

Predicting polar question embedding¹

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Abstract. This paper shows that it is fully predictable whether a polar interrogative clause can appear under a declarative embedding predicate. The idea in a nutshell is as follows: whenever a predicate appears to not embed polar interrogatives, the interpretative component independently derives a trivial meaning for the sentence. Such trivial meanings manifest themselves in unacceptability. A crucial property of this proposal is that interrogative embedding is polarity-sensitive, which is shown to be empirically supported. As a consequence, one must not stipulate in the lexical entry of a given predicate whether or not it embeds polar interrogative clauses.

Keywords: question embedding, logic in grammar, polarity, embedding predicates.

1. Introduction

Know can embed both declarative and polar interrogative clauses, as shown in (1). From this one might expect that any proposition-taking predicate (PTP) shows this behavior.² As is well-known, this is, however, not the case. For instance, the closely related PTP *believe* does not embed polar interrogative clauses, as shown in (2). This is somewhat unexpected. The lexical meaning of *believe* is the one of *know* modulo additional meaning components.³

- (1) a. John knows that Mary smokes.
b. John knows whether Mary smokes.
- (2) a. John believes that Mary smokes.
b. *John believes whether Mary smokes.

Following Lahiri (2002), I refer to PTPs embedding both declarative and interrogative clauses as responsive and those only embedding the former as non-responsive. The question posed by (1) and (2) can then be stated as in (3).

- (3) **The responsiveness puzzle:** Under what conditions is a PTP responsive?

The standard answer to this question, going back to Grimshaw (1979), is that predicates are lexically specified as to which type of complement clause they combine with. The assumption underlying such approaches is that whether a PTP embeds a given clause type is completely arbitrary and not predictable from independent principles. In other words, there simply are no special properties inherent to *know* that make it responsive, as implied by (3).

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²Since the standard assumption is that declarative clauses denote propositions, I refer to predicates embedding them as proposition-taking ones.

³See for instance Gettier (1963).

This paper takes (3) seriously and argues against Grimshaw's 1979 conviction. Based on the observation that certain PTPs embed polar interrogative clauses only in particular contexts, I suggest that a lexical stipulation approach is untenable. PTPs are generally not specified with respect to whether they embed interrogative clauses or not. Rather, I argue that the distribution of embedded interrogative clauses is fully predictable on semantic grounds alone. The strong thesis followed in this paper is that whenever a PTP is seemingly unable to embed a polar interrogative, this is due to the interpretative component necessarily generating a trivial meaning for the sentence as a whole. Trivial meanings are tautologies and contradictions, which make themselves felt as unacceptability of the sentence (see Gajewski 2002; Chierchia 2006, 2013; Fox and Hackl 2006; Abrusán 2014 a.o.). Two factors play a role in determining whether a meaning is trivial or not: (i) the particular lexical semantics of the PTP, and (ii) the polarity of the sentence as a whole. The apparent impossibility of interrogative embedding under *believe* in (2b), for instance, is due the sentence denoting the tautology. (1b), on the other hand, does not have such a trivial denotation, and thus no degradedness is felt.

I show in the following that this simple approach can deal with numerous types of PTPs. As will be seen, the key insight here is that interrogative embedding necessitates an existential semantics (Spector and Egré 2015, see also Lahiri 2002; Theiler et al. 2016 a.o.). Confining myself to the embedding of polar interrogatives, which is done for reasons of space, moreover allows me to work with completely standard meanings for the PTPs discussed. For *wh*-interrogatives, however, the lexical semantics would have to be somewhat complicated. I refer the reader to Mayr (2017) for discussion of *wh*-interrogatives.⁴

The structure of the paper is as follows. In section 2, I discuss the issue that interrogative embedding poses for a theory of grammar in more detail. Section 3 introduces the proposed system. Section 4 shows its application to the *know-believe* distinction. Section 5 discusses further classes of PTPs. Section 6 concludes the paper.

2. Problems of interrogative embedding

2.1. Arguments for lexical stipulation

Know when embedding a declarative clause, as in (1a), licenses the inference that that clause is true. That is, *know* is veridical.⁵ *Believe*, as in (2a), does not do so, i.e., it is non-veridical. An old intuition is therefore that a responsive PTP must be veridical (Hintikka, 1975; Berman, 1991; Ginzburg, 1995a, b; Egré, 2008). Indeed, many veridical PTPs, as in (4), embed interrogative clauses. And many non-veridical ones do not, as in (5). Here and below $\rightsquigarrow X$ and $\not\rightsquigarrow X$ indicate that the example has or does not have the proposition *that X* as an inference.

⁴Given what has just been said, I will not discuss the issue of emotive factive PTPs in this paper. These allow for embedding of *wh*-interrogatives but not of polar interrogatives (see Guerzoni 2007; Sæbø 2007; Nicolae 2013; Romero 2015; Roelofsen et al. ta; Mayr 2017 a.o.).

- (i) a. *John is amazed / happy / surprised whether Mary smokes.
b. John is amazed / happy / surprised which girls smoke.

⁵More precisely, *know* is, of course, not only veridical but also factive. A PTP is factive if the inference that the complement declarative clause is true remains under entailment-cancelling operators.

- (4) a. John *deduced / discovered / established / figured out / found out / forgot / learned / recalled / remembered* that Mary smokes. \rightsquigarrow Mary smokes
 b. John *deduced / discovered / established / figured out / found out / forgot / learned / recalled / remembered* whether Mary smokes.
- (5) a. John *alleged / asserted / claimed / conjectured / desired / expected / feared / hoped / inferred / wanted / wished* that Mary smokes. $\not\rightarrow$ Mary smokes
 b. *John *alleged / asserted / claimed / conjectured / desired / expected / feared / hoped / inferred / wanted / wished* whether Mary smokes.

This conclusion is, however, called into question by the fact that there are PTPs which embed interrogative clauses yet are non-veridical, as (6) shows (see Grimshaw 1979; Lahiri 2002; Uegaki 2015).

- (6) a. John *announced / confirmed / declared / heard / predicted / reported / told us* that Mary smokes. $\not\rightarrow$ Mary smokes
 b. John *announced / confirmed / declared / heard / predicted / reported / told us* whether Mary smokes.

Apart from veridicality, no other semantically discernible property has been found that would separate the responsive PTPs from the non-rogative ones. That is, neither the former nor the latter seem to form a coherent lexical class. It has thus been claimed that it is not predictable given formal semantic properties of a given PTP whether it is responsive or not (Grimshaw, 1979; Uegaki, 2015). In particular, Grimshaw has advanced the view that predicates are specified lexically for so-called s-selectional properties (see also Chomsky 1965; Baker 1968). That is, each PTP is at least specified for whether the embedded clause can be +-declarative and +-interrogative. The idea here is that such s-selectional specification does not follow from anything more basic.

2.2. Problems for lexical stipulation

According to the lexical specification hypothesis each PTP comes with a feature setting specifying whether an interrogative is a possible complement or not. The surrounding linguistic context should not be able to alter this setting. The data in (7) show that the PTP *be certain* contradicts this prediction. On its own *be certain* can embed declarative clauses as in (7a) but not polar interrogatives as in (7b). With negation as in (7c), however, embedding of a polar interrogative markedly improves (see for instance Eckardt 2007; Egré 2008).

- (7) a. John is certain that Mary smokes. $\not\rightarrow$ Mary smokes
 b. *John is certain whether Mary smokes.
 c. John isn't certain whether Mary smokes.

Transitive *say*, in contrast to its ditransitive use, and *be convinced* exhibit a behavior parallel to *be certain*, as is shown by (8).

- (8) a. John *said / is convinced* that Mary smokes. \nrightarrow *Mary smokes*
 b. *John *said / is convinced* whether Mary smokes.
 c. John *didn't say / isn't convinced* whether Mary smokes.

Be certain and the other PTPs just discussed are non-veridical. Interestingly, *be clear* is veridical, and yet it shows the same behavior as *be certain*. In other words, (non)-veridicality is once again not a good indicator as to whether interrogative embedding is possible at all.

- (9) a. It is clear that Mary smokes. \rightsquigarrow *Mary smokes*
 b. *It is clear whether Mary smokes.
 c. It isn't clear whether Mary smokes.

The distribution of polar interrogative clauses as complements of the PTPs above is reminiscent of negative polarity items (NPIs) like *any* (Adger and Quer, 2001), as in (10).

- (10) a. *John saw any girl.
 b. John didn't see any girl.

Contexts other than negation which allow for NPIs improve the embedding of polar interrogatives under *be certain* as well. Typical such contexts are downward monotonic environments (see Fauconnier 1979; Ladusaw 1979; Linebarger 1987; Krifka 1995; Giannakidou 1999; Chierchia 2004, among many others): antecedents but not consequents of conditionals, negative quantifiers, and restrictors but not scopes of universal quantifiers. Indefinites thus never allow for NPIs. The following demonstrate that polar interrogatives under *be certain* show an NPI-like behavior:

- (11) a. If John is certain whether Mary smokes, he knows her well.
 b. *If John knows Mary well, he is certain whether she smokes.
- (12) a. No student who is certain whether Mary smokes does not know her.
 b. No student who does not know Mary is certain whether she smokes.
- (13) a. Every student who is certain whether Mary smokes knows her well.
 b. ?Every student who knows Mary well is certain whether she smokes.
- (14) a. *Some student who is certain whether Mary smokes knows her well.
 b. *Some student who knows Mary well is certain whether she smokes.

2.3. Intermediate conclusion

Summarizing, I note two things: (i) the prediction of the lexical specification account that linguistic context cannot affect clausal embedding appears to be wrong. (ii) The way linguistic context affects clausal embedding is systematic and tracks the licensing of NPIs to a consider-

able extent. In light of this I conclude that the lexical specification hypothesis is untenable.⁶

Now, how could the embedding of polar interrogative clauses be similar to the distribution of NPIs? One of the main contending views regarding NPIs goes as follows: first, *any girl* in (10) denotes an existential quantifier over girls. Second, the sentence has alternatives about particular girls such as *John saw Mary* for (10a) and *John didn't see Mary* for (10b). Third, each sentence in (10) undergoes exhaustification with respect to its alternatives resulting in the conjunction of the sentence—its prejacent—with the negation of the alternatives. This leads to a contradiction without but not with negation, accounting for the pattern in (10) (see Heim 1984; Kadmon and Landman 1993; Krifka 1995; Chierchia 2006, 2013; Crnič 2014, among many others). In the following I show that something similar is happening in the case of the embedding of polar interrogatives.

3. A polarity system for polar interrogative embedding

In the case of polar interrogative clauses, it is the semantics for interrogative embedding necessitating existential quantification (Spector and Egré, 2015). The alternatives are contributed by the embedded interrogative (Klinedinst and Rothschild, 2011). The exhaustification process relative to these alternatives accounts for the patterns discussed in the preceding section.

Assume for *be certain* Hintikka's 1969 universal semantics for propositional attitudes:

$$(15) \quad \llbracket \text{be certain} \rrbracket = \lambda p_{st}. \lambda x_e. \lambda w_s. \forall w' [w' \in \text{Dox}_{x,w} \rightarrow p(w') = 1]$$

Be certain applied to a proposition p asserts that p is true in all of the subject's doxastic alternatives. This means p is true in all the worlds doxastically accessible to the subject from the world of evaluation w .

Consider now the sentences in (16) again. Assume that the denotation of the embedded interrogative is as in (17). This is an existential quantifier ranging over a set of propositions, i.e., over a question denotation in the sense of Hamblin (1973) and Karttunen (1977). The set contains the positive and the negative answer to the polar interrogative. In the following, I abbreviate this set as Q' —that is, $\{\lambda w. \text{Mary smokes in } w, \lambda w. \text{Mary doesn't smoke in } w\} = Q'$.

- (16) a. John isn't certain whether Mary smokes.
b. *John is certain whether Mary smokes.

$$(17) \quad \llbracket \text{whether Mary smokes} \rrbracket = \lambda Q_{\langle st,t \rangle}. \lambda w_s. \exists p [p \in \{\lambda w'. \text{M smokes in } w', \\ \lambda w'. \text{M doesn't smoke in } w'\} \wedge Q(p) = 1] \\ = \lambda Q_{\langle st,t \rangle}. \lambda w_s. \exists p [p \in Q' \wedge Q(p) = 1]$$

Now, since the denotation of *be certain* requires a proposition as argument, it cannot apply to

⁶To this one might add the observation that the embedding patterns appear to be cross-linguistically stable. From the perspective of a lexical stipulation based account this is unexpected. Languages should be allowed to differ widely with respect to which PTP embeds which clause-type.

(17). Assume therefore, following Lahiri (2002), that the embedded interrogative must take scope over the entire clause, which gives the LFs in (18a) and (18b) for (16a) and (16b), respectively. The operator *Exh* is discussed below.

- (18) a. $[[S_1 \text{ Exh}_{Alt} [S_1 \text{ not } [\text{whether Mary smokes }] \lambda p[\text{John is certain } p]]]]$
 b. $[[S_2 \text{ Exh}_{Alt} [S_2 [\text{whether Mary smokes }] \lambda p[\text{John is certain } p]]]]$

For (18a), on the one hand, the denotation of S_1 —its literal meaning—corresponds thus to (19). This says that there is no proposition in Q' which is true in all of John's doxastic alternatives. (18b), on the other hand, has as its literal meaning (19b) saying that there is a proposition in Q' that is true in all of John's doxastic alternatives.

- (19) a. $[[S_1]]^g = \lambda w. \neg \exists p [p \in Q' \wedge \forall w' [w' \in \text{Dox}_{J,w} \rightarrow p(w') = 1]]$
 b. $[[S_2]]^g = \lambda w. \exists p [p \in Q' \wedge \forall w' [w' \in \text{Dox}_{J,w} \rightarrow p(w') = 1]]$

Consider next the alternatives to the literal meanings in (19a) and (19b). I stipulate them to constitute sets of propositions satisfying the following requirement: each member corresponds to the denotation one would get by replacing the embedded interrogative in (17) with one of its answers in the set Q' . Since the answers are propositions *be certain* can be applied directly.⁷

- (20) a. $\text{Alt}([S_1]^g) = \{ \lambda w. \neg \forall w' [w' \in \text{Dox}_{J,w} \rightarrow \text{Mary smokes in } w'],$
 $\lambda w. \neg \forall w' [w' \in \text{Dox}_{J,w} \rightarrow \text{Mary doesn't smoke in } w'] \}$
 b. $\text{Alt}([S_2]^g) = \{ \lambda w. \forall w' [w' \in \text{Dox}_{J,w} \rightarrow \text{Mary smokes in } w'],$
 $\lambda w. \forall w' [w' \in \text{Dox}_{J,w} \rightarrow \text{Mary doesn't smoke in } w'] \}$

Finally, each literal meaning derived in (19) is strengthened relative to its alternatives in (20). This is done with the help of the *Exh*-operator defined in (21) (see Groenendijk and Stokhof 1984; Krifka 1995; van Rooij and Schulz 2004; Chierchia 2006, 2013; Fox 2007; Spector 2007, among many others). *Exh* takes a proposition p —the prejacent S_1 or S_2 —asserts it and states that all propositions which are not Strawson-entailed by p are false. In the following \Rightarrow indicates regular entailment, and \Rightarrow_S Strawson-entailment. In the particular case at hand and more generally whenever a sentence is presuppositionless, Strawson-entailment reduces to regular entailment. For more discussion, see section 4.2.⁸

- (21) $[[\text{Exh}_{Alt}]] = \lambda w_s. p(w) = 1 \wedge \forall q \in \text{Alt}[p \not\Rightarrow_S q \rightarrow q(w) = 0]$

The denotation of the prejacent S_1 of *Exh* in (18a), i.e., (19a), entails each of its alternatives in (20a). If John is ignorant with respect to whether Mary smokes, then it follows both that John is not certain that Mary smokes and that he is not certain that Mary does not smoke. As

⁷This can be derived more formally by having the existential quantifier ranging over Q' be restricted to exactly one of the answers in Q' . Such an implementation would use Chierchia's 2006 notion of domain alternatives.

⁸Entailment and Strawson-entailment (von Stechow, 1999) are defined as follows:

- (i) a. For any $p, q \in D_{st}$, p entails q , $p \Rightarrow q$, iff for all $w \in D_s$ such that $p(w) = 1$, $q(w) = 1$.
 b. For any $p, q \in D_{st}$, p Strawson-entails q , $p \Rightarrow_S q$, iff for any presupposition r of q and all $w \in D_s$ such that $p(w) = r(w) = 1$, $q(w) = 1$.

a consequence Exh does not negate any of the alternatives, and the strengthened interpretation of (16a) is equivalent to its literal one without Exh:

$$(22) \quad \llbracket S'_1 \rrbracket^g = \lambda w. \neg \exists p [p \in Q' \wedge \forall w' [w' \in \text{Dox}_{J,w} \rightarrow p(w') = 1]]$$

(22) corresponds to the intuitive interpretation of the sentence. In particular, consider the sentence in the context in (23). Here it is unacceptable because the truth-conditions in (22) require John to not believe any of the propositions in Q' , which contradicts the context. Notice that (23) provides direct evidence for the assumption that there is existential quantification over answers involved (Spector and Egré, 2015). If the truth-conditions were about a particular answer, the sentence should be acceptable.

- (23) **Context:** Mary smokes, but John believes she does not smoke.
#John isn't certain whether Mary smokes.

Consider next the denotation of the prejacent S_2 of Exh in (18b) given in (19b). Each of its alternatives in (20b) entails it. For instance, if John believes that Mary smokes, then there is a proposition in Q' that John believes. Consequently, Exh negates each of the alternatives and conjoins them with the denotation of the prejacent yielding (24).

$$(24) \quad \begin{aligned} \llbracket S'_2 \rrbracket^g &= \lambda w. \exists p [p \in Q' \wedge \forall w' [w' \in \text{Dox}_{J,w} \rightarrow p(w') = 1]] \wedge \\ &\quad \neg \forall w' [w' \in \text{Dox}_{J,w} \rightarrow \text{Mary smokes in } w'] \wedge \\ &\quad \neg \forall w' [w' \in \text{Dox}_{J,w} \rightarrow \text{Mary doesn't smoke in } w'] \\ &= \top \end{aligned}$$

(24) is equivalent to saying that John either believes that Mary smokes or that he believes that she does not smoke but that he neither believes that she smokes nor that he believes that she does not smoke. This is a contradiction. Following Gajewski (2002), Fox and Hackl (2006), Chierchia (2006, 2013), Abrusán (2014) a.o., I assume that such trivial meanings lead to judgements of degradedness.

This assumption regarding triviality thus derives the pattern in (16). In particular, the system sketched here explains why *be certain* and other PTPs are only sometimes responsive. Moreover, the crucial reason why negation did not result in a contradiction and allowed for embedding of polar interrogatives was that it reverses the entailment patterns between the literal interpretation and the alternatives. As a consequence it follows that any entailment reversing environment, such as the downward monotonic contexts discussed in section 2.2 above, are predicted to not result in contradictions either.

4. The *know-believe* distinction

Let me now return to the responsiveness puzzle and in particular the difference between *know* and *believe*. As already discussed, the former embeds polar interrogatives whereas the latter does not do so. Moreover, we need to add to this the observation that negation does not seem to affect either of these properties. The picture as it presents itself is thus as in (25) and (26).

- (25) a. John knows whether Mary smokes.
 b. John doesn't know whether Mary smokes.
- (26) a. *John believes whether Mary smokes.
 b. *John doesn't believe whether Mary smokes.

Now, both *know* and *believe* have lexical properties differentiating them from each other, but setting them also apart from *be certain*. *Know*, on the one hand, is factive, whereas the other two PTPs are not:

- (27) a. John (doesn't) know(s) that Mary smokes. \rightsquigarrow *Mary smokes*
 b. John (doesn't) believe(s) that Mary smokes. $\not\rightarrow$ *Mary smokes*
 c. John is(n't) certain that Mary smokes. $\not\rightarrow$ *Mary smokes*

Believe, on the other hand, is a neg-raising predicate (Horn, 1978). When negated it appears that the negation takes scope below *believe* giving rise to a stronger than expected inference, as shown in (28b). Neither *know* nor *be certain* is neg-raising, as (28a) and (28c) show.

- (28) a. John doesn't know that Mary smokes. $\not\rightarrow$ *John knows that Mary doesn't smoke*
 b. John doesn't believe that Mary smokes. \rightsquigarrow *John believes that Mary doesn't smoke*
 c. John isn't certain that Mary smokes. $\not\rightarrow$ *John is certain that Mary doesn't smoke*

In the following, I show how the lexical properties of neg-raising and factivity interact with the system sketched in the preceding section thereby deriving the patterns in (25) and (26).

4.1. Neg-raising

Following Bartsch (1973), Löbner (2003) and Gajewski (2007) a.o., I assume that neg-raising PTPs presuppose that the subject is opinionated about the truth of the complement clause. That is, *believe* has a denotation parallel to *be certain* but presupposes that the subject either believe the propositional argument to be true or believe it to be false:⁹

- (29)
$$\llbracket \text{believe} \rrbracket = \lambda p_{st} . \lambda x_e . \lambda w_s : \underbrace{\forall w' [w' \in \text{Dox}_{x,w} \rightarrow p(w') = 1]}_{\forall w' [w' \in \text{Dox}_{x,w} \rightarrow p(w') = 0]} \vee \forall w' [w' \in \text{Dox}_{x,w} \rightarrow p(w') = 1]$$

In the positive case of (27b) the presupposition in (29) is harmless as it is entailed by and in fact equivalent to the assertive component. In the negative case, however, the presupposition entails the assertion. The consequence of this is that even though the assertion has weak wide-scope negation, the presupposition strengthens the intuited inference to a meaning saying that John believes that Mary does not smoke.

⁹I adopt here and in the following Heim and Kratzer's 1998 notation for presuppositions, according to which $\lambda \chi : \phi . \psi$ is a function that is only defined for objects χ such that ϕ holds. In addition presuppositions are underlined.

Consider now the degraded (30) repeated from above. Its truth-conditions before exhaustification are as in (31). What is the presupposition of (31)? Taking the first of the propositions in Q' and setting it for p in (31) gives the presupposition that John either believes that Mary smokes or that she does not smoke. Taking the second proposition in Q' , however, yields exactly the same. As a consequence, the presupposition of (31) is that John either believes that Mary smokes or that she does not smoke. Given the existential quantification in the assertive component of (31), the assertion is equivalent to the presupposition. This means that whenever (31) has a defined truth-value, it is true. It is a tautology. Therefore (30) has a trivial literal meaning and is degraded even without exhaustification.

(30) *John believes whether Mary smokes.

$$(31) \quad \llbracket (30) \rrbracket^g = \lambda w. \exists p \in Q' : \forall w' [w' \in \text{Dox}_{J,w} \rightarrow p(w') = 1] \vee \underbrace{\forall w' [w' \in \text{Dox}_{J,w} \rightarrow p(w') = 0]} . \forall w' [w' \in \text{Dox}_{J,w} \rightarrow p(w') = 1]$$

Given this it is easy to see why (32) is also degraded.

(32) *John doesn't believe whether Mary smokes.

The truth-conditions are as in (33). The presupposition requires again that John either believes that Mary smokes or that she does not smoke. The assertive component now states that John does not believe any of the propositions in Q' . Thus whenever (33) is defined, it is false. (31) is therefore degraded because it also has a trivial literal meaning.

$$(33) \quad \llbracket (32) \rrbracket^g = \lambda w. \neg \exists p \in Q' : \forall w' [w' \in \text{Dox}_{J,w} \rightarrow p(w') = 1] \vee \underbrace{\forall w' [w' \in \text{Dox}_{J,w} \rightarrow p(w') = 0]} . \forall w' [w' \in \text{Dox}_{J,w} \rightarrow p(w') = 1]$$

This treatment of *believe* predicts, of course, that other neg-raising PTPs are similarly non-rogative regardless of the polarity of the surrounding linguistic context. This is indeed the case as (34) and (35) show.

(34) a. John doesn't *expect / reckon / think / assume / presume / reckon* that Mary drinks.
 \rightsquigarrow John P-s that Mary doesn't drink
 b. *John (doesn't) *expect(s) / reckon(s) / think(s) / assume(s) / presume(s) / reckon(s)* whether Mary drinks.

(35) a. It isn't *advisable / desirable / likely / probable* that Mary drinks.
 \rightsquigarrow It is P that Mary doesn't drink
 b. *It is(n't) *advisable / desirable / likely / probable* whether Mary drinks.

The idea that neg-raising PTPs lead to trivial meanings when embedding an interrogative goes back to Zuber (1982), though it is implemented differently there (see also Theiler et al. 2016).

4.2. Factivity

Assume the standard lexical entry for *know* in (36). (36) applied to a proposition p and an individual x states that x believes p and presupposes that p is true.

$$(36) \quad \llbracket \text{know} \rrbracket = \lambda p_{st} . \lambda x_e . \lambda w_s : \underline{p(w) = 1} . \forall w' [w' \in \text{Dox}_{x,w} \rightarrow p(w') = 1]$$

As a consequence the literal meaning of (37) is as in (38).

(37) John knows whether Mary smokes.

$$(38) \quad \llbracket (37) \rrbracket^g = \lambda w . \exists p \in Q' : \underline{p(w) = 1} . \forall w' [w' \in \text{Dox}_{J,w} \rightarrow p(w') = 1]$$

The literal meaning in (38) is non-trivial. It asserts that there is a proposition p in Q' that John believes. It presupposes that p is true in w . Thus in a world in which Mary smokes (38) says that John believes that Mary smokes, and in a world in which she does not smoke (38) says that she does not do so. That is, the factivity of *know* ensures that the subject stand in the know-relation to the true answer, whatever it is. Given the discussion in section 3, the alternatives to (38) used for strengthening by Exh are as in (39).

$$(39) \quad \text{Alt}(\llbracket S \rrbracket^g) = \{ \lambda w : \underline{\text{Mary smokes in } w} . \forall w' [w' \in \text{Dox}_{J,w} \rightarrow \text{Mary smokes in } w'], \\ \lambda w : \underline{\neg \text{Mary smokes in } w} . \forall w' [w' \in \text{Dox}_{J,w} \rightarrow \neg \text{Mary smokes in } w'] \}$$

Now recall that Exh negates only those alternatives that are not Strawson-weaker than its pre-jacent, i.e., those alternatives that are not Strawson-entailed by the pre-jacent. As defined in footnote 8 following von Stechow (1999), for a proposition p to Strawson-entail a proposition q the presuppositions of q must be assumed to be true. When we want to see whether (38) Strawson-entails the first alternative in (39), we must therefore assume that Mary smokes in some particular world w_o as in (40a), as this is the presupposition of the alternative. Now, (38) is true in w_o if (40b) holds. Since the two propositions in Q' contradict each other, the proposition in Q' that John knows in w_o must be that Mary smokes given (40a). Thus (40a) together with (40b) guarantees that Mary smokes is the true answer to Q' in w_o and that John believes that Mary smokes is true. Therefore, (38) Strawson-entails the first alternative in (39), as stated in (40c). By the same logic (38) also Strawson-entails the second alternative in (39). In fact, it is Strawson-equivalent to both its alternatives.

- (40) a. Mary smokes in w_o .
 b. For some $p \in Q'$, John knows p in w_o .
 c. (40a) & (40b) \Rightarrow_S John knows in w_o that Mary smokes.

As a consequence, Exh does not negate any of the alternatives, and the strengthened meaning of (37) is equivalent to its literal meaning in (38). Since this meaning is non-trivial, we have explained why (37) is acceptable. We also immediately explain why its negation in (41) is equally acceptable. Since it is the factive presupposition of *know* that makes the alternatives Strawson-equivalent to the literal meaning, it follows that further embedding under negation

will not affect the result just obtained.

(41) John doesn't know whether Mary smokes.

The first consequence of this treatment for *know* is that factive PTPs in general should be responsive. This is by and large borne out. All the veridical PTPs in (42), repeated from (4), are actually factive, thus explaining (42b).

(42) a. John *deduced / discovered / established / figured out / found out / forgot / learned / recalled / remembered* that Mary smokes. \rightsquigarrow *Mary smokes*
 b. John *deduced / discovered / established / figured out / found out / forgot / learned / recalled / remembered* whether Mary smokes.

Second, veridical PTPs that are not factive, such as *be clear*, are not predicted to license interrogative embedding across-the-board. Here a downward monotonic environment is necessary for embedding to be possible:

(43) a. It is clear that Mary smokes. \rightsquigarrow *Mary smokes*
 b. It isn't clear that Mary smokes. $\not\rightsquigarrow$ *Mary smokes*

(44) a. *It is clear whether Mary smokes.
 b. It isn't clear whether Mary smokes.

Third, it should be stressed that the polarity system proposed in section 3 makes the fact that *be certain* embeds interrogatives only under negation the flip-side of the fact that *know* always does so.

Finally, note that the use of Strawson-entailment rather than of regular entailment is crucial for the account. One might therefore ask why this particular type of entailment should be used. I do not have an answer to this. However, NPI-licensing in general is subject to Strawson-entailment. As is well-known, it is the Strawson-downward-monotonic property of *only* that lets it license NPIs (von Stechow, 1999).

5. Other non-veridical predicates

5.1. Ambiguous predicates and being about the true answer

Recall now the PTPs in (45). In section 2.1 they were shown to be problematic for accounts relating interrogative embedding to veridicality directly. The reason for this is that the PTPs are non-veridical.

(45) a. John *announced / confirmed / declared / heard / predicted / reported / told us* that Mary smokes. $\not\rightsquigarrow$ *Mary smokes*
 b. John *announced / confirmed / declared / heard / predicted / reported / told us* whether Mary smokes. \rightsquigarrow *John P-ed the true answer to "Does Mary smoke?"*

As seen in section 4.2, the present system does not rely on a connection between veridicality and responsiveness. Still, as it stands it does not predict the pattern in (45) either.

Now, notice that the PTPs are veridical with respect to the embedded interrogative: (45b) licenses the inference that the subject stand in the relation denoted by the PTP to the true answer to the embedded interrogative. Following Spector and Egré (2015), I assume that the PTPs in (45) come in both a factive and a non-factive version. Consider *tell* for concreteness. In (45a), on the one hand, its non-factive version in (46) is, or at least can be chosen. Thereby no veridicality inference is felt.

$$(46) \quad \llbracket \text{tell}_1 \rrbracket = \lambda p_{st} . \lambda y_e . \lambda x_e . \lambda w_s . \forall w' [w' \text{ is compatible with what } x \text{ tells } y \text{ in } w \rightarrow p(w') = 1]$$

The reason why, on the other hand, in (46b) the factive version in (47) must be chosen is now straightforwardly explained on the present account: using the non-factive version of *tell* in (46) would result in a trivial strengthened meaning and thereby degradedness. That is, it would lead to a contradiction after exhaustification completely parallel to what we have seen with *be certain* in section 3. On its factive interpretation, however, *tell* works just like *know*. Factivity blocks the contradiction otherwise derived by exhaustification, as seen in section 4.2.

$$(47) \quad \llbracket \text{tell}_2 \rrbracket = \lambda p_{st} . \lambda y_e . \lambda x_e . \lambda w_s : \underline{p(w) = 1} . \\ \forall w' [w' \text{ is compatible with what } x \text{ tells } y \text{ in } w \rightarrow p(w') = 1]$$

Recall moreover from section 4.2 that the factivity presupposition of *know* guarantees that the subject stand in the know-relation to the true answer to the embedded interrogative, whatever it is. The limited veridicality inference in (45b) with respect to the true answer thus follows on the present account: only (47) can be used here, and this necessitates a relation between the subject and the true answer. As far as I am aware, the present account is the first to be in a position to explain why seemingly non-veridical PTPs must be about the true answer when embedding an interrogative clause as in (45b).

This makes a testable prediction. Whenever one of the PTPs from (45) embeds an interrogative clause and moreover occurs in an environment where contradiction by exhaustification is avoided independently, the non-factive interpretation should be usable. That is, not even limited veridicality as in (45b) should ensue.

Consider (48). The sentence is odd in the context given. Now notice that on the factive interpretation of *tell* in (47) the sentence should be acceptable, as it would assert that John did not tell us the true answer to *Does Mary smoke?*. Since the context satisfies this, we conclude that the sentence does not have such truth-conditions. Without a factive presupposition, the sentence states that John did not tell us any possible answer to the question *Does Mary smoke?*. These truth-conditions are not fulfilled by the context accounting for the degradedness.

$$(48) \quad \text{Context: } \textit{John told us that Mary smokes, which is in fact false.} \\ \# \textit{John didn't tell us whether Mary smokes.}$$

The degradedness in (48) more precisely suggests that the factive version of *tell* and similarly ambiguous PTPs becomes usable only when the non-factive one would lead to a contradiction via exhaustification. This is unlike what Spector and Egré (2015) suggest. They argue that such PTPs can always have the non-factive interpretation when embedding interrogative clauses. They cite (49) as evidence for this, minimally modified to show a polar interrogative here. (49) seemingly does not require the subject to stay in a relation to the true answer.

- (49) Every day, the meteorologists *tell* the population / *predict* / *announce* whether it will rain the following day, but they are often wrong.

I suggest that the fact that (49) is not degraded is entirely expected on the present account. The surfacing of the non-factive interpretations of the PTPs involved is, in particular, due to the fact that they are embedded under the universal temporal quantifier *every day*. First, (49) becomes less acceptable when *every day* is absent:

- (50) #The meteorologists *tell* the population / *predict* / *announce* whether it will rain the following day, but they are often wrong.

Second, note that other universal quantifiers also license the use of the non-factive interpretation of the PTP:

- (51) The meteorologists are required to *tell* the population / *predict* / *announce* whether it will rain the following day, even if they don't know.

It is well-known that universal quantifiers obviate contradictions which would otherwise arise through exhaustification when occurring unembeddedly (e.g. Fox and Hackl 2006; Fox 2007; Chierchia 2013; Abrusán 2014). Let me show how this works for (51). Its LF with non-factive *tell* would be something like (52).

- (52) $[[S' \text{ Exh}_{Alt} [S \text{ required} [[\text{whether it will rain}] \lambda p [\text{the meteorologists to tell}_1 \text{ the population } p]]]]]$

The literal meaning of S states that in every deontically accessible world the meteorologists tell the population a possible answer to the question *Will it rain?*. This neither entails that in every such world the meteorologists tell the population that it will rain nor that in every world they tell them that it will not rain. That is, the literal meaning does not entail its alternatives. Therefore Exh negates them giving the strengthened meaning in (53).

- (53) $[[S']^g = 1 \text{ iff } \forall w'. \exists p [p \in Q' \wedge \text{the meteorologists tell the population } p \text{ in } w'] \wedge$
 $\neg \forall w' [\text{the meteorologists tell the population in } w' \text{ it will rain}] \wedge$
 $\neg \forall w' [\text{the meteorologists tell the population in } w' \text{ it will not rain}]$

Crucially, (53) is not trivial. (53) states that the meteorologists are required to tell the population some answer but that they are neither required to tell them that it will rain nor that they are required to tell them that it will not rain.

This raises the question why (54) with an existential modal is similarly acceptable, even though existential modals generally do not obviate contradictions via exhaustification.

- (54) The meteorologists are allowed to *tell* the population / *predict* / *announce* whether it will rain the following day, even if they don't know.

I suggest that in cases like (54) it is actually the factive version of the PTP that is used, as in the LF in (55), with Exh embedded under the modal.

- (55) [_{S'} allowed [_S Exh_{Alt} [[whether it will rain] λp[the meteorologists to tell₂ the population p]]]]

This delivers the interpretation of S' in (56). First, notice that the alternatives to the prejacent of Exh are Strawson-equivalent to the prejacent. That is, Exh does not negate any of them, as in the case of *know* discussed in section 4.2. Second, the factive presupposition of *tell* is interpreted with respect to the world bound by the existential modal. As a consequence (56) says that in some deontically accessible world the meteorologists tell the population the true answer to the interrogative in that world. This does not entail anything about the true answer in the actual world. Now, if *know* in (54) moreover introduces a presupposition about the actual world, this does not lead to a contradiction with (56). In other words, with embedded exhaustification and the factive use of *tell*, (54) does not come out as degraded.

- (56) $[[S']^g = 1$ iff $\exists w'. \exists p \in Q' : \underline{p(w')} = 1$. the meteorologists tell the population *p* in *w'*

5.2. Predicates with an order-based semantics

Recall now the following desiderative PTPs from (5). (57a) has the inference that John prefers Mary smoking to her not smoking. This is generally accounted for by attributing an order-based semantics to the PTPs.

- (57) a. John *desired* / *wanted* / *wished* that Mary smokes. $\not\rightarrow$ *Mary smokes*
 \rightsquigarrow *John prefers Mary to smoke*
 b. *John *desired* / *wanted* / *wished* whether Mary smokes.

Since the PTPs in (57) are all non-veridical, we might expect interrogative embedding to improve under negation, similarly to *be certain*. But this is not the case as (58) shows. The PTPs in (58) are thus closer to *believe*.

- (58) *John didn't *desire* / *want* / *wish* whether Mary smokes.

Indeed, such desiderative PTPs are neg-raising. Consider (59). If *want* were not neg-raising, (59) should be compatible with John not having a preference as to whether Mary smokes or not given the inference observed for (57a). However, (59) rather implies that John prefers Mary to not smoke.

(59) John doesn't want that Mary smokes. \rightsquigarrow *John prefers Mary to not smoke*

This suggests that the account offered for *believe* in 4.1 should be extendable to desiderative PTPs. Notice, however, that such PTPs are non-monotonic (see e.g. Asher 1987; Heim 1992; Villalta 2008; Lassiter 2011; Rubinstein 2012; Anand and Hacquard 2013 a.o.). (60a) does not entail (60b).

- (60) a. John *desired / wanted / wished* that Mary and Sue smoke.
 b. John *desired / wanted / wished* that Mary smokes.

To account for this non-monotonicity property, I adopt Heim's 1992 similarity-based account of desiderative predicates. The entry for *want*, for instance, is as in (61). (61) applied to a proposition p asserts that for all of the subject's doxastic alternatives w' the worlds most similar to w' in which p is true are more desirable to the subject in w than the worlds most similar to w' in which p is false.¹⁰ Applied to (60a), for instance, (61) says that John believes that if Mary and Sue smoke he is in a more desirable world than if they do not smoke. The counterfactual component in (61) blocks entailment in both directions in (60). Crucially, (61) has the opinionatedness presupposition familiar from *believe* built in.

$$(61) \quad \llbracket \text{want} \rrbracket = \lambda p_{st} . \lambda x_e . \lambda w_s . \frac{[\forall w' \in \text{Dox}_{x,w} . \text{Sim}_{w'}(p) >_{x,w} \text{Sim}_{w'}(\neg p)] \vee [\forall w' \in \text{Dox}_{x,w} . \text{Sim}_{w'}(\neg p) >_{x,w} \text{Sim}_{w'}(p)]}{\forall w' \in \text{Dox}_{x,w} . \text{Sim}_{w'}(p) >_{x,w} \text{Sim}_{w'}(\neg p)}$$

Consider now the ungrammatical (57b) with *want*. Its literal meaning is as in (62). Given the existential quantification over answers, the assertive component says that John prefers Mary smoking to her not smoking or he prefers the reverse.

$$(62) \quad \llbracket (57b) \rrbracket = \lambda w . \exists p \in Q' : \frac{[\forall w' \in \text{Dox}_{J,w} . \text{Sim}_{w'}(p) >_{J,w} \text{Sim}_{w'}(\neg p)] \vee [\forall w' \in \text{Dox}_{J,w} . \text{Sim}_{w'}(\neg p) >_{J,w} \text{Sim}_{w'}(p)]}{\forall w' \in \text{Dox}_{J,w} . \text{Sim}_{w'}(p) >_{J,w} \text{Sim}_{w'}(\neg p)}$$

Now, since the two possible answers are the negations of each other, they make the same contribution to the presuppositional component. Each says that John either prefers Mary to smoke or he prefers the reverse. Thus the presupposition of (62) is equivalent to the assertion. Therefore the literal meaning of (57b) is trivial. Now, the negation in (58) has the same presupposition as (62). But the assertive component now requires that John have no preference among the possible answers. This contradicts the presupposition and thus (58) also has a trivial literal meaning. In other words, the order-based semantics of desiderative PTPs does not interfere with their neg-raising property, and they come out as non-rogative, as desired. This treatment

¹⁰The similarity relation among worlds and the notion of desirability employed in (60) are defined as in (i) and (ii), following again Heim (1992: 195ff.).

- (i) $\text{Sim}_w(p) := \{w'' \in W : w'' \in p \text{ and } w'' \text{ resembles } w \text{ no less than any other world in } p\}$
 (ii) a. For any $w, w', w'' \in W$, $w' >_{\alpha,w} w''$ iff w' is more desirable to α in w than w'' .
 b. For any $w \in W, X \subseteq W, Y \subseteq W$, $X >_{\alpha,w} Y$ iff $w' >_{\alpha,w} w''$ for all $w' \in X, w'' \in Y$.

can be extended to other neg-raising PTPs in (5) with an order-based semantics, such as *expect*, *fear* and *hope*.

6. Conclusion and outlook

In this paper I argued that embedding of polar interrogative clauses under PTPs involves an existential semantics, as suggested more generally by Spector and Egré (2015). This allowed me to account for the surprising context-dependence of the embedding of such clauses under *be certain* and other PTPs. Specifically, I proposed an exhaustification-based polarity system (Krifka, 1995; Chierchia, 2006, 2013) which leads to a contradiction for polar interrogatives with unnegated *be certain*. This system moreover has the immediate consequence that polar interrogatives can be embedded under factive PTPs even when not negated. The reason is that factivity avoids contradiction by exhaustification. This proposal also explains why seemingly non-veridical PTPs like *tell* show a limited kind of veridicality when embedding polar interrogatives. The reason is, again, that otherwise a contradiction would ensue. Finally, the existential semantics for embedding of polar interrogatives predicts that neg-raising PTPs—even those with an order-based semantics—always give rise to trivial meanings. That is, the system predicts such PTPs to never embed polar interrogatives.

The most important issue for future research now is to investigate how the proposed system can be extended to *wh*-interrogatives. First, the existential semantics assumed in this paper does not directly work with *wh*-interrogatives. It would give rise to too weak mention-some interpretations. Second and connected to this, the factivity presupposition assumed in the present paper does not automatically yield Strawson-equivalence in the case of *wh*-interrogatives embedded under factive PTPs. I.e., they should not be licensed contrary to fact. The consequence of this is that the lexical semantics for the PTPs themselves must be altered somewhat. For discussion of how this can be done, I refer the reader to Mayr (2017).

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