Downward monotonicity in questions[1]

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Abstract. I show that the hypothesis that downward monotonicity is required for the licensing of negative polarity items (Fauconnier 1975, 1979, Ladusaw 1979) can account for why they appear in interrogatives. In particular, I show that strong exhaustive answers to questions with negative polarity items are downward monotone using three ingredients: (i) interrogatives denote sets of propositions (Hamblin 1973, Karttunen 1977), (ii) negative polarity items introduce alternatives and thereby enrich this denotation, and (iii) an answer operator (Heim 1994, Beck and Rullmann 1999) delivers the strong exhaustive answer. Among other things this accounts for Guerzoni and Sharvit's 2007 observation that only interrogatives embedded under predicates allowing for a strong exhaustive interpretation of that question license negative polarity items.

Keywords: negative polarity items, questions, monotonicity, exhaustivity.

1. Introduction

According to Fauconnier (1975, 1979) and Ladusaw (1979) negative Polarity Items (NPIs) like *any* and *ever* must occur in downward monotone (DE for downward entailing) environments (also cf. Fauconnier 1975, 1979), which accounts for their basic distribution in declarative sentences. Since at least Klima (1964), however, it is also known that NPIs are also licensed in interrogatives:

(1) *Context: A teacher inquiring about students' interests.*
Q: Has John ever shown any interest in poetry?

The question what property interrogatives share with, for instance, negation in declaratives – the paradigm case of NPI-licensing in such environments – is not straightforward to answer. Since (downward) monotonicity is defined over entailment, it is not obvious whether and how it extends to questions. Also, intuitively questions do not appear to be DE (cf. Giannakidou 1999, Guerzoni and Sharvit 2007 a.o.). Moreover Guerzoni and Sharvit (2007) have shown that NPIs in questions appear to be sensitive to a logical property different from downward monotonicity. In particular, they argue that NPIs are only licensed in questions that are interpreted as strongly exhaustive. These two facts have cast Fauconnier's and Ladusaw's generalizations and most of the theories about NPI-licensing stemming from them into serious doubt. The conclusion that has been drawn is that either there is no overarching empirical generalization about NPI-licensing and that the environments where they are licensed must be listed somehow (Guerzoni and Sharvit 2007) or that

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an altogether different generalization must be found (Giannakidou 1999, 2011, Israel 1996, 2011).

In this paper I argue that such a defeatist view is unwarranted. While questions in general are not DE environments, I will show that the strong exhaustive answers to those with NPIs in them are. In particular, NPIs are argued to introduce semantic alternatives into the computation of meaning (Heim 1984, Krifka 1995, Chierchia 2004, 2006). These alternatives enlarge the question denotation, which is viewed as a set of propositions (Hamblin 1973, Karttunen 1977). More precisely, the denotations of interrogatives with NPIs include those of interrogatives where the NPI is replaced by a more specific alternative. This necessitates a slight modification of the question semantics as well. I then show that the strong exhaustive answer to such a question entails the one to each alternative question. The notion of strong exhaustive answer is the one employed by Groenendijk and Stokhof (1984). In particular, I follow Heim (1994), Beck and Rullmann (1999) in assuming an operator that applies to the question denotation and delivers the strong exhaustive answer to that question. Moreover, I show that the non-exhaustive answer remains non-monotonic even under the modification sketched above. As a consequence, NPIs are only licensed in interrogatives whose answers receive a strong exhaustive interpretation. This accounts for Guerzoni and Sharvit's 2007 observation.

The paper is structured as follows: in section 2 the puzzle caused by NPIs in interrogatives is discussed. Section 3 introduces the proposed modification of the question semantics and shows how the strong exhaustive answer creates a DE environment. In section 4 I discuss some of the consequences of the proposal. Finally, section 5 concludes the paper.

2. Downward monotonicity and NPIs in interrogatives

2.1. Downward monotonicity and NPI-licensing

While NPI *any* and *ever* are licensed in the scope of negation, (2-b), and in the restrictor and scope of negative quantifiers (3), they are ungrammatical when occurring unembedded, (2-a). A simple generalization suggests itself: negative environments license NPIs. As is well-known, however, this cannot be the whole story. For instance, the restrictor of a universal quantifier, on the one hand, licenses NPIs, (4-a). Its scope, on the other hand, does not do so, (4-b).

(2) a. *Mary thinks that John has ever been to any foreign country.
b. Mary does not think that John has ever been to any foreign country.

(3) a. No one who thinks that John has ever been to any foreign country attended.
b. No one thinks that John has ever been to any foreign country.

(4) a. Every student who has ever been to any foreign country attended.

b. *Every student has ever been to any foreign country.

In order to account for the pattern observed, Ladusaw (1979) proposes the generalization in (5) (also cf. Fauconnier 1975, 1979). (5) can also be read as a necessary condition on NPI-licensing rather than a mere generalization. It requires NPIs to at least occur in a DE environment.

(5) *NPI-licensing generalization*
NPIs are only grammatical in a downward monotone environment.

A function creates an upward monotone (UE for upward entailing) environment if it does not change the entailment direction of its arguments. Correspondingly, a function makes an environment DE if it reverses the entailment pattern of its arguments. In other words, an UE environment is one that licenses inferences from a set to its supersets, whereas a DE environment licenses inferences from a set to its subsets.[2] According to (5) an NPI must occur in the latter kind of environment. Clearly, negation reverses the entailment found without negation in (6), as shown in (7). In particular, the intuitive entailments in (7) show that both the scope and the restrictor of a negative quantifier are DE (here and below $\Rightarrow$ stands for entailment).

(6) John has blond hair. $\Rightarrow$ John has hair.

(7) a. No one has hair. $\Rightarrow$ No one has blond hair.
b. No one who has hair attended. $\Rightarrow$ No one who has blond hair attended.

More interestingly, the scope of a universal quantifier is UE, while its restrictor is DE:

(8) a. Everyone has blond hair. $\Rightarrow$ Everyone has hair.
b. Everyone who has hair attended. $\Rightarrow$ Everyone who has blond hair attended.

The generalization in (5) thus correctly distinguishes between those environments licensing NPIs and those that do not do so. Although, problematic data have been taken to suggest that the original Fauconnier-Ladusaw generalization cannot be correct (Israel 1996, 2011, Giannakidou 1999, 2006, 2011, Linebarger 1987) and alternative generalizations have been proposed, it appears that suitable

[2]More formally, where $\Rightarrow$ denotes entailment, and σ and τ denote types:

(i) a. $f \in D_{\langle\sigma,\tau\rangle}$ is UE iff for all $a, b \in D_\sigma$, where $a \Rightarrow b$, $f(a) \Rightarrow f(b)$.
b. $f \in D_{\langle\sigma,\tau\rangle}$ is DE iff for all $a, b \in D_\sigma$, where $a \Rightarrow b$, $f(b) \Rightarrow f(a)$.

modifications to the original account can be made that preserve its spirit.[3]

2.2. NPIs in interrogatives

As the following examples show, NPI *any* and *ever* are licensed in both information-seeking yes-no questions and in information-seeking wh-questions. The continuations make sure that the interrogatives are not interpreted rhetorically:[4]

(9) *Context: A mother is worried whether her son ate at all.*
Q: Did John eat anything today? Usually he does.

(10) *Context: A person is unsure whether Tony has been to France.*
Q: Has Tony ever been to France? It's certainly possible.

(11) *Context: In a school canteen, the teacher inquires who ate what.*
Q: Since there is none left, who took any lasagna today?

(12) *Context: A teacher asks which students have been to France.*
Q: Who of you has ever been to France? I know some have been.

This raises the question whether (9)-(12) conform to the Fauconnier-Ladusaw generalization.

2.2.1. Are questions downward monotone?

In order for interrogative clauses to conform to the Fauconnier-Ladusaw generalization, they should be related by downward monotonicity. That is, given the intuitive entailment in (13), question (14-a) should entail question (14-b). Is this what we find?

[3]For instance, to deal with NPIs in the antecedent of a conditional various modifications have been suggested making them DE in a limited sense (Heim 1984, Kadmon and Landman 1993, von Fintel 1999). For an overview over other problematic environments see Atlas (1996), Israel (1996), Giannakidou (1999, 2006), Ladusaw (1979), Linebarger (1987) a.o. For NPIs under *only*, superlatives, adversative predicates, and quantifier *most* it has been suggested that the presuppositions of the elements in question must be somehow factored out when checking for downward monotonicity (von Fintel 1999, Gajewski 2010, Homer 2009, 2010, Wagner 2006).

[4]I will ignore rhetoric questions, such as (i), for reasons of space (see Krifka 1995, Guerzoni 2004 a.o.).

(i) Who has ever been to France from this class? None of the parents can afford such a trip.

(13) John read *War & Peace*. ⇒ John read a book by Tolstoy.

(14) a. Did John read a book by Tolstoy?
b. Did John read *War & Peace*?

Clearly, one can ask (14-a) without being interested in (14-b), and vice versa. Thus intuitively, asking one of the questions in (14) does not lead one to ask the respective other one as well, which might be expected if entailment held between the questions (cf. Guerzoni and Sharvit 2007).

Can we simply extend the notion of entailment from propositions to questions in order to account for NPIs in the latter? For yes-no-questions there is more or less agreement with regard to their denotations. In particular, we can view them as the sets containing the positive and possibly negative answer to the question (Hamblin 1973, Karttunen 1977), as shown in (15) for (14). None of the sets in (15) is a subset of the respective other set – that is, no entailment is expected. This formal fact might then be taken to account for the perceived lack of entailment in (14). But crucially, NPIs should not be licensed in interrogatives due to the lack of downward monotonicity.[5]

(15) a. $[\![(14\text{-a})]\!] = \{$that John read a book by Tolstoy, that John read no book by Tolstoy$\}$
b. $[\![(14\text{-b})]\!] = \{$that John read W&P, that John didn't read W&P$\}$

But maybe we have to tweak our notion of entailment for interrogatives. After all, they do not clearly denote propositions, and entailment is defined over propositions. A number of options have been pursued in the literature. They, however, also suffer from the problem already discussed in some way or other. For instance, Groenendijk and Stokhof (1997) suggest that for entailment from (14-a) to (14-b) to hold, every complete answer to the former should entail an answer to the latter (also cf. Karttunen 1977). Now in the case of yes-no questions the positive and the negative answers are the complete answers. The positive answer to (14-a) neither entails the positive nor the negative one to (14-b). So downward monotonicity is missing, and NPIs should not be licensed.[6]

2.2.2. A different condition – strong exhaustiveness

Guerzoni and Sharvit (2007) observe that the licensing of NPIs in embedded interrogatives depends on the embedding predicate. While interrogatives under *wonder* always license NPIs, those under

[5]Note that excluding the negative proposition from the denotations of the interrogatives does not change anything with respect to entailment. Groenendijk and Stokhof's 1984 question semantics suffers from a parallel problem.

[6]Similarly Groenendijk and Roelofsen (2009) working in the framework of inquisitive semantics suggest that (14-a) entails (14-b) only if every possibility raised by the former is contained in the ones raised by the latter. The possibilities raised by (14-a) and (14-b) are roughly the propositions in the Hamblin (1973)/Karttunen (1977) denotation, (15). But then clearly, this notion of entailment fails to make (14-a) and (14-b) DE.

know only do so for a subset of the speakers. Questions under *surprise* never license NPIs:

(16) a. Claire wonders which students have any books on Negative Polarity.
b. %Claire knows which students have any books on Negative Polarity.
c. *It surprised Bill which students had ever been to Paris.
(Guerzoni and Sharvit 2007:364)

Guerzoni and Sharvit suggest that this distribution correlates with *wonder* and *know* embedding strong exhaustive questions, while *surprise* not doing so. That is, only strong exhaustive questions are argued to license NPIs. For John to wonder who of his students passed, he has to wonder for *each* of them whether they passed or not (cf. Groenendijk and Stokhof 1982). Because of this strong exhaustiveness requirement of *wonder* the sentence in (17) sounds odd in the context given.

(17) *Context: Mary is one of John's students.*
#John wonders who of his students passed, but not whether Mary did.

Similarly, for John to know who was at the party, he must know for all people who were at the party that they were there and for all people who were not at the party that they were not there – the strong exhaustiveness requirement of *know*. For this reason the sentence in (18) is odd in the context given (cf. Karttunen 1977, Groenendijk and Stokhof 1982, Heim 1994).

(18) *Context: Mary was not at the party. John does not know if she was. But he knows for all people who were at the party that they were there.*
#John knows who was at the party.

Finally for John to be surprised about who was at the party, he need not be surprised about people who were not at the party. He need only be surprised about people who actually were there. Thus *surprise* does not embed a strong exhaustive question (Berman 1991, Heim 1994, Beck and Rullmann 1999, George 2011), and the sentence in (19) is odd in the context given.[7]

(19) *Context: Mary and Ann were at the party. Carl wasn't.*
#Although John had expected Mary and Ann to be at the party, he is still surprised who was at the party because he expected Carl to be there, too.

[7]There is some controversy as to whether *surprise* embeds weak exhaustive questions or mention-some questions (cf. George 2011). What is important for the discussion in the text is that there is agreement that the predicate does not embed strong exhaustive questions.

Thus only *wonder* and *know* but not *surprise* should license NPIs in embedded questions according to Guerzoni and Sharvit (2007). But then we also expect NPIs to only occur in direct questions that are interpreted as strongly exhaustive. Consider mention-some questions. When asking (20), it usually suffices if the addressee offers one place where one can buy the 'New York Times' and not an exhaustive list. That is, mention-some questions are inherently non-exhaustive in their interpretation. As a consequence, NPIs should not be licensed in them. This is what we find, as (21) shows. In other words, Guerzoni and Sharvit's 2007 observations extend to direct questions.

(20) Where can I buy the 'New York Times'?

(21) *Where can I buy any newspaper?

2.2.3. Intermediate conclusion

Given that questions fail to be DE, both alternative hypotheses being more inclusive than the Fauconnier-Ladusaw generalization and such that are entirely different in nature have been offered (Giannakidou 1999, 2011, Israel 1996, 2011, van Rooy 2003). For reasons of space I cannot go into the discussion of such accounts, but neither of them predicts strong exhaustiveness to be a crucial factor in the licensing of NPIs. Indeed, Guerzoni and Sharvit (2007) suggest that we have to give up the pretty picture painted so far and adopt a disjunctive statement of NPI-licensing: NPIs are licensed in DE contexts when appearing in declaratives and in strong exhaustive contexts when appearing in interrogatives. In the following section I will argue that this move is not necessary and that strong exhaustive questions with NPIs are in fact DE contexts if certain modifications in the semantics of questions are made.

3. Question semantics and strong exhaustive answers

3.1. The idea in a nutshell

Following Hamblin (1973) and Karttunen (1977) an interrogative denotes a set of propositions. In particular, a simple yes-no-question like *Did John read War & Peace?* has the singleton set in (22) as its denotation.[8]

(22) $[\![\text{Did John read 'War \& Peace'?}]\!]^w = \{\text{that John read W\&P}\}$

[8]Nothing of what is said below hinges on the denotation of a yes-no-question being actually a singleton. The proposal is compatible with the denotation containing the negative proposition as well. For reasons of space and for the ensuing immediately obvious compatibility of the proposal with wh-questions, I chose the singleton denotation.

A yes-no-question with an NPI in it, however, has an enlarged denotation. The NPI contributes alternatives to the denotation. These alternatives are chosen in such a way that they entail the meaning obtained when the NPI is interpreted as an existential quantifier (Krifka 1995, Chierchia 2004, 2006). For the question in (23) this means that propositions such as that John read 'War & Peace' are members of the question denotation because they entail that John read a book by Tolstoy, assuming that the only books written by Tolstoy are 'War & Peace' and 'Anna Karenina'.

(23) $[\![\text{Did John read any book by Tolstoy?}]\!]^w$ = { that John read W&P, that John read AK, that John read a book by Tolstoy}

From the question denotation we obtain a strong exhaustive answer by applying an operator to its intension and the world of evaluation (Heim 1994, Beck and Rullmann 1999). The consequence of this operator is that we get back a proposition stating that the true propositions in the question denotation are what they in fact are in the world of evaluation (Groenendijk and Stokhof 1982). This proposition thus contains negative information as it entails that all the propositions that are not in the set of true propositions in the world of evaluation are false. The operator is defined as in (24), where ans_s stands for strong exhaustive answer.

(24) $[\![\text{ans}_s]\!] = \lambda w_s \lambda Q_{\langle s,\langle\langle s,t\rangle,t\rangle\rangle} \lambda w'_s.\, \{p : Q(w')(p) \wedge p(w')\} = \{p : Q(w)(p) \wedge p(w)\}$

Consider what this means for our questions in (22) and (23). There are four possible states what the world can be like if 'War & Peace' and 'Anna Karenina' are Tolstoy's only books. First if the strong exhaustive answer, given (24), to (23) is that John read both books, the one to (22) is that he read 'War & Peace'. The former entails the latter, (25-a). If the strong exhaustive answer to (23) is that he read 'War & Peace' but did not read 'Anna Karenina', the one to (22) is that he read 'War & Peace'. Again, the former entails the latter, (25-b). If the strong exhaustive answer to (23) is that he read 'Anna Karenina' but not 'War & Peace', it entails that he did not read 'War & Peace', the strong exhaustive answer to (22), (25-c). Finally, if the strong exhaustive answer to (23) is that he did not read any book by Tolstoy, it once more entails the strong exhaustive answer to (22) which says that he did not read 'War & Peace', (25-d). In other words, whatever the world of evaluation is like, the strong exhaustive answer to the yes-no-question with an NPI in it in (23) will entail the one to the yes-no-question with one of the books in the alternatives introduced by the NPI in its place, i.e., the strong exhaustive answer to a yes-no-question with the NPI in it is DE.

(25) a. (i) $[\![\text{ans}_s]\!](w_1)(\lambda w'[\![(23)]\!]^{w'})$ = that John read W&P and AK
$\Rightarrow$
(ii) $[\![\text{ans}_s]\!](w_1)(\lambda w'[\![(22)]\!]^{w'})$ = that John read W&P
b. (i) $[\![\text{ans}_s]\!](w_2)(\lambda w'[\![(23)]\!]^{w'})$ = that John read W&P and not AK
$\Rightarrow$

(ii) $[\![\text{ans}_s]\!](w_2)(\lambda w'[\![(22)]\!]^{w'})$ = that John read W&P

c. (i) $[\![\text{ans}_s]\!](w_3)(\lambda w'[\![(23)]\!]^{w'})$ = that John read AK and not W&P

$\Rightarrow$

(ii) $[\![\text{ans}_s]\!](w_3)(\lambda w'[\![(22)]\!]^{w'})$ = that John did not read W&P

d. (i) $[\![\text{ans}_s]\!](w_4)(\lambda w'[\![(23)]\!]^{w'})$ = that John did not read W&P or AK

$\Rightarrow$

(ii) $[\![\text{ans}_s]\!](w_4)(\lambda w'[\![(22)]\!]^{w'})$ = that John did not read W&P

The strong exhaustive answer to (22) does, however, not entail the one to (23). In particular, if the strong exhaustive answer to (22) says that John did not read 'War & Peace', this does not entail the strong exhaustive answer to (23). The latter could be either of (26-b) or (26-c). So we find downward monotonicity but not upward monotonicity with yes-no-questions with NPIs in them.[9]

(26) a. $[\![\text{ans}_s]\!](w_5)(\lambda w'[\![(22)]\!]^{w'})$ = that John did not read W&P

$\not\Rightarrow$

b. $[\![\text{ans}_s]\!](w_5)(\lambda w'[\![(23)]\!]^{w'})$ = that John read read AK but not W&P

c. $[\![\text{ans}_s]\!](w_5)(\lambda w'[\![(23)]\!]^{w'})$ = that John did not read W&P or AK

The combination of a Karttunen-question semantics, alternatives introduced by NPIs, and a strong exhaustive answer operator has the effect of making questions or rather their answers DE. As a result, NPIs should be licensed. It is important to realize that only strong exhaustive answers to questions with NPIs in them are DE under this view, but not those to questions without such elements. Moreover, this proposal has the capacity to directly connect Fauconnier's 1975 and Ladusaw's 1979 NPI-generalization with Guerzoni and Sharvit's 2007 observations discussed above. I will return to discussion of this issue in subsection 4.1.

I now turn to a brief discussion of the compositional details of the proposal presented.

3.2. Compositional details

Following Krifka (1995) and Chierchia (2004, 2006) I assume that NPIs are interpreted as existential quantifiers. Moreover, following more specifically Chierchia NPIs come with a domain variable D over which the quantifier ranges. That is, *any* has the denotation in (27-a). I also assume that the interpretative system is bi-dimensional (Rooth 1985) in the sense that each constituent receives two interpretation values: an ordinary one, (27-a) in the case of *any*, and an alternative value. For *any* the latter value is a set of existential quantifiers, which differ from the existential

[9] This result is potentially important given that Lahiri (1998) has suggested that NPIs are licensed only if the relevant context is DE but not UE in addition (cf. also Guerzoni and Sharvit 2007).

quantifier in the ordinary value in that their domain variables D' are subsets of D, the one used in the ordinary value, except for the empty set. The alternative value for *any* is then as in (27-b).

(27) a. $[\![\text{any}]\!]^o = \lambda P_{\langle s,\langle e,t\rangle\rangle}\lambda Q_{\langle s,\langle e,t\rangle\rangle}\lambda w_s.\exists x \in D[P(w)(x) \wedge Q(w)(x)]$
b. $[\![\text{any}]\!]^{alt} = \{\lambda P_{\langle s,\langle e,t\rangle\rangle}\lambda Q_{\langle s,\langle e,t\rangle\rangle}\lambda w_s.\exists x \in D'[P(w)(x) \wedge Q(w)(x)]|D' \subseteq D \neq \varnothing\}$

To arrive at the right question-meanings we need a question operator. I suggest to slightly modify Karttunen's 1977 semantics for the ?-operator so that it makes use of alternatives, in particular the ones contributed by NPIs. The operator takes a set of propositions C and a proposition p as arguments and returns the intension of that set of propositions that are in C and moreover entail p, as defined in (28). Its alternative value is the singleton containing just the ordinary value.

(28) a. $[\![?]\!]^o = \lambda C_{\langle\langle s,t\rangle,t\rangle}\lambda p_{\langle s,t\rangle}\lambda w_s\lambda q_{\langle s,t\rangle}.C(q) \wedge q \Rightarrow p$
b. $[\![?]\!]^{alt} = \{\lambda C_{\langle\langle s,t\rangle,t\rangle}\lambda p_{\langle s,t\rangle}\lambda w_s\lambda q_{\langle s,t\rangle}.C(q) \wedge q \Rightarrow p\}$

Assume now that the yes-no-question in (29-a) has the LF in (29-b). What is crucial is that the ?-operator is restricted by a variable C.

(29) a. Did John read any book?
b. [$_X$? C [$_Y$ any book 1 [John read t_1]]]

The interpretation of (29-b) is as follows: Y denotes the proposition that John read a book, (30-a), where we assume that the context provides the set of books $\{a, b, c\}$ for the domain variable D of *any*. C gets its denotation via the assignment function g, (30-b). I will assume that it is generally set to denote the set of alternative propositions derived from the alternative domains introduced by *any*. In other words, it contains those propositions that differ from (30-a) in having the domain variable of *any* set to subsets of D. The interpretation of the whole question finally is the intension of the set of those propositions in $g(C)$ entailing the ordinary value of Y, as given in (30-c).[10] What is this set? All of the propositions in $g(C)$ entail (30-a). The reason is that if John read a book of $\{a, b\}$ he must have read one of $\{a, b, c\}$ and similarly for any other subset of the latter domain. Therefore all of the propositions in $g(C)$ are in the intension of the question denotation.

(30) a. $[\![\text{Y}]\!]^{o,g} = \lambda w.\exists x \in \{a, b, c\}[x \text{ is a book in } w \wedge \text{John read } x \text{ in } w]$
b. $[\![\text{C}]\!]^{o,g} = \{\lambda w.\exists x \in D'[x \text{ is a book in } w \wedge \text{ John read } x \text{ in } w]|D' \subseteq \{a, b, c\} \neq \varnothing\}$
c. $[\![\text{X}]\!]^{o,g} = \lambda p\lambda w\lambda q[g(C)(q) \wedge q \Rightarrow p]([\![\text{Y}]\!]^{o,g})$

[10]Note that this question denotation is actually independent of the world of evaluation. We will see, however, that for wh-questions abstraction over the world variable does make a difference.

$$= \lambda w \lambda p.g(C)(p) \wedge p \Rightarrow \lambda w'.\exists x \in \{a, b, c\}[x \text{ is a book in } w' \wedge \text{John read } x \text{ in } w']$$

Now the answer operator ans_s – repeated in (31) from (24) with both its ordinary and alternative values – applies to (30-c) giving us (32). (32) says that the set of true answers to (29-a) – i.e., to $[\![\text{X}]\!]^{o,g}$ in (30-c) – is what it is in w, the world of evaluation. So if John read books a and b in w, then the proposition in (32) says that the set of true answers is equivalent to the set {that John read a, that John read b}. From this it follows that John did not read c. I.e., (32) is equivalent to the proposition that John read a and b and not c.

(31) a. $[\![\text{ans}_s]\!]^o = \lambda w_s \lambda Q_{\langle s,\langle\langle s,t\rangle,t\rangle\rangle} \lambda w'_s.\, \{p : Q(w')(p) \wedge p(w')\} = \{p : Q(w)(p) \wedge p(w)\}$

b. $[\![\text{ans}_s]\!]^{alt} = \big\{\lambda w_s \lambda Q_{\langle s,\langle\langle s,t\rangle,t\rangle\rangle} \lambda w'_s.\, \{p : Q(w')(p) \wedge p(w')\} = \{p : Q(w)(p) \wedge p(w)\}\big\}$

(32) $[\![\text{ans}_s]\!]^{o,g}(w)([\![\text{X}]\!]^{o,g}) = \lambda w'.\, \{p : [\![\text{X}]\!]^{o,g}(w')(p) \wedge p(w')\} = \{p : [\![\text{X}]\!]^{o,g})(w)(p) \wedge p(w)\}$

Crucially, whatever the set of answers in the world of evaluation amounts to, (32) will entail the strong exhaustive answers to all those alternative questions where *any book* in (29-a) is replaced by one of the elements in the set of relevant books. If the domain variable D is set to $\{a, b, c\}$ in (29-a) by the context, the strong exhaustive answer in (32) says for each of the books a, b, and c whether John read them or not. Similarly, the strong exhaustive answer to an alternative question with a domain D' smaller than D specifies for each element x of D' whether John read x or not. But this means that (32) entails all such answers. I.e., we find downward monotonicity, as desired.

This approach is readily extendable to wh-questions given that I assume in essence Karttunen's 1977 semantics for questions. For simplicity, I follow Heim (2000) in assuming that the denotation of the wh-element takes an abstracted question intension as its argument, as defined in (33).[11] With the entry for wh at hand, we assume that a question such as (34-a) has the LF in (34-b). Crucially, the wh-expression is moved above the ?-operator.

(33) a. $[\![\text{wh}]\!]^o = \lambda P_{\langle s,\langle e,t\rangle\rangle} \lambda Q_{\langle e,\langle s,\langle\langle st\rangle,t\rangle\rangle\rangle} \lambda w_s \lambda p_{\langle s,t\rangle}.\exists x[P(w)(x) \wedge Q(x)(w)(p)]$

b. $[\![\text{wh}]\!]^{alt} = \big\{\lambda P_{\langle s,\langle e,t\rangle\rangle} \lambda Q_{\langle e,\langle s,\langle\langle st\rangle,t\rangle\rangle\rangle} \lambda w_s \lambda p_{\langle s,t\rangle}.\exists x[P(w)(x) \wedge Q(x)(w)(p)]\big\}$

(34) a. Which boy read any book?

b. [$_{\text{X}}$ which boy 2 [$_{\text{Y}}$? C [$_{\text{Z}}$ any book 1 [t_2 read t_1]]]]

[11] This allows us to use the regular rule of predicate abstraction for quantifying-in the wh-expression, rather than having to assume a special rule as Karttunen (1977) does.

The compositional steps for the interpretation of (34-b) are given in (35). Up to the point of constituent Y, the composition works as for the yes-no-question discussed above with the only difference that there is a free variable standing in for the subject argument. This variable gets bound by the wh-expression above the ?-operator, as shown in (35-d). Crucially, this will have the effect that also the free variable in $g(C)$ in (35-b) ends up bound by the wh-expression, as desired. Again, we get an intension of a set of propositions, and again it is the intension of the set of those propositions in $g(C)$ entailed by the ordinary value of Z. There is, however, one crucial difference to the yes-no-question discussed before. Due to binding by the wh-expression the set $g(C)$ and therefore also the one of the question denotation itself increases. For each boy x all propositions of the form *that* x *read a book in* D' are in $g(C)$, where D' is a non-empty subset of D. Now, for each boy x each of those propositions entails the ordinary value of Z in (35-a) with $g(2)$ replaced by x. In other words, (35-d) corresponds to the intension of the set of all of the propositions in $g(C)$.[12]

(35) a. $[\![\text{Z}]\!]^{o,g} = \lambda w.\exists x \in \{a,b,c\}[x \text{ is a book in } w \wedge g(2) \text{ read } x \text{ in } w]$

b. $[\![\text{C}]\!]^{o,g} = \{\lambda w.\exists x \in D'[x \text{ is a book in } w \wedge g(2) \text{ read } x \text{ in } w] | D' \subseteq \{a,b,c\} \neq \varnothing\}$

c. $[\![\text{Y}]\!]^{o,g} = \lambda p\lambda w\lambda q[g(C)(q) \wedge q \Rightarrow p]([\![\text{Z}]\!]^{o,g})$
$= \lambda w\lambda p.g(C)(p) \wedge p \Rightarrow \lambda w'.\exists x \in \{a,b,c\}[x \text{ is a book in } w' \wedge g(2) \text{ read } x \text{ in } w']$

d. $[\![\text{X}]\!]^{o,g} = \lambda Q\lambda w\lambda p.\exists x[x \text{ is a boy in } w \wedge Q(x)(w)(p)](\lambda x[\![\text{Y}]\!]^{o,g[x/2]})$
$= \lambda Q\lambda w\lambda p.\exists x[x \text{ is a boy in } w \wedge Q(x)(w)(p)]$
$(\lambda x\lambda w\lambda p.g(C)(p) \wedge p \Rightarrow \lambda w'\exists y \in \{a,b,c\}[y \text{ is a book in } w' \wedge x \text{ read } y \text{ in } w'])$
$= \lambda w\lambda p.\exists x[x \text{ is a boy in } w \wedge g(C)(p) \wedge$
$p \Rightarrow \lambda w'.\exists y \in \{a,b,c\}[y \text{ is a book in } w' \wedge x \text{ read } y \text{ in } w']]$

To (35-d) the strong exhaustive answer operator can apply. Crucially, for reasons already discussed above this makes the same predictions as for yes-no-questions: the strong exhaustive answer to a question with an NPI over domain D entails all the strong exhaustive answers to those questions where a subdomain of D is chosen for the NPI. I.e., the strong exhaustive answer is DE.

I now turn to the discussion of some implications of the present proposal.

4. Consequences of the proposal

4.1. Non-exhaustive interpretations

Reviewing Guerzoni and Sharvit's 2007 observations, we saw that NPIs are only licensed in embedded questions that are interpreted as strongly exhaustive. This follows directly from the present proposal if we make the assumption that predicates like *wonder* and *know* embed the strong ex-

[12] This time the extension of the interrogative does vary with the world of evaluation. In particular, it can vary in the set of boys considered. That is, abstraction over the world variable is not vacuous.

haustive answer to a question. For instance, *x wonders whether Q* then means something like *x wants to know the strong exhaustive answer to Q*, as given in (36-a). A similar entry obtains for *know*, (36-b). For predicates like *surprise*, however, we do not want the lexical entry to make reference to the strong exhaustive answer of the embedded question. Rather I follow Guerzoni and Sharvit (2007) in assuming that *surprise* simply states that there is a proposition in the set of true propositions in the question extension that the subject of the sentence did not expect to be true (also cf. George 2011).[13]

(36) a. $[\![\text{wonder}]\!]^o = \lambda w_s \lambda Q_{\langle\langle s,t\rangle,t\rangle} \lambda x_e.x$ wants to know $ans_s(w)(Q)$ in w
b. $[\![\text{know}]\!]^o = \lambda w_s \lambda Q_{\langle\langle s,t\rangle,t\rangle} \lambda x_e : ans_s(w)(Q)(w).x$ believes $ans_s(w)(Q)$ in w
c. $[\![\text{surprise}]\!]^o = \lambda w_s \lambda Q_{\langle\langle s,t\rangle,t\rangle} \lambda x_e.\exists p[p \in \{q : Q(w)(q) \wedge q(w)\} \wedge \neg x$ expected q in $w]$

Essentially, the entry for *surprise* makes reference to the mention-some answer to the embedded question. A mention-some answer is never DE, and as a result NPIs should not be licensed in them. To see this, recall from (21) repeated as (37) that NPIs are also not licensed in direct mention-some questions. If direct questions are taken to ask for either strong exhaustive or mention-some answers, we can account for this. Assume the following: shop X sells two newspapers, the 'Financial Times' and the 'Guardian', but crucially not the 'New York Times'. In that context the proposition *You can buy a newspaper at shop X* is a mention-some answer to (37), but it is not a mention-some answer to the question *Where can I buy the 'New York Times'?*. In other words, mention-some answers to questions with NPIs in them are not DE, and the interrogatives are therefore ungrammatical.

(37) *Where can I buy any newspaper?

Moreover, the entry for *surprise* in (36-c) itself does not involve downward monotonicity. If John is surprised about one of the true propositions $\{p, q, r\}$, he need not be surprised about one of the true propositions $\{p, q\}$ – namely in the case where he is only surprised about the truth of r. Thus *surprise* should not allow for NPIs in embedded questions.

[13]The entries given here are not quite adequate due to lack of space. Apart from the factivity presupposition of *know* – stated using Heim and Kratzer's 1998 convention – no presuppositions are given. For instance, the presupposition of *surprise* that the subject now believes all of the true propositions in the question extension to be true and all of the false ones to be false is not represented. *Wonder* also bears a presupposition. I will return to discussion of the latter below. Also notice that there might be a second variant of *know* not making reference to the strong exhaustive answer, as discussed by Groenendijk and Stokhof (1982). This latter entry might be responsible for the fact that NPIs in interrogatives embedded under *know* are not universally accepted (cf. (16-b) above), as speculated by Guerzoni and Sharvit (2007).

4.2. Embedding under *wonder*

If the strong exhaustive answer to a question with an NPI in it embedded under *wonder* is DE, we have to address the issue why (38-a) does not seem to entail (38-b). For instance, John might believe that Mary did not read 'War & Peace'. Then (38-a) could be true, while (38-b) would be false. If *x wonders whether Q* means more or less *x wants to know the strong exhaustive answer to Q*, then we might expect precisely such an entailment. After all both *know* and *want* are UE (but cf. Heim 1992 and references therein with respect to the latter).

(38) a. John wonders whether Mary read any book by Tolstoy.
$\not\Rightarrow$
b. John wonders whether Mary read 'War & Peace'.

I suggest that *wonder* comes with a presupposition that the subject neither believes the strong exhaustive answer to be true nor to be false, i.e., that he believes both to be possible.[14] The ordinary value for *wonder* should then be updated from (36-a) to (39).

(39) $[\![\text{wonder}]\!]^o = \lambda w_s \lambda Q_{\langle\langle s,t\rangle,t\rangle} \lambda x_e : \neg x$ believes $ans_s(w)(Q)(w) \wedge \neg x$ believes $\neg ans_s(w)(Q)(w).x$ wants to know $ans_s(w)(Q)$ in w

Now, once we control for the presupposition of *wonder*, it can be shown that downward monotonicity for sentences with *wonder* embedding a question with an NPI reappears. Consider (40). (40-b) spells out the presupposition of (40-c). If both (40-a) and (40-b) are assumed to be true, then (40-c) is true as well, it seems.[15] In other words, the presupposition of *wonder* blocks downward monotonicity for the whole sentence. This does not affect the licensing of the NPI, however, as it is the embedded strong exhaustive answer environment which is DE and thus licenses it.[16]

[14] von Fintel (1999) makes a related proposal for *want*, and Guerzoni and Sharvit (2007) suggest for *wonder* one half of the presupposition assumed in the text.

[15] This has already been noticed by Fauconnier (1980) who suggested to base the licensing of NPIs in questions on this fact. Such a proposal runs into problems with other embedding predicates, however.

[16] von Fintel (1999) makes a more specific claim. He suggests that the presuppositions must be factored out when checking for downward monotonicity with respect to the licensing of an NPI. One way to do so is his weakened *Strawson downward monotonicity*, which essentially requires that when we check for downward monotonicity between two propositions the presupposition of the entailed one must be satisfied. This is stated in (i).

(i) $f \in D_{\langle\sigma,\tau\rangle}$ is Strawson DE iff for all $a, b \in D_\sigma$, where $a \Rightarrow b$ and $f(a)$ is defined, $f(b) \Rightarrow f(a)$.

For the present purposes, it is tangential whether the theory of NPI licensing makes reference to simple downward monotonicity or to (i).

(40) a. John wonders whether Mary read any book by Tolstoy.
b. John believes it is both possible that Mary read 'War & Peace' and that she did not.
⇒
c. John wonders whether Mary read 'War & Peace'.

4.3. Embedding under *know*

If *know* is UE, then we expect downward monotonicity for sentences with *know* embedding a question with an NPI. In particular, we expect an inference from (41-a) to (41-b) given the present proposal. Recall that the NPI contributes alternatives to the semantic computation that figure in the question denotation. As a result the strong exhaustive answer to the embedded question in (41-a) specifies for each book in the domain D of *any book by Tolstoy* whether John read that book or not. So if 'War & Peace' is in D, an inference from (41-a) to (41-b) should go through. But that this is the case is not so clear. And this time, a presupposition of *know* does not seem to be the culprit.

(41) a. Mary knows whether John read any book by Tolstoy.
??⇒
b. Mary knows whether John read 'War & Peace'.

I must leave this issue for further research. There are, however, two issues that might affect our intuitions regarding the relations between (41-a) and (41-b). First, we already know that NPIs in interrogatives under *know* are not always licensed. Specifically, the availability of a *know* that allows for non-exhaustive interpretations could block the entailment in (41). In other words, the question has to be addressed whether those speakers who do not find an entailment also dislike the NPI in (41-a) to begin with. Second, if 'War & Peace' is not an element of the domain variable employed by *any book by Tolstoy* in (41-a), no entailment is expected even under the version of *know* that requires strong exhaustive answers to the embedded question. None of these suggestions is quite satisfactory, but both might be involved in the ultimate explanation for the perceived lack of entailment from (41-a) to (41-b).

5. Conclusion and outlook

I have shown that Fauconnier's 1979 and Ladusaw's 1979 generalizations concerning the licensing of NPIs can account for the occurrence of such elements in interrogatives. In particular, I argued for two things: first, a modification of Karttunen's 1977 question semantics where the ?-operator makes use of the alternatives contributed by NPIs (Krifka 1995, Chierchia 2004, 2006) is necessary. This increases the number of propositions in the question denotation. Second, the strong exhaustive question operator argued for by Heim (1994) and Beck and Rullmann (1999) now has the effect that the strong exhaustive answer to a question with an NPI in it entails those to alternative questions

where the NPI is replaced with an element of the domain that the existential quantifier denoted by the NPI ranges over. In other words, the strong exhaustive answer to a question with an NPI in it is DE. This readily explains Guerzoni and Sharvit's 2007 observation that NPIs are only licensed in questions embedded by predicates allowing for a strong exhaustive interpretation of that question. Previous accounts have not been able to connect the downward monotonicity hypothesis with the strong exhaustiveness requirement.

I have not touched upon the particular implementation needed to actually explain why NPIs are only licensed in DE environments. The present proposal is, however, compatible with Krifka's and Chierchia's suggestions that an obligatory exhaustivity operator is responsible for the licensing of NPIs. If the environment is not DE, this operator will yield a contradiction when an NPI is used, but not if the environment is DE. Due to the particular specification of the ?-operator argued for above, this proposal can be extended to the present account. I must leave explication of this to another occasion.

The present proposal makes a number of predictions. A potentially problematic one is that sentences with questions with NPIs in them embedded under *know* should exhibit downward monotonicity, which is not obvious. Here further research is required. Future research also has to ask whether other types of NPIs, such as strong ones, are licensed in interrogatives. For reasons of space I did not address the issue whether other sorts of questions exhibit downward monotonicity as well. In particular, interrogatives with scalar items in them come to mind. As is well known, scalar inferences are reversed in DE environments. An interesting question for future research arising at this point is whether there is a correlation between the types of embedding predicates and the types of scalar inferences arising in the embedded question. In particular, we might expect that *wonder* and *know* license reversed inferences, whereas *surprise* does not. This issue is, however, potentially complicated by the presence of presuppositions of the embedding predicates.

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