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Ciardelli, I.; Roelofsen, F.

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An Inquisitive Perspective on Modals and Quantifiers

Ivano Ciardelli and Floris Roelofsen

Institute for Logic, Language and Computation, University of Amsterdam, 1098 XG Amsterdam, The Netherlands; email: i.a.ciardelli@uva.nl, f.roelofsen@uva.nl

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Abstract

Inquisitive semantics enriches the standard truth-conditional notion of meaning, in order to facilitate an integrated semantic analysis of statements and questions. Taking this richer view on meaning as a starting point, this review presents a new perspective on modal operators and quantifiers, one that has the potential to address a number of challenges for standard semantic analyses of such operators. To illustrate the new perspective, we present an inquisitive take on the semantics of attitude verbs and on quantifiers taking scope out of questions.

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1. INTRODUCTION

1.1. Statements and Questions

The meaning of a sentence is traditionally taken to lie in its truth conditions: One knows the meaning of a sentence if one knows under which circumstances it is true. This notion of meaning has been very fruitful, but it also has a fundamental limitation: Although suitable for statements, it does not apply to sentence types that are not naturally thought of as being true or false in a given state of affairs. Prominent among such sentence types are questions.

Just like statements, questions play a central role in communication. They allow speakers to specify requests for information, which other participants are then expected to address. Thus, questions give structure to the process of information exchange, allowing speakers to steer it toward certain goals. Furthermore, statements and questions are so intimately connected that it is impossible to fully understand either of them in isolation from the other. One simple reason is that questions can occur embedded in statements and vice versa:

(1a) Bill wonders *who called him today*.

(1b) Who thinks *that the director should resign*?

Second, the interpretation of a statement often depends on the question that it addresses:

(2a) A: What did you do this morning?
B: I only read the newspaper. $\rightsquigarrow$ I didn't do the laundry

(2b) A: What did you read this morning?
B: I only read the newspaper. $\not\rightsquigarrow$ I didn't do the laundry

And third, questions and statements are to a large extent built up from the same parts. For instance, the disjunctive connective *or* is used to form both questions and statements:

(3a) Is he in London or in Paris?

(3b) He is in London or in Paris.

This means that one cannot fully identify the meaning contribution of disjunction (and other operators) by considering only its role in statements, that is, its effect on truth conditions. Its role in questions needs to be factored in as well.

These observations show that statements and questions do not constitute two separate domains that can be studied in isolation; rather, they should be analyzed in an integrated way. This requires a notion of sentence meaning that comprises not only informative content (i.e., truth conditions) but also inquisitive content (i.e., the potential to raise issues); for further elaboration of the arguments presented here, see Ciardelli et al. (2015).

1.2. Inquisitive Semantics: From Truth to Support

Recent research addressing this need has led to the development of a new semantic framework called inquisitive semantics. Rather than identifying the meaning of a sentence with the conditions under which it is true in a given state of affairs, inquisitive semantics identifies the meaning of a sentence with the conditions under which it is supported by a given information state, which requires that the information available in the state not only entail the information conveyed by the sentence but also resolve the issue that it raises. For instance, the statement *Bill sang* is supported by an information state s in case it follows from the information available in s that Bill sang. By contrast, the question *Did Bill sing?* is supported in s in case it either follows from the information

available in s that Bill sang or follows from the information available in s that Bill did not sing. Thus, it becomes possible to analyze both statements and questions using a single notion of meaning.

Because this simple switch in perspective takes place at such a basic level, it opens up new horizons for all disciplines that traditionally rely on the truth-conditional notion of meaning. But this potential, to a great extent, has yet to be deployed—inquisitive aspects of meaning are not nearly as well understood yet as truth-conditional aspects. Which linguistic constructions give rise to inquisitiveness? How do various operators propagate the inquisitive content of their argument? Which operators exploit the inquisitive content of their argument to produce a truth-conditional effect? Inquisitive semantics paves the way for systematic empirical and theoretical investigations to address these questions.

1.3. Beyond Connectives to Modality and Quantification

The meaning of a sentence is determined not only by its content words but also, to an important extent, by its function words, which form complex meanings out of simpler ones. These function words include connectives (e.g., *and*, *or*, *not*), quantifiers (e.g., *everyone*, *someone*), and modal operators (e.g., *may*, *must*). In logic, these three types of operators correspond to the three main classes of logical systems that have been considered: propositional logics (focusing only on connectives), predicate logics (adding quantifiers), and modal logics (adding modal operators). Similarly, connectives, quantifiers, and modal operators also constitute three major areas of research in linguistics.

Initial work on inquisitive semantics focused on the repercussions of the new semantic perspective in the most basic domain, that of connectives. This has led to a better understanding of the role of disjunction, conjunction, and negation in questions and in statements (e.g., AnderBois 2012, 2014; Roelofsen & Farkas 2015; Champollion et al. 2016; Ciardelli 2016a; Ciardelli et al. 2016b; Ciardelli & Roelofsen 2017) and, on the logical side, to in-depth investigations of propositional inquisitive logics (e.g., Ciardelli 2009, 2016b; Ciardelli & Roelofsen 2011; Roelofsen 2013a; Punčochář 2015, 2016; Frittella et al. 2016; Yang & Väänänen 2016).

Although these results are promising, in order to fully appreciate the repercussions of the approach, modal operators and quantifiers have to be brought under the inquisitive lens as well. We expect that doing so will not only shed new light on a number of long-standing puzzles but also raise new issues that were invisible through the more coarse-grained lens of truth-conditional semantics.

The goal of this review is twofold. First, we want to describe in general terms what the inquisitive perspective on modals and quantifiers amounts to. And second, we want to provide concrete illustrations of the benefits that this perspective may have, drawing on recently initiated (and, to a large extent, still ongoing) work in this direction. Thus, although this article provides a survey of some recent developments, as is expected of a review article, it should be considered mostly "programmatic," proposing directions for future research rather than providing a systematic and comprehensive summary of established results.

The review is structured as follows. After providing some technical background in Section 2, we discuss modals in Section 3 and quantifiers in Section 4. Section 5 concludes.

2. PROPOSITIONS AND PROPERTIES IN INQUISITIVE SEMANTICS

Following a tradition going back to Hintikka (1962), inquisitive semantics models information states as sets of possible worlds, the idea being that a body of information is determined by the set of states of affairs compatible with it. Let $\mathcal{S}$ denote the set of all information states. If $s, t \in \mathcal{S}$ and $t \subseteq s$, then t contains all the information that s contains, and possibly more; we say that t is an enhancement of s. As mentioned above, the fundamental semantic notion in inquisitive semantics

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is the relation of support, which relates sentences to information states. Support is construed as a persistent notion, meaning that if a sentence φ is supported at an information state s, it remains supported at every enhancement $t \subseteq s$.

The semantic value $[\![\varphi]\!]$ of a sentence φ in inquisitive semantics can be identified with a set of information states, namely those states that support φ. Because each information state is a set of possible worlds, $[\![\varphi]\!]$ is a set of sets of possible worlds—rather than a set of possible worlds, as is usually assumed. Moreover, the persistency condition on support implies that if $s \in [\![\varphi]\!]$ and $t \subseteq s$, then also $t \in [\![\varphi]\!]$. Thus, $[\![\varphi]\!]$ is a downward closed set of information states; we refer to such a set as an i-proposition. The maximal elements of the i-proposition $[\![\varphi]\!]$ are called the alternatives for φ; that is, the alternatives for φ are those information states that contain exactly as much information as is needed to support φ.

An i-proposition $[\![\varphi]\!]$ is said to be flat if there is a single classical proposition p—a set of worlds—such that $[\![\varphi]\!] = \{s \in \mathcal{S} \mid s \subseteq p\}$. This means that in order to support φ it is necessary and sufficient to establish that p holds. Clearly, a flat i-proposition always contains a unique alternative. If an i-proposition is not flat, we say that it is inquisitive. It is easy to see that, if $\mathcal{S}$ is finite, an inquisitive i-proposition always has two or more alternatives. For an illustration, consider the following three sentences:

(4a) Bob is home.

(4b) Is Bob home?

(4c) Where is Bob?

Let $s \in \mathcal{S}$. Statement 4*a* is supported in s if the information available in s implies that Bob is home—that is, if all worlds in s are worlds where Bob is home. Question 4*b* is supported in s if the available information determines whether Bob is home—that is, if all worlds in s agree on whether Bob is home. Finally, question 4*c* is supported in s if the available information determines where Bob is—that is, if Bob is in the same location in all worlds in s. Thus, sentences 4*a*–*c* express the following i-propositions:

(5a) $P_1 = \{s \mid s \subseteq \{w \mid \text{Bob is home at } w\}\}$

(5b) $P_2 = \{s \mid s \subseteq \{w \mid \text{Bob is home at } w\} \text{ or } s \subseteq \{w \mid \text{Bob is not home at } w\}\}$

(5c) $P_3 = \{s \mid s \subseteq \{w \mid \text{Bob is in } y \text{ at } w\} \text{ for some place } y\}$

Note that statement 4*a* expresses a flat i-proposition with $\{w \mid \text{Bob is home at } w\}$ as its only alternative. By contrast, questions 4*b* and 4*c* express inquisitive i-propositions. The polar question 4*b* has two alternatives, namely $\{w \mid \text{Bob is home at } w\}$ and $\{w \mid \text{Bob is not home at } w\}$. The *wh*-question 4*c* has multiple alternatives, namely all the states $\{w \mid \text{Bob is in } y \text{ at } w\}$, where y is a place.

In terms of meaning composition, inquisitive semantics is implemented within the standard intensional semantics framework, that is, the typed λ-calculus with basic types $\mathtt{e}, \mathtt{s}$, and $\mathtt{t}$ for entities, possible worlds, and truth values, respectively (for details, see Ciardelli et al. 2016b). Because its semantic value is a set of sets of worlds, a complete sentence is taken to have the type $\langle\langle \mathtt{s}, \mathtt{t}\rangle, \mathtt{t}\rangle$, abbreviated as $\mathtt{T}$. The types of subsentential constituents are inferred from this type, together with the assumption that the basic mode of composition is function application. In particular, in inquisitive semantics a VP has semantic type $\langle \mathtt{e}, \mathtt{T}\rangle$. This means that the semantic value of a VP is a function from individuals to i-propositions. We refer to such objects as i-properties. We say that an i-property is flat if it maps any individual to a flat i-proposition, and inquisitive otherwise. For an illustration, consider:

(6a) $[\![\text{sang}]\!] = \lambda x.\{s \mid s \subseteq \{w \mid x \text{ sang at } w\}\}$

(6b) $[\![\text{sang or danced}]\!] = \lambda x.\{s \mid s \subseteq \{w \mid x \text{ sang at } w\} \text{ or } s \subseteq \{w \mid x \text{ danced at } w\}\}$

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The VP *sang* denotes a flat i-property, mapping an individual x to a flat i-proposition having a unique alternative, $\{w \mid x \text{ sang at } w\}$. By contrast, the VP *sang or danced* denotes an inquisitive i-property, mapping an individual x to an i-proposition having two alternatives, namely the states $\{w \mid x \text{ sang at } w\}$ and $\{w \mid x \text{ danced at } w\}$.

3. MODALS

3.1. Some Challenges for the Standard View

On the standard view, modal auxiliary verbs like *may* and *must* and propositional attitude verbs like *know* and *believe* are analyzed as relating two classical propositions: the proposition expressed by their argument and a relevant set of worlds associated with the actual world, termed the modal base. Conditionals are handled similarly, by taking the antecedent to restrict the modal base in which the consequent is evaluated (e.g., Kratzer 2012).

Recently, several challenges have been raised for this approach. For instance, it has been argued that in order to account for deontic modals in the context of decision problems, it is crucial to take into account the decision problem at hand as a parameter of the evaluation (Lassiter 2011, Cariani et al. 2013, Charlow 2013). In the domain of conditionals, it has been observed that disjunctive antecedents appear to contribute two distinct propositions as assumptions, each corresponding to one of the two disjuncts, which are inevitably conflated on a truth-conditional approach (Alonso-Ovalle 2009, Fine 2012, Champollion et al. 2016). Finally, in the domain of attitude verbs, certain problems have been identified for the standard approaches to responsive verbs (verbs that take both declarative and interrogative complements); the argument is that they cannot always be regarded as applying to a single proposition contributed by the verb's complement (George 2011, Elliott et al. 2017). In the same spirit, philosophers have emphasized that question-directed attitudes such as *wonder* and *investigate* fall beyond the scope of current theories of propositional attitudes, and call for a generalization (Friedman 2013).

3.2. The Inquisitive Perspective

Inquisitive semantics suggests a new view on modal operators that has the potential to address all these issues. The central idea is to construe modal operators not as expressing a relation between two classical propositions but as expressing a relation between two i-propositions, comprising both information and issues.

What are the repercussions of this shift in perspective for the challenges above? First, when evaluating a deontic modal in the context of a decision problem, the relevant modal base will represent both the contextual information and the contextual issue—the decision problem at hand. Second, in evaluating a conditional, it is not only the truth-conditional content of the antecedent that matters but also its inquisitive content. Disjunctive antecedents are typically inquisitive; in other words, they introduce multiple alternatives, which the conditional can manipulate individually. Finally, generalizing the notion of modal base to include both information and issues paves the way for a uniform analysis of propositional attitude verbs like *believe*, *know*, and *wonder*. Thus, the inquisitive view on modal operators has the potential to address a number of limitations of the standard truth-conditional view. To exemplify concretely what this amounts to, we discuss in detail the case of propositional attitude verbs in the following section. For research on conditionals along the lines sketched above, see Champollion et al. (2016) and Ciardelli (2016a), as well as the closely related research of Alonso-Ovalle (2009), Fine (2012), and Santorio (2016).

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3.3. An Illustration: Attitude Verbs

We first review the traditional view on attitude verbs (Section 3.3.1) and then turn to the inquisitive perspective (Section 3.3.2).

3.3.1. The traditional view and its limits. Attitude verbs are usually analyzed as expressing propositional attitudes, that is, attitudes toward propositions. The traditional analysis of propositional attitudes, which goes back to Hintikka (1969), can be described succinctly as follows. For each attitude A, we consider a map σ_A that assigns to each individual x and possible world w a set $\sigma_A(x, w)$ of possible worlds—those which are in accordance with the relevant attitude of x at w. Thus, when we analyze *know*, $\sigma_{\text{know}}(x, w)$ will consist of those worlds that are compatible with what x knows at w; when we analyze *want*, $\sigma_{\text{want}}(x, w)$ will consist of those worlds that are compatible with what x wants at w; and so on. The set of worlds $\sigma_A(x, w)$ is referred to as the modal base for the attitude A. The attitude itself is then analyzed as a relation $A(x, w, p)$, which holds between an individual x, a possible world w, and a proposition p if and only if p is true at every world in $\sigma_A(x, w)$. When we analyze the proposition p itself as a set of possible worlds—those worlds in which it is true—this means that we have $A(x, w, p)$ if and only if $\sigma_A(x, w) \subseteq p$. Thus, for instance, we have:

(7a) $\text{know}(x, w, p) \iff \sigma_{\text{know}}(x, w) \subseteq p$

(7b) $\text{want}(x, w, p) \iff \sigma_{\text{want}}(x, w) \subseteq p$

Finally, a sentence like *Alice Vs that* α, involving an attitude verb V, is analyzed as being true if, in the actual world, Alice bears the relevant attitude to the proposition expressed by the declarative clause *that* α, that is, to the set of worlds where α is true. This analysis of propositional attitudes has been very fruitful, and has been extended and refined in a number of ways (e.g., Stalnaker 1984, Heim 1992). Yet the analysis is limited in several important respects. Let us review some of them.

Some attitude verbs, such as *know* and *remember*, can combine not only with declarative clauses but also with interrogative ones:

(8a) Alice knows/remembers whether Bob is home.

(8b) Alice knows/remembers where Bob is.

In order to account for sentences like those in examples 8*a* and 8*b*, maintaining the view that *know* and *remember* operate on a proposition even when they take an interrogative complement, two types of approaches have been pursued. Groenendijk & Stokhof (1984) proposed a uniform approach. In their theory, declarative and interrogative embedded clauses have the same type of denotation—a proposition, modeled as a set of possible worlds. In the case of a declarative clause *that* α, the denotation is the set of worlds where α is true; in the case of an interrogative clause μ, the denotation is the true complete answer to μ at the world of evaluation. In either case, the attitude verb can thus apply directly to the denotation of the embedded clause. Other authors, notably Karttunen (1977) and Spector & Egré (2015), have taken a reductive approach. On this approach, declarative clauses and interrogative clauses denote different types of objects, namely propositions and sets of propositions, respectively. The entry for the verb is designed to apply to a proposition, and can thus be applied directly to the denotation of a declarative clause. In order for the verb to combine with an interrogative clause, some type shifting needs to take place. In the approach of Karttunen (1977) it is the question denotation Q' that is type-shifted to fit the embedding verb, resulting in the proposition $\bigcap Q'$—the complete answer to Q' at the world of evaluation as given by Karttunen's theory. In the approach of Spector & Egré (2015), by contrast,

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it is the verb denotation V' that is type-shifted to fit the type of the interrogative complement, resulting in the entry $\lambda Q_{\langle\langle \mathtt{s},\mathtt{t}\rangle,\mathtt{t}\rangle}.\lambda x_{\mathtt{e}}.\exists p \in Q.V'(x, p)$.

Essentially, in the approaches of Groenendijk & Stokhof (1984) and Karttunen (1977), sentences like those in examples 8*a* and 8*b* claim that Alice stands in the relevant relation to the complete true answer to the embedded question. By contrast, in the approach of Spector & Egré (2015), these sentences claim that she stands in the relevant relation to some complete answer.

The first class of approaches rests on the assumption that sentences like examples 8*a* and 8*b* always express relations between an individual and a specific proposition—the complete answer to the embedded question. But not all questions have a single complete answer at a world. Consider example 9:

(9) Where can one buy an Italian newspaper in Amsterdam?

This question can be completely resolved by providing only one of multiple places where Italian newspapers are sold. Now, a question like example 9 may very well appear embedded under an attitude verb:

(10) Alice knows where one can buy an Italian newspaper in Amsterdam.

There is no single proposition that Alice needs to know for this statement to be true; rather, the statement may be true by virtue of Alice knowing one among various propositions, for instance, that one can buy an Italian newspaper at Central Station, that one can buy an Italian newspaper at the airport, and so forth. Thus, the approaches of Groenendijk & Stokhof (1984) and Karttunen (1977)—which would interpret sentence 10 as a claim that Alice knows a certain particular proposition—cannot assign the right truth conditions in this case.[1,2]

The account of Spector & Egré (2015) does not deal with cases like sentence 10 either, but it could in principle be adapted to do so. However, although such an account may be successful in the case of *know*, the situation seems different for verbs like *care*, as pointed out by Elliott et al. (2017). Suppose Alice is preparing for a long walk home and does not know whether it is raining outside. Then, sentence 11 is likely to be true:

(11) Alice cares whether it is raining.

On the account of Spector & Egré (2015), this is equivalent to the following statement:

(12) Alice cares that it is raining, or she cares that it is not raining.

But this statement, unlike the one in sentence 11, is not true in the given scenario. For Alice to care that it is raining, she would have to know that it is, and similarly for her to care that it isn't raining; because she lacks this knowledge, neither disjunct is true.[3] Thus, it seems that a reductive

[1]To deal with these cases, Groenendijk & Stokhof (1984) propose to treat example 9 as having a higher semantic type (namely $\langle\langle\langle \mathtt{s},\mathtt{t}\rangle,\mathtt{t}\rangle,\mathtt{t}\rangle$ instead of $\langle \mathtt{s},\mathtt{t}\rangle$), and to type-shift the entry for the embedding verb so that it can apply to objects of this type. We do not discuss this option in detail here. A problem with this lifting strategy is pointed out by Ciardelli (2017, footnote 20).

[2]Another challenge for the approaches of Karttunen (1977) and Groenendijk & Stokhof (1984) is raised by George (2011). He argues that the truth of sentences like example 10 requires not only that Alice know of at least one true answer to the embedded question that it is true but also that she not wrongly believe of any false answer that it is true. We do not discuss this issue here. For an account in inquisitive semantics, see Theiler et al. (2016a); for other accounts, see Uegaki (2015) and Xiang (2015), among others.

[3]Note that a similar problem arises for the accounts of Groenendijk & Stokhof (1984) and Karttunen (1977), which would interpret example 11 as claiming that Alice cares that it rains, if it in fact rains, and cares that it does not rain, if in fact it does not rain.

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account of *care* is bound to fail. In fact, this problem with analyzing the verb *care* stems from a deeper problem with analyzing the attitude of caring. It seems that the object of Alice's caring in the above scenario is the question as such, not some answer to it. If so, then the attitude of caring cannot in general be analyzed as a relation between an individual and a proposition. Rather, in some cases it must be understood as a relation between an individual and a question.

This point becomes even more evident when we consider attitude verbs like *wonder* and *investigate*, which can take only an interrogative complement. Consider example 13:

(13) Alice wonders where Bob is.

It is clear that Alice cannot be thought of as bearing the wondering relation to any answer to the question—or any proposition, for that matter (Friedman 2013). Rather, it is natural to regard the object of Alice's wondering to be the question expressed by the embedded interrogative, as a whole. Thus, the attitude of wondering falls squarely outside the traditional framework, which assumes the object of an attitude to be a set of possible worlds. For this reason, a verb like *wonder* has mostly been treated in the literature as an unanalyzed relation between individuals and questions. However, without some analysis of this relation, we lack an account of the entailments licensed by sentences involving *wonder*. We cannot predict, for instance, that conclusion 14*c* follows from premises 14*a* and 14*b*, but not from either premise alone:

(14a) Alice wonders who the culprit is.

(14b) Alice knows that the culprit is Bob or Charlie.

(14c) So, Alice wonders whether the culprit is Bob or Charlie.

3.3.2. The inquisitive view and its prospects. As discussed above, in inquisitive semantics, statements and questions are assigned the same kind of semantic value, namely an i-proposition—a downward closed set of information states. We assume that the same treatment applies to embedded declarative and interrogative clauses. For instance, complement clauses 15*a–c* will have the same semantic values as the corresponding main clauses (sentences 5*a–c*):

(15a) that Bob is home

(15b) whether Bob is home

(15c) where Bob is

This uniform treatment of declarative and interrogative complements allows for an analysis of verbs like *know* (as well as *remember*, *discover*, etc.) that is uniform with respect to the kind of complement that the verb is applied to.[4] The crucial move is that, now, we can construe *knowing* as a relation that involves an individual, a possible world (typically the actual world), and an i-proposition, rather than a classical proposition. In the case of *know*, a natural treatment is as follows (Ciardelli & Roelofsen 2015):

(16) $\mathrm{know}(x, w, P) \iff \sigma_{\mathrm{know}}(x, w) \in P$

That is, a claim like *Alice knows* φ is true if φ is supported by Alice's knowledge state $\sigma_{\mathrm{know}}(x, w)$, consisting of those worlds that are compatible with her knowledge. If we apply this analysis to the

[4]The uniform inquisitive approach to the semantics of attitude verbs presented here was first proposed by Ciardelli & Roelofsen (2015) and has been further developed by Theiler (2014) and Theiler et al. (2016b). A closely related approach, with similar advantages, has been pursued by Uegaki (2015). For a detailed comparison, see Theiler et al. (2016b, appendix).

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semantic values of our indirect clauses in complement clauses 15*a–c* (given in sentences 5*a–c*), we obtain the following:

(17a) $\text{know}(x, w, P_1) \iff \sigma_{\text{know}}(x, w) \subseteq \{w \mid \text{Bob is home at } w\}$

(17b) $\text{know}(x, w, P_2) \iff \sigma_{\text{know}}(x, w) \subseteq \{w \mid \text{Bob is home at } w\}$ or
$\sigma_{\text{know}}(x, w) \subseteq \{w \mid \text{Bob is not home at } w\}$

(17c) $\text{know}(x, w, P_3) \iff \sigma_{\text{know}}(x, w) \subseteq \{w \mid \text{Bob is in } y \text{ at } w\}$ for some place y

In words, x knows that Bob is home if and only if it follows from what x knows that Bob is home; x knows whether Bob is home if it follows from what x knows that Bob is home, or it follows from what x knows that Bob is not home; and x knows where Bob is if, for some place y, it follows from what x knows that Bob is in y. Finally, the attitude verb *know* can be assigned the following entry:

(18) $\lambda P_{\langle\langle \mathtt{s},\mathtt{t}\rangle,\mathtt{t}\rangle}.\lambda x_{\mathtt{e}}.\{s \mid s \subseteq \{w \mid \text{know}(x, w, P)\}\}$

This makes sure that the sentence *Alice knows* φ is supported in a state s if it follows from the information available in s that Alice bears the *know* attitude to the semantic value of φ.

Note that this treatment of *know*, unlike those of Groenendijk & Stokhof (1984) and Karttunen (1977), has no problems dealing with questions that have more than one true answer in a given world. To see this, consider again the *mention-some* question in example 9. This question expresses the following i-proposition:[5]

(19) $P_4 = \{s \mid \exists y : s \subseteq \{w \mid y \text{ sells Italian newspapers at } w\}\}$

Our analysis then predicts that sentence 10 is true under the following conditions:

(20) $\text{know}(a, w, P_4) \iff \exists y : \sigma_{\text{know}}(a, w) \subseteq \{w \mid y \text{ sells Italian newspapers at } w\}$

That is, sentence 10 is predicted to be true if and only if there is some place of which Alice knows that sells Italian newspapers. This is the expected result; as usual, the inquisitive meaning of the sentence consists of those information states in which it is established to be true. Thus, the inquisitive perspective yields a simple and transparent analysis of *know* that requires no special type shifting to interpret embedded interrogatives and is not restricted to questions with a unique complete answer in each world.[6] An analogous treatment can be given for similar verbs, such as *remember* and *discover*.

Now consider the verb *care*. In the inquisitive setting, we can model caring as a relation that holds directly between an individual and an i-proposition—say, the semantic value of an interrogative clause such as *whether it rains*—one that does not have to be reducible to a more basic relation holding between an individual and a classical proposition. This avoids the problem noted above for a reductive analysis of *care*.

Finally, consider the problem of accounting for inquisitive attitudes like *wonder* and *investigate*. In our analysis of *know*, above, we have followed Hintikka (1969) in supposing that the modal base $\sigma_A(x, w)$ used to relate the subject x to the object P of an attitude A is a set of possible worlds—a classical proposition. However, under the inquisitive perspective it is also natural to consider attitudes for which the modal base is not a classical proposition but rather an i-proposition $\sigma_A(x, w)$. Of course, the actual reading of $\Sigma_A(x, w)$ will depend on the specific attitude A under consideration. In the case of *wonder*, for instance, we can take the set $\Sigma_{\text{won}}(x, w)$ to consist of

[5]For the sake of succinctness, in describing the relevant meaning we rephrase "one can buy an Italian newspaper at y" as "y sells Italian newspapers." Of course, this rephrasing is not necessary.

[6]For an investigation of the epistemic logic that arises from this analysis of *know*, see Ciardelli (2014, 2016b).

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those information states in which every issue that x wonders about at w is resolved. Note that this corresponds exactly to the characterization of $\sigma_{\text{know}}(x, w)$ as consisting of those worlds in which everything that x knows at w is true. A simple analysis of *wondering* as an attitude is as follows:

(21) $\text{wonder}(x, w, P) \iff \Sigma_{\text{won}}(x, w) \subseteq P$ (to be refined)

That is, a claim like *Alice wonders* μ is true if, in every information state where the issues that Alice wonders about are resolved, μ is resolved as well—that is, if resolving μ is necessary in order for Alice's issues to be resolved. However, this minimal analysis needs to be refined slightly to take into account what the agent already believes. For instance, suppose Alice already believes that Bob is home, but she wonders whether he is cooking in the kitchen or reading a book on the couch. In this case, all the information states where her issues are resolved are states where the question *whether Bob is home* is indeed resolved—as all such states imply that he is home. Yet, in this situation we would not say that Alice wonders whether Bob is home: From her point of view, that question is resolved. To capture this, we add to our analysis a condition specifying that in order for x to wonder about a question the question must not already be supported by her belief state. This leads us to the following analysis of the attitude of wondering (Ciardelli & Roelofsen 2015):

(22) $\text{wonder}(x, w, P) \iff \sigma_{\text{bel}}(x, w) \notin P$ and $\Sigma_{\text{won}}(x, w) \subseteq P$

As an illustration of this analysis, consider again sentence 13, repeated as sentence 23, below. If we apply our proposal to the semantic value of the embedded question given in 5*a*–*c*, we obtain the truth conditions in 24:

(23) Alice wonders where Bob is.

(24) $\text{wonder}(a, w, P_3) \iff \forall y : \sigma_{\text{bel}}(x, w) \not\subseteq \{w \mid \text{Bob is in } y \text{ at } w\}$ but
$\forall s : \in \Sigma_{\text{won}}(a, x)\, \exists y : s \subseteq \{w \mid \text{Bob is in } y \text{ at } w\}$

Thus, sentence 23 is true if (*a*) Alice's current beliefs do not entail of any place y that Bob is in y, but (*b*) if the issues that Alice wonders about were resolved, the resulting state would entail of some place y that Bob is in y. This seems a natural analysis of sentence 23. The account also allows us to make predictions concerning the (in)validity of certain inference patterns. In particular, it is not hard to see that it would predict our earlier observation that sentence 14*c* is jointly entailed by premises 14*a* and 14*b*, but not by either premise alone.[7]

A question that naturally arises, given the view of attitude verbs that we are advocating, is the following: If all attitude verbs apply to i-propositions, and if both declarative and interrogative complements express i-propositions, why can't all attitude verbs embed both kinds of complements? We do not give a general answer to this question here, but we show that an explanation of the ungrammaticality of *wonder-that* arises naturally from our account of *wonder*, and extends to other inquisitive attitude verbs like *investigate*.[8]

The explanation is based on two components. The first is the fact that declarative complements express a very specific kind of i-proposition, namely flat i-propositions, which have a unique alternative.[9] For instance, the clause *that Bob is home*, discussed above, is supported exactly by the information state $\{w \mid \text{Bob is home at } w\}$ and its subsets.

[7]For a further refinement of the analysis of *wonder* given here, see Roelofsen & Uegaki (2016).

[8]For a possible explanation of the selectional restrictions of other attitude verbs, see Theiler et al. (2016b).

[9]This is because, in inquisitive semantics, the declarative complementizer is associated with a flattening operator, also referred to as noninquisitive closure (e.g., Ciardelli et al. 2015).

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The second component is the observation is that one can only meaningfully wonder about a certain question if one believes that the question can be resolved. For instance, one cannot wonder about the question in example 25 unless one believes that Bob indeed has a wife:

(25) What is Bob's wife's name?

This means that a tight connection must hold between the belief state $\sigma_{\text{bel}}(x, w)$ of an agent and her wondering state $\Sigma_{\text{won}}(x, w)$; specifically, we must have $\sigma_{\text{bel}}(x, w) \subseteq \bigcup \Sigma_{\text{won}}(x, w)$. This requirement is connected to the well-known observation, going back to Belnap (1966), that a question is always associated with a presupposition that some true answer exists; the requirement $\sigma_{\text{bel}}(x, w) \subseteq \bigcup \Sigma_{\text{won}}(x, w)$ means that, in order to wonder about a question, one needs to believe the associated presupposition.

Now consider example 26, in which the complement of *wonder* is a declarative. The truth conditions that our analysis predicts for this sentence are given in example 27, where $P_1 = \{s \mid s \subseteq \{w \mid \text{Bob is home at } w\}\}$ is the i-proposition expressed by the complement:

(26) #Alice wonders that Bob is home.

(27) $$\begin{aligned} \text{wonder}(a, w, P_1) &\iff \sigma_{\text{bel}}(a, w) \notin P_1 \text{ and } \Sigma_{\text{won}}(a, w) \subseteq P_1 \\ &\iff \sigma_{\text{bel}}(a, w) \not\subseteq \{w \mid \text{Bob is home at } w\} \text{ and} \\ &\qquad \forall s \in \Sigma_{\text{won}}(a, w) : s \subseteq \{w \mid \text{Bob is home at } w\} \end{aligned}$$

Given the connection that must hold between Alice's belief state and wondering state, these conditions can never be satisfied, because the second line implies that $\bigcup \Sigma_{\text{bel}}(a, w) \subseteq \{w \mid \text{Bob is home at } w\}$. The requirement that $\sigma_{\text{bel}}(a, w) \subseteq \bigcup \Sigma_{\text{won}}(a, w)$ then implies $\sigma_{\text{bel}}(a, w) \subseteq \{w \mid \text{Bob is home at } w\}$, which conflicts with the first condition.

In deriving this result we have not used anything specific about the embedded clause, other than the fact that it expresses a flat i-proposition—a fact that is common to all declarative complements. Thus, combining *wonder* with a declarative complement systematically results in a contradictory meaning, which can be taken to explain the ungrammaticality of this sort of construction (for the connections between systematic contradictions and ungrammaticality, see Gajewski 2002, Chierchia 2013). An analogous explanation can be given for the verb *investigate*.

In summary, inquisitive semantics suggests a new perspective on attitude verbs as expressing relations between individuals and i-propositions. First, this perspective allows for a simple, uniform account of verbs such as *know*, *remember*, and *discover*, which can embed both declarative and interrogative clauses. Second, it avoids some problems that arise when we try to reduce an attitude directed toward a question to the same attitude directed toward an answer to that question, as we discussed above in the case of *care*. Finally, it broadens the scope of the traditional theory of attitude verbs, bringing within reach an elegant analysis of inquisitive attitude verbs such as *wonder* and explaining their infelicity in combination with declarative clauses.

4. QUANTIFIERS

4.1. Some Challenges for the Standard View

On the standard view, quantifiers like *every man* and *many students* are treated as operators that map a property (denoted by the predicate that they combine with) to a truth value (denoted by the full clause that the quantifier and the predicate form together). Although this approach allows for an insightful characterization of the truth-conditional contribution of quantifiers, it also has some important limitations. First, interrogative quantifiers like *which men* and *how many students*

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are squarely beyond its scope, because these are used to form interrogative sentences, which do not denote truth values.

Second, even plain quantifiers like *every man* are problematic when they occur in questions. For instance, to derive the so-called pair-list reading of the question in example 28*a*, paraphrased in example 28*b*, it seems that the quantifier needs to scope out of the question, something that is impossible if its argument is required to be a standard property:

(28a) What did every man eat?

(28b) Pair-list reading: 'For every man x, what did x eat?'

Finally, puzzling differences have been observed between truth-conditionally equivalent quantifiers. For instance, sentence 29*a* conveys ignorance on the part of the speaker about the exact number of students who cheated, whereas the truth-conditionally equivalent sentence 29*b* does not seem to convey such ignorance, or at least not so robustly (e.g., Geurts & Nouwen 2007, Westera & Brasoveanu 2014, Ciardelli et al. 2016a). How can this difference in meaning be captured, alongside the truth-conditional equivalence?

(29a) At least three students cheated.

(29b) More than two students cheated.

4.2. The Inquisitive Perspective

Again, inquisitive semantics suggests a new perspective that allows us to address these issues. The central idea is to construe quantifiers not as operators mapping standard properties to truth values, but rather as mapping i-properties to i-propositions.

This move allows us to pursue an account of quantifiers that captures (*a*) their ability to propagate inquisitive content, which is necessary to deal with quantifiers scoping out of questions, and (*b*) their potential to generate inquisitive content, which is necessary to deal with interrogative quantifiers like *which men*, and which also provides a handle on the ignorance implications of quantifiers like *at least three students* (note that inquisitive constructions such as questions and disjunctions typically convey ignorance as well). Below, we focus on the case of quantifiers scoping out of questions. For research on quantifiers like *at least three students* in inquisitive semantics, see Coppock & Brochhagen (2013), Blok (2015), and Ciardelli et al. (2016a); for work on interrogative quantifiers, see Champollion et al. (2015).

4.3. An Illustration: Quantifiers Scoping out of Questions

We first take a closer look at the problem posed by quantifiers in questions (Section 4.3.1) and some proposed solutions (Section 4.3.2). Then we lay out the inquisitive perspective (Section 4.3.3) and briefly discuss some further empirical issues (Section 4.3.4).

4.3.1. A closer look at the problem. Let us consider in more detail the challenge that questions like example 28*a* pose under standard assumptions. Let us briefly make these standard assumptions a bit more explicit. Consider example 30:

(30) Exactly one woman kissed every man.

For concreteness, let us assume that quantifiers take scope by means of quantifier raising (the points we make here do not hinge on this assumption in any way). The inverse-scope reading

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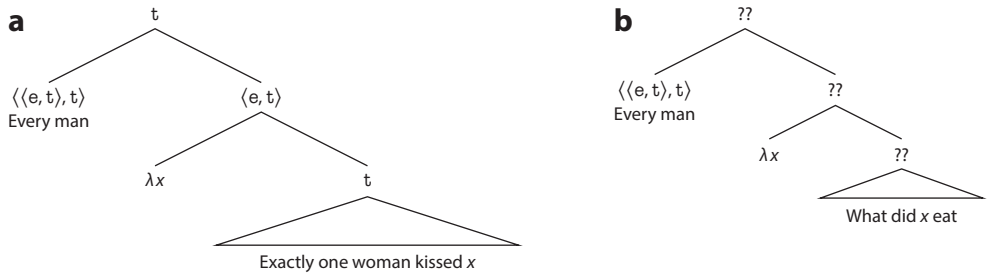

Figure 1

Logical forms in which quantifiers raise (*a*) out of a declarative clause and (*b*) out of an interrogative clause.

of example 30 is then derived from the logical form depicted in **Figure 1*a***. The clause *exactly one woman kissed x* denotes an object of type $\mathtt{t}$, that is, a truth value. Abstraction over x yields a property of type $\langle \mathtt{e}, \mathtt{t} \rangle$. The quantifier *every man* takes this property as its input and yields a truth value as its output.

Now consider example 28*a* again. One would expect that the pair-list reading of this question can be derived by letting the quantifier take wide scope, as in **Figure 1*b***. But this is problematic. Suppose that the interrogative clause *what did x eat* denotes a set of propositions, that is, is of type $\langle\langle \mathtt{s}, \mathtt{t} \rangle, \mathtt{t} \rangle$ (as assumed in Hamblin 1973, Karttunen 1977, and much subsequent work). Abstraction over x then yields an object of type $\langle \mathtt{e}, \langle\langle \mathtt{s}, \mathtt{t} \rangle, \mathtt{t} \rangle\rangle$, which is something that the quantifier *every man* cannot take as its input.

Different assumptions have been made about the semantic value of interrogative clauses. For instance, on the partition theory of Groenendijk & Stokhof (1984), questions denote propositions; in other words, they are of type $\langle \mathtt{s}, \mathtt{t} \rangle$. And on categorial approaches (e.g., Hull 1975, Tichy 1978, Hausser & Zaefferer 1978), they denote n-place relations, where n is the number of *wh*-phrases they contain. However, under any of these assumptions, the object that is obtained in example 30, after abstracting over x, is not a property of type $\langle \mathtt{e}, \mathtt{t} \rangle$—that is, not of the right type to serve as input for *every man*.

4.3.2. Some proposed solutions. Various approaches to address this issue have been pursued. We are unable to review all of them in detail, but we outline some of the main ideas (for recent overviews, see Dayal 2016, Xiang 2016).

First, it may seem promising to assume that *every* does not need an expression of type $\langle \mathtt{e}, \mathtt{t} \rangle$ as its second argument, but it can, in principle, take an expression of any type $\langle \mathtt{e}, \tau \rangle$, where τ is a conjoinable type (roughly, a type whose objects are sets of some kind) and essentially expresses set intersection. Under such an account, we would have the following:

(31) $[\![\text{[every man [}\lambda x\text{ [what did } x \text{ eat]]]}]\!]^{w,g} = \bigcap_{d \in [\![\text{man}]\!]^{w,g}} [\![\text{what did } x \text{ eat}]\!]^{w,g[x \mapsto d]}$

Whether this yields reasonable predictions, however, depends on one's background theory of questions. In the framework of Karttunen (1977), $[\![\text{what did } x \text{ eat}]\!]^{w,g[x \mapsto d]}$ is the set of true propositions of the form *d ate y* for some object y. But this means that, as soon as there are at least two men in w, $[\![\text{[every man [}\lambda x\text{ [what did } x \text{ eat]]}]\!]^{w,g}$ becomes the empty set of propositions—certainly not a desirable result (as noted by Karttunen 1977, p. 31). By contrast, in the framework of Groenendijk & Stokhof (1984), $[\![\text{what did } x \text{ eat}]\!]^{w,g[x \mapsto d]}$ is a single proposition, embodying the true exhaustive answer to *what did d eat* in w. Thus, $[\![\text{[every man [}\lambda x\text{ [what did } x \text{ eat]]}]\!]^{w,g}$ is a proposition that, for every $d \in [\![\text{man}]\!]^{w,g}$, exhaustively specifies what d ate in w. This seems to be the right result.

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Groenendijk & Stokhof (1984), however, are not satisfied with this account and ultimately opt for a rather different approach. One reason is that, whereas the analysis of *every* as expressing intersection works well in their framework, the corresponding analysis of *some* as expressing union does not. Consider, for instance, question 32*a*:

(32a) What book did some boy read?

(32b) Choice reading: 'For some boy, what book did he read?'

One would expect that the above choice reading could be derived by letting the existential scope out of the question. However, a treatment of existentials as expressing union, analogous to that of universals as expressing intersection, gives undesirable results in Groenendijk & Stokhof's framework. In fact, it does not yield a proper question meaning at all in their setting for questions such as 32*a*.[10]

The alternative approach that Groenendijk & Stokhof (1984) pursue assumes that quantifiers can combine with questions by use of a special "quantifying-in rule" (see also, e.g., Karttunen & Peters 1980, Higginbotham & May 1981, Belnap 1982). One weak point of this approach (pointed out in Chierchia 1993, among others) is that it does not treat quantifiers uniformly; a theory in which quantifiers are always combined with other material in the sentence using the same rule of meaning composition would be more parsimonious.

Another prominent approach is to derive the pair-list reading as a so-called functional reading (Engdahl 1980). Informally speaking, example 28*a* is analyzed under this approach as in example 33:

(33) Which function $f_{\langle e,e \rangle}$ is such that every man x ate $f(x)$?

A pair-list answer such as sentence 34*a* can be regarded as one way to specify the requested function, along with other answers like example 34*b*, which do not explicitly spell out the extension of the function but rather give a more "intensional" description of it:

(34a) Bill ate the chocolate cake, Tom the rice pudding, and Fred the raspberry pie.

(34b) Every man ate what his wife recommended.

Under this approach, one obtains pair-list readings without letting quantifiers scope out of questions, thereby avoiding the initial problem altogether.[11]

However, Pafel (1999) makes a general argument against all approaches that derive pair-list readings without letting the quantifier scope out of the question, including both the quantifying-in approach and the functional approach. Specifically, these approaches fail to capture the fact that pair-list readings and ordinary inverse-scope readings are constrained in similar ways. For

[10]This is only one of several reasons why Groenendijk & Stokhof (1984) develop an alternative account of the interaction between quantifiers and questions. In a footnote, they actually express some skepticism about the ability of existential quantifiers to trigger choice readings (Groenendijk & Stokhof 1984, p. 556). They are convinced, however, that choice readings can be generated by disjunction, and pursue a theory that treats disjunction and existential quantification uniformly. Szabolcsi (1997) has argued that choice readings do not exist at all, neither with existentials nor with disjunction. We agree that existentials have not been convincingly shown to trigger choice readings. On our view, the most prominent reading of question 32*a* is a *mention-some* reading: It can be resolved simply by specifying a book that some boy read, without necessarily specifying which boy read it. We do think, however, that disjunction can trigger choice-like readings (Ciardelli et al. 2015). Regardless of whether existentials can or cannot trigger choice readings, the partition theory of Groenendijk & Stokhof (1984) needs to be extended in order to deal with *mention-some* readings as well as the choice-like readings generated by disjunction.

[11]Groenendijk & Stokhof (1984) and Chierchia (1993) point out a number of shortcomings of Engdahl's functional approach that we cannot review in detail here, involving downward monotonic quantifiers, choice readings, and quantificational variability. Chierchia (1993) addresses these challenges by combining ideas from the quantifying-in approach with Engdahl's functional account.

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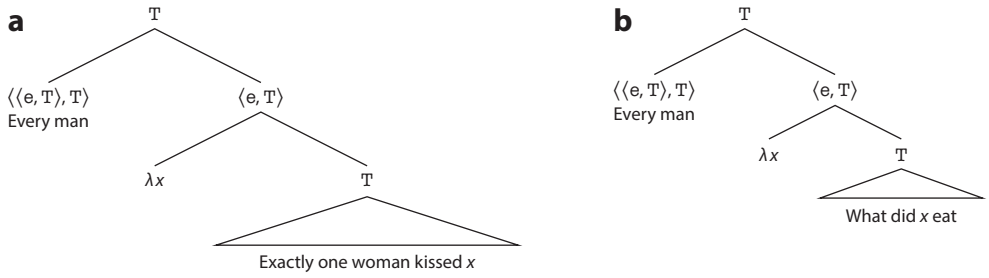

Figure 2

Logical forms in which quantifiers raise (*a*) out of a declarative clause and (*b*) out of an interrogative clause, with semantic types as given in inquisitive semantics.

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instance, because universal quantifiers cannot scope out of declarative finite clauses, statement 35*a* has no inverse-scope reading. Similarly, question 35*b* lacks a pair-list reading:[12]

(35a) Exactly one woman believes that every man loves her. [no inverse scope]

(35b) Which woman does Susan believe that every man loves? [no pair list]

This similarity is expected if pair-list readings require the universal quantifier to scope out of the question, but it is unexpected on the quantifying-in approach and the functional approach.

This brings us back to our initial problem: the fact that quantifiers, under standard assumptions, cannot scope out of questions. Neither of the two strategies to overcome this problem—devising a special rule for quantifying into questions and deriving pair-list readings without invoking scope at all—seems to be fully satisfactory. We do not attempt to "fix" either of the two approaches, or propose yet another way to overcome the problem. Instead, we attempt to identify the source of the problem, and show that this source is no longer present in inquisitive semantics. As a consequence, the problem no longer arises.

4.3.3. An inquisitive perspective. Which standard assumption is responsible for the fact that quantifier scope cannot be treated uniformly across declaratives and interrogatives? In our view, it is the assumption that declarative and interrogative sentences are of a different semantic type. As described above, in inquisitive semantics both kinds of sentences are taken to be of the same semantic type—both express i-propositions, which are downward closed sets of information states. The identity of semantic type, as discussed below, allows for a uniform account of quantifier scope-taking across the two kinds of sentences.

First, consider the logical form depicted in **Figure 2*a***, which is similar to that in **Figure 1*a*** but now with "inquisitive types" assigned to each constituent. Recall that $\mathtt{T}$ stands for $\langle\langle \mathtt{s}, \mathtt{t}\rangle, \mathtt{t}\rangle$, the type of full declarative and interrogative clauses in inquisitive semantics. The clause *exactly one woman kissed x* expresses an i-proposition, that is, an object of type $\mathtt{T}$. Abstraction over *x* yields an i-property, that is, an object of type $\langle \mathtt{e}, \mathtt{T}\rangle$. Finally, the quantifier *every man* takes this i-property as its input and yields, again, an i-proposition as its output.

Now consider the logical form in **Figure 2*b***, similar to that in **Figure 1*b*** but with inquisitive types. No type clash arises in this case, because the interrogative clause that the quantifier scopes

[12] Pafel does not discuss the finite-clause constraint; rather, he discusses several constraints on quantifier scope in German, which seem to lack a direct counterpart in English. Kuno (1991) also emphasizes parallels between quantifier scope-taking in statements and questions.

over in **Figure 2*b*** has exactly the same semantic type as the declarative clause in **Figure 2*a***. What remains to be determined, however, is whether a single semantic entry for *every* can be given that yields the desired result in both cases. This goal can indeed be achieved, simply by lifting the standard entry of the determiner to the inquisitive setting in a natural way (Ciardelli et al. 2016b). The first step is to formulate the standard interpretation of *every* at the intensional level (where it takes two properties of type $\langle \mathtt{e}, \langle \mathtt{s}, \mathtt{t} \rangle \rangle$ and delivers a proposition) rather than the extensional level (where it takes two properties of type $\langle \mathtt{e}, \mathtt{t} \rangle$ and delivers a truth value). The result is as follows:

(36) $[\![\textit{every}]\!] = \lambda P_{\langle \mathtt{e}, \langle \mathtt{s}, \mathtt{t} \rangle \rangle}.\lambda Q_{\langle \mathtt{e}, \langle \mathtt{s}, \mathtt{t} \rangle \rangle}.\bigcap_{x \in D}(Px \rightarrow Qx)$

Here, for any two classical propositions p and q, $p \rightarrow q := \{w \mid \text{if } w \in p \text{ then } w \in q\}$.

Now, lifting this entry to inquisitive semantics yields the following:[13]

(37) $[\![\textit{every}]\!] = \lambda P_{\langle \mathtt{e}, \mathtt{T} \rangle}.\lambda Q_{\langle \mathtt{e}, \mathtt{T} \rangle}.\bigcap_{x \in D}(Px \twoheadrightarrow Qx)$

Here, for two i-propositions $\mathcal{P}$ and $\mathcal{Q}$, $\mathcal{P} \twoheadrightarrow \mathcal{Q} := \{s \mid \forall s' \subseteq s : \text{if } s' \in \mathcal{P} \text{ then } s' \in \mathcal{Q}\}$.

What does this entry deliver for the two logical forms in **Figure 2**? First, consider the declarative in **Figure 2*a***. The noun *man* denotes an i-property that maps every individual x to the set of information states in which it is established that x is a man:

(38) $[\![\textit{man}]\!] = \lambda x.\lambda s.\forall w \in s : x \text{ is a man in } w$

Similarly, the sister node of *every man* in **Figure 2*a*** denotes an i-property that maps every x to the set of states in which it is established that x was kissed by exactly one woman:

(39) $\lambda x.\lambda s.\forall w \in s : x \text{ was kissed by exactly one woman in } w$

Applying the function expressed by *every* to these two i-properties, we find that the logical form in **Figure 2*a*** expresses the following i-proposition:

(40) $\left\{ s \;\middle|\; \begin{array}{l} \forall x \in D : \forall s' \subseteq s. \\ \text{if } \forall w \in s' : x \text{ is a man in } w \\ \text{then } \forall w \in s' : x \text{ was kissed by exactly one woman in } w \end{array} \right\}$

This i-proposition can be simplified as follows:

(41) $\left\{ s \;\middle|\; \begin{array}{l} \forall w \in s : \forall x \in D. \\ \text{if } x \text{ is a man in } w \\ \text{then } x \text{ was kissed by exactly one woman in } w \end{array} \right\}$

As desired, this is a downward closed set of information states with a unique maximal element: the set of all worlds in which every man was kissed by exactly one woman.

Now consider the logical form in **Figure 2*b***. In this case, the sister node of *every man* expresses an i-property that maps every individual x to the set of information states in which it is known what x ate:

(42) $\lambda x.\lambda s.\forall w, w' \in s : \text{what } x \text{ ate in } w \text{ is the same as what } x \text{ ate in } w'$

[13] In algebraic terms, $\mathcal{P} \twoheadrightarrow \mathcal{Q}$ is the pseudo-complement of $\mathcal{P}$ relative to $\mathcal{Q}$, that is, the weakest i-proposition $\mathcal{P}'$ such that $\mathcal{P} \cap \mathcal{P}'$ entails $\mathcal{Q}$ (Roelofsen 2013a). Similarly, $p \rightarrow q$ is the pseudo-complement of p relative to q, that is, the weakest classical proposition p' such that $p \cap p'$ entails q. So, from an algebraic perspective, the treatment of *every* given here is exactly the same as the standard treatment (see Ciardelli et al. 2016b for more detailed discussion).

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By applying *every*, we find that the logical form in **Figure 2*b*** expresses the following i-proposition:

$$(43)\quad \left\{ s \;\middle|\; \begin{array}{l} \forall x \in D : \forall s' \subseteq s. \\ \text{if } \forall w \in s' : x \text{ is a man in } w \\ \text{then } \forall w, w' \in s' : \text{what } x \text{ ate in } w \text{ is the same as what } x \text{ ate in } w' \end{array} \right\}$$

What does this mean? Suppose that s is an information state in which it is known exactly which individuals are men. Such a state supports the sentence just in case for each man x, it is known what x ate, as expected. But note that according to our semantics it is also possible for s to support the sentence if it is not known in s which individuals are men. For instance, it may be known in s that all men, whoever they are, ate raspberry pie (and nothing else). In that case, s supports the sentence as well.

Under which circumstances, then, is the sentence not supported by s? This is the case when there is an individual x such that the information available in s, together with the information that x is a man, is not sufficient to establish what x ate. For instance, if we do not know what Robin ate, and when given the information that he is a man we would still not know what he ate, then our information state fails to support the sentence. Of course, this also means that if we do already know that Robin is a man and we do not know what he ate, our information state fails to support the sentence. These predictions seem correct.

4.3.4. Some further empirical issues. Of course, the above analysis is intended as a proof of concept, not a full theory of the interaction between quantifiers and questions. In further developing this approach, it will be particularly important to ensure that it does not overgenerate. For instance, if we switch from *wh*-questions to polar questions, wide-scope readings are no longer available (Chierchia 1993):

(44a) Did every man eat an apple?

(44b) # For every man x: did x eat an apple?

Similarly, if we switch from universals (and perhaps existentials) to other kinds of quantifiers, as in example 45*a*, the reading paraphrased in example 45*b* is not available (as observed by, e.g., Szabolcsi 1997, Krifka 2001):

(45a) Which woman did {most/no/exactly three} men kiss?

(45b) # For {most/no/exactly three} men: which woman did they kiss?

Many quantifiers do, however, permit wide-scope readings if the question that they are part of is embedded under a responsive verb like *know* or *find out* (Szabolcsi 1997):

(46a) Bill found out which woman {most/two/exactly three} men kissed.

(46b) For {most/two/exactly three} men, Bill found out which woman they kissed.

How might these empirical observations be captured? Below, we outline an account of the absence of pair-list readings in matrix polar questions. An investigation of nonuniversal quantifiers must be left for future research.[14]

[14]There are at least two possible strategies to explore. First, the entry for certain nonuniversal quantifiers may be such that the resulting wide-scope reading is always contradictory or tautological. This would be the case, for instance, for quantifiers like *no man* under its most natural treatment in inquisitive semantics (Ciardelli et al. 2016b). Second, certain quantifiers may involve a definedness condition, requiring their input to be a flat i-property. Under such a treatment of, say, *most men*, logical form I*a* would be uninterpretable, whereas logical form I*b* would be

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To explain the contrast between polar and *wh*-questions, suppose (as suggested in Roelofsen 2013b) that questions involve an operator Q of type $\langle \mathtt{T}, \mathtt{T} \rangle$, which does two things.[15] First, Q ensures inquisitiveness. More precisely, if the input i-proposition is not yet inquisitive—that is, if it contains a single alternative—then the complement of this alternative is added. If the input i-proposition is already inquisitive, it is left untouched. Second, Q ensures noninformativeness. This is done by adding a presupposition, to the effect that the actual world is contained in some element of the given i-proposition.

Assume that Q always takes highest scope in its clause. Then the logical form of a polar question and a *wh*-question with a quantifier taking the widest possible scope below Q is as follows:

(47a) [Q [every man [λx [did x kiss Mary]]]]

(47b) [Q [every man [λx [which woman did x kiss]]]]

Assume that [did x kiss Mary] expresses a proposition containing a single alternative,[16] namely the set of all worlds in which x kissed Mary, and that [which woman did x kiss] expresses a proposition containing multiple alternatives, one for each woman y, consisting of all worlds in which y was the unique woman that x kissed. This provides the desired results. No pair-list reading arises in the case of the polar question, because the clause that the quantifier scopes over does not generate multiple alternatives yet (this is done later, by Q, to ensure inquisitiveness). By contrast, a pair-list reading does arise in the case of the *wh*-question, because now the clause that the quantifier scopes over already generates multiple alternatives (and Q only adds the presupposition that every man kissed exactly one woman).

5. CONCLUSION

Our aim in this review has been to lay out a new perspective on modality and quantification, arising from recent research in inquisitive semantics. We have illustrated the benefits of this new perspective in two concrete domains, and have briefly indicated some potential advantages of the approach in other empirical domains. As mentioned at the outset, this review is not intended as a comprehensive literature review but rather as a "programmatic" article, suggesting a path toward more systematic future investigations, which we hope will eventually lead to a deeper understanding of modality, quantification, and inquisitiveness.

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fine because the embedding verb neutralizes the inquisitiveness of its complement before the quantifier is applied:

(Ia) [most men [λx [which woman did x kiss]]] $\rightsquigarrow$ uninterpretable

(Ib) [most men [λx [Bill found out [which woman did x kiss]]]] $\rightsquigarrow$ interpretable

[15] Alternative questions are left out of consideration here because of space constraints, but the account sketched here can be extended to them under natural assumptions.

[16] This assumption can be motivated by considering cases in which polar questions are disjoined with other polar or *wh*-questions (e.g., Roelofsen 2013b).

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