Lecture Notes on the Semantics of Interrogative Clauses

1. A little pragmatics

The semanticist's task in the analysis of interrogative clauses is to propose suitable types of semantic values for them and to show how these semantic values are built up compositionally. But before we apply ourselves to this task, it is useful to say a little bit about speech acts, and about the relation between semantic values and speech acts.

Leaving semantics out of the picture for the moment, interrogative clauses differ from declarative clauses in their syntax and in their pragmatics. In English, interrogative clauses can be told apart syntactically from declarative clauses by the presence of a clause-initial wh-phrase and/or the inverted order of subject and auxiliary. The terminology "interrogative"/"declarative", however, alludes to a distinction not in grammatical form but in communicative function. When uttered as main clauses (i.e., not embedded in a larger structure), declarative sentences typically serve to make assertions, whereas interrogative sentences serve to ask questions. These two clause-types serve to perform different kinds of speech acts.

Stalnaker (1978) outlined an influential formal model of what happens in a conversation and what it means to make an assertion. The central concept is that of a body of publicly shared information, or "common ground", which evolves as the conversation proceeds. A proposition is in the common ground if each interlocutor is "disposed to act as if he assumes or believes the proposition is true, and as if he assumes or believes that his audience assumes or believes that it is true as well" (Stalnaker ibid). The common ground can be characterized by the set of worlds in which every proposition in the common ground is true; Stalnaker calls this set of worlds the "context set". The act of making an assertion is a proposal to update – in fact, to shrink[1] – the context set. The particular way in which the context set is to be shrunk depends on the semantic value of the asserted sentence, more specifically, on its intension. To assert a sentence ϕ is to propose that the current context set c be replaced by a new context set which is the intersection of c with the intension of ϕ, i.e., $c \cap [\![\phi]\!]_{¢}$.

Against this backdrop, how might we think about the speech act of asking a question? What is the point of this speech act? Questions, unlike assertions, don't provide information about the world and therefore do not in themselves lead to updates of the common ground.[2] Their purpose rather is to constrain the future course of the conversation in a certain way. In the absence of any particular question under consideration, a speaker might assert whatever they find interesting or

[1] Not "shrink" in the sense of reducing cardinality, as Maša Močnik pointed out. The cardinality of the context set may never become less than uncountably infinite.

[2] At least this is true if we stick to questions that don't have presuppositions (or to questions whose presuppositions are already common ground at the point when they are asked). As Suzana Fong noted in class, when a question that has a presupposition is asked in a context where the presupposition is not yet in the common ground, a listener can get new information by accommodating this presupposition.

useful. But if someone asks a question, they thereby express an expectation that the next conversational move will be one out of a very limited set of possible assertions – intuitively, the next assertion will "address the question" rather than provide some random other information.

Here is a way to formally model this intuition. A question partitions the context set in a certain way, and it amounts to a request for assertions which, so to speak, "carve up" the context set along the lines determined by this partition. The requested next assertion should not make any distinctions between worlds which the partition lumps together. This idea goes back to Hamblin (1958), who first described the role of questions in conversation as setting up partitions of the space of possible worlds.[3] As Hagstrom (2003) puts it: "Hamblin's (1958) third postulate embodies the claim that a question divides all of the possible worlds (or, at least, those possible worlds consistent with common background assumptions) into non-overlapping compartments. Thus, we might say that to ask a question is to present a particular way of compartmentalizing possible worlds, with a request for information about which compartment the actual world is to be found in."

(1) Definition: A set S is a partition of a set A iff
(i) every element of S is a non-empty subset of A,
(ii) any two non-identical elements of S are disjoint from each other, and
(iii) the union of all the elements of S is A.

The elements of a partition are also called its cells.

With this definition in hand, we refine Stalnaker's model of conversation. Each stage in a conversation is now characterized not just by its context set, but by its "partitioned context set", i.e., by a partition of some set of possible worlds. The union of this partition corresponds to Stalnaker's old context set, i.e., it contains the worlds compatible with every proposition in the common ground. The partitioning represents the interlocutors' shared commitment not to make distinctions between worlds that are "cell-mates" – at least not for the time being. This is a renegotiable commitment and, as we will see, it only stays in force until someone raises a new question. The definition of "relevant assertion" in (3) below spells out precisely what the commitment amounts to. In (2), we adapt Stalnaker's characterization of the context-changing role of assertions to our new, more elaborate set-up.

(2) Update by assertion:
To assert a sentence ϕ is to propose that the current partitioned context set C be replaced by a new partitioned context set which is constructed by intersecting each cell of C with the intension of ϕ. More precisely, C is to be replaced by
$\{p: p \neq \emptyset \;\&\; \exists p' \in C.\; p = p' \cap [\![\phi]\!]_{¢}\}$.

(3) An assertion is relevant w.r.t. to a partitioned context set C iff
the update it proposes results in a subset of C.

[3] Another important reference is Groenendijk & Stokhof (1984), ch. 4, "The semantics of questions and the pragmatic of answers".

The notion of "relevance" that is formalized here calls for a bit of clarification. First, here are a couple of more commonly used (and more transparent) definitions.

(3a) A proposition p (i.e. set of worlds) is relevant w.r.t. to a partition Q of a set of worlds iff p is identical to a cell in Q or to a union of cells in Q.

(3b) A proposition p is relevant w.r.t. to a partition Q of a set of worlds iff there is no pair of worlds w and w' such that both
- (i) there is a cell $c \in Q$ such $w \in c$ & $w' \in c$ (i.e., w and w' are cell-mates),
- (ii) and $w \in p$ & $w' \notin p$ (i.e. p has different truth values in w and w').

These two definitions differ slightly in that (3b) (unlike (3a)) allows p to include arbitrary worlds that are not in any cell of Q at all. But both express the essential requirement that a relevant proposition must not discriminate among cell-mates. It must not "cut up" the space of worlds (in the union of the partition) in any way that does not coincide with the boundaries between cells.

Definitions (3a) and (3b) apply to a proposition, whereas our definition (3) applies to an assertion and presupposes the rule for update-by-assertion. But apart from this difference, (3) captures the same notion of relevance. (To make the connections fully precise: If C is a partitioned context set and ϕ is an asserted sentence, then the assertion of ϕ is "relevant" w.r.t. C in the sense of definition (3) iff $\cup C \cap [\![\phi]\!]_{¢}$ is "relevant" w.r.t. C in the sense of definition (3a), which holds, in turn, iff $[\![\phi]\!]_{¢}$ is "relevant" w.r.t. C in the sense of definition (3b). Prove these equivalences as an exercise.)

To get an intuitive appreciation of this concept, it is important to see that "relevance" in this technical sense is a purely negative requirement, so to speak: it is just the absence of any irrelevant (i.e., not specifically asked for) information. By this criterion, a "relevant" answer may be totally uninformative; it could be a tautology, or any other proposition that is already entailed by the common ground. So evidently, relevance is not a sufficient condition for appropriate answers; there are additional conditions, notably that an answer – or any assertion, for that matter – should be informative. It is also worth pointing out that the formal requirement of relevance is *prima facie* violated by many answers which in actual fact are judged felicitous, e.g., when somebody responds to the question *Is it raining?* by saying: *Well, Ann just came in dripping wet*, or *Maybe*, or *I don't know*. To make sense of this wider range of intuitively felicitous answers, a proponent of the present formal model needs to say that in these cases, the answerer is implicitly changing or amending the question that was explicitly asked, and instead is addressing a different (though related) question that they don't formulate explicitly but expect their audience to infer ("accommodate").

Now the only piece of our story that is missing is a recipe for "update by question". The idea, as we have said, is that asking a question amounts to proposing a specific replacement of the current partitioned context set by a new one. As in the case of assertions, the construction of the new partitioned context set should be determined by the semantic value of the sentence that was uttered. We know what we have in mind for particular examples. E.g., when someone asks *Is it* *raining?*, the intended outcome is a two-membered partition, with one cell consisting of worlds in which it is raining and the other cell of worlds in which it is not raining. If the question asked is *Who among these two (John and Bill) came to the party?*, the result should be a partition with four cells: one with worlds in which John and Bill both came, one with worlds in which John but not Bill came, one with worlds in which Bill but not John came, and one with worlds in which neither John nor Bill came. What is the general recipe by which these outcomes are obtained as a function of the semantic value of each interrogative sentence? To answer this question, we have to carry out the semanticist's task, i.e., assign semantic values to interrogative clauses. For the time being, let us write down two *ad hoc* update recipes for interrogative clauses of specific forms. These will later be replaced by a general principle.[4]

(4)(a) Update by polar question:
To ask a question by uttering a sentence of the form *Is it the case that* ϕ*?* is to propose that the current partitioned context set C be replaced by the new (2-cell) partitioned context set $\{\cup C \cap [\![\phi]\!]_{¢}, \cup C - [\![\phi]\!]_{¢}\}$.

(b) Update by restricted *which*-question:
To ask a question by uttering a sentence of the form *Which of* α_1 *and* α_2 β*?*, where α_1 and α_2 are proper names and β is a VP, is to propose that the current partitioned context set C be replaced by the new (4-cell) partitioned context set

$$\{ \cup C \cap [\![\alpha_1\ \beta]\!]_{¢} \cap [\![\alpha_2\ \beta]\!]_{¢},\\ (\cup C \cap [\![\alpha_1\ \beta]\!]_{¢}) - [\![\alpha_2\ \beta]\!]_{¢},\\ (\cup C - [\![\alpha_1\ \beta]\!]_{¢}) \cap [\![\alpha_2\ \beta]\!]_{¢},\\ (\cup C - [\![\alpha_1\ \beta]\!]_{¢}) - [\![\alpha_2\ \beta]\!]_{¢} \}.$$

2. Compositional computation of semantic values for interrogative clauses

2.1. An updated version of Karttunen (1977)[5]

Interrogative clauses are built largely with the same lexicon and syntactic rules as declarative

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[4] These update rules imply that each new question "wipes out" the current partitioning of the context set and replaces it by a new one. This may not be right and isn't the only way we can go. Keny Chatain points out that sequences of questions (asked by the same speaker and connected by 'and') are naturally understood to successively refine the partition, in such a way that the second question further subdivides the cells created by the first question (and so on). I leave it as an exercise to formalize update rules that implement Keny's suggestion.

[5] The implementation here differs from Karttunen (1977, L&P) in not using the Montague Grammar framework; instead we presuppose a division of labor between syntax and semantics in line with Heim & Kratzer (1998). Aside from implementation, there are some small substantive differences as well. Most saliently, the extensions we will assign to interrogative clauses will include both true and false propositions. (In Hagstrom's (2003) terminology, they will correspond to ANSPOSS rather than ANSTRUE.) Moreover, we will depart from Karttunen in the treatment of polar questions.

Karttunen's motivation for including a restriction to true propositions had to do with the semantics of question-embedding constructions. So the time to discuss it is when we get to embedded questions. Right now we focus on matrix questions.

clauses; but they also contain certain interrogative-specific morphemes, syntactic features, or functional heads that make crucial contributions to their non-declarative meanings. Following Karttunen, our syntax for English posits an abstract (i.e., silent) complementizer that has a non-vacuous semantics, and a feature on wh-phrases that is semantically vacuous but subject to a certain distributional constraint.

(5) Karttunen's "proto-question" operator, syntactically a C-head:
$[\![\mathbf{?}]\!] = \lambda p_{st}.\ \lambda q_{st}.\ p = q$ [6]

(6) lexical entries for interrogative words, e.g.:
$[\![\mathbf{who}^{[WH]}]\!]^w = \lambda f_{et}.\ \exists x$ [x is human in w & f(x) = 1]

The meaning of **who** is exactly the same as the meaning of **somebody**. We will address the role of the feature [WH] in section 2.3.

In the syntactic derivation of a constituent question, wh-movement applies and puts the wh-word above the operator in C. For the example *Who did John see?* or *who John saw*[7], this gives rise to a structure like (7):

(7) **who 7[? John see $\mathbf{t_7}$]**

Unfortunately, when we examine the semantic types at each node in (7), we discover a type-mismatch that prevents us from interpreting the top-most node. We fix this problem by positing a slightly more complex C-head: We base-generate **?** together with another, covert operator as its sister. This covert operator is semantically vacuous, but it can move and leave a trace of type <s,t>.[8] The full syntactic derivation for a constituent question then proceeds as in (8).[9]

(8) Who did John see?
DS: $[_C$**? OP**] **John see who**
wh-movement:
who 7[[? OP] John see $\mathbf{t_{7_e}}$]
operator-movement:
LF: **OP 1[who 7[[? $\mathbf{t_{1_{st}}}$] John see $\mathbf{t_{7_e}}$]]**

We will usually drop the type-labels on the traces, but keep in mind that the operator leaves a trace of type <s,t> (i.e., a variable over propositions, not individuals). Accordingly the topmost application of Predicate Abstraction will yield a function from propositions to truth-values (type

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[6] This official denotation maps propositions to functions from propositions to truth-values, or equivalently, it maps propositions to characteristic functions of sets of propositions. If we replaced these characteristic functions by the corresponding sets, (5) would read as follows:

(5') $[\![\mathbf{?}]\!] = \lambda p_{st}.\ \{p\}$

In other words, it would be a function that maps each proposition to the singleton set that has it as its only member.

[7] We will ignore tense and auxiliary *do*, and thereby ignore the difference between matrix and embedded version.

[8] like H&K's relative pronouns (and their PRO in ch. 8).

[9] The movement of *who* is evidently overt (pre-SS) movement (in this example). For the movement of the operator, which is not pronounced, we can't tell whether it happens before SS or between SS and LF.

<st,t>, the characteristic function of a set of propositions).

Let's compute the meaning of this LF:

(9) computation for LF (8):

$[\![$**1. who 7.** [**? t$_1$**] **John see t$_7$**$]\!]^{w, \varnothing}$ [10]

= (by Predicate Abstraction)

λp . $[\![$**who 7.** [**? t$_1$**] **John see t$_7$**$]\!]^{w, [1\to p]}$

= (by entry for **who** and lambda reduction)

λp . $\exists x$ [x is human in w & $[\![$**7.** [**? t$_1$**] **John see t$_7$**$]\!]^{w, [1\to p]}(x) = 1$]

= (by Predicate Abstraction and lambda reduction)

λp . $\exists x$ [x is human in w & $[\![$[**? t$_1$**] **John see t$_7$**$]\!]^{w, [1\to p, 7\to x]} = 1$]

= (by IFA)

λp . $\exists x$ [x is human in w & $[\![$**? t$_1$**$]\!]^{w, [1\to p, 7\to x]}$ ($\lambda w'$. $[\![$**John see t$_7$**$]\!]^{w', [1\to p, 7\to x]}$) = 1]

= (by FA and dropping irrelevant superscripts)

λp . $\exists x$ [x is human in w & $[\![$**?**$]\!]$ ($[\![$**t$_1$**$]\!]^{[1\to p, 7\to x]}$) ($\lambda w'$.$[\![$**John see t$_7$**$]\!]^{w',[1\to p, 7\to x]}$) = 1]

= (by Traces rule)

λp . $\exists x$ [x is human in w & $[\![$**?**$]\!]$ (p) ($\lambda w'$.$[\![$**John see t$_7$**$]\!]^{w',[1\to p, 7\to x]}$) = 1]

= (by entry for **?**)

λp . $\exists x$ [x is human in w & p = $\lambda w'$. $[\![$**John see t$_7$**$]\!]^{w',[1\to p, 7\to x]}$]

= (by FA, entries for **John, see**, Traces Rule)

λp . $\exists x$ [x is human in w & p = $\lambda w'$. John sees x in w']

This characterizes a set of propositions that contains one proposition per human-in-w: the proposition that that human was seen by John.[11]

How about polar and alternative questions? Can we just posit the same operators in the C-head? Let's try.[12]

(10) Did John see Mary?

DS: [$_C$**? OP**] **John see Mary**

LF: **OP 1**[[**? t$_1$**] **John see Mary**]

(11) computation for LF of the polar question (10):

$[\![$**1.** [**? t$_1$**] **John see Mary**$]\!]^{w, \varnothing}$

= (by Predicate Abstraction)

λp_{st} . $[\![$[**? t$_1$**] **John see Mary**$]\!]^{w, [1\to p]}$

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[10] The vacuous operator **OP** is left out from the start. $\varnothing$ in the superscript stands for the empty variable assignment, see H&K ch. 5.

[11] This is the ANSPOSS in Hagstrom's (2003) terminology.

[12] Here I show an LF and computation that includes the vacuous operator. As I showed in class, in the case of polar questions, a simpler structure without **Op** is likewise interpretable, with equivalent results.

= (by IFA)

$\lambda p\ .\ [\![\mathbf{?\ t_1}]\!]^{w,\ [\mathbf{1}\rightarrow p]}\ (\lambda w'.[\![\mathbf{John\ see\ Mary}]\!]^{w',[\mathbf{1}\rightarrow p]})$

= (by FA)

$\lambda p.\ [\![\mathbf{?}]\!]^{w,\ [\mathbf{1}\rightarrow p]}\ ([\![\mathbf{t_1}]\!]^{w,\ [\mathbf{1}\rightarrow p]})\ (\lambda w'.[\![\mathbf{John\ see\ Mary}]\!]^{w',[\mathbf{1}\rightarrow p]})$

= (by Traces Rule and dropping irrelevant assignment superscripts)

$\lambda p.\ [\![\mathbf{?}]\!]^{w}\ (p)\ (\lambda w'.[\![\mathbf{John\ see\ Mary}]\!]^{w'})$

= (by entry for **?** and lambda reduction)

$\lambda p\ [\ p = \lambda w'.\ [\![\mathbf{John\ see\ Mary}]\!]^{w'}\ ]$

= (by FA and entries for **John, Mary, see**)

$\lambda p\ [\ p = \lambda w'.\ \text{John sees Mary in } w'\ ]$

This is the characteristic function of a singleton set containing one proposition. Is this a good result? If we have in mind that our denotations for interrogative clauses should directly correspond to an intuitive notion of "possible answer", then this is problematic. There is certainly more than one possible answer to a polar question! But we will conceive of the relation between the semantics and the pragmatics of interrogative clauses in a less simple-minded way. This will be spelled out in the next section.

To complete the current section, we consider an alternative question:

(12) Did John see Mary/ or did he see Sue\?[13]

DS: $[\ [_C \mathbf{?\ OP}]\ \ \mathbf{John\ see\ Mary}]\ \mathbf{or}\ [\ [_C \mathbf{?\ OP}]\ \ \mathbf{John\ see\ Sue}]$

LF: $\mathbf{OP}\ \ \mathbf{1}[\ [\ [\mathbf{?\ t_1}]\ \ \mathbf{John\ see\ Mary}]\ \mathbf{or}\ [\ [\mathbf{?\ t_1}]\ \ \mathbf{John\ see\ Sue}]\ ]$

In the alternative question in (12), operator movement must be "across the board" (ATB), with the result that a single binder binds two coindexed traces. This is the only way to obtain an interpretable structure, given the semantic type of **or**, which is <t,<t,t>>.

(13) computation for LF of the alternative question in (12):

$[\![\mathbf{1}.\ [\mathbf{?\ t_1}]\ \ \mathbf{John\ see\ Mary\ or}\ [\mathbf{?\ t_1}]\ \ \mathbf{John\ see\ Sue}]\!]^{w,\ \varnothing}$

= (by Predicate Abstraction)

$\lambda p_{st}\ .\ [\![[\mathbf{?\ t_1}]\ \ \mathbf{John\ see\ Mary\ or}\ [\mathbf{?\ t_1}]\ \ \mathbf{John\ see\ Sue}]\!]^{w,\ [\mathbf{1}\rightarrow p]}$

= (by FA twice and entry for **or**)

$\lambda p\ .\ \ [\![[\mathbf{?\ t_1}]\ \ \mathbf{John\ see\ Mary}]\!]^{w,\ [\mathbf{1}\rightarrow p]} = 1 \vee [\![[\mathbf{?\ t_1}]\ \ \mathbf{John\ see\ Sue}]\!]^{w,\ [\mathbf{1}\rightarrow p]} = 1$

= (by IFA, FA, entry for **?**, etc - see previous computations)

$\lambda p\ [\ p = \lambda w'.\ [\![\mathbf{John\ see\ Mary}]\!]^{w'} \vee\ p = \lambda w'.\ [\![\mathbf{John\ see\ Sue}]\!]^{w'}\ ]$

= (by FA and entries for **see** etc.)

$\lambda p\ [\ p = \lambda w'.\ \text{John sees Mary in } w'\ \vee\ p = \lambda w'.\ \text{John sees Sue in } w']$

This is the characteristic function of a set containing two propositions – the same set, in fact, that is denoted by the constituent question *who did John see* if the set of humans happens to be just

[13] The slashes are intended as a crude representation of the distinctive intonational contour that characterizes the alternative-question reading.

{Mary, Sue}.

2.2. Back to pragmatics: mapping interrogative-denotations to partitions

In the section on pragmatics, we adopted the view that the speech act of asking a question amounts to imposing a partition on the set of worlds compatible with the common ground. The Kartttunen-style compositional semantics that we have now set up does not fit quite seamlessly with this pragmatics. The semantic values that this semantics computes are not the partitions envisaged by Hamblin (1958). In fact, they are generally not partitions at all. This is most glaringly obvious in the case of polar questions. The denotation for the sentence *Did John see Mary?* that we computed above is (the characteristic function[14] of) the singleton set whose sole member is the proposition that John saw Mary. Let's refer to this proposition as p_m and to the singleton as $\{p_m\}$. Now recall the definition of a "partition": A partition of a set A is a set of non-empty subsets of A such that the union of those subsets equals A and no two of those subsets overlap. Clearly $\{p_m\}$ does not qualify as a partition of the set of all worlds W (nor as a partition of any subset of W other than p_m itself). The sets of worlds that are plausible candidates for the context set when this polar question is felicitously uttered will typically include some worlds not in p_m (and hence not in the union of the sets in $\{p_m\}$).

Our semantic values for alternative questions and constituent questions are not partitions of W or of most subsets of W either. Let's illustrate with the question *Who did John see?*, interpreted in a context where the domain of relevant people is Mary, Bill, and Sue, and where there is not yet any information about who saw whom in the common ground. The semantic value that our semantics assigns to *Who did John see?* is (as we have computed) the three-membered set $\{p_m, p_b, p_s\}$, i.e., the set containing the propositions that John saw Mary, that he saw Bill, and that he saw Sue. The context set, on the other hand, includes worlds that are not in the union $p_m \cup p_b \cup p_s$ (namely worlds in which John saw none of the three people). Moreover, the members of $\{p_m, p_b, p_s\}$ overlap with each other, both in W at large and in the context set. For example, p_m overlaps with p_b because there are possible worlds (in the context set) in which John saw both Mary and Bill.

Should we therefore redo our semantics so that it does, after all, map interrogative clauses to semantic values that are partitions? This can be done and has been argued for, and we will return to a discussion of this possibility. For now, however, we observe that it is not necessary. An equally reasonable take on the discrepancy between our semantics and our pragmatics is that it simply reflects the division of labor between semantics and pragmatics. We don't necessarily need a semantics that directly delivers partitions as semantic values. All we need is to make precise how the semantic values delivered by the semantics help determine the partitions that figure in the pragmatics. In other words, we need to formulate our pragmatic rule for "update by question" in such a way that it spells out how the partition effected by a question-act is determined by the semantic value of the uttered sentence. We will work up to this formulation in

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[14] In the remainder of this section, I will equivocate between sets and their characteristic functions. Our official semantics is in terms of functions, but set-talk is more intuitive here. So I talk as if propositions are sets of worlds and functions of type <st,t> are sets of propositions.

a few steps. As we will see, there is a straightforward and general recipe for converting an arbitrary set of propositions into a partition of a given set of worlds, and our update principle will make use of that recipe.

Informally speaking, each proposition in the question-denotation defines a "dividing line" across the space of worlds in the context set, and as we use multiple propositions to draw multiple lines across this space, we get increasingly fine-grained partitions as the number of propositions goes up. The first proposition cuts the space into two regions or "cells" (the region where it is true and the region where it is false). The second proposition subdivides these two cells further into four; the third proposition leaves us with eight cells; and so on.[15]

Another way of describing this process is that each new proposition introduces a new condition that cell-mates must satisfy. At the beginning, before any line has been drawn, all of the context set is one big cell and every world counts as a cell-mate of every other one. Then we draw a line for the first proposition (call it p_1), and if two worlds differ with respect to the truth-value of p_1, they now are no longer cell-mates. w and w' are cell-mates now only if $p_1(w) = p_1(w')$.[16] With the second proposition, p_2, we draw a second line and "break up" yet more of the original cell-mate relations. At this point, only those pairs of worlds remain cell-mates which are treated alike by <u>both</u> p_1 and p_2. I.e., w and w' are cell-mates now iff $p_1(w) = p_1(w')$ & $p_2(w) = p_2(w')$. And so on for the third and all other propositions in the given set of propositions.

So a set of propositions can be used to define a cell-mate relation, and thus a partition.

(14) Let S be a set of propositions and c a set of worlds.

(a) $\sim_{S,c}$, the cellmate relation in c based on S, is defined as follows:
For every w and w': $w \sim_{S,c} w'$ iff $w \in c$ & $w' \in c$ & $\forall p \in S$: $p(w) = p(w')$.

(b) PART(S, c), the partition of c based on S, is defined as follows:
$\text{PART}(S, c) = \{p : \exists w \in c.\ p = \{w' : w \sim_{S,c} w'\}\}$

We can now be fully precise about the relation that holds between the semantic values of interrogative sentences and the partitions that are imposed on the context set when these sentences are used to ask questions.[17]

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[15] This assumes that the propositions are all "logically independent" of each other and of the propositions in the original common ground. I.e., none of them contradicts or is entailed by any other (or any conjunction or disjunction of others). If there are logical relations between the propositions, then the total number of cells is smaller. Note that the definition of "partition" requires all cells to be non-empty, so the intersection of two incompatible propositions is not a cell.

[16] This formulation treats propositions as functions again, not as sets. If we stick to set-talk, we should say: w and w' are cell-mates iff either [$w \in p_1$ & $w' \in p_1$] or [$w \notin p_1$ & $w' \notin p_1$]. Or more concisely: w and w' are cell-mates iff [$w \in p_1 \leftrightarrow w' \in p_1$].

[17] (15) inherits the "wipe-out" feature that Keny Chatain objected to in (4a,b). See footnote 5.

A difference from (4a,b) is that (15) mentions the utterance world. This is necessary because it cannot always be taken for granted that ϕ denotes the same set of propositions regardless of which world it is evaluated in. For example, the restrictor in the lexical semantics of **who** refers to humans *in the evaluation world*, and therefore a **who**-question will denote different sets of propositions in worlds that are inhabited by different sets of humans. As far as these lecture notes are concerned, we disregard this

(15) Update by question:
To ask a question in the utterance world w by uttering a sentence ϕ is to propose that the current partitioned context set C be replaced by the new partitioned context set $\text{PART}([\![\phi]\!]^w, \cup C)$.

(15) subsumes and replaces the two *ad hoc* rules (4a,b) from section 1 above.

Exercise for the reader: Apply (14) and (15) to the examples whose denotations we computed in section 2.1, specifically to the polar question *Did John see Mary?* whose semantic value is the singleton set $\{p_m\}$, and to the constituent question *Who did John see?* whose semantic value (given suitable contextual restriction for *who*) is $\{p_m, p_b, p_s\}$.

2.3. Syntax: the role of the [WH] feature

In the theory as it stands so far, the semantic identification of wh-words with indefinites (e.g. $[\![\textbf{who}]\!]^w = [\![\textbf{somebody}]\!]^w$) leads to overgeneration of readings. Consider the minimal pair in (16).

(16) (a) Who did John see?
(b) Did John see somebody?

We have shown in 2.1 how the Karttunen theory derives the intended denotation for (16a) (=(8)). But from the Deep Structure we posited in (8), we could have derived more than one interpretable structure, namely not just (17a) (which we considered in (8) above) but also (17b).[18]

(17) (a) LF-high: **OP 1[who 7[[? t_1] John see t_7]]**
(b) LF-low: **OP 1[[? t_1] who 7[John see t_7]]**

Similarly we can derive two interpretable LFs for (16b).

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complication. For our examples, we make the simplifying assumption that the set of humans is identical across all the worlds compatible with the common ground. This amounts to assuming that the questioner and his audience already know, or agree on, who the (relevant) humans are. (With polar and alternative questions, the issue does not arise; their semantics does guarantee an evaluation-world-independent set of propositions.)

[18] English has a requirement that wh-phrases must move overtly (unless they are in an interrogative clause in which another wh-phrase is moving overtly). Still, I assume that (17b) could be derived by reconstruction, and so we must worry about it.

As Samia Hesni points out, it is not totally obvious that the mechanisms of reconstruction do allow us to get from (the S-structure of) (16a) to the LF in (17b). This depends on details of how we implement reconstruction in our syntactic theory. It is conceivable – and indeed we might hope at this point – that reconstruction of an overtly moved wh-phrase to a scope position below **?** is simply not syntactically possible. In that case, our overgeneration problem may be less pervasive (though we'd still have to worry about (18a), and also about multiple wh-questions).

Section 4 below, on "pied-piping", will be relevant to this point. As we will argue there, there is independent motivation to assume a reconstruction mechanism that *is* powerful enough to get us from (16a) to (17b). If that is so, then the overgeneration problem does arise in the form that it is stated here.

(18) DS: $[_C$**? OP**$]$ **John see somebody**

(a) LF-high: **OP 1[somebody 7[[? t_1] John see t_7]]**

(b) LF-low: **OP 1[[? t_1] somebody 7[John see t_7]]**

In all of these potential LFs, the IP-sister of C, as well as the mother-node of C, are semantically of type t. Therefore, both should be suitable adjunction sites for the generalized quantifiers **who** and **somebody** as far as type-compatibility goes. (I have used the mnemonic labels 'high' and 'low' to indicate the difference in the quantifier's scope.)

But what do these LFs mean? We have already computed (17a) and seen that it expresses an appropriate meaning for (16a). Specifically, if we combine our semantics with our pragmatics, and if the domain of people that *who* ranges over consists of just Mary and Sue, (17a) determines a 4-cell partition. This matches the intuition that the possible fully exhaustive answers to (16a) are that John saw only Mary, that he saw only Sue, that he saw both Mary and Sue, and that he saw neither. But such a 4-cell partition is clearly *not* what an utterance of (16b) sets up. (16b) is a polar question and elicits answers such as *Yes* or *No*, expressing the propositions that John saw somebody and that he saw nobody. So here we want our semantics and pragmatics to determine a 2-cell partition. The LF-low in (18b) does deliver precisely this. (Compute this as an exercise.)

So LF-high in (17a) captures the attested meaning of the wh-question in (16a), and LF-low in (18b) captures the attested meaning of the polar question in (16b). In each case, this is the only attested reading for the English sentence: the wh-question cannot be read as a polar question, and the polar question cannot be read as a wh-question.[19] Our theory so far fails to derive this un-ambiguity. The LF-low in (17b) is semantically equivalent to the LF-low in (18b) and thus represents an unattested polar reading for the wh-question. Similarly, the LF-high in (18a) is equivalent to the LF-high in (17a) and thus represents an unattested wh-question reading for the polar question with *somebody*. We need to amend our theory so that only one of the LFs is generated for each of the sentences.

A standard solution – effectively Karttunen's (1977) – is to invoke a syntactic constraint that regulates scopal relations between existential DPs (*who*, *somebody*) and the interrogative complementizer. As our example teaches us, **who** apparently can only scope above **?** (more

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[19] We appeal here to intuitions about what constitutes an exhaustive but not an over-informative answer to each of these questions. In real-life dialogues, a greater variety of responses to questions can be felicitous, and this somewhat muddies the distinction between (16a) and (16b). Consider (i) and (ii).

(i) Q: Who did John see?
A: He saw somebody.

(ii) Q: Did John see somebody?
A: He saw Mary.

These dialogues are not incoherent. A speaker may be unable or unwilling to give all the requested information, as in (i); or he may choose to volunteer more information than is strictly asked for, as in (ii). Still, there is a robust intuition that the two questions are not synonymous and that the *who*-question asks for more detailed information than the polar question with *somebody*. We can also sharpen this intuition by comparing the truth conditions of sentences in which such questions are embedded. Consider e.g. *I have forgotten whether I ate something* vs. *I have forgotten what I ate*.

specifically, between **?** and its associated **OP**), whereas **somebody** is barred from scoping there and must instead scope below **?**. The following stipulation enforces this generalization.

(19) Wh-Licensing Principle:
At LF, a phrase α occupies a specifier position of **?** if and only if α has the feature [WH].

(19) relies on appropriate assumptions about which phrases have the feature [WH]. For the time being, assume that certain words such as **who**, **what**, **how** are marked as [WH] in the lexicon. These then will be the only phrases that can be located right above **?** in well-formed LFs, and moreover, they cannot be located anywhere else. LF-high for the wh-question in (17a) complies with (19), as does LF-low for the polar question in (18b). LF-low in (17b) is ruled out because it has a phrase marked [WH] in a location other than spec-of-**?**, and LF-high in (18a) is prohibited because it has a phrase in spec-of-**?** which lacks [WH].

Exercises

(a) Consider the multiple wh-question (20).

(20) Who likes who?

Propose an LF, say how it is derived in the syntax, compute its semantic interpretation, and then compute the partition it imposes. For simplicity, assume in this last part that the domain of people that *who* ranges over is just {j, m}, and that the common ground before the question is totally uninformative, i.e, it is a partitioned context set whose union is W (the set of all worlds whatsoever).[20] How many cells does the partition have and what are its cells? Regarding syntax, attend in particular to the satisfaction of the Wh-Licensing Principle.

(b) In written language, a question containing *or*, such as (21), can be ambiguous.[21]

(21) Did you talk to David or Norvin?

The questioner may want to know which of the two professors you talked to ("alternative-question reading") or just whether you talked to at least one of them ("polar-question reading"). Perhaps the alternative reading is more salient out of the blue, but the polar reading can be facilitated by an appropriate context. (E.g. imagine that your squib is on multiple-wh-constructions, and I have previously told you that you ought to consult a faculty member who has published on this topic, namely David or Norvin.)

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[20] A question like (20) is often, maybe almost always, understood in the sense of 'who likes who else?', i.e., in such a way that the speaker is taken not to be interested in which people like themselves. To capture this reading, our LF would have to include a covert restrictor on the second *who*, effectively equivalent to *else*, i.e., meaning 'other than x', where the variable x is bound by the first *who*. If no such restrictor is included, the meaning of the question will include propositions about self-liking as well as propositions about other-liking.

For the purpose of the homework, feel free to analyze either the 'who else' reading or the unrestricted one, but be sure to assume the appropriate LF for your choice.

[21] In spoken language, prosody will usually, perhaps always, disambiguate.

Your task in the exercise is to analyze the two readings of (21), by proposing an appropriate LF for each reading and discussing its syntactic derivation as well as its semantic and pragmatic interpretation. You should assume that English has only one unambiguous word **or**, and its semantic type is $<t,<t,t>>$. This means that, for both readings, you must posit some amount of elided material in the right disjunct, since **or** can only coordinate constituents of type t.

3. Embedded questions and question-embedding verbs

A first superficial survey of English verbs that take complement clauses turns up three groups.[22] One group, exemplified by the verb *believe*, consists of verbs that take *that*-clauses but are ungrammatical with an embedded interrogative clause.

(1) (a) John believes that Ann called.
    (b) *John believes who called.

Another rather large second group consists of verbs that can take either. This includes *know*, *remember*, and *tell*.

(2) (a) John knows/remembers/told Mary that Ann called.
    (b) John knows/remembers/told Mary who called.

Third, there are verbs which take interrogative complements but are ungrammatical with *that*-clauses.

(3) (a) *John asked/is wondering that Ann called.
    (b) John asked/is wondering who called.

We will focus at first on the middle group, which Lahiri (2002) dubbed the class of "responsive" verbs.

3.1. Responsive verbs, a type-mismatch, and Dayal's strategy

Let's look at the responsive verb *know*. From earlier in the semester, we have at least a preliminary analysis for verbs like *know* in sentences like *John knows that Ann called*. Such verbs take a proposition and a person as their arguments, and their meaning encodes universal quantifcation over a certain set of possible worlds. Since *know* is a factive verb, it also triggers the presupposition that its complement is true. For simplicity, we assume here that apart from the factive presupposition, the meaning of *know* is the same as the meaning of *believe*, and so we can write the lexical entry in (4).

(4) $[\![\textbf{know}]\!]^w = \lambda p_{<s,t>}: p(w) = 1.\ \lambda x_e.\forall w'$ [w' conforms to x's beliefs in w $\rightarrow$ p(w') = 1]

This entry was designed to work for *know* with *that*-clause. What would happen if we tried to

[22] This classification abstracts away from the observation that not every verb that is grammatical with *some* interrogative complements is grammatical with *all* of them. E.g., there are verbs that take *who*-complements but not *whether*-complements, and vice versa.

interpret an LF with an interrogative clause as the sister of *know*? Evidently, we would run into a type-mismatch. On our current analysis of interrogative clauses, their extensions are of type <st,t> and their intensions of type <s,<st,t>>. Neither type can compose with the type of *know* in (4) by means of any of our semantic rules.

What shall we do? Older literature on question-embedding made verbs like *know* lexically ambiguous, with distinct (though not unrelated) lexical entries for declarative-taking *know* and interrogative-taking *know*. More recent work has pursued the strategy of positing a single unambiguous verb and readjusting the semantic type of the interrogative complement. Groenendijk & Stokhof (1982) did this first, and another influential version of this approach originates with Dayal (1996). Dayal proposed that the combination of the verb with the Karttunen-denotation of its complement is mediated by an "answer operator", which maps sets of propositions to propositions. We will follow Dayal's general strategy in these notes. We will entertain a couple of possible meanings for the answer operator and talk about the empirical considerations that bear on the question which meaning is correct.

The rough intuition to be implemented is that "to know who called" means something like "to know the answer to the question 'who called?'". (Paraphrases of this form work for all the verbs in this group, hence Lahiri's term "responsive verbs".) The answer to a question is a proposition, hence an object of a suitable semantic type to feed to the meaning of *know* in (4). If the LFs of sentences like (2b) contain an operator that maps a question-denotation to the proposition that's the answer to that question, we have a solution to the type-mismatch problem.

Since our syntax for interrogative clauses already happens to posit a silent operator at the top edge of the clause (albeit one that we have so far treated as semantically vacuous) we need not actually make the structure more complex. Instead we can assume (following a suggestion by Danny Fox) that our new answer operator appears *instead* of the previous vacuous one.[23] This means that we base-generate it inside C as the sister of **?** and move it up for interpretability, leaving a type-<s,t> trace as before. Our LF-structure for a sentence with *know* and an interrogative complement then looks as in (5b).

(5) (a) John knows who called.

(b) **John** $[_{VP}$ **knows** $[_{CP}$ **ANS** 1[**who** 2[$[_{C}$**?** $t_1]$ t_2 **called**]]]]

We will now focus on the task of proposing a meaning for **ANS** which not only fixes the type-mismatch, but also yields reasonable truth conditions for the *know*-sentence.

3.2. An ANS operator inspired by Karttunen

Our initial proposal for the semantics of **ANS** effectively follows Karttunen (1977) in terms of the truth conditions it predicts for the *know*-sentence as a whole (although the compositional

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[23] This raises a question: Do we mean to replace the vacuous **Op** by the new **ANS** *everywhere* – i.e., in matrix interrogatives as well as in embedded ones, and in *all* embedded interrogatives, regardless of the higher verb? Or is **ANS** generated only in the complements of responsive verbs, whereas interrogative clauses in other environments have operators different from **ANS**? For the moment, we are only talking about responsive verbs, and we postpone this broader question until section 3.4. below.

implementation is different). The **ANS** operator defined in (6) maps the set of propositions denoted by the interrogative to the single proposition which is the conjunction of all its true elements.

(6) $[\![\textbf{ANS}]\!]^w = \lambda Q_{<st,t>}.\ \lambda w'.\ \forall p\ [Q(p) = 1\ \&\ p(w) = 1 \rightarrow p(w') = 1]$

(6') equivalent formulation (modulo sets vs. characteristic functions)
$[\![\textbf{ANS}]\!]^w = \lambda Q_{<st,t>}.\ \cap\{p \in Q\text{: } w \in p\}$
(the intersection of all members of Q which are true in w)

Let's put this entry to work in a computation for the example sentence.

(7)(a) computation of presupposition:
Let w be a world. Then
$[\![(5b)]\!]^w$ is defined
iff (by FA twice[24])
$[\![\textbf{know}]\!]^w\ ([\![\textbf{ANS}\ 1.\ \textbf{who}\ 2.\ \textbf{?}\text{-}t_1\ \ t_2\ \textbf{called}]\!]^w)\ (j)$ is defined
iff (by entry (4) for **know**)
$[\![\textbf{ANS}\ 1.\ \textbf{who}\ 2.\ \textbf{?}\text{-}t_1\ \ t_2\ \textbf{called}]\!]^w(w) = 1$
iff (by FA)
$[\![\textbf{ANS}]\!]^w\ ([\![1.\ \textbf{who}\ 2.\ \textbf{?}\text{-}t_1\ \ t_2\ \textbf{called}]\!]^w)(w) = 1$
iff (by entry (6) for **ANS**)
$\forall p\ [\ [\![1.\ \textbf{who}\ 2.\ \textbf{?}\text{-}t_1\ \ t_2\ \textbf{called}]\!]^w(p) = 1\ \&\ p(w) = 1 \rightarrow p(w) = 1]$
This is a tautology, so we know that $[\![(5b)]\!]^w$ is defined for all w.

(7)(b) computation of truth condition:
Let w be a world. Then
$[\![(5b)]\!]^w = 1$
iff (by FA twice)
$[\![\textbf{know}]\!]^w\ ([\![\textbf{ANS}\ 1.\ \textbf{who}\ 2.\ \textbf{?}\text{-}t_1\ \ t_2\ \textbf{called}]\!]^w)\ (j) = 1$
iff (by entry for **know**, and given truth of presupposition)
$\forall w'\ [w'$ conforms to j's beliefs in $w \rightarrow [\![\textbf{ANS}\ 1.\ \textbf{who}\ 2.\ \textbf{?}\text{-}t_1\ \ t_2\ \textbf{called}]\!]^w(w') = 1]$
<u>embedded computation</u>: $[\![\textbf{ANS}\ 1.\ \textbf{who}\ 2.\ \textbf{?}\text{-}t_1\ \ t_2\ \textbf{called}]\!]^w(w') = 1$
iff (by entry for **ANS**)
$\forall p\ [[\![1.\ \textbf{who}\ 2.\ \textbf{?}\text{-}t_1\ \ t_2\ \textbf{called}]\!]^w(p) = 1\ \&\ p(w) = 1 \rightarrow p(w') = 1]$

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[24] Observe that the mother node of *know* is interpreted by plain Functional Application (not by Intensional Functional Application, which would have applied if *know* were taking a *declarative* complement). This is because the <u>*ext*</u>*ension* of the constituent headed by **ANS** is of type <s,t>. (Related to this point: Mitya Privoznov asked whether the answer operator could have been of the simpler type <<st,t>,t>, rather than type <<st,t>,st> as it is in (6). As far as avoiding type-mismatch, the simpler type could have served. But I bet you cannot define a concrete function of this type that generates viable truth conditions.)

iff (by computations in earlier section)

$\forall p\ [\exists x[x \text{ is a human in } w\ \&\ p = \lambda w''.\ x \text{ called in } w'']\ \&\ p(w) = 1 \rightarrow p(w') = 1]$

iff (by logic of quantifiers)

$\forall p \forall x\ [x \text{ is a human in } w\ \&\ [p = \lambda w''.\ x \text{ called in } w'']\ \&\ p(w) = 1 \rightarrow p(w') = 1]$

iff (by logic of identity)

$\forall x\ [x \text{ hum in } w\ \&\ [\lambda w''.\ x \text{ called in } w''](w) = 1 \rightarrow [\lambda w''.\ x \text{ called in } w''](w') = 1]$

iff (by λ-reduction)

$\forall x\ [x \text{ is a human in } w\ \&\ x \text{ called in } w \rightarrow x \text{ called in } w']$

end of embedded computation

resuming main computation:

...... iff (by plugging in result of embedded computation)

$\forall w'\ [w' \text{ conforms to j's beliefs in } w \rightarrow$
$\quad \forall x\ [x \text{ is a human in } w\ \&\ x \text{ called in } w \rightarrow x \text{ called in } w']]$

iff (by logic of quantifiers)

$\forall x\ [x \text{ is a human in } w\ \&\ x \text{ called in } w \rightarrow$
$\quad \forall w'\ [w' \text{ conforms to j's beliefs in } w \rightarrow x \text{ called in } w']]$

In other words, the sentence *John knows who called* is true in w if and only if, for every person who in fact called in w, John believes (in w) that this person called.

3.3. Problems, and an ANS operator inspired by Groenendijk & Stokhof

The present analysis is well known to make some troublesome predictions. Let's start with the most glaring case, then move to subtler ones, before we diagnose the general problem and proceed to solve it.

The example we analyzed above involved an embedded constituent question. What if we embedded a *polar* question instead?

(8) (a) John knows whether Ann called.

(b) LF: **John knows** $[_{CP}$ **ANS** 1[$[_C$**?** $t_1]$ **Ann called**]]

Recall that our denotation for a polar question is a singleton set. The sister of **ANS** in (8b) denotes the set whose only member is the proposition that Ann called. If we complete the calculation, we get the following truth condition.

(9) presupposition of (8b): tautological

$[\![(8b)]\!]^w = 1$ iff

Ann called in $w \rightarrow \forall w'\ [w' \text{ conforms to j's beliefs in } w \rightarrow \text{Ann called in } w']$

This says that the sentence (8a) is true in w if either one of the following two conditions is met: either (i) Ann did not call in w, or else (ii) she did call in w and John believes in w that she did. This is not satisfactory. What it gets right is that, if Ann called but John is unaware of this, then the sentence is false. But it also predicts that, if Ann didn't call, then the sentence is true no matter what John believes – even if he wrongly believes that she did call.

A gut reaction to this problem is that the culprit is our semantics for polar questions, not our **ANS** operator. This is what Karttunen would have said. Indeed, he gave a different semantics for polar questions and did not have this problem. In our variant of his theory, if we minimally changed[25] the semantics of polar questions so that the sister of **ANS** were to denote the 2-membered set {that Ann called, that Ann didn't call}, the truth conditions would come out correct without any revision to entry (6). (Exercise: Convince yourself of this.) This looks like a good way out – at least at first. But when we look at further problem cases, we will come to see it is a move that is neither sufficient nor necessary.

Let's return to the case of the embedded constituent question in (5) and scrutinize the truth conditions we derived in (7) a bit more carefully. Suppose that w is a world in which nobody called. Then the universal quantification we computed in (7b) is trivially true: Whatever John's beliefs in w may be, the material conditional '[x called in w $\rightarrow$ John believes in w that x called]' is true for every x (since the antecedent is always false). So the sentence (5a) is predicted true, for example, in a world where nobody called but John falsely believes that Ann and Mary called. This does not conform to our intuitions.[26,27]

Finally, as Groenendijk & Stokhof (1982) forcefully pointed out, even if we only consider worlds in which some people did in fact call, the truth conditions imposed by our current (and Karttunen's) semantics are too lax. Suppose that only Mary called, but John thinks that Mary, Sue, and Ann all called. Would we say that John knows who called? We'd be reluctant to. But our semantics deems the sentence *John knows who called* to be true in this scenario. After all, John does believe of every person who in fact called (namely, of Mary), that that person called.

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[25] How might we do that? Perhaps by giving a meaning to *whether*, letting it denote a function that maps a singleton set {p} to the set {p, ¬p}.

[26] Karttunen (1977) noticed this problem in a footnote, and fixed it by complicating his lexical entry for interrogative-taking *know*. He ended up stating the truth condition in the form of a disjunction, with a special clause for the case where the question-denotation only contains false propositions. Heim (1994) showed how to generalize Karttunen's special clause to a general solution for all the problem cases we consider in this section. The solution we will present in these lecture notes is not quite the same as Heim's. See papers by Beck & Rullmann (SALT 1998, NALS 1999), Sharvit (NALS 2002), and Sharvit & Guerzoni (Amsterdam Colloquium 2003) for discussion and comparison.

[27] Some researchers have claimed that every constituent question has an existence presupposition, e.g. *who called?* presupposes that somebody called. Suppose this is correct, and we amend the present theory so that it generates this presupposition. Then the sentence *John knows who called* will not be predicted to be true in the scenario where nobody called and John falsely believes that Ann and Mary called. Rather, it will be truth-value-less (a presupposition failure) in this scenario. This prediction fits intuitive judgment better (especially bearing in mind that the theoretical distinction between falsity and lack of truth value may not match up cleanly with pretheoretical usage of the predicate 'false'). Notice, however, that this theory will also predict that the sentence is truth-value-less in a scenario in which nobody called and John *knows that nobody called*! In other words, this amended theory still predicts that when nobody called, John's beliefs make no difference one way or the other to the truth value of the sentence *John knows who called*. This does not seem right. Even if you judge the sentence somehow misleading and not fully felicitous when the putative existence presupposition is not met, you probably are more inclined to call it true than false if John knows that nobody called, and more inclined to call it false than true if John falsely believes that some people called.

This is all that our predicted truth conditions require. If our analysis were right, it simply shouldn't matter how many false beliefs John has about people calling who did not in fact call.

Groenendijk & Stokhof argued that the correct semantics for *John knows who called* is what they dubbed "strongly exhaustive" – i.e., the *know*-sentence is true only when John is fully informed about who called and who didn't. He believes that they called of all the people who did in fact call, and he believes that they didn't call of all the ones who didn't.

Can we revise our entry for the answer operator so that it delivers this more stringent truth condition? Yes, here is how.

(10) strongly exhaustive answer operator:
$[\![\textbf{ANS}]\!]^w = \lambda Q_{<st,t>}.\ \lambda w'.\ \forall p\ [\ p \in Q\ \rightarrow\ p(w) = p(w')\ ]$

(10') equivalent formulation, using the definition of "cell-mate" from (14a) in section 2.2:
$[\![\textbf{ANS}]\!]^w = \lambda Q_{<st,t>}.\ \{w':\ w' \sim_{Q,W} w\}$
(where capital W in the subscript is the set of all possible worlds)

This new semantics solves all the problems that we saw in this section. For embedded polar questions, it delivers the prediction that if Ann didn't call, then *John knows whether Ann called* is only true if John knows that Ann didn't call. For embedded constituent questions, it predicts that if x didn't call, then *John knows who called* is not true unless John knows that x didn't call. As a special case of this latter prediction, we derive that if nobody called, then *John knows who called* is only true if John knows about each person that they didn't call.

Exercise: Verify these claims, by doing the computations.

3.4. Matrix questions, embedding under rogative verbs

Our latest, strongly exhaustive answer operator bears an obvious logical relation to the pragmatic rule "update by question" that we posited earlier to link the semantic values of matrix interrogative clauses to the speech acts that they serve to perform. In fact, our theory now has the unappealing feature that it encodes some of the same formal operations in two separate modules, in the pragmatics and in the lexical semantics of **ANS**. We can eliminate this duplication and simplify the pragmatics if we posit that the **ANS** operator is present in the LFs of matrix questions as well. The pragmatic rule then can use the intension of the uttered sentence to construct the cells of the new partition. (The recipe, informally, is to apply this intension to each world in the current context set and intersect each result with the current context set.)

(11) Update by question (revised from (15) in section 2.2)
To ask a question by uttering a sentence ϕ is to propose that the current partitioned context set C be replaced by the new partitioned context set
$\{p: \exists w \in \cup C.\ p = [\![\phi]\!]^w \cap \cup C\}$,
provided that $[\![\phi]\!]^w = [\![\phi]\!]^{w'}$ for any two w, w' $\in \cup C$. Otherwise update is undefined[28].

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[28] The qualification in the last line is necessary because of the issue that I mentioned in footnote 18 in section 2.2. When this proviso is not met, the set defined in (11) is typically not a partition at all. Intuitively, the proviso again encodes the assumption that for each wh-phrase that is used, the

Access to the *in*tension of the LF headed by **ANS** also figures plausibly in the semantics of sentences with non-responsive ("rogative") question-embedders, such as the verbs *ask* and *wonder*. These verbs have lexical meanings that suggest rough paraphrases in which *know* or *tell* is in the scope of another intensional operator, e.g., *ask* = 'request to be told', *wonder* = 'want to know'. Following Groenendijk & Stokhof, let's hypothesize that these verbs differ in semantic type from responsive verbs. Their (internal) argument is of type <s,<s,t>> rather than <s,t>. A concrete entry for *wonder* along these lines is (12).

(12) $[\![\textbf{wonder}]\!]^w = \lambda q_{<s,<s,t>>}.\ \lambda x_e.$
$\forall w'$ [w' conforms to x's desires in w $\rightarrow$
$\forall w''$ [w" conforms to x's beliefs in w' $\rightarrow q(w')(w'') = 1$]]

The higher semantic type straightforwardly gives us the prediction that *wonder* cannot combine with a *that*-clause. If we attempted to interpret such an LF, we would encounter a type-mismatch. A *that*-clause has an extension of type t and an intension of type <s,t>. Whether we used plain FA or IFA, we wouldn't obtain the type-<s,st>-function that *wonder* is looking for.[29] But if we embed an interrogative clause (headed by **ANS**) under *wonder*, we will succeed. The *ex*tension of the mother-node of **ANS** is type <s,t>, and its *in*tension is type <s,st>. So IFA allows us to interpret the structure.

Exercise: Convince yourself that, given entry (12), the predicted truth condition for *John wonders who called* matches the informal paraphrase that I gave in the text.

3.5. Predictions about veridicality

Returning again to responsive verbs, there is a prediction of the current analysis that Karttunen highlighted as interesting and empirically correct.[30] This prediction has to do with what is called "veridicality". A rough definition of this term for our purposes is (8).

(13) A verb *V* is veridical iff 'x *Vs* ϕ' entails 'x *Vs* something true'.

It says 'entail' in (13), not 'presuppose', but we count presupposition as a special case of entailment. This being so, a factive verb like *know* is *ipso facto* veridical. 'x knows that S' entails both that S is true and that x believes that S, and therefore it entails that x knows something true.

Now ϕ in (13) was not specified to be a declarative complement (*that*-clause), so in principle we

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interlocutors agree on a specific set of individuals as its intended range.

[29] As Maša Močnik pointed out, this prediction may be rather specific to Heim & Kratzer's rule system, and might be lost if their IFA rule were replaced by a different mechanism for resolving the *prima facie* type-mismatch between intensional verbs and their complements.

[30] Actually, of course, Karttunen was talking about his own analysis, not the one with the strongly exhaustive answer-operator. The prediction we'll be talking about is made by both the latter (= our current) analysis and by Karttunen's own analysis as he actually worked it out in Karttunen (1977) – including his special treatment of polar questions and his disjunctive truth-condition for interrogative-taking *know*. The latter two ingredients are crucial here. Our own, simpler, variant of Karttunen's approach, in section 3.2, does *not* exactly make the prediction under consideration. (You should think about why this is so. But first, of course, I have to tell you what prediction I am talking about.)

can apply the definition also to interrogative-taking verbs. Specifically, we can ask whether a verb that occurs with both types of complements will always behave identically with respect to veridicality, whether we restrict ϕ to declarative or to interrogative complements. The answer to the latter question, as Karttunen pointed out, appears to be 'no'.

Some verbs do qualify as veridical in both their uses. *know* is an example. *know* with *that*-clause is veridical because it is factive. And *know* with *wh*-clause also passes the test, since 'x knows who called', 'x knows whether Ann called', and so on mean that x knows the true(!) answer to the embedded question. This is so both as a matter of intuitive judgment and as a formal prediction of our theory.[31] But consider another responsive verb, the verb *tell*. *tell* is not factive nor veridical when it takes *that*-clauses. Consider: "*He lied to me! He told me that he was divorced, when in fact he was still married*." On the other hand, if we apply the test in (13) to *tell* + interrrogative, it seems to be veridical. As Karttunen observed, "*John told me how old he was*" conveys that John told me the truth about his age.

This turns out to be precisely what our current analysis predicts. A responsive verb that does not presuppose or (otherwise) entail the truth of its argument according to its lexical meaning still will be veridical when it embeds a question. The reason for this prediction is not mysterious: the **ANS** operator, by definition, picks out a proposition that is true in the evaluation world (i.e., in the same world in which we evaluate the embedding verb).

Unfortunately, the full range of data regarding veridicality turns out to be more nuanced than it appeared on superficial inspection and ends up not supporting our current semantics for the answer operator. A few responsive predicates, such as *be certain* and *agree*, are clearly not veridical in either their declarative-embedding or their interrogative-embedding uses.

(14) (a) John is certain that Ann called. (But he is wrong.)
(b) John is certain (about) who called. (But he is wrong.)

(15) (a) John agrees with Bill that Ann is qualified. (But they are both wrong.)
(b) John agrees with Bill on who is qualified. (But they are both wrong.)

Moreover, Egré & Spector (2014) have recently argued that even *tell* and other communication verbs were not really described correctly by Karttunen (1977). Egré & Spector claim that these verbs are always ambiguous between a factive and a non-veridical reading, and in suitable pragmatic contexts they can be read as factive when combined with a *that*-clause, and as non-

[31] It may be worth pointing out that it can be misleading to describe interrogative-taking *know* as 'factive', at least if this is meant as a theory-neutral description of the data. As we formally computed in (7a) in section 3.2 – and as you also found in 3.3 if you did the computations assigned in the exercise – sentences with *know* and interrogative complement do not have any presupposition. (Technically, they presuppose a tautology, but that is what it means not to presuppose anything.) So if factivity is by definition a matter of presupposition, one should not call these constructions 'factive'. Our Dayal-style compositional analysis, of course, commits us in the end to say that the <u>verb</u> *know* <u>is</u> factive. There is only one unambiguous verb *know* in our lexicon, after all, and if we don't write factivity into its lexical entry, we fall short of predicting the judgments about *know-that* sentences. Our analysis in fact explains exactly how and why the combination of *know* with its interrogative complement gives rise, despite the lexical factivity of *know*, to a non-presuppositional sentence.

veridical when combined with a *wh*-clause. In fact, Egré & Spector argue for a new descriptive generalization, namely that a responsive verb is veridical with declarative complements if and only if it is veridical with interrogative complements. See their paper and Uegaki (2015) for discussion.[32] These authors also offer formal theories designed to capture the amended empirical generalization. Egré & Spector, for example, effectively replace our current answer operator by one that maps the question denotation not to a particular proposition, but to an existential quantifier over propositions. Their proposal, in a nutshell, is that '*x Vs who called*' is true in w iff *there is some world* w' such that the *V*-relation holds in w between x and ⟦**ANS who called**⟧$^{w'}$ (where **ANS** is the strongly-exhaustive answer operator from entry (10).)

We will leave the discussion of question-embedding predicates in this preliminary state, and will now return to issues in the *internal* semantic structure of the interrogative clause.

4. Wh-movement with pied-piping and reconstruction

As an example of the phenomenon of so-called pied-piping, we will analyze the sentence *How many cats did you adopt?* Before we get to the point that makes the example interesting for our purposes, we must fill in a rudimentary account of plurals and gradability.

4.1. Background on plurals and *many*

The basic idea in most current semantic treatments of plural DPs is that plural definites and pronouns denote entities in D_e, just like singular definites, pronouns, and proper names. The only difference is that the entities denoted by plurals are more complex (and typically spatially discontinuous). A distinction is made within the domain D_e, between so-called “atoms” or “atomic individuals” (the referents of singular DPs) and “pluralities” or “non-atomic individuals” (the referents of plural DPs). Non-atomic individuals contain atomic individuals as (proper) parts; e.g., if John is one of the boys, then ⟦**John**⟧ (i.e., John) is an atomic part of ⟦**the boys**⟧. An atomic individual, on the other hand, has no atomic parts other than itself. (An atom counts as an atomic part of itself.)

Given that D_e contains pluralities along with atoms, predicate extensions of type <e,t> are functions that apply to both atoms and pluralities. In the case of common nouns, English has a morphological number distinction which seems to have semantic import:

(1) (a) ⟦**cat**⟧^{w} = λx. x is a cat in w
(b) ⟦**cats**⟧^{w} = λx. every atomic part of x is a cat in w

Being a cat entails being an atomic individual (this is how we agree to understand our metalanguage). Therefore, the denotation of the singular noun as defined in (1a) maps every plurality to 0. The pluralized noun in (1b), on the other hand, maps to 1 those pluralities whose atomic parts are all cats.[33]

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[32] Uegaki also offers an explanation for why the *preferred* readings in each case pattern with Karttunen's original description.

[33] Notice that an entity that ⟦**cats**⟧^{W} maps to 1 is not *necessarily* a plurality. As interpreted in (1b), the

Verbs can show morphological number too, but we assume that this is always due to morphological agreement with a number-marked subject, and that the number morphology on the verb is not interpreted itself. As far as semantics is concerned, verbs are "number neutral" and typically can be true indiscriminately of both atoms and pluralities. This is reflected, for example, in a lexical entry like (2).

(2) $[\![$**meow**$]\!]^w = \lambda x$. every atomic part of x meows in w

The condition in (2) can be met by both pluralities and atoms. A plurality is mapped to 1 iff all its atomic parts meow, and an atom is mapped to 1 if it itself meows. (Recall that every atom counts as an atomic part of itself.)

We can count the atomic parts of a plural individual. For example, the plural individual composed of John, Mary, and Bill has 3 atomic parts. Let's have a concise notation for this.

(3) Let x be an element of D. Then
$\#(x) :=$ the cardinality of the set {y: y is an atomic part of x}.

With this little bit of plural semantics in place, we can now introduce Hackl's[34] semantics for *many* and an appropriate semantics for interrogative *how* that will go with it. Hackl proposes that *many* is not by itself a quantificational determiner of type <et,<et,t>>. Rather it is looking for an argument which denotes a number, and only after it has been saturated with such an argument, the resulting phrase is a quantificational determiner. So the type of *many* is type <e,<et,<et,t>>> – assuming that numbers are abstract individuals of some kind, hence members of D_e – and its entry is as in (4).[35]

(4) $[\![$**many**$]\!] = \lambda n$: n is a number. $\lambda f_{<e,t>}. \lambda g_{<e,t>}. \exists x\, [\#(x) = n \;\&\; f(x) = 1 \;\&\; g(x) = 1]$

When building a sentence with *many*, in the simplest case we would fill the first argument slot of *many* with a word that refers to a number. This might be an anaphoric demonstrative pronoun *that*, which in appropriate discourse contexts can refer to a previously mentioned number, say the number 3. Or it could be a numeral word, like *three*, which we take here to have a meaning of type e and be a proper name of the number 3. These options give us interpretable syntactic representations like (5a,b).

(5) (a) [[**that$_7$ many**] **cats**] **meowed**
(b) [[**three many**] **dogs**] **barked**

---

plural noun **cats** is also true of a single cat, because of the fact that an atom is an atomic part of itself. It would be possible to revise (1b) so that it requires x to be non-atomic. But as we will see below, the current formulation actually works better. The reason is, in a nutshell, that "One." is a perfectly good answer to a *how-many* question.

[34] M. Hackl (2001) Comparative Quantifiers, MIT PhD thesis.

[35] Actually, Hackl assumes (with most of the literature on adjectives and gradability) that there is an additional basic type d (for "degrees") separate from type e. The number argument of *many* is a special case of a degree argument, and the type for *many* is then <d,<et,<et,t>>>.

Hackl's analysis implies that the superficially simplest uses of *many*, as in *Many cats meowed*, are actually more complex at LF: the argument position of *many* is bound by a covert **POS** ("positive operator"), which is a quantifier over numbers (degrees) and means something like 'a number (degree) above the contextually specified threshold'.

(5a) is straightforwardly pronounced as it stands, whereas for (5b), Hackl assumes that *many* is unpronounced after numeral words, so this structure surfaces as *Three dogs barked*. Let us compute truth-conditions, using (4). Suppose we have a contextually given assignment for (5a) which maps the variable **7** to the number 3, and we evaluate the sentence in the actual world @. Then, by using FA three times to apply ⟦**many**⟧ to its three arguments, we obtain the truth-condition in (6).

(6) $\exists x\ [\#(x) = 3\ \ \&\ [\![\textbf{cats}]\!]^{@}(x) = 1\ \ \&\ [\![\textbf{meow}]\!]^{@}(x) = 1]$

Now we use our entries for **cats** and **meow**, and this becomes (7).

(7) ∃x [#(x) = 3
& every atomic part of x is a cat in @
& every atomic part of x meows in @]

In other words, there is a plurality composed of three meowing cats.

4.2. *How-many* questions[36]

In a *how-many* question, the argument slot that was saturated by *that* or *three* in (5) is instead occupied by the wh-word *how*. In Karttunen's theory, this will be an existential quantifier, equivalent to *some number*.

(8) $[\![\textbf{how}]\!] = \lambda f_{<e,t>}.\ \exists n\ [n \text{ is a number}\ \ \&\ \ f(n) = 1]$
(type <et,t>, i.e., a generalized quantifier[37])

This semantic type is not interpretable *in situ* as the sister of *many*, and must undergo (covert) movement for interpretability. With this in mind, let's attempt a syntactic derivation for the question *How many cats did you adopt?*

(9) base-generate: (a) $[_C$ **? OP**] [**you adopted how many cats**]
operator movement: (b) **OP 5**[[**? t_5**] [**you adopted how many cats**]]
overt movement to Spec of C: (c) **OP 5**[**how many cats 1**[[**? t_5**] **you adopted t_1**]]
covert movement of **how**: (d) **OP 5**[**how 2**[**t_2 many cats 1**[[**? t_5**] **you adopted t_1**]]]

We can check the semantic types to confirm that we have derived an interpretable structure (do this as an exercise). Let's compute what (9d) means. (The details are left as an exercise. Here I conflate sets of propositions with their characteristic functions.)

(10) $[\![(9d)]\!]^{@} =$
.....
$= \{p\!: \exists n\ [n \text{ is a number}\ \ \&\ \ \exists x\ [\#(x) = n\ \ \&\ \ [\![\textbf{cats}]\!]^{@}(x) = 1$
$\&\ \ p = \lambda w.[\![\textbf{adopt}]\!]^{w}(x)(\text{you})]]\}$

With a little bit of Predicate Logic reasoning[38], we can rewrite this equivalently as follows:

---

[36] The main source for the argument in this section is A. v. Stechow's paper "Against LF pied-piping," *Natural Language Semantics* 2006.

[37] For Hackl, it would be type <dt,t>, a generalized quantifier over degrees.

[38] We are exploiting the equivalence of various scopal arrangements in a formula with existential

(11) $\{p: \exists x\ [\underline{\exists n[n \text{ is a number } \& \ \#(x) = n]} \ \& \ [\![\mathbf{cats}]\!]^{@}(x) = 1 \ \& \ p = \lambda w.[\![\mathbf{adopt}]\!]^{w}(x)(you)]\ \}$

We can now contemplate the part that I have underlined and convince ourselves that this part is a tautology. It just says that x has some number or other of atomic parts, which cannot fail to be true. So we might as well drop this conjunct and rewrite (11) as (12).

(12) $\{p: \exists x\ [\ [\![\mathbf{cats}]\!]^{@}(x) = 1 \ \& \ p = \lambda w.[[\![\mathbf{adopt}]\!]^{w}(x)(you)]\ \}$

Interestingly now, this is precisely the meaning we would have derived for the question *Which cats did you adopt?* In other words, if (9d) really were the LF (or one of the LFs) for the *how-many*-question *How many cats did you adopt?*, then we would be making the bad prediction that this question is synonymous with (or at least shares a reading with) the *which*-question *Which cats did you adopt?* This would be unfortunate for our theory.

Upon closer inspection of (9d), however, it turns out that our theory does not actually generate this LF. We have neglected to check whether (9d) conforms to the Wh-Licensing Principle, repeated here.

(13) At LF, a phrase α occupies a specifier position of **?** if and only if α has the feature [WH].

In (9d), we have two phrases that are scoped above **?**, namely **how** and **t_2 many cats**. Let's say that the positions they occupy both count as specifier positions of **?** (similar to what one has to say for multiple questions like *who ate what?* – see your homework). Then (13) would require that both of these phrases have the feature [WH]. But only **how** actually does, at least on our current assumption that [WH] is a lexical property possessed by only a small set of words. The other phrase that is scoped above **?** in (9d) is [**t_2 many cats**], which does not carry the feature [WH]. So the structure (9d) is filtered out by the Wh-Licensing principle as syntactically ill-formed. And this is a good thing, because it means we don't generate the unwelcome reading in (12).

We still have to worry, however, about how we generate the reading that our example actually does have. Is there a second, well-formed, LF for our example? The answer is yes if our syntax allows for "reconstruction", i.e. some mechanism by which overtly moved phrases can be restored to (one of) their pre-moved positions at LF. In order to satisfy the Wh-Licensing Principle, reconstruction must apply to the phrase [**t_2 many cats**] (though not, of course, to **how**). Where can this phrase be reconstructed to? Well, if we restored it all the way down to its original base position as the object of *adopt*, it wouldn't be interpretable there, because quantifiers are not interpretable in object positions. But if we can assume that wh-movement proceeds (or at least is allowed to proceed) successive cyclically, and that an object wh-phrase can stop over e.g. at the edge of VP before it moves on to Spec-CP, we can target this

---

quantifiers and conjunctions. The following four are all equivalent.

$\exists x[Fx \ \& \ \exists y[Rxy \ \& \ Gy]]$
$\exists x\exists y[Fx \ \& \ Rxy \ \& \ Gy]$
$\exists y\exists x[Fx \ \& \ Rxy \ \& \ Gy]$
$\exists y[\exists x[Fx \ \& \ Rxy] \ \& \ Gy]$

intermediate landing site for reconstruction. (Assuming the VP-internal subject hypothesis, VPs are semantically of type t and hence quantifiers are interpretable at their edges.) By means of reconstruction, we can thus obtain another LF that is both interpretable and in compliance with the WH-Licensing principle.

(14) **OP 5[how 2[$[_C$? $t_5]$ t_2 many cats 1[you adopted t_1]]**

The denotation of (14) (which you should compute as an exercise!) is (15).

(15) $\{p: \exists n$ [n is a number &
$p = \lambda w.\ \exists x\ [\#(x) = n\ \ \&\ [\![\textbf{cats}]\!]^w(x) = 1\ \&\ \ [\![\textbf{adopt}]\!]^w(x)(you) = 1]\ ]\}$

This set contains one proposition per number. It contains the proposition that you adopted 1 cat, the proposition that you adopted 2 cats, the proposition that you adopted 3 cats, etc. This prediction accords well with what we feel are expected answers to the question *how many cats did you adopt?*

4.3. Excursion on reconstruction

The von Fintel & Heim lectures notes on intensional semantics briefly introduced a version of the "copy theory of movement", in which reconstruction can be implemented as deletion of a higher copy:

> ... a version of the so-called Copy Theory of movement introduced in Chomsky (1993). This assumes that movement generally proceeds in two separate steps, rather than as a single complex operation as we have assumed so far. Recall that in H& K, it was stipulated that every movement effects the following four changes:
>
> (i) a phrase α is deleted,
> (ii) an index i is attached to the resulting empty node (making it a so-called trace, which the semantic rule for "Pronouns and Traces" recognizes as a variable),
> (iii) a new copy of α is created somewhere else in the tree (at the "landing site"), and
> (iv) the sister-constituent of this new copy gets another instance of the index i adjoined to it (which the semantic rule of Predicate Abstraction recognizes as a binder index).
>
> If we adopt the Copy Theory, we assume instead that there are three distinct operations:
>
> "Copy": Create a new copy of α somewhere in the tree, attach an index i to the original α, and adjoin another instance of i to the sister of the new copy of α. (= steps (ii), (iii), and (iv) above)
> "Delete Lower Copy": Delete the original α. (= step (i) above)?
> "Delete Upper Copy": Delete the new copy of α and both instances of i.
>
> The Copy operation is part of every movement operation, and can happen anywhere in the syntactic derivation. The Delete operations happen at the end of the LF derivation and at the end of the PF deletion. We have a choice of applying either Delete Lower Copy or Delete Upper Copy to each pair of copies, and we can make this choice independently at LF and at PF. (E.g., we can do Copy in the common part of the derivation and than Delete Lower Copy at LF and Delete Upper Copy at PF.)

When we try to apply this machinery to reconstruction of pied-piped material in wh-movement, there is a detail that needs attention: After having created two copies (or more) of *how many cats*, what happens when we "move" *how*? Presumably we create another, higher, copy of *how* and coindex it with the lower copy of *how*. With which lower copy of *how*? With the one in the uppermost copy of *how many cats*? If so, then after deletion of that uppermost copy of *how many cats*, the binder index next to the top copy of *how* will no longer bind any trace and the structure will not be interpretable. What we want is to end up with is an LF in which the top copy of *how* binds a variable in a lower (retained) copy of *how many cats*. There may be various ways to achieve this. Perhaps we can simply choose a derivation in which *how* "moves" out of a lower copy of *how many cats*, not out the highest copy. (Richards's Principle of Minimal Compliance might explain why this long movement is legitimate and yet relies for its legitimacy on the previous movement of the larger phrase.) Alternatively, we may posit a general principle "Copies must remain copies", which says that, as long as a structure contains more than one copy of a given phrase, every alteration to one of these copies must identically affect them all. In our case, this would mean that when we create the top copy of *how*, we must coindex it with all its existing copies, in the highest as well as all lower instances of *how many cats*. This principle could hopefully be made to fall out from a suitable formalization of copy theory, perhaps in a multi-dominance framework.