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Interrogative semantics and Karttunen's semantics for *know*

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0. Introduction

Much of the motivation for Groenendijk & Stokhof's (1982) analysis of interrogative clauses comes from considerations of the truth conditions of sentences like (1).

- (1) John knows which students called.

They point out two counterintuitive aspects in the earlier treatment of such sentences by Karttunen (1977) and devise an alternative analysis to overcome them. I find Groenendijk & Stokhof's points against Karttunen well-taken¹, but would like to pursue an alternative to the conclusions that they draw from them about the semantics of interrogative clauses. They conclude that Karttunen's failure to account for the meaning of (1) is due to an inappropriate interpretation of the embedded question, and it is this that they modify. I will explore to what extent the same result can be achieved by leaving the semantics of the complement essentially as Karttunen had it, amending instead the lexical semantics of the embedding verb *know*, along lines he already suggested for a special case in a footnote. It will emerge that such an approach is quite successful in matching Groenendijk & Stokhof's predictions, and that it might actually have some advantages (partly anticipated in work by Berman 1991) when one looks beyond sentences with the embedding verb *know*. The match of predictions is not perfect, however, and in order to make the new approach competitive with Groenendijk & Stokhof's, I will need to adopt an enriched variant of Karttunen's semantics that employs structured propositions.

¹I am indebted to James Higginbotham and Roger Schwarzschild for essential corrections. I have also benefitted from the feedback of audiences at Cornell, Amherst, MIT, Tübingen, and Beer-Sheva, in particular comments by Stephen Berman, Fred Landman, Tanya Reinhart, Mats Rooth, Arnim von Stechow, and Ede Zimmermann.

¹In this I differ from Berman (1991), who rejects their crucial judgments.

1. Karttunen

Karttunen (1977) proposed that an interrogative clause refers to a set of true propositions, intuitively the set of its true answers. The intensions of a couple of representative questions in this analysis are as follows.²

- (2) yes-no question:

$$[[\textit{whether it rained}]](w) =$$

$$\{p: p(w) \ \& \ [p = \lambda w' [[\textit{rain}]](w') \vee p = \lambda w' \sim [[\textit{rain}]](w')]\}$$
- (3) constituent question:^{3,4}

$$[[\textit{which students called}]](w) =$$

$$\{\lambda w' [[[\textit{call}]]](w')(x) : [[\textit{students}]](w)(x) \ \& \ [[[\textit{call}]]](w)(x)\}$$
henceforth abbreviated as: $\{\lambda w' Cw'x : Swx \ \& \ Cwx\}$

Regarding the semantics of question-embedding *know*, the basic intuition that Karttunen implements is that you stand in the *know*-relation to a question if you believe all the true answers to it. More formally:

- (4) simplified Karttunen-analysis:
For any world w , question-intension q , and individual x :

$$[[[\textit{know}]]](w)(q)(x) = 1 \text{ iff } x \text{ believes } \cap q(w) \text{ in } w.$$

$\cap q(w)$ is the intersection of the set $q(w)$. This being a set of propositions, intersection amounts to conjunction. If $q(w)$ is a unit set, $\cap q(w)$ is its only member. For example, to know whether it rained is to believe that it rained if it did, and that it didn't rain if it didn't. That is, to believe the one member of the extension of $[[[\textit{whether it rained}]]]$ as defined in (2) above. To know which students called is to believe (the conjunction of) all the propositions that x called for x a group of students that actually called.

²Notation: $[[[\alpha]]]$:= the intension of α . ' $p(w)$ ' is short for ' $p(w) = 1$ ' (similarly, ' $[[[\textit{call}]]](w)(x)$ ' for ' $[[[\textit{call}]]](w)(x) = 1$ ', etcetera).

³Throughout this paper I use a generalized version of the set-abstraction notation. The last line in (3), for example, is shorthand for: $\{p : \exists x(p = \lambda w' Cw'x \ \& \ Swx \ \& \ Cwx)\}$.

⁴This is Karttunen plus a modern plural semantics. See Srivastav (1991) and Lahiri (1991) for motivation and discussion. The plural common noun *students* is true of any group of students. Karttunen himself did not distinguish plurals from singulars and assigned to both *which student called* and *which students called* the meaning $\{\lambda w' Cw'x : [[[\textit{student}]]](w)(x) \ \& \ Cwx\}$. I use plural examples in this paper mostly to keep uniqueness presuppositions out of focus, but this is not very crucial.

I call (4) the "simplified" Karttunen analysis because it is not actually the entry for *know* that Karttunen adopts, for a reason we get to presently.⁵

If no students called, the extension of *which students called*, as defined in (3), is the empty set. The intersection of this is the tautological proposition, which one cannot fail to believe, however ignorant one may be. It is predicted thus that when no student called, (1) *John knows which students called* is automatically true, even if John is as ignorant as can be. This prediction is undesirable, and in order to avoid it, Karttunen refines (4) as follows:

- (5) actual Karttunen-analysis:
 $[[\text{know}]](w)(q)(x) = 1$ iff
 (i) x believes $\cap q(w)$ in w , and
 (ii) if $q(w) = \emptyset$, then x believes $\lambda w' [q(w') = \emptyset]$ in w .

So we have two cases: when the interrogative complement is non-empty, *know* works as before, but when it is empty, an additional requirement must be met for one to stand in the *know*-relation to it, namely one must believe that it is empty.

What does this amount to in a concrete case? Suppose no student called in the actual world w . Clause (ii) applies and predicts that John knows in w which students called iff he believes p in w , where p is the proposition $\lambda w' [(\lambda w'' Cw''x : Sw''x \ \& \ Cw''x) = \emptyset]$. What proposition is this? To any w' in which no students called, it assigns 1, and to any w' where some students did call, it assigns 0. In other words, p turns out to be simply the proposition that no students called. And this indeed is what John has to believe in w if he is to qualify as knowing which students called.

2. Exhaustiveness⁶

Karttunen himself observed a problem with his analysis: Suppose student Mary didn't call, but John fails to know this. He is either agnostic as to whether Mary called, or he even falsely believes she did call. Intuitively, this implies that John doesn't really know

⁵The following reasoning doesn't occupy a prominent place in Karttunen's paper; it's all tucked away in footnote 11 (1977, p. 18) and easy to miss.

⁶By "exhaustiveness", I always mean strong exhaustiveness in the sense of Bäuerle & Zimmermann (1991) and Berman (1991).

which students called (at least not completely).⁷ But (5) predicts no such implication: As long as John believes that they called of all the students that did call, he qualifies under (5) as knowing which students called, regardless of what opinions he holds regarding any of the non-callers. Karttunen is uncomfortable with this prediction but doesn't do anything about it, and this is one of the main reasons he later gets criticized by Groenendijk & Stokhof (1982, 1992).⁸

It is interesting to note that there is one special case in which Karttunen does correctly predict that John's lack of knowledge about student Mary's calling falsifies (1) *John knows which students called*. This is the special case where no students called at all. In this case, clause (ii) of (5) applies and says that (1) is not true unless John believes that no students called. And this, of course, he doesn't believe if he thinks that Mary might be among the students who called.

3. De dicto readings

Groenendijk & Stokhof see another problem with Karttunen's analysis: it predicts (6) to entail (1).

- (6) John knows who called.

⁷Berman (1991, ch. 4, sec. 3.2) rejects this judgment. According to him, (1) is "in an objective sense" true in the situation described and merely has a false conversational implicature. If he is uncertain regarding Mary, John still knows which students called, he just doesn't know that he knows it.

I think that Berman's comments would be appropriate if the example were (17) below *John knows the answer to the question which students called*, but they are not convincing for (1). Intuitive judgments for these two cases differ. Once the distinction is seen, Berman's comments can be reinterpreted as contributing towards a characterization of the difference, and so reinterpreted, they are very much in the spirit of the analysis to be explored in this paper. See below for more discussion.

⁸Karttunen entertains but rejects a remedy: an alternative semantics for the *which*-clause that would assign it the meaning in (i) instead of (3) above:

- (i) $[[\text{which students called}]](w) =$
 $\{\lambda w' Cw'x : Swx \ \& \ Cwx\} \cup \{\lambda w' \sim Cw'x : Swx \ \& \ \sim Cwx\}$

Given (i) and the entry for *know* in (5), John couldn't know which students called unless he also knew that they didn't call of all the students who didn't call. But while he considers this particular prediction welcome, Karttunen decides against (i), for a good reason: the analysis underlying (i) predicts a general equivalence between *which α β* and *which α not- β* . But there is often a clear difference in intuitive meaning, for instance in Bromberger's example (ii) (cited in Lahiri 1991).

- (ii) Feynman knew which elementary particles had been discovered by 1978, but he didn't know which ones hadn't been.

Karttunen thus prefers to stick with the analysis containing (3) and (5), and to live with the problematic prediction implied by these two together.

- (1) John knows which students called.

The entailment goes through because the set $\{\lambda w' Cw'x : \text{people}(w)(x) \ \& \ Cwx\}$ is a superset of $\{\lambda w' Cw'x : Swx \ \& \ Cwx\}$ for any world w . So if John believes all the propositions in the first set, he cannot fail to believe the ones in the second one.

Groenendijk & Stokhof concede that (6) has a reading where it does entail (1). But it can also be understood in a way where it doesn't. Imagine John has no idea which people are students. So if you asked him: 'Which students called?' he wouldn't be able to tell you -- even if he knew exactly who called. In this sense he doesn't know which students called. Groenendijk & Stokhof call the reading of (1) where it isn't entailed by (8) a 'de dicto' reading, and the reading where it is 'de re'. They argue that both should be generated by an adequate analysis.

Once again, it turns out that Groenendijk & Stokhof's objection doesn't bite in one special case, namely when no students called. If we take this possibility into consideration, we see that (6) actually doesn't strictly entail (1) under Karttunen's analysis: If some people called but no students did, then (6) can be true while (1) is false. Just suppose that John knows of each person who called that they did so, yet fails to know that none of those people are students. So we might say, in Groenendijk & Stokhof's terminology, that Karttunen predicts 'de dicto' truth conditions for (1) in one special circumstance, namely when there happen to be no students that called.

4. Generalizing from Karttunen's special case

We saw that Karttunen has problems with predicting exhaustiveness and de dicto readings, but we also saw that he avoids these problems in one very special case, namely when he gets to apply clause (ii) of (5). This suggests that clause (ii) may contain something that should perhaps be made part of the truth-conditions for *know*-sentences in general.

- (5) actual Karttunen-analysis (repeated from above):

$[[\text{know}]](w)(q)(x) = 1$ iff

(i) x believes $\bigcap q(w)$ in w , and

(ii) if $q(w) = \emptyset$, then x believes $\lambda w'[q(w') = \emptyset]$ in w .

The intuitive import of (ii) is that, when the extension of q is empty, then x should know that it is empty. Put differently, x should know that q 's extension is what it actually is. This requirement could conceivably be general: maybe one never really bears the

know-relation to a question unless one also knows that the answer to this question is the answer to it. Let us implement this idea.

(5)(ii) is equivalently written as follows:

- (7) if $q(w) = \emptyset$, then x believes $\lambda w'[q(w') = q(w)]$ in w .

By dropping the if-clause, this is straightforwardly turned into an unrestricted requirement. (5) then gives way to (8), which I dub the "generalized Karttunen-analysis".

- (8) $[[\text{know}]](w)(q)(x) = 1$ iff
(i) x believes $\bigcap q(w)$ in w , and
(ii) x believes $\lambda w'[q(w') = q(w)]$ in w .

Before turning to examples, I show that clause (i) of (8) is redundant: Whenever q is the intension of an interrogative clause, (i) follows from (ii). Proof: Given Karttunen's semantics for interrogative clauses (see (2) and (3) above), the following holds for all w : every proposition in $q(w)$ is true in w , and therefore $\bigcap q(w)$ is true in w . Now assume (ii), and let w' be an arbitrary one of x 's belief-worlds in w . From (ii) we get $q(w') = q(w)$, hence $\bigcap q(w') = \bigcap q(w)$. As we just saw, we can take for granted that $\bigcap q(w')$ is true in w' . Therefore $\bigcap q(w)$ is true in w' . But since w' was an arbitrary belief-world of x 's in w , this means that x believes $\bigcap q(w)$ in w . QED. So (9) is an equivalent formulation of (8).

- (9) generalized Karttunen-analysis:
 $[[\text{know}]](w)(q)(x) = 1$ iff x believes $\lambda w'[q(w') = q(w)]$ in w .

Another general point is that nothing at all has changed for yes-no (*whether*) questions. (4), (5), and (9), the simplified, actual, and generalized Karttunen analyses, all predict identical truth-conditions for sentences of the form *NP knows whether ϕ* . This proof is left to the reader.

So what are the predictions of (9) for constituent questions? Let's try it out on our example (1) *John knows which students called*. Together with (3), (9) says that (1) is true in w iff John in w believes the proposition defined in (10).

- (10) $\lambda w'[\{\lambda w'' Cw''x : Sw'x \ \& \ Cw'x\} = \{\lambda w'' Cw''x : Swx \ \& \ Cwx\}]$

What proposition is this? I argue that it is the same proposition as (11) below.

- (11) $\lambda w' \forall x[Sw'x \ \& \ Cw'x \leftrightarrow Swx \ \& \ Cwx]$

That (11) entails (10) is pretty obvious: if the same individuals satisfy the conditions after the colons in the two sets in (10), then the same propositions will be in these sets. It remains to show that (10) entails (11), which I do by reductio: Suppose there were a world w' in which (10) was true but (11) false. The latter means there is some individual u such that $Sw'u \& Cw'u$ but $\neg[Swu \& Cwu]$. (Or the other way round; but since the two cases are fully parallel, I need explicitly consider just one.) Because of $Sw'u \& Cw'u$, we have $\lambda w"Cw'u \in \{\lambda w"Cw'x : Sw'x \& Cw'x\}$. Since (10) is true, $\{\lambda w"Cw'x : Sw'x \& Cw'x\} = \{\lambda w"Cw'x : Swx \& Cwx\}$, and thus also $\lambda w"Cw'u \in \{\lambda w"Cw'x : Swx \& Cwx\}$, which means that there is an individual v such that $Swv \& Cwv \& \lambda w"Cw'v = \lambda w"Cw'u$. We know that $v \neq u$, since we are supposing $\neg[Swu \& Cwu]$. Yet the proposition that v called is to be the same proposition as that u called; in other words, u and v called in exactly the same possible worlds. This, I take it, cannot be. For any two distinct individuals, it has to be a logical possibility that one of them calls without the other doing so as well. So $\lambda w"Cw'v = \lambda w"Cw'u$ is not compatible with $v \neq u$, and we have disproved our original supposition that w' makes (10) true and (11) false. So (10) entails (11) and the two are equivalent. QED.

What does this imply for the issues of exhaustiveness and de dicto readings? Let us recall the problematic scenarios from section 2 and 3 above:

Re exhaustiveness: If student Mary didn't call in w but John fails to know this, then there are worlds w' compatible with John's beliefs in w such that in w' Mary is a student who ^{called} didn't call. Hence such w' falsify $\forall x[Sw'x \& Cw'x \leftrightarrow Swx \& Cwx]$, and this means that John in w does not believe the proposition (11). It is thus correctly predicted that (1) is false.⁹

Re de dicto reading: If in w Mary is a student who called, and John doesn't know that she is a student, then there are worlds w' compatible with what John believes in w where Mary is not a student. Any such w' falsify $\forall x[Sw'x \& Cw'x \leftrightarrow Swx \& Cwx]$, so

⁹Notice also that no problem arises with Bromberger's Feynman sentence (see footnote 8). Suppose in the actual world w there are exactly two elementary particles, x and y , of which only x is discovered by 1978. Suppose w is compatible with Feynman's beliefs in 1978 in w , and so is another world w' . In w' , particle x is also the only one discovered by 1978, but there it is also the only elementary particle that there is. If these two are all the worlds compatible with Feynman's belief, then the set of discovered particles in all his belief-worlds is the same as in the actual world, but the set of undiscovered particles in one of his belief-worlds is empty and thus distinct from what it is in the actual world. Given the entry for *know* in (9), this implies that Feynman knows which particles have been discovered, but he does not know which particles haven't been discovered. The account of this example is exactly the same as in Groenendijk & Stokhof's analysis, see below.

John does not believe proposition (11), whatever else he may believe (in particular, whether or not he has correct beliefs about which people called). So it is predicted that John's failure to know that Mary is a student (when in fact she is a student who called) suffices to make (1) false, as befits a de dicto reading in the sense of Groenendijk & Stokhof. (In order to generate an alternative de re reading, we can do just what they do, namely quantify in the CN *students*.)

It is beginning to look as if the generalized Karttunen analysis in (9) accomplishes what we hoped it might: It seems to be immune to Groenendijk & Stokhof's two objections against Karttunen's actual proposal, at least to the specific counterexamples by which we have illustrated them. In fact, its predictions seem to coincide exactly with those of Groenendijk & Stokhof's own proposal. Are they actually equivalent? I need to introduce Groenendijk & Stokhof's proposal before we can study this question.

5. Groenendijk & Stokhof

Groenendijk & Stokhof take a rather different route to their goal of capturing exhaustiveness and de dicto readings. They depart from Karttunen not only in the semantics of question-embedding verbs like *know*, but already in their interpretation of interrogative sentences. In contrast with (2), (3) above, they propose the denotations in (12), (13). Note that their interrogative extensions are just propositions, not sets thereof.¹⁰

- (12) yes-no question:
 $[[\text{whether it rained}]](w) = \lambda w'[[\text{rain}]](w') \leftrightarrow [[\text{rain}]](w)$
- (13) constituent question:
 $[[\text{which students called}]](w) =$
 $\lambda w' \forall x[Sw'x \& Cw'x \leftrightarrow Swx \& Cwx]$

Their entry for *know* is (14).

- (14) For any world w , question-intension q , and individual x :
 $[[\text{know}]](w)(q)(x) = 1$ iff x believes $q(w)$ in w .

¹⁰This gives them an advantage in treating coordination examples like *John knows which students called and that Mary wasn't among them*. See Groenendijk & Stokhof (1982).

For *know*-sentences with yes-no questions, Groenendijk & Stokhof derive the same predictions as all Karttunen variants above.¹¹ We concentrate again on constituent questions. (14) and (13) imply that (1) *John knows which students called* is true in *w* iff John in *w* believes the proposition $\lambda w' \forall x [Sw'x \& Cw'x \leftrightarrow Swx \& Cwx]$. This was also the prediction of the generalized Karttunen analysis, so I needn't repeat what I have already pointed out: that this prediction captures an exhaustive, *de dicto* reading of (1).

6. Comparative evaluation: preliminary sketch

The central difference between the two approaches is in the notions of answerhood they allow us to define. Karttunen's theory is, in a sense, the richer of the two, as it lets us define two answer relations. Let $[[\alpha]]_K$ be the intension of an interrogative clause α according to Karttunen's semantics (cf. (2), (3)). In the first sense to be defined, the (true, complete¹²) answer to a question is simply the intersection of its extension. In the second sense, the answer is the proposition that the answer-in-the-first-sense is the answer-in-the-first-sense. More precisely:

- (15) The answer₁ to the question α in *w* [abbreviation: $ans_1(\alpha, w)$] is the proposition $\cap [[\alpha]]_K(w)$.
- (16) The answer₂ to the question α in *w* [abbreviation: $ans_2(\alpha, w)$] is the proposition $\lambda w' [ans_1(\alpha, w') = ans_1(\alpha, w)]$.

The first notion is not definable in Groenendijk & Stokhof's theory. What their semantics directly captures is the second one: As far as we can tell so far (though see below), the extension that their semantics assigns to an interrogative clause α , $[[\alpha]]_{G\&S}(w)$, is just $ans_2(\alpha, w)$. As (16) shows, $ans_2(\alpha, w)$ is uniquely determined by *w* and $\lambda w' ans_1(\alpha, w')$, but it is fairly evident that there is no unique route back from ans_2 to ans_1 . For instance, *which A are B* and *which B are A* typically have distinct ans_1 , but their ans_2 coincide. It is this "neutralization" that makes the conceptual apparatus of Karttunen's theory genuinely richer than Groenendijk & Stokhof's.

¹¹Proof: Consider the sentence schema *John knows whether ϕ* . (9) in conjunction with (2) predicts that this is true in *w* iff John in *w* believes the following proposition (i).

(i) $\lambda w' [(p: p(w')) \& [p = [[\phi]] \vee p = [[\neg\phi]]]] = (p: p(w) \& [p = [[\phi]] \vee p = [[\neg\phi]]])$

These two sets of propositions are equal just in case $[[\phi]]$ has the same truth value in *w* and *w'*. So (ii) is the same proposition which Groenendijk & Stokhof take to be the extension of *whether ϕ* in *w* (see (12) above).

¹²Notions of g (possibly false and/or incomplete) answer are also definable, but not relevant to us here.

So an obvious question to bring to bear on a choice between the two approaches is whether we really need the ans_1 -relation or can define anything of interest to the semanticist in terms of ans_2 alone. If the former, we have an argument for (generalized) Karttunen, if the latter, for Groenendijk & Stokhof. In this section, I want to indicate some places where reference to ans_1 seems called for in the lexicon or elsewhere in the grammar. My discussion remains extremely superficial, however, and a more serious investigation of the examples touched on here may well overturn the initial evidence they offer for Karttunen's approach.

The question-embedding verb *know* - this is the gist of Groenendijk & Stokhof's argument with Karttunen - expresses a relation to ans_2 ; ans_1 are irrelevant. How about other lexical items which embed interrogatives? Quite a few other verbs - *find out*, *realize*, *remember*, *wonder*, ... - have meanings that are roughly definable in terms of 'know' (e.g. *find out* \approx 'come to know', *wonder* \approx 'want to know'), and for those, it is not surprising that Groenendijk & Stokhof's points regarding exhaustiveness and *de dicto* readings carry over and we need not refer to ans_1 in their lexical entries either.

The above were verbs of mental attitude. What about speech act verbs like *tell*, *write down*, *divulge*, *remind*, *ask* etc.? We might try to define these too in terms of 'know', e.g. *tell* \approx 'cause to know by uttering something'. This is a very transparent sense of *tell*, one where it doesn't matter at all what words the teller used, as long as they somehow get certain information across. I think one needs to fix on this sense in order to share the judgments of Groenendijk & Stokhof (see especially Groenendijk & Stokhof 1992) and to agree with them, e.g., that John told us which students called iff he told us which callers were students. More commonly, however, we would be reluctant to accept this equivalence, and a possible explanation for this is that the normal sense of *tell* involves both ans_1 and ans_2 : To tell us which students called means to cause us to know the ans_2 to this question by asserting its ans_1 . If something like this is on the right track, speech act verbs may favor Karttunen's approach.

An interesting case to consider in this connection is the semantics of the speech act noun *answer*. The following minimal pair lends itself quite readily to a *prima facie* argument in favor of Karttunen.

- (1) John knows which students called.
- (17) Johns knows the answer to the question which students called.

(17) is ordinarily understood to convey the same information as (1). But it is arguable that what corresponds to the sole meaning of (1) is merely a preferred reading in (17). (17) can in suitable contexts be understood in a way where it doesn't imply (1), but asserts merely that John knows something which happens to be the answer to the question which students called.¹³ Suppose John doesn't know who is a student and/or falsely believes that student Mary called when in fact she didn't. Still the following sounds like a valid argument:

(18) premise 1: John knows that Bill and Sue called.

premise 2: That Bill and Sue called happens to be the answer to the question which students called.

conclusion: John knows the answer to the question which students called.

The valid reading of this argument is apparently due to the fact that *answer* in English can have the meaning of *answer₁* rather than *answer₂*.

The ambiguity in (17), incidentally, is a very widespread one. Barbara Partee has pointed out (19), and the contrasting salient readings of (20a,b) give another illustration.

(19) I didn't find your house.

(20) (a) I identified the culprit.

(b) I identified the striped animal in your drawing.

One reading implies the subject's awareness that the object falls under the definite description by which it is referred to: awareness that your house is your house, that the culprit is the culprit, and - in the case of (17) - that the answer to this question is the answer to this question. The other reading lacks this implication.

This is not the occasion to get into a serious analysis of this type of ambiguity. I just want to make the point that the weaker reading of (17) (the one which validates inference (18)) is a non-trivial challenge for Groenendijk & Stokhof: Compositionality demands that we be able to define the denotation of the NP *the answer to the question which students called* as a function of the denotation of the embedded interrogative clause. But then *answers₁* would have to be recoverable from *answers₂*.

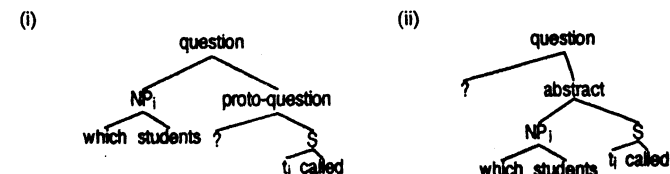
¹³This is Berman's knowledge "in an objective sense". He claims, however, that even (1) can be read in this way.

My intuitions regarding question-embedding emotive factives like *surprise* are not so certain. I assume if one stands in the surprise relation to a proposition *p*, one expected not-*p*. Given Groenendijk & Stokhof's approach, *It surprised me who called* then should mean that I expected the negation of *answer₂* to this question. This might be, but needn't be, because I expected the negation of *answer₁* (recall that *answer₂* always entails *answer₁*). Suppose I perfectly expected all those who did call to do so, but I also expected someone else to call who in fact didn't. Is it still true that it surprised me who called? Berman (1991) judges that in such a situation he would have to say *It didn't surprise me who called* (it just surprised me who didn't call). If he is right, *surprise* is problematic for Groenendijk & Stokhof, and a lexical entry for *surprise* requiring that one not expect *answer₁* is more adequate.

Apart from lexical semantics, an advantage of Karttunen's denotations is that they fit well with the so-called Alternative Semantics of focus (Rooth 1985, 1992). Rooth (1992) gives a straightforward account of how a question influences the felicity of various focus-structures on the answer following it. He uses Hamblin-meanings, but Karttunen-meanings would work as well. It is less clear how his account would carry over to a Groenendijk & Stokhof-semantics for interrogatives.

If any of these points hold up to scrutiny, we do have some motivation to prefer a Karttunen-based approach like the generalized Karttunen analysis over Groenendijk & Stokhof's alternative.¹⁴

¹⁴Considerations pertaining to the syntax-semantics interface do not provide reasons to favor either approach. Both approaches fit with an independently plausible syntax for interrogative clauses and standard principles of semantic composition. Abstracting away from the Montague Grammar trappings and many details, Karttunen's Logical Forms for constituent questions look as in (i), Groenendijk & Stokhof's as in (ii). (I use the authors' own category labels, but the real syntactic categories presumably are various projections of I and C.)



Each combines a sentence containing a trace with two other pieces: a wh-phrase and an interrogativizing operator (?), though in different orders of combination, and assuming different inherent meanings for these two pieces. Karttunen's ?-operator is interpreted as $\lambda p \lambda w (q: q(w) \ \& \ q=p)$. His *which*-NP is a restricted existential quantifier (equivalent to *some students*) and combines with its sister by cross-categorical quantifying-in. (See e.g. Rooth (1985) for a generalization of the quantifying-in operation to

7. Non-equivalence

I argued that the generalized Karttunen analysis assigned the same truth-conditions as Groenendijk & Stokhof's to the sentence (1) *John knows which students called*. But was this due to special properties of the example, or are the analyses generally equivalent for all knowledge reports with constituent question complements? If you look again at my equivalence proof regarding (1) in section 4, you will spot one crucial premise that won't generalize to arbitrary other examples. That is the assumption that no two distinct individuals call in exactly the same possible worlds. I'll stand by it for run-of-the-mill simple predicates like *call*, but in the vast space of properties there undoubtedly also exist some which don't behave in this way.

An unimaginative case in point is the universally necessary property, which every individual has in every world. For concreteness let us examine sentence (21).

(21) John knows which students are identical with themselves.

According to Groenendijk & Stokhof, (15) is true in w iff John in w believes the proposition in (22).¹⁵

(22) $\lambda w' \forall x [Sw'x \ \& \ x=x \leftrightarrow Swx \ \& \ x=x]$
equivalently: $\lambda w' \forall x [Sw'x \leftrightarrow Swx]$

So their prediction is, in effect, that (21) means that John knows what students there are. Our new alternative, by contrast, deems (21) true in w iff John believes proposition (23).

(23) $\lambda w' [\{\lambda w''x=x : Sw'x \ \& \ x=x\} = \{\lambda w''x=x : Swx \ \& \ x=x\}]$
equivalently: $\lambda w' [\{\lambda w''x=x : Sw'x\} = \{\lambda w''x=x : Swx\}]$

It takes a little calculating to see this, but (23) is actually the proposition $\lambda w' [\exists x Sw'x \leftrightarrow \exists x Swx]$.¹⁶ So what (21) is predicted to mean, in effect, is that John knows whether

arbitrary conjoinable types.) Groenendijk & Stokhof's ? means $\lambda P \lambda w \lambda w' [P(w') = P(w)]$. Their *which*-NP is just a predicate (equivalent to *students*) and combines with its sister by intersective modification. (Both analyses assume that some well-formedness constraint forces the *wh*-phrase to appear in the immediate vicinity of ?.)

¹⁵ I assume here that the extension of *identical with oneself* in a given world contains all possible individuals, not just those that exist (or have counterparts) in that particular world. Otherwise the example would not make its point, or at least not so simply. It would then become relevant whether there are any two distinct individuals that exist in exactly the same worlds.

¹⁶ If we undo the generalized set-abstraction notation (see fn. 3) and replace ' $x=x$ ' by a constant T which names the value True, the left term of the equation in (23) looks as follows:

there are students. This prediction is clearly wrong. Whatever (21) may mean, it isn't this. Whether it is what Groenendijk & Stokhof predicted instead is another matter. The salient spontaneous intuition about (21) is that it ascribes trivial knowledge to John, which isn't captured by either of the theories being compared. We would have to dig deeper here, and it remains to be seen whether we would turn up anything relevant to the present comparison.

The universally necessary property is not the only one which undercuts the general equivalence of the generalized Karttunen analysis with Groenendijk & Stokhof.¹⁷ A sentence like (24) also spells trouble.

(24) John knows which students live with their actual spouses.

Suppose in the actual world w , Bill is married to Sue. So the proposition that Bill lives with his actual spouse is the proposition that he lives with Sue. Likewise, the proposition that Sue lives with her actual spouse is the proposition that she lives with Bill. Living-with being a symmetrical relation, these two propositions are one and the same.¹⁸ To round out the picture of w , suppose further that both Bill and Sue are students and indeed live with each other (and that there are no other students living with their spouses). Finally, assume that John is basically well-informed about all these facts, except that he falsely believes Sue not to be a student.

It is arguable that sentence (24) is false in this world w . We are led to this verdict if we compare the intuitively correct answer to the question *Which students live with their actual spouses?* to the one that John would give if we put it to him. He'd be liable to answer: "Bill," or even: "Only Bill." But the correct answer in w is: "Bill and Sue."

As it turns out, Groenendijk & Stokhof make the right prediction. For them, (24) is not true in w unless John believes the following proposition:

(25) $\lambda w' \forall x [Sw'x \ \& \ Lw'x \ f(x) \leftrightarrow Swx \ \& \ Lwx \ f(x)]$
where $f(x) := x$'s spouse in w

$\{p : \exists x [p = \lambda w''T \ \& \ Sw'x]\}$

This is the singleton set containing $\lambda w''T$ if there are students in w' , and the empty set if there aren't. The right term of the equation in (23) simplifies analogously, and when we put it all together, (23) is true in w' iff there are students either in both w and w' or else in neither.

¹⁷ I am greatly indebted to Roger Schwarzschild for making me see this.

¹⁸ I assume that it is false in worlds where Bill doesn't exist, and likewise in worlds where Sue doesn't exist.

Both Bill and Sue satisfy the right side of the biconditional. But in a typical belief world w' of John's, only Bill satisfies the left side. So (25) is false in such w' .

But our generalized Karttunen analysis gets it wrong. According to it, for (24) to be true in w , it suffices that John believe proposition (26).

$$(26) \lambda w' [(\lambda w'' Lw''x f(x) : Sw'x \& Lw'x f(x)) = (\lambda w'' Lw''x f(x) : Swx \& Lwx f(x))]$$

The set on the right, by assumption, has as its only member the proposition that Bill and Sue live with each other. It so to speak qualifies for membership twice: once because Bill satisfies the condition $Swx \& Lwx f(x)$, and again because Sue does. The set on the left, for a typical w' among John's belief worlds, will likewise contain exactly this proposition. Here it qualifies for membership on the sole grounds that Bill satisfies $Sw'x \& Lw'x f(x) \rightarrow$ Sue, not being a student in w' , is irrelevant. But no matter: the sets are the same, and that's all the analysis cares about. Thus (26) is true in all John's belief worlds, and (24) is wrongly predicted a true report of his knowledge.

8. Generalized Karttunen analysis with structured propositions

The picture we have arrived at is uncomfortable. We were very nearly successful in our attempt to define Groenendijk & Stokhof-intensions for interrogatives in terms of their Karttunen-intensions (see the definition of ans_2 in terms of ans_1 in (16) above), and consequently very nearly successful in matching Groenendijk & Stokhof's truth-conditions for knowledge reports in the generalized Karttunen analysis. It took pretty contrived examples to get a divergence. And there was also a rather simple intuition behind the definition of $answers_2$ in terms of $answers_1$, which makes it unlikely that the near match was just a fluke. So why did we get counterintuitive results in certain contrived cases?

The problem seems to lie less with our recipe for constructing $answers_2$ from $answers_1$ than with the notion of $answer_1$ itself. When first introduced to Karttunen's analysis, one has no difficulty relating it to a natural pretheoretical notion of answerhood. But the technical concept departs from the natural one in precisely the cases we have been looking at. Consider again the two worlds we constructed above which differed only in that Sue was a student in one and not the other. There is an intuition that the question which students live with their actual spouses has different answers in these two worlds: In one, the answer is that Bill and Sue live with their actual spouses, in the other it is that Bill lives with his actual spouse. But the sense in which these are different answers

is beyond the reach of Karttunen's theory, since they express one and the same proposition.

A remedy that suggests itself at this point is to construe $answers_1$ not as propositions but as structured propositions.¹⁹ Concretely, replace Karttunen's semantics for constituent questions in (3) by (27).

$$(27) \llbracket \text{which students called} \rrbracket(w) = \{ \langle x, C \rangle : Swx \& Cwx \}$$

Where we previously had the proposition that x called (for each calling student x), we now have the structured proposition which is the ordered pair of x and the property of calling. Maintaining the generalized-Karttunen entry for *know* from (9), we now predict that our sentence (1) is true in w iff John believes the proposition in (28).

$$(28) \lambda w' [\{ \langle x, C \rangle : Sw'x \& Cw'x \} = \{ \langle x, C \rangle : Swx \& Cwx \}]$$

That (28) is the same proposition as Groenendijk & Stokhof's (11) is evident and holds independently of any special characteristics of the property C . So this variant of the generalized Karttunen analysis is truly equivalent to Groenendijk & Stokhof in its predicted truth-conditions for all *know*-sentences. In view of the intuitions we had about the contrived examples (21) and (24), this is an improvement.

Otherwise, not much of what I said in the earlier sections should be affected by the introduction of structured propositions. In particular, if any of the evidence for reference to $answers_1$ in the lexical semantics of question-embedding constructions (see section 6) is sound, then the appropriate lexical entries can certainly still be formulated. After all, the old unstructured $answers_1$ are always recoverable from our new Karttunen-intensions (though not vice versa). Whether there is positive evidence for the added richer structure (apart from our contrived predicates), I don't know at this point. This may be an interesting question for further research.

¹⁹In the sense of Crosswell & von Stechow (1982).

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