The semantics of question-embedding predicates

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Abstract

The complementation pattern of certain question-embedding predicates, such as *know* and *agree*, presents a puzzle for the compositional semantics of clausal complementation, as the predicates seem to be able to combine with two distinct types of semantic objects: propositions and questions. The traditional approach to the semantics of these predicates, where embedded questions are *reduced* to propositions, faces two problems. First, it cannot account for the observation that *know-wh* sentences require the subject not to believe any false answer to the embedded question ([George, 2011]). Second, it makes a problematic prediction concerning the interpretation of Predicates of Relevance, such as *care* and *matter* ([Elliott et al., 2017]). We review three alternative approaches to the semantics of question-embedding predicates, i.e., the PROPOSITION-TO-QUESTION reduction ([Uegaki, 2015, 2016]), the UNIFORM approach ([Ciardelli et al., 2013]) and the AMBIGUITY approach ([George, 2011]), and argue that only the Proposition-to-Question reduction and the uniform approach can deal with the interpretation of the Predicates of Relevance. The paper concludes with a remark on how lexical denotations of question-embedding predicates are constrained in general.

Keywords question-embedding predicates, responsive predicates, complementation, know-wh, semantics of interrogatives, Inquisitive Semantics

1 Introduction: responsive predicates

This paper surveys approaches to the issue concerning the compositional semantics of pairs of sentences like (1):

(1) a. Alice {**knows/realized/reported**} that Ann left.　　(declarative complement)
　　b. Alice {**knows/realized/reported**} who left.　　(interrogative complement)

These examples show that the same predicate (i.e., *know*, *realize* and *report*) can embed either a declarative complement or an interrogative complement. Following Lahiri (2002), I refer to the predicates that show the complementation pattern exemplified in (1) as RESPONSIVE PREDICATES. Responsive predicates pose a non-trivial puzzle for the compositional semantics of complementation, in view of the following two fairly standard hypotheses:

(2) **Semantic distinction of clause types**　Declarative complements and interrogative complements denote semantic objects with distinct types.

　　Non-ambiguity　Responsive predicates are unambiguous between its declarative-embedding use and its interrogative-embedding use.

Of these two hypotheses, the non-ambiguity of responsive predicates is not only intuitively plausible but also empirically motivated by an example involving gapping, as follows:

(3) Alice **knows/realized/reported** that Ann left and Bill ~~**knows/realized/reported**~~ which other girls left.

In this example, the first conjunct involves a declarative complement while the latter conjunct involves an interrogative complement. The fact that the predicate can be gapped in the second conjunct suggests that the predicates are non-ambiguous between the declarative-embedding use and the interrogative-embedding use (see Sennet 2016 for discussion of this and similar diagnostics for ambiguity).

In addition, across multiple languages, clause-embedding predicates with similar lexical semantics behave as responsive predicates, i.e., they can embed either declarative or interrogative complements. For example, the Japanese counterparts of the predicates in (1) can embed both types of complements, as demonstrated in (4) below:

(4) a. Alice-wa dono onnanoko-ga kita-ka **sitteiru/kizuita/hookoku-sita**.
　　　　Alice-TOP which girl-NOM　　came-Q know/realized/reported
　　　　'Alice knows/realized/reported which girl came.'
　　b. Alice-wa Mary-ga　kita-to　　**sitteiru/kizuita/hookoku-sita**.
　　　　Alice-TOP Mary-NOM came-DECL know/realized/reported
　　　　'Alice knows/realized/reported that Mary girl came.'

The problem, then, is how to account for the complementation pattern of responsive predicates given these empirical motivations for their non-ambiguity, while considering the plausibility of the semantic distinction of declarative and interrogative clause types.

In this paper, I will survey four approaches to this problem in the literature. Two of the approaches adhere to the basic hypotheses in (2) and reconcile their conflict by

positing an operation that turns one kind of semantic object into the other. Depending on the *direction* of this extra semantic operation, these two approaches will be called QUESTION-TO-PROPOSITION REDUCTION approach (or Q-TO-P REDUCTION) and PROPOSITION-TO-QUESTION REDUCTION approach (or P-TO-Q REDUCTION). On the other hand, the other two approaches each reject one of the hypotheses in (2). The one that rejects the non-ambiguity hypothesis is the AMBIGUITY approach while the one that rejects the semantic distinction of clause types will be referred to as the UNIFORM approach.

The structure of the paper will be the following. I will first present characteristics of the most traditional approach to question-embedding, namely the Question-to-Proposition reduction approach, together with examples of compositional implementations in the literature (§2). After this, I will present two arguments against the Q-to-P reduction (§3). These arguments concern 'non-reducibility' of certain presuppositional responsive predicates discussed by George (2011) and interpretation of Predicates of Relevance, such as *be relevant*, *matter* and *care* (Elliott et al., 2017). I will then introduce three alternative approaches, i.e., the Proposition-to-Question reduction, the uniform approach and the ambiguity approach, and compare them in view of whether they can deal with the two problems for the Question-to-Proposition reduction (§5). Finally, in §6, I discuss how the approaches can be compared in view of restrictions they place on the space of possible responsive predicate denotations.

2 Question-to-Proposition reduction

The Q-to-P reduction approach is the most traditional approach to the semantics of responsive predicates. This approach dates back at least to Hintikka (1962) and is also adopted by most of subsequent analyses of question-embedding in the formal semantic literature, such as Karttunen (1977); Heim (1994); Dayal (1996); Beck and Rullmann (1999); Lahiri (2002), and more recently by Spector and Egré (2015) and Cremers (2016).[1] The characteristics of the Q-to-P reduction approach can be summarized as follows:

(5) **The Question-to-Proposition reduction**

- Responsive predicates semantically select for the denotation of the declarative complement, i.e., propositions.

- The compositional semantics involves a mechanism that reduces the denotation of an interrogative complement into a proposition.

Analyses within this approach differ in the exact formulation of the reduction mechanism. One of the prominent formulations employs an ANSWERHOOD OPERATOR, which maps the

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[1]Technically, Karttunen (1977) and Spector and Egré (2015) define two lexical entries for a responsive predicate, one with a proposition-taking denotation and the other with a question-taking denotation. Thus, prima facie, they might seem to fall under the ambiguity approach. However, I categorize them as the Q-to-P reduction approach since their theories include a general mechanism that derives a interrogative-embedding denotation from a declarative-embedding denotation. That is, they analyze the interpretation of interrogative-embedding case in terms of proposition-taking denotation of responsive predicates. Similarly, I categorize Ginzburg's (1995) theory as an instance of the Q-to-P reduction as the mechanism of question-to-fact/proposition coercion in his theory effectively plays the role of the Q-to-P reduction.

question meaning denoted by an interrogative complement to a specific 'answer' of the question (Heim, 1994; Dayal, 1996; Beck and Rullmann, 1999; Cremers, 2016). I will give a concrete example of such an operator shortly below, but doing this requires explicit assumptions about (a) the semantics of interrogative complements and (b) what counts as an 'answer' to a question expressed by an interrogative complement.

As for (a), we follow Hamblin (1973) and assume that interrogative complements express *sets of propositions* that are obtained by, roughly, varying the argument corresponding to the *wh*-item. For example, the question expressed by *who left* is the set of propositions, as in the following:[2]

(6) $[\![\text{who left}]\!] = \{\, p \mid \exists x[p = \lambda w'.\mathbf{left}_{w'}(x)]\,\}$
         $= \{\, \text{'Ann left'}, \text{'Bill left'}, \text{'Carol left'},... \}$

As for (b), the issue of what counts as an answer to a question concerns the notion of EXHAUSTIVITY, i.e., how much true information an answer must convey relative to the question meaning. In the literature, at least three levels of exhaustivity are discussed: MENTION-SOME, WEAK EXHAUSTIVITY and STRONG EXHAUSTIVITY. Answers having these different levels of exhaustivity correspond to the following propositions in the case of (6), in the world where only Ann and Bill left.:

(7)   *Situation: Only Ann and Bill left.*
    a.   **Mention-some answers**: 'Ann left', 'Bill left'
    b.   **Weakly-exhaustive answer**: 'Ann left and Bill left'
    c.   **Strongly-exhaustive answer**: 'Ann left and Bill left, and no one else left.'

Comparing different theoretical accounts of exhaustivity in embedded questions requires a space for another survey article. Thus, here, I will gloss over this issue and assume that the default reading of embedded questions involves the *weakly-exhaustive* answer, following Karttunen (1977); Heim (1994); Dayal (1996); Klinedinst and Rothschild (2011) and Uegaki (2015). In addition to these works, see Groenendijk and Stokhof (1984); Beck and Rullmann (1999); Guerzoni and Sharvit (2007); George (2011); Spector and Egré (2015); Xiang (2016); Theiler et al. (2018) for overall treatments of exhaustivity in embedded questions.

With these assumptions in place, a concrete answerhood operator can be defined as follows.[3]

(8) $\mathbf{Ans}_w := \lambda Q_{\langle st,t\rangle}: \underline{\exists p \in Q[p(w)]}.\ \lambda w'_s.\ \forall p' \in Q[p'(w) \rightarrow p'(w')]$

This operator takes a question meaning as its input and outputs its weakly-exhaustive answer (i.e., the conjunction of all true propositions in the question meaning), presupposing that at least one proposition in the question meaning is true. Using this operator, we can analyze interrogative-embedding sentences as follows:

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[2]For reasons of space, I will not discuss the issue concerning the 'de re'/'de dicto' ambiguity of the *wh*-term. The interested reader is referred to the survey by Hagstrom (2003) and references cited therein.

[3]Following Heim and Kratzer (1998), I model presuppositions using domain restrictions on functions, written after the colon (':') in a lambda term with an underline. Truth conditions projected from presuppositions are also underlined.

(9) a. $[\![\text{know}]\!]^w = \lambda p_{\langle s,t\rangle}\lambda x_e: \underline{p(w)}.\ \textbf{know}_w(x, p)$

  b. $[\![\text{Alice knows who left}]\!]^w = [\![\text{know}]\!]^w(\textbf{Ans}_w([\![\text{who left}]\!]))(\textbf{a})$
  $= 1 \text{ iff } \underline{\exists x[\textbf{left}_w(x)]} \wedge \textbf{know}_w(\textbf{a}, \textbf{Ans}_w([\![\text{who left}]\!]))$

Under this analysis, the denotation of a responsive predicate, e.g., *know*, takes a proposition as its first argument. The question meaning is turned into a proposition by the **Ans**-operator, which is then fed to the proposition-taking denotation of the predicate.

Another implementation of reduction is seen in Spector and Egré (2015), who analyze interrogative-embedding sentences in terms of existential quantification over answers to the question.[4] Letting $\textbf{pot}(Q)$ be the set of potential weakly-exhaustive answers of Q and $\textbf{exh}_Q(p)$ be the strongly-exhaustive answer of Q that corresponds to p (i.e., that has p as the 'positive part'), they roughly analyze a strongly-exhaustive reading as follows:[5]

(10) $[\![\text{Alice knows who left}]\!]^w = 1 \text{ iff } \exists p \in \textbf{pot}(Q)[\textbf{know}_w(\textbf{a}, \textbf{exh}_Q(p))]$

Lahiri (2002) proposes yet another form of reduction, where an LF operation called INTER-ROGATIVE RAISING resolves the type-mismatch between the proposition-taking denotation of responsive predicates and the interrogative complement. These different forms of reduction make distinct predictions with respect to the interpretation of embedded questions, but such differences within the Q-to-P reduction are irrelevant for the purpose of this survey.

Note that this approach adheres to the two basic hypotheses in (2). Declarative and interrogative complements have distinct types of objects. In the formulation illustrated above, declarative complements denote *propositions* while interrogative complements denote *sets* of propositions. At the same time, responsive predicates are unambiguous between the declarative-embedding and interrogative-embedding use. They have a proposition-taking denotation, and the embedding of interrogative complements involve some form of reduction.

The discussion in the rest of the paper will center around the following two predictions of the existing Q-to-P reduction accounts as summarized above.[6] To aid readability, I intentionally conflate variables in the object language and metalanguage.

(11) **Predictions of the Q-to-P reduction**

  a. **Q-to-P Reducibility**: Let V be a responsive predicate. Then, for every entity-denoting term x and every interrogative complement Q, whether $\ulcorner x\ Vs\ Q\urcorner$ is true depends only on which declarative complements p are such that $\ulcorner x\ Vs\ p\urcorner$.

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[4]Incidentally, this analysis is close to one of the first formal semantic analysis of 'knowing-who' by Hintikka (1962, 131), who analyzes the meaning of 'S knows who is P' as $\exists x[K_S(P(x))]$.

[5]Spector and Egré (2015) analyze weakly-exhaustive readings also in terms of an existential quantification over $\textbf{Pot}(Q)$ but using a different operator from **exh** in the assertive component, while keeping the strongly-exhaustive semantics in the presupposition.

[6]It is worth noting that the two predictions are not necessarily entailed by the Q-to-P reduction as defined in (5). For example, if a reduction mechanism involves a negation in $\textbf{Ans}_w$, (11b) is not predicted. However, such a reduction mechanism would have an empirical difficulty capturing the basic truth conditions of *know-wh*. Also, see the last paragraph of §3.1 for Q-to-P reduction analyses that avoid the prediction in (11a) based on additional assumptions.

b. **Entailment Prediction**: Let *V* be a responsive predicate. Then, for every entity-denoting term *x* and every interrogative complement *Q*, ⌜*x Vs Q*⌝ entails that there is a proposition $p \in Q$ such that ⌜*x Vs p*⌝.

The first prediction states that the truth conditions of an interrogative-embedding sentence with a responsive predicate is sufficiently described by declarative-embedding sentences with the same predicate. For example, the prediction states that whether ⌜*Alice knows which students left*⌝ is true depends only on what declarative clauses *p* are such that ⌜*Alice knows p*⌝ is true. On the other hand, the second prediction states that an interrogative-embedding sentence entails that some answer to the embedded question makes the declarative-embedding variant true. For example, the interpretation of ⌜*Alice knows Q*⌝ conforms to this prediction as ⌜*Alice knows Q*⌝ entails that some proposition *p* in *Q* is such that Alice knows *p*. In the rest of the paper, we evaluate the viability of Q-to-P reduction as a general theory of responsive predicates by examining these two predictions.

3 Problems with the Question-to-Proposition reduction

The Q-to-P reduction approach has been the standard approach to question-embedding at least since Karttunen (1977). Moreover, it fares well with the standard view in epistemic logic after Hintikka (1962) that *know* is a modal operator applying to a proposition. However, in recent years, there have been a number of empirical counterarguments against the approach. In this section, I review two such arguments: one based on non-reducibility of presuppositional predicates, the other based on the so-called Predicates of Relevance.[7]

3.1 Non-reducibility of some presuppositional predicates

The first argument concerns the Q-to-P reducibility prediction in (11a). George (2011) points out that there are examples involving the responsive predicate *know* that go against (11a). The problematic example George describes involves a situation where two individuals have exactly the same set of propositional knowledge, but have different question-knowledge. The concrete example goes as follows.

(12) **Scenario for** *know*

- Newstopia sells an Italian newspaper, but PaperWorld doesn't.
- Alice and Bill know that one can buy an Italian newspaper at Newstopia.
- Alice neither believes nor disbelieves that one can buy an Italian newspaper at PaperWorld.
- Bill wrongly believes that one can buy an Italian newspaper at PaperWorld.
- Otherwise, Alice and Bill have exactly the same beliefs.

(13) a. Alice knows where one can buy an Italian newspaper.

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[7]See Uegaki (2016) for another argument against the Q-to-P reduction based on nominal complements of attitude predicates.

b. #Bill knows where one can buy an Italian newspaper.

In the scenario described in (12), sentence (13a) is intuitively true, but (13b) isn't.[8]

This is problematic for the Q-to-P reduction analysis of *know*. This is so since Alice and Bill have exactly the same set of relevant 'propositional' knowledge. That is, all sentences with the declarative-embedding *know* do not differ in truth values, regardless of whether *Alice* or *Bill* is the subject. Both sentences in (14) are true while both sentences in (15) are presupposition failures because of the factivity of *know*.

(14)   a.   Alice knows that one can buy an Italian newspaper at Newstopia.

       b.   Bill knows that one can buy an Italian newspaper at Newstopia.

(15)   a.   Alice knows that one can buy an Italian newspaper at PaperWorld.

       b.   Bill knows that one can buy an Italian newspaper at PaperWorld.

Thus, if question-knowledge can be reduced to propositional knowledge, Alice and Bill should have the same question-knowledge. The fact that (13a) and (13b) differ in the truth values speaks against this prediction.[9]

One way to describe the data above is that the question-embedding meaning of *know* is sensitive to the subject's false belief (Berman, 1991; Preuss, 2001; Spector, 2005; George, 2011; Spector and Egré, 2015; Theiler et al., 2018). If the subject believes a false proposition in the question meaning, an interrogative-embedding sentence involving factive predicates like *know* does not sound true. However, it turns out that the phenomenon is not restricted to the 'false-belief' sensitivity of factive predicates. We can observe a similar phenomenon with the predicate *agree* in the construction *A agrees with B on...*. This is shown in the following example:

(16)   **Scenario for *agree*.** In addition to the scenario in (12), we assume that Sue believes that Newstopia sells an Italian newspaper, but PaperWorld doesn't.

(17)   a.   Alice agrees with Sue on where one can buy an Italian newspaper.

       b. #Bill agrees with Sue on where one can buy an Italian newspaper.

The contrast in the judgment in (17) is problematic for the Q-to-P reduction. This is so since truth values of sentences of the form ⌜*Alice/Bill agrees with Sue that p*⌝ doesn't differentiate Alice and Bill in the scenario. Both sentences in (18) are true while both sentences in (19) are presupposition failures, given that ⌜*x agrees with Sue that p*⌝ presupposes that Sue believes that *p*.

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[8]Some native speakers express that the judgment depends on the proportion of the false propositions believed by Bill with respect to the set of all propositions in the question meaning. For example, even if (13b) sounds false in the given situation to these speakers, they feel that the falsity is not clear in a situation where Bill knows a hundred stores that sell Italian newspapers and incorrectly believes for just one store that it does. Note, however, that this judgment is not a problem for the argument here as long as there is a situation in which these speakers too find a contrast in (13).

[9]George's (2011) example above is based on examples that intuitively have a MENTION-SOME interpretation of the complement. Spector (2005), on the other hand, reports a non-reductive judgment of question-embedding *know* embedding a complement with a weakly-exhaustive interpretation (see also Berman 1991, §4.3.2, Groenendijk and Stokhof 1984, 180 for similar observations). See (7) for the distinction between the two interpretations.

(18) a. Alice agrees with Sue that one can buy an Italian newspaper at Newstopia.
      b. Bill agrees with Sue that one can buy an Italian newspaper at Newstopia.

(19) a. Alice agrees with Sue that one can buy an Italian newspaper at PaperWorld.
      b. Bill agrees with Sue that one can buy an Italian newspaper at PaperWorld.

What the above example involving *agree* shows is that the empirical range of predicates that exhibit the non-reductive interpretation of question-embedding is broader than just factive predicates, and includes non-factive presuppositional predicates like *agree (with)*. The general diagnosis of the examples would then be the following: sentences involving certain[10] presuppositional responsive predicates with an embedded question are not true if the subject believes a possible answer to the embedded question that does *not* satisfy the presupposition. The existence of such systematic counterexamples is a problem for the Q-to-P reduction approach to responsive predicates.

There have been attempts to analyze the kind of non-reductive examples discussed in this section *within* the Q-to-P reduction approach employing the mechanism of exhaustification (Cremers 2016, cf. Uegaki 2015), drawing on the analysis of 'intermediate exhaustivity' by Klinedinst and Rothschild (2011), or decomposition of a lexical meaning into the assertive and presuppositional component (Spector and Egré, 2015). Due to space limitations, we are unable to detail such analyses here. Interested readers are referred to the cited works.

3.2   Predicates of relevance

The second problem for the Q-to-P reduction concerns the behavior of PREDICATES OF RELEVANCE (PoRs) (Elliott et al., 2017). PoRs are responsive predicates in that they are compatible with both declarative and interrogative complements, as shown in (20).

(20) a. Alice cares which students left.
      b. Alice cares that Mary left.

What is crucial is the presuppositions of these examples. The declarative embedding use in (20b) presupposes that Alice believes that Mary left. In contrast, (20a) does *not* presuppose that there is a student such that Alice believes that they left. It can be true as long as Alice has interest in knowing which students left, even if there is no student such that Alice knows that they left.

Note that this is a counterexample to the Entailment Prediction of the Q-to-P reduction in (11b) above. The observation about (20) suggests that ⌜x cares Q⌝ does *not* entail that there is a proposition $p \in Q$ such that ⌜x cares that p⌝. This is so since ⌜x cares that p⌝ presupposes that x believes that p, but ⌜x cares Q⌝ can be true even if there is no proposition $p' \in Q$ such that x believes p'. Thus, the observed difference between (20a) and (20b) is difficult to capture under the Q-to-P reduction approach. Under the approach, given the Entailment Prediction, (20a) is incorrectly predicted to entail that there is a student such that Alice believes that they left.

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[10]I do not generalize this diagnosis to all presuppositional responsive predicates since it is not clear if emotive factives such as *surprise* and *annoy* exhibit non-reducibility.

4 Alternative approaches to responsive predicates

In the last section, we saw two empirical phenomena that are problematic for the Q-to-P reduction approach to responsive predicates: (i) non-reductive interpretations of certain presuppositional responsive predicates and (ii) presuppositions of PoRs.

In this section, I will introduce three alternative approaches to the semantics of responsive predicates, i.e., the PROPOSITION-TO-QUESTION REDUCTION (P-TO-Q REDUCTION) approach, the UNIFORM approach, and the AMBIGUITY approach. After outlining characteristics of these approaches together with short reviews of an existing analysis, I will compare them by considering how they would deal with the two phenomena examined in the previous section.

4.1 Proposition-to-Question reduction

As the name suggests, the P-to-Q reduction can be conceived of as the mirror image of the Q-to-P reduction. Both approaches posit reduction mechanisms to deal with the complementation pattern of responsive predicates, but in different directions. Unlike the Q-to-P reduction, the P-to-Q reduction assumes that the basic denotation of a responsive predicate is *question*-taking and posits an operation that turns a proposition denoted by a declarative complement into a question. This way, the interrogative-embedding use of responsive predicates is straightforwardly analyzed with their denotation while their declarative-embedding use is analyzed as involving the P-to-Q reduction mechanism. Also, note that the approach adheres to the two basic hypotheses discussed in the beginning of the paper: semantic distinction of clause types and the non-ambiguity of responsive predicates.

Uegaki (2015, 2016) proposes an instance of this approach. According to the analysis, responsive predicates like *know* take a question qua a proposition-set as its first argument:

(21) $[\![\text{know}]\!]^w = \lambda Q_{\langle st,t\rangle}: \underline{\exists p \in Q[p(w)]}.\lambda x. \mathbf{know}_w(x, \mathbf{Ans}_w(Q))$

Such a denotation can be directly combined with a question meaning, as follows:

(22) $[\![\text{Alice knows who left}]\!]^w = [\![\text{know}]\!]^w([\![\text{who left}]\!])(\mathbf{a})$
$= 1 \text{ iff } \underline{\exists x[\mathbf{left}_w(x)]} \wedge \mathbf{know}_w(\mathbf{a}, \mathbf{Ans}_w([\![\text{who left}]\!]))$

As the reader can verify, the truth conditions in (22) are exactly the same as what is predicted in the Q-to-P reduction in (9b) above.

Declarative-embedding sentences involve a reduction from propositions to questions. The is carried out by the **Ident** type-shifter proposed in the domain of NP-interpretation by Partee (1986):

(23) **Ident** $= \lambda p_{\langle s,t\rangle}.\{p\}$ (after Partee 1986)

With this type-shifter, the propositional denotation of a declarative complement can be turned into a question-type object, which in turn serves as an argument of the predicate *know* in (21). As a result, we can derive the intuitive interpretation of *know-that* sentences. This is illustrated in the derivation of the truth conditions of the following sentence:

(24) $\llbracket$Alice knows [that Mary left]$\rrbracket^w = \llbracket$know$\rrbracket^w(\mathbf{Ident}(\lambda w'.\mathbf{left}_{w'}(\mathbf{m})))(\mathbf{a})$
$= 1$ iff $\underline{\mathbf{left}_w(\mathbf{m})} \wedge \mathbf{know}_w(\mathbf{a}, \mathbf{Ans}_w(\{\lambda w'.\mathbf{left}_{w'}(\mathbf{m})\}))$
$= 1$ iff $\overline{\underline{\mathbf{left}_w(\mathbf{m})}} \wedge \mathbf{know}_w(\mathbf{a}, \lambda w'.\mathbf{left}_{w'}(\mathbf{m})))$

Here, the presupposition triggered by *know* in (21) that the question contains a true answer boils down to factivity, capturing the factive presupposition of *know-that*. The last step of (24) is guaranteed by the fact that, if $\mathbf{left}_w(\mathbf{m})$ is true, $\mathbf{Ans}_w(\{\lambda w'.\mathbf{left}_{w'}(\mathbf{m})\})$ is defined and is equivalent to the proposition $\lambda w'.\mathbf{left}_{w'}(\mathbf{m})$.

4.2 Uniformity

In contrast to the two reduction approaches, which assume the semantic distinction of clause types, the uniform approach argues that declarative and interrogative complements have the *same* semantic type. Under this approach, then, the selectional restriction of responsive predicates does not pose a problem. Rather, it is something that is *expected* from the semantic uniformity of declarative and interrogative complements, without the involvement of any extra reduction mechanism.

Inquisitive Semantics (Ciardelli et al., 2013) offers a concrete analysis of responsive predicates in the uniform approach (Theiler, 2014; Ciardelli and Roelofsen, 2015; Theiler et al., 2018).[11] According to inquisitive semantics, both declarative and interrogative clauses denote a set of propositions. Here, I will illustrate the treatment in a version of inquisitive semantics without the property of downward closure (referred to as possibility semantics by Ciardelli et al. 2017) in order to make the comparison with other approaches transparent.[12]

In this semantics, both declarative and interrogative complements express sets of propositions, as follows (see Ciardelli et al. 2017 for compositional derivations):

(25) a. $\llbracket$that Mary left$\rrbracket = \{\,\lambda w'.\mathbf{left}_{w'}(\mathbf{m})\,\}$
  b. $\llbracket$who left$\rrbracket = \{\,p \mid \exists x[p = \lambda w'.\mathbf{left}_{w'}(x)]\,\}$

Given this uniform semantics for complements, the complementation pattern of responsive predicates can be analyzed with the denotation for *know* we introduced in the discussion of P-to-Q reduction analysis above. I repeat the denotation for *know* below:

(26) $\llbracket$know$\rrbracket^w = \lambda Q_{\langle st,t\rangle}: \underline{\exists p \in Q[p(w)]}.\lambda x.\,\mathbf{know}_w(x, \mathbf{Ans}_w(Q))$ (= (21))

By simply applying this predicate denotation to the complements in (25), the truth conditions of *know-wh* and *know-that* sentences are derived in almost exactly the same way as in the P-to-Q reduction approach. The difference between the uniform and P-to-Q reduction approach lies in whether the analysis assumes the set of propositions to be the

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[11]Groenendijk and Stokhof (1984) can be considered as a predecessor of the uniform approach since, for them, both declarative and interrogative complements express propositional concepts, which are selected by responsive predicates such as *guess*. Their treatment of veridical predicates such as *know*, however, involves Q-to-P reduction in the form of 'extensionalization', and thus is unable to deal with the problem of non-reducibility.

[12]See Ciardelli et al. (2017) for a comparison of the semantics with and without the downward closure, and theoretical and empirical motivations for preferring the former.

basic semantic type of a declarative complement. In the P-to-Q reduction, a declarative complement denotes a proposition *simpliciter*. Thus, an extra reduction mechanism is needed to convert the proposition into a set of propositions. On the other hand, in the uniformity analysis, declarative complements denote a set of propositions, just like interrogative complements do. Therefore, there is no need for an extra reduction operation. Because of this difference, the P-to-Q reduction and uniform approach offer distinct analytical possibilities for treating predicates that only embed declarative complements (e.g., *believe*). The interested reader is referred to Uegaki (2016) and Theiler et al. (2018).

4.3 Ambiguity

Instead of rejecting the semantic distinction of declarative and interrogative clause types, the ambiguity approach rejects the assumption that responsive predicates are non-ambiguous. Thus, the ambiguity approach posits distinct denotations for the proposition-taking and question-taking denotations of responsive predicates.

A potential problem with the ambiguity approach in general is the intuitive connection between the declarative-embedding and interrogative-embedding use of responsive predicates. As pointed out in the beginning of this survey, this intuition is also empirically motivated by data involving coordinations (see (3)).

George (2011) addresses this problem by proposing the TWIN RELATIONS THEORY of responsive predicates. According to this theory, every responsive predicate V is associated in the lexicon with two meaning components V_1 and V_2. Given these two meaning components, there are general schemata that specify the question-taking denotation V_Q and the proposition-taking denotation V_P. Thus, the analysis captures the intuitive semantic connection between the question-taking and proposition-taking denotation in terms of their relations to the same semantic core, the two relations V_1 and V_2.

For example, *know* is associated with the two meaning components as shown below.

(27) a. $\mathbf{know}_1 := \lambda p_{\langle s,t\rangle}\lambda x\lambda w: \underline{p(w)}.\ \mathbf{know}_w(x,p)$

   b. $\mathbf{know}_2 := \lambda p_{\langle s,t\rangle}\lambda x\lambda w.\ \mathbf{believe}_w(x,p) \to p(w)$

These meaning components are used to derive the predicate's question-taking and proposition-taking denotations according to the following general schemata (adapted from George 2011 to make the comparison with other approaches transparent).

(28) a. $V_Q := \lambda Q_{\langle st,t\rangle}\lambda x_e\lambda w.\left(\begin{array}{c} V_1(\mathbf{Ans}_w(Q))(x)(w)\wedge \\ \forall p' \in Q[V_2(p')(x)(w)] \end{array} \right)$

   b. $V_P := \lambda p_{\langle s,t\rangle}\lambda x\lambda w.V_1(p)(x)(w) \wedge V_2(p)(x)(w)$

Instantiating the schemata with $\mathbf{know}_1$ and $\mathbf{know}_2$, we get the following denotations of *know*, one question-taking and the other proposition-taking.[13]

(29) a. $\mathbf{know}_Q = \lambda Q_{\langle st,t\rangle}\lambda x\lambda w : \underline{\exists p \in Q[p(w)]}.\left(\begin{array}{c} \mathbf{know}_w(x,\mathbf{Ans}_w(Q))\wedge \\ \forall p' \in Q[\mathbf{believe}_w(x,p') \to p'(w)] \end{array} \right)$

   b. $\mathbf{know}_P = \lambda p_{\langle s,t\rangle}\lambda x\lambda w: \underline{p(w)}.\ \mathbf{know}_w(x,p)$

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[13]I assume that the factive presupposition of $\mathbf{know}_1$ is existentially projected in $\mathbf{know}_Q$.

A substantial feature of the analysis is that the denotation already incorporates a solution to the problem of non-reducibility of *know* discussed in §3.1. The denotation in (29a) predicts that ⌜*Bill knows Q*⌝ would be true only if all propositions in *Q* that Bill believes are true. This is obviously not the case in George's scenario in (12). Thus, the analysis correctly captures the fact that *know* is sensitive to the subject's false beliefs. In fact, George's (2011) ambiguity theory is devised as a direct reaction to the non-reducibility of the question-embedding denotation of some responsive predicates.

5 Comparing the non-traditional approaches

How do the three non-traditional approaches fare with the two problems for the Q-to-P reduction approach? In this section, I go through the two problematic phenomena and examine if the three approaches have resources to account for them.

5.1 Non-reducibility of presuppositional predicates

5.1.1 P-to-Q reduction and uniformity

Both the P-to-Q reduction and uniform approach can straightforwardly capture the Q-to-P non-reducibility of presuppositional responsive predicates: the denotation of the predicates can simply include the condition that the subject cannot believe any proposition that fails the presupposition of the predicate. For example, *know* and *agree with* in such accounts would look like the following:

(30)　a.　$[\![\mathbf{know}]\!]^w = \lambda Q_{\langle st,t\rangle}: \underline{\exists p \in Q[p(w)]}.\lambda x.\left(\begin{array}{c} \mathbf{know}_w(x, \mathbf{Ans}_w(Q)) \wedge \\ \forall p' \in Q[\mathbf{believe}_w(x,p') \to p'(w)] \end{array} \right)$

　　　b.　$[\![\mathbf{agree\ with}]\!]^w = \lambda y \lambda Q_{\langle st,t\rangle}: \underline{\exists p \in Q[\mathbf{believe}_w(y,p)]}.\lambda x.$
$$\left(\begin{array}{c} \mathbf{know}_w(x, \lambda w'.\ \forall p' \in Q[\mathbf{believe}_w(y,p') \to p'(w')]) \wedge \\ \forall p'' \in Q[\mathbf{believe}_w(x,p'') \to \mathbf{believe}_w(y,p'')] \end{array} \right)$$

The second line of the body of the denotation in (30a) states that all propositions in the question meaning that the subject believes are true. In (30b), the condition is modified so that all propositions in the question meaning that the subject believes are also believed by the comitative ('with') argument.[14] These conditions adequately capture the relevant conditions that are Q-to-P non-reducible.

Also, note that there is no distinction between the P-to-Q reduction and uniform approach with regard to the solution to this problem. This is so since the only difference between the two approaches concerns the treatment of declarative complements, and what the solution above hinges on is the question-taking semantics for responsive predicates, which is constant across the P-to-Q reduction and uniform approach.

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[14]In footnote 8, I discussed native speaker judgments that are sensitive to the *proportion* of false propositions (or propositions that are not believed by the 'with'-argument) in the set of relevant propositions believed by the subject. The condition in the second line of the denotations in (30) can be minimally modified to capture such sensitivity to the proportion of false propositions.

5.1.2 Ambiguity

George's (2011) ambiguity approach was proposed as a response to the observation of the Q-to-P non-reducibility of factive predicates, and we have already seen in §4.3 how the analysis would account for the Q-to-P non-reducibility of *know*. Here, I will simply show that the analysis can be extended to *agree* by defining appropriate meaning components **agree-with**$_1$ and **agree-with**$_2$ as follows:

(31) a. **agree-with**$_1$:= $\lambda y\lambda p_{\langle s,t\rangle}\lambda x\lambda w$: $\underline{\textbf{believe}_w(y,p)}$. $\textbf{believe}_w(y,p) \wedge \textbf{believe}_w(x,p)$

  b. **agree-with**$_2$:= $\lambda y\lambda p_{\langle s,t\rangle}\lambda x\lambda w$. $\textbf{believe}_w(x,p) \rightarrow \textbf{believe}_w(y,p)$

The condition requiring that the subject believes no proposition that fails the presupposition of (the declarative-embedding version of) the predicate is contributed by **agree-with**$_2$. In sum, just like the the P-to-Q reduction and uniform approach, George's (2011) ambiguity approach has resources to capture the Q-to-P non-reducibility of *know* and *agree*.

5.2 Predicates of Relevance

Next, we turn to how the three approaches deal with PoRs like *care*, *be relevant* and *matter*. The relevant examples with *care* are repeated below from §3.2.

(20) a. Alice cares which students left.

  b. Alice cares that Mary left.

Recall that the problem lies in the presupposition of (20a): it presupposes that Alice believes that some student left, but not that there is a student such that she believes they left. This cannot be accurately described in a Q-to-P reduction approach. Given the Entailment Prediction in (11b) and the fact that (20b) presupposes that Alice believes that Mary left, the Q-to-P reduction predicts (20a) to entail that there is a student such that Alice believes that they left.

5.2.1 P-to-Q reduction and uniformity

The P-to-Q reduction and uniform approach can accurately account for the presupposition of (20a) by making the denotation of *care* refer to its question argument itself. For example, the denotation of *care* can be analyzed as follows:

(32) $[\![\text{care}]\!]^w = \lambda Q_{\langle st,t\rangle}$: $\underline{\exists p \in Q[p(w')]}$. $\lambda x : \underline{\textbf{believe}_w(x, \lambda w'. \exists p' \in Q[p'(w')])}$. $\textbf{care}_w(x,Q)$

The presupposition with the second underline states that x believes that some answer of the embedded question is true. This captures the presuppositions of (20a): it only presupposes that Alice believes that some student left, not that there is a student such that Alice believes that they left.

  The denotation for *care* in (32) correctly captures the presuppositions of the declarative-embedding sentence in (20b) as well, given that the P-to-Q reduction and uniform approach assign a singleton-set meaning to declarative complements, either through a reduction operation or as the basic meaning of the complement itself.

(33) $[\![(20\text{b})]\!]^w = 1$ iff $\underline{\textbf{left}_w(\textbf{m})} \wedge \textbf{believe}_w(\textbf{a}, \lambda w'.\textbf{left}_{w'}(\textbf{m})) \wedge \textbf{care}_w(\textbf{a}, \{\lambda w'.\textbf{left}_{w'}(\textbf{m})\})$

Since a belief that some proposition in a singleton set question is true is equivalent to the belief that the unique proposition in the singleton set is true, the second presupposition of *care* in (32) boils down to the presupposition that the subject believes the complement.

5.2.2 Ambiguity

How would the ambiguity approach deal with PoRs? Interestingly, there is no obvious way in which the approach can capture the problematic presuppositions of PoRs.

To see how George (2011) would deal with PoRs, let us start with the predicted denotations of the question-taking **care**$_Q$ and the proposition-taking **care**$_P$ according to the proposed schema:

(34)   a. $\mathbf{care}_Q = \lambda Q_{\langle st,t\rangle}\lambda x_e \lambda w. \left(\begin{array}{l} \mathbf{care}_1(\mathbf{Ans}_w(Q))(x)(w)\wedge \\ \forall p' \in Q[\mathbf{care}_2(p')(x)(w)] \end{array} \right)$

       b. $\mathbf{care}_P = \lambda p_{\langle s,t\rangle}\lambda x\lambda w.\mathbf{care}_1(p)(x)(w) \wedge \mathbf{care}_2(p)(x)(w)$

The content of these meanings are still unclear unless **care**$_1$ and **care**$_2$ are substantiated. However, we already know that the belief presupposition of *care-that*—that the subject believes the complement—has to be encoded in **care**$_1$ or **care**$_2$ in (34b). But then, in either case, **care**$_Q$(Q)(x)(w) is predicted to entail that, for some proposition $p \in Q$, x believes p. Here is why: if **care**$_1$ triggers the belief presupposition, given the first line of (34a), **care**$_Q$(Q)(x)(w) would be true only if there is some proposition in Q that is believed by x in w; On the other hand, if **care**$_2$ triggers the belief presupposition, given the second line of (34a), **care**$_Q$(Q)(x)(w) would be true only if all propositions in Q are believed by x in w. Thus, whether the belief presupposition is encoded in **care**$_1$ or in **care**$_2$, **care**$_Q$(Q)(x)(w) would entail that there is a proposition in Q that is believed by x in w. What we see here is that the predicted belief presupposition of the question-embedding *care* in George's (2011) theory is too strong, just as in the case of Q-to-P reduction approach.

6   Constraints on the denotations of responsive predicates

In addition to the empirical considerations made in the previous sections, we can compare the approaches based on the *restrictiveness* of theories, i.e., whether each approach places a reasonable constraint on the space of possible denotations of responsive predicates. Spector and Egré (2015) discuss this point, using the fictitious responsive predicate *shknow, which means 'know' with declarative complements and 'wonder' with interrogative complements. They argue that a semantic theory of responsive predicates should be able to explain why it is hard to imagine a language having *shknow in its lexicon.

Under the Q-to-P reduction, *shknow* is impossible because ⌜x *shknows* Q⌝ would be analyzed as ⟦shknow⟧^{w}($\mathbf{Ans}_w(Q)$)(x) in the Q-to-P reduction, which in turn would mean 'x knows $\mathbf{Ans}_w(Q)$' instead of 'x wonders Q'. George's (2011) twin relations theory also makes it impossible to define *shknow*. On the other hand, it is *possible* to define *shknow* under the P-to-Q reduction or the uniform approach, as follows:

(35)   ⟦*shknow⟧$^w = \lambda Q_{\langle st,t\rangle}\lambda x. \left(\begin{array}{l} |Q| = 1 \rightarrow \exists p \in Q[\mathbf{know}_w(x,p)]\wedge \\ |Q| \neq 1 \rightarrow \mathbf{wonder}_w(x,Q) \end{array} \right)$

What this means is that the Q-to-P reduction/uniform approaches *by themselves* are not restricted enough to rule out the unrealistic predicate *shknow* (George, 2011, §4.5.2).

This said, it is possible to posit additional constraints on responsive predicate denotations in the Q-to-P reduction/uniform approaches. As a concrete example, I will propose an original constraint that hasn't been discussed in the previous literature. This constraint requires responsive predicate denotations to obey a weaker version of the Entailment Prediction, which I will call the STRAWSON-ENTAILMENT PROPERTY, as defined below:[15]

(36) A responsive predicate V has the STRAWSON-ENTAILMENT PROPERTY iff for every entity-denoting term x and every interrogative complement Q, $\ulcorner x\ Vs\ Q \urcorner$ entails that there is a proposition $p \in Q$ such that, **if the presupposition of $\ulcorner x\ Vs\ p \urcorner$ is satisfied**, $\ulcorner x\ Vs\ p \urcorner$ is true.

(37) **A constraint on responsive predicate denotations**:
All responsive predicates have the Strawson-entailment property.

This constraint essentially states that a responsive predicate has to obey the Entailment Prediction in the assertive component of its meaning. The predicate *shknow in (35) violates this constraint since $\ulcorner x\ shknows\ Q \urcorner$ (which means 'x wonders Q') does *not* entail that there is $p \in Q$ such that, if $\ulcorner x\ shknows\ p \urcorner$ (which means 'x knows p') is defined, it is true. On the other hand, *care* under the analysis in (32) can be made to obey this constraint by requiring that for every x, Q, w, $\mathbf{care}_w(x, Q) \rightarrow \exists p \in Q[\mathbf{care}_w(x, \{p\})]$,[16] without making it conform to the Entailment Prediction.

Theiler et al. (2018, §6) propose further constraints on the denotations of responsive predicates within the uniform approach. To the extent that it *is* possible to posit feasible constraints on the denotation of responsive predicates in the P-to-Q reduction/uniform approaches, the unrestricted nature of the approaches themselves does not provide a strong argument against them.

It is worth noting that the issue here is reminiscent of the constraints on generalized quantifier denotations (Barwise and Cooper, 1981; Keenan and Stavi, 1986). Natural languages lexicalize only a small subset of meanings that can in principle be expressed as a generalized quantifier. The generalized quantifier theory has sought to formulate empirically feasible constraints on quantifier denotations (e.g., conservativity). At the same time, researchers have investigated the question of *why* such constraints exist from computational and learnability standpoints (e.g., Hunter and Lidz, 2013; Steinert-Threlkeld and Szymanik, to appear). Following the lead of research in this domain, an imminent task for the theory of responsive predicates is to discover feasible constraints on the denotation of responsive predicates, and seek explanations for the existence of such constraints.

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[15]The choice of the term is based on von Fintel's (1999)'s notion of STRAWSON ENTAILMENT.

[16]Proof: Given the analysis in (32), for every x, Q, w, $[\![\text{cares}]\!]^w(Q)(x)$ is true only if $\mathbf{care}_w(x, Q)$. Given the above requirement on **care**, this in turn is true only if there is a proposition $p \in Q$ such that $\mathbf{care}_w(x, \{p\})$. Given (32), such a proposition p is such that, if $[\![\text{care}]\!]^w(\{p\})(x)$ is defined, $[\![\text{care}]\!]^w(\{p\})(x)$ is true. This means that if $\ulcorner x\ cares\ that\ p \urcorner$ is defined, it is true.

	Q-to-P reducibility	Entailment Prediction
Q-to-P reduction	Yes/No[a]	Yes
P-to-Q reduction	No	No
Uniformity	No	No
Ambiguity (esp. George 2011)	No	Yes

[a] No, if the non-presuppositional counterpart of a presuppositional predicate can be retrieved through, e.g., decomposition (Spector and Egré 2015; see the last paragraph of §3.1)

Table 1: Comparison of the four approaches

7 Conclusions

In this survey, we reviewed the traditional Q-to-P reduction approach to the semantics of responsive predicates, as well as three non-traditional approaches. The latter three approaches, i.e., the P-to-Q reduction approach, the uniform approach and the ambiguity approach, were compared in view of how they would treat two phenomena that pose problems for the Q-to-P reduction approach. The non-reducibility of presuppositional predicates can be accounted for in all three approaches by encoding the appropriate conditions in the lexical denotations (or meaning cores) of relevant predicates. On the other hand, when it comes to the other problem with the traditional approach, i.e., Predicates of Relevance, only the P-to-Q reduction and uniform approach, but not the ambiguity approach, have necessary resources to account for their behavior. In Table 1, the comparison is summarized in terms of whether a theory shares the two problematic predictions, i.e., Q-to-P reducibility and the Entailment Prediction, with the Q-to-P reduction approach.

Although the current survey is mostly concerned with the behavior of English responsive predicates, it is evident that in-depth cross-linguistic investigation of the lexical semantics of responsive predicates sheds additional light on the debate. For example, Roberts (2017) claims that the Estonian verb *mõtlema*—whose meaning is close to 'wonder' with an interrogative complement while it is close to 'think' with a declarative complement—can be adequately analyzed only under the P-to-Q reduction/uniform approaches to responsive predicates. At the same time, as discussed in §6, whichever approaches that turn out to be cross-linguistically empirically adequate should be evaluated in view of their predictive powers, in particular, how they can explain cross-linguistically stable generalizations about the interpretations of responsive predicates.

Finally, theories of responsive predicates can also be assessed in view of their predictions concerning the selectional restrictions of other clause-embedding predicates, such as those that only embed interrogative complements (e.g., *wonder*, *inquire*) and those that only embed declarative complements (e.g., *believe*, *hope*). The selectional restrictions of these predicates is an active domain of research in the current literature. In particular, Uegaki (2015, 2016) and Ciardelli and Roelofsen (2015) explain why *wonder* cannot embed declarative complements, based on the following line of analysis of ⌜x wonders Q⌝:

(38) $[\![\text{wonder}]\!]^w(Q)(x) = 1$ only if

    (i)   there is some $p \in Q$ such that x neither believes p nor believes $\neg p$

(ii) x believes that there is some $p' \in Q$ that is true.

This semantics predicts that $\ulcorner x$ wonders that $p \urcorner$ results in a systematic contradiction under the P-to-Q reduction/uniform approach since the two conditions in (38) contradict each other if $Q = \{p\}$.

Theiler et al. (2018) furthermore deal with the selectional restrictions of verbs of dependency (e.g., *depend on*). Theiler et al. (2017) and Mayr (2017) explain the selectional restrictions of neg-raising attitude predicates (e.g., *believe*) and truth-evaluating predicates (e.g., *be true*), drawing on an earlier observation by Zuber (1982). Among non-neg-raising predicates, Uegaki and Sudo (2017, 2018) propose an explanation for the selectional restrictions of non-veridical preferential predicates (e.g., *hope*, *fear*) under the uniform approach.

References

Barwise, Jon and Robin Cooper. 1981. Generalized quantifiers and natural language. *Linguistics and Philosophy* 4(2):159–219.

Beck, Sigrid and Hotze Rullmann. 1999. A flexible approach to exhaustivity in questions. *Natural Language Semantics* 7:249–298.

Berman, Stephen R. 1991. *On the Semantics and Logical Form of wh-clauses*. Ph.D. thesis, University of Massachusetts at Amherst.

Ciardelli, Ivano, Jeroen Groenendijk, and Floris Roelofsen. 2013. Inquisitive semantics: a new notion of meaning. *Language and Linguistics Compass* 7(9):459–476.

Ciardelli, Ivano and Floris Roelofsen. 2015. Inquisitive dynamic epistemic logic. *Synthese* 192(6):1643–1687.

Ciardelli, Ivano, Floris Roelofsen, and Nadine Theiler. 2017. Composing alternatives. *Linguistics and Philosophy* 40(1):1–36.

Cremers, Alexandre. 2016. *On the semantics of embedded questions*. Ph.D. thesis, École normale supérieure.

Dayal, Veneeta. 1996. *Locality in wh-quantification: Questions and Relative Clauses in Hindi*. Dordrecht: Kluwer Academic Publishers.

Elliott, Patrick D., Nathan Klinedinst, Yasutada Sudo, and Wataru Uegaki. 2017. Predicates of relevance and theories of question embedding. *Journal of Semantics* 34(3):547–554.

von Fintel, Kai. 1999. NPI licensing, Strawson entailment, and context dependency. *Journal of Semantics* 16(2):97–148.

George, B.R. 2011. *Question Embedding and the Semantics of Answers*. Ph.D. thesis, UCLA.

Ginzburg, Jonathan. 1995. Resolving questions. *Linguistics and Philosophy* 18(5):459–527 (Part I) and 567–609 (Part II).

Groenendijk, Jeroen and Martin Stokhof. 1984. *Studies on the Semantics of Questions and the Pragmatics of Answers*. Ph.D. thesis, University of Amsterdam.

Guerzoni, Elena and Yael Sharvit. 2007. A question of strength: on NPIs in interrogative clauses. *Linguistics and Philosophy* 30:361–391.

Hagstrom, Paul. 2003. What questions mean. *Glot International* 7(7):188–201.

Hamblin, Charles L. 1973. Questions in Montague English. *Foundations of Language* 10(1):41–53.

Heim, Irene. 1994. Interrogative semantics and Karttunen's semantics for *know*. In *Proceedings of IATL 1*, 128–144.

Heim, Irene and Angelika Kratzer. 1998. *Semantics in Generative Grammar*. Oxford: Blackwell.

Hintikka, Jaakko. 1962. *Knowledge and Belief*. Cornell University Press.

Hunter, Tim and Jeffrey Lidz. 2013. Conservativity and learnability of determiners. *Journal of Semantics* 30(3):315–334.

Karttunen, Lauri. 1977. Syntax and semantics of questions. *Linguistics and Philosophy* 1(1):3–44.

Keenan, Edward L and Jonathan Stavi. 1986. A semantic characterization of natural language determiners. *Linguistics and Philosophy* 9(3):253–326.

Klinedinst, Nathan and Daniel Rothschild. 2011. Exhaustivity in questions with non-factives. *Semantics and Pragmatics* 4(2):1–23.

Lahiri, Utpal. 2002. *Questions and Answers in Embedded Contexts*. Oxford: Oxford University Press.

Mayr, Clemens. 2017. Predicting polar question embedding. In R. Truswell, ed., *Proceedings of Sinn und Bedeutung 21*. Edinburgh: University of Edinburgh.

Partee, Barbara H. 1986. Noun phrase interpretation and type-shifting principles. In J. Groenendijk, D. de Jongh, and M. Stokhof, eds., *Studies in Discourse Representation Theory and the Theory of Generalized Quantifiers*, 115–143. Dordrecht: Foris Publications.

Preuss, Susanne Marie-Luise. 2001. *Issues in the semantics of questions with quantifiers*. Ph.D. thesis, Rutgers University.

Roberts, Tom. 2017. The selectional restrictions of responsive predicates in Estonian. Paper presented at Sinn und Bedeutung 22.

Sennet, Adam. 2016. Polysemy. In *Oxford Handbooks online*.

Spector, Benjamin. 2005. Exhaustive interpretations: what to say and what not to say. Unpublished paper, presented at the LSA workshop on Context and Content, Cambridge, July 15, 2005.

Spector, Benjamin and Paul Egré. 2015. A uniform semantics for embedded interrogatives: an answer, not necessarily the answer. *Synthese* 192(6):1729–1784.

Steinert-Threlkeld, Shane and Jakub Szymanik. to appear. Learnability and semantic universals. *Semantics and Pragmatics* .

Theiler, Nadine. 2014. *A Multitude of Answers: Embedded Questions in Typed Inquisitive Semantics*. MSc thesis, ILLC, University of Amsterdam.

Theiler, Nadine, Floris Roelofsen, and Maria Aloni. 2017. What's wrong with believing whether? In *Semantics and Linguistic Theory (SALT) 27*.

Theiler, Nadine, Floris Roelofsen, and Maria Aloni. 2018. A uniform semantics for declarative and interrogative complements. *Journal of Semantics* .

Uegaki, Wataru. 2015. *Interpreting Questions under Attitudes*. Ph.D. thesis, Massachusetts Institute of Technology.

Uegaki, Wataru. 2016. Content nouns and the semantics of question-embedding. *Journal of Semantics* 33(4):623–660.

Uegaki, Wataru and Yasutada Sudo. 2017. The anti-rogativity of non-veridical preferential predicates. Amsterdam Colloquium 2017.

Uegaki, Wataru and Yasutada Sudo. 2018. The **hope-wh* puzzle. Ms., Leiden University and University College London.

Xiang, Yimei. 2016. *Interpreting questions with non-exhaustive answers*. Ph.D. thesis, Harvard University.

Zuber, Richard. 1982. Semantic restrictions on certain complementizers. In *Proceedings of the 12th International Congress of Linguists, Tokyo*, 434–436.