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## Polarity sensitivity of question embedding: experimental evidence\*

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**Abstract** Attitude predicates can be classified by the kinds of complements they can embed: declaratives, interrogatives or both. However, several authors have claimed that predicates like *be certain* can only embed interrogatives in specific environments. According to Mayr, these are exactly the environments that license negative polarity items (NPIs). In his analysis, both NPIs and embedded interrogatives are licensed by the same semantic strengthening procedure. If this is right, one would expect a correlation between acceptability of *be certain whether* and NPIs. The analysis also predicts a contrast between antecedents vs. consequents of conditionals and restrictors vs. scopes of universal quantifiers. This paper tests these predictions experimentally through an acceptability judgment task. We find that judgments for *be certain whether* do not correlate with judgments on NPIs, which suggests that *be certain whether* and NPIs are in fact licensed by different mechanisms.

**Keywords:** clause-embedding predicates, selectional restrictions, negative polarity items

### 1 Introduction

Most attitude predicates are easy to classify by the kinds of complements they can embed. They are either rogative (only embedding interrogatives, e.g., *wonder*), anti-rogative (only embedding declaratives, e.g., *believe*) or responsive (embedding both types of complements, e.g., *know*).

However, it appears that there are also borderline cases such as *be certain*. Although this predicate is often classified as a responsive predicate (Karttunen 1977; Preuss 2001; Lahiri 2002; Uegaki 2015; Theiler, Roelofsen & Aloni 2018),

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some authors claim that it can only embed interrogative complements under specific circumstances (Egré 2008; Hölker 2014; Mayr 2017).

Specifically, Mayr (2017) argues that *be certain whether* can appear whenever negative polarity items (NPIs) can. For instance, on his view, *be certain whether* is degraded in positive sentences, but fine under negation, just like NPI *any*:

- (1) a. #John is certain whether Mary smokes.  
b. John is not certain whether Mary smokes.
- (2) a. # John saw any girl.  
b. John didn't see any girl.

This contrasts with predicates like *know* and *believe*: the former can always embed interrogatives, while the latter never can.

According to Mayr, it is not a coincidence that *be certain whether* and NPIs are licensed in the same environments: he hypothesizes that both NPIs and embedded interrogatives involve a semantic strengthening procedure which restricts their distribution, and he provides a formal analysis that implements this idea. The present paper is concerned with testing this analysis empirically.

We will start by reviewing some previous theoretical work, including Mayr's analysis, in section 2. At the end of this section, we point out three empirical issues that we want to address in this paper. In order to do this, we performed three experiments, which are described and discussed in section 3. We will end with a conclusion and a discussion of further directions for research in section 4.

## 2 Previous theories

### 2.1 Adger & Quer, Eckardt

Before we turn to Mayr's theory, let us first briefly review some of the earlier related work on this topic.

Adger & Quer (1997, 2001) observe that there exist predicates that normally only embed declarative complements, but can embed questions in negative environments. They call this phenomenon *unselected embedded questions* (UEQs) and offer a syntactic explanation. Their analysis is based on the stipulation that these embedded questions are headed by a silent operator, which is licensed by NPI licensers. Setting aside the issue that this stipulation may lack explanatory value, their account is also not fully satisfactory for the data that Mayr discusses, for two reasons.

First, their analysis mainly concerns *if*-clauses, and not *whether*-clauses. That is, the polarity sensitivity that Adger & Quer are interested in is claimed to only occur with *if*, and not with *whether*. Further, the predicates *know*, *admit*, *hear* and *say* are discussed as examples of predicates that may take unselected embedded questions,

but they do not discuss *be certain*. Therefore, it is not clear how their analysis could be extended to capture the polarity sensitivity of *be certain whether*.

Second, although there indeed seem to be some proposition embedding predicates that allow for UEQs in certain contexts, there are also predicates that never allow interrogatives to be embedded, such as *think* or *believe*. This is not accounted for by Adger & Quer.

Eckardt (2007) criticizes this syntactic approach and instead claims that the explanation should be sought in pragmatics. One of her criticisms of Adger & Quer's analysis is that it cannot account for the polarity sensitivity of German *sich sicher sein ob* (which translates to *be certain if/whether*).

On Eckardt's view, the unacceptability of polar interrogative complements under some predicates in positive sentences is explained by competition with declarative complements:

- (3) a. # John admits if Mary smokes.  
b. John admits that Mary smokes.

Her assumption, following Bolinger (1978), is that the complement *if p*, in contrast to *whether p*, presupposes that *p* is more relevant than  $\neg p$ . This would mean that (3a) presupposes that the fact that Mary smokes is worth admitting, while this is not the case for the fact that she does not smoke. It follows then, that (3a) can only be true if (3b) is. The fact that the latter sentence is less complex should explain why the former is suppressed. This competition disappears under negation, which in turn explains the observed polarity sensitivity.

A problem with Eckardt's approach, however, is that it does not account for the case of *be certain whether*, for two reasons: first, *whether* is assumed not to have the asymmetric presupposition that *if* has. That means the theory could at most account for the polarity sensitivity of *be certain if*. The German example could only be accounted for as far as *ob* has the asymmetric presupposition that *if* is said to have – but it is suggested that *ob* is more like *whether* in this respect.

Second, even if we assume that *John is certain if/whether Mary smokes* presupposes that it is more relevant if Mary does smoke than if she does not, then from the statement that John is certain about either of the two propositions, it still does not logically follow that it has to be the first one. In the case where it is more relevant or surprising if Mary does smoke, it might still be worth mentioning that John is certain she does not. So it seems that in contrast to the predicate *admit*, the competition story does not go through with *be certain*.

## 2.2 Mayr's theory

Mayr's account of the licensing of *be certain whether* is inspired by existing theories of NPI licensing (e.g., Krifka 1995; Chierchia 2013) that go roughly as follows.

Sentence (2a) has a literal meaning in which *any* is simply an existential quantifier. But it also has a strengthened meaning (obtained by an operator *EXH*) which is a combination of the literal meaning and the negations of all its non-weaker alternatives. Mayr assumes that the alternatives of (2a) are of the form *John saw x*, and that there is one such alternative for each girl *x*.<sup>1</sup>

This strengthened meaning turns out to be systematically trivial (a contradiction), which should explain why the sentence is perceived as ungrammatical. Because the negation in (2b) reverses the direction of entailment, the alternatives of this sentence are in fact weaker than the literal meaning of the sentence itself, so the strengthened meaning will be the same as the literal meaning.

Mayr's analysis of *be certain whether* follows the same scheme. Again, the literal meaning of a sentence  $\phi$  is strengthened by means of an exhaustivity operator *EXH*. This operator negates all formal alternatives of  $\phi$  which are not Strawson-entailed by  $\phi$ :

$$EXH(p) = \lambda w.p(w) \wedge \forall q \in ALT(p)[p \not\#_S q \rightarrow \neg q(w)]$$

The formal alternatives of a sentence are constructed in a point-wise manner. Mayr assumes that the alternatives of a polar interrogative complement (*whether p*) are *that p* and *that not p*.

The contrast between (1a) and (1b) can then be explained as follows: Since (1b) entails both of its alternatives, its strengthened meaning is the same as its literal meaning. In contrast, (1a) does not entail either of its alternatives. Their negations are therefore added to the strengthened meaning. But the literal meaning expresses that John is either certain that Mary smokes or that she does not. So combining this literal meaning with the negations of its alternatives will result in a contradiction. This explains the presumed degradedness of the sentence.

The fact that *know whether* and *believe whether* do not show this polarity sensitive behavior can also be explained by this theory.

(4) John knows whether Mary smokes.

*ALT*: John knows that Mary smokes / John knows that Mary doesn't smoke

For *know whether*, the fact that Mayr uses the notion of Strawson entailment becomes relevant. To check whether (4) Strawson-entails an alternative, we have to check

<sup>1</sup> This is different from the approach in Chierchia 2013: there, each alternative for (2a) replaces the contextually determined domain of girls that the existential quantifier ranges over with a subset of that domain.

whether it entails it under the assumption that the presupposition of the alternative is satisfied. Since *know* is factive, the alternatives both carry a presupposition that the embedded clause is true. So (4) indeed Strawson-entails both its alternatives, and applying *EXH* will not have any effect. This correctly predicts that *know whether* is licensed both in positive and in negative environments.

Mayr further predicts that *believe whether* is never licensed. This prediction is based on the neg-raising property of *believe*: a sentence with *believe* presupposes that the subject either believes the complement or its negation. This makes (5a) a tautology: whenever its truth value is defined, it is true. By similar reasoning, it makes (5b) a contradiction.

- (5) a. John believes whether Mary smokes.  
b. John does not believe whether Mary smokes

This explains why *believe whether* is not polarity sensitive: both with and without negation its meaning turns out to be trivial.<sup>2</sup>

### 2.3 Empirical issues to address

Mayr's analysis raises three issues that need to be addressed experimentally.

First, if the analysis is right, then we would expect that in a given environment, a speaker's acceptance of *be certain whether* should correlate with their acceptance of NPI *any* (see Chemla, Homer & Rothschild 2011 for similar ideas and tests applied to Chierchia's predicted link between NPIs and scalar implicatures).

Second, apart from the contrast between (1a) and (1b), an analysis based on NPI licensing also predicts that *be certain whether* is fine in antecedents but not consequents of conditionals and in restrictors but not scopes of universal quantifiers, to the extent that NPIs are.<sup>3</sup>

Third, Mayr only discusses polar questions. If his analysis of *be certain whether* is right, the question arises how it should be extended to *wh*-complements. A first step in this direction is to test whether *be certain wh* exhibits the same polarity sensitivity as *be certain whether*.

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<sup>2</sup> See Theiler, Roelofsen & Aloni 2017 for a similar account of the fact that *believe* does not take interrogative complements.

<sup>3</sup> Mayr (2017) in fact expresses some doubt concerning the prediction that there be a contrast between restrictors and scopes of universal quantifiers when it comes to licensing *be certain whether*.

### 3 Experiments

#### 3.1 Experiment 1

##### 3.1.1 Goal

The goal of our first experiment was to address the first two empirical issues mentioned above: First, we wanted to test Mayr’s intuitions about the superficial pattern of acceptability of the construction *be certain whether* and to compare it with the NPI *any*. In addition, we decided to test whether the acceptability of the two constructions would correlate. Indeed, if their distribution is explained by the same mechanism, we expect participants who find *any* particularly degraded in a certain context to also find *be certain whether* equally degraded, and conversely for participants who would be more tolerant of a violation.

##### 3.1.2 Method

We performed an acceptability judgment task through Mechanical Turk in which participants saw a collection of sentences, one at a time. Their task was to judge to what extent each sentence was acceptable, on a five point scale from *odd* to *natural*. The instructions included the following text:

A school class is having a geography quiz. The teacher asks questions like “Is Paris the capital of France?”. When the children want to answer, they have to raise their hand.

Target sentences were of the form of (6a)–(6f), where COMP had the form of one of the complements in (7).<sup>4</sup>

- |     |   |                 |
|-----|---|-----------------|
| (6) | a. Bob is certain COMP.                                     | (unembedded)    |
|     | b. Madison is not certain COMP.                             | (negation)      |
|     | c. If Michael is certain COMP, then he will raise his hand. | (antecedent)    |
|     | d. If Chris raised his hand, then he is certain COMP.       | (consequent)    |
|     | e. Everyone who is certain COMP raised their hands.         | (restrictor)    |
|     | f. Everyone who raised their hands is certain COMP.         | (scope)         |
|     |   |                 |
| (7) | a. whether Milan is the capital of Italy or not             | (interrogative) |
|     | b. that Moscow is the capital of Russia                     | (declarative)   |

<sup>4</sup> With *be certain*, the city could either be the real capital city of the country or another major city to control for truth/falsity of the complement. However, declarative complements under *know* were constrained to always be true in order to satisfy the factive presupposition, while declarative complements under *think* were always false to satisfy the anti-presupposition of *think* (Percus 2006; Sauerland 2008).

<b>Predicate/determiner:</b>		<b>Environment:</b>		<b>Complement:</b>
know		unembedded		interrogative
be certain		negation		declarative
think		antecedent		
	+	consequent	+	
any		restrictor		declarative
a		scope		

**Table 1** Combinations of predicate/determiner, environment, and complement that were included in Experiment 1

We added control sentences with a different predicate (*know*, *think*) and sentences of the form (8a)-(8d), which contained NPI *any* in the same six environments, allowing us to test the correlation between the acceptability of *any* and *be certain whether*.

- (8)
- a. The teacher asked *any/a* question about France.
  - b. The teacher did not ask *any/a* question about Germany.
  - c. If Sarah answers *any/a* question correctly, then she will receive *any/a* reward.
  - d. Everyone who answers *any/a* question correctly will receive *any/a* reward.

Associated control sentences had the indefinite *a* in place of *any*.

See Table 1 for an overview of all combinations of predicates/determiners, environments and complement types. Each participant saw one of each possible combination (total: 48 items). The order of the items and the combinations of countries and capitals were randomized for each participant.

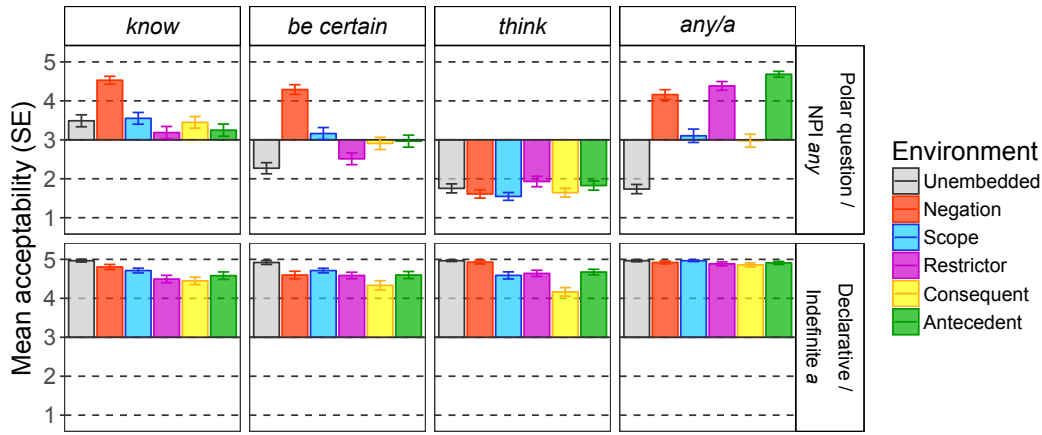
We recruited 100 participants (age range: 19–71), who were paid \$0.70 for their participation. The experiment took about 5min. One participant was removed from the analysis for reporting a native language other than English and 12 more because their error rate on controls exceeded the mean by more than one standard deviation.<sup>5</sup>

### 3.1.3 Results

The results are presented in Figure 1. The results for NPI *any* are as expected: high acceptability in downward-entailing environments (negation, restrictor, antecedent), much lower in upward-entailing environments. The picture is more complicated

<sup>5</sup> The raw data and analysis scripts for all experiments are available online at <https://semanticsarchive.net/Archive/DRhZTM3Y/vanGessel-Cremers-Roelofsen.html>.



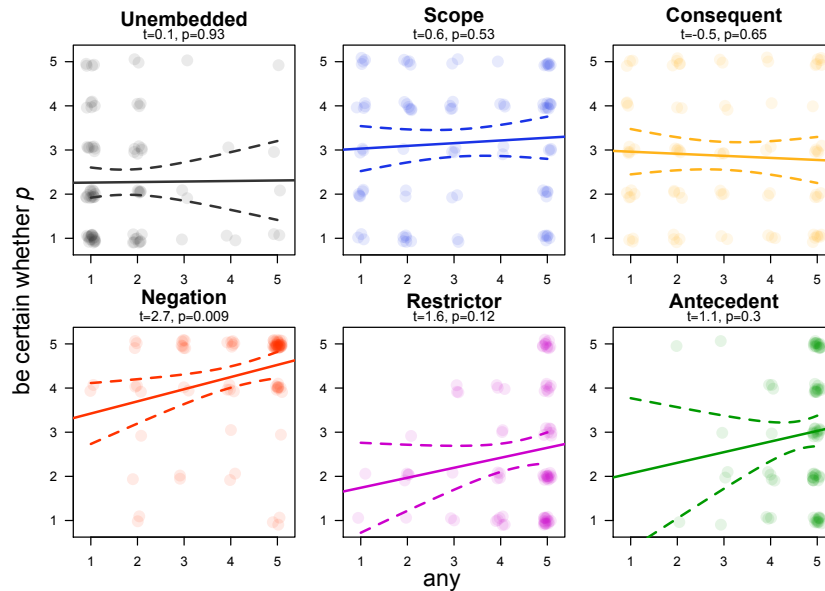


**Figure 1** Results of Experiment 1: mean (SE) acceptability for each environment on a 1–5 scale. The results for NPI *any* are presented in the same row as polar questions, while controls with *a* are in the same row as declarative controls for *know*, *be certain* and *think*.

with *be certain whether*, which only seems clearly acceptable under negation, but the pattern for *know* is also rather different from what is usually assumed.

We compared the predicates *be certain* and *know* by running a linear mixed model on z-scored answers with PREDICATE, COMPLEMENT, ENVIRONMENT (baseline: negation) and all of their interactions as fixed effects. With declarative complements, the different environments varied in acceptability, but crucially this effect only marginally interacted with PREDICATE in the restrictor of universals ( $t = 1.96, p = .0498$ ) but not in any other ENVIRONMENT (all  $|t| < 1.3, p > .20$ ). Under negation, questions were slightly degraded compared to declaratives ( $t = -2.7, p = .006$ ), but they were significantly more degraded in all other environments (all  $t < -6.0, p < .001$ ). We found no difference between the two predicates when they embed questions and are themselves embedded under negation ( $t = .16, p = .88$ ), but *be certain* was significantly degraded in comparison to *know* in plain affirmative sentences ( $t = 4.8, p < .001$ ) and in the restrictor of universals ( $t = 3.2, p = .001$ ). In short, we found a contrast between plain affirmative and negative sentences with both predicates, but it was stronger with *be certain*. In other environments, the picture is less clear.

We further tested the correlation between the acceptability of *be certain whether* and *any*. We found a small correlation across environments ( $\chi^2(1) = 4.9, p = .026$ ) and no interaction with environment ( $\chi^2(5) = 6.9, p = .23$ ). However, the individual



**Figure 2** Experiment 1: Participants’ response to *be certain whether* as a function of their response to *any* in each environment. Each patch of color corresponds to one participant. The correlation lines and corresponding *t*-values are fitted for each environment separately.

data broken down by environment in Figure 2 shows that this correlation is mainly driven by the three downward entailing environments, where both constructions are acceptable.

### 3.1.4 Discussion

In this experiment, we observed the usual pattern for NPI *any*, but the pattern for *be certain whether* differed on the more complex environments and the correlation between the two was rather limited. This may be related to the rather surprising and puzzling results for *know*. As a post-hoc analysis, we tested the effect of the truth/falsity of *p* on the acceptability of *whether p*, but it did not interact with any other effect ( $\chi^2(11) = 12.4, p = .34$ ).

## 3.2 Experiment 2

We hypothesized that the addition of *or not* to the polar interrogative complements may have caused the unexpected degradedness of variants with *know whether*. We ran a new experiment in which this was removed, and which contained animal

classifications (e.g., *tigers are mammals*) instead of capital-country pairs which made complex sentences very long and possibly hard to process. It was otherwise the same.

We recruited 103 participants (age range: 22–70), who were paid \$0.70 for their participation. Two participants were removed from the analysis for reporting a native language other than English and 15 more because their error rate on controls exceeded the mean by more than one standard deviation.

The results were very similar. In the comparison between *know* and *be certain*, only the difference between the interactions with the Restrictor ENVIRONMENT weren't replicated ( $t = 0.8, p = .42$  for PREDICATE×ENVIRONMENT,  $t = -1.2, p = .23$  for PREDICATE×ENVIRONMENT×COMPLEMENT). The correlation between participants' answers to *be certain whether* and *any* wasn't replicated either ( $\chi^2(1) = 1.4, p = .23$ ).

Crucially, *know whether* again showed polarity-sensitivity, suggesting that the *or not* in the polar questions of Experiment 1 did not play any particular role.

### 3.3 Experiment 3

#### 3.3.1 Goal

We considered the possibility that the degradedness of *know whether* was due to competition with *know that*. Crucially, while *know that* may be preferred over *know whether* in case their complement is known to be true, if the truth value of the complement is not known, this competition should be blocked. Therefore, in our final experiment the animal classification context was replaced by one with fictional properties of aliens. Since participants cannot have any prior knowledge about these properties, this should rule out any expectations about their truth or falsity.

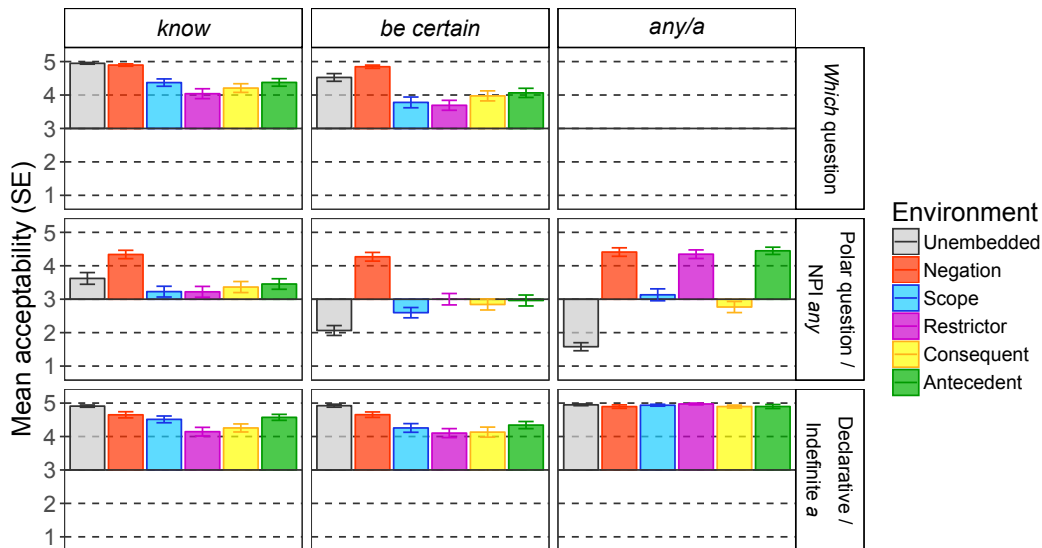
Finally, we set out to address our last empirical issue, regarding the generalizability of the pattern to *wh*-questions. We therefore tested *which*-questions in all environments, to see to what extent they behave like polar *whether*-questions.

#### 3.3.2 Method

Like in the previous experiments, target sentences were of the form of (6a)-(6f). This time, COMP had the form of one of the complements in (9).

- (9) a. whether the Ikreht aliens are fluffy (polar interrogative complement)  
 b. which aliens are speckled (wh-complement)  
 c. that the Gryjihq aliens are red (declarative complement)

Control sentences with *know* followed the same scheme, and fillers with *think* and



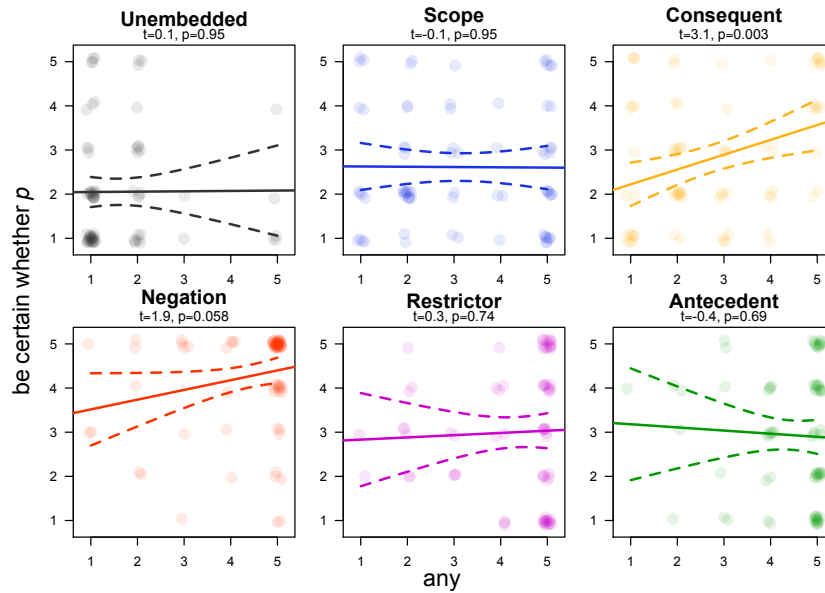
**Figure 3** Results of Experiment 3: mean (SE) acceptability for each environment on a 1–5 scale. The results for NPI *any* are presented in the same row as polar questions, while controls with *a* are in the same row as declarative controls for *know* and *be certain*.

*wonder* were included to balance the ratio of expected odd/natural responses. As before, sentences with NPI *any* in the same environments and associated control sentences with *a* were added. The order of the items was randomized, as well as the combinations of aliens and properties.

89 participants were recruited on Mechanical Turk and paid \$1 for their participation (age range: 22–62). The experiment took about 7 minutes. All participants reported English as their native language, but 11 participants who exceeded the mean error rate by at least one standard deviation were removed from the analysis.

### 3.3.3 Results

The results are presented in Figure 3. As in the previous experiments, we ran a model to compare *know* and *be certain*, this time with three levels for COMPLETMENT (declarative, polar question, *which*-question). The results for declarative and polar question complements were very similar: no difference between the verb with declarative complements, no difference with question when embedded under negation, but in other environments both verbs were significantly degraded with



**Figure 4** Experiment 3: Participants’ response to *be certain whether* as a function of their response to *any* in each environment. Each patch of color corresponds to one participant. The correlation lines and corresponding *t*-values are fitted for each environment separately.

polar question (all  $t < -3.8, p < .001$ ), and *be certain* was even more degraded in plain affirmative sentences ( $t = -5.5, p < .001$ ). *Which*-questions were rated higher than declarative complements in negative environment ( $t = 2.2, p = .025$ ), but in other environments they were equally or less acceptable (all  $t < -2.2, p < .028$ ). Here there was no difference between the two verbs (all  $|t| < 1.4, p > .16$ ).

We found a significant correlation between the judgments for *be certain whether* and *any* ( $\chi^2(1) = 4.2, p = .041$ ). Once again, looking at the details in Figure 4 shows that this effect is mainly driven by Negation and, this time, Consequent.

#### 4 Conclusions and further work

Our results suggest that *be certain whether* is indeed degraded in positive episodic sentences. Moreover, they confirm that this effect disappears under negation. In these two sentence types, *be certain whether* shows a similar overall pattern as NPIs, confirming Mayr’s judgment.

However, when looking at individual participants, judgments for *be certain whether* do not generally correlate with judgments on NPIs. Furthermore, the similarity found in plain positive and negative sentences does not seem to extend

to conditionals and quantified sentences. This suggests that *be certain whether* and NPIs are (anti-)licensed by different mechanisms.

Two more pieces of data are worth highlighting as well: first, Experiment 3 shows that *be certain* is much less polarity sensitive with *which*-questions than with *whether*-questions; and second, quite unexpectedly, *know whether* appears to be somewhat polarity sensitive, similar to *be certain whether*. Note that according to Mayr's analysis *know* is not polarity sensitive at all, because it is factive, in contrast to *be certain*. More work is needed, however, to determine what causes these effects.

The fact that our results do not support a unified analysis of *be certain whether* and NPI *any* does not necessarily mean that the analysis based on exhaustification is not on the right track for any of the two phenomena. If we give up the unified analysis, there are still two options.

The first option is to give up the exhaustification analysis of NPI *any* (this is somewhat suggested by Chemla et al. 2011). It can also be adapted in several ways: for instance, Chierchia (2013) offers a more refined version of the exhaustification story than Mayr does, which is required to deal with quantified cases.

A second option is to give up Mayr's analysis of *be certain whether*. Although there is no fully satisfactory explanation available yet, we do want to suggest two directions that seem worth further investigation.

First, since the acceptability of *be certain whether* is higher under negation than in the restrictor of a universal quantifier or the antecedent of a conditional, it seems that *be certain whether* is more similar to strong NPIs like *in years* than to weak NPIs like *any*. Roughly, weak NPIs are licensed in all downward entailing environments, while strong NPIs are only licensed in a subset of those environments, namely ones that are anti-additive (Zwarts 1998). For instance, *in years* is not licensed in the restrictor of a universal quantifier or in the antecedent of a conditional, which are not anti-additive environments.

- (10) a. \*Everyone who has gone hiking in years should be in good shape.
- b. \*If Sue goes hiking in years she will be in good shape.

On the other hand, *in years* is licensed under sentential negation, under negative quantifiers like *none of my friends* and under *without*, which do create anti-additive environments.

- (11) a. Sue hasn't gone hiking in years.
- b. None of my friends has gone hiking in years.
- c. Sue attempted the Mont Blanc this summer without having hiked in years.

These anti-additive environments are ones in which *be certain whether* seems

perfectly acceptable as well:

- (12) a. John isn't certain whether Sue likes to hike.  
 b. None of my friends is certain whether Sue likes to hike.  
 c. Sue went hiking without being certain whether it would rain or not.

These observations suggest that it would be worth investigating whether there is indeed a general correlation between the acceptability of *be certain whether* and that of strong NPIs like *in years*. If this is indeed the case, this should guide our further theoretical analysis of the polarity sensitive nature of predicates like *be certain*.

Second, in positive sentences *be certain* behaves similar to emotive factive predicates like *surprise*, in the sense that these are also incompatible with *whether*-complements, but not with *wh*-complements:

- (13) a. #It surprises Mary whether John showed up.  
 b. It surprises Mary who showed up.

According to Herbstritt (2014); Roelofsen, Herbstritt & Aloni (2016); Roelofsen (2017), the fact that emotive factives like *surprise* do not license *whether*-complements is related to the strong existential presupposition they trigger when taking a *wh*-complement, witnessed by the oddness of (14a) compared to (14b):

- (14) a. #It surprises Mary who showed up, if anyone.  
 b. Bill will tell Mary who showed up, if anyone.

Interestingly, we observe that *be certain*, when taking a *wh*-complement, seems to trigger the same kind of existential presupposition in positive environments, but not in negative ones:<sup>6</sup>

- (15) a. # John is certain who smokes, if anyone.  
 b. John isn't certain who smokes, if anyone.

If this contrast indeed exists, the explanation of why emotive factives are incompatible with *whether*-complements may carry over to *be certain* in positive environments. Further work is needed, however, to experimentally confirm the contrast in (15), and to understand why this presupposition would be polarity sensitive.

For now we conclude that our results confirm the polarity sensitivity of *be certain whether*, but challenge Mayr's hypothesis that the same mechanism is responsible for both unlicensed NPIs and the degradedness of *be certain whether* in positive sentences.

<sup>6</sup> Our results suggest that (15a) is slightly degraded even without *if anyone*, but the native speakers we consulted agreed that there is a clear contrast between the sentences with and without *if anyone*.

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