_2 \wedge x_2 \text{ is a donkey}, \neg(x_1 \text{ feed } x_2))$

In evaluating the sentence, we only check the nuclear scope relative to files that have been ‘temporarily updated’ with the restrictor. That is, we only check it relative to a *local context* incorporating the update given by the restrictor. Since the restrictor contains the variables x_1 and x_2 , these variables will be in the domain of the local context that we check the nuclear scope relative to. And therefore the existential force associated with negation will bypass these variables, allowing the topmost universal quantifier to bind them.

The problem with this simpler clause for the universal quantifier emerges in cases where the nuclear scope itself introduces a new discourse referent. For example:

- (10) Every farmer who owns a donkey sells it to a merchant. (Kamp [1981])
 $\forall(x_1 \text{ is a farmer} \wedge x_1 \text{ owns } x_2 \wedge x_2 \text{ is a donkey}, x_1 \text{ sells } x_2 \text{ to } x_3 \wedge x_3 \text{ is a merchant})$

(This can be read with ‘a merchant’ taking widest scope, but we are interested in the narrow scope reading.) Here we don’t want the universal quantifier to bind x_3 . This is why Heim (and Kamp) introduce a level of existential quantification within the clause for the universal quantifier. Whenever there are ‘extra variables’ appearing in the nuclear scope which are not in the restrictor clause (or already in the domain) and not bound by anything in the restrictor, they will get bound by this level of existential quantification.

3.2.4 The novelty-familiarity condition

The semantics for the universal quantifier just described comes with a catch: it does not get intuitive results if all the variables within its scope are already in the domain of the file being updated. Take:

- (11) Every cat died.
 $\forall(x_1 \text{ is a cat}, x_1 \text{ died})$ (Heim [1983a])

Consider what happens when we apply the context-change potential of this sentence to a file which already has x_1 in its domain. Since the universal quantifier is not permitted to bind variables in the domain, it will bypass this variable, rendering the quantification vacuous. As a result, the sentence just add a constraint on the possible values of x_1 to the satisfaction set of the file (viz., x_1 is a cat \supset x_1 died). But this is not a possible reading of the sentence.

¹⁶Assuming, that is, that we postulate a further constraint the (re)use of variables in context, about which more in the next section.

We evidently need some kind of prohibition on “reusing variables” in certain contexts. Heim argues that the required constraint is one independently needed to model the distinction between definiteness and indefiniteness. We turn to this topic now.

Thus far we have only discussed examples involving indefinite noun phrases and the pronouns that corefer with them. But if both indefinite and definite noun phrases express open sentences (as Heim postulates), we face the basic question what explains the differences between the two, especially in respect of their anaphoric potential. For example, the discourse (12b) seems equivalent to the discourse (12a): *the cat* can function like *it*, and be anaphoric with the indefinite *a cat* appearing earlier in the discourse. By contrast, in (12c), the indefinite is not naturally read as anaphoric with the earlier definite. Neither can it be anaphoric with an earlier indefinite, as shown by (12d).

- (12) a. A cat walked in. It meowed.
b. A cat walked in. The cat meowed.
c. The cat walked in. A cat meowed.
d. A cat walked in. A cat meowed.

We also observe that definites can sustain anaphoric reference later in the discourse, even when appearing in the scope of negation (13a):

- (13) a. I don't own the car. It/the car belongs to Daniel.
b. I don't own a car. ??It/the car belongs to Daniel.

Similar points arise in the intrasentential context. Observe that (14a) seems equivalent to (14b), but neither are equivalent to (14c), which could be true if farmers only beat their neighbor's donkeys.

- (14) a. Every farmer who owns a donkey beats it.
b. Every farmer who owns a donkey beats the donkey.
c. Ever farmer who owns a donkey beats a donkey.

If indefinite and definite noun phrases both contribute variables to logical form, these examples show that they are subject to different constraints in respect of what variables they can contribute relative to the discourses in which they occur. The variable contributed by the second indefinite in (14c), for example, must differ from the variable contributed by the first indefinite, whereas this is not the case for the corresponding definite in (14b). Evidently, indefinites can introduce a new referent for subsequent anaphoric reference, but cannot be anaphoric with an earlier expression; and definites seems to want to be anaphoric with an already-established discourse referent, even under negation. Building on earlier work, Heim [1982, 1983a] sums up the empirical generalization as follows:

Familiarity theory of definiteness¹⁷

A definite is used to refer to something that is already *familiar* at the current stage of the conversation. An indefinite is used to introduce a *new* referent.

To formalize this idea in FCS and predict the distribution of facts just observed, Heim does two things. First, she proposes to view (in)definiteness as an abstract property of noun phrases in general, and not just noun phrases headed by (in)definite determiners. We can describe noun phrases as \pm -marked for the definiteness feature (\pm DEF). Since, as illustrated above, pronouns pattern with definites, Heim takes them (or their corresponding noun phrases) to be +DEF. By contrast, she takes the restrictor clauses of quantifiers to be -DEF, as these clauses cannot be anaphoric with earlier expressions. Second, she postulates a condition associating indefiniteness with the introduction of new discourse referents, and definiteness with already established discourse referents:

Novelty/familiarity condition (NF)

Given a file F and an atomic proposition α , then α is appropriate with respect to F iff for every noun phrase NP_i contained in α :

- (i) if NP_i is definite, then $NP_i \in d_F$.
- (ii) if NP_i is indefinite, then $NP_i \notin d_F$.

The reader can verify that this constraint does correctly predict the distribution of facts just observed. For example, this constraint entails that the variable associated with second indefinite in (12c) cannot be one already in the domain of the file updated by the first sentence; hence it cannot be anaphoric with the earlier indefinite. Or again, the constraint entails that in (13a), the existential quantification introduced by the negation does not bind the variable associated with the definite, because it requires that this variable already be in the domain of the file being updated.

This account also addresses the problem about universal quantification this section began with. It remains the case that if a file F whose domain contains x_1 is updated with $\forall(x_1 \text{ is a cat, } x_1 \text{ died})$, the resulting file will not incorporate the information that every cat died; rather it will incorporate the information that a certain (discourse-familiar) entity is such that if it is a cat, it died. But this is not a problem, because if F is the file of one's conversation, then *there is nothing one can say in English* whose logical form is correctly characterized as $\forall(x_1 \text{ is a cat, } x_1 \text{ died})$. If one says 'Every cat died' in such a context, this simply cannot be translated as $\forall(x_1 \text{ is a cat, } x_1 \text{ died})$. Because the restrictor is indefinite, a different variable is required, as encoded by (NF). The possible assignment of variables to the noun phrases of a sentence is constrained by the input file. The proper characterization of the syntax of the sentence, in other words, is discourse-relative.

¹⁷As Heim notes, this observation goes back to the early grammarians Christophersen [1939] and Jespersen [1949], and the label is due to Hawkins [1978].

What exactly is the status of (NF)? As Heim [1982] writes,

This is not a constraint on the wellformedness of logical forms, but what might be called a “felicity condition”: it imposes certain limitations on which readings an utterance admits of w.r.t. a given file.
(203)

From the theorist’s perspective, the condition governs the translation of discourses from surface form to logical form, understood as the level of syntactic description relevant to semantic interpretation. One could view it as a syntactic constraint at the discourse level, analogous to the intrasentential syntactic constraints described by the binding theory (such as that the pronouns in ‘He loves himself’ must be coindexed). The reason that, e.g., the discourse (12c) does not map to the formalization:

$(x \text{ is a cat} \wedge x \text{ walked in}), (x \text{ is a cat} \wedge x \text{ meowed})$

is not that the logical forms in this discourse are syntactically ill-formed, or that this formalized discourse as a whole is ill-formed. Rather, the reason is simply that this is not a possible formalization of the discourse at the relevant level of theoretical description: it does not have a reading corresponding to this formalization. The role of definiteness just is to delimit the range of possible ways of associating the noun phrases of a discourse with variables.

3.2.5 On the file metaphor

At the outset we drew a distinction between DYNAMIC REPRESENTATION and DYNAMIC INTERPRETATION, and we located FCS on the DYNAMIC INTERPRETATION side of the fence. But we are now in a position to see why this is a bit simplistic. While satisfaction sets are content-like objects, domains are sets of variables. Variables are linguistic expressions. They are representational devices of a certain kind. So there is some pull towards saying that Heim’s files are really best understood as an intermediate layer of representation, representations that then get assigned truth-conditions in accordance with the definition of truth for files supplied above.

3.2.6 Conversation system of FCS: formal properties

Recall we noted above that on one (restrictive) conception of what it is for a conversation system to be static, staticness coincides with the satisfaction of idempotence and commutativity. As we now review, Heim’s semantics for negation and for universal quantification makes for commutativity failures in the conversation system for FCS.

Take first negation.¹⁸ Consider a file F with an empty domain whose satisfaction set incorporates only the information that there exists something which is (in the extension of) H . That is, for every w such that there is some $(f, w) \in s_F$,

¹⁸The following kind of example was pointed out to me by Daniel Rothschild.

something is H relative to w . Consider some G strictly weaker than H (such that Hx implies Gx). Now by the semantics for negation, $F + \neg Hx$ will have an empty satisfaction set: this update serves to exclude any possibility where something is H , and that means it excludes every possibility left open by F . (Thus $\neg Hx$ “crashes” F .) Since update can never expand the satisfaction set, it follows that for any subsequent update, for example $F + \neg Hx + Gx$, will also have an empty satisfaction set. But now consider the commutation of these updates, namely $F + Gx + \neg Hx$. Since by stipulation, F is compatible with the information that something is G , $F + Gx$ yields a nonempty satisfaction set, and adds x to the domain. Because x is now in the domain, when we next update with $\neg Hx$, the existential force associated with the negation is bypassed; the sentence serves to add the information that the discourse-familiar G -thing, with the file labeled x , is not also H . This second update will *not* crash the satisfaction set, since according to our stipulations, F is compatible with the information that something which is G is not H . Thus $F + Gx + \neg Hx \neq F + \neg Hx + Gx$. Hence commutativity fails.

When we say that commutativity fails in the conversation system of FCS, we mean this as a claim at the level of the logical forms of sentences and discourses. Since the relation between logical form and surface form is subtle and discourse-sensitive in Heim’s system owing to (NF), the commutativity failure just described is not easy to observe at level of surface form. For example, if we ask for a discourse which is the commutation, at the level of logical form, of:

(15) There is an animal. It is not a cat.

$Ax, \neg Cx$

We cannot cite the discourse which merely commutes the surface sentences:

(16) It is not a cat. There is an animal.

(a) yes: $\neg Cx, Ay$

(b) no: $\neg Cx, Ax$

The discourse (16) does not correspond to the commutation the logical forms of the discourse (15), because the (NF) disallows the variable corresponding to the indefinite in (16) to be the same as the variable used in the prior sentence (i.e., it disallows (16b)). So while it is intuitively obvious that the discourse update associated with (15) is not equivalent to the update corresponding to (16), this is not a counterexample to commutativity in the sense that matters. A discourse closer to a true commutation of (15), in the relevant sense, would be:

(17) It is not the case that there is a cat. There is an animal.

since this admits of formalization as $\neg Cx, Ax$.¹⁹ But of course, this does not look like a commutation of (16) on the surface.

¹⁹This example is imperfect, however, since (17) could also be formalized as $\neg Cx, Ay$ (assuming the relevant domain does not contain y), whereas a parallel flexibility is not available for (15).

Commutativity also fails in Heim’s system owing to the semantics for universal quantification. Here again, the gap between surface form and logical form is important for understanding the nature of the failure. As we noted in the previous section, at the level of logical form, a universal quantifier will lose its quantificational force if its restrictor is anaphoric with a variable in the domain. Thus in general, if the domain of F does not contain x ,

$$F + \forall(Gx, Hx) + Gx \neq F + Gx + \forall(Gx, Hx)$$

But again, as already noted, there is no discourse in English with the logical form $Gx, \forall(Gx, Hx)$. So this failure of commutativity has no natural language illustration.

We might also ask about the “dynamicness” of Heim’s system from the perspective of van Benthem’s result that eliminative, distributive update systems are static. Since every eliminative, distributive system is commutative, we know that the conversation system induced by FCS cannot be both eliminative and distributive. It is interesting to ask which of these properties it violates. The application of van Benthem’s result to Heim’s system is not as straightforward, however, because Heim’s contexts are not sets, but pairs of sets. Given that the eliminativity and distributivity properties are defined only for update functions defined on sets, the question is therefore not well-posed. However, there is a coherent question in the vicinity. To frame the question, we can define more abstract counterparts of the eliminativity and distributivity properties, as follows:

Def. An update system is **eliminatively representable** just in case it is isomorphic to an eliminative update system.

Def. An update system is **distributively representable** just in case it is isomorphic to a distributive update system.

Then what we are asking is: is FCS either eliminatively representable or distributively representable?

As [Rothschild and Yalcin \[2012\]](#) show, eliminative representability is equivalent to the antisymmetry property:

Def. An update system is **antisymmetric** just in case: if context c' is reachable from c by some series of updates, and context c is reachable from c' by some series of updates, then $c = c'$.

The connection between eliminativity and antisymmetry should be intuitive. In antisymmetric systems, there is “no going back”: if update moves you from a context c to a new context c' , there is no set of updates which will take you back to c . Eliminative systems are the special case of this where movement to a new context is always movement to a proper subset of the original context.

Now it is easy to see that there is no going back in FCS. If an update takes one from F to a new file F' , then either the satisfaction F' contains a strictly smaller satisfaction set than F , or a strictly larger domain than F , or both.

Therefore once one has left F , there is no sequence of updates back. To get back, one would require an update that could erase variables from the domain, or add new assignment worlds to the satisfaction set; and there are no such operations in FCS as defined. Thus FCS is antisymmetric and eliminatively representable. Hence FCS is not distributively representable.

It should be noted that Heim does not cite any of these formal properties as motivation for the dynamic formulation of her system.

3.2.7 Must FCS be dynamic?

From the point of view of motivating the dynamic character of the compositional semantics of FCS, it is helpful to separate two questions: one about the necessity of the dynamic formulation, and another about its comparative elegance and explanatory power.

- I. Can the work done by file change semantics—specifically, its treatment of donkey and intersentential anaphora—in principle be done within a static semantics, one defined on exactly the same syntactic structures, and without ad hoc stipulations?
- II. Does the balance of evidence support the view that a dynamic semantics for donkey and intersentential anaphora is comparatively more elegant and explanatory than any static alternative?

The first question is not directly addressed by Heim, and to my knowledge has not been settled, or much discussed.

Since we know that the conversation system of FCS is not commutative or distributively representable, we know there is no way to redescribe the system so that for every sentence, there is a proposition such that the CCP of the sentence is just a matter of adding that proposition to the common ground. However, because FCS is eliminatively representable, one can represent all update in FCS in terms of proposition-adding (i.e., intersectively). It is just that the proposition that a sentence adds to the common ground is potentially context-sensitive—that is, dependent on the input context. To say that again: for every sentence, the CCP of the sentence in FCS can be represented as a matter of adding a proposition to the common ground. But what proposition is ‘expressed’ by the sentence may vary with the input context. (See the discussion of *information-sensitivity* in [Rothschild and Yalcin \[2012\]](#).)

So there exists a context-sensitive proposition map for the sentences of FCS. (Exercise: define it.) But this does not yet settle the question whether the mapping can be determined in a locally compositional fashion as a function of the parts of the sentences. And this is what (I) is asking about.

It should be noted that whether the answer to (I) is interesting depends much on whether there exists a principled specification of what makes a compositional semantics (as opposed to a conversation system) “really static” or “really dynamic” at an abstract level. We have not yet given any such specification here; this remains an open question. If there is not such a specification, it is unclear what interest (I) would have.

There is no hope of answering (II) here, but the question highlights the basic point that one does not need to show that a static formulation of a semantics is impossible (in some technical sense of “impossible”) before one is allowed to explore dynamic formulations. There is no clear sense in which the a static approach to semantics has a presumptive status. Even if what can be had dynamically can always be had statically, there may be considerations of simplicity or elegance that favor a dynamic formulation. For example, in contrast to the static system developed in Heim and Kratzer [1998], FCS has no need for a separate rule of predicate modification over and above functional application. In that respect, then, the system is simpler. If enough such efficiencies were to accumulate, that would suffice to motivate a dynamic approach over static alternatives.

Heim herself, in Heim [1982] and Heim [1983b], famously suggested that one reason for favoring the dynamic character of FCS was that it allowed for a compelling approach to the projection problem for presuppositions. The problem of presupposition projection is another important locus of work in the dynamic tradition. We turn now to the treatment of presupposition projection in FCS.

4 Presupposition projection in FCS

4.1 Some explananda

Sometimes the presuppositions of a sentence are inherited by the larger sentences in which it appears—in that case, we say the presupposition *projects*—and sometimes not. The pattern in the data is not random. We should like a theory of it. Here is a small fraction of the data we should want a theory of presupposition projection to account for.

(I) **Conjunctions.** Consider:

- (18) (a) Bill has a son.
 (b) Bill’s son is bald.

(18b) presupposes (18a). When the sentences are conjoined (in order):

- (19) Bill has a son and the Bill’s son is bald.

the resulting conjunction does not inherit the presupposition of the second conjunct. We should like to predict this fact.

(II) **Conditionals.** Consider:

- (20) If Bill has a son, then Bill’s son is bald.

Again, the presupposition of the consequent is not inherited by the whole conditional. We should like to predict this fact.

(III) **Definites under quantifiers.** Consider:

(21) Spain’s king is tall.

This sentence presupposes

(22) Spain has a king.

The presupposition is clearly triggered by the definite noun phrase ‘Spain’s king’. Similarly,

(23) Every nation cherishes its king.

$\forall(x \text{ is a nation, } x \text{ cherishes } x\text{'s king})$

presupposes

(24) Every nation has a king.

This presupposition is evidently triggered by the interaction of the quantifier with the definite constituent

(25) x ’s king

We should like to predict these presuppositions of (21) and (23).

(IV) **Definites anaphoric with indefinites.** Consider:

(26) A fat man was pushing his bicycle. (Karttunen and Peters [1979])

x was a fat man \wedge x was pushing x ’s bicycle

We expect ‘ x ’s bicycle’ to perform as a presupposition trigger, analogous to the examples above, but we want to avoid the prediction that (26) presupposes that a fat man had a bicycle. Rather, as Heim notes, “What one would like to predict is, vaguely speaking, a presupposition to the effect that the same fat man that verifies the content of [(26)] had a bicycle” (258).

4.2 Presupposition as undefinedness of CCP

Heim’s modeling idea is that a sentence presupposes some information just in case the CCP of the sentence is defined only on contexts (files) that incorporate that information. The presuppositions of a sentence are thus reflected in its CCP. Since the CCP of a complex sentence is determined compositionally (given DYNAMIC), presupposition projection is ultimately a matter of whether and how the (un)definedness of the component parts of a sentence affect the definedness of the CCP of the sentence as a whole.

Here are the details of implementation. Heim defines a notion of admittance:

Def. F **admits** ϕ iff $F + \phi$ is defined.

We can then define a notion of presupposition between sentences in terms of admittance:²⁰

Def. ϕ **presupposes** ψ iff all F that admit ϕ support ψ .

Heim’s key move to associate all complex definite noun phrases with presuppositions. She does this by modifying (NF), and by construing this appropriateness condition as a constraint on the definedness of CCPs. Here is the modified condition:

Extended novelty/familiarity condition (ENF)

Given a file F and an atomic proposition α , then α is appropriate with respect to F iff for every noun phrase NP_i contained in α :

- (i) if NP_i is definite, then
 - (a) $\text{NP}_i \in d_F$.
 - (b) if NP_i is a formula, $F + \text{NP}_i = F$ (i.e., F supports NP_i).
- (ii) if NP_i is indefinite, then $\text{NP}_i \notin d_F$.

The key addition is (ib), the demand that if NP_i is a formula, $F + \text{NP}_i = F$.²¹ This means that definite NPs will only be appropriate relative to (local) files that already incorporate the descriptive information that they encode. For example, if we have a definite NP such as ‘the cat’ whose logical form is ‘ x_2 is a cat’, then by (ENF), this NP is only appropriate relative to files having the following properties: (1) x_2 is in the domain; (2) x_2 is a cat relative to every assignment world left open by the file’s satisfaction set. So the entity referred to must be familiar, and moreover it must already be taken for granted that this familiar entity is a cat. Heim then takes appropriateness to constrain definedness: “From the point of view of the task of assigning file change potentials to logical forms, we may take appropriateness conditions [such as (ENF)] as delimiting the range of pairs $\langle F, p \rangle$ for which the file change operation $F + p$ is at all defined” [Heim, 1983a, 234].

Let us bring these ideas to bear on (I)-(IV) above.

- (I) **Conjunction.** Consider (18b). Since ‘Bill’s son’ is definite, it is defined only relative to files already incorporating the information that Bill has a son. So the sentence (18b) containing this constituent presupposes that Bill has a son. However, the conjunction (19) is predicted *not* to inherit this presupposition. Although its second conjunct has this presupposition, this presupposition is satisfied by the update action of the first conjunct, and hence not inherited by the conjunction as a whole. The conjunction as a whole remains well-defined relative to contexts which fail to incorporate the information that Bill has a son. Observe that this account relies

²⁰Heim [1983b]’s exact definition is slightly different (it relates sentences and propositions, and in terms of a notion of entailment rather than support), but it comes to the same.

²¹Strictly speaking, the condition Heim adds to (NF) is articulated in terms of a notion of entailment rather than support, but the difference is immaterial.

crucially on the non-commutative dynamic semantics for conjunction described in §3.2 above.

- (II) **Conditionals.** Consider next (20). Heim proposes that the admittance requirements of the presuppositional constituent (‘Bill’s son’) get locally satisfied in the compositional semantics of the indicative conditional, and as a result the presupposition does not get projected. She postulates the following semantics (setting domains aside):

$$(27) s[\phi \rightarrow \psi] = s - (s[\phi] - s[\phi][\psi])$$

The basic idea of this update action is:

Consider those assignment worlds which would survive update with the antecedent, but would not survive update with the antecedent followed by the consequent. Remove these assignment worlds from the satisfaction set.

Much could be said about this semantics for conditionals, but the crucial point to note for our purposes is that to calculate the CCP of a conditional, we need not consider the CCP of the consequent relative to arbitrary contexts. Rather, all that matters is how the consequent would operate on the local contexts that would result from updating an input context with the antecedent. This means that if the update effect of the antecedent of a conditional fulfills the special admittance requirements (presuppositions) of its consequent, those admittance requirements (presuppositions) will not be projected up to the whole conditional. This is what is predicted to happen with (20), given (27).

- (III) **Definites under quantifiers.** Consider next (23), repeated:

$$(23) \text{ Every nation cherishes its king.} \\ \forall(x \text{ is a nation, } x \text{ cherishes } x\text{'s king})$$

As we noted, the sentence presupposes that every nation has a king, and this presupposition is plausibly triggered by the definite ‘ x ’s king’. An initial difficulty is to characterize the presupposition of this constituent in isolation. This is a challenge for accounts which identify presuppositions with propositions, the latter understood as objects not variable with respect to assignment functions. But there is no difficulty for Heim here: she takes ‘ x ’s king’ to be an open sentence whose update is defined only relative to files such that for every assignment world (f, w) in the satisfaction set of the file, $f(x)$ has a king in w . Thus in a clear technical sense, ‘ x ’s king’ presupposes that x has a king in FCS. We assume this presupposition is inherited by the larger constituent ‘ x cherishes x ’s king’. Now to see how this presupposition of ‘ x ’s king’ results in (23) carrying the presupposition that every nation has a king, recall the semantics for the universal quantifier described above (repeated):

$$s + \forall(\alpha, \beta) = \{(f, w) \in s : \text{for every } f' \sim_{d_F} f \text{ such that} \\ (f', w) \in s + \alpha, \text{ there is some } f'' \sim_{d_{F+\alpha}} f' \\ \text{such that } (f'', w) \in s + \alpha + \beta\}$$

Observe that $s + \forall(\alpha, \beta)$ is defined only if $s + \alpha + \beta$ is. If β carries the presupposition that x has a king, and α is the open sentence ‘ x is a nation’, then $\alpha + \beta$ carries the presupposition that if x is a nation, then x has a king. Since the universal quantifier binds x , this presupposition must be satisfied for all values of x in order for the CCP of (23) to be well-defined. Hence the sentence as a whole presupposes that for all x , if x is a nation, then x has a king.

- (IV) **Definites anaphoric with indefinites.** Consider finally (26). The constituent ‘ x was pushing x ’s bicycle’ presupposes that x has bicycle. This means that for a file F to admit (26), $F +$ ‘ x is a fat man’ must support ‘ x has a bicycle’. But for this to be true, F must incorporate the information that *every* fat man has a bicycle. (Remember that x must be free in F .) On its face, then, Heim’s system seems to go wrong here: she associates (26) with an overly strong presupposition.²²

In response, Heim suggests that this is a case where the desired presupposition comes about as a result of presupposition failure plus accommodation in the sense of Lewis [1979a]. Since $F +$ ‘ x is a fat man’ does not admit ‘ x was pushing x ’s bicycle’, we have presupposition failure. We respond by minimally adjusting the input context so as to satisfy the relevant presupposition. In effect, we understand ‘ x was pushing x ’s bicycle’ to take as input the context $F +$ ‘ x is a fat man’ + ‘ x has a bicycle’. This appeal to accommodation is enabled by Heim’s nonquantificational analysis of indefinites. Heim effectively argues that we need accommodation anyway, and that her system lets us appeal to this mechanism in ways that would be impossible on other systems.

4.3 The question of explanatory power

It might be thought that any linguistic connective can be associated with three items: (1) a truth-conditional contribution (a *content* property); (2) a specification the presuppositions it generates, if such there be (a *presupposition* property); ad (3) a specification of its permeability for the presuppositions of its arguments (a *heritage* property). The heritage property of the indicative conditional, for instance, might specify that an indicative conditional $\phi \rightarrow \psi$ (a) presupposes whatever ϕ does, and (b) presupposes $\phi \rightarrow \psi'$, where ψ' is what ψ presupposes.

Karttunen and Peters [1979] presented a framework in which these three properties were treated as mutually independent and specified separately for

²²Something like this stronger presupposition might be correct for nonspecific indefinites. (For example, the oddity of ‘Find me a boy who loves his giraffe’ might owe to its presupposing that boys generally have giraffes.)

each connective. But it is natural to conjecture that the heritage property of an expression can somehow be derived from a specification of its content and presupposition properties. Else we have a theory which

... implies—implausibly—that someone who learns the word “if” has to learn not only which truth function it denotes and that it contributes no presupposition, but moreover that it has the heritage property specified... It also implies that there could well be a lexical item—presumably not attested yet—whose content and presupposition properties are identical to those of “if”, while its heritage property is different. Heim [1983b]

The worry isn’t that such an expression would be logically impossible. There is no contradiction in the idea of such a lexical item. Rather, the worry is that an apparently robust empirical generalization about natural languages (roughly, that heritage properties supervene on content-and-primitive-presupposition properties) is being stipulated rather than predicted.

Gazdar [1979] argued that Karttunen and Peters’s theory was subject to this kind of objection, and Heim [1983b] agreed. Her account was intended to satisfy this demand for explanatory adequacy while being superior to Gazdar’s account in its empirical coverage. Heim thought she had an explanatory advantage over Karttunen and Peters partly because, given only the CCP clause for a connective, one could read off both the truth-conditional content and heritage properties; and she thought that the truth-conditional content of an expression fully determined its contribution to CCP.

But as subsequently noted by Rooth (p.c. in 1987 to Heim, quoted in Heim [1990]) and Soames [1989], differing specifications of the context change potentials of the connectives Heim discusses—differing, in particular, in the heritage conditions they would impose—could in principle generate the same predictions vis-a-vis the informational contribution of the expression to context. To illustrate, contrast the standard dynamic semantics for conjunction (C1) (repeated from our toy semantics) with the deviant entry (C2), where the conjuncts update the context in reverse order:

$$(C1) \ c[\phi \wedge \psi] = c[\phi][\psi]$$

$$(C2) \ c[\phi \wedge^* \psi] = c[\psi][\phi]$$

The key observation is that the classical, truth-conditional semantic contribution of ‘and’ could theoretically be captured on either of these CCPs. The truth-conditional contribution of this connective *per se* does not force the choice of (C1) over (C2). Moreover, these two choices of CCP differ in their heritage conditions. So just as Karttunen and Peters need to stipulate that one among a range of possible heritage properties is the correct one for (say) the conditional, Heim is compelled to stipulate that one among a range of possible context change potentials, all equally good from the point of view of capturing the truth-conditional contribution of ‘and’, is the one with the correct heritage

condition. Heim conceded this worry, and agreed that the explanatory power of her account had been overstated—specifically, insofar as she assumed that “context change potentials were fully determined by truth-conditional meaning” (Heim [1990]).

On reflection, it is not surprising that the classical truth-conditional contribution of ‘and’ does not dictate a CCP, and neither is it surprising that a candidate CCP such as (C1) does not dictate a classical truth-conditional contribution. These are just different approaches to the compositional semantics of ‘and’. Indeed, naively, one might have thought that much of the power in the dynamic approach owes precisely to the way that it disentangles the compositional semantics of an expression from its ultimate truth-conditional contribution to discourse.

To be clear: it would be incorrect to say, concerning the limited array of projection facts Heim’s account was directed at, that the account is completely stipulative, hence not explanatory or predictive in character. On the contrary: on the basis of a finite set of stipulations, Heim’s account generates predictions about the presuppositions of an infinite class of sentences. Moreover, it is not an objection that the dynamic semantics (C1) cannot retroactively justify the interest of the classical truth-conditional semantics for ‘and’. It is not incumbent upon a dynamic semantics to vindicate prevailing static preconceptions. Rather, the explanatory worry Heim concedes is more narrow than this. It is that (i) a theory which got by with less—specifically, which built-in fewer assumptions about heritage conditions—would be more explanatory; and (ii) there is reason to think that an alternative theory, better in specifically this respect, can be had. We have the feeling that (e.g.) it is no accident that (C1) rather than (C2) is the CCP correct for ‘and’, and we would therefore like a nonstipulative account of this fact.

This is a worry for an account along Heim’s lines, insofar as it shows the account does less than one might have hoped. Is it an objection to the account? Not really—not, anyway, until some relevantly more explanatory alternative theory is actually put on the table. For recent efforts in that direction, see Schlenker [2008, 2009], and the critical replies to Schlenker by Beaver [2008], Fox [2008], and Rothschild [2008b]. See also Rothschild [2011].

Another important attempt to fill the explanatory gap in dynamic accounts of presupposition projection occurs in Beaver [2001]. He writes:

I will borrow from Veltman’s work to show how the context sensitivity of [epistemic modal] words like ‘might’ and ‘must’ motivates a dynamic semantics. None of the alternative CCPs for connectives that have been suggested by Rooth and Soames would be compatible with this semantics, and it is hard to imagine how a relevantly different dynamic semantics could still get the facts right about the meanings of the epistemic modalities. (146)

Beaver is correct: the dynamic semantics for epistemic modals he considers is not compatible with the deviant context change potentials offered by Rooth

and Soames. Its addition to Heim’s system would thus appear to increase the system’s overall explanatory power *vis-a-vis* the problem of presupposition projection. So let us have a look at this semantics and its motivation.

5 Epistemic modals in update semantics

The dynamic semantics Beaver has in mind is a refinement of the update semantics for epistemic modals developed by Veltman [1996] (see also Stalnaker [1970], Groenendijk and Stokhof [1975, 1991a] Groenendijk et al. [1995]). To illustrate the basic idea of the semantics, we can extend our toy dynamic semantics from section 2.3 with an epistemic possibility operator \diamond (for epistemic *might*, *may*, *possibly*, etc.), adding the following clause:

$$c[\diamond\phi] = \{w \in c : c[\phi] \neq \emptyset\}$$

(Epistemic *must* can then be introduced as the dual of \diamond .) Given ϕ is not itself modalized, this captures the thought that $\diamond\phi$ is accepted with respect to a context just in case, roughly, there is a ϕ -world left open by (in) the context. Applied to c , the function $[\diamond\phi]$ returns either c or the empty set. Veltman uses the metaphor of a test: “sentences of the form *might* ϕ provide an invitation to perform a test on c rather than to incorporate some new information in it” ([Veltman, 1996, 10]. Sketching roughly the same idea in earlier work, Stalnaker writes: “A sentence of the form ‘It may be that P ’... may be interpreted as making explicit that the negation of P is not presupposed in the context” ([Stalnaker, 1970, 286-7]).

On this account, $\diamond\phi$ -sentences never, as a matter of their semantics, add information to the context when tokened unembedded (where “adding information” corresponds to winnowing down the possibilities, without excluding all possibilities). As a result, even as one strictly increases the information taken for granted by the context, the context can go from accepting $\diamond\phi$ to failing to accept it. This is to say, $\diamond\phi$ is not *persistent*:

Def. ϕ is **persistent** just in case if $c[\phi] = c$, then if c' is reachable from c by some series of updates, $c'[\phi] = c'$.

Before we added \diamond , our toy dynamic semantics contained only persistent sentences.

It should be evident that this semantics leads to a failure of distributivity. Whether a set of worlds as a whole contains a ϕ -world is ‘global’ property of that set. Thus if one wants to know whether some $\neg\phi$ -world w left open by a context c will survive update with $\diamond\phi$, the answer cannot necessarily be settled by inspecting w ; rather, one needs to know something about what other worlds there are in c .

All this makes it especially confused to speak of the “content” or “proposition expressed” by $\diamond\phi$ in a dynamic setting. Such sentences do not semantically serve to represent the world as being a certain way, or serve to add a proposition to

the common ground; their discourse impact is just different than that of straight factual sentences. Neither is it helpful to say that \diamond corresponds to a special ‘force’ on this account. Speech act forces, whatever those are, don’t embed, at least on the usual way of understanding them; but epistemic modals are embeddable on this dynamic account.

The point that epistemic modal claims don’t determine truth-conditions in this semantics—that they aren’t the kind of clauses that determine conditions on points, the sets of which constitute truth-conditional contents—highlights the falsity of the assumption, common especially in early discussions of presupposition projection, that we can always factor out a truth-conditional contribution for any connective or operator.

What is the empirical motivation for this dynamic semantics? Perhaps the most frequently cited data point in its favor concerns an alleged asymmetry in acceptability between the following two sorts of discourse:

(28) Billy might be at the door (and)... it isn’t Billy at the door.

$$(\diamond\phi \wedge \neg\phi)$$

(29) ? It isn’t Billy at the door (and)... Billy might be at the door.

$$(\neg\phi \wedge \diamond\phi)$$

—Where we are to imagine that what happens between the dots is that the speaker sees who is at the door. Pairs like this one were first discussed by Veltman, and are cited approvingly by Groenendijk et al. [1995], Veltman [1996], Beaver [2001], Gillies [2001], and von Stechow and Gillies [2007], among others. The dynamic account predicts the supposed difference between these discourses. The update corresponding to (29) is guaranteed by dynamic lights to “crash” the context, since for all c and ϕ , $c[\neg\phi \wedge \diamond\phi] = c[\neg\phi][\diamond\phi]$, which in turn will always be \emptyset . Once the context comes to accept $\neg\phi$, it will fail the test corresponding to $\diamond\phi$. But not so for (28), the other ordering of the conjuncts: $c[\diamond\phi][\neg\phi]$ will be non-empty as long as c contains some ϕ -worlds and some $\neg\phi$ -worlds.

If correct, this semantics for epistemic modals would, as Beaver suggests, help to constrain the space of possible context change potentials for connectives *vis-a-vis* the problem of presupposition projection. For example, on this semantics it is no longer the case that the ordinary conjunction (C1) and deviant conjunction (C2) have the same truth-conditional impact where both defined. On the contrary, they would come apart exactly on pairs such as (28)-(29). If ordinary conjunction were defined as in (C2), then (29) would be predicted to be felicitous and (28) infelicitous—the incorrect result, according to proponents of dynamic semantics for epistemic modals.

But, stepping back, what is the right thing to say about pairs such as (28)-(29)? First, it should be duly noted that sentences of the form $\diamond\phi \wedge \neg\phi$ and $\neg\phi \wedge \diamond\phi$ are virtually always both marked, and equally so. Likewise for the discourses $\diamond\phi, \neg\phi$ and $\neg\phi, \diamond\phi$. Generally these sound just as bad as contradictions. Second: even if it is agreed that, with sufficient rigging of context,

(28) can be made to sound okay, this alone tells us nothing; for with sufficient rigging, (29) will sound okay. What then is the point?

The point is supposed to be that pairs such as (28)-(29) manifest an asymmetry in markedness *in a certain kind of situation*: namely, one in which *monotonic* information growth happens in context mid-sentence. The thought is that if we restrict to such cases we will see that (28), but not (29), will sound fine. This is supposed to highlight the need for a non-persistent update semantics for $\diamond\phi$, and a matching non-commutative conversation system. Hence it shows a need for a step into dynamicness.

This idea is interesting and worthy of development, but there remains much room for argument. The way that the notion of monotonic information growth is used in setting up the data may be questioned. To see why, consider a view according to which the transition from believing $\diamond\phi$ to believing $\neg\phi$ normally involves non-monotonic information growth. Egan [2007] is perhaps one such example (see also Stephenson [2007]): on his view, roughly, to believe that Billy might be at the door is to ‘locate oneself’, in the sense of Lewis [1979b], on a person whose evidence leaves the possibility of Billy’s being at the door open, where the possibilities left open by one’s state of belief or knowledge are centered worlds. In the background scenario stipulated for (28)-(29), the speaker’s belief state would, on Egan’s account, normally non-monotonically change in respect of the speaker’s views about his evidence: his belief state would go from excluding centered worlds where the center’s evidence entails Billy is not at the door to including such worlds. Now we can ask: is there reason for Egan to be fazed by anything about (28)-(29)? It seems not: he can simply deny that there really is strictly monotonic information growth in the (28)-case, and just explain that insofar as the sentences are felicitous, it is because they express propositions rationally believed at the relevant times of utterance. Could it be objected against Egan that it is intuitively obvious that the (28)-case involves only monotonic information growth? That would be desperate. It is not obviously legitimate to appeal to brute intuitions about the technical notion of monotonic information growth.

While it remains a matter of debate whether (28)-(29) constitute a (dynamic semantics-motivating) failure of commutativity, there is support for the idea that there is some semantically significant kind of incompatibility between $\diamond\phi$ and $\neg\phi$, of the sort predicted on Veltman’s dynamic semantics. See Yalcin [2007] for relevant data. The account of that paper does not assume DYNAMIC, but it does define semantic notions of acceptance and of consequence analogous to those usual in a dynamic semantics. The abstract idea behind Veltman’s semantics, that the transition from believing/presupposing $\diamond\phi$ to believing/presupposing ϕ is generally monotonic, certainly has empirical motivation (though see Willer [2010], Yalcin [2011] for some further problems and extensions). But to a great extent, it can be realized in a semantic framework that many would regard as static.

6 A few more references

For more on presupposition and anaphora see, in addition to the citations already given, [Van der Sandt \[1992\]](#), [Geurts \[1999\]](#), [Breheny \[2001\]](#), [Rothschild \[2008a\]](#), [Kripke \[2009\]](#). For a start on dynamics for temporal anaphora, see [Ter Meulen \[1997\]](#), [[Steedman, 1997](#), sec. 3.2.3], [Stone \[1997\]](#), [Stone and Hardt \[1999\]](#). For a start on dynamics for modal anaphora, see [Roberts \[1989, 1996\]](#), [Frank and Kamp \[1997\]](#), [Stone \[1997\]](#), [Brasoveanu \[2007\]](#).

Conditionals form an active area of dynamic semantic research. On counterfactuals, see [von Stechow \[2001\]](#), [Gillies \[2007\]](#), [Moss \[2010\]](#). See [Gillies \[2004\]](#) for an account of indicative conditionals in the spirit of Veltman’s update semantics for epistemic modals. See [Yalcin \[2012\]](#) for a dynamic semantics for conditionals using probabilities.

Interrogatives and focus have formed another active area of dynamic semantic inquiry. See [Ginzburg \[1996\]](#), [Erteschik-Shir \[1997\]](#), [Hulstijn \[1997\]](#), [Groenendijk \[1999\]](#), [Aloni and Van Rooy \[2002\]](#), and the papers in [Aloni et al. \[2007\]](#).

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