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Published in:
Proceedings of the 4th Symposium on Logic and Language

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January 22, 1993

1. To appear in: K. Bimbo & A. Mate (eds), *Proceedings of the 4th Symposium on Logic and Language*

1 Introduction

This paper is about a topic in the semantics of interrogatives.[1] In what follows a number of assumptions figure at the background which, though intuitively appealing, have not gone unchallenged, and it seems therefore only fair to draw the reader's attention to them at the outset.

The first assumption concerns a very global intuition about the kind of semantic objects that we associate with interrogatives. The intuition is that there is an intimate relationship between interrogatives and their answers: an interrogative determines what counts as an answer.[2] Given a certain, independently motivated, view on what constitutes the meaning of an answer, this intuition, in return, determines what constitutes the meaning of an interrogative. For example, starting from the observation that answers are true or false in situations, we may be led to the view that answers express propositions, i.e., objects which determine a truth value in a situation. Given that much, our basic intuition says that interrogatives are to be associated with objects which determine propositions. Such objects will be referred to as 'questions' in what follows. Notice that all this is largely framework independent: we have made no assumptions yet about what situations, propositions, and questions are, we have only related them in a certain systematic way. In fact we will use a more or less standard, but certainly not uncontroversial, specification in what follows: situations are identified with (total) possible worlds; propositions with sets of worlds; and questions with equivalence relations on the set of worlds.

The second assumption that plays a role in what follows is of a more linguistic nature. Interrogatives typically occur in two ways: as independent expressions, and as complements of certain verbs. The assumption is that these two ways of occurring are systematically related, not just syntactically but also semantically.[3] Notice that the exact nature of this relationship is underdeter-

1. It is a slightly modified and extended version of our 'A Note on Interrogatives and Adverbs of Quantification', which appeared in the proceedings of the Second Conference on Semantics and Linguistic Theory (Barker & Dowty 1992).
The main difference with the previous version — which is basically a reaction on part of Steve Berman's 1991 dissertation — is that we also take into consideration some of the remarks on the subject made by Utpal Lahiri in his 1991 dissertation (for the larger part in the newly added section 5 and in some extensive footnotes), and we react (in two more extensive footnotes) to some critical remarks raised by Jonathan Ginzburg in his 1992 dissertation against the analysis of questions and answers we presented in our 1984 dissertation. It goes without saying that in all four of these dissertations there is a lot more being said than we can do justice to in this paper.
We would like to thank Craige Roberts, and the participants of the Second Conference on Semantics and Linguistic Theory (Columbus Ohio, May 1–3, 1992), the Fourth Symposium on Logic and Language (Budapest, August 4–9, 1992), and the Workshop on Computational Semantics (Freudenstadt, November 17–21, 1992) for their helpful comments and criticisms.
The preparation of this paper was supported by the Esprit Basic Research Action DYANA (EBRA-6852).
2. This intuition is what Belnap (in Belnap 1981) calls the 'answerhood thesis'.
3. Belnap (op. cit.) calls this the 'independent meaning thesis'. It can be viewed as a special instance of the principle of compositionality, given a certain rather natural view on the

mined by this assumption: the most strict specification would require an interrogative to have the same meaning when occurring independently and embedded, but weaker specifications would also satisfy this requirement. The strict view combined with the previous assumption entails that both embedded and independent interrogatives express questions, and that verbs embedding interrogatives express relations to questions. Such relations may be of various kinds: a verb may express a relation to the question as such, in which case we call it 'intensional', or it may express a relation to the proposition which is the value of the question in the actual world, in which case it is labelled 'extensional'.[4]

The third assumption that plays a role in what follows is of a more methodological nature. It concerns the way in which a semantic analysis deals with the general, 'cross-categorial' phenomena of coordination and entailment. Roughly the assumption is that coordination and entailment are cross-categorial not only in a syntactic sense, but also semantically: a semantics of coordination and entailment which is general in the sense of being specified independently of the category/type of expressions involved is to be preferred to one which is defined for each category/type of expressions separately. Again, this assumption is to a large extent framework independent. Within the classical intensional type-theoretic framework that we will employ in what follows we will assume that coordination is defined point-wise by the standard boolean connectives, and that entailment is defined as meaning inclusion.[5]

It is interesting to note that if we combine this third assumption with the kind of analysis that emerges from what we said above, certain predictions result concerning entailment relations between interrogatives. Given our first assumption the meaning of an interrogative is an object which determines in a situation what counts as an answer. Given that entailment is meaning inclusion, an interrogative I entails another interrogative I' iff every answer to I is an answer to I'. This seems to be an intuitively acceptable result: asking a question involves asking another one if the latter is answered if the former is.

This gives a rough sketch of the contours of the space within which a reasonable semantics for interrogatives is to be found, but in order to appreciate the problems that we are interested in, we have to be a little more specific about what we take the basic semantics of interrogatives to be. As we indicated above, we assume that an interrogative expresses an equivalence relation between worlds. What is this equivalence relation? Roughly speaking it is the relation of being extensionally the same with respect to some relation. More concretely, an interrogative is based on a relational expression: it expresses an inquiry about the extension of a relation. A sentential interrogative can be viewed as based

syntactic status of embedded interrogatives.

4. I.e., 'extensional' is used here in the sense of operating on the extensions of its arguments, not in the sense of operating on an extensional argument. Zimmermann (1985) uses the terms 'core-extensional'and 'core intensional' to distinguish between these two classes of verbs.

5. The empirical problems with this claim, for example those concerning non-boolean coordination and free choice permission, are not relevant for the issues discussed in this paper.

on a zero-place relation, i.e., a sentence, and thus expresses an inquiry about a truth value. The worlds which are indistinguishable with respect to the extension of a certain relation together make up a proposition, which can be identified with the proposition expressed by an answer to the corresponding interrogative. Such a proposition gives an exhaustive specification of the positive extension of the relation involved. Notice that it follows that in each world the question expressed by an interrogative determines exactly one proposition: the complete true answer to the interrogative. In section 2 we will outline how this view can be implemented, now we turn to some observations that seem to be at odds with this analysis.

In his 1991 dissertation Stephen Berman (see also Berman 1990) has argued that *wh*-terms like *which student(s)* in many ways behave like indefinite terms such as *a student/students*. Berman's main argument concerns their behavior under adverbs of quantification, as in the following example:[6]

(1) The principal usually finds out which students cheat on the final exam

According to Berman, this sentence has two readings. Besides the reading paraphrased in (2), there is also a reading that can be paraphrased as in (3):

(2) In most (final exam) situations the principal finds out which students cheat in that situation.

(3) Of most students who cheat on the final exam the principal finds out that they cheat on the final exam.

Berman convincingly argues that these two readings of (1) are different. Suppose that in each of the (final exam) situations the principal catches 75 percent of the cheaters, then on paraphrase (2), sentence (1) would be true, but on the reading paraphrased by (3), sentence (1) would be false. For (2) to be true, it should be the case that for most of the (final exam) situations the principal catches all cheating students.

This is taken to indicate that a *wh*-term like *which student* does not contain a quantifier by itself, but gets its quantificational force from an adverb of quantification, much in the same way as this has been argued to be the case for indefinites as in (4):

(4) If a student cheats on the final exam then the principal usually finds out that he does.

Of course the adverb of quantification may be implicit, in which case it is supposed to have universal quantificational force. On this assumption Berman gets

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6. Lahiri (see Lahiri 1991) distinguishes between adverbs of frequency and adverbs of quantity and precision. Only the latter give rise to quantificational variability involving indefinites. According to Lahiri *usually* falls in the first class, and *mostly* in the second. So, according to him, the meaning that is a stake here is expressed, not by (1), but rather by (1′):

(1′) The principal mostly finds out which students cheat on the final exam.

Although this does seem correct, in the sense that the most obvious reading of (1) is not the one we are discussing here (but the one in which the quantification is over exam-situations), we stick to Berman's original examples in what follows.

the interpretation paraphrased in (6) for a sentence like (5):

(5) The principal found out which students cheated on the final exam.

(6) For all students who cheated on the final exam the principal found out of them that they cheated on the final exam.

This paraphrase of the meaning of (5) is not quite what one would expect assuming the kind of semantics outlined above. Recall that on that approach questions are strongly exhaustive in the following sense: a question determines in a possible world a unique proposition, one which gives a complete specification of the positive extension in that world of the relation involved. It is precisely this aspect of strong exhaustiveness that is lacking from the semantic interpretation that Berman assigns to the embedded interrogative in (5). For it is clear that (6) is compatible with it being the case that the principal accuses a number of non-cheaters of having cheated. But in the analysis outlined earlier the proposition which the question expressed by the embedded interrogative determines in the actual world, and to which the principal stands in the relation of having found out, is strongly exhaustive. Hence on that analysis the principal should not accuse non-cheaters, if (5) is to be true.

Of course the same holds for sentence (1) and Berman's paraphrase (3). Clearly (1) entails (3), but it is not entailed by (3): if the principal indeed found out about most cheaters that they cheated, but also accused more than just a few non-cheaters of having cheated, then whereas (1) would be false according to the strong exhaustiveness approach, its proposed paraphrase is not.

Berman's paraphrases represent a different view on answers, and hence, on the meaning of interrogatives. According to this view the answer to an interrogative need only be weakly exhaustive. The difference with the strongly exhaustive approach is most easily explained in terms of question-answer pairs. Consider the following example:

(7) Which girls are asleep?
—Mary, Suzy and Jane (are asleep).

According to the weakly exhaustive view, the answer in (7) means simply that Mary, Suzy and Jane are girls that are asleep. According to the strongly exhaustive view it means that Mary, Suzy and Jane are the girls that are asleep, i.e., it says that only Mary, Suzy and Jane are girls that are asleep. In other words, the two views differ with respect to what proposition counts as the true answer to the question which girls are asleep, and hence to what is the meaning of the interrogative.

Different views on what constitutes the meaning of an interrogative lead to different predictions regarding the logical properties of (embedded) interrogatives. Let us give one simple illustration. We saw above that given the standard analysis of entailment as meaning inclusion, and given the general characterization of the meaning of interrogatives in terms of their answerhood conditions, an interrogative I entails an interrogative I' iff whenever a propositions p gives a true answer to I, p gives a true answer to I' as well. If we combine this with strong exhaustiveness we predict that the interrogative in (7) entails (8) (assuming that we know that Claire is a girl):

(8) Is Claire asleep?

But under weak exhaustiveness this does not follow. If only Mary, Suzy and Jane are asleep, the interrogative in (7) would denote the proposition that they are asleep, but that does not entail that Claire is not asleep, which in that situation would be the true answer to (8). Similarly, strong exhaustiveness predicts that (9):

(9) John knows which girls are asleep.

entails (10):

(10) John knows whether Claire is asleep.

But weak exhaustiveness makes (9) compatible with John believing that Claire is asleep, in case she is not, and still know which girls are asleep.

In various places (see Groenendijk & Stokhof 1982,1984) we have argued that the strongly exhaustive interpretation of interrogatives is the basic one. In our opinion, predictions such as the ones illustrated above constitute arguments in favour of this position. Other arguments can be added. To indicate just one, suppose Hilary wants to find out which girls are asleep. She asks Peter, who replies that he doesn't know, but adds that John does. Now suppose, as we did above, that John believes that Mary, Suzy, Jane and Claire are asleep, whereas in fact only the first three of them are. Asked by Hilary which girls are asleep, John answers that Mary, Suzy, Jane and Claire are. Suppose further that Hilary subsequently finds out that Claire isn't asleep. Would she not quite rightly claim that the answer she got from John was wrong, that in fact he did not know which girls were asleep, and that Peter was wrong in claiming that he did?[7]

Another difference between the weak and strong exhaustiveness views shows up when we consider other embedding verbs such as *wonder*. Berman observes that if we replace the verb *find out* in (1) by the verb *wonder* the result is a sentence which has one reading less:

(11) The principal usually wonders which students cheat on the final exam.

This sentence can only be paraphrased, Berman notes, as in (12):

(12) In most (final exam) situations, the principal wonders which students cheat in that situation.

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7. There is one objection that is often raised against strong exhaustiveness, also by Berman and Lahiri, that we want to say something about. The objection is that strong exhaustiveness requires not just knowledge of the positive extension of a relation, but also of its negative extension, a requirement that is considered too strong. However, this argument rests on a misapprehension of what strong exhaustiveness is. By itself it requires merely a specification of the positive extension and the additional information that this specification is a complete one. As such this does *not* entail that a complete specification of the negative extension is also available. The latter can be obtained only if, in addition, the (relevant part of the) domain is known. Of course, in actual situations this may, or may not be the case. But strong exhaustiveness is independent of this. And hence, the entailments that some object to, do not depend on it either.

but lacks a reading corresponding to paraphrase (3) of (1).

Obviously, the source of the difference between (1) and (11) is a difference in lexical semantic properties of the verbs *find out* and *wonder*. What you find out if you find out which students cheat, is the true answer to the question which students cheat, i.e., you stand in the relation of finding out to the proposition that is the true answer to the question which students cheat. In case you wonder which students cheat, you do not stand in a relation to the proposition that expresses the true answer, rather you bear a particular relation to the question as such expressed by the interrogative, a relation which can be roughly paraphrased as that of wanting to find out the true answer to that question. Using the terminology introduced above, we can say that the difference between verbs such as *find out* and verbs such as *wonder* is that whereas the latter are intensional the former are extensional.

One thing to note here, is that this distinction between extensional and intensional embedding verbs does not coincide with the distinction between factive and non-factive verbs. Verbs like *know* or *find out* are factive with respect to their indicative complements. Knowing or finding out that Mary is asleep entails (presupposes) that Mary is actually asleep. Verbs like *tell* or *believe* on the other hand, are not factive. Telling or believing that Mary is asleep does not entail (presuppose) that she actually is. Note however that, unlike *believe*, *tell* can also take interrogatives as argument, as in *John tells whether Mary is asleep*. And in that case *tell* does behave in a factive manner: if John tells whether Mary is asleep, then it follows that if Mary actually is asleep, he tells that she is asleep, and that if she is not, he tells that she is not.

It is remarkable that this property of *tell* simply falls out the independently motivated assumption that it is an extensional embedding verb. To tell whether Mary is asleep means to tell the true answer to the question whether Mary is asleep, which if Mary is asleep is the proposition that Mary is asleep, and if she is not, is the proposition that she is not.

Returning to the contrast between (1) and (11), it may suggest that it is merely the extensional character of a verb that accounts for the possibility of quantificational variability. However, Lahiri points out several examples of verbs which according to our classification are intensional, but which nevertheless exhibit quantificational variability. Consider:

(13) John is certain, for the most part, about who loves Mary.
(14) John and Bill agree, for the most part, on who Mary's ex-lovers are.

So, the picture is more complicated. Though it are specific lexical properties of verbs which determine whether or not quantificational variability is possible, extensionality is not necessarily the only factor involved. For example, *be certain about* is not an extensional verb, since it does not denote a relation between an individual and what happens to be the actually true answer to the question involved. So it is intensional. What distinguishes it from *wonder* is that, unlike the latter, it does express that some relation holds between the subject and a definite answer, viz., the answer that according to the subject is the actually true answer.

Let us take stock. It seems that the phenomenon of quantificational variability in interrogatives is a real one. And on the face of it, it seems to be in conflict with exhaustiveness. However, the latter is an independently motivated feature, and giving it up has all kinds of drawbacks. What we want to show in the remainder of this paper is that, appearances (and Berman) not withstanding, quantificational variability can be accounted for in an approach which complies with strong exhaustiveness.

The remainder of the paper is organized as follows. In section 2, we sketch how the semantic analysis of interrogatives outlined above can be implemented. In section 3 we discuss the challenge that Berman's proposals form for this analysis. In section 4 we show how this challenge can be met, making use of some insights from dynamic semantics. Here we are mainly concerned with the cases discussed by Berman. Section 5 outlines how some of Lahiri's examples can be dealt with. The final section 6 contains some concluding remarks.

2 A semantics for interrogatives

In the previous section we sketched informally the basics of a semantics for interrogatives within a classical intensional framework. This section indicates how such an analysis can be implemented, and investigates the difference between the weak exhaustiveness view and the strong exhaustiveness view. (See Groenendijk & Stokhof 1982,1984,1989) for more details.)

Starting point is the assumption that in a world an interrogative denotes the proposition that is expressed by its true answer in that world. For a simple sentential interrogative such as (15a), this means that in case Mary sleeps, it denotes the proposition that Mary sleeps, and in case she does not sleep, it denotes the proposition that she does not. Identifying propositions with sets of possible worlds, this amounts to the following. In a world w, the set of possible worlds denoted by (15a) consists of those worlds w' such that Mary sleeps in w' iff she sleeps in w. Using two-sorted type theory as a representation language, (15c) represents the extension of (15a) in w. By abstracting over w, we get (15d) as a representation of its meaning. Another assumption we have made implies that the *whether*-complement (15b) that corresponds to the interrogative (15a) has the same extension and intension.

(15) a. Does Mary sleep?
b. whether Mary sleeps
c. $\lambda w'[S(w)(m) \leftrightarrow S(w')(m)]$
d. $\lambda w \lambda w'[S(w)(m) \leftrightarrow S(w')(m)]$

We noted above that interrogative embedding verbs exhibit a distinction that we find quite generally in functional expressions, viz., that between expressions which operate on the extension of their arguments, and those which take their intension. Examples of extensional verbs are *know* and *tell*, and *wonder* is an example of an intensional verb. This gives a straightforward account of the fact that (16a) and (16c) together entail (16e):

(16) a. John knows whether Mary sleeps.
b. $K(w)(j, \lambda w'[S(w)(m) \leftrightarrow S(w')(m)])$
c. Mary sleeps.
d. $S(w)(m)$
e. John knows that Mary sleeps.
f. $K(w)(j, \lambda w'[S(w')(m)])$

Notice that this does not hinge on the factivity of the verb *know*. For as is shown in (17) the same entailment goes through for the non-factive verb *tell*:

(17) a. John tells whether Mary sleeps.
b. $T(w)(j, \lambda w'[S(w)(m) \leftrightarrow S(w')(m)])$
c. Mary sleeps.
d. $S(w)(m)$
e. John tells that Mary sleeps.
f. $T(w)(j, \lambda w'[S(w')(m)])$

Given that *wonder* is an intensional verb, similar entailments do not occur with (18), wondering being a relation between individuals and questions, and not between individuals and propositions:

(18) a. John wonders whether Mary sleeps.
b. $W(w)(j, \lambda w \lambda w'[S(w)(m) \leftrightarrow S(w')(m)])$

The meaning of a constituent interrogative, like (19a), is derived in a two-step process. As we pointed out above, a constituent interrogative is associated with a relation. In the case of (19a) it is the property (one-place relation) of being a girl that sleeps, which is expressed by (19b). What the constituent interrogative asks for is a specification of the positive extension of the corresponding relation. The equivalent expressions (19c,d) give such a specification for the property in (19b), for in a world w they denote the proposition that is true in a world w' iff the girls that sleep in w', are the same as the girls that sleep in w. This proposition gives an exhaustive specification of the positive extension of the property of being a sleeping girl in w. The expression (19e) represents the corresponding intension, i.e., the question expresssed by (19a). [8,9] In what follows we will use

8. Of course, it may happen that two questions Q_1 and Q_2 have different intensions, but the same extension, i.e. the same true answer, in a particular world. That is to say, questions are individuated with finer grain than the corresponding answers. In his 1992 dissertation, Jonathan Ginzburg argues against this. He notes that in case Q_1 and Q_2 express different questions, but in a given world happen to have the same extension, then in that world the following discourse is contradictory:

(a) A: I asked you Q_1, not Q_2.
B: In that case, I'll tell you Q_1, not Q_2.

The point is that *ask* is an intensional verb, i.e., operates on a question, whereas *tell* is extensional, i.e., takes as its argument a proposition, viz., the true answer to the question. If the intension of Q_1 and Q_2 is different, but their extension in a particular world w is the same, then what A says can very well be the case in w, but B's reaction will then be contradictory. For, if Q_1 and Q_2 denote the same proposition in w, then in w telling Q_1 is the same as telling Q_2. You can't tell the one and not tell the other. Notice that Ginzburg's argument is *not* meant as an objection to the closure of extensional verbs such as *tell* under equivalence, but rather as an argument against our analysis as such.
Ginzburg discusses the following concrete instance of (a):

(b) A: I asked you what Jill likes, not what Bill likes.
B: In that case, I'll tell you what Jill likes, not what Bill likes.

Suppose, Ginzburg's argument runs, that in a particular world w, Jill and Bill like exactly the same things, whereas in other worlds their likes are different. Then the two questions, viz., what Jill likes, and what Bill likes, are different semantic objects, but their true answers in w would be the same. Hence, Ginzburg concludes, what B says is contradictory. 'An utterly false prediction'.
However, the argument is flawed. It is simply not the case that in the situation that Ginzburg sets up the two questions denote the same proposition. Although the extensions of the properties of being an object that Jill likes and being an object that Bill likes are indeed the same in w, it does not follow that the propositions that according to our analysis express the answers to the two questions are also the same. The two answers are the proposition that Jill likes ..., and the proposition that Bill likes ..., respectively. But even if the dots contain a specification of the same objects, the propositions will in general be different. So the situation as Ginzburg sets it up is not a real instantiation of the schema involving (a). As far as the situation is specified, not only the two questions, but also the two answers in w are different.
The misunderstanding is that from the *extensional* identity of two relations in a world the identity of the corresponding *intensional* (propositional) specifications of this extension is inferred. But this is incorrect. (If identity of the actual extension of the relations underlying two questions would imply that the true answers would express the same proposition, then, e.g., any two sentential questions — which correspond to 0-place relations — with the same answer 'yes' (or 'no'), would have the same proposition as answer. This is certainly not predicted by our analysis.)
But what about the general argument involving schema (a)? Observe that in the particular situation that Ginzburg sketches, the answers to the questions what Jill likes and what Bill likes, would be the same if moreover for any world w' in which Jill likes the same things as she does in w, it would hold that Bill also likes the same things in w' as he does in w, and vice versa. In other words, the answers only express the same proposition if 'Jill likes ...', and 'Bill likes ...', with on the dots a specification of what they both happen to like in w, express *logically equivalent* propositions. This is not the case in the situation in Ginzburg's example, and as a matter of fact, it is a situation which is quite unlikely to occur. Moreover, it seems that in such a situation it does make sense to call what B says contradictory. If we assume that *tell* is closed under logical equivalence, then indeed telling Q_1 is telling Q_2 if the answers are logically equivalent.
So, it seems that, after all, the objectionable status of the type of situation exemplified in

the explicitly universally quantified representations.

(19) a. Which girl(s) sleep(s)?

b. $\lambda x[G(w)(x) \wedge S(w)(x)]$

c. $\lambda w'[\lambda x[G(w)(x) \wedge S(w)(x)] = \lambda x[G(w')(x) \wedge S(w')(x)]]$

d. $\lambda w' \forall x[[G(w)(x) \wedge S(w)(x)] \leftrightarrow [G(w')(x) \wedge S(w')(x)]]$

e. $\lambda w \lambda w' \forall x[[G(w)(x) \wedge S(w)(x)] \leftrightarrow [G(w')(x) \wedge S(w')(x)]]$

This analysis represents the strong exhaustiveness view on the meaning of constituent interrogatives. For an answer to (19a) should express the proposition denoted by (19c,d), and hence it should not just say that $a_1 \ldots a_n$ are girls that sleep, but also that no other individual is. That is, an answer should specify that $a_1 \ldots a_n$ together form the entire positive extension of the property of being a girl that sleeps, not just that they are (among the) girls that sleep.[10] An answer

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schema (a) can only constitute an argument against the framework employed, viz., that of classical intensional semantics, not against the analysis of questions provided within that framework.

9. The following observation, ascribed to Stanley Peters, is brought forward by Ginzburg (see Ginzburg 1992) as pointing out a weakness of our analysis. Consider the following two questions:

(a) Which bachelors (here) are bachelors?

(b) Which males (here) are bachelors?

According to our analysis, (a) and (b) express the same question. The underlying property in both cases is the same. Both the property of being a bachelor and a bachelor, and the property of being a male and a bachelor, are identical with the property of being a bachelor. Hence both questions ask for a specification of the actual extension of the property of being a bachelor (here). This is not according to intuition. Intuitively, (b) can be taken as asking for such a specification, but (a) would rather lead to a reaction like "What do you mean? Of course *all* bachelors are bachelors." And to tell or wonder which males (here) are bachelors, seems a much more sensible thing to do than to tell or wonder which bachelors are bachelors. This is indeed not accounted for in our analysis. The source of this shortcoming resides in the way the property underlying a question is derived from the properties expressed by the constituents of the interrogative. It is obtained by simply taking the conjunction of the property expressed by the *wh*-term (being a bachelor in (a), and being male in (b)) and the property which is the topic of the interrogatives (being a bachelor in both cases). This does not take into account the different roles that these two properties play. The property provided by the *wh*-term focusses attention on a particular subdomain, and the question as a whole asks to specify a particular part of that subdomain, viz. that part which contains the individuals that have the property that is the topic of the question. This explains what is odd about (a): given the subdomain of bachelors, it makes no sense to ask who is a bachelor within that subdomain. This feature of the meaning of constituent interrogatives is indeed not accounted by our way of deriving the property underlying a question.

However, it does not seem to be too hard to refine this part of the analysis, by taking the topic-focus structure of constituent interrogatives into account. As a matter of fact, the process of restricted λ-abstraction that we use in deriving constituent interrogatives (see Groenendijk & Stokhof 1982, 1984) seems amenable in the right way.

10. Recall what was said above, in footnote 7, about what strong exhaustiveness by itself does and does not entail. As a matter of fact, the framework that we make use of here, that of classical intensional logic, does validate the inference from knowledge of the positive extension of a relation to knowledge of its negative extension, by virtue of the fact that relations are interpreted totally over a fixed domain. However, this has nothing to do with the strongly exhaustive interpretation of interrogatives as such. And indeed in a framework

that contains only the latter information is weakly, but not strongly exhaustive. The weak exhaustiveness view can be represented in a similar fashion as the strong exhaustiveness approach:

(20) a. Which girl(s) sleep(s)?
b. $\lambda x[G(w)(x) \wedge S(w)(x)]$
c. $\lambda w' \forall x[[G(w)(x) \wedge S(w)(x)] \rightarrow [G(w')(x) \wedge S(w')(x)]]$
d. $\lambda w \lambda w' \forall x[[G(w)(x) \wedge S(w)(x)] \rightarrow [G(w')(x) \wedge S(w')(x)]]$

The derivation of multiple constituent interrogatives follows the same pattern as that of single constituent interrogatives. Starting point is an expression R^n which expresses an n-place relation. The denotation of the interrogative based on R^n in a world w is the proposition which is true in those worlds w' for which it holds that the extension of R^n in w' is the same as that in w. Thus we arive at the following general schema:

$$\lambda w' \forall x_1 \dots x_n[R(w)(x_1 \dots x_n) \leftrightarrow R(w')(x_1 \dots x_n)]$$

Again, this is the strong exhaustiveness view. Weakly exhaustive interpretations result if we require not identity of extension, but only inclusion:

$$\lambda w' \forall x_1 \dots x_n[R(w)(x_1 \dots x_n) \rightarrow R(w')(x_1 \dots x_n)]$$

Notice that it is only on the strong exhaustiveness approach that sentential interrogatives fall out of in the general schema: they result if $n = 0$. The weak exhaustiveness analysis would need a separate interpretation rule for sentential interrogatives.

Embedded constituent interrogatives are derived by the same process as embedded sentential interrogatives. Verbs like *wonder* operate on the intension of their argument, verbs like *tell* or *know* on its extension. This means that sentences like (21a) and (22a) translate as (21b) and (22b) on the weak exhaustiveness approach, and that (21c) and (22c) are the representation that the strong exhaustiveness view gives rise to:

(21) a. John wonders which girl(s) sleep(s).
b. $W(w)(j, \lambda w \lambda w' \forall x[[G(w)(x) \wedge S(w)(x)] \rightarrow [G(w')(x) \wedge S(w')(x)]])$
c. $W(w)(j, \lambda w \lambda w' \forall x[[G(w)(x) \wedge S(w)(x)] \leftrightarrow [G(w')(x) \wedge S(w')(x)]])$

(22) a. John tells which girl(s) sleep(s).
b. $T(w)(j, \lambda w' \forall x[[G(w)(x) \wedge S(w)(x)] \rightarrow [G(w')(x) \wedge S(w')(x)]])$
c. $T(w)(j, \lambda w' \forall x[[G(w)(x) \wedge S(w)(x)] \leftrightarrow [G(w')(x) \wedge S(w')(x)]])$

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in which relations are interpreted partially, and/or in which the domain is allowed to vary from information state to information state, the inference in question does not go through anymore. Notice that in such a modified framework the equivalence between (19b) and (c) need not hold anymore either. Although for ease of exposition, we use representations like (19c) rather than (b) in what follows, this is not problematic. Whatever we have to say does not depend essentially on this choice. More in particular, in the crucial steps of our argumentation, we will always use quantification over the positive extension only. See also footnote 15.

On both approaches *wonder* expresses a relation to the question which girl(s) sleep(s), and *tell* a relation to the true answer to that question. Moreover, notice that neither approach needs an additional factivity postulate for *tell*.

Let us look a little bit closer at what the two notions of exhaustiveness amount to in the case of (22). Under the assumption that *tell* is closed under entailment, the weakly exhaustive interpretation (22b) follows from the strongly exhaustive interpretation (22c).[11] And if we assume that it is closed under conjunction,[12] then the weakly exhaustive reading (22b) is equivalent with (23), and hence, the latter is also entailed by the strongly exhaustive reading (22c):

(23) $\forall x[[G(w)(x) \wedge S(w)(x)] \rightarrow T(w)(j, \lambda w'[G(w')(x) \wedge S(w')(x)])]$

In the case of (21), which contains the intensional *wonder*, an analogous paraphrase/entailment is not obtainable. The quantification over girls that sleep in w cannot be raised over the verb, because it is inside the scope of the intensionalizing λw. So, it is the specific lexical properties of *tell* that account for the

11. Within a classical intensional framework this assumption leads to well-known problems. However, the entailments that we are considering here are unproblematic, and would need to survive when using a more fine-grained notion of meaning.

12. So, the fact that the weakly exhaustive reading (22b) of (22a) can be represented as (23) depends on two lexical features of the verb *tell*, its extensionality and its closure under conjunction. These two factors together make it possible to 'raise' the universal quantification over girls that actually sleep outside the complement. As will become more clear in section 3, it is essential for our treatment of quantificational variability of these cases that a logical paraphrase like (23) is available for sentences like (22a). This predicts that if a complement-embedding verb is extensional, but does not show closure under conjunction, it would not (at least not in the same way) allow for quantificational variability. In Lahiri (1991) several such cases, e.g., the verb *be surprised about*, are discussed. Consider the following example:

(a) John is surprised about who were at the party.

Suppose Mary, Bill, and Suzy were at the party, then (a) says that

(b) John is surprised that Mary, Bill, and Suzy were at the party.

This means that *be surprised about* is an extensional verb. But notice that it is not closed under conjunction. In the situation at hand, (a) does not necessarily say that of each of Mary, Bill and Suzy individually, John was surprised that (s)he was at the party. The only reason for John's surprise might be that he knows that Bill and Suzy try to avoid visiting the same parties at all costs. In other words, the extensional verb *be surprised about* does not show closure under conjunction, at least not in this type of context. A logical paraphrase like (23) of (22a) is not adequate for cases like (a). And hence, the analysis of quantificational variability we propose predicts that (c) not necessarily means something like (d):

(c) John is mostly surprised about who were at the party.

(d) Of most persons who were at the party, John is surprised that (s)he was at the party.

This prediction seems to square with intuitions. By the way, Lahiri uses examples like these to argue against Berman's analysis of sentences with factive verbs. For Berman, (23) is not just a logical paraphrase of the meaning of (22c), which falls out of the lexical properties of the particular verb. Rather, Berman gets the equivalent of (23) for all sentences with factive verbs as their logical form. This gives the wrong results in cases like (a)–(c).

Notice, finally, that having either strong or weak exhaustiveness leads to different predictions concerning sentences such as (a). It seems that (a) can also be used if John is surprised because David was *not* at the party, for example because he knows that David and Suzy are always seen together. This falls out only under a strongly exhaustive analysis.

entailment.

The expression in (23) represents the paraphrase that Berman would give for (22a). But Berman arrives at such a result only by means of a factivity postulate for *tell* with embedded interrogatives, whereas no such assumption is necessary on the approach outlined above.[13]

Before we turn to the strongly exhaustive interpretation, let us be a little bit more explicit about the transition from (22b) to (23). The two assumptions we made concerning the meaning of *tell*, viz., that if one tells p and p entails q, one also tells q, and that if one tells p and tells q, then one tells p and q, can be explicated in a Hintikka-style semantics for proposition embedding verbs. Within that framework every such verb V is associated with a predicate of possible worlds $V_{x,w}$. For example, with T for *tell* and j for John, the extension of $T_{j,w}$ is the set of worlds compatible with what John tells in w. Then it is laid down that John tells p in world w iff all worlds w' for which $T_{j,w}$ holds are worlds in which p is true. This gives us equivalences such as:[14]

$$T(w)(j,p) \Leftrightarrow \forall w'[T_{j,w}(w') \rightarrow p(w')]$$

Given that much, (22b) can be represented as (24), and (23) as (25):

(24) $\forall w'[T_{j,w}(w') \rightarrow \forall x[[G(w)(x) \wedge S(w)(x)] \rightarrow [G(w')(x) \wedge S(w')(x)]]]$

(25) $\forall x[[G(w)(x) \wedge S(w)(x)] \rightarrow \forall w'[T_{j,w}(w') \rightarrow [G(w')(x) \wedge S(w')(x)]]]$

The equivalence of (24) and (25), and hence of (22b) and (23), is a simple matter of predicate logic.

Turning to the strongly exhaustive reading of (22a), which was given as (22c) above, we notice that it can also be represented as (26):

(26) $\forall w'[T_{j,w}(w') \rightarrow \forall x[[G(w)(x) \wedge S(w)(x)] \leftrightarrow [G(w')(x) \wedge S(w')(x)]]]$

Observe that (26) can be 'decomposed' into the conjunction of (24), which represents the weakly exhaustive reading, and (27):

(27) $\forall w'[T_{j,w}(w') \rightarrow \forall x[[G(w')(x) \wedge S(w')(x)] \rightarrow [G(w)(x) \wedge S(w)(x)]]]$

The latter gives the additional information which distinguishes the strongly exhaustive interpretation from the weakly exhaustive one.[15] What this additional information amounts to, is perhaps more perspicuously formulated in (28),[16] which is equivalent to (27):

13. See Lahiri (1991) for a more extensive argumentation that factivity is not the distinguishing factor.

14. See footnote 12. Again, these equivalences are not completely unproblematic. But the actual usage we make of them is restricted to onproblematic cases.

15. As a follow-up to footnotes 7 and 10, notice that in (27), which precisely represents the additional information that strong exhaustiveness provides, only the postive extension of the property of being a girl that sleeps (in worlds compatible with what John tells) is explicitly quantified over. This illustrates once more that strong exhaustiveness as such does not inherently involve a specification or knowledge of the negative extension of the relation that the question is about.

16. Representations which make use of the compatibility predicate induced by proposition embedding verbs are more perspicuous, at least for our present purposes, and we will use them in what follows when appropriate. But note that, for example, (28) is equivalent with:

(28) $\forall x[\exists w'[T_{j,w}(w') \wedge G(w')(x) \wedge S(w')(x)] \rightarrow [G(w)(x) \wedge S(w)(x)]]$

This expresses that if it is compatible with what John tells that someone is a girl who sleeps, then this person actually is a girl who sleeps. For one thing, this means that if John tells of someone that she is a girl who sleeps, which implies that this is compatible with what he tells, then she actually is. (This gives us the factivity of *tell* when embedding an interrogative.) From the formulation (28) it is also obvious that the possibility that of some individuals John is not sure whether they are girls that are asleep is excluded on the strongly exhaustive reading. If it is compatible with what he tells that someone is a girl who sleeps, then, as (28) implies, she actually is. And from the weakly exhaustive part, expressed in (25), we know that if the latter is the case he tells that she sleeps.

Having thus pinpointed the difference between the weakly and the strongly exhaustive reading, we finally note that we can put together the two conjuncts into which we decomposed (26), viz., (24) and (28), as follows:

(29) $\forall x[[[G(w)(x) \wedge S(w)(x)] \vee \exists w'[T_{j,w}(w') \wedge G(w')(x) \wedge S(w')(x)]] \rightarrow$
$[G(w)(x) \wedge S(w)(x) \wedge \forall w'[T_{j,w}(w') \rightarrow [G(w')(x) \wedge S(w')(x)]]]]$

To see that this is equivalent to the original representations (22c) or (26), note that (24) is of the form $\forall x[\phi \rightarrow \psi]$, and (28) is of the form $\forall x[\chi \rightarrow \phi]$, which combine to $\forall x[[\phi \vee \chi] \rightarrow [\phi \wedge \psi]]$, which is the form of (29). And (29) expresses that if an individual is actually a girl who sleeps or such that it is compatible with what John tells that she is a girl who sleeps, then she actually is a girl who sleeps and such that John tells that she is a girl who sleeps.

It is the observation that (29) (also) represents the strongly exhaustive interpretation that forms the basis of our account of quantificational variability in sentences such as (22a), which is presented in section 4. But first we turn to a closer examination of Berman's proposals.

3 Berman's challenge

In the semantics sketched above, *wh*-terms do not translate as independent quantificational expressions, but rather function as (restricted) λ-abstraction. Yet it seems that, given the (weakly or strongly) exhaustive nature of questions, they in effect inherently amount to universal quantification. Hence the phenomenon of quantificational variability seems to pose a serious problem for this semantics. The following examples, taken from Berman (1991), illustrate what is at stake:

(28′) $\forall x[\neg\forall w'[T_{j,w}(w') \rightarrow \neg[G(w')(x) \wedge S(w')(x)]] \rightarrow [G(w)(x) \wedge S(w)(x)]]$

which, using the Hintikka-style definition in the other direction, gives us:

(28″) $\forall x[\neg T(w)(j, \lambda w' \neg[G(w')(x) \wedge S(w')(x)]) \rightarrow [G(w)(x) \wedge S(w)(x)]]$

This means that we can always get our more familiar type of representation back, if we want (or need) to.

(30) a. The principal usually finds out which students cheat on the final exam.
b. Sue mostly remembers which of her birthday presents arrived special delivery.
c. With few exceptions, Mary knows which students submitted which abstracts to which conferences.
d. Bill seldom acknowledges which colleagues he gets a good idea from.
e. John discovered which books were stolen from the library.

These sentences have a reading in which the adverbs of quantification, *usually*, *mostly*, *with few exceptions*, *seldom*, seem to have the effect of lending variable quantificational force to the *wh*-terms in these sentences. Notice that the main verb in (30a), *find out*, is factive, but that in (30b), *remember*, is not. Sentence (30c) illustrates that quantificational variability can pertain to several *wh*-terms at the same time. And (30d) shows that it may affect both *wh*-terms and indefinite terms. Finally, (30e) is a case with a non-explicit adverb of quantification. Berman provides the following paraphrases:

(31) a. For most students who cheat on the final exam, the principal finds out of them that they cheat on the final exam.
b. For most of her birthday presents that arrived special delivery, Sue remembers that they arrived special delivery.
c. For most triples of a student, an abstract and a conference such that the student submitted the abstract to the conference, Mary knows that the student submitted the abstract to the conference.
d. For few pairs of a colleague and a good idea such that Bill gets the good idea from the colleague does he acknowledge he gets the good idea from the colleague.
e. For all books that were stolen from the library, John discovered that they were stolen from the library.

If *wh*-phrases inherently have universal quantificational force, how can we explain the quantificational variability exemplified by these sentences? Exhaustiveness, even weak exhaustiveness, seems to be at odds with examples like (30a)–(d). Berman describes the situation in the following way. He notes that although sentence (32a) is contradictory, (32b) is not:

(32) a. John knows who is running, but he doesn't know that George is running.
b. John mostly knows who is running, but he doesn't know that George is running.

Likewise, he observes that although (33c) follows from (33a) and (33b), no such entailment holds between (34c) and (34a)–(34b):

(33) a. John knows who is running.
b. George is running.
c. John knows that George is running.

(34) a. John mostly knows who is running.
b. George is running.
c. John knows that George is running.

These observations, Berman concludes, show that exhaustiveness is not an inherent property of interrogatives, and that hence an alternative account of the semantics of embedded constituent interrogatives is needed.

We will now sketch what we take to be the core of Berman's analysis. Starting point is that *wh*-phrases should not be treated as inherently quantificational expressions, but rather in the way indefinites are treated in Lewis/Kamp/Heim-style discourse representation theory. (See Lewis (1975), Kamp (1981), Heim (1982).) This means that, like indefinites, *wh*-terms are associated with clauses expressing conditions on free variables. Constituent interrogatives correspond to open formulae. So parallel to example (20) in the previous section, the logical form assigned to (35a) is (35b):

(35) a. which girl(s) sleep(s)
b. $G(x) \wedge S(x)$

A crucial feature of Berman's analysis is that the embedding verbs which we have dubbed 'extensional', such as *know* and *tell*, operate on these open sentences directly. As is to be expected, the binding of the free variables is taken care of by implicit or explicit adverbs of quantification. Via a process of presupposition accommodation the open sentence which is the argument of the embedding verb is 'raised' to act as the restriction of the quantifier corresponding to the adverb. What we have called 'intensional' verbs, such as *wonder*, behave differently, however. Such verbs do not take open sentences as such as their argument, but the questions that can be formed from them. In these cases the free variables in the embedded interrogative get bound as a result of this process of question formation.

Before turning to Berman's account of embedded constituent interrogatives, we first take a look at his rule of question formation. Questions result by prefixing a so-called Q-morpheme to an open sentence containing one of more occurrences of *wh*-terms. The semantic interpretation of the Q-morpheme results in a Hamblin-type interpretation of constituent interrogatives. (See Hamblin 1973.) It is given in (36):[17]

17. Notice that the interpretation scheme for the Q-morpheme does not give proper results in case we are dealing with a sentential interrogative. Since in that case the sentence does not contain *wh*-terms, no existential quantifiation would be involved. The result would be

$$[\![Q\phi]\!]^{M,g} = \{p \mid p = [\![\phi]\!]^{M,g}\}.$$

This gives us only the proposition expressed by ϕ, i.e., only the 'positive' answer. But that is not the only possible answer. Hence, in case of sentential interrogatives, we should rather interpret the Q-morpheme as follows:

$$[\![Q\phi]\!]^{M,g} = \{p \mid p = [\![\phi]\!]^{M,g} \vee p = [\![\neg\phi]\!]^{M,g}\}.$$

In fact, this flaw in Berman's analysis is directly related to the matter of exhaustiveness. For recall that the general scheme for interrogative formation that was stated in the previous

(36) $[\![Q\phi]\!]^{M,g} = \{p \mid \exists x_1 \ldots x_n \colon p = [\![\phi]\!]^{M,g}\}$

The existential quantifiers in this definition bind the free variables introduced by the *wh*-terms in the open formula ϕ that corresponds to the constituent interrogative. We see that the semantic result of application of the Q-morpheme to the open sentence is a set of propositions that each represent a possible partial answer. So the interrogative (37a) is represented as (37b), which in terms of the representation language used in this paper amounts to (37c):

(37) a. Which girl(s) sleep(s)?
b. $Q[G(x) \wedge S(x)]$
c. $\lambda p \exists x[p = \lambda w[G(w)(x) \wedge S(w)(x)]]$

Let us now look at Berman's analysis of embedded constituent interrogatives. We start with the 'intensional' case. As was indicated above, 'intensional' verbs take as their argument the question expressed by the embedded interrogative. Hence a sentence such as (38a) is assigned the logical form (38b):

(38) a. John wonders which girl(s) sleep(s).
b. $W(j, Q[G(x) \wedge S(x)])$

If we compare this analysis with the one given in the previous section we notice that in both the argument of the verb is a question, which in its turn determines answerhood. However, the analyses differ substantially in their view on the nature of answers, and hence questions. The analysis of section 2 associates an interrogative in a world with one complete true answer. In Berman's analysis an interrogative is linked to the same set of all possible partial answers in every world. From this set we can extract the true partial answers in a world, by selecting the propositions which are true in that world. That, in effect, would amount to Karttunen's analysis. (See Karttunen 1977.) If we take the intersection of the resulting set of propositions, we end up with the weakly exhaustive analysis outlined in the previous section. And if we add a clause stating that no other individuals satisfy the relation on which the interrogative is based, the strongly exhaustive analysis results. It is worth noticing that Berman could have chosen any of these alternative interpretations of the Q-morpheme. The only thing that is essential for his approach is that the Q-morpheme takes care of the binding of the variables introduced by the *wh*-terms in the embedded interrogative. Of course, the choice between these alternatives, Hamblin-type, Karttunen-type, weakly exhaustive, strongly exhaustive, is not a matter of taste but has to be made on empirical and methodological grounds, as we have argued extensively elsewhere.

Now we come to Berman's account of the 'extensional' cases. As we said above, Berman assumes that these verbs operate on the open formulae associated with the constituent interrogatives, and not on the questions that can be

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section, which starts from an n-place relation, with sentential interrogatives in the case of $n = 0$, and which lets the question be the equivalence relation on possible worlds of having the same (positive) extension, results in strongly exhaustive readings.

formed from them. A further assumption which he makes, in line with the standard approach to adverbs of quantification (see Lewis 1975) is that the logical form of sentences such as (39a) and (40a) is a tripartite structure. The three constituents of this structure are: an adverb of quantification (if no adverb occurs, universal quantification is the default); the restriction of the quantification; and the nuclear scope of the quantification. Consider the following simple examples, one with and one without an explicit adverb of quantification:

(39) a. John usually knows which girl(s) sleep(s).
  b. $\textsc{most}_x[G(x) \wedge S(x)][K(j, \text{girl}(x) \wedge S(x))]$

(40) a. John tells which girl(s) sleep(s).
  b. $\textsc{all}_x[G(x) \wedge S(x)][T(j, \text{girl}(x) \wedge S(x))]$

The logical forms (39b) and (40b) illustrate the general pattern. The nuclear scope consists of the embedding verb and its two arguments: the subject and the open formula corresponding to the constituent interrogative. The restriction is formed by the same open formula. It gets there via a process of presupposition accommodation. In case of verbs such as *know*, this process operates with the presupposition standardly associated with factive verbs. In case of non-factive verbs such as *tell*, the assumption has to be made that such verbs are factive when embedding an interrogative, despite the fact that they are not factive in general. The adverb quantifies non-selectively over the free variables in its arguments, and thus takes care of the binding.

In Berman's analysis the difference between the 'intensional' and the 'extensional' cases is taken to reside in different structural properties of the sentences in question. It is assumed that a sentence such as (38a), in which the intensional verb *wonder* occurs, does not give rise to a tripartite structure because *wonder* is not factive and because it operates on questions rather than open formulae. In the resulting logical form there are no free variables left for an adverb of quantification to bind, since they are bound already by the Q-morpheme. Hence such sentences do not exhibit quantificational variability.

Let us now turn to an evaluation of Berman's proposal. (See also Lahiri 1991.) The main thing to note is that at essential points his analysis of embedded and non-embedded interrogatives is not in accordance with some of the general assumptions outlined in the introductory section. The 'stand alone' and embedded occurrences of interrogatives are not treated uniformly throughout. Remarkable is the radical difference between the kind of semantic object associated with an interrogative embedded by a verb like *wonder* and that expressed by an interrogative that is the argument of verbs such as *know* and *tell*. The latter verbs operate on open formulae, not on questions, as the former do.[18]

Also note that these open formulae as such cannot be associated with answers to the corresponding questions. A reasonable semantics for sentences of this type results not simply after combining the verb with its argument, but only

18. Lahiri (1991, chapter 2) argues at length that there is no syntactic evidence to show that *wh*-complements embedded under these verbs are different.

after the subsequent procedure of accommodating the embedded interrogative as a presupposition in the restriction of an (implicit or explicit) adverb of quantification. Also, this procedure requires an assumption of factivity for such verbs as *tell* which ascribes them the property of presupposing their argument just in cases this is an interrogative. This makes a lexical semantic property dependent on a structural syntactic one, which is unusual, to say the least. Finally, observe that this difference in type of semantic objects prohibits a uniform account of coordination and entailment.

It seems to us that an analysis that does accord with the general assumptions made in the introductory section, and which is able to explain the differences in possible quantificational variability in terms of a general mechanism, is to be preferred. Therefore, we will outline in the next section how the semantics of interrogatives described above can be made to handle the phenomenon of quantificational variability.

4 Berman's challenge met

We will show stepwise how the analysis of section 2 can be made to meet Berman's challenge. We start by showing how quantificational variability can be had on the weak exhaustiveness view, since the latter is nearest to Berman's own analysis. Then we will strengthen the result to comply with strong exhaustiveness.

Recall from section 2 that in a weakly exhaustive analysis, a sentence like (41a) is translated as (41b). The latter is equivalent to (41c), which we could also write in 'adverbs of quantification'-style as (41d):

(41) a. John tells which girl(s) sleep(s).
b. $T(w)(j, \lambda w' \forall x[[G(w)(x) \wedge S(w)(x)] \rightarrow [G(w')(x) \wedge S(w')(x)]])$
c. $\forall x[[G(w)(x) \wedge S(w)(x)] \rightarrow T(w)(j, \lambda w'[G(w')(x) \wedge S(w')(x)])]$
d. $\textsc{all}_x[G(w)(x) \wedge S(w)(x)][T(w)(j, \lambda w'[G(w')(x) \wedge S(w')(x)])]$

The last representation is virtually the same as what results in Berman's analysis, but notice that it is obtained without having to assume that *tell* is factive, and without presupposition accomodation, due to the fact that the embedded interrogative is assigned a meaning of its own.

But, as we saw in the previous section, the reason for Berman to deviate from this straightforward analysis are sentences containing explicit adverbs of quantification, such as (42a). As we remarked earlier it seems an inherent feature of both the weakly and the strongly exhaustive analysis that *wh*-terms have universal quantificational force. So the problem is how we can get rid of the universal quantifier $\textsc{all}_x$ and 'replace' it by the quantifier $\textsc{most}_x$ in order to obtain (42b), which represents the meaning Berman assigns to (42a):

(42) a. John usually tells which girl(s) sleep(s).
b. $\textsc{most}_x[G(w)(x) \wedge S(w)(x)][T(w)(j, \lambda w'[G(w')(x) \wedge S(w')(x)])]$

This is were dynamic semantics comes in.

In dynamic semantics (see Groenendijk & Stokhof 1990,1991) indefinites are not analyzed as introducing free variables, as in discourse representation theory, but as quantificational expressions in their own right. A simple donkey-sentence like (43a) is translated as (43b). The dynamic interpretation assigned to the existential quantifier makes (43b) equivalent to the ordinary translation (43c) in standard predicate logic:

(43) a. If John owns a donkey he beats it.
b. $\exists x[D(x) \wedge H(j,x)] \rightarrow B(j,x)$
c. $\forall x[[D(x) \wedge H(j,x)] \rightarrow B(j,x)]$

The interpretation of the existential quantifier in dynamic semantics ensures that the existentially quantified antecedent of (43b) outputs assignments in which the value of the variable x is a donkey that John owns. The interpretation of the implication as a whole is defined in such a way that it takes all such output assignments, and checks whether the values of x satisfy the consequent, i.e., whether they are indeed beaten by John. If so, the implication is considered true. So the truth conditions of (43b) in dynamic semantics are the same as the truth conditions of (43c) in ordinary static semantics. The relevant fact that we make use of here is that in dynamic semantics the following equivalence holds without the usual restriction that x does not occur freely in the consequent:

$$\exists x\phi \rightarrow \psi \Leftrightarrow \forall x[\phi \rightarrow \psi]$$

Observe that, given this fact, in dynamic semantics (41c) is equivalent to (44):

(44) $\exists x[G(w)(x) \wedge S(w)(x)] \rightarrow T(w)(j, \lambda w'[G(w')(x) \wedge S(w')(x)])$.

What we need to know next is how adverbs of quantification can be dealt with in a dynamic framework. Following the proposals of Dekker and Chierchia this can be done as follows.[19] As we noted above, a formula of the form $\exists x\phi$ outputs all those assignments that assign values to x that satisfy ϕ. This makes the variable x available for further quantification. And because of that, the adverb of quantification in $AQ_x[\exists x\phi][\psi]$ can quantify over the output of $\exists x\phi$, and require that a Q-amount of such outputs satisfy the condition ψ. In other words, given the dynamic interpretation of the existential quantifier we obtain equivalences of the following form:

$$AQ[\exists x\phi][\psi] \Leftrightarrow Q_x[\phi][\psi]$$

where Q is the ordinary quantifier corresponding to the adverb of quantification AQ, even though the variable x is existentially quantified in the antecedent.

For the purposes of the present paper, this much suffices, and we must refer to reader to the papers by Dekker and Chierchia for a substantiation of this claim and more details.

19. See Dekker (1992), Chierchia (1992). What is said in the text makes use of only a small part of their analyses. For example, we completely disregard the issue of symmetric versus non-symmetric readings, which both Dekker and Chierchia discuss extensively.

Given these two facts of dynamic semantics, we may rest assured that when an implicational structure of the form (45a) is combined with an adverb of quantification, it can be represented as in (45b), which in the dynamic framework is equivalent with (45c):

(45) a. $\exists x\phi \rightarrow \psi$
b. $AQ[\exists x\phi][\psi]$
c. $Q_x[\phi][\psi]$

Once we know this much, sentences with adverbs of quantification no longer present a problem. Consider again example (42a), repeated below as (46a). We know that we can represent its meaning without the adverb of quantification in the form of the implicational structure (46b), which is equivalent with (46c). The result of combining it with the adverb of quantification can be represented as in (46d), which is equivalent with (46e):

(46) a. John usually tells which girl(s) sleep(s).
b. $\forall x[[G(w)(x) \wedge S(w)(x)] \rightarrow T(w)(j, \lambda w'[G(w')(x) \wedge S(w')(x)])]$
c. $\exists x[G(w)(x) \wedge S(w)(x)] \rightarrow T(w)(j, \lambda w'[G(w')(x) \wedge S(w')(x)])$
d. $\textsc{usually}[\exists x[G(w)(x) \wedge S(w)(x)]][T(w)(j, \lambda w'[G(w')(x) \wedge S(w')(x)])]$
e. $\textsc{most}_x[G(w)(x) \wedge S(w)(x)][T(w)(j, \lambda w'[G(w')(x) \wedge S(w')(x)])]$

In this way we can obtain the meanings Berman wants to assign to sentences like (46a), but in a more straightforward and simple way. We make use of the lexical properties of the verb *tell* without having to assume it to be factive when embedding an interrogative. Interrogatives are assigned an independent and uniform (weakly) exhaustive interpretation. And the quantificational variability induced by the occurrence of adverbs of quantification is obtained by making use of equivalences which rest on independently motivated clauses in dynamic semantics.

This shows how Berman's readings of sentences with adverbs of quantification can be obtained by combining the weakly exhaustive interpretation of interrogatives from section 2 with a dynamic semantic approach to quantification. However, we argued earlier that the weakly exhaustive interpretation is not the right one, and that strong exhaustiveness is needed. Let us repeat what is at stake here. Consider (47)(a)–(c):

(47) a. John knows which girl(s) sleep(s).
b. Of every girl who sleeps, John knows that she is a girl who sleeps.
c. Of no girl who doesn't sleep, John believes that she is a girl who sleeps.

In section 1 we argued that (47a) entails both (47b) and (c). However, a weakly exhaustive interpretation only accounts for the entailment between (47a) and (b), but it does not give us the other one. The latter entailment is what strong exhaustiveness adds to weak exhaustiveness: If it is compatible with what John knows that an individual is a girl who sleeps, then she actually is.[20]

20. Another relevant observation is that weak exhaustiveness predicts that *Noone is running*

Similar observations can be made with respect to sentence (48a), which differs from (47a) only in that it contains the adverb of quantification *usually*. Again, (48a) should entail both (48b) and (c), but the weakly exhaustive reading accounts only for the first entailment:

(48) a. John usually knows which girl(s) sleep(s).
b. Of most girls who sleep, John knows that they are girls who sleep.
c. Of few girls who don't sleep, John believes that they are girls who sleep.

Establishing the truth conditions of sentences such as (48a) is a complicated matter. In order to decide whether it is true or not, we need access to two sets of individuals: the set of individuals that actually are girls who sleep; and the set of individuals of whom it is compatible with John's information that they are girls who sleep. In order to see what the actual truth conditions are, observe that the latter set may contain not only individuals that actually are girls that sleep, but also individuals of whom John wrongly believes that they are, and individuals of whom he is in doubt as to whether they are girls who sleep or not. Notice further that individuals that actually are girls who sleep may be lacking from it. So from the two sets we start out with we can construct four other sets: the set of individuals John has a definite and correct opnion about; the set containing the individuals about whom he has a wrong opinion; the set consisting of the ones he is in doubt about; and the set containing the ones he misses. The truth conditions of (48a) can be stated in terms of a comparison between the union of the last three sets with the first one: the cardinality of the first should be (considerably) less than that of the second.

Now we turn to quantificational variability and strong exhaustiveness. Repeated below as (49b) is the representation which we gave at the end of section 2 of the strongly exhaustive analysis of sentence (49a):

(49) a. John tells which girl(s) sleep(s).
b. $\forall x[[[G(w)(x) \wedge S(w)(x)] \vee \exists w'[T_{j,w}(w') \wedge G(w')(x) \wedge S(w')(x)]] \rightarrow [G(w)(x) \wedge S(w)(x) \wedge \forall w'[T_{j,w}(w') \rightarrow [G(w')(x) \wedge S(w')(x)]]]]$

Within the framework of dynamic semantics this is equivalent to (50):

(50) $\exists x[[G(w)(x) \wedge S(w)(x)] \vee \exists w'[T_{j,w}(w') \wedge G(w')(x) \wedge S(w')(x)]] \rightarrow [G(w)(x) \wedge S(w)(x) \wedge \forall w'[T_{j,w}(w') \rightarrow [G(w')(x) \wedge S(w')(x)]]]$

And this represents the required strongly exhaustive interpretation. Notice that we obtain this result without recourse to the assumption that sentences like this contain an implicit adverb of quantification.

Also, we know that given the dynamic treatment of adverbs of quantification (51a) can be represented as (51b):

(51) a. John usually tells which girl(s) sleep(s).

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entails *Everyone knows who is running*, and that *John tells that everyone is running* entails *John tells who is running*. In our opinion this is not quite what one would like to have.

b. $\text{USUALLY}[\exists x[[G(w)(x) \wedge S(w)(x)] \vee \exists w'[T_{j,w}(w') \wedge G(w')(x) \wedge S(w')(x)]]]$
$[G(w)(x) \wedge S(w)(x) \wedge \forall w'[T_{j,w}(w') \rightarrow [G(w')(x) \wedge S(w')(x)]]]$

And (51b), we know, is equivalent with (52):

(52) $\text{MOST}_x[[G(w)(x) \wedge S(w)(x)] \vee \exists w'[T_{j,w}(w') \wedge G(w')(x) \wedge S(w')(x)]]$
$[G(w)(x) \wedge S(w)(x) \wedge \forall w'[T_{j,w}(w') \rightarrow [G(w')(x) \wedge S(w')(x)]]]$

This gives the right quantificational results. According to the restriction clause the quantification is over individuals that are either girls that actually sleep or individuals of whom it is compatible with what John tells that they are girls who sleep (or both). The quantifier requires that most of them should be girls who sleep and that John should tell that they are. It is easy to see that this strongly exhaustive interpretation entails Berman's weakly exhaustive reading. For if we simply drop the second disjunct in the restriction clause in (52) the number of individuals quantified over becomes potentially less. If John is correct about most individuals in the larger set, then he is certainly also right about most individuals in potentially smaller set.

The quantifiers ALL and MOST that correspond to the adverbs *always* and *usually* have in common that they are upward monotonic. Let us conclude this section with an investigation of two downward monotonic cases. If we replace MOST in (52) by FEW, we may observe that because of the downward monotonicity of FEW, Berman's weakly exhaustive interpretation now entails the strongly exhaustive one, rather than the other way around, as in the case of ALL and MOST. To see that this is so, suppose that of about 50 percent of the girls that are asleep, John tells that they are, then according to Berman's analysis it is false that John seldomly tells which girl(s) sleep(s), even if at the same time John tells of a large amount of individuals that are not girls that sleep, that they are. This is clearly not correct. The strongly exhaustive analysis correctly predicts that in this case it is true that John rarely tells which girl(s) sleep(s). If we look at the individuals that actually sleep and at those that actually do not but of whom John tells that they do, then he is correct only in few cases.

With NO things are slightly different. In that case the two approaches give equivalent results. This can be seen as follows. The second disjunct in the restriction clause potentially adds cases that have to be taken into consideration. But if it really adds an individual, this should not be a girl that actually sleeps, i.e., this should not be an individual that already satisfies the first disjunct of the restriction clause. But such individuals cannot satisfy the nuclear scope clause, since they will not satisfy the first conjunct of it. These results seem to be in accordance with the facts.

The discussion of these examples shows that quantificational variability and strong exhaustiveness, contrary to appearance and Berman, are not incompatible. Recasting the analysis of section 2 in the framework of a dynamic semantics allows us to retain the original strongly exhaustive interpretation of interrogatives, which is in accordance with the general assumptions laid down in section 1, and to account for the phenomenon of quantificational variability in embedded interrogatives.

5 Lahiri's examples

In his dissertation (Lahiri 1991), Lahiri extensively discusses Berman's analysis of quantificational variability in embedded interrogatives. Many of his criticisms coincide with ours. However, some of the points he raises may appear to apply also to the analysis presented in the preceding section. Here we will discuss one.

Lahiri argues that the distinction between embedding verbs that do and those that do not give rise to quantificational variability does not coincide with the distinction between factive and non-factive verbs. This is in accordance with our findings above, where we showed that the possibility of quantificational variability with the non-factive verb *tell* can be accounted by exploiting its extensionality, together with certain other lexical properties. This may suggest that extensionality is the crucial feature that allows quantificational variability. Lahiri, however, presents examples such as (53) and (54), which we already referred to in the introductory section (we slightly changed the examples here, in order to facilitate comparison), which show that there is a class of non-factive, *intensional* verbs, such as *be certain about*, and *agree on*, which allow for quantificational variability:

(53) John is mostly certain about which girls are asleep.
(54) John and Bill agree, for the most part, on which girls are asleep.

In view of these examples it is evident that extensionality is not necessary feature for a verb to allow quantificational variability, either.

What we will argue now is that, appearances not withstanding, our approach does not depend on the extensionality of the verbs in question. It only requires more generally that the lexical semantic properties of such verbs should provide the possibility of a logical paraphrase that has the required universally quantified implicational structure. We will do so by sketching, by way of example, how the lexical semantic properties of the verb *be certain (about)* make it possible to account for the quantificational variablility exemplified in (53).

Consider first the following two examples without adverbs of quantification:

(55) John is certain that Mary is asleep
(56) John is certain about which girls are asleep

Although there is undoubtedly more to the meaning of *be certain*, (55) minimally means that in all worlds compatible with the information John has, it holds that Mary is asleep. There is no question of factivity here: (part of) John's information may be wrong, i.e., the actual world need not be among the worlds compatible with his information. (This is a feature that distinguishes *be certain* from *know*.) This means that the translation (57) of (55), can be logically paraphrased as (58):

(57) $C(w)(j, \lambda w'[S(w')(m)])$

(58) $\forall w'[C_{j,w}(w') \to S(w')(m)]$

Sentence (56) means that the question which girls are asleep is settled in John's information. It provides a complete answer to the question which girls are asleep, but, again, since not all of this information needs to be true, the answer need not be the actually true answer. What this amounts to is that in any two worlds compatible with John's information the answer to the question (the denotation of the question) is the same. In other words, in any two worlds compatible with John's information the positive extension of the property of being a girl that is asleep should be the same. This leads to the following representation of the meaning of (56):

(59) $\forall w' \forall w''[[C_{j,w}(w') \wedge C_{j,w}(w'')] \to$
$\forall x[[G(w')(x) \wedge S(w')(x)] \leftrightarrow [G(w'')(x) \wedge S(w'')(x)]]]$

The double implication in the consequent is superfluous, a single implication expresses the same meaning:

(60) $\forall w' \forall w''[[C_{j,w}(w') \wedge C_{j,w}(w'')] \to$
$\forall x[[G(w')(x) \wedge S(w')(x)] \to [G(w'')(x) \wedge S(w'')(x)]]]$

And this is logically equivalent with:

(61) $\forall x[\exists w'[C_{j,w}(w') \wedge G(w')(x) \wedge S(w')(x)] \to$
$\forall w'[C_{j,w}(w') \to [G(w')(x) \wedge S(w')(x)]]]$

From here, the story is completely analogous to the cases discussed above. Using the dynamic donkey-equivalence, we can write (61) as (62):

(62) $\exists x \exists w'[C_{j,w}(w') \wedge G(w')(x) \wedge S(w')(x)] \to$
$\forall w'[C_{j,w}(w') \to [G(w')(x) \wedge S(w')(x)]]$

And this means that sentence (63a) with the adverb of quantification *mostly*, can be represented as (63b), which is equivalent with (63c):

(63) a. John is mostly certain about which girls are asleep.
b. $\textsc{mostly}[\exists x \exists w'[C_{j,w}(w') \wedge G(w')(x) \wedge S(w')(x)]]$
$[\forall w'[C_{j,w}(w') \to [G(w')(x) \wedge S(w')(x)]]]$
c. $\textsc{most}_x[\exists w'[C_{j,w}(w') \wedge G(w')(x) \wedge S(w')(x)]]$
$[\forall w'[C_{j,w}(w') \to [G(w')(x) \wedge S(w')(x)]]]$

Representation (63c) is virtually identical to the logical form that Lahiri assigns to (63a), viz.:

(64) $\textsc{most}_x$[John considers it likely that x is a girl that sleeps][John is certain that x is a girl that sleeps]

The only difference is that in Lahiri's representation the resctriction clause imposes the condition that John consider it likely that x is a girl that sleeps, whereas (63c) merely requires this to be compatible with John's information. It seems that the weaker condition is empirically more adequate. In determining whether (63a) is true, one should not leave out of consideration individuals of whom John considers it unlikely, but possible that they are girls that sleep. Doing so would make (56) and (63a) true in situations in which John is uncertain about which girls are asleep. But of course this is not an essential difference, since Lahiri's representation could easily be remedied in this way.

A more fundamental difference concerns the way in which representations such as (63c) or (64) are derived. Like Berman, Lahiri views the contents of the restriction clause as a presupposition of the main clause, which ends up in the restriction via a process of presupposition accommodation. The difference is that in this case it is not a factive presupposition that is accomated. On this point the Berman/Lahiri approach and our analysis differ, a point to which we return in the next section.

6 Final remarks

First of all, we want to draw attention to what seems to be a rather fundamental difference between the approach presented in the previous two sections, and Berman's way of dealing with quantificational variability. (We restrict ourselves here to a dicussion of Berman's analysis, but our remarks largely carry over to Lahiri's proposals as well.) The two kinds of approaches resemble each other in that both associate sentences containing adverbs of quantification with tripartite structures in which an adverb of quantification takes a restriction clause and a nuclear scope clause as arguments. But the approaches differ not only in what they consider to be the contents of the arguments of the adverb, but also in how they arrive at them. In Berman's case the restriction clause is formed by accommodating a presupposition. The analysis presented in the previous sections derives the contents of both arguments of the adverb by 'decomposing' the meaning of the sentence without the adverb into two parts, that can be viewed as the antecedent and the consequent of an implicational structure. In Berman's case the relevant presupposition is identical to the propositional argument of the main verb, and hence extractable from surface syntactic structure. In our analysis the restriction clause and the nuclear scope clause cannot be determined at this level. For the surface form of these sentences is not that of an implication. However, we have shown that their semantic representations can be cast in this format within a dynamic framework. So, this analysis seems bound to the view that it is only on the basis of the semantic content of an entire sentence that we can determine what constitutes the restriction and the nuclear scope of an adverb of quantification occurring in it, and that its syntactic structure does not suffice. We are not sure what conclusions can be drawn from this, but we note that this aspect of our analysis seems to be in line with Roberts' argument that domain restriction in general is not simply a matter of what she calls a 'structure driven algorithm', but largely depends on different kinds of contextual (semantic and pragmatic) factors. (See Roberts 1991.)

Another remark we want to make is that in the analysis proposed in the previous sections, a crucial feature of Berman's analysis, viz., that *wh*-terms are to be treated in the same way as indefinites, playes no role. Treating them like indefinites in a dynamic framework would mean translating them in terms of dynamic existential quantification. But this we did not do. (We did make use of dynamic existential quantification, but not in the translation of *wh*-terms as such, but only in order to arrive at the required implicational structure.) Still, it might be interesting to point out that we might do so if for whatever reason this seems to be desirable after all.[21] We have seen that if existential quantification is dynamic, we can 'disclose' the property $\lambda x \phi$ from the existentially quantified formula $\exists x \phi$. This means that in the end it makes no difference whether we deal with *wh*-terms as a form of restricted λ-abstraction, or as dynamic existential quantification.

A perhaps more interesting observation is that in some cases indefinites behave like *wh*-terms. It seems that a sentence like (65a) has a reading (maybe it is even its most likely one) in which it is equivalent with (65b):

(65) a. John (usually) knows whether a girl sleeps.
b. John (usually) knows which girl(s) sleep(s).

On a dynamic account of indefinites, this reading easily falls out.

In fact, even universally quantified terms sometimes lend themselves to quantificational variability, viz., in sentences with so-called pair-list readings. Sentence (66a) has a reading on which it is equivalent with (66b).

(66) a. John (usually) knows which professor recommended every/each student.
b. John (usually) knows which professor recommended which student.

Elsewhere (see Groenendijk & Stokhof 1984, chapter 6), we have given an analysis of sentences like (66a) (but without the adverb of quantification) which makes it equivalent to (66b). That being so, such sentences lend themselves equally easily to quantificational variability.[22]

The following sentence is a variant of Berman's sentence (30c), cited in section 3. It contains a *wh*-term, an indefinite and a universally quantified term, and illustrates that all three of them can be subject to binding by the same adverb of quantification:

(67) With few exceptions, Mary knows which abstract every student submitted to a conference.

The conclusion we draw from these observations is that although it may be appealing at first sight to treat *wh*-terms in the same way as indefinites in order to account for quantificational variability, in fact this hypothesis seems unwarranted. As the example (67) indicates, we can treat them either as restricted λ-abstraction, or in terms of dynamic existential quantification, or in terms of universal quantification. It does not really matter. As long as we assign inter-

21. The analysis of free relatives might be a case in point.
22. Examples similar to (65a) and (66a) can also be found in Lahiri (1991).

rogatives a strongly exhaustive interpretation, quantificational variability can be accounted for in any of these three alternatives.

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