A Multitude of Answers:
Embedded Questions in Typed Inquisitive Semantics

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Nadine Theiler
(born 29 September 1987 in Celle, Germany)

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Members of the Thesis Committee:
Prof Dr Benedikt Loewe (chair)
Dr Maria Aloni
Dr Raquel Fernández Rovira
Prof Dr Jeroen Groenendijk
Dr Floris Roelofsen
Prof Dr Martin Stokhof

INSTITUTE FOR LOGIC, LANGUAGE AND COMPUTATION

Abstract

This thesis develops a semantic account of question embedding. The compositional framework in which this account is formulated is based on inquisitive semantics: it is shown how the inquisitive conception of sentence meaning can be implemented on a type-theoretical level. The resulting framework is motivated on technical and conceptual grounds.

The empirical picture of question embedding is explored, and the different readings exhibited by embedded questions are organised along a set of interpretive features. This determines the desiderata for the subsequent formal implementation. A grammar fragment is devised, which can capture the semantics of interrogative and declarative clauses embedded under responsive verbs: interrogative-embedding and declarative-embedding uses of responsive verbs receive a uniform treatment. The proposed account allows to express several different readings of sentences with embedded questions, deriving the differences between those readings from the interplay between the embedding predicates and various elements in the semantics of the embedded clauses.

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Contents

1 Introduction

This thesis is concerned with the semantics of questions, especially with that of embedded questions. Research in question semantics, however, follows an indirect strategy: its primary objects of investigation are often not the questions themselves but the *answers* to these questions—which are taken to provide a window into the meanings of the questions. Hence, this thesis actually is about the semantics of *answers*, or—more specifically then—of answers to embedded questions. Usually, a sentence with an embedded question expresses that some individual stands in a given relationship to some answer to this question. For example, in (1a) this relation is a *know* relation between Mary and "the" answer to the question which bands are playing tonight; in (1b) it is a *tell* relation between John, Bob and some piece of information that answers both the question who is dating whom and the question who John is planning to ask out.

(1) a. Mary knows which bands are playing tonight.
    b. John told Bob who is dating whom and also whom he was planning to ask out.

Indeed, there are many different kinds of answers—a sheer multitude of them! There are *mention-some* answers and *mention-all* answers, *strongly exhaustive* answers, *weakly exhaustive* answers and of course *true* answers as well as *false* answers. There also is a substantial amount of disagreement which of these notions are the relevant ones; and different authors have provided vastly different answers to this question—again, a sheer multitude of answers! One objective of this thesis is to organise the different notions of answerhood in a perspicuous fashion and thereby facilitate a more systematic analysis.

The focus taken in the pages to come is decidedly semantic, i. e., on the truth-conditional aspects of the question-answer relationship; pragmatic considerations are largely left out. In light of this, limiting our attention to *embedded* questions as opposed to *root* questions is very convenient. For root questions, uttered in a discourse, we cannot determine on a purely semantic basis what counts as a felicitous answer to a given question: there are too many pragmatic factors interfering. Turning to embedded contexts, on the other hand, the questions do not directly constitute utterances in a discourse, but are only indirectly reported. What is more, a statement containing an embedded question will be either true or false. Thus, we are back on familiar, truth-functional grounds and can study the semantics of answers in relative isolation from the pragmatics of question-answer discourse. We will approach sentences like (1a) by asking ourselves things like: what does Mary's knowledge have to be like in order for (1a) to be true? This way, we can examine—through our truth-conditional lens—with which answers to the embedded question or, more generally, with which pieces of information the individual is allowed to enter into the given relation. In a compositional semantics, we further have to assume that questions denote the same semantic object regardless whether they appear in a root or an embedded context. Hence, the above way of examining an *embedded* question will indirectly inform us about what can principally count as an answer to this question *per se*. In the realm of question semantics, embedded questions may thus be regarded as a controlled testbed of sorts.

We will make extensive use of this testbed and eventually—this is the second main objective of this thesis—try to capture our findings within a formal account. The framework of our choice will be inquisitive semantics (see e. g. Ciardelli et al., 2012), which is designed to provide a principled and unified formal footing for the representation of both declarative *and* interrogative sentence meanings. More specifically, we will implement the inquisitive conception of sentence meaning on a type-theoretical level. The resulting framework, called *typed inquisitive semantics*, will allow us to formulate a rather fine-grained and flexible treatment of question embedding.

1.1 Structure of the thesis

This thesis is organised as follows. The remainder of this chapter tells a very brief history of the classical works in question semantics. This overview is by no means comprehensive or up-to-date; it only serves to make available the fundamental concepts needed for the subsequent parts. Chapter 2 will introduce inquisitive semantics. In particular, typed inquisitive semantics ($\mathsf{Inq}^{\lambda}_{\mathsf{B}}$) will be presented, a compositional framework based on the inquisitive understanding of sentence meaning. A small grammar fragment will be specified in this framework, covering root declaratives and root interrogatives. Starting with Chapter 3, the focus will shift to embeddded questions. First, empirical data will be discussed and organised along a set of interpretive features. This will allow us to talk about the different readings of embedded questions in a more systematic fashion and to pinpoint the meanings that our account is expected to produce. Finally, Chapter 4 provides an implementation: the $\mathsf{Inq}^{\lambda}_{\mathsf{B}}$ grammar fragment will be extended to embedded interrogatives and declaratives. Along the way of this implementation, several observations will be made and new predictions will arise. Chapter 5 concludes.

1.2 Classical frameworks for questions semantics

Customary approaches to question semantics, to be discussed in this section, share a fundamental idea: they identify the meaning of a question with its *answerhood conditions*—that is, those conditions under which a given statement counts as an answer to the question.[1] Originally, this strategy is due to Hamblin (1958) and was inspired by the analogous treatment of declarative sentences in formal semantics: knowing the meaning of a declarative is equivalent to knowing under which circumstances the declarative is true (knowing its *truth*

1 The term *answer* is not unproblematic. In fact, it would be safest to postpone its introduction until we can define it with some formal rigour. Due to the intuitive appeal of the term, however, we will not choose this route. Rather, our understanding of what an *answer* is will continuously sharpen as we progress. In this chapter, we use the term in a pre-theoretic way; in Chapter 2 it receives a formal, but not yet very differentiated definition; in Chapter 3 we develop a more fine-grained picture of different kinds of answers; and eventually in Chapter 4 these different answer kinds are formally defined.

conditions). Likewise, knowing what a question means amounts to knowing what it takes for a statement to *answer* the question.

The different approaches come apart, broadly speaking, in two respects. Firstly, they differ in the formal machinery used to express the answerhood conditions. Secondly, different frameworks take different notions of answerhood as the default or the conceptually prior version. This in turn gives rise to subtle conceptual distinctions, which will emerge from the following discussion.

1.2.1 Alternative semantics

Hamblin, in his influential paper from 1973, develops an analysis of questions as sets of their possible answers. This means, the denotation of an interrogative is taken to be a set of propositions, each of which (or a conjunction of which) could be used to answer the question at hand. In the case of a polar interrogative like (2), this set will always contain exactly two elements: an affirmative answer (*Yes, it stopped raining*) and a negative answer (*No, it did not stop raining*).

(2) Has it stopped raining?

In the case of the *wh*-interrogative (3), on the other hand—assuming that Alice, Bob and Mary are the only salient individuals—the answer set would consist of the propositions *that Alice is coming for dinner*, *that Bob is coming for dinner* and *that Mary is coming for dinner*. Note that these answers are not mutually exclusive; it could well be the case that several of Alice, Bob and Mary are coming for dinner.

(3) Who is coming for dinner?

It is clear from (3) that the set of possible answers in the sense of Hamblin can be obtained by instantiating the *wh*-pronoun with all salient individuals from the domain. We will call this set ANS_H for now:

(4) $\text{ANS}_\text{H}(\text{Who is coming for dinner?}) = \{p \mid p = [\![\text{come}(x)]\!]_{\mathcal{M},g[x/\mathbf{d}]} \wedge \mathbf{d} \in D\}$[2]

Indeed, for Hamblin it is the *wh*-element that gives rise to the formation of alternative propositions. In a so-called *Hamblin semantics*, all expressions denote sets. For most kinds of expressions, however, these sets are singleton sets. Only certain elements like *wh*-pronouns denote multi-membered sets (e. g. sets of individuals). Through an amended, pointwise version of functional application, these set-valued meanings are combined compositionally—causing the alternatives introduced by the *wh*-element to percolate upwards in the tree, until, at sentence level, they manifest themselves as alternative propositions.

Karttunen (1977) revises Hamblin's analysis; he includes only *true* answers in the question denotation. His world-relative question meaning ANS_K^w can hence be captured as:

(5) $\text{ANS}_\text{K}^w(\text{Who is coming for dinner?}) = \{p \mid p = [\![\text{come}(x)]\!]_{\mathcal{M},g[x/\mathbf{d}]} \wedge p(w) \wedge \mathbf{d} \in D\}$

2 Where $[\![\alpha]\!]_{\mathcal{M},g}$, the extension of a FOL-formula α relative to a model $\mathcal{M} = \langle D, W, I \rangle$ and a variable assignment g, is defined in a standard way. In particular, for some $\mathbf{d} \in D$, $[\![\text{come}(x)]\!]_{\mathcal{M},g[x/\mathbf{d}]}$ is the set $p \subseteq W$ such that the individual $\mathbf{d}$ is "coming for dinner at all worlds $w \in p$".

In contrast to Hamblin, who focused on root questions, Karttunen mainly considered embedded questions. His restriction to true answers is motivated by certain embedding facts: in (6), the verb *depend* clearly selects for the true answers of *Who else will be there?*; the false ones do not matter. Similarly, to *know-wh* in example (7), according to Karttunen, means knowing the true answers to *Who is coming for dinner?*.

(6) Whether I am coming depends on who else will be there.

(7) John knows who is coming for dinner.

It is however possible to make a point against Karttunen's restriction (Lahiri, 2002; Rullmann and Beck, 1996), since certain verbs are not interpreted relative to only the true answers, but to *all* possible answers: for two people to e. g. *agree-on-wh* it is immaterial whether they are right in their beliefs; it only matters that their beliefs coincide. Sentence (8) can be true even if Alice and Bob wrongly believe that, for example, India has a pacific coast. We will get back to these differences under the heading of *veridicality* in Chapter 3.

(8) Alice and Bob agree on which countries have a pacific coast.

1.2.2 Partition semantics

According to Groenendijk and Stokhof (1982, 1984), the notions of answerhood that Hamblin's and Karttunen's analyses provide are too weak. Groenendijk and Stokhof maintain that, when considering embedding under *know-wh*, the knowledge attributed to an individual seems to encompass information both about those instances that answer the question affirmatively *and* about those that answer it in the negative. To see what this amounts to, first consider Karttunen's definition of knowledge-*wh* in (9): knowing a question α means believing the conjunction of all the propositions in $\text{ANS}_{\text{K}}^{w}(\alpha)$.[3]

(9) $[\![\text{know}(x)]\!]_{\mathcal{M},g,w}(\text{ANS}_{\text{K}}^{w}(\alpha)) = 1$ iff
   1. $[\![\text{believe}(x)]\!]_{\mathcal{M},g,w}(\bigcap\text{ANS}_{\text{K}}^{w}(\alpha)) = 1,$ and
   2. if $\text{ANS}_{\text{K}}^{w}(\alpha) = \emptyset$, then $[\![\text{believe}(x)]\!]_{\mathcal{M},g,w}(\{w' \mid \text{ANS}_{\text{K}}^{w'}(\alpha) = \emptyset\}) = 1$

Recall that $\text{ANS}_{\text{K}}^{w}$ only contains those propositions from ANS_{H}which are true in w. Under this definition, in order to know who is coming for dinner, it suffices to know of all *those* people who *are* actually coming that they are coming. There are two immediate problems with this definition. To begin with, imagine a situation in which Alice is *not* coming, but Bob wrongly believes she is. It seems obvious that in such a situation Bob does not know who is coming. In order to know, he would have to know of each person whether or not she is coming. Under definition (9), Bob would however be predicted to have the respective knowledge-*wh*. We will re-encounter scenarios like this under the heading *intermediate exhaustivity* or *no-false-answers constraint* in Chapter 3.

3 Clause (ii) of (9) applies to *wh*-questions for which there is no instantiation of the *wh*-pronoun that would yield a true statement in the world of evaluation. For example, it would hold that $\text{ANS}_{\text{K}}^{w}$(Who is coming for dinner?)$= \emptyset$ if nobody was coming for dinner. In this case, demanding that x is aware of this fact amounts to requiring he believes the proposition $\{w' \mid \text{ANS}_{\text{K}}^{w'}(\alpha) = \emptyset\}$.

The second problem with Karttunen's notion of knowledge is that it does not license inferences like the following. However, if we assume that John knows what the relevant domain is (and that proper names refer rigidly), then, so Groenendijk and Stokhof argue, (10) constitutes a valid entailment.

(10) John knows who is coming for dinner.
Mary is not coming for dinner.
∴ John knows that Mary is not coming for dinner.

The relevant distinction at this point is that between answers that are *strongly exhaustive* and answers that are merely *complete*, but not strongly exhaustive. *Wh*-questions can be understood in different ways: under a complete interpretation, they ask for a complete specification of which individuals have a certain property. This interpretation is also customarily referred to as the *weakly exhaustive* reading. Under a strongly exhaustive reading, they ask for a complete specification of which individuals have a certain property and also which do *not*. Any strongly exhaustive reading is therefore also a complete reading. A reading that is not complete (and hence not strongly exhaustive either) is usually called a *mention-some* reading. Under this interpretation, it does not take a complete specification of all individuals with a given property to answer the question, but naming a subset of those individuals will suffice. Returning to our dinner example, assume that Alice and Bob are indeed coming for dinner, but not Mary and John. In this situation, (11a-11b) qualify as strongly exhaustive answers to (3), while (11d) only counts as a mention-some answer. The response in (11c), finally, does give a complete list of all individuals who are coming, but does not indicate itself that this list is complete. That is, there is no mentioning of who will not come for dinner. It hence is a weakly, but not a strongly exhaustive answer.

(11) a. Alice and Bob are coming, but Mary and John are not.
$\rightsquigarrow$ complete and strongly exhaustive
b. Only Alice and Bob are coming.
$\rightsquigarrow$ complete and strongly exhaustive
c. Alice and Bob are coming.
$\rightsquigarrow$ complete, not strongly exhaustive (= weakly exhaustive)
d. Bob is coming.
$\rightsquigarrow$ not complete, not strongly exhaustive (= mention-some)

The question whether Karttunen's account can be adapted to yield an acceptable interpretation of *knowing-wh* will be taken up again soon. For now, we turn to the solution proposed by Groenendijk and Stokhof (1982, 1984). To formally represent interrogatives, Groenendijk and Stokhof (1997) use predicate logical sentences of the form $?\vec{x}\varphi$, where ? is a question operator, binding the sequence of variables $\vec{x}$. Under this view, what a question does is to inquire possible instantiations of these bound variables; in the case of a *wh*-question, the variables correspond to the *wh*-phrase(s), and in the case of a polar question, the sequence $\vec{x}$ is empty.

Groenendijk and Stokhof distinguish between the *local* meaning of a question at a given world (the question's *extension*) and its *global* meaning (its *intension*): the extension of a question α relative to a world w is a proposition, viz. the strongly exhaustive answer to α

that is true at w, while the intension of α denotes a *partition* of the logical space such that worlds in the same partition block agree in the extension of α. This is made explicit in (12): $g[\vec{x}]g'$ requires that the assignments g and g' may only differ in the values they assign to the variables $\vec{x}$. Hence, (12a) expresses that $?\vec{x}\varphi$ has the same extension at two worlds w and w' exactly if the same instantiations of $\vec{x}$ make φ true in w and w'.

(12) a. $[\![?\vec{x}\varphi]\!]_{\mathcal{M},g,w} = \{w' \mid \forall g'[\vec{x}]g : [\![\varphi]\!]_{\mathcal{M},g',w'} = [\![\varphi]\!]_{\mathcal{M},g',w}\}$ [extension]

b. $[\![?\vec{x}\varphi]\!]_{\mathcal{M},g} = \{[\![\varphi]\!]_{\mathcal{M},g,w} \mid w \in W\}$ [intension]

For example, assume there are only two relevant individuals, namely Alice and Bob. Thus, depending on who of the two is coming for dinner, the logical space can be divided into four groups: $W_\emptyset$, W_a, W_b and W_{ab}. In all worlds in $W_\emptyset$ nobody is coming for dinner; in all worlds in W_a only Alice is coming and in those in W_b only Bob is coming for dinner; in the worlds in W_{ab} both Alice and Bob are coming. Then, clearly, the four sets are disjoint and together they exhaustively cover the space of possible worlds. This already gives us everything we need both for the extensions and for the intension of *Who is coming for dinner?*. At all worlds $w \in W_\emptyset$, the extension is $[\![?x\,Cx]\!]_{\mathcal{M},g,w} = W_\emptyset$, at all worlds $w \in W_a$, it is $[\![?x\,Cx]\!]_{\mathcal{M},g,w} = W_a$, and so on. The corresponding intension, on the other hand, is simply $[\![?x\,Cx]\!]_{\mathcal{M},g} = \{W_\emptyset, W_a, W_b, W_{ab}\}$.

For Groenendijk and Stokhof, knowing $?\vec{x}\varphi$ amounts to knowing in which partition block of $[\![?\vec{x}\varphi]\!]_{W,g}$ the actual world is situated. Equivalently, an individual y knows $?\vec{x}\varphi$ in w just in case the set of worlds compatible with y's beliefs at w (B^w_y) is a subset of the extension of $?\vec{x}\varphi$ at w.

(13) $[\![\text{know}(y)(?\vec{x}\varphi)]\!]_{\mathcal{M},g,w} = 1$ iff $B^w_y \subseteq [\![?\vec{x}\varphi]\!]_{\mathcal{M},g,w}$

It is clear from this definition that Groenendijk and Stokhof—in contrast to Hamblin and Karttunen—are able to account for the entailment in (10). If John knows who is coming for dinner, this means his beliefs are informative enough to entail a strongly exhaustive answer to the embedded question. Consequently, his beliefs incorporate information both about who is coming and about who is not coming.

1.2.3 Flexible accounts

Groenendijk and Stokhof's perspective is not uncontested, though. A common criticism concerns the fact that their partition analysis is limited to strongly exhaustive answers and does not make any weaker kind of answer available.[4] As pointed out among others by Heim (1994) and Beck and Rullmann (1999), however, there is reason to *not* treat embedded questions as strongly exhaustive across the board. Questions embedded under certain verbs such as *surprise* or *predict* seem to require a reading that is weaker than the strongly exhaustive one. As a point in case, the following example (Beck and Rullmann, 1999, p. 282) for

4 It is worth mentioning however that Groenendijk and Stokhof's analysis allows to define *partial* answers and to draw a distinction between such partial answers and information which is irrelevant to a given question: for a proposition to count as a partial answer, it suffices if this proposition rules out one or more partition blocks. That is, a partial answer is a disjunction of several (true or false) strongly exhaustive answers. Reversely, if a proposition does not rule out any partition cell, it is irrelevant with respect to the given question.

instance can only be sensibly interpreted if the question does not receive a strongly exhaustive reading. For, if it did, both the non-negated interrogative in (14) and its negated version would have the same denotation.

(14) I was better at predicting who would show up than I was at predicting who wouldn't show up.

There are many more things to be said regarding the exhaustive strength of embedded questions and we will return to these matters in detail in Chapter 3. More recent works in question semantics, starting with Heim (1994), usually take such data at face value; they are not limited to just one notion of answerhood, but incorporate answers of several levels of informational strength. One way in which weakly exhaustive and strongly exhaustive answers can be related is based on an insight from Heim. She distinguishes between what she calls answer1, the conjunction of all propositions in Karttunen's question denotation, and answer2, which is the proposition that the answer1 to the given question is the answer1 to that question in the actual world. Since Karttunen's question meaning only contains *true* answers, answer1 is the true complete answer. In contrast, Heim's definition of answer2 includes the information that answer1 is the complete answer, thereby conveying information about possible negative answers as well. Hence, answer2 is strongly exhaustive.

(15) $\mathsf{answer1}_w(\mathrm{ANS}^w_\mathrm{K}(\alpha)) = \bigcap \mathrm{ANS}^w_\mathrm{K}(\alpha)$

(16) $\mathsf{answer2}_w(\mathrm{ANS}^w_\mathrm{K}(\alpha)) = \{w' \mid \mathsf{answer1}_{w'}(\mathrm{ANS}^w_\mathrm{K}(\alpha)) = \mathsf{answer1}_w(\mathrm{ANS}^{w'}_\mathrm{K}(\alpha))\}$

Heim also notes that this derivation only works in one direction: while it is possible to obtain answer2 from answer1, we cannot get back to answer1 from answer2. In this sense—counterintuitively—answer2 contains strictly less information than answer1.

This concludes our very short tour of the landmark works in question semantics. Almost all the concepts introduced in this chapter will be addressed again at some later point of this thesis, and usually in more detail. The following chapter, however, will take a (seemingly untimely) detour into more formal matters and introduce the framework of typed inquisitive semantics. This detour will facilitate subsequent discussion about the empirical picture. While the treatment to be presented in Chapter 2 has a limited coverage and does *not* attempt a comprehensive analysis of all relevant phenomena, in those aspects of question semantics that it does cover, it is formally explicit; and acquainting ourselves with one such fully explicated account will sharpen our understanding of certain rather abstract notions that would be difficult to lay hold of on an intuitive level.

2 Typed inquisitive semantics

Inquisitive semantics (see e. g. Ciardelli et al., 2012, 2013) is a framework for natural language semantics. Importantly, it is *not* a specific theory of any specific phenomenon in any specific natural language. In particular, this means that inquisitive semantics makes available a certain space of meanings and provides a semantics which associates these meanings with formulas in a logical language. What the framework does not specify is *how exactly* these logical formulas correspond to natural language expressions: no compositional translation procedure from natural language to semantic meaning is supplied. This is where the work presented in this chapter comes into play. We will spell out one possible way in which such a translation from natural language expressions to inquisitive meanings can be set up.

With minor changes, this work has already appeared as part of a project report on a research project, which was conducted at the ILLC in the autumn term of 2013 under the supervision of Floris Roelofsen and Ivano Ciardelli (Theiler, 2013).

Inquisitive semantics is based on an enriched notion of sentence meaning: under the inquisitive view, the utterance of a sentence in a discourse is a proposal to change the common ground in one of possibly *many* different ways. Compared to the standard picture in dynamic semantics, which equates semantic content with update potential, the inquisitive conception of sentence meaning is thus more differentiated: it does not reduce this meaning to only *one* unique update, but allows one and the same sentence to express *several alternative* updates. For this reason, the concept of semantic alternatives (Hamblin, 1973), which has been fruitfully explored in formal semantics (a. o. Karttunen, 1977; Rooth, 1985; Kratzer and Shimoyama, 2002; Simons, 2005; Menéndez-Benito, 2005; Alonso-Ovalle, 2006; Aloni, 2007), is quasi *built into* the inquisitive notion of semantic content.

In this chapter, we will show how this fact can be exploited and how a compositional framework for alternative semantics can be constructed based on the inquisitive conception of sentence meaning. This framework will be somewhat akin to those in the spirit of Hamblin (1973), but—as also highlighted in Ciardelli and Roelofsen (2014a)—conceptually more solidly founded and technically less troubled. In particular, the setup of our framework will allow us to retain the standard rules for semantic composition as well as the general type-theoretic notions of entailment and conjunction.

Here, we will eventually formulate a small fragment of English, covering both root declaratives and root interrogatives. In Chapter 4, this fragment will be extended to embedded clauses. Before taking up this work, however, we first introduce the central ideas of inquisitive semantics and present an inquisitive semantics for first-order logic as an illustration (Section 2.1). Subsequently, these ideas will be translated into a type-theoretical setting (Section 2.2) and it will be demonstrated how this system can handle a range of empirical phenomena. Finally, the compositional inquisitive framework will be compared with other alternative semantics systems in the tradition of Hamblin semantics[1] (Section 2.3).

2.1 Basic inquisitive semantics

2.1.1 The inquisitive conception of sentence meaning

In formal semantics, the meaning of a sentence is classically modelled as a set of possible worlds—namely those worlds that are compatible with the statement made by the sentence. In a dynamic framework, this conception directly relates to updating the common ground, which itself is modelled as a set of worlds—namely those worlds compatible with what is commonly known among the discourse participants. Adding new information to the common ground then amounts to eliminating from it all worlds that are not contained in the proposition[2] expressed by the sentence.

Inquisitive semantics departs from this picture: The meaning of a sentence is perceived not as a direct update of the common ground, but as a *proposal* to do so in one of possibly many different ways. Under this view, a sentence denotes a set of alternative *states*, which are themselves sets of worlds. Each of these states represents one possible way of changing the common ground; and other discourse participants are invited to choose among them. While an utterance like (17) specifies just one possible way of enhancing the common ground (namely with the piece of information that John is coming), (18) leaves a choice between several alternative updates (if the domain of discourse consists of e. g. only Mary and John, this choice is between updating with the information that Mary is coming, that John is coming, that both of them are coming or that neither of them is coming).

(17) John is coming for dinner.

(18) Who is coming for dinner?

Utterances are conceived as having a two-fold effect: the speaker can use them both to *convey* information and/or to *request* information. As in the classical setting, conveying information amounts to locating the actual world w_0 in a subset of all possible worlds. We will return to the corresponding notion of a sentence's *informative content* in Section 2.1.3; what interests us at this point is the *requesting* of information.

If a speaker requests information, this means he asks the other discourse participants to locate the actual world more precisely within the already established common ground. More specifically, through an utterance of ϕ, he invites a reply that locates w_0 in one of the states in the denotation of ϕ. Any reply meeting this request will be said to *resolve* or *settle*

1 We will use the term *Hamblin semantics* in a very general sense to refer to all frameworks for alternative semantics whose technical essence is based on Hamblin (1973).

2 The way in which the term *proposition* is used in inquisitive semantics deviates from the standard usage of this term. To preserve clarity, throughout this thesis, *proposition* will only refer to the classical understanding of a proposition as a set of worlds. In an inquisitive context, this term will be avoided altogether. Instead, we will just talk about *sentence meaning* or about the *denotation* of a sentence. Forestalling a bit, the sets of worlds contained in an inquisitive sentence meaning will be called *states*. The maximal elements among these states will be referred to interchangeably as *possibilities* or *alternatives*. Additionally, however, *alternatives* will be used in the sense of *Hamblin alternatives*. Which sense applies, should either emerge from the context or be negligible.

the issue raised by ϕ. It is clear that, if a piece of information resolves an issue, then a more informative piece of information will also resolve this issue. Translated into the inquisitive setting: if locating w_0 in a state s in the meaning of ϕ resolves the issue raised by ϕ with sufficient precision, then locating w_0 in a subset $t \subseteq s$ will be precise enough too. This is one of the reasons why inquisitive semantics construes sentence meanings not just as sets of states, but as *downward-closed* sets of states: if a state is contained in a meaning, then all its subsets will be too. The maximal elements among the states are called *possibilities* or *alternatives*; they correspond to the information *minimally* required to settle the issue.

In this sense, possibilities can be taken to constitute something like *minimally informative* resolving information states—a concept similarly also found in frameworks for alternative semantics in the spirit of Hamblin (1973), where they are called *basic answers*. In this regard, there seems to be a close connection between inquisitive and Hamblin frameworks. But although their respective notions of what constitutes an answer can be made to coincide, both systems approach the concept of answerhood from different angles. Hamblin semantics takes the notion of basic answers as conceptually prior, while in inquisitive semantics, it is the notion of resolution which is conceptually prior and from which the notion of answerhood is derived. This lends a certain flexibility to the inquisitive system—which will become especially clear once we define answer operators to "extract" different kinds of answers from a question denotation (Section 4.4). Within the scope of this chapter, however, *answer* will be used as an umbrella term—for now synonymous with *resolving information state*—and will encompass very different types of answers. In Chapter 3, this term will be further differentiated into e. g. *complete* answers, *exhaustive* answers, *basic* answers, *true* and *false* answers. Crucially, through these differentiations, some concepts of answerhood will become world-dependent: what is a *true* answer at some world, for instance, might be a *false* one at some other world. In Chapter 4, finally, all these distinctions will be made formally precise within typed inquisitive semantics.

2.1.2 An inquisitive semantics for predicate logic

We start by looking at a basic inquisitive semantics (the so-called system $\mathsf{Inq_B}$) for propositional logic. In due course, it will be extended to the first-order setting. Importantly, note that this semantics merely serves as an *illustration* of the ideas underlying inquisitive frameworks. It will *not* be used in the eventual type-theoretical system, called $\mathsf{Inq}^{\lambda}_{\mathsf{B}}$. However, the setup of $\mathsf{Inq}^{\lambda}_{\mathsf{B}}$ will be directly influenced by the same conception of sentence meaning that is also the basis for the $\mathsf{Inq_B}$-semantics. Many of the type-theoretical lexical entries we devise in Section 2.2 will therefore be strongly reminiscent of the clauses below.

In (19), the inquisitive meaning $[\phi]$ of a propositional sentence ϕ is defined recursively, making use of basic algebraic operations (Roelofsen, 2013). We will leave most clauses uncommented and mostly focus on the atomic case and the semantics for disjunction. In particular, we will not expand on the clause for implication.[3] For a detailed exposition of $\mathsf{Inq_B}$, the reader is referred to Ciardelli et al. (2012).

3 The $\Rightarrow$-operation used in that clause denotes *relative pseudo-complementation*, which in our setting can be defined the following way: $A \Rightarrow B = \{s \mid \text{for every } t \subseteq s, \text{ if } t \in A \text{ then } t \in B\}$.

(19) Inquisitive semantics for a propositional language
1. $[p] := \wp(|p|)$
2. $[\bot] := \{\emptyset\}$
3. $[\phi \wedge \psi] := [\phi] \cap [\psi]$
4. $[\phi \vee \psi] := [\phi] \cup [\psi]$
5. $[\phi \rightarrow \psi] := [\phi] \Rightarrow [\psi]$
6. $[\neg\phi] := [\phi]^* = \wp(\overline{\bigcup[\phi]})$

There are two things to say about the **atomic case**. Firstly, note that in order for a set of worlds to be contained in $[p]$, p has to be true at every world in that set. We will use this insight extensively when defining type-theoretical translations in Section 2.2. Secondly, the denotation of p comprises the truth set for p *as well as* all subsets of this truth set. Through the recursive definition of the non-atomic cases, this *downward-closedness* pertains to inquisitive sentence meanings in general. It is an important design feature of certain inquisitive systems—having repercussions on the treatment of many sentence connectives. We will discuss this in detail when comparing Hamblin and inquisitive frameworks in Section 2.3.

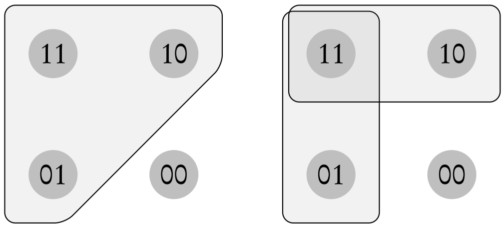
The treatment of **disjunction** is the decisive feature of $\mathsf{Inq_B}$that gives rise to the formation of alternative states. We obtain the denotation of a disjunction $\phi \vee \psi$ simply by taking the union of the denotations $[\phi]$ and $[\psi]$. Since these are sets of world-sets, their union will be, too. To see how this treatment differs from that in classical logic, consider the classical notion of the *truth set* of a sentence ϕ: it is the set of all worlds in which ϕ is classically true. If worlds are represented as propositional valuation functions v, then this amounts to the following definition.

(20) $|p| = \{v \mid v(p) = 1\}$

Now, in order to form the classical truth set $|\phi \vee \psi|$ of a disjunction, we take the union $|\phi| \cup |\psi|$ of the disjuncts' truth sets. Hence, $|\phi| \cup |\psi|$ is plainly a set of worlds without any further structure imposed on it. In contrast, the union $[\phi] \cup [\psi]$ of two denotations in inquisitive semantics is a set of *sets* of worlds. It has an internal structure with (usually) at least two alternatives.

This difference becomes clear from Figure 1, where both a classical truth set $|p \vee q|$ and an inquisitive sentence meaning $[p \vee q]$ are depicted. To keep pictures like Figure 1a simpler, all states are left out from the picture that are properly contained in another state; only the possibilities, i. e. the maximal states, are depicted. Comparing figures 1a and 1b, notice that the truth set has no internal structure, while the inquisitive meaning contains two separate world-sets: one such that in all contained worlds p holds, and likewise one for q.

Turning to the clause for **negation**, however, it is this same internal structure of inquisitive meanings which complicates matters somewhat. While, in the classical setting, negation simply amounts to taking the complement set of the original proposition, here, this does not yield the desired results: $\overline{[\phi]}$, of course, contains all world-sets not in $[\phi]$—even those that have worlds in common with some state in $[\phi]$. What we are after for the meaning of $\neg\phi$ instead, is the set of only those states that do not have *any* overlap with states in $[\phi]$. This set can be obtained through the algebraic operation of *pseudo-*



(a) $|p \vee q|$ (b) $[p \vee q]$

Figure 1: Classical and inquisitive treatment of disjunction.

complementation: $[\neg\phi] = [\phi]^* = \wp(\overline{\bigcup[\phi]})$. Also note that, given this definition, a negated sentence will always only contain a single possibility.

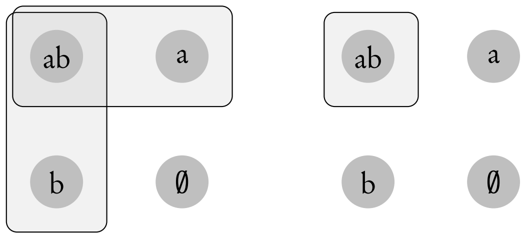
Making only a few modifications, the semantics in (19) can be lifted to suit a first-order language: Possible worlds are no longer valuations, but FOL-models consisting of an interpretation function I and a domain D, where this domain is the same at every possible world. The definition of a truth set changes accordingly. The atomic clause is substituted by the analogous one below, and clauses for the quantifiers are added. For us, it is important to observe that the existential quantifier is treated in terms of a large disjunction—with each disjunct corresponding to one way of instantiating the variable with an individual from the domain. Due to this disjunctive semantics, the meaning of existentially quantified sentences often contains more than one possibility.[4] Analogously, the universal quantifier is treated in terms of a large conjunction. Whether the denotation of a universally quantified sentence $\forall x\phi(x)$ contains more than one possibility, depends on the nature of ϕ; in contrast to existential quantification, universal quantification itself does not create different states in the denotation of the quantified sentence.

(21) Inquisitive semantics for a first-order language
  1'. $[R(t_1,\ldots,t_n)] := \wp(|R(t_1,\ldots,t_n)|)$
  7. $[\forall x\phi(x)] := \bigcap_{d\in D}[\phi(\overline{d})]$[5]
  8. $[\exists x\phi(x)] := \bigcup_{d\in D}[\phi(\overline{d})]$

To see the connection even more clearly, take each world to be a FOL-model. Further let the domain $D = \{a,b\}$ be shared by all such models. Then, $[\exists x P(x)]$ can be depicted in just the same way as $[p \vee q]$ in Figure 1b above (repeated here in Figure 2a): in world $\mathscr{M}_{ab} = \langle D, I_{ab}\rangle$, both $a \in I_{ab}(P)$ and $b \in I_{ab}(P)$; in world $\mathscr{M}_a = \langle D, I_a\rangle$, only $a \in I_a(P)$,

4 This is not *always* the case, though: if the domain contains only one individual, there will clearly be only one possibility; and, more interestingly, if there are no maximal states in the sentence denotation, there will not be any possibilities at all (see Ciardelli, 2010).

5 We assume that, for any $d \in D$, our FOL-language contains an individual constant $\overline{d}$ such that, for any interpretation I, $I(\overline{d}) = d$. If necessary, we add new constants to the language, and we expand I accordingly. Nothing hinges on these details; the semantics could also be defined in terms of assignments. Here, it simply makes the transition from the propositional setting easier: we do not have to redefine the entire semantics relative to an assignment.



(a) $[\exists x P(x)] = [Pa \vee Pb]$ (b) $[\forall x P(x)] = [Pa \wedge Pb]$

Figure 2: Existential and universal quantification

but $b \notin I_a(P)$; and so on. Thus, the two possibilites for $\exists x P(x)$ directly correspond to two ways of instantiating the existential statement. The denotation of $\forall x P(x)$ on the other hand contains only one possibility, namely the intersection of all possibilities for $\exists x P(x)$. We will make use of this view on quantification when defining translations for various natural language expressions in the next section.

2.1.3 Informativeness and inquisitiveness

As already outlined above, we conceive utterances in a discourse as having a two-fold effect: on the one hand, the speaker can *convey* information; on the other hand, she can *request* information. With notions like sentence meaning and alternatives now in place, it is easy to formally describe this double sidedness.

Conveying information amounts to locating the actual world w_0 in a subset of all possible worlds. By uttering ϕ, a speaker expresses that w_0 is located in at least one of the states in $[\phi]$, that is, within $\bigcup[\phi]$. We call this union the *informative content* $\mathsf{info}(\phi)$ of ϕ.

(22) $\mathsf{info}(\phi) = \bigcup[\phi]$

In contrast, if a speaker requests information, he asks the other discourse participants to locate w_0 more precisely within $\mathsf{info}(\phi)$, namely, to locate it in one of the states in $[\phi]$.

This conception suggests a natural way to characterise sentences along two dimensions: *inquisitiveness* and *informativeness*. We call a sentence ϕ *inquisitive* if its informative content $\mathsf{info}(\phi)$ is not contained in $[\phi]$. Intuitively, such a sentence requests information, but does not provide enough information itself to satisfy this request. Any sentence whose meaning contains at least two possibilities is inquisitive.[6] Along with inquisitiveness comes the related notion of *informativeness*: intuitively, an informative sentence is one that conveys new information. Formally, this means it has the potential to eliminate worlds from the common ground. For a sentence ϕ to have this potential, $\mathsf{info}(\phi)$ must be a proper subset of the set of all possible worlds ω.

6 However, the converse does not hold (Ciardelli, 2009, 2010).

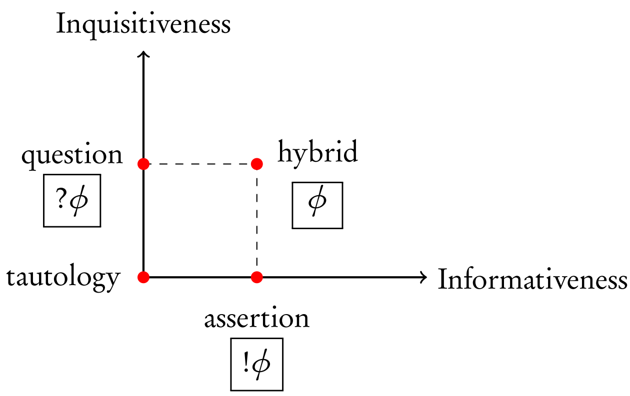


Figure 3: The different sentence types in a two-dimensional space

(23) ϕ is *inquisitive* iff $\text{info}(\phi) \notin [\phi]$.
ϕ is *informative* iff $\text{info}(\phi) \neq \omega$.

It is important to note that this distinction is just a terminological one and does not determine any specific discourse-theoretical interpretation of inquisitiveness. Here, we will endorse what has been coined the *strong* perspective on inquisitiveness (Ciardelli et al., 2012): in uttering a sentence ϕ, a speaker *always* requests a response which contains sufficient information to locate the actual world in one of the states in $[\phi]$. If ϕ is not inquisitive to begin with, this locating-task is trivial, and the utterance does not "actually" request information.

As illustrated in Figure 3, the binary properties inquisitiveness and informativeness span a two-dimensional space. Four different types of sentences can be distinguished in this space: *questions*, which are non-informative, *assertions*, which are non-inquisitive, *hybrids*, which are both informative and inquisitive, and finally *tautologies*, which are neither.

(24) ϕ is a question iff $\text{info}(\phi) = \omega$.
ϕ is an assertion iff $\text{info}(\phi) \in \omega$.

Observe that this way of characterising assertions and questions (namely in terms of inquisitiveness and informativeness) makes reference to *semantic* concepts. It is also possible, however, to give conditions for assertionhood and questionhood that are based on *syntactic* criteria. The following are examples of syntactic conditions sufficient for assertionhood.

(25) Sufficient conditions for assertionhood:
1. An atomic sentence $R(t_1, \ldots t_n)$ is an assertion;
2. $\bot$ is an assertion;
3. if ϕ and ψ are assertions, then so is $\phi \wedge \psi$;
4. if ψ is an assertion, then so is $\phi \rightarrow \psi$ for any sentence ϕ;
5. if $\phi(\overline{d})$ is an assertion for all $d \in D$, then so is $\forall x \phi(x)$.

Recall that a negation $\neg\phi$ is defined as an abbreviation for $\phi \rightarrow \bot$. With conditions 2 and 4, it immediately follows from this that negations are assertions:

(26) $\neg\phi$ is an assertion for any ϕ.

Analogously, we can give some sufficient syntactic conditions for questionhood.

(27) Sufficient conditions for questionhood:
1. Any classical tautology is a question;
2. if ϕ and ψ are questions, so is $\phi \wedge \psi$;
3. if ψ is a question, then for any ϕ so are $\phi \vee \psi$ and $\phi \rightarrow \psi$;
4. if $\phi(\overline{d})$ is a question for all $d \in D$, then so is $\forall x \phi(x)$;
5. if $\phi(\overline{d})$ is a question for some $d \in D$, then so is $\exists x \phi(x)$.

2.1.4 Declarative and interrogative projection

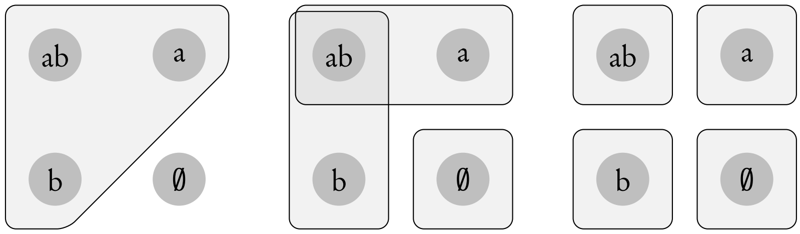
Under the threefold categorisation of sentences into questions, assertions and hybrids, our introductory example, $\phi := p \vee q$, is a hybrid. Turning it into a question can be thought of as projecting it onto the inquisitiveness axis; turning it into an assertion analogously as a projection onto the informativeness axis. We add operators ? and ! to our logical language, and denote the non-informative (*interrogative*) projection as $?\phi$, the non-inquisitive (*declarative*) projection as $!\phi$.

We already know a way to obtain the declarative projection $!\phi$: the informative content $\mathsf{info}(\phi)$ contains exactly those worlds in which ϕ holds. The powerset $\wp(\mathsf{info}(\phi))$ therefore conveys exactly the same information as $[\phi]$—without however being inquisitive. Roelofsen (2013) shows that $\wp(\mathsf{info}(\phi))$ indeed is the only way to define the declarative projection that satisfies these criteria (preservation of informative content, non-inquisitiveness). We add the following clause to the existing semantics in (21).

(28) Semantics of the declarative projection:
9. $[!\phi] := \wp(\mathsf{info}(\phi))$

For the interrogative projection, we need to (i) turn a sentence ϕ into a question, that is, a non-informative sentence—while (ii) preserving its inquisitive content *as much as possible*. Roelofsen (2013) shows that these criteria uniquely determine how the interrogative projection has to be defined. To accomplish (i), we have to ensure that $\mathsf{info}(\phi) = \omega$. This also means, however, that the interrogative projection cannot just leave the inquisitive content completely unaltered. Recall that the informative content is defined as $\mathsf{info}(\phi) = \bigcup[\phi]$. Thus, if we augment the informative content, the inquisitive content will necessarily change with it. What we *can* do, though, is to keep intact the *decision set* of ϕ, i. e., the set of those pieces of information which *decide* on the issue raised by ϕ. A piece of information is said to decide on an issue if it either resolves the issue (by locating the actual world in one of the states in $[\phi]$) or *dismisses* it (by locating the actual world outside of any state in $[\phi]$). Hence, we need to define the interrogative projection $?\phi$ in such a way that a piece of information decides on the issue raised by $?\phi$ just in case it decides on the issue raised by ϕ.

Locating the actual world outside the possibilities in $[\phi]$ means locating it in one of the states in $[\neg\phi] = [\phi]^*$. Taking the union of $[\phi]$ and $[\phi]^*$ therefore allows us to obtain a set of possibilities which exhaustively covers ω while also preserving the decision set of ϕ.



(a) $[!\exists x P(x)]$ (b) $[?\exists x P(x)]$ (c) $[\forall x ? P(x)]$

Figure 4: Informative and interrogative projections in combination with quantifiers

(29) Semantics of the interrogative projection:
9. $[?\phi] := [\phi \vee \neg\phi] = [\phi] \cup [\phi]^*$

There is a natural way to strengthen the interrogative projection, namely by universal quantification: $\forall x ? \phi(x)$ denotes a partition on ω such that, within each block of this partition, exactly the same individuals have property ϕ. We can hence understand $\forall x ? \phi(x)$ as a more demanding question than $?\phi$; it asks for an exhaustive specification of the property ϕ.

Wrapping up this brief introduction to inquisitive semantics, the interplay of different projection operators and quantifiers is exemplified in Figure 4. We will encounter type-theoretical counterparts of these constructions when computing the meaning of declarative and interrogative natural language sentences in the next section.

2.2 Typed basic inquisitive semantics

We will now start to define a small fragment of English in a framework to which we will refer as *typed basic inquisitive semantics*, short $\mathsf{Inq}^\lambda_\mathsf{B}$. In detail, we will spell out a two-step approach towards a compositional semantic treatment of natural language: first, English sentences are *translated* to an intensional type-theoretic language; then, the expressions in this language receive a model-theoretic *interpretation*. Crucially, it is only the first step whose implementation reflects the inquisitive notion of meaning; the model-theoretic interpretation in the second step proceeds classically. Our models $\mathcal{M} = (D, W, I)$ for the intensional type-theoretical language consist of a non-empty domain D, a non-empty set of possible worlds W and an interpretation function I. All worlds share domain D. For syntax and semantics of the intensional theory of types, see appendix B.[7]

The grammar fragment we define here will be limited to root declaratives and interrogatives. In Chapter 4, the coverage will be extended to embedded clauses.

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7 When writing expressions in the type-theoretic language, we will employ the customary abbreviations. E. g., we will write $\lambda X.\lambda Y.X \cap Y$ instead of $\lambda X.\lambda Y.\lambda x.X(x) \wedge Y(x)$ or $\forall x \in X : (P(x))$ instead of $\forall x(X(x) \to P(x))$.

Alternative-generating expression	can appear in the scope of...
someone	$\boxed{!}$
who, which	$\boxed{?}$
or	no restrictions

Table 1: Constraints on the distribution of alternative-generating expressions

2.2.1 Lexicon and fundamentals

Before we get started, we state a couple of syntactic (and otherwise) assumptions. $\mathsf{Inq}_\mathsf{B}^\lambda$ contains a set of elements which take care of the generation or evaluation of semantic alternatives. Accordingly, these elements can be divided in *alternative-generating* expressions and *alternative-evaluating* operators. What exactly this means, will become clear in due course. Among the alternative-generating expressions, it is especially the pronouns *someone* and *who* that are of interest to us. The two alternative-evaluating operators are the $\boxed{!}$ and $\boxed{?}$. The former of these essentially is the $[\exists]$ operator in Kratzer and Shimoyama (2002); the latter—albeit technically different—is in the same spirit as Kratzer and Shimoyama's $[Q]$ operator. We assume that declaratives contain an instance of the covert syntactic marker $\text{M}_!$, situated at the top of their syntactic structure, and that interrogatives contain an instance of the covert syntactic marker $\text{M}_?$ at the same position. Semantically, these markers contribute the operators $\boxed{!}$ and $\boxed{?}$ respectively. So, $\boxed{!}$ will always apply at the top of a declarative clause. Additionally, however, it can apply at subclausal nodes of type $\langle\langle s,t\rangle,t\rangle$[8]. In contrast, $\boxed{?}$ can only apply at the top of an interrogative clause, when contributed by $\text{M}_?$. The alternative-evaluating operators constrain the distribution of alternative-generating expressions: *who* and *which* can only appear in the immediate scope of $\boxed{?}$, while *someone* can only appear in the immediate scope of $\boxed{!}$ (see Table 1). Note that this does not mean *someone* cannot appear in interrogatives; it only means that the *first* alternative-evaluating operator which *someone* meets in the derivation must be $\boxed{!}$. Likewise, the first alternative-evaluating operator that *wh*-pronouns encounter has to be $\boxed{?}$; and if necessary, they will undergo movement to achieve the required scope configuration (30). For an account that follows work in the minimalist generative tradition and spells out the above restrictions in terms of feature-checking, see Kratzer and Shimoyama (2002) and Kratzer (2005).

(30) Who gave someone what?
$\boxed{?}$ [who$_2$ [what$_1$ [$\boxed{!}$ [t_2 gave someone t_1]]]]

We start in the thick of things and directly specify the grammar fragment (that is, the translation function *Tr* from natural language to type-theoretical logical language) to be used in the rest of this thesis. We then spell out the rationale behind it and explain some of the trans-

8 Later abbreviated as type T.

lations in detail. The grammar will be able to handle the following range of constructions and phenomena:

1. declaratives (*John smiled*, *John saw Mary*)
2. negated declaratives (*John did not smile*, *John did not see Mary*)
3. *wh*-questions (*Who smiled?*, *Who saw Mary?*), including in-situ *wh*-questions (*Mary saw whom?*) and multiple *wh*-questions (*Who saw whom?*)
4. polar questions (*Did John call?*)
5. inverse quantifier scope (*Some students were assigned to every project*)
6. bound variable pronouns (*Everybody phoned his mother*)

Lexical entries for all the relevant syntactic categories are listed in Table 2.[9] Although we will see that the system at hand produces results in the spirit of an alternative semantics, no

9 The $\boxed{\neg}$ denotes a type-theoretical version of inquisitive negation, which will be introduced in Section 2.2.2.1.

cat.	α	$Tr(\alpha)$	type
PN	John	$\mathbf{j}$	e
DP	he$_i$/t_i	x_i	e
CN	man	$\lambda x_e.\lambda p_{\langle s,t\rangle}.\forall w \in p : man(w)(x)$	$\langle e, T\rangle$
IV	smiled	$\lambda x_e.\lambda p_{\langle s,t\rangle}.\forall w \in p : smile(w)(x)$	$\langle e, T\rangle$
TV	saw	$\lambda x_e.\lambda y_e.\lambda p_{\langle s,t\rangle}.\forall w \in p : see(w)(x)(y)$	$\langle e,\langle e, T\rangle\rangle$
DP	who	$\lambda P_{\langle e,T\rangle}.\lambda p_{\langle s,t\rangle}.\exists x P(x)(p)$	$\langle\langle e, T\rangle, T\rangle$
DP	someone	$\lambda P_{\langle e,T\rangle}.\lambda p_{\langle s,t\rangle}.\exists x P(x)(p)$	$\langle\langle e, T\rangle, T\rangle$
DP	everybody	$\lambda P_{\langle e,T\rangle}.\lambda p_{\langle s,t\rangle}.\forall x P(x)(p)$	$\langle\langle e, T\rangle, T\rangle$
DP	nobody	$\lambda P_{\langle e,T\rangle}.\lambda p_{\langle s,t\rangle}.\boxed{\neg}\exists x P(x)(p)$	$\langle\langle e, T\rangle, T\rangle$
D	a	$\lambda P_{\langle e,T\rangle}.\lambda P'_{\langle e,T\rangle}.\lambda p_{\langle s,t\rangle}.\exists x(P(x)(p) \wedge P'(x)(p))$	$\langle\langle e, T\rangle,\langle\langle e, T\rangle, T\rangle\rangle$
D	which	$\lambda P_{\langle e,T\rangle}.\lambda P'_{\langle e,T\rangle}.\lambda p_{\langle s,t\rangle}.\exists x(P(x)(p) \wedge P'(x)(p))$	$\langle\langle e, T\rangle,\langle\langle e, T\rangle, T\rangle\rangle$
C	and	$\lambda X_T.\lambda Y_T.X \cap Y$	$\langle T,\langle T, T\rangle\rangle$
C	or	$\lambda X_T.\lambda Y_T.X \cup Y$	$\langle T,\langle T, T\rangle\rangle$
Neg	not	$\lambda X_T.\lambda p_{\langle s,t\rangle}.\boxed{\neg}X(p)$	$\langle T, T\rangle$

Table 2: Exemplary translations with their types

special rules are needed to compute the meaning of a sentence; the derivation is driven by the ordinary rules for *functional application* and *predicate abstraction* in (31) and (32).

(31) **Functional application (FA):**
If α is a branching node and $\{\beta, \gamma\}$ the set of its daughters, then $Tr(\alpha)$ is defined if $Tr(\beta)$ and $Tr(\gamma)$ are defined and $Tr(\beta)$ is of type $\langle\sigma, \tau\rangle$ and $Tr(\gamma)$ is of type σ. In this case, $Tr(\alpha) = Tr(\beta)(Tr(\gamma))$.

$$Tr(\alpha) = Tr(\beta)(Tr(\gamma)) :: \tau$$
$$Tr(\beta) :: \langle\sigma, \tau\rangle \qquad Tr(\gamma) :: \sigma$$

Functional application is the default case of semantic composition: The translation $Tr(\beta)$ of a subtree is applied to the translation $Tr(\alpha)$ of its sister subtree. Which subtree acts as the function and which as the argument is determined by their types. In contrast, predicate abstraction is triggered by the presence of an index λ_i in the syntactic structure: all free occurrences of the variable x_i within $Tr(\beta)$ are λ-bound.

(32) **Predicate abstraction (PA):**
If α is a branching node whose daughters are the movement index λ_i and β, then $Tr(\alpha)$ is defined if $Tr(\beta)$ is defined. In this case, $Tr(\alpha) = \lambda x_i.Tr(\beta)$.

$$Tr(\alpha) = \lambda x_i.Tr(\beta) :: \langle e, \tau\rangle$$
$$\lambda_i \qquad Tr(\beta) :: \tau$$

2.2.1.1 Sentences

As we have seen above, in inquisitive semantics the meaning of a sentence is represented as a set of states, i. e. a set of sets of worlds. In terms of semantic types, this means that sentences have type $\langle\langle s, t\rangle, t\rangle$. We will abbreviate this type as T.

While this notion of alternativehood at sentence level is roughly shared by both inquisitive and Hamblin semantics, we will see that *compositionally* it comes about somewhat differently in either system. In Hamblin semantics, all expressions denote sets, most of which are singleton sets. It is only certain quantification-like elements such as *wh*-phrases that translate as multi-membered sets (in the case of *wh*-phrases, as sets of individuals). Through a special, pointwise version of functional application, these sets are combined to compute the entire sentence-meaning. This way, the alternatives percolate upwards in the tree.

In inquisitive semantics, on the other hand, the conception of sentence meanings as sets of alternative states lies at the very foundation of the logical framework, predetermining the way in which we will capture the meaning of a sentence. For the type-theoretic system laid out here, one might even say that the only "meaningful" alternativehood exists at sentence level. The denotations of all subexpressions derive from that sentence-meaning. But let us now see what this means in practice.

Recall from Section 2.1.1 that the denotation of a sentence $R(t_1, \ldots, t_n)$ contains all subsets of $|R(t_1, \ldots, t_n)|$. Accordingly, we now let a sentence denote all those states p in which the predication expressed by the sentence holds at every $w \in p$. For example, the sentence *John smiled* denotes the set of all states p such that John smiled in every world in p. Once this denotation is pinpointed, the translations of the subexpressions fall into place, too.

(33) $Tr(\text{John smiled}) = \lambda p_{\langle s,t\rangle}.\forall w \in p : smile(w)(\mathbf{j})$

2.2.1.2 Verbs

Intransitive verbs like *smile* need to combine with an individual to form a sentence. This means they have type $\langle e, T\rangle$. Their denotation differs from that of the entire sentence only in so far that the subject variable is lambda-bound:

(34) $Tr(\text{smiled}) := \lambda x_e.\lambda p_{\langle s,t\rangle}.\forall w \in p : smile(w)(x)$

Analogously, transitive verbs, expecting two individuals, are of type $\langle e, \langle e, T\rangle\rangle$:

(35) $Tr(\text{saw}) := \lambda x_e.\lambda y_e.\lambda p_{\langle s,t\rangle}.\forall w \in p : see(w)(x)(y)$

The type conflict that would ensue through quantified DPs in object position is circumvented by assuming that these DPs move out of the VP to a landing site just above the subject. Their movement index triggers a predicate abstraction, ensuring that the displaced constituent fills in the object argument slot (see Section 2.2.4).

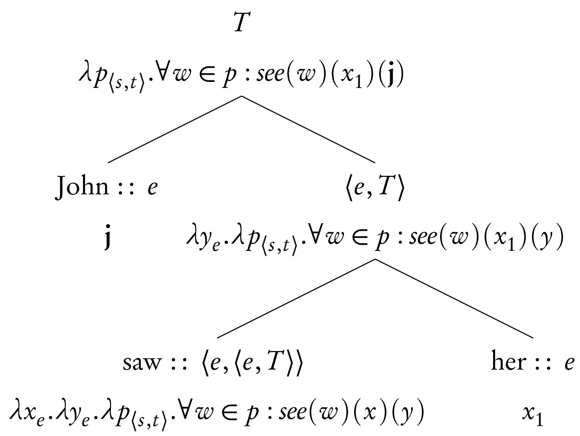
2.2.2 Declaratives

2.2.2.1 Declaratives with e-type DPs

The translations of all DP-like constituents fall into two categories, depending on their semantic type. While proper names and pronouns are directly translated as logical constants and variables of type e, quantifiers, *wh*-phrases and actual determiner phrases have denotations of type $\langle\langle e, T\rangle, T\rangle$.

In order to see how the grammar up to now can handle simple declaratives with e-type DPs, consider the following derivation. Note that the sentence meaning only contains a single possibility, namely the classical truth set of the sentence.

(36) John saw her.



Turning to *negated* declaratives, matters become a little more complicated. Uttering (37), a speaker provides the information that the actual world is not located in any state such that John smiled in every world in that state. The speaker does not, however, request any information beyond that. Hence, a negated sentence is not inquisitive.

(37) John did not smile.

Recall that negation in $\mathsf{Inq_B}$ cannot simply be treated as the complement set of the original denotation. Analogously, we cannot naively translate sentence level negation as the set $\lambda X_T.\lambda p_{\langle s,t\rangle}.\neg X(p)$, since this term would also yield world-sets overlapping with states in X, while what we want is only those world-sets which are completely disjoint from any set in X. As in $\mathsf{Inq_B}$, we hence need to form the pseudo-complement of X, that is, the set $\wp(\overline{\bigcup X})$. Exactly this is done in (38).

(38) $\boxed{\neg} := \lambda X_T.\lambda p_{\langle s,t\rangle}.\forall w \in p : \neg\exists q \in X : q(w)$

(39) $Tr(\text{not}) := \lambda X_T.\lambda p_{\langle s,t\rangle}.\boxed{\neg}X(p)$[10]

In order to keep the translations more readable, we will employ a number of inquisitive operators and connectives in our type-logical language that are not part of the syntax of that language, but only serve to abbreviate longer λ-expressions. The first such operator is $\boxed{\neg}$ in (38), denoted by a boxed version of its analogue in $\mathsf{Inq_B}$. We will stick to this notational convention with the following operators as well.

Finally, the example derivation illustrates how this operator is put to use. To get accustomed to the notation, here, both the $\boxed{\neg}$-abbreviated and the unabbreviated variant of the translations are spelled out. In later examples, we will settle with only the abbreviated notation. Also note that, indeed, the translation of (40) only contains a single possibility (this might be easier to observe when thinking of $\boxed{\neg}$ in terms of $\wp(\overline{\bigcup P})$). Here, this is hardly worth mentioning since the corresponding non-negated sentence would not be inquisitive, either; but the observation carries over to sentences with more than one possibility, too.

(40) John did not smile.

T

$\boxed{\neg}(\lambda p_{\langle s,t\rangle}.\forall w \in p : smile(w)(\mathbf{j}))$

$= \lambda p_{\langle s,t\rangle}.\forall w \in p : \neg\exists q(\forall w' \in q : smile(w')(\mathbf{j}) \wedge q(w))$

not :: $\langle T,T\rangle$ — $\lambda X_T.\lambda p_{\langle s,t\rangle}.\boxed{\neg}X(p)$

T — $\lambda p_{\langle s,t\rangle}.\forall w \in p : smile(w)(\mathbf{j})$

John :: e — $\mathbf{j}$

smile :: $\langle e,T\rangle$ — $\lambda x_e.\lambda p_{\langle s,t\rangle}.\forall w \in p : smile(w)(x)$

10 To make $\boxed{\neg}$ resemble the classical negation symbol more closely, a few brackets have been omitted. With meticulous bracketing, $Tr(\text{not})$ is $\lambda X_T.\lambda p_{\langle s,t\rangle}.(\boxed{\neg}(X))(p)$.

2.2.2.2 Declaratives with $\langle\langle e, T\rangle, T\rangle$-type DPs

Moving on to the other types of DPs, we notice that *wh*-phrases (*who*) as well as certain indefinite (*a man*) and quantificational (*someone*) DPs share a common characteristic: their existential semantics. On some level, they all express that some (further specified) individual exists. This meaning is naturally captured by existential quantification:

(41) $Tr(\text{who/someone}) := \lambda P_{\langle e,T\rangle}.\lambda p_{\langle s,t\rangle}.\exists x P(x)(p)$

$Tr(\text{a/which man}) := \lambda P_{\langle e,T\rangle}.\lambda p_{\langle s,t\rangle}.\exists x(\forall w \in p : man(w)(x) \wedge P(x)(p))$

Recall that in $\mathsf{Inq_B}$ the disjunctive semantics of existential quantifiers gives rise to alternative possibilities. In some cases, most prominently in questions, this is desired: by asking *Who smiled?*, a discourse participant requests information as to which individuals smiled. The issue raised by her question could be settled in several different ways—with *Mary smiled* or with *John smiled*, but also with *Mary and John smiled*. Each resolving piece of information should correspond to a state in the translation of *Who smiled?*. On the other hand, sentences like *A man smiled* with only simple non-*wh* determiner phrases do not seem to request information. Since we adopted the strong perspective on inquisitiveness (see Section 2.1.3), we do not want the meanings of those sentences to come out as inquisitive. Hence, we have to make sure that different denotations are assigned to sentences like *Who smiled?* on the one hand and *Someone smiled* on the other hand. However, the lexical entries in (41) can remain unchanged.[11] Recall that we assumed declarative and interrogative markers $\text{M}_!$ and $\text{M}_?$ to be present in the syntactic structures. It is the operators denoted by these markers which will take care of establishing the above distinction.

The semantics of the alternative-evaluating operator $\boxed{!}$ is based on the declarative projection operator ! in $\mathsf{Inq_B}$. Recall that this latter operator has the effect of turning the meaning of ϕ into $\wp(\mathsf{info}(\phi))$. The same can be expressed in our typed language: $\boxed{!}$ is a function that takes an inquisitive sentence meaning P and also returns an inquisitive sentence meaning. The latter of these two meanings, however, is non-inquisitive: it simply contains all subsets of $\bigcup P$.

(42) $\boxed{!} := \lambda X_T.\lambda p_{\langle s,t\rangle}.\forall w \in p : \exists q \in X : q(w)$

To see how the computation of declaratives works out in practice, consider the examples below. In (43), it can be nicely observed how the application of $\boxed{!}$ changes the widest-scoping quantifier from $\exists x$ to $\forall w$—hence folding all states from $\lambda p_{\langle s,t\rangle}.\exists x \forall w \in p : smile(w)(x)$ into one single possibility.

11 This synonymy might have independent motivations, too: cross-linguistically, there is a strong tendency for *wh*- and indefinite pronouns to be morphologically related (Haspelmath, 1997; Bhat, 2000). Several accounts have been motivated by this affinity. Kratzer and Shimoyama (2002) propose to capture the interpretational variability displayed by indefinite pronouns in a Hamblin framework: indefinites introduce alternatives that are further up in the tree selected by an operator. The interpretation that the indefinites receive (interrogative, existential or even universal) is determined by which operator they associate with. More recently, Haida (2007) put forward an account that addresses, among other things, the above-mentioned morphological affinity, assuming the same (existential) denotation for both indefinites and *wh*-pronouns.

(43) Someone smiled.

$$T$$
$$\boxed{!}(\lambda p_{\langle s,t\rangle}.\exists x \forall w \in p : smile(w)(x))$$
$$= \lambda p_{\langle s,t\rangle}.\forall w \in p : (\exists q(\exists x \forall v \in q : smile(v)(x) \wedge q(w)))$$

$$\text{M}_! :: \langle T, T\rangle$$
$$\boxed{!} = \lambda X_T.\lambda p_{\langle s,t\rangle}.\forall w \in p : \exists q \in X : q(w)$$

$$T$$
$$\lambda p_{\langle s,t\rangle}.\exists x \forall w \in p : smile(w)(x)$$

$$\text{someone} :: \langle\langle e, T\rangle, T\rangle$$
$$\lambda P_{\langle e,T\rangle}.\lambda p_{\langle s,t\rangle}.\exists x P(x)(p)$$

$$\text{smiled} :: \langle e, T\rangle$$
$$\lambda x_e.\lambda p_{\langle s,t\rangle}.\forall w \in p : smile(w)(x)$$

(44) Everybody smiled.

$$T$$
$$\boxed{!}(\lambda p_{\langle s,t\rangle}.\forall x \forall w \in p : smile(w)(x))$$
$$= \lambda p_{\langle s,t\rangle}.\forall w \in p : (\exists q(\forall x \forall v \in q : smile(v)(x) \wedge q(w)))$$

$$\text{M}_! :: \langle T, T\rangle$$
$$\boxed{!} = \lambda X_T.\lambda p_{\langle s,t\rangle}.\forall w \in p : \exists q \in X : q(w)$$

$$T$$
$$\lambda p_{\langle s,t\rangle}.\forall x \forall w \in p : smile(w)(x)$$

$$\text{everybody} :: \langle\langle e, T\rangle, T\rangle$$
$$\lambda P_{\langle e,T\rangle}.\lambda p_{\langle s,t\rangle}.\forall x P(x)(p)$$

$$\text{smiled} :: \langle e, T\rangle$$
$$\lambda x_e.\lambda p_{\langle s,t\rangle}.\forall w \in p : smile(w)(x)$$

2.2.3 Interrogatives

2.2.3.1 *Wh*-interrogatives

We want to be able to derive the meaning of *wh*-questions like (45) and polar questions like (46)—both of which we will treat as purely inquisitive, non-informative sentences. The main objective is thus to have their translations reflect the set of propositions that resolve the question: we need to make sure that there is a one-to-one correspondence between those pieces of information that settle the issue raised by the question and the states contained in the interpretation of the question.

(45) a. Who failed the exam?
b. (Only) John/(Only) Mary/(Only) John and Mary/Everybody/Nobody.

(46) a. Was the exam difficult?
b. Yes (it was difficult)/No (it was not difficult).

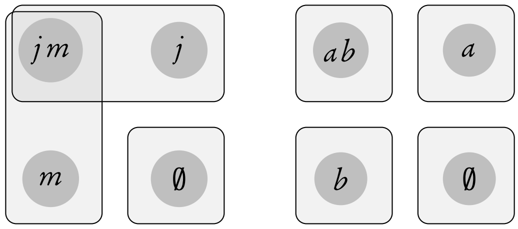
As we have seen in Chapter 1, *wh*-questions can be understood in different ways: under a *strongly exhaustive* interpretation, they ask for a complete specification of which individuals have a certain property and also which do not; interpreted as *mention-some questions* on the other hand, they only ask for a subset of those individuals that do have the property. Under either of these interpretations, people tend to have clear intuitions about which propositions resolve the issue raised by the question. Imagine a situation in which a group of students, including John, Mary and others, have taken an exam. Both John and Mary failed it, all the others passed. Under a strongly exhaustive reading of (45a) the only true resolving reply from (45b) will be *Only John and Mary*, whereas under a mention-some reading also either of *John* and *Mary* will be true resolving replies.

What the resolving propositions under both interpretations have in common is that they specify possible instantiations of the existential statement expressed by the *wh*-question. Additionally it is possible under both readings to negate this existential statement (*Nobody*). On these grounds, the already familiar interrogative projection operator ? (recall that in $\mathsf{Inq_B}$ we have $[?\phi] = [\phi \vee \neg\phi]$) appears well suited for the mention-some case; and the semantics of the alternative-evaluating operator $\boxed{?}$ can be modelled after ?.

(47) $Tr(\textsc{m}_?) := \lambda P_T.\lambda p_{\langle s,t\rangle}.P(p) \vee \boxed{\neg} P(p) \quad =: \boxed{?}$

(48) Who smiled? [mention-some interpretation]

- T
  $\boxed{?}(\lambda p_{\langle s,t\rangle}.\exists x \forall w \in p : smile(w)(x))$
  $= \lambda p_{\langle s,t\rangle}.\exists x \forall w \in p : (smile(w)(x)) \vee \forall w \in p : (\neg\exists q(q(w) \wedge \exists x \forall v \in q : (smile(v)(x))))$
  - $\textsc{m}_? :: \langle T, T\rangle$
    $\boxed{?} = \lambda P_T.\lambda p_{\langle s,t\rangle}.P(p) \vee \boxed{\neg} P(p)$
  - T
    $\lambda p_{\langle s,t\rangle}.\exists x \forall w \in p : smile(w)(x)$
    - who :: $\langle\langle e, T\rangle, T\rangle$
      $\lambda P_{\langle e,T\rangle}.\lambda p_{\langle s,t\rangle}.\exists x P(x)(p)$
    - smiled :: $\langle e, T\rangle$
      $\lambda x_e.\lambda p_{\langle s,t\rangle}.\forall w \in p : smile(w)(x)$



(a) Who smiled? (b) Who smiled? (exh.)

Figure 5: Visualisation of *wh*-questions under a mention-some and an exhaustive interpretation.

2.2.3.2 Exhaustivity operator

In contrast, the strongly exhaustive interpretation corresponds to partitioning the set of worlds relative to the predication expressed by the question: in our example, this means that worlds in the same partition block would agree exactly on the extension of *smile*. In the context of $\mathsf{Inq}_{\mathrm{B}}$, we have already seen that such a partition can be induced by combining universal quantification and interrogative projection ($\forall x ?\phi(x)$). In $\mathsf{Inq}_{\mathrm{B}}^{\lambda}$, we will use a similar strategy and derive the partition reading from the mention-some interpretation. To this end, we define an exhaustivity operator EXH, which we assume to sit atop the syntactic structure of strongly exhaustive *wh*-questions.

We take the mention-some interpretation to be the default reading of *wh*-questions, since, in our framework, the strongly exhaustive question meaning is easily derivable from the non-exhaustive denotation—but not the other way around: the non-exhaustive meaning has a richer internal structure, and going from non-exhaustive to exhaustive interpretation entails loosing the information about this structure. However, we can find languages with overt mention-some markers (e. g. *zoal* in Dutch, see Section 3.4), which explicitly select for the mention-some reading of their containing interrogative. In a language with such markers, the strongly exhaustive interpretation cannot be the default one in our framework. For if it was, we would have no way to derive the non-exhaustive reading of sentences like (49) which contain a mention-some marker (glossed as MSM).

(49) *Wat heb je* ***zoal*** *gedaan vandaag?*
what have you MSM done today
What have you been doing today?

Now, before devising a lexical entry for the exhaustivity operator, let us reflect for a moment on what exactly we require of the partition that EXH is supposed to induce. One way to think of an exhaustive question like *Who smiled?* is as a conjunction of polar questions, one for each individual: *Did Mary smile, and did John smile, and did Carol smile, and…?* An exhaustive answer provides an answer to each single one of these polar questions. We hence need to split up the logical space in such a way that worlds in the same partition block coincide in the answers they give to the polar questions. This condition can be rephrased in terms of true alternatives: given a question ϕ, two worlds are in the same partition cell just in case they are contained in exactly the same alternatives. This idea is expressed in the following lexical entry for EXH.

(50) $\text{EXH} := \lambda X_T.\lambda p_{\langle s,t\rangle}.\forall w, w' \in p : \{q \in \text{ALT}(X) \mid q(w)\} = \{q \in \text{ALT}(X) \mid q(w')\}$

This operator makes use of the following auxiliary definition. The term $\text{ALT}(X)$ denotes the set of alternatives from a sentence denotation X.

(51) $\text{ALT} := \lambda X_T.\lambda p_{\langle s,t\rangle}.X(p) \wedge \neg\exists q \in X : p \subsetneq q$

For all the cases discussed so far, these definitions do a good job. However, shifting to a more general perspective, there are two reasons why they fall short. Firstly, under the above definition, the exhaustivity operator does not preserve the informative content of a sentence: consider an informative sentence ϕ, that is, a sentence ϕ such that there are worlds $w \notin \text{info}(\phi)$. Then these same worlds w *will* be contained in $\text{info}(\text{EXH}\,\phi)$, meaning that $\text{info}(\phi) \subsetneq \text{info}(\text{EXH}\,\phi)$. While for questions (which are non-informative sentences) this does not matter, we would in principle want to devise an operator that can exhaustify interrogatives as well as declaratives. Furthermore, by making reference to the set ALT, the exhaustivity operator relies on the existence of maximal states in a sentence denotation. However, it has been brought to attention by Ciardelli (2010) that there are in fact sentences whose denotations do *not* contain maximal elements. For simplicity, we will leave aside these complications here. A generalised version of the exhaustivity operator is defined and discussed in appendix A.

To see how definition (50) yields the desired results for the examples so far, we will again look at some visualisations. Consider once more a set of worlds $\{w_{mj}, w_m, w_j, w_\emptyset\}$ such that in w_{mj} both Mary and John smile, in w_m only Mary smiles, in w_j only John smiles and in $w_\emptyset$ none of them smiles. Under the mention-some reading, (48) can then be depicted as Figure 5a. Applying the EXH-operator to this state set yields the partition in 5b. Note that in our example the partition blocks are singleton sets since no two distinct worlds are contained in exactly the same alternatives from the original denotation. This need not always be the case, though.

2.2.4 Examples

To conclude our exposition of $\text{Inq}_\text{B}^\lambda$, we demonstrate how this system can handle bound variable pronouns, quantified DPs in object position and inverse quantifier scope. The scope taking mechanism employed for these phenomena is *quantifier raising* (May, 1985, also see Heim and Kratzer, 1998): we assume a DP α_i can move out of its base position, subsequently c-commanding its co-indexed trace t_i. To ensure the trace variable x_i is bound, predicate abstraction takes place, with the index of movement on α_i acting as the λ-binder.

Example (52) illustrates how this mechanism can ensure that *wh*-pronouns appear in the immediate scope of $\boxed{?}$; example (53) demonstrates how quantifier raising can handle reflexive pronouns in object position; in examples (54) and (55), readings with inverse quantifier scope are derived: (54) clearly does not express that *one* student was simultaneously sitting at every table; rather, it has to be a *different* student at every table. This scope configuration emerges if the universally quantified DP *every table* moves to a higher syntactic position than the existentially quantified DP *some student*. In contrast, (55) allows both surface scope and inverse quantifier scope readings. Which constraints govern the availability of the respective readings goes beyond the span of this account. The purpose of the below examples is merely to demonstrate that the different scopal configurations can be derived within the proposed grammar fragment in a completely standard way.

(52) Who saw someone?

$$T$$
$$\boxed{?}(\lambda p_{\langle s,t\rangle}.\exists y(\forall v \in p : (\exists q(\exists x(\forall w \in p : (see(w)(x)(y)))) \wedge q(v))))$$

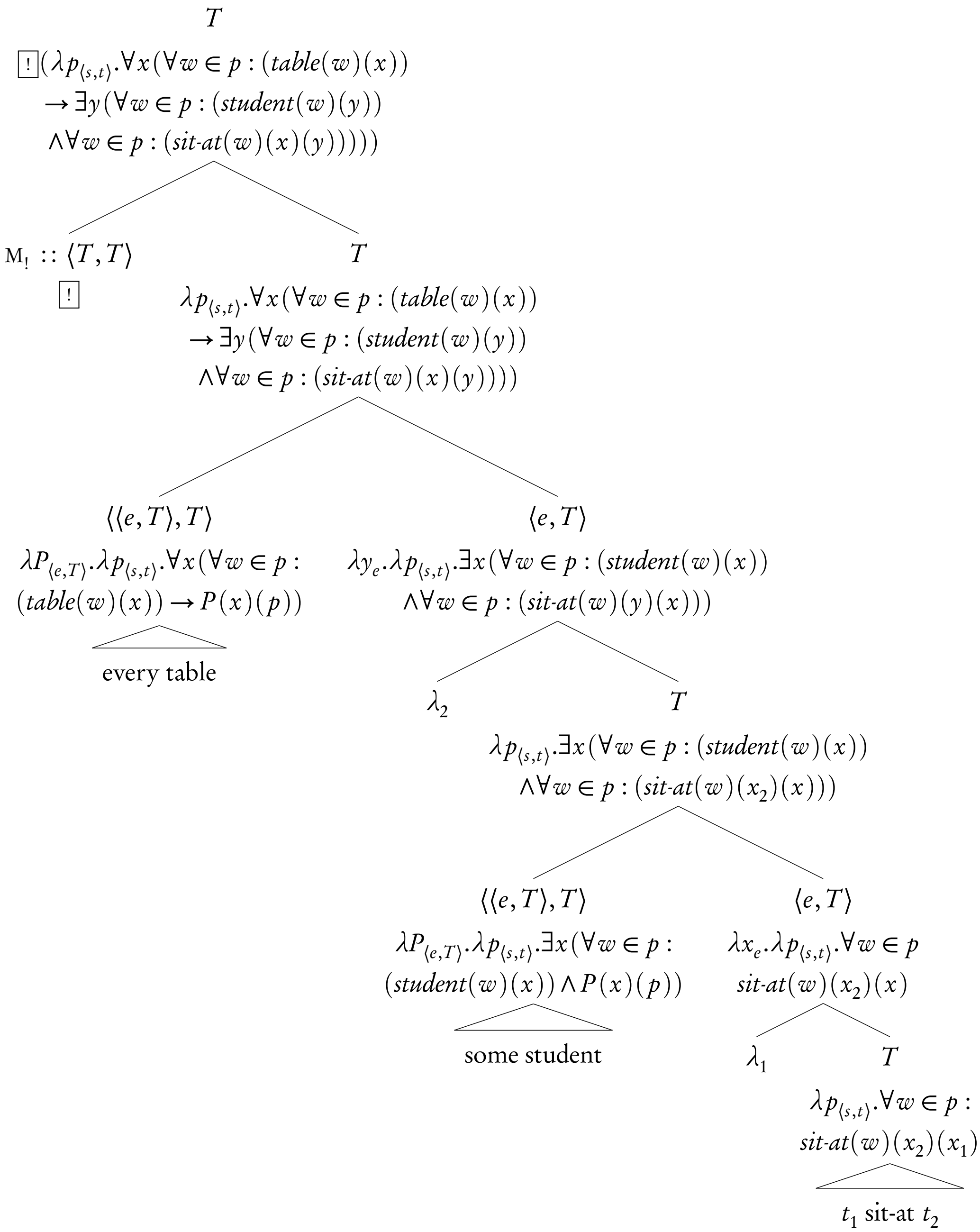
- $\text{M}_{?} :: \langle T, T\rangle$ — $\boxed{?}$
- T — $\lambda p_{\langle s,t\rangle}.\exists y(\forall v \in p : (\exists q(\exists x(\forall w \in p : (see(w)(x)(y)))) \wedge q(v)))$
  - who $:: \langle\langle e, T\rangle, T\rangle$ — $\lambda P_{\langle e,T\rangle}.\lambda p_{\langle s,t\rangle}.\exists x P(x)(p)$
  - λ_1
  - T — $\lambda p_{\langle s,t\rangle}.\forall v \in p : (\exists q(\exists x(\forall w \in p : (see(w)(x)(x_1))) \wedge q(v)))$
    - $\boxed{!} :: \langle T, T\rangle$ — $\lambda X_T.\lambda p_{\langle s,t\rangle}.\forall w \in p : \exists q \in X : q(w)$
    - T — $\lambda p_{\langle s,t\rangle}.\exists x \forall w \in p : see(w)(x)(x_1)$
      - t_1 saw someone

(53) Everybody defended himself.

$$T$$
$$\boxed{!}(\lambda p_{\langle s,t\rangle}.\forall x \forall w \in p : defend(w)(x)(x))$$

- $\text{M}_{!} :: \langle T, T\rangle$ — $\boxed{!}$
- T — $\lambda p_{\langle s,t\rangle}.\forall x \forall w \in p : defend(w)(x)(x)$
  - everybody $:: \langle\langle e, T\rangle, T\rangle$ — $\lambda P_{\langle e,T\rangle}.\lambda p_{\langle s,t\rangle}.\forall x P(x)(p)$
  - $\langle e, T\rangle$ — $\lambda x_e.\lambda p_{\langle s,t\rangle}.\forall w \in p : defend(w)(x)(x)$
    - λ_1
    - T — $\lambda p_{\langle s,t\rangle}.\forall w \in p : defend(w)(x_1)(x_1)$
      - t_1 defended himself$_1$

(54) Some student was sitting at every table.



(55) a. Who did everybody see? (surface scope: $\exists > \forall$)

- T — $\boxed{?}(\lambda p_{\langle s,t\rangle}.\exists y \forall x \forall w \in p : see(w)(y)(x))$
  - $\text{M}_? :: \langle T,T\rangle$ — $\boxed{?}$
  - T — $\lambda p_{\langle s,t\rangle}.\exists y \forall x \forall w \in p :$ $see(w)(y)(x)$
    - $\langle\langle e,T\rangle,T\rangle$ — $\lambda P_{\langle e,T\rangle}.\lambda p_{\langle s,t\rangle}.\exists x P(x)(p)$ — who
    - $\langle e,T\rangle$ — $\lambda y_e.\lambda p_{\langle s,t\rangle}.\forall x \forall w \in p :$ $see(w)(y)(x)$
      - λ_1
      - T — $\lambda p_{\langle s,t\rangle}.\forall x \forall w \in p :$ $see(w)(x_1)(x)$
        - $\langle\langle e,T\rangle,T\rangle$ — $\lambda P_{\langle e,T\rangle}.\lambda p_{\langle s,t\rangle}.\forall x P(x)(p)$ — everybody
        - $\langle e,T\rangle$ — $\lambda x_e.\lambda p_{\langle s,t\rangle}.\forall w \in p :$ $see(w)(x_1)(x)$ — see t_1

b. Who did everybody see? (inverse scope: $\forall > \exists$)

- T — $\boxed{?}(\lambda p_{\langle s,t\rangle}.\forall y \exists x \forall w \in p : \mathit{see}(w)(y)(x))$
  - $\text{M}_? :: \langle T, T\rangle$ — $\boxed{?}$
  - T — $\lambda p_{\langle s,t\rangle}.\forall y \exists x \forall w \in p : \mathit{see}(w)(y)(x)$
    - $\langle\langle e, T\rangle, T\rangle$ — $\lambda P_{\langle e,T\rangle}.\lambda p_{\langle s,t\rangle}.\forall x P(x)(p)$ — everybody
    - $\langle e, T\rangle$ — $\lambda y_e.\lambda p_{\langle s,t\rangle}.\exists x \forall w \in p : \mathit{see}(w)(y)(x)$
      - λ_2
      - T — $\lambda p_{\langle s,t\rangle}.\exists x \forall w \in p : \mathit{see}(w)(x_2)(x)$
        - $\langle\langle e, T\rangle, T\rangle$ — $\lambda P_{\langle e,T\rangle}.\lambda p_{\langle s,t\rangle}.\exists x P(x)(p)$ — who
        - $\langle e, T\rangle$ — $\lambda x_e.\lambda p_{\langle s,t\rangle}.\forall w \in p : \mathit{see}(w)(x_2)(x)$
          - λ_1
          - T — $\lambda p_{\langle s,t\rangle}.\forall w \in p : \mathit{see}(w)(x_2)(x_1)$
            - t_1 see t_2

2.3 Comparison with Hamblin-style alternative semantics

At first glance, typed inquisitive semantics and Hamblin semantics seem akin both in their empirical targets (questions, disjunction, etc.) and their semantic machinery (sets of "alternatives"). Closer inspection, however, reveals rather principled differences between the conceptual foundations underlying either framework. In particular, the systems differ in their conception and implementation of alternatives—with the notion of downward-closedness playing a crucial role. We will address the conceptual differences and their practical consequences in Section 2.3.1. In addition, however, there are purely technical differences as well: the mode of semantic composition in Hamblin semantics is not the same as that in the type-theoretical inquisitive system proposed in the previous section. This is why certain technical difficulties arising from the combination of Hamblin alternatives with variable binding are not an issue in our framework. We will not go into these compositional matters here, however. For details, consult Theiler (2013) and Ciardelli and Roelofsen (2014a).

2.3.1 Notion of alternatives

2.3.1.1 Conceptual point of departure

Inquisitive semantics and Hamblin semantics approach the notion of answerhood from different points of departure. Inquisitive semantics starts with the pre-theoretic notion of what it takes to resolve a question. As we have already seen, these resolution conditions are formally captured as information states, which, taken together, make up the denotation of a question. They are those pieces of information that settle the issue raised by a question. This means that sentence denotations necessarily are downward-closed: because, if some state s settles a given issue, then any substate $t \subseteq s$ will settle that issue as well; after all, t specifies the location of the actual world within the logical space ω with higher precision than s does. Under this resolution-centric view, answerhood becomes a derived notion—a desirable outcome, since it is an intuitively more vague concept than resolution, and the algebraic perspective taken in inquisitive semantics allows us to define different conceptions of answerhood (e. g. exhaustive answers, complete answers, mention-some answers) in a natural and formally sound way. We will see how this works in practice in Chapter 4. Crucially, though, certain algebraic operations for computing these different answers (e. g. intersection) can only be used since sentence denotations are downward-closed. Why this is will fall into place shortly when we look at coordinated questions in the next section.

In conclusion, inquisitive semantics departs from an intuitively clear pre-theoretic notion and, based on this, is flexible enough to derive different conceptions of what constitutes an answer. In Hamblin semantics, in comparison, it is the notion of answerhood which is conceptually prior. The denotation of a question consists of all *basic* answers to that question, where basic answerhood is a pre-theoretic concept. On a theory-internal level, however, Hamblin semantics does not provide a precise characterisation of basic answerhood (as opposed to non-basic answerhood). In this respect, the conceptual point of departure taken in Hamblin frameworks appears less solid than that of inquisitive semantics.

2.3.1.2 Conjunction and explanatory adequacy

Chomsky (1965) suggests that, when evaluating a grammar, there are distinct, hierarchically ordered levels of adequacy to take into account: starting with the most elementary level, these are *observational*, *descriptive* and *explanatory* adequacy. While Chomsky's criteria for each level are mostly geared to theories of syntax, Groenendijk and Stokhof (1984, p. 10ff) adapt them to the evaluation of semantic frameworks, in particular spelling out relevant requirements for explanatory adequacy. In their view, explanatory adequacy demands a certain systematicity in constructing the semantic space: the computation of meanings has to proceed *compositionally*, and the notions and principles employed by the semantic theory have to be *general*: they should be applicable outside the theory's specific domain as well. For example, consider a theory that aims at capturing the meaning of sentences coordinated by *and*. In order to make this precise, let $[\![\cdot]\!]$ be a function specified by the semantic theory which translates natural language expressions to semantic objects. Further, let α and β be natural language sentences. Then, the requirements for descriptive adequacy would amount to the following. In order for the computation to be compositional, α *and* β has to translate as $[\![\alpha \textit{ and } \beta]\!] = [\![\alpha]\!] \odot [\![\beta]\!]$ where, in order to satisfy the generality requirement, $\odot$ has to be a suitably domain-independent operation for sentence conjunction. What constitutes a suitable operation in a given framework, is usually determined by the framework itself. If our semantic account is based on set theory for example—that is, $[\![\alpha]\!]$ and $[\![\beta]\!]$ are sets of e. g. possible worlds—then, $\odot$ will be intersection: $[\![\alpha \textit{ and } \beta]\!] = [\![\alpha]\!] \cap [\![\beta]\!]$. However, we can view this from a yet more general perspective if we look at the semantic space as a partially ordered set: the elements in this set are propositions and a reasonable choice for the partial order is the entailment relation between propositions. Then, we desire of a suitable operation $\odot$ for sentence conjunction that (a) it is commutative, associative and idempotent, and that (b) $[\![\alpha]\!] \odot [\![\beta]\!]$ is the "weakest" proposition which entails both $[\![\alpha]\!]$ and $[\![\beta]\!]$. This is precisely what characterises a so-called *meet* operation in a partially ordered set (see Keenan and Faltz, 1985; Partee et al., 1990; Landman, 1991). Hence, now speaking in full generality, what we demand of $\odot$ is that it is a meet operation. Under this view, set intersection becomes just one specific implementation of such an operation.

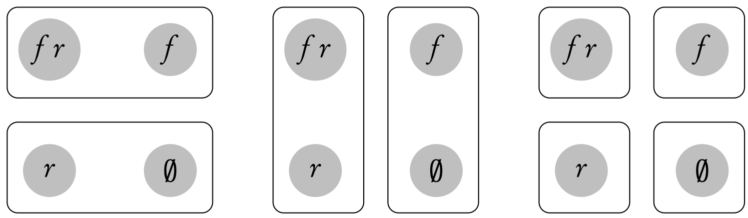
Now, applying these criteria to the two frameworks at hand, clearly, both inquisitive and Hamblin semantics are compositional; it is mostly their generality in the sense described above which needs further investigation. There would indeed be a lot to say about the algebraic foundations of inquisitive semantics and in particular about the treatment of disjunction they give rise to. Here, however, we will just point the reader to Roelofsen (2013) and instead continue investigating the more straightforward example of sentence conjunction.

Since in both inquisitive semantics and Hamblin semantics sentence denotations are sets of propositions[12], the conjunction of sentences would classically amount to set intersection. We will see that, while inquisitive semantics allows us to adhere to this classical picture[13], in Hamblin semantics it has to be given up. At least in this respect, inquisitive semantics thus achieves a higher degree of explanatory adequacy.

Consider example (57) from Ciardelli et al. (2012). We can capture its meaning using the lexical entry (56) for *and*, which applies uniformly to declaratives and interrogatives. Taken individually, each of the two polar questions has a denotation with exactly two possibilities—one corresponding to a positive and one corresponding to a negative reply (figures 6a and 6b). When the questions are coordinated by *and* as in (57), though, the resulting denotation contains exactly four possibilities (Figure 6c): the coordinated question can only be settled by exhaustively specifying which of the two languages John speaks. Crucially, however, the meaning of the entire question is obtained by intersecting the meanings of the two subquestions. This is exactly the classical treatment of conjunction we had been after—only now the objects that get intersected are more fine-grained: in the classical setting,

12 Again, we use the term *proposition* in the classical sense. For us, a proposition is a set of possible worlds. Hence, the terms *state* and *proposition* refer to the same kind of semantic object.

13 Or rather, the algebraic foundation underlying inquisitive semantics is even more general: the space of semantic meanings Σ, ordered by an entailment ordering $\leq$ which is sensitive to both informative and inquisitive content, forms a Heyting algebra $\langle \Sigma, \leq \rangle$ with *meet*, *join* and (*relative*) *pseudo-complement* operators (Roelofsen, 2013). In this setting, intersection becomes just a specific instantiation of the *meet* operator.



(a) Does John speak French? (b) Does John speak Russian? (c) Does John speak French, and does he speak Russian?

Figure 6: Conjunction of interrogatives

semantic objects are world-sets; now they are downward-closed sets of world-sets. Observe that downward-closedness really is vital in order for the intersection to yield the desired result: since the denotations of the two conjuncts are downward-closed, they do not only contain the maximal states depicted in Figure 6a and 6b, but also all subsets of these maximal states, including—and this is what it comes down to—those states that are contained in the denotation of the entire conjunction.

(56) $Tr(\text{and}) := \lambda X_T.\lambda Y_T.\lambda p_{\langle s,t\rangle}.X(p) \wedge Y(p)$

(57) Does John speak French, and does he speak Russian?

$$\lambda p_{\langle s,t\rangle}.(\forall w \in p : (\textit{speak-French}(w)(\mathbf{j})) \vee \boxed{\neg}\,\forall w \in p : (\textit{speak-French}(w)(\mathbf{j})))$$
$$\wedge\, (\forall w \in p : (\textit{speak-Russian}(w)(\mathbf{j})) \vee \boxed{\neg}\,\forall w \in p : (\textit{speak-Russian}(w)(\mathbf{j})))$$

T
$\boxed{?}(\lambda p_{\langle s,t\rangle}.\forall w \in p : \textit{speak-French}(w)(\mathbf{j}))$
M$_?$ does John$_1$ speak French

and :: $\langle T, \langle T, T\rangle\rangle$
$\lambda X_T.\lambda Y_T.\lambda p_{\langle s,t\rangle}.X(p) \wedge Y(p)$

T
$\boxed{?}(\lambda p_{\langle s,t\rangle}.\forall w \in p : \textit{speak-Russian}(w)(x_1))$
M$_?$ does he$_1$ speak Russian

In Hamblin semantics, on the other hand, the denotations of the subquestions are not downward-closed:

(58) $[\![\text{Does John speak French?}]\!]_{\text{Hamblin}} = \{\{fr, f\}, \{r, \emptyset\}\}$

(59) $[\![\text{Does John speak Russian?}]\!]_{\text{Hamblin}} = \{\{fr, r\}, \{f, \emptyset\}\}$

In order to combine these sets in a way that produces the desired meaning for sentence (57), clearly, we cannot just intersect them. What we need instead is an operation for pointwise intersection. While such a mechanism reliably yields the appropriate interpretation of coordinated questions, in a framework based on set-theory, it seems a less generally motivated choice than intersection. In particular, pointwise intersection is not idempotent and hence not a meet operation.

2.3.2 Mode of semantic composition

In the proposed inquisitive framework, semantic composition is driven by classical rules for functional application and predicate abstraction (see (31)). In Hamblin semantics, by contrast, we need pointwise versions of both rules since all denotations are set-valued. In the previous section, it has been outlined that a classical, non-pointwise mode of composition has conceptual merits. Additionally, we shall soon see that there also is a more practical difficulty arising with pointwise functional application. On the other hand, that pointwise predicate abstraction poses serious problems as well has been shown by Shan (2004). For a proposal how to overcome the difficulties Shan points out, see Romero and Novel (2013). For a demonstration that such problems do not arise in $\mathsf{Inq}_{\mathsf{B}}^{\lambda}$, see Theiler (2013).

(60) **Pointwise functional application**

$$\lambda X_{\tau}.\exists A \in Tr(\alpha) : \exists B \in Tr(\beta) : X = A(B) :: \langle \tau, t \rangle$$

$$Tr(\alpha) :: \langle\langle \sigma, \tau \rangle, t\rangle \qquad Tr(\beta) :: \langle \sigma, t \rangle$$

The pointwise fashion of composition has direct repercussions on the treatment of certain operators in Hamblin systems: In the inquisitive grammar fragment, we are able to specify lexical entries for the projection operators $\boxed{!}$ and $\boxed{?}$. In Hamblin semantics, this is not possible; instead, such operators require syncategorematic translation rules. To see why, consider e. g. the case of $\boxed{!}$, which turns a possibly multi-membered set of states into one with at most a single possibility. This single possibility could be thought of as a "large classical disjunction" of the individual pieces of information from the old set. In order for an operator to produce such a disjunction, all states from that old set have to be "simultaneously" available to the operator. If the set is processed pointwise, however, only one state will be avaible at a time. There is a number of alternative-evaluating operators from the literature that hence cannot receive a meaning of their own in a Hamblin framework, but rather require a syncategorematic treatment. Examples of such operators are the existential and universal closure operators by Kratzer and Shimoyama (2002), the exclusive strengthening operator by Menéndez-Benito (2005), conditionals in Alonso-Ovalle (2006) and modals in Aloni (2007).

In summary, we have seen how the inquisitive conception of sentence meaning can inspire the setup of a type-theoretical alternative semantics. A grammar fragment for such a semantics has been specified and shown capable of accounting for an elementary range of phenomena in the realm of question semantics and variable binding. Although this type-theoretical inquisitive system bears resemblance to Hamblin semantics, there are fundamental conceptual and technical differences between both frameworks. Conceptually, it seems that the notion of resolution conditions allows us to formulate a flexible and theoretically solid definition of answerhood in the inquisitive system. The Hamblin notion of basic answerhood, on the other hand, appears to lack a precise formal definition. Technically, semantic composition in the inquisitive system—as opposed to semantic composition in Hamblin frameworks—does not rely on pointwise versions of functional application and predicate abstraction.

3 A multitude of answers: what embedded questions can mean

At the outset of this thesis, question embedding was referred to as a *controlled* testbed to probe the truth-functionally relevant meaning aspects of questions. This promise is only partly borne out. It is true that embedded interrogatives provide an environment where question meaning can be studied in relative isolation from the pragmatics of question-answer discourse. At the same time, however, there are other, non-pragmatic factors interfering: the embedding verbs have a semantics of their own, and as long as this semantics is not properly understood—as long as it is rather regarded as some sort of *noise*—our testbed is not nearly as controlled as we could wish for. This already sets the goal for this chapter: while we will not try to give a state-of-the-art account of, for example, *knowledge-wh*, we will pay close attention to that place where embedder meaning and question meaning meet—that is, to the "noise" we can witness when examining the interpretation of an embedded interrogative.

As we have seen, questions are usually analysed as sets of *answers*. We have also seen some (and we will yet see more) notions of answerhood that were proposed in the literature, differing from one another essentially in their *informational strength*: from mention-some answers on the lower end of the informativity scale to weakly exhaustive and finally strongly exhaustive answers on the upper end of the scale. A lot of work in this area of semantics has been centred around determining which notions of answerhood are adequate for which embedding predicates, and there still is tremendous disagreement. Certain embedders seem to be restricted in the readings they allow for their complement clauses. However, in view of the debate which has been raging on that score for 30-odd years, I would feel uncomfortable entirely dismissing any of the classical readings.

Instead, we will try to do some *disentangling*: we will identify a set of distinct sources that contribute to the ambiguity of embedded questions. By doing so, we will be able to pull apart certain interpretive dimensions which are easily conflated. When we finally put these dimensions back together, we will emerge with a more fine-grained perspective. I would like to argue that this is a good thing: if the empirical picture has often appeared rather incongruous, it might have been because we did not distinguish *enough* interpretive categories: that is, if two actually different things get mistakenly sorted into the same category, one will be left wondering why they behave differently, while, if they are sorted into different categories from the start, then they will also be *predicted* to behave differently.

The upshot of these endeavours will be that we want to include *all* of the classically advertised question readings in our account. If we overgenerate, it will not hurt as much as excluding some reading a priori only to then be proven wrong. The system can be restricted at will later on; at this point, the focus is on showing that *any* of the standard theories of question semantics *can* be formulated in our framework.[1]

In the course of this chapter, a set of binary features will be introduced—each corresponding to one of the following interpretive dimensions: *veridicality* ([+/–ver]), *literalness* ([+/–lit]), *exhaustivity* ([+/–exh]) and *completeness* ([+/–cmp]). These features will provide us with a way to describe the different interpretations that embedded interrogatives receive without having to rely on the customary terminological categories. One advantage of doing so is that it allows us to avoid those customary categories whenever we wish so (e. g. because there might be certain preconceptions attached to them). Another advantage is that our perspective on question meanings will be more differentiated: the classical categories of weak and strong exhaustivity and mention-some readings can still be expressed, but so can some subcategories of them.

Forestalling a bit, the features can be grouped into those that pertain to the embedder (veridicality and literalness) versus those that pertain to the question (exhaustivity and completeness). If we want to be even more precise, we can further distinguish between features that characterise a question denotation (exhaustivity) and those that characterise an answer at a world (completeness).[2] If a question denotation is [+exh], then it is strongly exhaustive or, as we have seen in Chapter 1, a partition of the logical space in the sense of Groenendijk and Stokhof (1984). In contrast, if the question denotation is not a partition, then it is [–exh]. We will also use the exhaustivity feature in a derived sense and talk about [+exh] *answers*. Those will be answers conveying sufficient information to resolve a [+exh] question. In contrast, by characterising an answer as [–exh], we express that it is not informative enough to resolve a [+exh] question. The completeness feature has also been mentioned in Chapter 1: if an answer to a *wh*-question is [+cmp] at world w, this means the answer contains a complete specification of all entities having the inquired property at w (in other words, it is a mention-all answer). Conversely, if the answer only contains a partial specification of such entities (if it is a mention-some answer at w), it is [–cmp] at w. We will also use the completeness feature in a derived sense and talk about [+cmp] questions. Intuitively, a [+cmp] question is one that demands a complete specification of the individuals with a certain property (an incomplete specification will not suffice). On the other hand, [–cmp] questions are mention-some questions: they only demand partial specifications of a property—or, in other words, they can always be resolved by a [–cmp] answer. If these distinctions are still somewhat obscure, they will become sharper once we turn to the formal implementation in Chapter 4. For now, observe that a [+cmp, +exh] answer is strongly exhaustive and a [+cmp, –exh] answer weakly exhaustive. A [–cmp, –exh] answer, finally, is a mention-some answer. Whenever a question denotation is [+exh], however, it is impossible to obtain a [–cmp] answer from it—any answer extracted from it will therefore

1 In this respect, we do things in a similar way as Égré and Spector (2014), whose principal objective also lies with devising a *unified* semantics that can provide *all* possible intuitive translations of embedded interrogatives—rather than with *restricting* this semantics.

2 For us, the denotation of a question Q contains states p such that every p *resolves* Q. Before, we had used *answer* and *resolving state* synonymously. As we shall see, however, these concepts come apart as soon as we consider special kinds of answers. Then, for a given state q, it does not automatically follow from $q \in Q$ whether q is also a *true/false* or a *complete/incomplete answer* to Q at some world w.

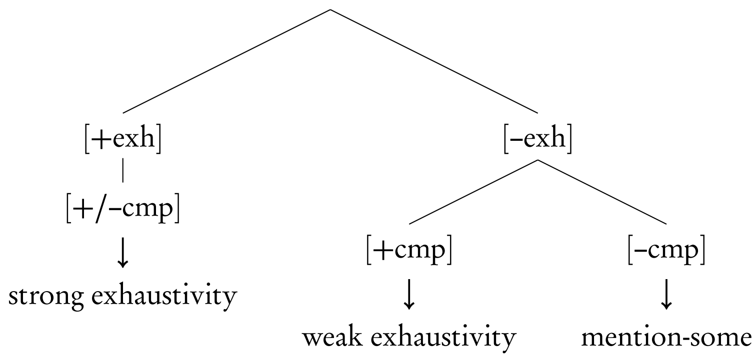


Figure 7: Mention-some, weak and strong exhaustivity as combinations of binary features

be [+exh, +cmp], that is, strongly exhaustive. To see why, recall that a [+exh] question is a partition with each partition cell corresponding to a complete specification of which individuals have a certain property and which do not. Any answer extracted from such a denotation will be at least as informative as a partition cell and hence [+cmp].[3] To the extent that the configuration [–cmp, +exh] exists, it would hence correspond to a strongly exhaustive answer. How the traditional interpretive categories can be expressed by combining these features is summarised in Figure 7.

Forestalling yet a bit more in order to make the proposed choice of interpretive features more perspicuous: in the eventual Inq_B^λ implementation the work of establishing individual feature values will be divided over several lexical items. Exhaustivity will be taken care of by the exhaustivity operator that is already familiar from the previous chapter; completeness will be implemented by different answer operators; veridicality and literalness will be lexical features of the embedding verb. This division of labour is summarised in Table 3.

feature	**taken care of by...**
exhaustivity	exhaustivity operator
completeness	answer operator
veridicality	embedding verb
literalness	embedding verb

Table 3: Division of labour

3 At least with the answerhood operator we will use for this purpose. Groenendijk and Stokhof, for example, allow for mention-some answers by taking the union of several partition cells. We will not need this strategy here since our default question denotation is weaker than a partition denotation.

3.1 Factivity and veridicality

Lahiri (2002) provides a typology in which he classifies interrogative-embedding predicates according to syntactic and semantic criteria (Figure 8). *Rogative* predicates such as *wonder* exclusively take interrogative complement clauses; they cannot embed declaratives (61).

(61) a. I wonder who will win the election.
b. I wonder whether/*that the current president will win the election again.

In this chapter, we will sometimes mention rogatives, but primarily concentrate on the class of *responsive* predicates. These are verbs that accept both interrogative and declarative complements (62).[4]

(62) a. Alice is certain which students cheated on the final exam.
b. Alice is certain whether/that Bob cheated on the final exam.

Responsives are usually given what George (2011) calls a *reductive* account: the meaning of the interrogative-embedding variant of the verb is reduced to that of the declarative-embedding variant. Using the example of (62b), if Alice is certain *that* Bob cheated, she is also certain *whether* he cheated. This is the case since the proposition *that Bob cheated* is a possible answer to the embedded polar question *whether Bob cheated*. Responsive predicates hence express a relation between an individual and some answer to the embedded interrogative. Depending on whether they require a *true* answer for this relation to hold, responsives are again divided into two subcategories, *veridical* and *non-veridical* embedders. Veridical embedder such as *know* express a relation to a *true* answer, whereas non-veridicals like *be certain* do not require the answer to be true. To illustrate this difference, if Alice *knows* whether Bob cheated, it is clear that whatever she believes regarding the embedded question is actually true: if she believes Bob cheated, then he really cheated; if she believes, Bob did not cheat, then he did not cheat. In contrast, if we learn that Alice *is certain* whether Bob cheated, we are only informed she has a firm belief as for whether Bob cheated—but for all we know she could be mistaken.

Note, however, that the classification of an answer as *false* is world-dependent. When we talk about an answer being false, what we really mean is *false in the actual world*. For every possible answer to a given question, there are worlds in which this answer is the true answer to the question. An alternative way of looking at the difference between veridicals and non-veridicals is therefore the following. While veridicals express a relation to an answer that is true in the actual world, non-veridicals express a relation to an answer such that there is some world in which this answer is true.

Veridicality is a property of interrogative-embedding verbs. The corresponding property of declarative-embedding verbs is called *factivity*. A factive verb presupposes the truth of its complement clause. Sentence (63a) presupposes that Bob cheated, while (63b) does not give rise to this presupposition.

4 Note that Lahiri's classification into responsives and rogatives does not coincide with Groenendijk and Stokhof's classification into *intensional* and *extensional* predicates. The class of extensional predicates contains only veridical responsives; hence the class of intensional verbs contains both rogatives and non-veridical responsives (see Lahiri, 2002, p. 285).

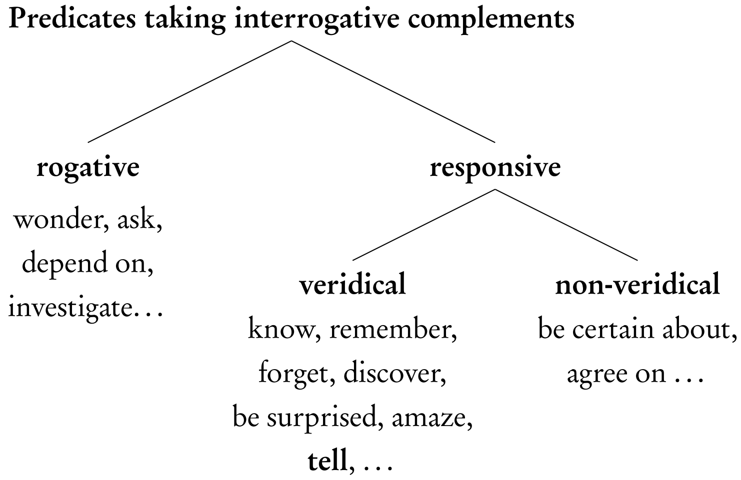


Figure 8: Lahiri's typology of embedding verbs

(63) a. Alice knows that Bob cheated on the final exam. [factive embedder]
b. Alice is certain that Bob cheated on the final exam. [non-factive embedder]

In the above examples, the properties of veridicality and factivity seem to coincide: *know-wh* is veridical and *know that* is factive. Likewise, *be certain-wh* is non-veridical and *be certain that* is non-factive. Is this pattern consistent among responsive predicates? That is, do the class of veridical-responsives and that of factives coincide? For Lahiri (2002) and many others (Karttunen, 1977; Groenendijk and Stokhof, 1984; Berman, 1991) the answer is no. It is so-called *verbs of communication* like *tell* which seem to form an exception from the rule: in their declarative-embedding use they are non-factive (64a), but become veridical when occurring with an interrogative complement (64b).

(64) a. John told me that Mary visited yesterday. ($\not\rightsquigarrow$ Mary visited yesterday)
b. John told me who visited yesterday. ($\rightsquigarrow$ those persons that John said visited yesterday actually visited yesterday)

Based on some novel data, however, Égré and Spector (2014) argue that a responsive predicate is veridical *exactly if* it is factive. According to them, verbs of communication are no counterexample to this generalisation: contrary to what has classically been observed, there are also interrogative-embedding uses of communication verbs in which they receive a non-veridical interpretation (65a); and there are declarative-embedding uses in which they receive a factive interpretation (65b) (examples from Égré and Spector).

(65) a. Every day, the meteorologists tell the population where it will rain the following day, but they are often wrong. [interrogative-embedding, non-veridical]
b. Did Sue tell anyone that she is pregnant? [declarative-embedding, factive]

Égré and Spector capture this behaviour of communication verbs in terms of lexical ambiguity. Although I believe it would be possible at least in part to predict the respective reading of communication verbs from factors such as the sentence's focus structure[5], we will treat this meaning variation as a lexical ambiguity, assuming that each communication verb comes in two variants: a factive/veridical and a non-factive/non-veridical one. Based on this, it is clear that veridicality is a property of the embedding verb, and we will use the positive veridicality feature, [+ver], to characterise veridical/factive verbs and the negative veridicality feature, [−ver], to characterise non-veridical/non-factive verbs. Sometimes, this feature will also be used in a derived sense to describe an entire sentence which contains an embedding verb. The veridicality feature will then be understood as pertaining to the embedding verb. This is different for some other features: as we shall see, exhaustivity and completeness seem to depend partly on the embedding predicate, but partly also on context and the presence of certain markers in the embedded interrogative.

3.2 Literal and deductive readings

I would like to suggest that many question-embedding verbs are ambiguous between two readings—and that this ambiguity can most prominently be felt with emotives and verbs of communication. I will call these readings the *literal* ([+lit]) and the *deductive* ([−lit]) reading respectively. Roughly, the literal reading takes the question just that way: *literally*, that is, possibly as some linguistic object or some object of thought. The deductive reading on the other hand abstracts away from the literal content and instead concerns the logical *facts*. It is insensitive to differences in linguistic form and allows a certain amount of background knowledge to enter into the equation. The proposed ambiguity is relevant for two reasons. Firstly, depending on their reading, predicates exhibit different monotonicity properties. Secondly, also depending on whether they are understood deductively or literally, question-embedding verbs allow or disallow certain kinds of inferences; and all customary tests for distinguishing weak from strong exhaustivity are based on the availability of exactly these inferences. Hence, if we do not clearly keep apart the two readings, those tests will yield inconsistent results.

3.2.1 Emotive verbs

Let us start with *be happy about*, an emotive verb. Consider the following scenario: Among others, Bob and Alice have been applying for a waiting job at a café. Alice's friend Mary already works at the café and is hoping that Alice will be hired so they can chit-chat during their shift. In fact, Mary knows that there is just one open position, but she is not informed so well about who else applied. In particular, she does not spend much thought on Bob's application. However, she does not hold any grudge against Bob, either: if he does not get the job, this fact in itself will not make Mary happy. In this scenario, Alice calls Mary and tells her she will really start at the café, and Mary is happy about this news. Hence, (66) is judged true for sure—but is (67) automatically true as well?

(66) Mary is happy about who got the job.

(67) Mary is happy about who did not get the job.

5 For example, in order to get the factive reading of (65b), the focus must not be on the embedded declarative.

This seems to depend on how we understand the embedding verb. Under the literal reading, *being happy* is concerned with Mary's state of mind/her attentive state: with the facts that are part of her awareness and which caused in her a feeling of happiness. Under this reading, the entailment does *not* go through since, as already mentioned, the fact that Bob did not get the job does not by itself make Mary happy. Actually, the moment that Alice calls Mary with her news, Bob might not even be part of Mary's attentive state. In contrast, the deductive reading is sensitive to something like the "larger picture"—including certain implications. In order for a fact to make Mary happy on the deductive reading, this fact need not even be part of her attentive state. Under this reading of *being happy*, (67) follows from (66): Mary knows that there was just one position available, and since she wanted Alice in that position, she is automatically happy that Bob was not hired.

There are expressions which seem to disambiguate embedding verbs in favour of the deductive reading. Examples of such phrases are *in a sense* or *in effect*. They appear to relax the definition of what constitutes *being happy* for instance. That is, inserting *in a sense*, it is justified to talk of *Mary being happy* about a proposition p even if characteristic features of Mary being happy about p—such as p being part of Mary's attentive state—are absent.

(68) **In a sense**, Mary is happy about who did not get the job.

On the other hand, the sentence gets disambiguated in favour of the literal reading as soon as it is made clear that Mary's being happy is an *event* as opposed to a *state*—i. e. that it takes place at some given point of time. This might be the case since a temporarily bounded event is naturally more sensitive than a temporarily unbounded state to what is *momentarily* part of Mary's attention:

(69) Yesterday, when Mary entered the café, Alice was already waiting tables there. Mary realised and was immediately very happy about who got the job (#and who didn't).

Now consider another scenario. Suppose Mary expected three people, namely Alice, Bob and Charles, to attend a party. What happened, however, is that only Bob and Charles showed up, and noone else did (Table 4). In this situation, is the following statement true?

(70) Mary is surprised who was at the party.

George (2013) maintains that (70) is not true in this scenario. According to him, while Mary is indeed surprised by who is *not* at the party (she is surprised by Alice's absence), she is *not* surprised by who *is* at the party (she expected Bob and Charles to come). This judgement corresponds to the literal understanding of *surprise*. However, there seems to be a second way to understand (70), namely corresponding to a deductive reading. Under this interpretation, again, Mary's attentive state does not matter. All that counts is that her expectations clash with the real-world facts (they do since Mary expected Alice to come). Hence, Mary was surprised who was at the party. Another way of thinking about this is that she was surprised by something like the composition of the group of party guests. Since the composition of that group deviated from her expectations, she was surprised by the composition of that group—or in other words, surprised by who was at the party.

	Alice	Bob	Charles
Mary's expectations	✓	✓	✓
facts	✗	✓	✓

Table 4: A party scenario

3.2.2 Verbs of communication

With emotive verbs, it is sensitivity/insensitivity to the subject's attentive state that divides literal from deductive readings. For verbs of communication, however, the ambiguity manifests itself differently: under a literal reading, those verbs primarily express an *act* of communication, an event, which is associated with some specific, "literal" content, while under a deductive reading, the focus is on the *effect* such an act has rather than on the act and its content itself.

The following example illustrates this ambiguity. Under the literal reading, again, the entailment in (71a) does not go through: after all, we just know that Mary has made a prediction about which bands *would* cancel—she might not even have said anything at all about which *wouldn't*. However, under the deductive reading it does not matter what exactly Mary *said*. She predicted which of a fixed set of bands would cancel, so she implicitly predicted of all the others from this set that they would not cancel. Hence, in this sense, she predicted which bands would not cancel, and the entailment is licensed. Analogously, under the deductive reading the statement in (71b) is perceived as contradictory, while under the literal reading it is consistent.

(71) a. Mary predicted which of the bands from the original line-up would cancel their concerts.
∴ Mary predicted which of the bands from the orignal line-up would not cancel their concerts.

b. Mary predicted which of the bands from the original line-up would cancel their concerts, but she didn't predict which wouldn't.

Again, expressions such as *in a sense* or *in effect* seem to disambiguate embedding verbs in favour of the deductive reading. In the case of communication verbs, this might be seen as stressing the *result* of the communicative act. They appear to say that, even though there might not have been an explicit speech act, the communicative effect is just the same. Inserting *in effect* into the above sentence for instance makes the entailment go through unambiguously.

(72) Mary predicted which of the bands from the original line-up would cancel their concerts.
∴ **In effect,** Mary predicted which of the bands from the orignal line-up would not cancel their concerts.

On the other hand, it can be indicated that the embedding verb is used literally, for example by explicitly modifying the act of communication as in (73).

(73) Mary predicted **at length** which of the bands from the original line-up would cancel their concerts.

3.2.3 Monotonicity properties

Let us now examine how the monotonicity properties of embedding verbs vary between the literal and the deductive reading. We are going to look at several entailment patterns like the following and discuss whether a given verb validates them. To give one clear example, in the case of (74), at least under a standard understanding of knowledge, the entailment is licensed—telling us that *know that* is upward-monotonic.

(74) x knows that $p \wedge q$
∴ x knows that p

As in this example, the inferences under investigation will always involve at least one instance of the *declarative*-embedding use of the respective verb. This might strike one as odd at first sight. Is it not *interrogative*-embedding that we are studying here? Indeed. But our eventual implementation will be uniform and include only one lexical entry for both the interrogative- and declarative-embedding uses of responsive verbs: for example, knowledge-*wh* will be defined in terms of the propositions to which the subject stands in a *know-that* relation: which knowledge-*that* does it take to make e. g. (75) true? In particular, we will have to determine the exact set of propositions such that, if an individual knows any one of them, (75) holds true. In order to determine which pieces of information are contained in this set, it is vital finding out about the monotonicity properties of *know-that*.

(75) John knows who was at the party.

Let us start with the monotonicity properties of *surprise*, though. In contrast to many other question embedders, emotives are not upward-entailing with respect to their complement clauses. This was noted by Lahiri (2002), who observes that *surprise*-like predicates do not “distribute” over their complements (76).

(76) x is surprised that $p \wedge q$
$\not\therefore$ x is surprised that p

To see why, imagine that Alice and Bob strongly dislike each other and avoid each other whenever possible. So, when both of them showed up at the party yesterday, Mary was very surprised. Had only either of them, but not the other one, attended the party, Mary would not have been surprised. In this situation, it is true that Mary was surprised *that Bob and Alice were at the party*, but not that she was surprised *that Bob was at the party* for example. This stands in marked contrast to epistemic verbs such as *know* (74).

Seeing it is not upward-monotonic—is *surprise* then downward-monotonic with respect to its complement? Égré and Spector (2014) conjecture that the answer might be negative, and *surprise* might be entirely non-monotonic. To me it seems, however, that this depends on whether the embedding verb is understood literally or deductively. Consider a literal reading of (77).

(77) Mary was surprised that Alice was at the party.

What Mary was surprised by is then *exactly* the proposition *that Alice was at the party*—no other proposition. *Exactly this* is the proposition which is part of Mary's attentive state, and on the basis of (77) we cannot conclude that, at the given moment in time, any other proposition is part of Mary's awareness and caused surprise in her. Hence, on the literal reading, *surprise* is characterised by a complete lack of monotonicity. Under the deductive interpretation, on the other hand, *surprise* receives something like a sufficiency reading: which facts does it take to cause surprise? The more facts the more likely for someone to be surprised. This reading is exemplified in (78).

(78) If you are already surprised that *Mary* is coming, wait until I tell you *who else* is coming!

Here, the listener is described as surprised by the proposition that Mary is coming. A more specific proposition than this—so the speaker implies—will not reduce the listener's surprise, but on the contrary increase it. Hence, it seems that there is also an—at least *truth-functionally*—downward-monotonic reading of *surprise* and that this reading can be associated with the deductive understanding of *surprise*. What is meant by *truth-functionally* downward-monotonic here is the following. In practice, *surprise* carries a knowledge presupposition: in order to be surprised by some fact, you need to know this fact. Since the *know*-relation is clearly not downward-entailing, this knowledge presupposition blocks the downward-monotonicity of *surprise*. We can still get the downward-entailing sufficiency reading, though, if it is made obvious that the knowledge-presupposition is satisfied. In (78), for example, it is clear that the listener will know *who else is coming* once the speaker tells him so. Hence, abstracting away from the knowledge-presupposition, *surprise* seems to create a downward-entailing environment.

We will later analyse an agent's surprise in the deductive sense as that situation when his expectations are irreconcilably at odds with some proposition p. This fits well with the above sufficiency understanding of surprise, since the more specific either p or the agent's expectations are, the more likely for them to clash with each other.

Of course, to say that—if Mary finds some proposition p surprising—she will automatically find any more specific proposition $p' \subseteq p$ surprising as well is a crude simplification: making p more specific might mean including facts which explain away the oddness responsible for Mary's surprise. Also, the more specific p' becomes, the smaller the "contribution" of p to p' will be. At some point, it seems we will no longer be able to justify calling p' surprising for Mary. But determining the (probably very fuzzy) nature of such a threshold is a question for a different occasion. For the time being, we will assume that declarative-embedding *surprise* is indeed downward-entailing with respect to its complement on the deductive reading. The lexical properties of other emotives are a wide field, and I will not take a stance regarding their monotonicity behaviour here.

Now on to communication verbs. Regarding their monotonicity behaviour, such embedders exhibit similar patterns as emotive predicates—the main difference being that, *if* they are monotonic, they are (something like) *upward-* and not *downward-*entailing with respect to their complements. We will later describe this restricted form of upward-monotonicity as "upward-monotonicity modulo the no-false-answers constraint". In the literature, it has been discussed under the heading of *intermediate exhaustivity* (Klinedinst and Rothschild, 2011). But let us look at this in detail. To begin with, let us check when communication verbs are monotonic at all and when they are not. Imagine John and Mary are playing a game in which John thinks of a number n between 1 and 100, and Mary has to guess this number. John is giving her hints. In one round, he announces that n is prime and that it is larger than 2. Clearly, any number that is prime and larger than 2 is not divisible by 2. But not any number that is not divisible by 2 also is prime. Hence, the proposition that John announced is a proper subset of the proposition that n is not divisible by 2. If *announce* in (79) was upward-monotonic, it would allow the inference given there.

(79) John announced that n is prime and larger than 2.
$\not\therefore$ John announced that n is not divisible by 2.

It seems, however, that the use of *announce* in (79) tends towards a literal reading, and does not permit the inference. We have already seen that *in effect* can disambiguate embedding verbs in favour of the deductive reading. Indeed, inserting this adverbial into (79) for instance ensures the previously blocked entailment is licensed—suggesting that communication verbs are upward-entailing under the deductive reading.

(80) John announced that n is prime and larger than 2.
$\therefore$ **In effect**, John announced that n is not divisible by two.

This upward-monotonicity also shows up without explicitly marking a communication verb as deductive. The dialogue in (81) has Bob telling Mary whom he has already invited, namely his friends from highschool.

(81) Mary: Can you tell me who you've already invited? I don't want to call anyone twice.
Bob: Not so many people, in fact... Only my friends from highschool.

Assume Mary knows that Bob's only friends from highschool are Alice and John. Hence, we can infer from the fact that Bob told Mary *he invited his friends from highschool* that he has also told her *he invited Alice* and that he has told her *he invited John* (82). This is an upward entailment.

(82) Bob told Mary that he invited his friends from highschool.
It is common knowledge among Mary and Bob that Bob's only friends from highschool are Alice and John.
$\therefore$ Bob told Mary he invited Alice.

Since *tell* in this example has a clearly defined purpose (namely to prevent Mary from calling someone who has already been invited), the deductive reading seems to be dominant. Note also that, again, the deductive reading seems to allow some background knowledge—this time it is knowledge from the common ground—to enter the picture.

There is one catch regarding this upward-monoticity, however, showing up in connection with the interrogative-embedding uses of communication verbs. From the upward-monotonicity of e. g. deductive *tell-that*, one could draw the following conclusions. To determine what needs to be the case in order for (83) to be true, we need to say which proposition p John *minimally* needs to tell Mary.

(83) Bob told Mary whom he has already invited.

Once we have found this minimally-informative p, we know that (83) will be likewise true if John told Mary a more specific proposition $p' \subseteq p$. After all, by telling p', he will still communicate all information he would have communicated by just telling p. Indeed, this reasoning matches what we can observe with declarative-embedding predicates: the entailment in (84) is licensed; for what Bob told Mary about Carol is immaterial to the truth of the conclusion.

(84) The only people Bob has already invited are Alice and John.
Bob told Mary that he has already invited Alice, John and Carol.
∴ Bob told Mary that he has already invited Alice and John.

This is different for (85), however, where the entailment is blocked because Bob wrongly told Mary that he has already invited Carol.

(85) The only people Bob has already invited are Alice and John.
Bob told Mary that he has already invited Alice, John and Carol.
$\not\therefore$ Bob told Mary whom he has already invited.

In (86), finally, the entailment goes through even in situations where Bob is lying about having ordered pizza.

(86) The only people Bob has already invited are Alice and John.
Bob did not order pizza.
Bob told Mary that he has already invited Alice and John and that he ordered pizza.
∴ Bob told Mary whom he has already invited.

Here, again, for the truth of the conclusion it is immaterial what Bob said to Mary about ordering pizza. The difference between (85) and (86) is that, in the former sentence, the more specific proposition p' is a *false answer* to the question *Whom has Bob already invited?*. In the latter sentence, by contrast, what made p more specific is a piece of information that is not relevant to the embedded question at all. Therefore, although p' is false and is an answer, it is not a *false answer*.

Note that, on closer inspection, this behaviour really strikes us as odd: after all, it is possible to start out from the premise that Bob told Mary a *false* answer to the embedded question and—via only one additional step of reasoning—reach the conclusion that Bob told Mary *whom he has already invited*. This is done in (87).

(87) The only people Bob has already invited are Alice and John.
Bob told Mary that he has already invited Alice, John and Carol.
∴ Bob told Mary that he has already invited Alice and John.
∴ Bob told Mary whom he has already invited.

What our eventual semantics will have to take care of is therefore to prohibit the individual from standing in the specified relation with a false answer. We will call this the *no-false-answers constraint* (NFA). Interrogative-embedding communication verbs are hence upward-entailing on the deductive reading, but they respect the NFA: for a tell-*wh* relation to obtain between an individual and a proposition, the proposition may be arbitrarily specific, as long as it is not a false answer. A similar restriction has been mentioned by Groenendijk and Stokhof (1984, p. 85f) and more recently been rediscovered by Spector (2005). For most authors, including Spector, the no-false-answers constraint gives rise to an additional level of exhaustive strength—which is situated in between weak and strong exhaustivity and has thus been dubbed *intermediate exhaustivity* by Klinedinst and Rothschild (2011). To be more specific, Klinedinst and Rothschild assume that the constraint is only relevant for weakly exhaustive question interpretations and for a certain class of embedders. We will see in Section 3.5.4, however, that the exclusion of false answers is a far more general property. It pertains to *all* upward-monotonic interrogative-embedding predicates—regardless of the embedded question's interpretive strength. The only verbs for which the no-false-answers constraint has no relevance are those that are *not* upward-entailing, e. g. emotive verbs like *surprise*. To see why, assume that $p' \subsetneq p$, where p is a true answer to some question Q and p' is a false answer. If our semantics correctly predicts the lack of upward-monotonicity—i. e. that *surprised that* p' does not entail *surprised that* p—then the problems motivating the no-false-answers constraint will not show up for *surprise*: an individual x will never be wrongly predicted to be surprised by Q on the basis of x's being surprised that p'. For x to be surprised by Q, she has to be surprised by p itself or by some $p'' \supseteq p$. Accordingly, we can write up the no-false-answers constraint as follows.

(88) **No-false-answers constraint**:
Let R_q be the relation between individuals and questions that is expressed by some responsive, upward-entailing predicate. Let R_d be the corresponding relation between individuals and pieces of information, expressed by the same responsive predicate. Assume p is a false answer to a question Q at world w. Then, in order for an individual a to stand in relation R_q to Q at w, it must not be the case that, at w, a stands in relation R_d to any piece of information entailing p.

Naturally, the restriction to true answers only makes sense for veridical predicates. The above examples did indeed contain veridical embedders since the default reading of interrogative-embedding communication verbs is veridical. Recall, however, that we can simply view non-veridicality in terms of a world shift: the individual stands in relation to a proposition such that there is a world in which this proposition is an answer to the embedded question and is not a false answer to this question. This means we can safely assume that, just like veridicals, non-veridicals do not permit "false" answers. The only difference is that the world of evaluation, which determines whether an answer is a false one, is not the actual world. This also means that in practice the NFA has no consequences for the semantics of non-veridicals—as evidenced by (89)—simply because it is always possible to find a world such that some proposition is a true answer to the given question.

(89) The only people Bob has already invited are Alice and John.
Mary is certain that Bob has already invited Alice, John and Carol.
∴ Mary is certain whom Bob already invited.

At first sight, the NFA appears like the kind of meaning component that could be derived by pragmatic reasoning. After all, the subject is allowed to stand in relation to the true complete answer, but not to a *stronger* answer. Conceivably, the constraint could therefore be derived by appealing to the Grician maxim of quantity. However, such a pragmatic account would fail to capture certain facts. Consider the following example. Alice, Bob and Charles are running for parliament. It is election day and John watches the first projections on TV. He has not really grasped that those projections do not necessarily coincide with the final results. So, when it is announced that according to the projections Alice, Bob and Charles have made it into parliament, John takes this for a fact and switches off the TV. What really happens, however, is that only Alice and Bob win a seat, but Charles does not. In this situation, (90) is a true statement.

(90) John didn't learn who was elected into parliament.

In order for (90) to come out true, however, the NFA needs to apply. Note that the question is embedded under a negated sentence, though, and that Gricean implicatures do not project through negation. Under an account that treats the NFA (or [+exh] for that matter) as a Gricean implicature, the implicature would hence be blocked by the negation. That is, the NFA would not apply (or the [+exh]-implicature would not arise) and (90) would be predicted to be false. I will take this to indicate that a non-pragmatic treatment is called for.

For the moment, this concludes our discussion of the no-false-answer costraint (it will be taken up again in Section 3.5.4). Now on to a different class of verbs, which are also subject to the literal/deductive ambiguity—rogatives like *ask* and *wonder* (the former of which could also be seen as a verb of communication and the latter as an emotive verb). With rogatives, the ambiguity has repercussions on something like monotonicity as well. It determines whether the interrogative complement clause can be decomposed into subquestions or, in other words, whether an inference from embedded question to embedded subquestion is admissible. To see this, consider example (91).

(91) Mary asked which of the bands from the original line-up cancelled their concerts.
The Knife were on the original line-up.
∴ Mary asked whether The Knife cancelled their concert.

Under the literal reading of *ask*, Mary must be understood to have uttered a question very similar to "Which of the bands from the original line-up cancelled their concerts?". That is, she did not explicitly inquire about The Knife. Therefore, the entailment is blocked. If we take (91) in the deductive sense, however, the entailment goes through since, by requesting information about which bands cancelled, Mary *in effect* also requested information about The Knife. So, once again the focus of this reading is on the *effect* of Mary's asking, namely on her communicating a request for certain information.

This observation might be relevant in view of so-called *quantificational variability effects* (QVE), first observed by Berman (1991). In sentences like (92a), the quantificational adverb occurring in the matrix clause seems to be quantifying over some part of the embedded question; hence, intuitively, a paraphrase along the lines of (92b) appears adequate: John can identify most cheaters.

(92) a. For the most part, John knows which students cheated.
b. For most students x who cheated, John knows that x cheated.

Not all interrogative-embedding verbs allow for QVE, though, and the data on which exactly do are contradictory. Berman (1991) and Lahiri (2002) maintain that rogatives such as *wonder* and *ask* cannot exhibit QVE: in (93a), the quantification cannot be over the embedded question. The account of Beck and Sharvit (2002), in contrast, predicts QVE with rogatives—based on examples like (93b) and (93c) (p. 143), where the quantificational adverbial seems to target the embedded question.

(93) a. # Bill mostly asked which students cheated.
b. A: Did the police give you guys any trouble last night?
B No. For the most part, they didn't even ASK who was under 21.
c. A: Has John found out which students cheated?
B: No. For the most part, he is still wondering.

While there certainly is a lot more to be said about the availability of QVE with different embedders, the distinction between literal and deductive readings might be a good starting point. We have seen that under the literal interpretation, the complement clause seems to be an atomic object: it is not decomposable into subquestions. Since Beck and Sharvit (2002) analyse QVE in terms of quantification over subquestions, under their analyis, it would make sense if QVE were blocked for rogatives under the literal reading. Indeed, if we interpret the adverbials in (93b) and (93c) as targetting the embedded question, this will automatically disambiguate *ask* in favour of the deductive reading.

3.2.4 Other verbs

Verbs that are neither emotives nor verbs of communication usually do not display the literal/deductive ambiguity so clearly. For example, *know* seems to lean strongly towards a deductive interpretation. What might contribute to this are two things. Firstly, different from emotives/verbs of communication, *know* unambiguously belongs to the aspectual class of *state* verbs. Verbs of this class generally tend towards the deductive reading: they do not express events or punctual actions, but states that stretch over time. As such, they do not to the same extent exhibit an attention dimension as *achievement* or *activity* verbs might. Secondly, even though this might be quite an idealisation, we assume an agent's knowledge to be closed under entailment. That means, those additional steps of reasoning involving background knowledge that we have seen above as part of the deductive reading (cf. examples (67) and (82)) might already implicitly be contained in the semantics of *know*.

Concluding this section on the literal/deductive ambiguity, we have seen that this ambiguity pertains to verbs of communication and to emotive verbs. It manifests itself in terms of the monotonicity behaviour exhibited by such verbs and in terms of certain entailments that these verbs do or do not license. We will return to the latter aspect in Section 3.5 and link it to the exhaustive strength of the embedded question.

3.3 Strong exhaustivity

We will now turn to the different levels of informational strength that have classically been proposed for the interpretation of embedded interrogatives—starting with one of the less controversial ones, namely strong exhaustivity. Question denotations that are strongly exhaustive will be characterised as [+exh]; all weaker denotations will be referred to as [–exh].

As we have already seen in Chapter 1, there is a salient understanding of interrogatives embedded under e. g. *know* which licenses the following entailment.

(94) John knows who is coming for dinner.
Mary is not coming for dinner.
∴ John knows that Mary is not coming for dinner.

In order to capture this inference, a [+exh] question denotation—that is, a partition—is needed; anything weaker will not do. In the same vein, the following sentences are perceived as inconsistent.

(95) a. John knows which of his three favourite novels have won the Booker prize, but he doesn't know which haven't.
b. John and Mary agree on which countries have a Pacific coast, but they don't agree on which don't.

This, too, can only be captured if the denotation of the embedded question is [+exh]. Note, however, that in order to actually produce an inconsistency, several factors need to be controlled: to begin with, the domain of quantification has to be fixed. Above, this is done by restricting the *wh*-phrase as *which of his three novels* or *which countries*. Similarly, the inference in (94) only goes through if John is aware of what constitutes the domain of discourse. Furthermore, for the contradictions in (95) to arise, the predications in the embedded sentences have to express properties that are clearly dichotomous (for example, a country either has a Pacific coast or not, but there is nothing in between).

Markers for strong exhaustivity

Mandarin Chinese has a quantificational question particle, *dou* 'all', which among other things marks its containing questions as "exhaustive" (Li, 1995). Li does not specifiy whether he is talking about weak or strong exhaustivity, but from his examples (p. 318) we can conclude that the former is the case: *dou* enforces a [+cmp] interpretation (that is, a weakly exhaustive interpretation) of the question it appears in. In a context in which the speaker knows exactly three people, namely Zhangsan, Lisi and Wangsu, the mention-some answer in (96b) is an inacceptable reaction to (96a), whereas the [+cmp] answer in (96c) is perceived as congruent.

(96) a. *Ni dou renshi shei?*
you all know who
'Who-all do you know?'

b. # *Wo renshi Lisi.*
I know Lisi
'I know Lisi.'

c. *Wo renshi Zhangsan, Lisi he Wangwu.*
I know Zhangsan, Lisi and Wangwu
'I know Zhgnsan, Lisi and Wangsu.'

However, Li limits his attention to root interrogatives and does not examine the semantic contribution of *dou* in embedded interrogatives. Once we turn to such interrogatives, it emerges that the effect of *dou* might be even stronger: it seems to not only contribute a [+cmp], but also a [+exh] requirement. As a point in favour of this view, note that the following example sentence becomes semantically infelicitous/contradictory if *dou* occurs in the embedded question. Without this particle, (97) gives rise to a certain oddness, but can be accomodated/repaired. If *dou* is present, such a repair becomes impossible.[6] This effect can only be accounted for under a [+exh] interpretation; a [−exh] reading does not entail a contradiction (cf. Section 3.5).

(97) *Yuehan gaosu wo zai ta zuixihuan de sanben xiaoshuo zhong* ***(#dou you)***
John told me among he favourite POSS three novel in all have
naben yingle Buke jiang, dan ta bu gaosu wo naben mei ying.
which have won Booker prize but he didn't tell me which haven't won
'John told me which of his three favourite novels have won the Booker prize, but he didn't tell me which haven't.'

Li suggests that the exhaustivity requirement contributed by *dou* is the same as that of the German quantificational question particle *alles* 'all'. However, as we will see later, there are reasons to analyse German *alles* not as a marker for strong exhaustivity, but only for completeness. For example, the German sentence corresponding to (97) does not give rise to a contradiction:

(98) *Er hat mir erzählt, wen seiner Freunde er gestern* ***alles*** *gesehen hat, aber er hat*
he has me told who of his friends he yesterday all seen has but he has
mir nicht erzählt, wen er nicht gesehen hat.
me not told who he not seen has
'He told me who(-all) he saw yesterday, but he didn't tell me who he didn't see.'

6 Many thanks to Ciyang Qing for his help with the Mandarin data.

3.4 Completeness

Among the possible interpretations of embedded questions, strongly exhaustive ones demand the most information to be resolved. In contrast, mention-some readings, at which we are about to look now, demand the least information. Mention-some readings are called for in a question semantics due to examples like (99).

(99) Where can I buy an Italian newspaper?

Usually, what a speaker requests by an utterance of (99) is not a complete specification of all (relevant) shops that sell Italian newspapers (let alone information about which shops do *not* sell them), but just a pointer to one or maybe two of such shops which are close by. Essentially, any information that enables the speaker to go and purchase an Italian newspaper (or that tells him there is no suitable shop) will suffice as a reply to (99). Analogously, the knowledge ascribed to John by (100) does not necessarily concern a complete list of all places stocking Italian newspapers—this would impose far too strong truth-conditions.

(100) John knows where one can buy an Italian newspaper.

On the other hand, knowing such a complete list won't hurt, either: it will still enable John to buy an Italian newspaper. Hence, it is clear that a [+cmp] answer is an acceptable reply to a mention-some question, too. In the later implementation, [+cmp] and [−cmp] will not be mutually exclusive categories, but [+cmp] knowledge will entail [−cmp] knowledge.

If there is *no* shop selling Italian newspapers, a mention-some reading of (100) seems infelicitous. The exact status of this infelicity would require further investigation. Conceivably, it could be treated in terms of presupposition failure. I will not have anything to say about this here, however.

Completeness and incompleteness markers

Some languages, for example German and Dutch, have overt markers for completeness (Rullmann and Beck, 1996) : they enforce a [+cmp] reading of their containing interrogative. This effect is nicely illustrated for the German marker *alles* 'all' (glossed as CMPM) by the following example from an online forum[7].

(101) *Ich hab da mal ne Frage… und zwar, wer kommt* ***alles*** *mit zum*
I have there PTC a question namely who comes **CMPM** with to the
Standesamt? Familie is klar, aber auch Freunde, Bekannte und so weiter?
register office family is clear but also friends acquaintances and so on
'I've got a question…who is it that usually joins the [part of a wedding ceremony at the register office]? Of course, members of the family do—but also friends, acquaintances and so on?'

The author of the post inquires about the group of people usually present at the legal part of a wedding ceremony. She then clarifies that she already knows a partial answer to that question, but is not sure whether this knowledge constitutes a complete answer. Her original

7 www.hochzeitsplaza.de/hochzeits-forum/hochzeitsbereich/trauung-und-organisatorisches/35881-wer-kommt-mit-zum-standesamt/

question containing the exhaustivity marker must hence be understood as [+cmp]. Interestingly, however, after the author will have learned the answer to her question, she will be aware that this answer is complete (since she explicitly requested a complete answer). This again enables her to draw inferences in the style of (94), meaning that in a sense the question is also [+exh].[8]

The occurrence of *alles* in this example is in fact not essential for a strongly exhaustive interpretation: the strength of the author's request for information would have been communicated by the context, too. However, there are also questions for which the presence of a completeness marker does make a difference. In the Dutch example (102), the embedded interrogative strongly tends towards a mention-some reading (cf. Section 3.4): for the sentence to be true, it suffices if Jan knows of at least *one* place that sells Italian newspapers.

(102) *Jan weet, waar je een Italiaanse krant kan kopen.*
Jan knows where you a Italian newspaper can buy
'Jan knows where you can buy an Italian newspaper.'

Inserting the completeness marker *allemaal* 'all' changes this interpretation: for (103a) to hold true, Jan has to know the complete list of (relevant) places where you can buy such a newspaper.

(103) a. *Jan weet, waar je* ***allemaal*** *een Italiaanse krant kan kopen.*
Jan knows where you **CMPM** a Italian newspaper can buy
'Jan knows (all the places) where you can buy an Italian newspaper.'

This seems to establish that the embedded question in (103a) is [+cmp]. But can we also argue that it is [+exh], as in the wedding example above? Again, there seems to be an ambiguity. The completeness marker in (103a) could be understood as attributing the awareness that his knowledge is [+cmp] to *Jan himself*. In fact, this understanding would amount to something like a de-dicto reading. The completeness marker could also be interpreted as attributing this awareness merely to the *speaker*. This latter reading could be labelled de re. Under the de-re interpretation, that is, without Jan being aware that his own knowledge constitutes a [+cmp] answer to the embedded question, however, this question cannot be interpreted as [+exh]. Hence, it appears that—in their core use—*alles/allemaal* really only mark *completeness*, not strong exhaustivity. Especially in root questions or in embedded questions for which the speaker and the subject of the embedding predicate coincide,

8 Both German *alles* and Dutch *allemaal* further naturally occur in questions that demand not a list of entities, but rather a characterisation of all entities that would be on the list. Sentence (i) for example, taken from the website of a company offering bartending courses (`www.barschool.nl`), certainly does not request a list of individuals, but rather a description of who would profit from participating in their courses. This is interesting in so far as such a characterisation allows inferences of the same kind as a strongly exhaustive answer would: given an individual, it is possible to check whether he fits the characterisation and, on the basis of this, say whether taking the bartending course would be a good decision for him or not. Actually, in a sense, the wedding example in (101) also requests a characterisation (the characterisation could be *being a family member or a friend* for instance) rather than a list answer.

(i) *Voor wie allemaal is deze Top Cursus Cocktail Bartending?*
for who CMPM is this Top Course Cocktail Bartending
'For whom is the *Top Course Cocktail Bartending* suitable?'

however, it is possible that this completeness is understood de dicto—that is, it is taken to be part of e. g. the attributed knowledge itself. We will discuss this later on. However, the strongly exhaustive interpretation need not always be available: the following example from a German magazine interview[9] only makes sense if the denotations of the two embedded questions are not identical—hence, if the questions are not interpreted strongly exhaustively (cf. the discussion of weak exhaustivity in Section 3.5).

(104) *SPIEGEL:* *Hat es Sie überrascht, wer alles auf der Liste steht?*
(name of magazine) has it you surprised who CMPM on the list stands
Jaksche: *Ja. Aber noch mehr hat mich überrascht, wer alles nicht*
(name of interviewee) yes but even more has me surprised who CMPM not
draufsteht – bei all dem Wissen, das jetzt bekannt ist.
stands-on-it given all the knowledge that now known is

'Interviewer: Did it surprise you who is on the list? Interviewee: Yes. But it surprised me even more who is not on the list—given all the information that has leaked by now.'

In general, the behaviour of *alles* in questions embedded under emotives nicely illustrates the *maximality effect* that this marker has. The most salient understanding of the following example is that Peter expected (considerably) fewer people at the party.

(105) *Peter war überrascht, wer alles zur Party gekommen ist.*
Peter was surprised who CMPM to the party come.PART is

'Peter was surprised who-all came to the party.'

Hence, he was surprised by the attendance not of individual guests, but by the (size and composition of the) entire group. This means, his surprise clearly concerns the complete answer. Analogously, Peter's disappointment in (106) is triggered by the fact that more people cheated than he would have wished for—and maybe even those of whom he would not have expected such betrayal. Again, his disappointment concerns the complete answer.

(106) *Peter ist enttäuscht, wer alles geschummelt hat.*
Peter is disappointed who CMPM cheated has

'Peter is disappointed who-all cheated.'

As a brief final note, just as interrogatives can be marked for a mention-all reading, they can also be marked for a mention-some reading. In root questions, an easy way of doing so in English is to restrict the *wh*-phrase with *for example* (Beck and Rullmann, 1999).

(107) A: Who for example was at the party yesterday?
B: Let me think... So: Mary, Ann, Mark, Cathrin, Bob, Michael, Sven, Adam, Emma, Charles, Chris, Susan, Pat... [wants to go on]
A: Hang on, hang on! That's enough! "Who *for example*," I said.

At this point, we have already seen two different ways to understand questions in general and embedded questions in particular: as [+cmp, +exh] and as [–cmp, –exh] questions.

9 www.spiegel.de/sport/sonst/jaksche-beichte-nur-wer-dopt-gewinnt-a-492216.html

This leaves only one[10] more feature combination to examine, namely the rather controversial [+cmp, –exh], also known as weak exhaustivity.

3.5 Answers that are complete, but not strongly exhaustive

There are two kinds of examples classically used to argue for the existence of a [+cmp, –exh] reading. We will inspect both and relate them to the ambiguity between literal and deductive readings, arguing partly contra George (2013), who challenges the existence of a weakly exhaustive interpretation. What we will find is that [+cmp, –exh] readings exist, but are tied to the literal interpretation. The deductive interpretation on the other hand always corresponds to [+cmp, +exh]; and if this does not seem to be the case, it usually is because the domain is not fixed. Further, we will return to a topic already encountered in Section 3.2, namely the no-false-answer cosntraint, which applies to upward-entailing embedders.

Examples in favour of a [+cmp,–exh] reading (e. g. Sharvit, 2002; Guerzoni and Sharvit, 2007) usually feature emotive verbs or communication verbs as embedding predicates:

(108) Maggie is surprised which of her three favourite novels won the Booker Prize, but she isn't surprised which didn't.

(109) Maggie told me which of her three favourite novels won the Booker Prize, but she didn't tell me which didn't.

In contrast to otherwise identical examples with *know* (110), sentences like (108) and (109) are not necessarily judged as inconsistent.

(110) Maggie knows which of her three favourite novels won the Booker Prize, but she doesn't know which didn't.

This fact can only be accounted for if the embedded question is interpreted as [–exh]. Under a [+exh] interpretation, (108) and (109) would be inconsistent. However, whether they are judged as inconsistent, seems to depend on whether they are interpreted literally or deductively: under the literal reading, (108) and (109) are consistent, while under the deductive reading they seem inconsistent.[11] Hence, we find [–lit] associated with [+exh], while [+lit] seems to be associated with [–exh]. In line with this, *know*, which can only be [–lit], is always [+exh].[12]

Another kind of evidence used to advocate a [+cmp, –exh] reading comes from sentences like (111), which we have also encountered in Section 3.2.

(111) Alice was surprised by who was at the party.

It was Heim (1994) who observed that (111) can fail to be true in cases where Alice's expectations are at odds only with the [+cmp, +exh] answer to the embedded question, but not with the [+cmp, –exh] answer. Consider for example the following party scenario: Alice expects John and Bob to be at the party, but has no expectations about Carol. What happened

10 Since, as discussed ealier, the fourth possible combination, [–cmp, +exh], amounts to the same reading as [+cmp, +exh], namely to strong exhaustivity.

11 Or rather, upon reading the negated second part of those sentences, the deductive reading is almost unavailable for (108) and (109) as one automatically repairs the inconsistency that a deductive understanding would cause.

12 At least if *know-wh* is also [+cmp]. There are mention-some uses of *know*.

	John	Bob	Carol
Alice's expectations	✓	✓	?
facts	✗	✓	✓

Table 5: Party scenario

in fact, is that Bob and Carol were the only guests at the party. So, the proposition that Bob and Carol were the only guests at the party is the strongly exhaustive answer to *Who was at the party?*. As evidenced by the truth of (112), this strongly exhaustive answer surprised Alice. Yet, on this scenario, (111) is sometimes (e. g. by George) judged false, while (113) is judged true.

(112) Alice was surprised that Bob and Carol were the only ones at the party.

(113) Alice was surprised by who wasn't at the party.

As discussed in Section 3.2, however, these judgements only seem appropriate for the literal reading. Under the deductive reading, (111) is judged true. So, once again, [–exh] seems to be associated with [+lit], while [+exh] seems to be tied to [–lit]. This position goes against all accounts that assume *surprise* is inherently [–exh] (e. g. Sharvit, 2002; Guerzoni and Sharvit, 2007), but it does not plough a lonely furrow (e. g. Klinedinst and Rothschild, 2011, footnote 18).

3.5.1 Weak exhaustivity as mention-some?

So far, we have established the need for a [–exh] reading. Such a reading is necessary to account for questions that are embedded under [+lit] emotives or [+lit] communication verbs. However, this still leaves two options open: the questions could be interpreted as [+cmp, –exh] (weakly exhaustive) or [–cmp, –exh] (mention-some). George (2013) suggests to go exclusively the latter route, arguing that the semantics of *surprise* can *always* be captured in terms of mention-some answers. According to him, a mention-some analysis of *surprise* is even preferable in certain scenarios. We will argue against George—not necessarily claiming that mention-some readings are *generally* the wrong choice for *surprise*, but rather maintaining that there do exist cases in which a [+cmp, –exh] interpretation is needed for this embedder.

Let us examine George's argument. To begin with, we desire (111) to come out as false under a literal reading. For this, we indeed do not need a [+cmp] answer, but a [–cmp] answer suffices. To see why, observe that in the given scenario there are three possible [–cmp] answers: *that Bob came*, *that Carol came* and *that Bob and Carol came*. Alice was surprised by neither of those answers. Hence, a [–cmp] interpretation of the embedded interrogative will render (111) false. This goes to show that (111) and the associated scenario are not sufficient to distinguish between mention-some and weakly exhaustive readings.

However, George presents a scenario which *is* sufficient to draw this distinction and which, according to him, disambiguates the meaning of the embedded interrogative in favour of a [–cmp] interpretation. Suppose, again, that Carol and Bob were the only guests at a party. Hence, (115) is the weakly exhaustive answer to (114).

(114) Who was at the party?

(115) Carol and Bob were at the party.

Assume further that Alice knows Carol was at the party, but she does not know anything about who else was there. This means, she knows a [–cmp] answer to (114). Also, the fact that Carol was there surprised Alice since she did not expect her to come. In this setting, (116) is true—meaning that Alice was surprised by a [–cmp] answer.

(116) Alice was surprised that Carol was at the party.

In contrast, (117) does not hold since surprise requires knowledge: Alice cannot be surprised that Carol and Bob were at the party because she does not *know* that Bob was at the party.

(117) Alice was surprised that Carol and Bob were at the party.

George (2013, p. 421) maintains that in this situation (118) is judged true and "shows no obvious signs of unnaturalness or presupposition failure".

(118) Alice was surprised by who was at the party.

This would indeed confirm that Alice stands in a surprise relation to a [–cmp] answer but not to the [+cmp] answer—suggesting that the [–cmp] interpretation is the preferable one for interrogatives embedded under *surprise*. However, I disagree with George and concur with Égré and Spector (2014, footnote 36): in the above scenario, I would find an utterance of (118) infelicitous, most likely due to presupposition failure. Reacting to (118) with a *wait-a-minute* reply like (119) would seem very warranted to me, indicating that the kind of knowledge required for surprise in this situation indeed corresponds to a [+cmp] answer to (114), not just a [–cmp] one.

(119) Wait a minute! She doesn't even know who was at the party.

As a further point against an exclusively [–cmp] semantics for *surprise*, consider example (120), where the completeness marker *alles* occurs in the embedded interrogative.

(120) Maria war überrascht, wer **alles** auf der Party war.
'Mary was surprised who-all was at the party.'

As discussed in Section 3.4, here *surprise* selects for the [+cmp] answer. While it is of course true that the [+cmp] answer is just a specical case of a mention-some answer, it has to be stressed that in (120) *surprise* selects for *exactly this* special case; not just *any* mention-some answer will do.

Hence, summing up the case of communication verbs and emotives in general and of *surprise* in particular: we have seen that a [–exh] question denotation is needed for the [+lit] understanding of these verbs and that George's proposal of an exclusively [−cmp, −exh] semantics is not tenable because it brushes aside the infelicity of its key example sentence. Furthermore, there are cases in which emotives and communication verbs clearly express a relation to a [+cmp, −exh] answer. We conclude that [+lit] embedders can really select for a [+cmp, −exh] reading. Consequently, such a reading will be included in our account. However the feature combination [+cmp, −exh] seems tied to a [+lit] interpretation of the embedding verb. In Section 3.5.3, we will briefly contemplate why this might be.

3.5.2 Availability of different feature combinations

Before that, however, a word of caution might be due: saying that the feature combinations [−lit, +cmp, −exh] and [+lit, +cmp, +exh] seem unavailable for embedded questions is *not* tantamount to predicting that there is no situation that *would* make such a reading true. For example, consider the case of *know*, which we assume to be an inherently [−lit] embedder. Hence, we predict it to disallow [+cmp, −exh] readings. However, this prediction does *not* say that an individual cannot have [+cmp, −exh] knowledge-*wh*; of course it is possible that someone knows the complete specification of a property without knowing that what he knows actually is the complete specification. This would be [+cmp, −exh] knowledge-*wh*. The question that interests us in the context of question embedding, though, is not whether such knowledge is generally possible, but merely whether there is a reading of questions embedded under *know* which attributes exactly this knowledge to an individual. I would argue that this is not the case. The reasoning is the familiar one. Consider example (121), which is perceived as inconsistent (for an extensive discussion of this test see George, 2013).

(121) John knows who of his friends were at the party, but he doesn't know who of them weren't.

If *know* allowed a [+cmp, −exh] reading, then—in order to repair this sentence—we would automatically understand it as [+cmp, −exh]. Since the contradiction seems irreparable, however, we conclude that *know* does not permit a [+cmp, −exh] reading. Similarly, if *tell* had a [−lit, +cmp, −exh] reading, then this reading should be available for (122).

(122) John told me who of his friends are invited, but he didn't tell me who aren't.

In contrast to the previous example, (122) does not give rise to a contradiction, but it seems that a consistent reading only becomes possible because *tell* is understood as [+lit]. Informants who judged (122) as consistent, typically gave reasons for their judgement along the lines of "The sentence is not contradictory because John hasn't actually *said* anything about who isn't invited. He was only talking about who is invited." This clearly corresponds to a literal interpretation of *tell*.

Turning to the unavailability of [+lit, +exh] readings, again we want to find examples that would enforce a [+lit, +exh] reading if it did exist. From the fact that these examples fail to enforce such a reading, we would then conclude that the reading does not exist. For [+lit, +exh] readings it appears a little more difficult identifying suitable examples than before for [−lit, +cmp, −exh]. As a first attempt, however, consider the following entailment:

(123) John told me at length who is invited.
Mary is not invited.
$\not\therefore$ John told me that Mary is not invited.

It seems safe to say that the entailment is not licensed. It would be licensed if we enforced a [–lit] interpretation instead: that is, if we (i) omitted the *at length* modification, which disambiguates *tell* in favour of the literal reading, and if we (ii) inserted *in effect* into the consequence, which would disambiguate *tell* in favour of the deductive reading. However, the fact that under a [+lit] reading the entailment does not go through, indicates that a [+lit, +exh] reading is not available for *tell*. A similar reasoning applies to the following contrast: a [+exh] reading seems to be available for [–lit] *tell*, but not for the [+lit] version of this verb.

(124) John told me at length who is invited.
$\not\therefore$ John also told me (at length) who is not invited.

(125) John told me who is invited.
$\therefore$ In effect, John also told me who is not invited.

Regarding the crosslinguistic availability of [+lit, +exh] readings, however, it would of course be interesting to see whether there are languages which both have overt exhaustivity markers and which make an (ideally even lexical) distinction between deductive and literal embedders. If those languages allowed the exhaustivity marker in clauses embedded under [+lit] verbs, then this would call for reconsidering and relaxing our predictions.

To recapitulate, the different readings we predict are summarised in Figure 9. Crosses and question marks indicate that the respective feature combination appears to be unavailable. Crosses signal that this unavailability might have principled reasons (for example, similar to the ones discussed in the next section); a question mark signifies that we have not found a suitable example of this configuration, yet—without being able to explain why. In particular, there does not seem to be a categorical reason why [+lit] mention-some readings should not exist. The problem is rather that they would be very difficult to keep apart from [–lit] mention-some questions. Further note that on the left side the tree is collapsed into just one branch for [+cmp] and [–cmp]. This is the case since, as soon as the question denotation is strongly exhaustive, the value of the completeness feature does not make a difference: to the extent that the combination [+exh, –cmp] exists, it is the same as [+exh, +cmp].

3.5.3 The exhaustivity of deductive readings and the non-exhaustivity of literal readings: attempting an explanation

As illustrated by several examples in the previous sections, only two kinds of [+cmp] readings seem to be available: [+lit, –exh, +cmp] on the one hand and [–lit, +exh, +cmp] on the other hand. Here, I will attempt to find reasons for this limitation. The arguments I provide will not offer a fully satisfactory explanation; they might however inspire further reflection on the problem.

Regarding the [+lit, –exh, +cmp] interpretation, consider that literal readings are sensitive to something like linguistic surface form. Now, what an interrogative expresses *on*

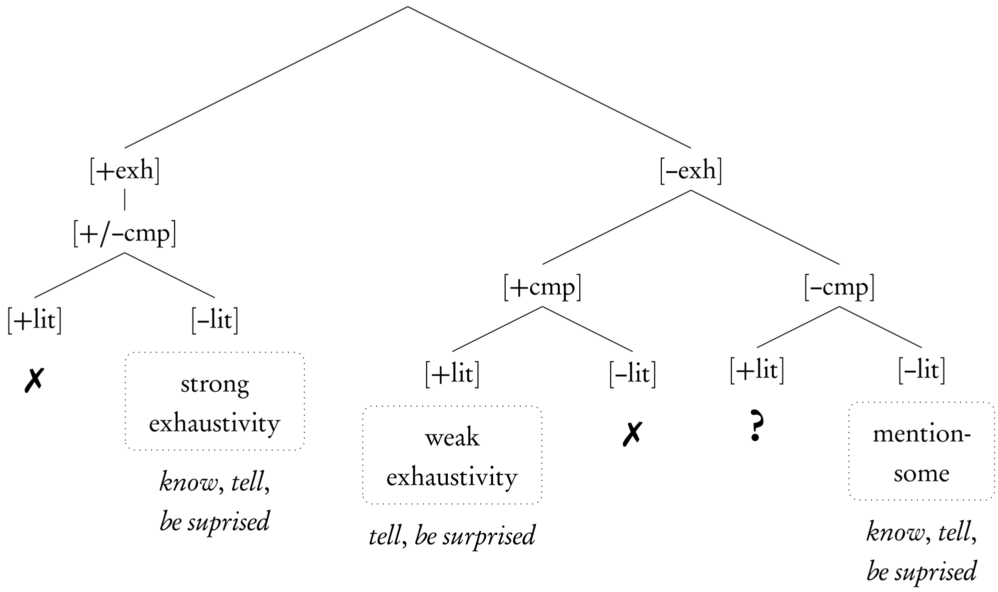


Figure 9: Availability of different feature configurations

the surface is a request for positive information (who actually *was* at the party?) as opposed to negative information (who was *not* there?). A [–exh] question denotation also consists exclusively of positive information, whereas a [+exh] denotation incorporates negative information as well. With this in mind, it makes sense that an interrogative is *not* read as [+exh] when it occurs under a [+lit] predicate.

Conversely, however, can we also find a reason behind the fact that there do not seem to be [–exh, +cmp, –lit] readings—or, in other words, that [–lit, +cmp] seems to imply [+exh]? I would conjecture that this could be to do with the background knowledge that is included in the deductive reading. In detail, assume we have a [–lit, +cmp] reading of a sentence containing a communication verb, for example (126).

(126) Mary told John who was at the party.

Since *tell* is read as [–lit], (126) makes a statement about the *result* of Mary's discourse move. This discourse move must hence be understood as a successful discourse move. We can therefore assume that Mary's telling John about the party guests was somehow warranted—for example because John had requested this information. We may then—and this is likely a rather objectionable leap—also assume that it was mutually understood (hence part of the common ground) whether the information Mary provided was a [+cmp] or [–cmp] answer to *Who was at the party?*. Now there are two cases to distinguish: Mary provided a [+cmp] answer or Mary provided a [–cmp] answer. If she gave a [+cmp] answer and it is part of the common ground that this was a [+cmp] answer, then what she communicated *effectively* is a [+exh] answer.[13] An additional step of reasoning is required to get from the

13 See Heim (1994).

literally communicated information and the information contained in the common ground to a [+exh] answer to the embedded question. This additional step of reasoning is only allowed under the deductive reading.[14] Thus, if we assume a [–lit, +cmp] reading of (126) and if we make the above assumption about the common ground, then this will amount to a [+exh, –lit, +cmp] reading. This might shed some light on why we cannot find the feature combination [–exh, –lit, +cmp].

By contrast, if Mary in the above example gave a [–cmp] answer, then there is not enough information to infer an [+exh] answer to the embedded question. Hence, in contrast to [–lit, +cmp], it is not the case that [–lit, –cmp] implies [+exh]. This could explain why [–exh, –lit, –cmp] readings do exist.

The above argument, apart from relying on a questionable assumption, seems to make a very problematic prediction, however—namely that strong exhaustivity can originate from several different sources: it can either be hardcoded into the question denotation (if this denotation is a partition) or it can be derived via the above reasoning. It is not obvious how to relate these two different notions or whether there are any empirical grounds for distinguishing them. However, *if* the above line of thought has some point, then it might be worth taking a critical look at the overall setup of the proposed system. Maybe it would be possible to give a unified account of the two different "kinds" of exhaustivity that also incorporates the above observations. Here, I will leave it at these sketchy remarks, however.

It would be a pleasant outcome of all this, though, that sentences with *know* would be predicted to receive either a [+cmp, +exh] or a [–cmp, –exh] interpretation. A [+cmp, –exh] reading is not available for them since we take *know* to be intrinsically [–lit]. This prediction indeed agrees with the empirical picture (e. g. George, 2013).

3.5.4 Intermediate exhaustivity?

While we have established by now that a [+cmp, –exh] reading is needed for certain embedders, the exact formulation of such a reading is still an open issue. In particular, Klinedinst and Rothschild (2011) point out that the classical notion of weak exhaustivity cannot capture the semantics of certain embedders—they talk about *tell* and *predict*—since this would yield too weak truth-conditions. To see why, let us look again at (85), repeated here as (127).

(127) The only people Bob has already invited are Alice and John.
Bob told Mary that he has already invited Alice, John and Carol.
$\not\therefore$ Bob told Mary whom he has already invited.

Under the traditional version of a weakly exhaustive reading, the entailment would go through because all that is required for the consequence to hold is that Bob told Mary the true complete answer to the embedded question—which he did (what he told her on top of

14 This is inspired by the treatment of epistemic *must* in von Fintel and Gillies (2010). Essentially, von Fintel and Gillies take this modal to signal an additional step of reasoning: a set of propositions can either *directly* or *indirectly* resolve an issue. In the former case, one of the propositions itself resolves the issue, while in the latter case the intersection of all propositions does—and taking the intersection corresponds to the "additional step of reasoning". For us, the literal reading would be limited to directly resolving the issue raised by the embedded question, while the deductive reading also allows to resolve this issue indirectly.

that does not matter). This goes to show that there are certain cases in which vanilla weak exhaustivity does not care about providing false information.

Klinedinst and Rothschild solve this problem by strengthening the [+cmp, –exh] reading. They call the resulting reading *intermediate exhaustive* because its informational strength lies between weak and strong exhaustivity. We came across a very similar concept when we were exploring the monotonicity behaviour of different embedders. In Section 3.2.3, we had found that certain [–lit] embedders are upward-monotonic but adhere to the *no-false-answers constraint* (NFA): for the consequence in (127) to hold, Bob must tell Mary a proposition which (i) informs her that he invited Alice and John and which (ii) may be arbitrarily specific, as long as it—and this is the NFA—is not a false answer to the question.

Our view is different from Klinedinst and Rothschild's in that they limit their considerations to questions which are (i) embedded under non-factive predicates[15] and which (ii) receive a [+cmp, –exh] reading. For us, the no-false-answer constraint, repeated here in (128), is a more general property. We predict that it applies to *all* upward-entailing interrogative-embedding predicates—such as *know-wh* or *tell-wh*. This means, the constraint applies regardless of whether the embedding predicate is veridical or not and independent of the embedded question's informational strength. In some cases, it will be vacuously satisfied, while in others it will actually make a crucial difference.

(128) **No-false-answers constraint**:
Let R_q be the relation between individuals and questions that is expressed by some responsive, upward-entailing predicate. Let R_d be the corresponding relation between individuals and pieces of information, expressed by the same responsive predicate. Assume p is a false answer to a question Q at world w. Then, in order for an individual a to stand in relation R_q to Q at w, it must not be the case that, at w, a stands in relation R_d to any piece of information entailing p.

Curiously, however, the reading which Klinedinst and Rothschild originally had in mind has little significance for us as we assume that [+cmp, –exh] readings only exist for [+lit] embedders; and such embedders are non-monotonic anyway. So, in a way, they are subject to a much more radical monotonicity restriction than the no-false-answer constraint: any [+cmp, –exh, +lit] reading will automatically satisfy this costraint. We will get to all that in

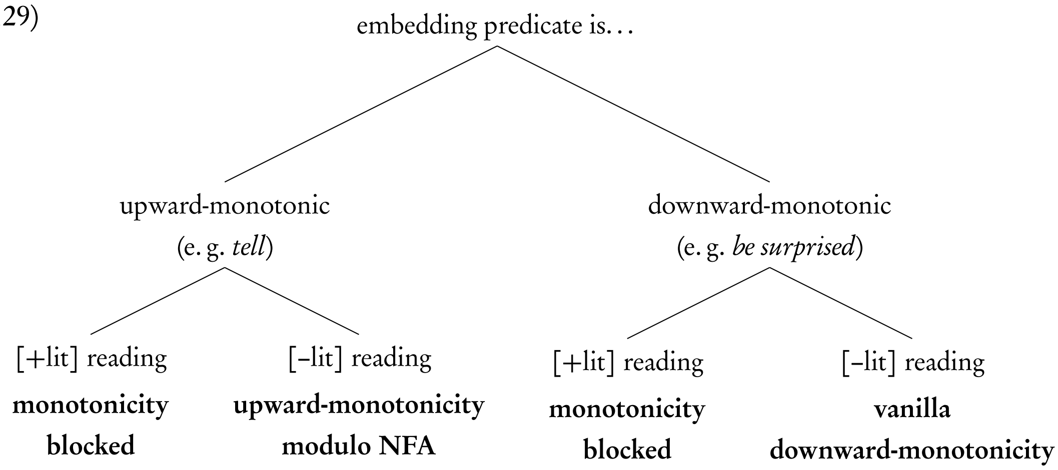
15 Klinedinst and Rothschild explicitly assume that their intermediate exhaustive reading is not available for factive predicates like *know*. In contrast, for us, the no-false-answers constraint is not limited to non-factive embedders. If anything, it would make sense to have this constraint apply only to *veridicals*, but not to *non-veridicals* (as proposed by Spector, 2005; Égré and Spector, 2014). Why this is has briefly been discussed in Section 3.2.3. For an illustration, consider example (ii), which features a non-veridical predicate. Imagine, once again there was a party, which Alice and Bob attended, but not Carol. In this situation, (ii) will be true *even if* Mary is certain that Alice, Bob *and Carol* attended (that is, even if she is certain of a proposition that contains all information of the true complete answer, but which is a false answer).

(ii) Mary is certain who was at the party.

Thus, the no-false-answers condition does not seem necessary for non-veridicals. On the other hand, as also discussed previously, this condition does not hurt, either. Non-veridicals express a relation to some possible answer, i. e. a proposition that is a true answer in some world w. Hence, even if we include the no-false-answer constraint in the truth conditions for non-veridicals, it is always possible to find a world w such that, whichever proposition p the individual stands in relation to, p is a true answer in w. Thus, for non-veridicals this constraint will always be fulfilled and therefore vacuous.

detail. First, to make things more concrete, we assume three different levels of "monotonicity" of embedding verbs with respect to their complement clauses: blocked monotonicity, vanilla downward-monotonicity[16] and upward-monotonicity modulo NFA. They are associated with the embedding predicates and the literal/deductive contrast as follows.

(129)



Let us now see how this perspective is already sufficient for dealing with the problematic scenario pointed out by Klinedinst and Rothschild. Suppose that there was a party yesterday and Alice and Bob were the only guests. Carol did not come. Now, Mary tells John that Alice, Bob *and* Carol were at the party. In this context, we do not perceive (130) as true, since Mary *wrongly* told John that Carol was at the party.

(130) Mary told John who was at the party.

Yet, the proposition that Mary told John is a subset of the [+cmp, –exh] answer to the embedded question. Under a classically weak exhaustive analysis, *tell* would be taken to select for this [+cmp, –exh] answer and to be vanilla upward-entailing. Thus, (130) would be predicted to be true. This is the problem that Klinedinst and Rothschild had identified. However, on our account, the problematic [+cmp, –exh] reading can only appear with [+lit] embedders. If *tell* is understood as [+lit] in (130), however, it is non-monotonic anyway. Hence, (130) comes out as false—simply because Mary did not tell John *exactly* the true complete answer, but a *subset* of this answer. This means that, in the [+cmp, –exh] case, we assume even more rigorous monotonicity restrictions than Klinedinst and Rothschild.

What about the other question readings, though? Let us start with [+cmp, +exh]. We predict [+cmp, +exh] to show up only with [–lit] embedders. If these embedders are upward-entailing, the no-false-answers constraint applies. However, it is easy to see that the constraint is automatically satisfied in this case: if a proposition p is a strongly exhaustive answer to a question Q, there cannot be a a more specific proposition $p' \subsetneq p$ which is a false answer to Q.

Turning to [–cmp, –exh] readings, on the other hand, we find that the no-false-answer constraint *does* matter. To begin with, [–cmp, –exh] or mention-some readings are typically

16 Where, as discussed in Section 3.2.3, the downward-monotonicity of *surprise*, however, only holds if we abstract away from the knowledge-presupposition of this verb. Taking the knowledge-presupposition at face value, *surprise* is non-monotonic.

understood in a sufficiency sense: if you talk of someone knowing where you can buy an Italian newspaper, then you are expressing that this person knows *enough* information to go and buy an Italian newspaper. Hence, mention-some embedders typically seem to be interpreted as [–lit], meaning that, again, the no-false-answers constraint applies. This has also been observed by George (2011), who constructs a scenario analogous to the party example above: essentially, Red and Janna both know Rupert can buy a newspaper at a shop called PaperWorld. In addition, Red falsely believes that Rupert can also buy a newspaper at a place called Newstopia, while Janna is agnostic about whether Newstopia sells newspapers. In this setting, (131a) is true, whereas (131b) is false since Red's beliefs regarding the availability of newspapers do not conform with reality.

(131) a. Janna knows where Rupert can buy a newspaper.
b. Red knows where Rupert can buy a newspaper.

This outcome is predicted by the no-false-answers constraint. Notice, however, the subtlety involved: knowledge-*wh* does not only depend on knowledge-*that*, but also on *belief*. The subject has to know a true answer p, but must not *believe* any more specific answer $p' \subsetneq p$ that is a false answer. In the terminology of George (2011), this makes *know* a *non-reducible* predicate: its interrogative-embedding meaning cannot be reduced to its declarative-embedding meaning. He concludes that a reductive semantics of question-embedding predicates is not possible. However, our eventual semantics will be something like a special case of reductive: it will be uniform (see Section 4.5.4).

3.6 Conclusion

This chapter has proposed one way to organise the multiplicity of possible readings that are found with embedded interrogatives. To this end, a set of interpretive features was introduced: embedding verbs can be categorised along the veridicality and the literalness dimension, while questions can be categorised along the completeness and exhaustivity dimension. Among these, exhaustivity, completeness and veridicality relate to well-known distinctions in the semantics of questions, while literalness to the best of my knowledge has not been explicitly treated in the field. We found that the [+/–lit] contrast has repercussions on monotonicity behaviour. Examining the entailment patterns licensed by different embedders, we arrived at a slightly non-standard understanding of weak exhaustivity and mention-some interpretations: our weakly exhaustive readings are completely non-monotonic, while our mention-some readings are subject to a no-false-answers constraint. This constraint generalises a notion discussed in the literature under the heading of intermediate exhaustivity. The [+/–lit] contrast further seems to be associated with the ambiguity between [+/–exh] and [+/–cmp]: for example, we found [–exh, +cmp] (weak exhaustivity) tied to a [+lit] reading, while [+exh, +cmp] (strong exhaustivity) seems go hand in hand with a [–lit] interpretation. The desiderata for the implementation in the next chapter are summarised again in Figure 10. The presentation should be relatively self-explanatory. Observe, however, that the readings falls into three different categories with respect to the NFA: *applies non-vacuously* means that the NFA applies and that it makes a difference (that is, the reading would have different truth-conditions without the NFA); *vacuously satisfied* on the

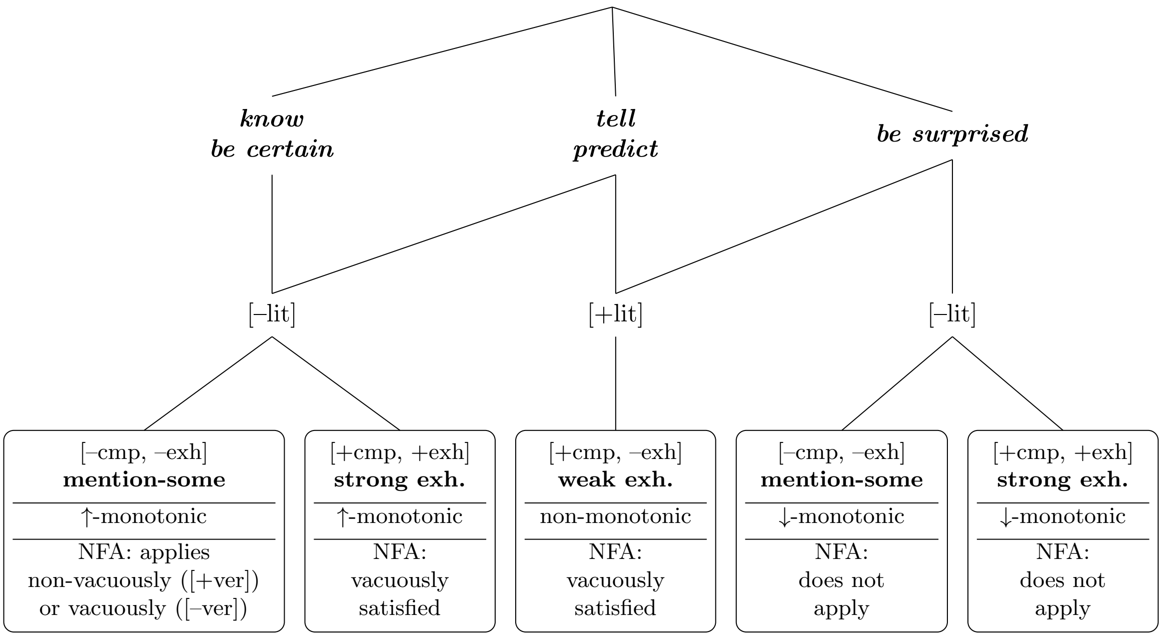


Figure 10: Summary of available readings, monotonicity properties and applicability of the NFA

other hand means that the NFA applies, but that it does not effect the truth-conditions of the respective reading; *does not apply* means what it says. Also, as before, the downward-monotonicity of *surprise* is to be understood modulo knowledge presupposition.

So, cutting a long story short—the familiar categories are all indeed still there: the weakly exhaustive, the strongly exhaustive and the mention-some reading. We did deviate from the canon somewhat, but not by excluding any readings. The changes we made are merely aimed at more fine-grained predictions about which readings are available for which embedders and what exactly the truth-conditions are for these readings. The insights gained in the preceding sections will be put to critical use in the next chapter. There we will actually implement an $\mathsf{Inq}^{\lambda}_{\mathsf{B}}$ fragment for embedded questions.

This chapter contained countless oversimplifications and idealised assumptions, which are relatively standard in question semantics, but which will need to be addressed at some point (to name but one, fixed and mutually known domains of discourse). Likewise, there is a multitude of facets to the semantics of embedded questions which would warrant further investigation but which we have hardly touched. In particular, this is the case for presuppositions, both arising from *wh*-questions themselves and from interrogative-embedding predicates. Another area worthwhile exploring concerns the surface form of interrogatives: are there inherent differences between *who*- and *which*-interrogatives, for example, and can these differences perhaps be linked to already established interpretive categories like exhaustivity and completeness? Finally, the proposed ambiguity between literal and deductive readings is a *first attempt* at a distinction that I think should be made. Likely, this attempt is still at fault in several aspects and would have to be critically reconsidered in the future. The apparent unavailability of [+exh, +lit] readings the one hand and [–exh, +cmp, –lit] readings on the other hand has not been satisfactorily explained and would warrant further attention. Finally, since the literal/deductive distinction is posited here as a lexical ambiguity, it would be interesting to see whether some languages actually possess distinct lexical items for literal and deductive embedders.

4 Embedded questions in typed inquisitive semantics

At this point, we are already acquainted with typed inquistive semantics and have seen how this framework can be used to account for root questions (Chapter 2). We have further explored the rather nuanced empirical picture of question embedding (Chapter 3). Now we are about to combine the insights from these two areas; the $\mathsf{Inq}_{\mathsf{B}}^{\lambda}$ grammar fragment will be extended to cover *embedded* interrogatives and *embedded* declaratives.

This extension will build on elements that are already available in $\mathsf{Inq}_{\mathsf{B}}^{\lambda}$ (the basic denotation of root questions, the exhaustivity operator), but will of course add elements that are specific to clause embedding (most prominently, the embedding predicates). In particular, the focus will be on determining what kind of relations are expressed by the embedding predicates and which pieces of information from the question denotation enter into this relation. The semantics we give will be *flexible*, *uniform* and *modular*: flexible in that it allows for all the different interpretive dimensions that were teased apart in the previous chapter; uniform in that the same lexical entry will cover both the declarative- and the interrogative-embedding uses of responsive verbs; and modular in that the task of establishing the interpretive differences will be distributed over several distinct lexical items.

Additionally, it will emerge that the concept of inquisitiveness and its propagation in different syntactic constructions extends naturally to constructions with embedded clauses. Certain embedding predicates act as *holes* for inquisitiveness: if the embedded clause is inquisitive, then the matrix clause will be inquisitive as well. Other predicates are *inquisitiveness plugs*: even if the embedded clause is inquisitive, the matrix clause need not be so.

The route we will take is this. First we will—still somewhat informally—take stock of which results we would like the eventual semantics to produce (Section 4.1). Only then will we give thought to how to actually obtain these results. That is, we will return to the set of interpretive features from Chapter 3 and implement the distinctions associated with these features. We will start with exhaustivity (Section 4.3), then continue with completeness and discuss in some detail how the no-false-answers constraint can be implemented (Section 4.4 and 4.5.2). Subsequently, we will turn to embedding verbs and examine different aspects of their semantics, especially veridicality (Section 4.5.1), literalness (Section 4.5.5 and 4.5.6) and differences with respect to the propagation of inquisitiveness (Section 4.5.3 and 4.7).

Something that is not provided here, on the other hand, is a systematic comparison of the proposed semantics with other more recent works in the field. While Chapter 1 has indeed given a brief overview over the classical accounts in question semantics, any more state-of-the-art treatments (e. g. Beck and Rullmann, 1999; Guerzoni, 2007; George, 2011; Égré and

Spector, 2014) have not been discussed in technical detail. This is largely due to the limited scope of this thesis project; a rigorous comparison is left for future work.

4.1 Taking stock: what we need

In this section, we will spell out (roughly) what it takes for a sentence with an embedded interrogative to be true. We will do so using the embedded interrogatives in (132) and (133) as examples.

(132) John knows who has a lighter. [+ver]

(133) John is certain who has a lighter. [–ver]

Specifically, we want to find out what John minimally needs to know/be certain of in order for the sentences to hold true—that is, we are interested in the minimally informative pieces of information from the question denotation to which John must stand in a *know*- or *be-certain*-relation. What we find here will serve as a guidance for the actual implementation in the next section.[1]

These examples are chosen to allow for varying as many interpretive parameters as possible: the embedding verb in (132) is [+ver] and that in (133) is [–ver]. With a suitable context, the embedded interrogative is in principle open to both a [+cmp] and a [–cmp] interpretation and also permits both a [+exh] and a [–exh] reading. Again, [+exh, +/–cmp] corresponds to strong exhaustivity, [–exh, +cmp] to weak exhaustivity and [–exh, –cmp] to a mention-some interpretation. In Table 6, yet another parameter is added—namely a world of evaluation. For each feature combination and each world w_i, it is indicated in the table what minimally needs to be the case at w_i so that (132) or (133) are judged true.

The visualisations in the table are familiar from Chapter 2—but we will see presently that they are used in a slightly imprecise manner here. Let the worlds be numbered with w_1 being the upper left one, w_2 the upper right one, w_3 the lower left one and w_4 the lower right one. Assume w_1 is a world such that both Alice and Bob have a lighter in this world, while in w_2 only Alice has a lighter, in w_3 only Bob has one, and in w_4 nobody has one. Then, the [–exh] denotation of the question *Who has a lighter?* is represented as ; the [+exh] denotation as . Hence, in the leftmost column of the table, the visualisations depict inquisitive sentence denotations of type T. By contrast, in the right part of the table, , etc. are used to visualise single information states of type $\langle s, t\rangle$. The symbols "K" and "C" denote relations between information states and individuals.[2]

Finally, note the following peculiarity: the state corresponds to the information that both Alice and Bob have a lighter; and since Alice and Bob are the only two individuals in the domain of discourse, simultaneously is the [+exh, +cmp] *and also* the [–exh, +cmp] true answer at world w_1—there is no difference between strong and weak

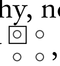
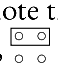
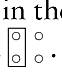
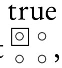
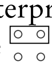
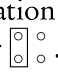
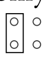
1 For the moment, we will leave aside the question which readings are available for *know* and *be certain*. We are only interested in what the respective readings would look like—*assuming* they *are* available. For example, we do not in fact predict *know* to allow a [–exh, +cmp] reading; but we will still consider such a reading in this section. Hence, for the purposes of this section, *know* and *be certain* are best viewed as some kind of template: a *generic* veridical and a *generic* non-veridical verb.

2 This differs from the later usage of these symbols. Later, we will write K_x^w for the set of all worlds that are compatible with an individual x's knowledge at world w.

exhaustivity at this world. The same goes for w_4. At worlds w_2 and w_3 in contrast, weakly and strongly exhaustive answers come apart. This makes sense, since in these worlds only a proper subset of the individuals from the domain actually have a lighter.

For an example of how to read the table, consider the feature configuration [–exh, –cmp] and world of evaluation w_2. In the table, we can look up this combination and find the condition that K . This is to be read as “John knows, minimally, that Alice has a lighter”. Of course, for (132) to be true, John may also know that *only* Alice has a lighter (as this is the true [+exh] answer at w_2). But this is not what John *minimally* needs to know under a [–exh, –cmp] reading; and for the moment we are only interested in minimally required knowledge. To give another example, the condition for [–exh, –cmp] at w_1 is more complex, namely K  ∨ K . This means “John knows, minimally, that Alice has a lighter, or John knows, minimally, that Bob has a lighter.” Again, this does not preclude John from knowing that both of them have a lighter; it just states what he minimally has to know.

The representation in Table 6 is only a sketch. In view of the eventual $\mathsf{Inq}^{\lambda}_{\mathsf{B}}$-implementation, it does not meet our objectives for two reasons. Firstly, as we have seen in Chapter 2, in $\mathsf{Inq}^{\lambda}_{\mathsf{B}}$, not *truth*-conditions are the fundamental notion, but *resolution*-conditions—and those apply not to individual worlds, but to world sets. However, this does not mean the representation in Table 6 is useless. At least the informative content of a sentence can be expressed through truth-conditions: in $\mathsf{Inq}^{\lambda}_{\mathsf{B}}$, a world w is contained in some state in a sentence denotation if the sentence is classically true at w. Hence, the information in the table conveys the classical, truth-functional side of the picture, and we still need to fill in those aspects that are specific to inquisitive semantics. Secondly, the conditions in the table are heavily underspecified: What exactly does “minimally” required knowledge amount to? Do the disjunctive conditions give rise to inquisitiveness? Also, given that the meaning of *know-wh* does not only depend on knowledge but also on beliefs (cf. Section 3.5.4), the actual lexical entry for *know* will contain more complex conditions than those specified in the table. The same goes for other embedders. Again, what remains to be done is to pinpoint and fill in such details.

These inaccuracies notwithstanding, there are some interesting observations to be made from the table. To begin with, it was already remarked above that, if a question denotation is [+exh], the value of the completeness feature is inconsequential: both [+exh, +cmp] and [+exh, –cmp] are strongly exhaustive. Accordingly, in the [+exh] rows in the table, the conditions do not differ between [+cmp] and [–cmp]. For [–exh], on the other hand, they do sometimes come apart—e. g. between [+ver, –exh, +cmp] and [+ver, –exh, –cmp] at world w_1. To see why, note that in the [–exh] question denotation there are several true answers at w_1, namely ,  and . A [+cmp] interpretation uniquely singles out , since it requires John to know a *complete* answer, whereas a [–cmp] interpretation leaves open the possibility that John only knows an incomplete answer, hence  or . However, K  implies K  and K , and is therefore not the kind of minimal condition we are looking for here. This is why, K  would be redundant if it appeared in the conditions for [+ver, –exh, –cmp] and is consequently left out.

Let us now compare veridicals and non-veridicals. For veridicals the truth-conditions differ from world to world, whereas for non-veridicals they stay constant across all worlds. Why is this so? Veridicals express a relation to a true answer—and what the true answer is

[+ver]: veridical-responsives (*know*...)								
embedded clause	"minimal truth-conditions" at w_i							
	w_1		w_2		w_3		w_4	
	[+cmp]	[−cmp]	[+cmp]	[−cmp]	[+cmp]	[−cmp]	[+cmp]	[−cmp]
[+exh]	K	K	K	K	K	K	K	K
[−exh]	K	K ∨ K	K	K	K	K	K	K

[−ver]: non-veridical-responsives (*be certain*...)								
embedded clause	"minimal truth-conditions" at w_i							
	w_1		w_2		w_3		w_4	
	[+cmp]	[−cmp]	[+cmp]	[−cmp]	[+cmp]	[−cmp]	[+cmp]	[−cmp]
[+exh]	C ∨ C ∨ C ∨ C							
[−exh]	C ∨ C ∨ C							

Table 6: Overview of intuitive outcomes of embedding a *wh*-question with different feature configurations

depends on the world of evaluation. Non-veridicals on the other hand express a relation to merely a possible answer—and the set of possible answers to a given question is the same in all worlds. Equivalently, we can think of non-veridicals as expressing a relation to a proposition that is a true answer in not necessarily the actual world, but in just some world w. In other words, we shift to a possible world and check what is the true answer at that world. This also explains the disjunctive truth-conditions found in the table for non-veridicals: depending on which world w we shift to, we will get a different true answer—with each of these possible answers corresponding to a disjunct in the truth-conditions. Consider the case of [−ver, +exh] for example. C corresponds to John being certain of a proposition that is a true answer at world w_1, while C corresponds to John being certain of a proposition that is a true answer at world w_2, and so on. Now, of course, there are four possible worlds but only three disjuncts for [−ver, −exh, +/−cmp]. The missing disjunct corresponds to C . Again, C implies two of the other disjuncts, namely C and C . Hence, is not the kind of minimally informative answer that we are looking for at this point, and there is no harm in omitting it from the conditions for [−ver, −exh, +/−cmp].

This concludes our preliminary overview of the results we expect the eventual account to produce. In the remainder of this chapter, we will explore how to actually obtain these results. In particular, we will look at how to pick out the desired pieces of information—and only those—from the question denotation.

4.2 How to get what we need: division of labour

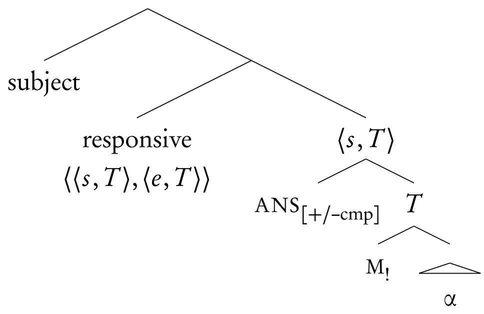
As mentioned above, the to be proposed treatment of question embedding in $\mathsf{Inq}_\mathsf{B}^\lambda$ will be *modular*: establishing the interpretive differences between mention-some, weakly and strongly exhaustive readings does not solely fall to the embedding predicate. Rather, this task is divided over different lexical elements, each of which takes care of one or two interpretive features. These lexical items can be combined to obtain the desired feature configuration. In detail, the exhaustivity feature is taken care of by an exhaustivity operator and the completeness feature by an answer operator. These operators can be present in both root and embedded interrogatives.[3] The embedding predicate is responsible for the veridicality and the literalness feature. Needless to say, veridicality and and literalness are hence features which pertain specifically to embedded and not to root questions. This division of labour is summarised in Table 7. The rationale behind it will be laid out in more detail in the following sections.

Figure 11 shows the syntactic configurations of sentences with (a) embedded declaratives and (b) embedded interrogatives. We will get to the individual elements in due course. For now, note that the same answer operator ($\textsc{ans}_{[+/-\mathrm{cmp}]}$) is present in both structures—also with embedded declaratives. We shall see that it has a different effect in either case.

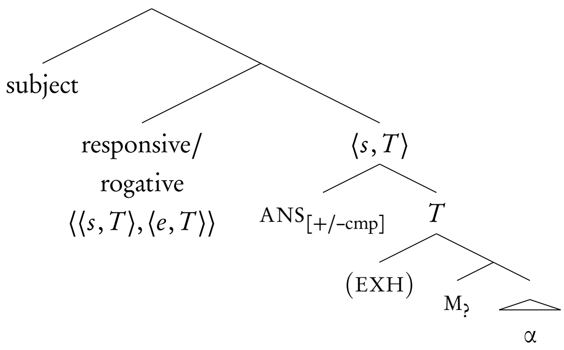
In Chapter 3, we found that in particular two feature configurations do not seem to be available, namely [+exh, +lit] and [−exh, +cmp, −lit].[4] Formally, this unavailability will

3 Although they have not been part of the $\mathsf{Inq}_\mathsf{B}^\lambda$-treatment of root interrogatives that was exposed in Chapter 2.

4 In fact, we found a third unavailable combination, namely [−exh, −cmp, +lit], but said that there seems to be no principled reason why this combination is impossible. If we also wanted to prevent [−exh, −cmp, +lit] readings, however, we could restrict the permitted combinations of embedding verbs and answer operators yet further.



(a) Embedded declarative



(b) Embedded interrogative

Figure 11: Syntactic configurations when embedding declaratives and interrogatives

come about by restricting the permissible combinations of embedding verbs, answer operators and exhaustivity operator. In detail, we postulate that the exhaustivity operator EXH cannot occur in the scope of a [+lit] embedder, and that the [+cmp] version of the answer operator ($\text{ANS}_{[+\text{cmp}]}$) is prohibited from the scope of a [−lit] embedder.[5] The first of these restriction has a fairly obvious effect: interrogatives embedded under [+lit] verbs will not receive a strongly exhaustive interpretation. The second restriction is more indirect. Essentially, given a [−lit] embedder, only two configurations are permissible under this restriction: $\text{ANS}_{[-\text{cmp}]}$ without EXH—which amounts to a mention-some reading—and $\text{ANS}_{[-\text{cmp}]}$ with EXH—which amounts to strong exhaustivity. The possible combinations of embedders and operators are summarised in Figure 12.

5 These restrictions will remain postulates. Finding principled motivations for them beyond the explanation that was attempted in Section 3.5.3 is left for further work.

feature	**taken care of by...**
exhaustivity	exhaustivity operator
completeness	answer operator
veridicality	embedding verb
literalness	embedding verb

Table 7: Division of labour

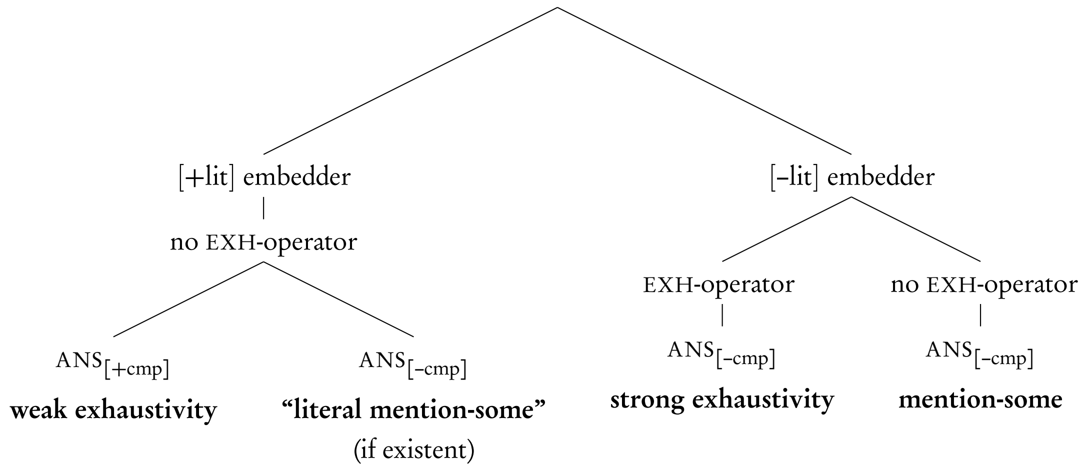


Figure 12: Admissible combinations of embedders, exhaustivity operator and answer operators.

4.3 Exhaustivity operator

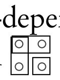
We need to decide at which level our semantics will capture the distinction between [+exh] and [–exh]: is it a property of the embedding verb or the question denotation? What counts in favour of the latter option is that there appear to be exhaustivity markers occurring at the level of the question denotation. We have seen Mandarin *dou* as an example of such markers (see Section 3.3). Another reason in favour of treating exhaustivity as a property of the question itself is that this notion can sensibly be applied to the denotations of root questions: there is an intuitive interpretation of what it means for a question denotation to be [+exh], namely to incorporate information not only about the instances that answer the question affirmatively, but also about those that answer it negatively. As is well known (Groenendijk and Stokhof, 1984), formally this amounts to being a partition of the logical space. Conversely, any question denotation that is not a partition is [–exh]. We will see below that it is impossible to determine whether a given proposition p is a [+cmp] or [–cmp] answer without making reference to a world of evaluation. In contrast, the difference between [+exh] and [–exh] arises independent of a world of evaluation: given a proposition p and a property P, we can determine whether p is informative enough to resolve a [+exh] question that inquires the specification of P: all it takes is to check whether in all worlds from p exactly the same individuals have property P. If that is the case, we know that p is a subset of or equal to a partition cell of a partition of the logical space with respect to P. Therefore, in this case we know that p resolves a [+exh] question regarding P. Hence, it is possible to determine the [+/–exh] feature based on a question denotation/a proposition and an inquired property. On the other hand, in order to determine the [+/–cmp] feature, we do not only need a question denotation/proposition and an inquired property, but additionally a world of evaluation. This will emerge in the next section.

The alternative, treating exhaustivity as a lexical property of the embedding verb, is not appealing: many verbs can take [+exh] and [−exh] complement clauses. This ambiguity seems to be relatively persistent among embedding predicates (in contrast to the ambiguity between [+/−ver] readings of the same embedder, for example, which only shows up with communication verbs). The clearest illustration of a predicate varying between [+/−exh] reading are, again, exhaustivity markers like Mandarin *dou*: if they appear in an embedded interrogative, they enforce a [+exh] interpretation; if they are not present in an otherwise identical sentence, usually a [−exh] reading is allowed. Including exhaustivity in the lexical semantics of embedding predicates would therefore require us to posit multiple lexical entries for almost every embedding verb. Moreover, given that there can be [−exh] and [+exh] root question denotations, if the ambiguity was situated within the semantics of the embedding verb, we would need a separate exhaustifying mechanism for root questions. This is unneccessary since the exhaustivity operator we already know from Chapter 2 can deal with root questions and embedded questions alike. We will hence assume that exhaustivity is a property of the question denotation, handled by EXH. The semantics of this operator is repeated in (134). It turns a [−exh] question denotation like  into the corresponding [+exh] denotation, in this case .

(134) $\text{EXH} := \lambda X_T.\lambda p_{\langle s,t\rangle}.\forall w, w' \in p : \{q \in \text{ALT}(X) \mid q(w)\} = \{q \in \text{ALT}(X) \mid q(w')\}$

4.4 Answer operator

Moving on to completeness, we will again have to decide at which level of our semantics this feature will be captured: as with exhaustivity, it could be a characteristic of the question denotation or a lexical property of the embedding predicate. A reason to assume the former is that some languages have completeness markers occurring at the level of the question denotation. Such markers—e. g. Dutch *allemaal*—enforce a [+cmp] interpretation of their containing interrogative and can appear both in embedded and root interrogatives (see Section 3.4). Furthermore, there are certain questions whose most salient interpretation clearly is [−cmp] (Italian-newspaper examples) and others that rather tend towards a [+cmp] reading (party-guest examples). Here, again, the [+/−cmp] contrast seems to stem from the question itself: even when they occur under the *same* embedding verb, embedded Italian-newspaper examples receive a salient [−cmp] reading, while embedded party-guest examples receive a salient [+cmp] reading. Hence, as with exhaustivity, we find that embedding verbs vary rather persistently between [+/−cmp] readings of their complement. We conclude that completeness is a property of the question itself.

However, there is a subtle difference between the status of completeness and of exhaustivity. Let P be a property whose specification is inquired by some *wh*-question Q. Then, as discussed in the previous section, exhaustivity describes a feature of the question denotation Q with respect to P. In contrast, the property of completeness only arises once a world of evaluation enters the picture. This means only world-dependent objects can be described as [+cmp] or [−cmp]; but question denotations are not world-dependent. To understand this distinction, take the state  from the question denotation . Is  a complete answer? We cannot tell. All we can say is that, *at world* w_1, it is a [−cmp] answer (there, the

[+cmp] answer is ), whereas, *at world* w_2, it is indeed a [+cmp] answer. So, we need to make reference to a world of evaluation in order to say anything about an answer being [+cmp] or [–cmp]. In the framework up to now, however, the denotation of a question is not sensitive to a world of evaluation. In the remainder of this section, we will introduce an additional level in the semantic structure of questions—the level of true answers.

As suggested by its name, the answer operator (ANS) will extract answers from a question denotation. Strictly speaking, though, it should be dubbed *true-answer* operator—since it takes a question denotation and a world w and returns the set of all states that resolve the question and do not entail a false answer to this question at w. Accordingly, the ANS-operator has type $\langle T, \langle s, T\rangle\rangle$. We shall see that its world-sensitivity allows us to distinguish between veridical and non-veridical embedders. The operator comes in two versions: one that extracts complete answers ($\text{ANS}_{[+\text{cmp}]}$) and one that extracts mention-some answers ($\text{ANS}_{[-\text{cmp}]}$). These operators can apply uniformly both to the denotations of interrogatives and of declaratives. Roughly, if they apply to an interrogative denotation, they usually change this denotation, but they cannot cause a presupposition failure. If they apply to declarative denotations on the other hand, they leave these denotations intact, but *can* give rise to a presupposition failure.

Which states from a question denotation Q do we want to include in our set of "answers to Q that are not false answers to Q at w"? Let us begin with [+cmp] answers—that is, with examining the set $\text{ANS}_{[+\text{cmp}]}(Q)(w)$ for some question Q and some world w. We want to include all those pieces of information that entail all alternatives from Q that are true at w while *not* entailing any alternative from Q that is false at w. The following lexical entry incorporates these two conditions.[6]

(135) Preliminary definition of the [+cmp] answer operator:

$$\text{ANS}_{[+\text{cmp}]} := \lambda Q_T.\lambda w.\lambda p.\begin{pmatrix} \forall q \in \text{ALT}(Q) : (q(w) \rightarrow p \subseteq q) \\ \wedge\, \forall q \in \text{ALT}(Q) : (\neg q(w) \rightarrow p \nsubseteq q) \end{pmatrix}$$

It is clear from (135) that the pieces of information in $\text{ANS}_{[+\text{cmp}]}(Q)(w)$ differ in their informativeness. The least informative proposition in this answer set expresses exactly the true complete answer to Q—and does not contain any information on top of that. We will adopt the following terminology to refer to such minimally informative answers: any piece of information p such that p is one of the maximal states in $\text{ANS}_{[+\text{cmp}]}(Q)(w)$ will be called a *basic complete answer* to Q at w. However, in addition to the basic complete answer r, which can be thought of as an intersection of all true alternatives at w, $\text{ANS}_{[+\text{cmp}]}(Q)(w)$ contains propositions which provide all information that r does, plus some more on top of that. However, we cannot just include all subsets $r' \subseteq r$; the catch is that, while all of them contain at least as much information as r, some of them entail an alternative from Q that is false in w. This is why the second conjunct in (135) is needed: it ensures that states entailing *more* alternatives than all the true ones are excluded from the answer set.

Note that this is not at all the same as excluding all states that do not contain w. Assume, for some state p, we find that $\forall q \in \text{ALT}(Q)(w) : (q(w) \rightarrow p \subseteq q)$, but $w \notin p$. Then, it is

6 Although we will not do so here (since this is not central to our semantics), the definition in (135) can, as always, be generalised to the case in which no alternatives exist.

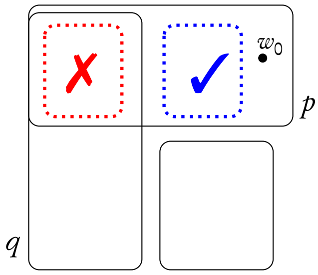
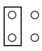
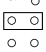
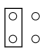


Figure 13: Downward-closedness modulo NFA (*Who came?*)

still possible that $p \in \text{ANS}_{[+\text{cmp}]}(Q)(w)$, namely exactly if p does not entail any false alternatives. Note that such a p is included in the answer set, although it provides false information! The point is that p does not entail an alternative from Q that is false in w. In general, the resulting answer sets are unlike sentence denotations in inquisitive semantics—in that they are *not* vanilla downward-closed. Instead, they are what has been called *downward-closed modulo NFA* (see Chapter 3). This will be crucial in actually implementing the no-false-answers constraint. In what follows, we will also talk about a piece of information p *truthfully and completely resolving* Q *in* w to mean that $p \in \text{ANS}_{[+\text{cmp}]}(Q)(w)$.

To see what downward-closedness modulo NFA amounts to in practice, consider the following example, visualised in Figure 13. Let Alice and Bob be the only two individuals in the domain. Then, in the denotation Q of the question *Who came?* there are three alternatives: let p be the proposition that Alice came and q the proposition that Bob came. Assume the actual world w_0 is situated in p, but not in q. This means that p is the true complete answer at w_0. It will therefore be the minimally informative state in $\text{ANS}_{[+\text{cmp}]}(Q)(w_0)$. Now we want to find out which subsets of p are and which are not included in $\text{ANS}_{[+\text{cmp}]}(Q)(w_0)$. Take an arbitrary false proposition r (that is, $w_0 \notin r$). The fact that $w_0 \notin r$ does not tell us anything about whether $r \in \text{ANS}_{[+\text{cmp}]}(Q)(w_0)$. Assume r is the proposition that both Bob and Alice came (in the picture, the crossed-out state). Then, r violates the no-false-answers constraint. In terms of (135), this means r entails a false alternative (namely q) and therefore does not satisfy the condition that $\forall s \in \text{ALT}(Q) : (\neg s(w_0) \to q \nsubseteq s)$. On the other hand, take another false proposition r' such that $r' \subseteq p$ and $r' \nsubseteq q$ (for example, the one with the tick in the picture). This proposition entails the true complete answer to Q in w_0—which means r' satisfies the first conjunct in (135)—and it does not entail any alternative from Q that is false in w_0—which means r' satisfies the second conjunct as well. Hence, we find that $r' \in \text{ANS}_{[+\text{cmp}]}(Q)(w_0)$. In other words, at w_0, r' resolves Q truthfully and completely.

Now on to the extraction of mention-some answers. It works almost the same. The difference is that in order for a state p to be contained in the answer set, we no longer require that p entails *all* true alternatives—entailing just one of them will suffice. For an illustration, recall that the question  has three [–cmp] answers which are true at w_1, namely ,  and . For a state p to entail a true [–cmp] answer, it is therefore enough if p is a subset of  or of :

(136) Preliminary definition of the [–cmp] answer operator:

$$\text{ANS}_{[-\text{cmp}]} := \lambda Q_T.\lambda w.\lambda p.\begin{pmatrix} \exists q \in \text{ALT}(Q) : (q(w) \wedge p \subseteq q) \\ \wedge\, \forall q \in \text{ALT}(Q) : (\neg q(w) \rightarrow p \nsubseteq q) \end{pmatrix}$$

For one thing, observe that the NFA also applies to mention-some readings. This has been motivated in Section 3.5.4. For another thing, note that under the above definition [+cmp] and [–cmp] are not mutually exclusive. Rather, due to the contrast between existential and universal quantification over alternatives, we find that, if $p \in \text{ANS}_{[+\text{cmp}]}(Q)(w)$, then also $p \in \text{ANS}_{[-\text{cmp}]}(Q)(w)$.[7] The converse does not necessarily hold. We will hence speak about the pieces of information in $\text{ANS}_{[-\text{cmp}]}(Q)(w)$ as *truthfully resolving* Q *at w* (as opposed to $p \in \text{ANS}_{[+\text{cmp}]}(Q)(w)$, which we described as *truthfully **and completely** resolving* Q *at w*). Finally, whether the [+cmp] or [–cmp] version of the answer operator occurs in a sentence is largely determined by context. We may however assume that overt completeness and incompleteness markers as they occur in some languages (see Section 3.4) are only licensed if the suitable kind of answer operator is present.

The answer operators in (135) and (136) can deal with interrogatives, but do not yet yield the desired results when applied to declaratives. Let X be a declarative denotation with $\text{ALT}(X) = \{q\}$ (recall that declarative denotations contain at most one alternative). What is undesired about the preliminary definition of the answer operator is that $\text{ANS}_{[-\text{cmp}]}(X)(w)$ will be empty whenever $w \notin q$; and $\text{ANS}_{[+\text{cmp}]}(X)(w)$ will be $\{p \mid p \nsubseteq q\}$ whenever $w \notin q$. This latter result is clearly not what we want. But also $\text{ANS}_{[-\text{cmp}]}$ does not yield the desired result for those cases in which the statement made by the declarative does not hold in w. Why not? In the following section, we will define the lexical entries of veridical embedders in such a way that their truth-conditions cannot be satisfied if the answer set is empty. This means, sentences in which our declarative X from above is embedded under a veridical verb would only contain states p such that $w \in q$ for all $w \in p$. This amounts to handling $w \in q$ on a truth-functional level. However, consider the following examples with a factive embedder, uttered in a world w in which Mary did *not* get the job.

(137) a. John is surprised that Mary got the job.
b. John is not surprised that Mary got the job.

It is safe to say that what is violated here is not of a truth-functional nature, but rather is the factivity presupposition of *surprise*: an appropriate response to either sentence would be "Wait a minute! But Mary didn't get the job!" Also note that for both (137a) and (137b) the same implication arises—namely that Mary got the job. This further confirms the presuppositional status of this implication (negation is a presupposition hole).

Hence, if the proposition expressed by the embedded declarative X is false at world w, we want $\text{ANS}_{[+/-\text{cmp}]}(X)(w)$ to give rise to a presupposition failure. On the other hand, if that proposition is true at w, we want to keep the declarative denotation intact. While answer sets obtained from interrogative denotations are only downward-closed modulo NFA, the "answer sets" computed from declarative denotations are vanilla downward-closed. As for another difference, while declaratives embedded under factive verbs can give rise to a presupposition failure, embedded interrogatives cannot—even when embedded under veridical

7 Under the assumption that alternatives exist in Q.

verbs. Intuitively, this is because in the interrogative-embedding case the veridical embedder has a choice: it can simply pick out a true answer from the *several* possible answers to the embedded question as there will always be a true answer among them. In contrast, embedded declaratives do not offer this choice since they express a quasi already fixed proposition.

Including a factivity presupposition of sorts in the definition of the answer operator yields the following lexical entries. Whether the [+cmp] or the [–cmp] version is used for declaratives does not matter since their denotation contains at most one alternative. The presupposition is taken care of by the underlined part, to be read as *this term is only defined if…*

(138) Presuppositional version of the [+cmp] answer operator:

$$\textsc{ans}_{[+\mathrm{cmp}]} := \lambda Q_T.\lambda w.\lambda p.\underline{\exists q \in \textsc{alt}(Q) : q(w)}.\begin{pmatrix} \forall q \in \textsc{alt}(Q) : (q(w) \rightarrow p \subseteq q) \\ \wedge\, \forall q \in \textsc{alt}(Q) : (\neg q(w) \rightarrow p \not\subseteq q) \end{pmatrix}$$

(139) Presuppositional version of the [–cmp] answer operator:

$$\textsc{ans}_{[-\mathrm{cmp}]} := \lambda Q_T.\lambda w.\lambda p.\underline{\exists q \in \textsc{alt}(Q) : q(w)}.\begin{pmatrix} \exists q \in \textsc{alt}(Q) : (q(w) \wedge p \subseteq q) \\ \wedge\, \forall q \in \textsc{alt}(Q) : (\neg q(w) \rightarrow p \not\subseteq q) \end{pmatrix}$$

It is easy to see that $\textsc{ans}_{[+/-\mathrm{cmp}]}$ is always defined if Q is a question denotation since the alternatives from a question denotation cover the entire semantic space. Consequently, there will always be an alternative in Q that is true at world w. For non-tautological declaratives on the other hand, it can happen that there is no such alternative. In that case, $\textsc{ans}_{[+/-\mathrm{cmp}]}$ will indeed be undefined. In the next section, we will see how the embedding predicates draw on this contrast.

More generally, we will investigate how the embedding predicates make use of the world-sensitive answer sets they are handed by the answer operator. In particular, it will also become clear how the difference between veridical and non-veridical embedders can be established and how the no-false answer constraint (see sections 3.2 and 3.5.4) arises quite naturally once the embedding predicate combines with the answer set.

As a final remark, however, note that what we have just done is to lift the denotations of both embedded and of root sentences from type T to type $\langle s, T\rangle$. This must have repercussions on how the effect of an utterance in a discourse is treated. For example, while the utterance of a root question Q in a discourse will still invite a felicitous answer to Q, the question could now be represented as e. g. the world-dependent set $\lambda w.\textsc{ans}(Q)(w)$. Essentially, however, the set of felicitous answers to Q must comprise $\textsc{ans}(Q)(w)$ for *any* value of w. Conceivably, we would therefore need another level of existential quantification over worlds. For one thing, this strategy seems to introduce some redundancy into our formal system. For another thing, our attention is limited to question embedding; we are not really concerned with the effects the utterance of a root question would have in a discourse. Hence, we will leave the discourse-theoretical implications of having type-$\langle s, T\rangle$ sentence denotations in $\mathsf{Inq}^{\lambda}_{\mathsf{B}}$ for future work.

4.5 Embedding predicates

The lexical semantics of embedding verbs takes care of two features: veridicality and literalness. As we have seen in Section 3.1, veridicality can be regarded as a lexical property.

Where a verb can be both veridical and non-veridical, we posit a lexical ambiguity and assume a separate lexical entry for each reading. What further counts in favour of treating this ambiguity as part of the verb semantics is that some languages seem to possess separate lexical items for the [+ver] and the [–ver] version of the same predicate (Égré and Spector, 2014). In contrast, the ambiguity between [+/–cmp] and [+/–exh] has to my knowledge never been claimed to have a comparable lexical manifestation. Moreover, embedding predicates vary rather persistently between [+/–cmp] and [+/–exh] readings, whereas the [+/–ver]-ambiguity concerns only communication verbs. If we also treated completeness and exhaustivity as lexical properties, we would hence need multiple lexical entries for *almost every* embedding verb. Similarly, the contrast between literal and deductive interpretations is not persistent among embedding verbs, but only applies to communication verbs and emotive predicates. Further, this contrast does not seem to concern the question interpretation, but rather the understanding of the embedding verb. The difference between [+/–lit] is thus treated in terms of lexical ambiguity as well.

4.5.1 Veridicality

Veridical predicates express a relation to a piece of information that is a true answer in the actual world, while non-veridicals express a relation to a piece of information that is a true answer in some possible world (Égré and Spector, 2014). By means of the answer operator, we can extract the set of true answers at any given possible world. This mechanism is utilised in the semantics of embedding predicates. In the following lexical entries, K_x^w is the set of all worlds that are compatible with what x knows in world w, while C_x^w is the set of all worlds that are compatible with what x is certain of in world w.[8]

(140) Preliminary lexical entry for *know*:

$$Tr(\text{know}) := \lambda \mathcal{Q}_{\langle s,T\rangle}.\lambda x.\lambda p.\left(\frac{\forall w \in p : \mathcal{Q}(w) \text{ is defined.}}{\forall w \in p : K_x^w \in \mathcal{Q}(w)}\right)$$

(141) Lexical entry for *be certain*:

$$Tr(\text{be certain}) := \lambda \mathcal{Q}_{\langle s,T\rangle}.\lambda x.\lambda p.\left(\frac{\exists w' : \mathcal{Q}(w') \text{ is defined.}}{\exists w'' \forall w \in p : C_x^w \in \mathcal{Q}(w'')}\right)$$

As can be seen from (140), veridicals fill the world argument slot of ANS with the actual world.[9] In contrast, non-veridicals add a layer of existential quantification over possible worlds: as exemplified in (141), the world fed to the answer operator is not necessarily the actual world (although it *may* be the actual world)[10], but some possible world. Recall the world-shift associated with non-veridicals that we discussed above. It is the outermost existential quantification in the lexical entries of non-veridical embedders which implements

8 We will not be concerned with what exactly it means to *be certain* of a proposition as opposed to *believing* this proposition. In particular, we do not attempt to express C_x^w in terms of B_x^w (x's belief-compatible worlds at w).

9 Or to be more precise, put in terms of resolving states: if a world w is a candidate for inclusion in a state p, a veridical predicate will pass w (and not some other world) to the answer operator.

10 Again, when talking about the *actual* world here, we are talking about some world w that is a candidate for inclusion in a state p. See previous footnote.

this world-shift. The result should be self-evident: whereas $\mathscr{Q}(w)$ in (140) is a true answer at the actual world, $\mathscr{Q}(w')$ in (141) denotes a true answer at some possible world.

The requirement that $\mathscr{Q}(w)$ is defined for all $w \in p$ respectively that $\mathscr{Q}(w')$ is defined for some w' only becomes relevant if the verb embeds a declarative sentence—because only then can it happen that $\mathscr{Q}(w)/\mathscr{Q}(w')$ is undefined (see Section 4.4). If it happens, this undefinedness stems from a factivity presupposition failure: the world fed to the answer operator lies outside the declarative denotation. As a result, if a declarative embedded under a factive verb does not hold true at a world w, then the denotation of the matrix sentence will be undefined. For non-factive embedders, by contrast, the definedness-requirement *usually* does not make any difference: there, it does not have to be the case that $\mathscr{Q}(w)$ is defined for all $w \in p$, but it is merely demanded that there exists some w' such that $\mathscr{Q}(w')$ is defined. The only case when there exists no such w' is if $\mathscr{Q}$ is an answer set obtained from the denotation of a contradiction. Hence, unless a contradiction is embedded, sentences with non-factive embedders will always be defined in our framework; and if a contradiction is embedded, this will result in undefinedness.

4.5.2 Implementing the no-false-answers constraint

Although we have now seen how the embedding predicates distinguish between true and possible answers, we have not yet taken a look at what kind of relations these predicates actually denote. Observe that in the lexical entry for e. g. *know* it is required that "$K_x^w \in \mathscr{Q}(w)$"; that is, x's knowledge in world w has to be an element of the answer set. This is different from merely demanding x knows a certain proposition q. In the latter case, q is one of the (usually) many propositions that x knows, while in (140) x's *entire* knowledge is specified. To understand why this is a reasonable requirement, recall that the answer set is downward-closed modulo NFA. Hence, $K_x^w \in \mathscr{Q}(w)$ can be arbitrarily specific. What the lexical entry in (140) does is simply to impose conditions on x's knowledge; but it is not very demanding: x is free to know *anything* as long as she knows a true answer to the embedded question. If *know* embeds an interrogative, $\text{ANS}_{[+/-\text{cmp}]}$ ensures that the answer set $\mathscr{Q}$ is downward-closed modulo NFA—which means it obeys the no-false-answers constraint. Accordingly, *know-wh* comes out as upward-monotonic modulo NFA. In contrast, if *know* embeds a declarative, the answer set $\mathscr{Q}$ yielded by $\text{ANS}_{[+/-\text{cmp}]}$ will be vanilla downward-closed—which means the no-false-answers constraint does not apply. Consequently, *know-that* comes out as vanilla upward-monotonic.

A word on the significance of downward-closedness for embedded clauses in general. In $\mathsf{Inq}_\mathsf{B}^\lambda$, sentence denotations, both those of declaratives and of interrogatives, are downward-closed. For one of the reasons behind this design decision, see Section 2.3.1.2. Now, our semantics is compositional: interrogatives and declaratives have the same denotation regardless whether they appear in a root or an embedded context. It hence goes without saying that the denotations of *embedded* sentences will have to be downward-closed as well. These are still *sentences*, however. *Answer sets* in contrast might be a different matter. In the proposed setup, $\text{ANS}_{[+/-\text{cmp}]}$ overrides the vanilla downward-closedness of the question denotation and replaces it by a more restricted version of downward-closedness. As for *restricting* the downward-closedness, we have just seen how this can be useful. But in fact—why do we have to make the answer set downward-closed in the first place? Quite simply, for the same reasons that have already motivated the downward-closedness of sentence denotations. That is, it helps us achieve an explanatorily more adequate treatment of clause conjunction—this time in embedded contexts.

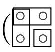
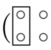
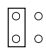
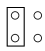
Consider e. g. the conjunction of two embedded clauses in (142), a modified version of (57).

(142) Mary knows whether John speaks French and that he speaks Russian.

Again, we can capture this conjunction using the uniform lexical entry (143) for *and*; it applies to both embedded declaratives and embeddded interrogatives (or rather, to their respective "answer sets").

(143) $Tr(\text{and}) := \lambda\mathcal{Q}_{\langle s,T\rangle}.\lambda\mathcal{Q}'_{\langle s,T\rangle}.\lambda w_s.\lambda p_{\langle s,t\rangle}.\mathcal{Q}(w)(p) \wedge \mathcal{Q}'(w)(p)$

The syntactic structure of example (142) is sketched in Figure 14.[11] Note that the denotation of the conjunction is computed simply by intersecting the two conjuncts. Modulo the type-lift, this is the classical treatment of conjunction. As discussed in Section 2.3.1.2, being able to use ordinary intersection in an alternative semantics hinges crucially on the fact that the objects that get intersected are downward-closed. If they are not, *pointwise* intersection is required instead. In a framework based on set-theory, however, this choice would be less generally motivated since pointwise intersection, other than classical intersection, is not a meet operation.

The answer sets in Figure 14 are indeed vanilla downward-closed: one stems from a declarative clause (it has been laid out above that applying the answer operator to a declarative denotation does not remove any states from this denotation) and the other one stems from an exhaustive question denotation (all states from an exhaustive question denotation satisfy the NFA and thus none of them are excluded from the answer set). However, does the classical treatment of sentence conjunction still work reliably if the answer sets are not vanilla downward-closed, but only downward-closed modulo NFA? Yes. In general, recall that the reason why those pieces of information that are excluded from an answer set by virtue of the NFA need to be excluded is that they are not allowed from entering into the specified relation (e. g. knowledge) with the individual. This basic fact does not change only because we are dealing with sentence conjunction instead of with single sentences: pieces of information not complying with the NFA have to be excluded. Since such excluded pieces will never be relevant for the specified relation anyway, they need not "participate" in the clause conjunction either. What kind of problem then could arise from the lack of vanilla downward-closedness? It might be the case that, for a given world w, the intersection of two answer sets $\mathcal{Q}(w)$ and $\mathcal{Q}'(w)$ is empty. However, it appears that the only worlds in which this can happen are those where the conjunction would give rise to a contradiction; and those cases already come out as undefined by virtue of the factivity presupposition. Consider the following example. Assume that what gets coordinated by *and* are $\mathcal{Q} = \text{ANS}_{[+\text{cmp}]}($  $)$ and $\mathcal{Q}' = \text{ANS}_{[+\text{cmp}]}($  $)$. Then, because $\mathcal{Q}$ is only downward-closed modulo NFA, we find that  is not an element of $\mathcal{Q}(w_2)$. Intersecting $\mathcal{Q}(w_2)$ with  would therefore indeed yield the empty set. However, notice that  is not true at w_2. Hence, $\mathcal{Q}'(w_2)$ simply

11 Although in this example both clauses contain the [+cmp] version of the answer operator, nothing hinges on this choice: for declaratives and polar/exhaustive questions, $\text{ANS}_{[+\text{cmp}]}$ and $\text{ANS}_{[-\text{cmp}]}$ yield the same result.

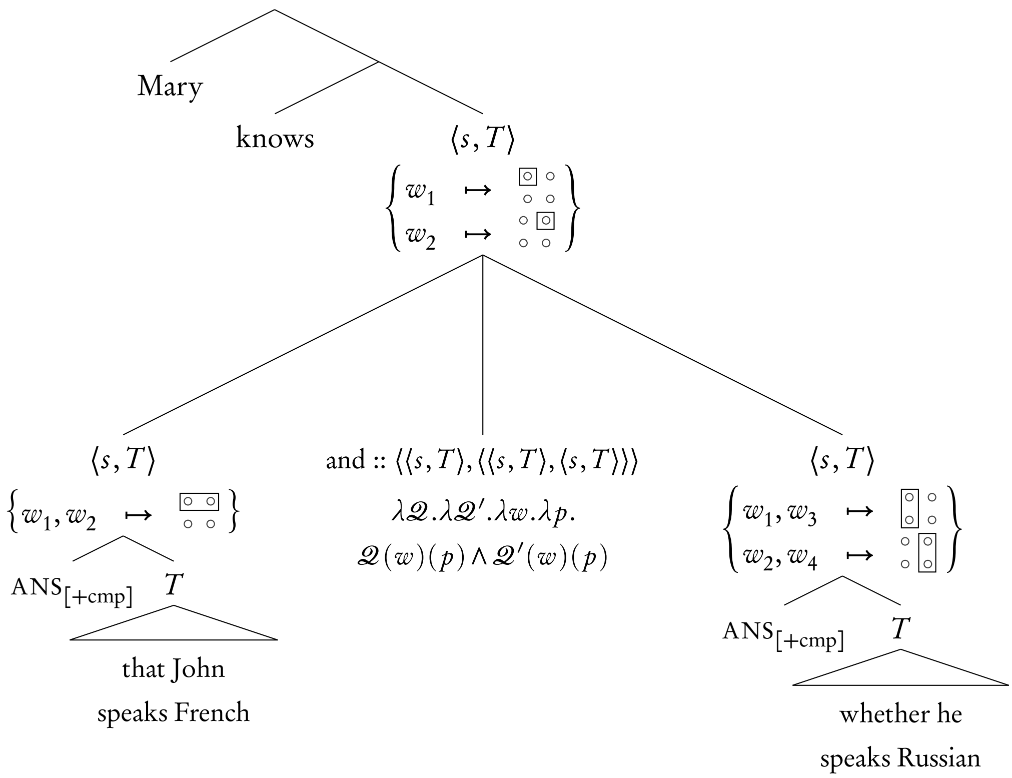


Figure 14: Conjunction of embedded clauses

is not defined (likewise for $\mathcal{Q}'(w_4)$). The conjunction of $\mathcal{Q}$ and $\mathcal{Q}'$ is thus only defined for the worlds w_1 and w_3.

In this section it has been shown how restricted downward-closedness can be used to implement upward-monotonic predicates which obey the no-false-answers constraint. This is exactly what we wanted for verbs like *know* and *be certain*: since they only allow [–lit] readings, they are always upward-monotonic. However, our account does not yet take care of emotive predicates and verbs of communication, which—depending on whether they are read deductively or literally—differ in their monotonicity behaviour and their sensitivity to background knowledge. Before turning to the [+/–lit] distinction, though, we will first explore a contrast that shows up already with the above lexical entries—namely the contrast between inquisitiveness holes and inquisitiveness plugs.

4.5.3 The propagation of inquisitiveness

In inquisitive semantics, the utterance of a sentence is conceived as having a two-fold effect: it can both *convey* and *request* information. Based on this conception, sentences are characterised as inquisitive or non-inquisitive, depending on whether they themselves provide enough information to satisfy the request for information they express (see Chapter 2).

To recapitulate, a sentence ϕ is inquisitive if its informative content $\mathsf{info}(\phi)$ is not an element of $[\phi]$ (for, otherwise any issue that ϕ might raise will already be settled by ϕ itself). Consequently, a sentence whose denotation contains more than one alternative is always inquisitive.

Let ϕ and ψ be sentences in $\mathsf{Inq_B}$. Whether larger sentences constructed from ϕ and ψ are inquisitive or not depends on (i) whether ϕ and/or ψ themselves are inquisitive and (ii) the way in which ϕ and ψ are syntactically combined. As an example, consider $\phi \to \psi$. If ψ is inquisitive, the entire implication is inquisitive as well (see the conditions for questionhood (27) in Chapter 2). Hence, in an implication the inquisitiveness of the consequent propagates to the "matrix level". We will refer to this kind of embedding construction, which allows the inquisitiveness of an embedded sentence to percolate upwards, as an *inquisitiveness hole*. By way of contrast, $\neg\phi$ never is inquisitive, regardless of whether ϕ is inquisitive or not (see (26)). In other words, negation blocks the propagation of inquisitiveness. We will describe embedding constructions of this kind as *inquisitiveness plugs*. Both plugs and holes can also be found among the question embedding predicates in $\mathsf{Inq_B^\lambda}$: veridical verbs are inquisitiveness plugs, while non-veridicals are inquisitiveness holes.

Veridical verbs can be thought of as resolving the issue expressed by the embedded question: they pick out an answer from the question denotation that we know to be a true answer. Non-veridicals on the other hand do not necessarily pick a true answer. Rather, they *leave it open* to which possible answer the subject stands in relation. In the lexical entries of non-veridical embedders, this underspecification is implemented as an existential quantification over worlds, which outscopes all other quantifiers (notably also the familiar "$\forall w \in p$"-quantification). This means that sentences with questions embedded under non-veridicals come out as inquisitive—at least if the true answer to the embedded question varies from world to world (as it usually does). To see why, consider sentence (144).

(144) John is certain who called.

Let Alice and Bob be the only individuals in the domain. Let r be the proposition that Alice called and s the proposition that Bob called. Observe that $r \nsubseteq s$ and $r \nsupseteq s$. Then, there will be two distinct states $p, p' \in Tr((144))$ such that p is the proposition consisting of all worlds in which John is certain of r and p' is the proposition consisting of all worlds in which John is certain of s. It is neither the case that $p \subseteq p'$ nor that $p \supseteq p'$. Moreover, we find that $(p \cup p') \notin Tr((144))$. This is the case because, $p \cup p'$ is the set of worlds in which John is certain of the proposition that *Alice called or Bob called*. Let q be this proposition. In order for $p \cup p'$ to be a state in $Tr((144))$, there would hence have to be some world v such that $q \in \text{ANS}_{[+/-\text{cmp}]}(\text{Who called?})(v)$. This can only be the case if $\forall p \in \text{ALT}(\text{Who called?}) : (p(v) \to q \subseteq p)$ (for [+cmp] answers) or $\exists p \in \text{ALT}(\text{Who called?}) : (p(v) \wedge q \subseteq p)$ (for [−cmp] answers). The set $\text{ALT}(\text{Who called?})$ contains exactly the propositions *that Alice called*, *that Bob called* and *that nobody called*. None of these are entailed by q. Hence, there exists no v such that $q \in \text{ANS}_{[+/-\text{cmp}]}(\text{Who called?})(v)$, and consequently $(p \cup p') \notin Tr((144))$.[12] With the above reasoning, it follows that the denotation of (144) is inquisitive.

12 More formally, we want to show that $(p \cup p') \notin Tr((144))$. Let $Q = Tr(\textit{Who called?})$ and $\mathbf{j} = Tr(\textit{John})$. We know that $Tr((144)) = \lambda p.\exists w' \forall w \in p : \mathrm{C}_{\mathbf{j}}^{w} \in \text{ANS}_{[+/-\text{cmp}]}(Q)(w')$ and that $\text{ANS}_{[+/-\text{cmp}]}(Q)(w') =$

Hence, non-veridical predicates are inquisitiveness holes: if they embed a question, the resulting sentence is inquisitive. In comparison, veridical predicates are inquisitiveness plugs. They determine that the individual stands in relation to a true answer. Thus, they lack the element of underdetermination which is characteristic of non-veridical embedders and which allows the inquisitiveness to percolate upwards. Formally, this difference is captured by the outermost level of existential quantification over possible worlds that is present only in the lexical entries of non-veridical verbs. Of course, a sentence with a question embedded under a veridical verb may still be inquisitive; but this inquisitiveness would have to be introduced *above* the level of the question embedding.

As a final remark, bear in mind that so far all we have done is to examine the formal properties of inquisitiveness holes and plugs. We have *not* discussed yet whether the treatment of non-veridicals as inquisitiveness plugs is desirable at all. In this respect, the proposed account will yet have to hold up to empirical scrutiny. We will return to the matter in Section 4.7 and demonstrate that our treatment indeed makes correct (and novel) predictions.

4.5.4 A uniform account of knowledge-*wh*

There is a further intricacy involved in the meaning of knowledge-*wh*. As discussed in Chapter 3, whether an individual *knows-wh* does not only depend on the individual's knowledge, but also on his *beliefs*. Recall the newspaper examples from George (2011), repeated here as (145a) and (145b).

(145) a. Janna knows where Rupert can buy a newspaper.
b. Red knows where Rupert can buy a newspaper.

Assume again these sentences are uttered in a situation in which Red and Janna both *know* Rupert can buy a newspaper at a shop called PaperWorld. Additionally, Red falsely *believes* that Rupert can also buy a newspaper at a place called Newstopia. Janna, in contrast, is agnostic about whether Newstopia sells newspapers. While (145a) is judged true in this scenario, (145b) is perceived as false since Red's beliefs provide a false answer to the embedded question. This illustrates that a definition of knowledge-*wh* will also have to impose restrictions on a subject's beliefs: while the subject has to *know* a true answer p, he must not *believe* any more specific answer $p' \subsetneq p$ that is a false answer. According to George, *know* therefore is a *non-reducible* predicate: it is impossible to reduce the interrogative-embedding meaning of *know* to its declarative-embedding meaning. However, George does not take into account another option, which could be considered a special, even stronger case of a reductive

$\lambda p.\forall q \in \text{ALT}(Q) : (q(w') \rightarrow p \subseteq q) \wedge \forall q \in \text{ALT}(Q) : (\neg q(w') \rightarrow p \nsubseteq q)$. Assume for contradiction that $(p \cup p') \in Tr((144))$. Then, $\exists w' \forall w \in (p \cup p') : \forall q \in \text{ALT}(Q) : (q(w') \rightarrow C_j^w \subseteq q)$. Let w' be this world. Let p_a be the proposition that Alice called and p_b the proposition that Bob called. With $\text{ALT}(Q) = \{p_a, p_b\}$, we get that $\forall w \in (p \cup p') : ((p_a(w') \rightarrow C_j^w \subseteq p_a) \wedge (p_b(w') \rightarrow C_j^w \subseteq p_b))$. There are two cases to distinguish: $w' \in p_a$ and $w' \in p_b$. Assume $w' \in p_a$. It follows that $\forall w \in (p \cup p') : C_j^w \subseteq p_a$. This cannot be the case since there exist $v \in p'$ such that $C_j^v \nsubseteq p_a$. Analogous reasoning applies to the case $w' \in p_b$. Contradiction. It follows that $(p \cup p') \notin Tr((144))$.

treatment: a *uniform* analysis of *know* uses one and the same lexical entry for declarative-embedding and interrogative-embedding *know*. We will attempt such a uniform account.

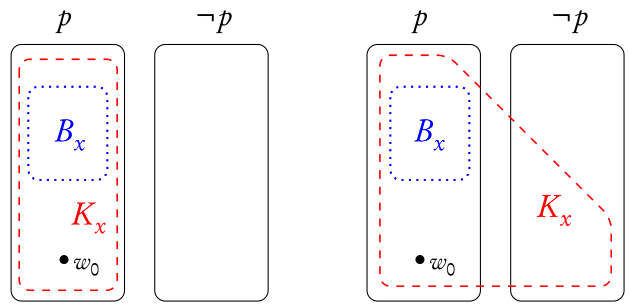
The preliminary lexical entry for *know* in (140) is clearly insufficient. While it does require the subject to know a proposition that truthfully resolves the embedded question, it does not make any statement about the subject's beliefs; and beliefs are (typically) more specific than knowledge. Hence, in the above example, (140) would not prohibit Red from wrongly believing that Rupert can buy a newspaper at Newstopia. An easy remedy is to simply include a restriction on the subject's beliefs as well. This restriction is just the same as that for knowledge: the set of all worlds compatible with what the subject believes must be a state from the answer set. Since, in the case of interrogative-embedding *know*, this answer set is downward-closed modulo NFA, the subject's beliefs must thus truthfully resolve the embedded question.

(146) Lexical entry for *know*:

$$Tr(\text{know}) := \lambda \mathcal{Q}_{\langle s,T\rangle}.\lambda x.\lambda p.\left(\frac{\forall w \in p : \mathcal{Q}(w) \text{ is defined.}}{\forall w \in p : (K_x^w \in \mathcal{Q}(w) \wedge B_x^w \in \mathcal{Q}(w))}\right)$$

By the nature of belief and knowledge, it will always be the case that $B_x^w \subseteq K_x^w$. Whereas K_x^w necessarily contains the actual world, B_x^w typically incorporates a lot of false assumptions. Critically, though, B_x^w will still truthfully resolve the embedded question. Hence, (146) does prohibit Red from wrongly believing Rupert can buy a newspaper at Newstopia.

One might be wondering whether the above lexical entry is redundant. Is it really necessary to specify *both* knowledge *and* belief? Does not maybe one of them follow from the other? This depends on our notion of knowledge. The lexical entry in (146) can be seen as a template in which to plug one's favourite definition of knowledge. For very simple-minded such definitions, (146) will indeed be redundant. However, all it takes is an account in terms of justified true belief, and the redundancy will no longer persist. Let us reflect on this in detail. First assume that knowledge is true belief. That is, x knows p just in case x believes p and p is true. Under this definition, x's knowledge is to a relatively high degree determined by x's beliefs. Consider the following example, visualised in Figure 15a. I believe that $p \wedge q$ (depicted as the dotted blue set B_x, the set of all worlds compatible with my beliefs). In the actual world, however, only p holds, but not q. It is clear that my beliefs are false, but truthfully resolve the polar question $?p$ (in the picture, B_x is entirely contained in the alternative for p). Now, what does this configuration tell me about my knowledge (in the picture, the dashed red set K_x)? Recall that we treat knowledge as true belief. Since I correctly believe that p, it follows that I also know p. Hence, all worlds that are compatible with my knowledge are p-worlds; there are no $\neg p$-worlds in K_x (this is why in the picture K_x is situated inside the alternative for p). It follows that my knowledge is specific enough to resolve $?p$. Additionally, since knowledge is intrinsically true, my knowledge resolves $?p$ *truthfully*. This observation holds with more generality: analysing knowledge as true belief, whenever my beliefs truthfully resolve a question Q, my knowledge will truthfully resolve Q as well. In terms of the lexical entry in (146), this means that the knowledge specification is redundant and can be omitted:



(a) Knowledge as true belief

(b) Knowledge as justified true belief

Figure 15: Our notion of knowledge determines admissible knowledge/belief configurations

(147) Lexical entry for *know* under an analysis of knowledge as true belief:

$$Tr(\text{know}) := \lambda \mathcal{Q}_{\langle s,T\rangle}.\lambda x.\lambda p.\left(\frac{\forall w \in p : \mathcal{Q}(w) \text{ is defined.}}{\forall w \in p : B_x^w \in \mathcal{Q}(w)}\right)$$

However, once we assume instead that knowledge is *justified* true belief, knowledge is not to the same extent as before determined by belief. In the above example, there are many conceivable reasons why my belief about p is not justified. Perhaps, someone lied to me about p. Perhaps, I was talking via a poor phone connection. So I understood p when what my collocutor actually said was $\neg p$. And so on. We cannot conclude from the fact that I truthfully believe p that I know p. This means, we cannot be sure that, just because all my belief-compatible worlds are situated within the alternative for p, the same goes for my knowledge-compatible worlds. Nothing prevents my belief/knowledge configuration from looking, for example, like the one in Figure 15b. This goes to show that under an analysis of knowledge as justified true belief, the knowledge-specification in (146) is not redundant.

Conversely, that the *belief*-specification is really needed and does not already follow from the knowledge-condition should be clear from the introductory motivation: even if my knowledge truthfully resolves a question, it might well be the case that my beliefs provide a false answer to the question. Hence, we cannot drop the belief-specification, either.

Now for the crucial question: is our account still uniform? That is, does the above lexical entry—we will use the more general one in (146)—also capture the declarative-embedding use of *know*? It does. Recall that *know-that* combines with an ordinary, vanilla downward-closed sentence denotation. This means, q' in (146) can be arbitrarily specific. The only way in which the subject's beliefs are restricted is that she has to believe the proposition expressed by the *that*-complement clause. This condition is trivially satisfied since the lexical entry also requires her to *know* this proposition. Hence, the proposed lexical entry for *know* caters to both interrogative and declarative complement clauses. Our account is still uniform.

4.5.5 Non-monotonicity of literal readings

The semantics of epistemic verbs like *know* or *be certain* is comparably easy to capture as these verbs do not display an ambiguity between literal and deductive readings, but are intrinsically deductive. Once we direct our attention to communication verbs and emotives on the other hand, we do have to take care of the literal/deductive ambiguity. Essentially, it manifests itself in two respects: monotonicity behaviour and sensitivity to background knowledge. We will deal with these in turn.

In Chapter 3, we saw that embedders on the [+lit] reading are characterised by a complete lack of monotonicity. Communication verbs on this reading describe an event in which a specific literal content gets communicated; emotive verbs on this reading describe a subject's state of mind at a given point in time and express that the subject's attention is centred on a specific piece of information at that point in time. In both cases, we find a *literal content* of sorts associated with the event or the state that the embedding verb describes: *literally communicated content* for communication verbs and the subject's *attentive state* for emotive verbs. Also, in both cases, this literal content is more or less fixed. Consider the following example. Bob and Alice are arranging a dinner party, and Alice wants to invite Mary, John and Carol. Let p be the proposition that Alice wants to invite Mary, John and Carol. What she *literally* tells Bob in (148) must then be *exactly* p and, in particular, *not* some subset of p. Although we have seen that [–lit] *tell* is upward-entailing with respect to its complement, this monotonicity is blocked under the [+lit] reading.

(148) When I entered the room, Alice was just telling Bob who she wants to invite.

Similarly, what Bob's attention is centred on in (149) is exactly p and not some superset of p. Although we have found *surprise* to be "truth-functionally"[13] downward-entailing on the [–lit] reading, this monotonicity is blocked on the [+lit] reading.

(149) When Alice told him, Bob was very surprised by who she wants to invite.

Formally, the monotonicity will be blocked by imposing restrictions on the literal content associated with the embedding verb. For *tell*, this literal content will be identified with the *literally told message* (what the speaker literally says) of type $\langle s,t\rangle$: $\textit{lit-tell}(w)(q)(y)(x)$ expresses that in world w speaker x literally told listener y the proposition q.

Let Q be the denotation of the embedded question. Now, the restriction for *tell* is the following. While under the deductive reading the literal message q may be any of the states from the answer set of Q, under the literal reading it is not as free: there, q must be one of the *maximal* states from this answer set:

(150) Preliminary lexical entry for [–lit, +ver] *tell*:

$$\mathit{Tr}(\text{tell}) := \lambda \mathcal{Q}_{\langle s,T\rangle}.\lambda y.\lambda x.\lambda p.\left(\frac{\forall w \in p : \mathcal{Q}(w) \text{ is defined.}}{\forall w \in p : \exists q : (\textit{lit-tell}(w)(q)(y)(x) \wedge q \in \mathcal{Q}(w))}\right)$$

13 Cf. Section 3.2.3.

(151) Lexical entry for [+lit, +ver] *tell*:

$$Tr(\text{tell}) := \lambda \mathcal{Q}_{\langle s,T\rangle}.\lambda y.\lambda x.\lambda p.\left(\frac{\forall w \in p : \mathcal{Q}(w) \text{ is defined.}}{\forall w \in p : \exists q : (\textit{lit-tell}(w)(q)(y)(x) \wedge q \in \text{ALT}(\mathcal{Q}(w)))}\right)$$

(152) Preliminary lexical entry for [–lit, –ver] *tell*:

$$Tr(\text{tell}) := \lambda \mathcal{Q}_{\langle s,T\rangle}.\lambda y.\lambda x.\lambda p.\left(\frac{\exists w' \in p : \mathcal{Q}(w') \text{ is defined.}}{\exists w'' \forall w \in p : \exists q : (\textit{lit-tell}(w)(q)(y)(x) \wedge q \in \mathcal{Q}(w''))}\right)$$

(153) Lexical entry for [+lit, –ver] *tell*:

$$Tr(\text{tell}) := \lambda \mathcal{Q}_{\langle s,T\rangle}.\lambda y.\lambda x.\lambda p.\left(\frac{\exists w' \in p : \mathcal{Q}(w') \text{ is defined.}}{\begin{array}{l}\exists w'' \forall w \in p : \exists q : (\textit{lit-tell}(w)(q)(y)(x) \\ \wedge\, q \in \text{ALT}(\mathcal{Q}(w'')))\end{array}}\right)$$

Now on to *surprise*—a verb, whose semantics has proven notoriously difficult to capture (e. g. Guerzoni, 2007; Égré and Spector, 2014). Accordingly, the following is to be taken as a sketch rather than a fully worked out proposal. What is certain, though, is that the lexical entries for *surprise* will look slightly different from those for upward-entailing *know*, *be certain* or *tell*—given that *surprise* is downward-entailing. We no longer specify that two pieces of information *match*, but rather that they *clash*. To be exact, we demand that one of the subject's "expectations" clashes with a minimally informative true answer to the embedded question. For us, expectations are essentially just beliefs at a previous point of time (which, at the present point of time, might already have been revised); but beyond this we will not attempt a formalisation of what expectations are.

Under the deductive reading, *being surprised* can then be captured by requiring that the set of all worlds compatible with the subject's expectations is disjoint from a true basic answer $q \in \text{ALT}(\text{ANS}(Q)(w))$. For a literal reading, we add to this the condition that q is also part of x's attentive state. The attentive state of x in w is formally captured by the term ATT_x^w of type T. This complex type allows a subject's attentive state to comprise more than just one proposition.[14]

(154) Lexical entry for [–lit] *be surprised*:

$$Tr(\text{be surprised}) := \lambda \mathcal{Q}_{\langle s,T\rangle}.\lambda x.\lambda p.\left(\frac{\forall w \in p : (\mathcal{Q}(w) \text{ is defined} \wedge K_x^w \in \mathcal{Q}(w)).}{\forall w \in p : \exists q \in \text{ALT}(\mathcal{Q}(w)) : q \cap \text{EXP}_x^w = \emptyset}\right)$$

(155) Lexical entry for [+lit] *be surprised*:

$$Tr(\text{be surprised}) := \lambda \mathcal{Q}_{\langle s,T\rangle}.\lambda x.\lambda p.\left(\frac{\forall w \in p : (\mathcal{Q}(w) \text{ is defined} \wedge K_x^w \in \mathcal{Q}(w)).}{\begin{array}{l}\forall w \in p : \exists q \in \text{ALT}(\mathcal{Q}(w)) : (q \cap \text{EXP}_x^w = \emptyset \\ \wedge\, q \in \text{ATT}_x^w)\end{array}}\right)$$

14 Furthermore, if ATT_x^w contains more than one maximal state, this could also be interpreted as x entertaining the issue expressed by ATT_x^w. As Ciardelli and Roelofsen (2014b) show, this concept can be useful when defining what it means to *wonder-wh*.

There are several remarks in order. For a start, note that the existential quantification over basic answers ($\exists q \in \text{ALT}(\mathcal{Q}(w))$) is only relevant if there can be more than one element in $\text{ALT}(\mathcal{Q}(w))$. This will only be the case for [–cmp] answers: there always is at most one true minimally informative [+cmp] answer, while there can be several true minimally informative [–cmp] answers. For a mention-some understanding of *surprise*, it suffices if x's expectations clash with one of these answers.[15]

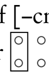
Further, as in the [+lit] entry for *tell*, we again impose restrictions on the literal content—here, on ATT_x^w. We require ATT_x^w to coincide with a maximal state q from the answer set such that q clashes with x's expectations. As a result, if an answer to the embedded question clashes with your expectations, but you are not "thinking" about this answer, then you will not come out as surprised-*wh*. This restriction of ATT_x^w makes [+lit] *surprise* a non-monotonic predicate.

Briefly recapitulating, our semantics can now capture the different monotonicity properties that arise from the literal/deductive ambiguity. Essentially, the literal reading has become stricter, while the deductive reading has stayed the same. In what follows, we will (tentatively) explore another possible refinement of deductive readings.

4.5.6 Knowledge-sensitivity of deductive readings

What also sets deductive readings apart from literal readings is the fact that the former but not the latter are sensitive to a certain amount of background knowledge and allow unlimited deductive reasoning on part of the agents. In the case of *tell*, this background knowledge is the common ground of the discourse in which the telling takes place. What follows is a sketch of how this knowledge-sensitivity *could* be implemented in our semantics. We will not endorse it unreservedly, though, as it makes some controversial predictions; and we will completely stay away from an analogue formalisation of knowledge-sensitive *surprise*.

As before, an act of telling is still associated with a literally communicated message. Previously, we had required this literal message to be informative enough to resolve the embedded question *on its own*. Now, we loosen this requirement: the common ground is allowed to come to the aid. That is, the question may also be resolved by what follows from combining the literal message and the information from the common ground of the discourse in which the telling takes place (we will refer to this as the *inner* common ground as opposed to the *outer* common ground of the discourse in which the containing sentence of *tell* is uttered):

15 It has to be noted that the [+lit, –cmp] reading resulting from (155) is somewhat peculiar in that it is stricter than the corresponding [+cmp] reading. In particular, [+cmp] does not come out as a special case of [–cmp]. To see why, observe that in world w_1, in order for x to be surprised under a [–cmp] reading,  or  must clash with x's expectations. Under a [+cmp] reading in contrast, it suffices if  clashes with x's expectations—this is a less strict condition. Is this outcome desirable? This is difficult to judge. To begin with, recall that [+lit, –cmp, –exh] readings do not seem to show up empirically. We had therefore tentatively stipulated they are unavailable (see Figure 9 in Section 3.5.3). So, we do not have any data to probe our intuitions. What seems undesirable, however, is that (155) predicts it is impossible to be [+lit] surprised by anything *in between* a mention-a-single-individual answer and a complete answer: what causes the surprise has to be either an alternative in the question denotation ([–cmp] case) or the complete true answer ([+cmp] case). However, imagine Alice, Bob and Mary were at the party, and Bob and Mary usually avoid each other. Then, if I am [+lit] surprised who was at the party, my surprise might well concern the presence of *exactly* Bob and Mary. The lexical entry in (155) does not provide this reading.

(156) Alternative lexical entry for [–lit, +ver] *tell*:

$$Tr(\text{tell}) := \lambda\mathcal{Q}_{\langle s,T\rangle}.\lambda y.\lambda x.\lambda p.\left(\frac{\forall w \in p : \mathcal{Q}(w) \text{ is defined.}}{\begin{array}{l}\forall w \in p : \exists q : (\textit{lit-tell}(w)(q)(y)(x) \\ \wedge (q \cap \mathrm{CG}^{w}_{\{x,y\}}) \in \mathcal{Q}(w) \wedge \mathrm{CG}^{w}_{\{x,y\}} \notin \mathcal{Q}(w))\end{array}}\right)$$

However—and this is what the second conjunct prevents—the information from the inner common ground must not by itself resolve the embedded question; it still needs to be what literally is told which provides the decisive bit of information. Possibly this is too strong a requirement; we will discuss this in due course.

There are examples for which the previous lexical entry (150) can*not* account, but (156) can. The following one is repeated from Section 3.2.3. Assume it is common knowledge among Mary and Bob that Bob's only friends from highschool are Alice and John. Further assume Bob told Mary "I have invited my friends from highschool." In this situation, (157) seems to be true under a deductive understanding of *tell*.

(157) Bob told Mary he invited Alice.

This sentence would be predicted as false under the definition of [–lit] *tell* in (150), since the proposition that Bob literally told Mary, namely $[\forall x(\text{friend}(x) \rightarrow \text{invited}(\mathbf{b}, x))]$, is not an element of the embedded sentence's "answer set", which comes out as $\wp([\text{invited}(\mathbf{a})])$. Only by adding information from the common ground—as (156) allows us to do—can we obtain a piece of information contained in this answer set: the common ground incorporates the information that Alice is a higschool friend of Bob's (friend($\mathbf{a}$)), and it is easy to see that $[\forall x(\text{friend}(x) \rightarrow \text{invited}(\mathbf{b}, x))] \cap [\text{friend}(\mathbf{a})] \in \wp([\text{invited}(\mathbf{a})])$. Hence, (157) comes out as true under lexical entry (156).

There is one drawback, however. As already mentioned, the condition that $\mathrm{CG}^{w}_{\{x,y\}} \notin \mathcal{Q}(w)$ might be too strict. To see why, observe that this condition predicts it is impossible to $tell_{[\text{-lit}]}$ Q if Q is already settled by the inner common ground. On the one hand, this might be desirable as it captures our understanding of deductive readings as expressing the *result* or the *success* of a communicative act: if the inner common ground resolves the issue at hand, the communicative result has already been obtained and another act of telling would be of no consequence. On the other hand, however, it is uncertain whether such a reading actually corresponds to a natural understanding of *tell*. Consider the following dialogue, taking place in a situation where speaker *A* already knows who is invited for dinner and speaker *B* knows that *A* knows.

(158) A: Mary told me who is invited for dinner.
B: Huh? But you already knew who is invited. So, how could she still *tell* you?

If *B*'s reply—albeit overly nitpicky—is warranted here, then the definition in (156) gets it right; if *B* is not even making any sense, on the other hand, $\mathrm{CG}^{w}_{\{x,y\}} \notin \mathcal{Q}(w)$ is too strong a requirement. Note however that simply omitting this condition from (156) would not solve the problem either. For then, if $\mathrm{CG}^{w}_{\{x,y\}} \in \mathcal{Q}(w)$, x could tell y just *anything* and would always be predicted to have *told* Q. This is clearly undesirable.

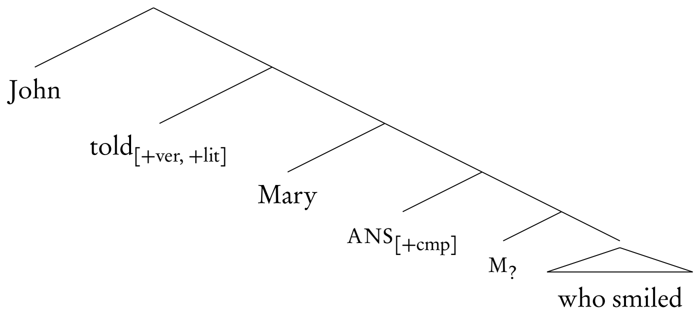
As another outcome, note that under the new definition $tell_{[\text{+lit}]}$ does no longer entail $tell_{[\text{-lit}]}$ telling. This entailment had been valid before since the literal reading was merely a stricter version of the deductive reading in that it imposed stricter conditions on the literal content of the telling act. Now, however, the deductive reading additionally contains the requirement that $\text{CG}^{w}_{\{x,y\}} \notin \mathcal{Q}(w)$—which we could view as demanding that the communicative act has been successful. Under this view, the lack of entailment between $tell_{[+\text{lit}]}$ and $tell_{[-\text{lit}]}$ makes sense: to literally tell something does not ensure that the message actually gets across and that the desired communicative result is established. Now, as a matter of fact, what $\text{CG}^{w}_{\{x,y\}} \notin \mathcal{Q}(w)$ expresses is not a sufficient condition for communicative success, but arguably a necessary one. If we actually wanted to capture $tell_{[-\text{lit}]}$ from a discourse theoretical perspective, many more subtleties would be needed. However, we will stop at this point.

4.6 Example derivations

Before we move on, we will walk through two example derivations, one where a *wh*-question is embedded under the veridical variant of *tell* and one where the same question is embedded under the non-veridical variant of *tell*. In order to keep those derivations readable, diagrams such as or are sometimes used in place of λ-terms. Unless otherwise indicated, these diagrams stand for exactly the sets of worlds they depict. That is, stands for the set $\{w_1, w_2\}$—and not for its downward-closure $\wp(\{w_1, w_2\})$.

First, we are going to compute the meaning of the following sentence with the veridical, literal variant of *tell*:

(159) John told$_{[+\text{ver}, +\text{lit}]}$ Mary who smiled. [+ver, +lit, +cmp, –exh]



We proceed bottom-up, first computing the denotation of the embedded question.

$$Tr(\text{M}_?(\text{who smiled})) = \lambda p_{\langle s,t\rangle}.\exists x \forall w \in p : (smile(w)(x)) \vee \boxed{\neg} \exists x \forall w \in p : (smile(w)(x))$$

This question denotation contains exactly three alternatives:

$$\text{ALT}(Tr(\text{M}_?(\text{who smiled}))) = \{ \; , \; , \; \}$$

These intermediate results can be used in computing the answer set of the question:

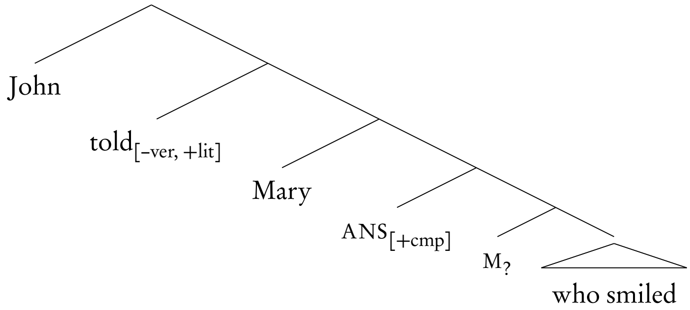
$$
\begin{aligned}
& \text{ANS}_{[+\text{cmp}]}(\mathit{Tr}(\text{M}_?(\text{who smiled})))\\
= & \left[\lambda Q_T.\lambda w.\lambda p.\underline{\exists q \in \text{ALT}(Q) : q(w)}.\begin{pmatrix} \forall q \in \text{ALT}(Q) : (q(w) \rightarrow p \subseteq q) \\ \wedge \forall q \in \text{ALT}(Q) : (\neg q(w) \rightarrow p \nsubseteq q) \end{pmatrix}\right]\\
& (\mathit{Tr}(\text{M}_?(\text{who smiled})))\\
= & \lambda w.\lambda p.\underline{\exists q \in \{\ , \ , \ \} : q(w)}.\begin{pmatrix} \forall q \in \{\ , \ , \ \} : (q(w) \rightarrow p \subseteq q) \\ \wedge \forall q \in \{\ , \ , \ \} : (\neg q(w) \rightarrow p \nsubseteq q) \end{pmatrix}\\
= & \left\{\begin{array}{lll} w_1 & \mapsto & \\ w_2 & \mapsto & \\ w_3 & \mapsto & \\ w_4 & \mapsto & \end{array}\right\}, \text{ where } \ , \ , \ \text{and} \ \ \text{are} \downarrow\text{-closed mod. NFA}
\end{aligned}
$$

Finally, we can compute the denotation of the entire sentence: the answer set is related to the subject *John* and the indirect object *Mary* by means of the embedding predicate:

$$
\begin{aligned}
& \mathit{Tr}(\text{told}_{[+\text{ver}, +\text{lit}]})(\text{ANS}_{[+\text{cmp}]}(\mathit{Tr}(\text{M}_?(\text{who smiled}))))(\mathit{Tr}(\text{Mary}))(\mathit{Tr}(\text{John}))\\
= & \left[\lambda \mathcal{Q}_{\langle s,T\rangle}.\lambda y.\lambda x.\lambda p.\left(\frac{\forall w \in p : \mathcal{Q}(w) \text{ is defined.}}{\forall w \in p : \exists q : (\mathit{lit\text{-}tell}(w)(q)(y)(x) \wedge q \in \text{ALT}(\mathcal{Q}(w)))}\right)\right]\\
& \left(\left\{\begin{array}{lll} w_1 & \mapsto & \\ w_2 & \mapsto & \\ w_3 & \mapsto & \\ w_4 & \mapsto & \end{array}\right\}\right)(\mathbf{m})(\mathbf{j}), \text{ where } \ , \ , \ \text{and} \ \ \text{are} \downarrow\text{-closed mod. NFA}\\
= & \lambda p.\begin{pmatrix} & (p(w_1) & \rightarrow & \mathit{lit\text{-}tell}(w_1)(\ )(\mathbf{m})(\mathbf{j})) \\ \wedge & (p(w_2) & \rightarrow & \mathit{lit\text{-}tell}(w_2)(\ )(\mathbf{m})(\mathbf{j})) \\ \wedge & (p(w_3) & \rightarrow & \mathit{lit\text{-}tell}(w_3)(\ )(\mathbf{m})(\mathbf{j})) \\ \wedge & (p(w_4) & \rightarrow & \mathit{lit\text{-}tell}(w_4)(\ )(\mathbf{m})(\mathbf{j})) \end{pmatrix}
\end{aligned}
$$

For comparison, we now compute the denotation of (160). It only differs from (159) in that the question is not embedded under the veridical, but under the non-veridical variant of *tell*. In particular, the question denotation is the same as before; so we do not need to recompute it.

(160) John told$_{[\text{–ver, +lit}]}$ Mary who smiled. [–ver, +lit, +cmp, –exh]



Observe how the difference between the universal outermost quantification in the denotation of (159) and the existential outermost quantification in the denotation of (160) manifests itself. Above, we have obtained conjunctive conditions, yielding a non-inquisitive sentence meaning; below the conditions are disjunctive and the sentence meaning inquisitive (cf. Section 4.5.3). This contrast is discussed in the next section.

$$Tr(\text{told}_{[\text{–ver, +lit}]})(\text{ANS}_{[\text{+cmp}]}(Tr(\text{M}_?(\text{who smiled}))))(Tr(\text{Mary}))(Tr(\text{John}))$$

$$= \left[\lambda\mathcal{Q}_{\langle s,T\rangle}.\lambda y.\lambda x.\lambda p.\left(\frac{\exists w' \in p : \mathcal{Q}(w') \text{ is defined.}}{\exists w''\forall w \in p : \exists q : (\textit{lit-tell}(w)(q)(y)(x) \wedge q \in \text{ALT}(\mathcal{Q}(w'')))}\right)\right]$$

$$\left(\left\{\begin{array}{lll} w_1 & \mapsto & \\ w_2 & \mapsto & \\ w_3 & \mapsto & \\ w_4 & \mapsto & \end{array}\right\}\right)(\mathbf{m})(\mathbf{j})\ , \text{ where } \ , \ , \ \text{and} \ \text{ are } \downarrow\text{-closed mod. NFA}$$

$$= \lambda p.\left(\begin{array}{ll} & \forall w \in p : \textit{lit-tell}(w)\left(\ \right)(\mathbf{m})(\mathbf{j}) \\ \vee & \forall w \in p : \textit{lit-tell}(w)\left(\ \right)(\mathbf{m})(\mathbf{j}) \\ \vee & \forall w \in p : \textit{lit-tell}(w)\left(\ \right)(\mathbf{m})(\mathbf{j}) \\ \vee & \forall w \in p : \textit{lit-tell}(w)\left(\ \right)(\mathbf{m})(\mathbf{j}) \end{array}\right)$$

4.7 Predictions: the propagation of inquisitiveness

In Section 4.5.3, we found that non-veridical predicates come out as inquisitiveness holes under the proposed semantics: if they embed a question, the resulting sentence is inquisitive. To my knowledge, this is a novel prediction. Here, we will explore it a bit further, checking whether this treatment of non-veridicals is empirically warranted.

4.7.1 The disjunctive-antecedent problem as a test for inquisitiveness

Alonso-Ovalle (2009) uses example (161) to argue that disjunctions are alternative-generating constructions.

(161) If we had had good weather this summer or the sun had grown cold, we would have had a bumper crop.

Intuitively, (161) is clearly false: if the sun had grown cold, there would certainly not have been a good crop. The sentence comes out true, however, under a standard analysis of disjunction and a minimal-change semantics of counterfactuals (Stalnaker, 1968; Lewis, 1973). This is the case, since, among the worlds satisfying the antecedent, those closest to the actual world are good-weather worlds (and not worlds where the sun has grown cold). Hence, the truth of the consequent is only checked in good-weather worlds. If we assume that in all the good-weather worlds that differ minimally from the actual world, we would indeed have had a great crop, then (161) comes out as true in the actual world.

This has sometimes been considered a problem for the minimal-change semantics for counterfactuals (a. o. Ellis et al., 1977). However, Alonso-Ovalle points out that we can keep this semantics *and* avoid the problem if we assume—as is done in alternative semantics—that disjunction introduces a set of propositional alternatives and that, for (161) to be true, the consequent has to hold in all the closest worlds in *each* of those alternatives.

That the problem arises in the first place, can thus be seen to indicate that the denotation of the antecedent contains more than one alternative (or, in the terminology of inquisitive semantics, that it is inquisitive). We can utilise this fact and employ counterfactuals like (161) as a diagnostic for whether a sentence is inquisitive.

4.7.2 The disjunctive-antecedent problem with non-veridical question embedders

Consider the following example. The national parliament was discussing (and voting on) two law proposals yesterday: proposal X (which has been known in advance to be very uncontroversial) and proposal Y (which, in contrast, has been known to be rather controversial). All in all, it was much more likely that the parliament would reach an agreement in favour of proposal X than of proposal Y. What happened in fact, however, is that the required majority could not be reached for either proposal. In this context, you utter:

(162) If the parliament had agreed on which proposals are a good idea, law X would have been passed.

This is clearly false; if the parliament had agreed that proposal Y, but not X is a good idea, X would of course not have been passed.

Note that the antecedent contains a question embedded under the non-veridical predicate *agree*.[16] Now assume we do not treat *agree* as an inquisitiveness hole—that is, we analyse the

16 According to all expectations, the test would yield the same result for other non-veridicals such as *be certain* as well. The difficulty rather is in setting up a suitable scenario. One of the "outcomes" of the antecedent needs to be much more likely than the other (*having a good summer* versus *the sun growing cold*). With *be certain*, we would hence have to assign likelihoods to an individual having different sets of beliefs. However, this is not as straightforward as assigning likelihoods to a parliament agreeing on certain law proposals.

antecedent as *non*-inquisitive. Then, all worlds in which the parliament reached an agreement regarding which proposals are good ideas are pooled together: all worlds in which the parliament agreed that only proposal X is a good idea, all worlds in which they agreed that only proposal Y is a good idea, all worlds in which they agreed that both proposals are good ideas and all worlds in which they agreed that neither X nor Y are good ideas. From among all these worlds, those closest to the actual world are ones in which the parliament agreed that X is a good idea. Hence, the truth of the consequent is only checked in such agreement-on-X worlds. Let us make the reasonable assumption that in all these worlds X would indeed have been passed. Then, as was the case with (161), the counterfactual (162) comes out as true. This means that analysing the antecedent as non-inquisitive yields too weak truth-conditions.

If we analyse *agree* as an inquisitiveness hole on the other hand, the antecedent is inquisitive. The truth of the consequent will then have to be checked in the closest worlds in each alternative in the denotation of the antecedent. This way, we obtain a more intuitive analysis of (162). Which alternatives exactly are contained in the antecedent denotation depends on whether the question is interpreted weakly or strongly exhaustively. In either case, however, there will be alternatives in which the closest worlds do not make the consequent true. Thus, (162) will come out as false.

Hence, the disjunctive-antecedent problem provides evidence to treat sentences in which *wh*-questions are embedded under non-veridical predicates as inquisitive—or, in other words, to treat non-veridical predicates as inquistiveness holes. This is in line with the semantics proposed in this thesis.

5 Conclusion

In this thesis, we have developed a semantic account of question embedding in a type-theoretical inquisitive semantics. We arrived at this outcome in three steps: first, $\mathsf{Inq}_{\mathsf{B}}^{\lambda}$, a compositional framework based on inquisitive semantics was introduced; second, the empirical picture of question embedding was explored and desiderata for the formal account were distilled from it; third, an $\mathsf{Inq}_{\mathsf{B}}^{\lambda}$-treatment of embedded questions was given, following the previously established desiderata.

Returning to the first step in more detail, inquisitive semantics—although it is ultimately designed for application in natural language semantics—does not yet supply a compositional translation procedure from natural language expressions to inquisitive meanings. Chapter 2 fills this gap: one possible way to set up such a translation was proposed. The framework specified there, $\mathsf{Inq}_{\mathsf{B}}^{\lambda}$, is closely related to systems in the tradition of Hamblin (1973). As has been demonstrated, however, $\mathsf{Inq}_{\mathsf{B}}^{\lambda}$ brings with it some conceptual and technical advantages: since inquisitive sentence meanings are downward-closed, the standard set-theoretic operations for entailment and clause conjunction can be retained, whereas in Hamblin systems they have to be given up. In $\mathsf{Inq}_{\mathsf{B}}^{\lambda}$, composition is driven by the standard composition rules of functional application and predicate abstraction, whereas in Hamblin systems these have to be given up too. There, they are replaced by pointwise versions of such rules, which were noted as problematic on several grounds: certain alternative-evaluating operators need to be defined syncategorematically, and pointwise predicate abstraction does not combine well with quantifier raising (Shan, 2004). Finally, inquisitive semantics and thus also $\mathsf{Inq}_{\mathsf{B}}^{\lambda}$ make the notion of resolution conditions fully explicit. From this, they can derive different notions of answerhood. Conceptually, this appears to provide a more solid footing for a definition of answerhood than the approach taken in Hamblin semantics: there, basic answerhood is treated as a pre-theoretic concept.

The second step undertaken in this thesis was to get a firmer grasp of the empirical picture of question embedding. To this end, we explored, categorised and re-examined the many different readings the literature has proposed for embedded questions. In Chapter 3, we have seen how these readings can be organised along a set of interpretive dimensions: completeness and exhaustivity on the one hand, which characterise the informational strength of the question denotation, and, one the other hand, veridicality and literalness, which are properties of the embedding verbs. In particular, some time was spent discussing the (to my knowledge) novel distinction between literal and deductive readings, which pertains to communication verbs and emotive verbs. For one thing, we found this ambiguity associated with differences in monotonicity behaviour: literal readings are completely non-monotonic, whereas—depending on the respective embedder—deductive readings can be downward-entailing or upward-entailing with respect to their complements. Upward-entailing embedders are subject to a certain restriction, which we dubbed the no-false-answer constraint (NFA). This constraint generalises restrictions that were previously formulated in the context of intermediate exhaustivity (Spector, 2005; Klinedinst and Rothschild, 2011). Further, we found differences in exhaustive strength to be tied to the literal/deductive contrast: strong exhaustivity seems to go hand in hand with deductive interpretations of embedding verbs, whereas weak exhaustivity seems bound to literal interpretations. Teasing apart literal and deductive readings might thus help to shed some light on why opinions are so divided regarding the exhaustive strength of embedded questions.

The third step consisted in implementing the previously made observations in a formal account of embedded questions. In Chapter 4, we devised a grammar fragment in $\mathsf{Inq}_\mathsf{B}^\lambda$ which is capable of accounting for the semantics of questions embedded under a small sample of verbs: epistemics like *know*/*be certain*, communication verbs like *tell* and emotives like *be surprised*. The focus is on responsive embedders; and the treatment of those embedders is uniform: the same lexical entry can capture both the interrogative-embedding and the declarative-embedding use of a responsive verb. In particular, we have provided a uniform lexical entry for *know*, which had previously been deemed to defy a reductive treatment (George, 2011).

The proposed account is flexible in that it allows for several levels of exhaustive strength: mention-some readings as well as weakly exhaustive and strongly exhaustive interpretations. The interpretive differences between those readings are established by the interplay of several distinct lexical elements: strongly exhaustive readings can be obtained by virtue of an exhaustivity operator and the difference between mention-some and weak exhaustivity is taken care of by an answer operator. It also falls to this answer operator to implement the no-false-answer constraint. This is accomplished by excluding certain pieces of information from the set of answers that the answer operator extracts from the original question denotation. As a result, such answer sets are no longer classically downward-closed, but only downward-closed modulo NFA.

Finally, it is the lexical semantics of embedding predicates that is in charge of the differences between literal/deductive embedders and veridical/non-veridical embedders. The former contrast primarily amounts to blocking versus permitting monotonicity with respect to the embedded clause. The latter contrast is implemented in terms of a world shift: veridicals express a relation to a true answer in the actual world, while non-veridicals express a relation to a piece of information that is a true answer in some possible world. Which possible world exactly this is, is left open. Due to this element of underspecification, non-veridicals behave differently from veridicals with respect to the preservation of semantic alternatives in the derivation. We referred to non-veridicals as inquisitiveness holes as they allow the inquisitiveness of embedded clauses to percolate upwards in the tree: if the embedded clause is inquisitive, the matrix clause will be inquisitive too. In contrast, veridicals were called inquisitiveness plugs since they block the propagation of inquisitiveness: even if the embedded clause is inquisitive, the matrix clause will not necessarily be so too. To test these novel predictions, the behaviour of inquisitiveness holes was examined in the context of the disjunctive-antecedent problem (Alonso-Ovalle, 2009). Our predictions proved valid.

A Generalising the notion of alternatives

The following takes up the discussion from Section 2.2.3.2, where the $\mathsf{Inq}^{\lambda}_{\mathsf{B}}$ exhaustivity operator EXH was defined as:

(163) $\text{EXH} := \lambda X_T.\lambda p_{\langle s,t\rangle}.\forall w, w' \in p : \{q \in \text{ALT}(X) \mid q(w)\} = \{q \in \text{ALT}(X) \mid q(w')\}$

Recall that there are two reasons why this definition falls short. Firstly, it does not preserve the informative content of a sentence: consider an informative sentence ϕ, that is, a sentence ϕ such that there are worlds $w \notin \mathsf{info}(\phi)$. Then these same worlds w *will* be contained in $\mathsf{info}(\text{EXH}\,\phi)$, meaning that $\mathsf{info}(\phi) \subsetneq \mathsf{info}(\text{EXH}\,\phi)$. For questions (which are non-informative sentences) this does not matter; but in principle we would want to devise an operator that can exhaustify interrogatives as well as declaratives. An easy fix to ensure that the informative content is preserved, is to allow only such states in the exhaustified sentence denotation that were already present in the original sentence denotation. For the above lexical entry, this simply means adding the requirement that $X(p)$. Observe that this does not impose too strict conditions; the original sentence denotation is downward-closed and all states needed for the exhaustified denotation are already contained in the original one.

(164) First revision of exhaustivity operator:

$$\text{EXH} := \lambda X_T.\lambda p_{\langle s,t\rangle}.\begin{pmatrix} X(p) \land \forall w, w' \in p : \\ \{q \in \text{ALT}(X) \mid q(w)\} = \{q \in \text{ALT}(X) \mid q(w')\} \end{pmatrix}$$

The second shortcoming of the definitions so far has to do with the fact that, by using the concept of true alternatives, the operator relies on the existence of maximal states in a sentence denotation. However, it has been brought to attention by Ciardelli (2010) that, making certain assumptions, there are in fact sentences whose denotations do *not* contain maximal elements. A prominent example of such problematic sentences is the *boundedness formula* $\phi = \exists x B(x)$. It is true in a model $\mathcal{M}$ precisely if there exists an upper bound for a natural number n, where n is the cardinality of the extension of a predicate N in $\mathcal{M}$. The problems arising from this sentence have to do with the fact that, *assuming standard arithmetic*, if e. g. 1 is a bound for n, then so are 2, 3, 4 and so on. Hence, each of the states that resolve ϕ by providing an instantiation of the existence statement is properly contained in infinitely many other states which also resolve ϕ. Owing to this infinite inclusion hierarchy, there are no maximal states. The picture emerging from this situation is sketched in Figure 16. We can however avoid a structure like this by letting the laws of arithmetic vary from world to world—just as other facts about the world do as well. The crucial implication that, for all natural numbers n, if $B(n)$, then also $B(m)$ for all $m > n$, would no longer

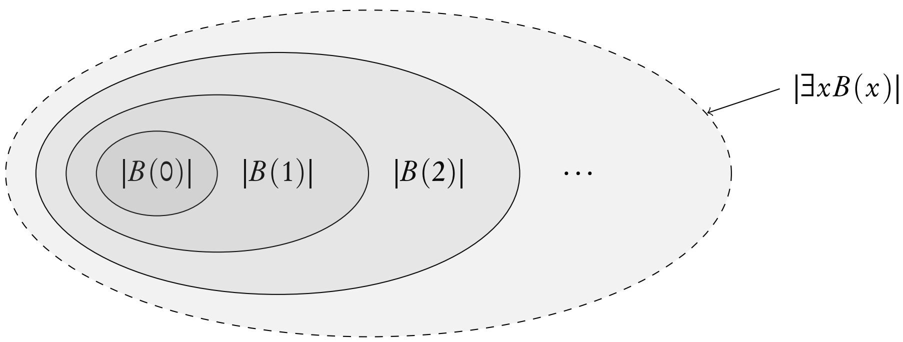


Figure 16: Visualisation of the boundedness formula

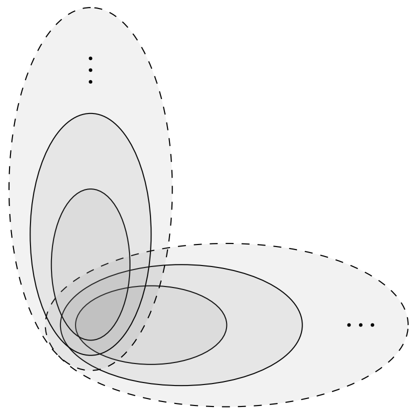
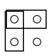
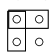


Figure 17: A state set with two distinct infinite inclusion hierarchies.

hold across worlds. Unfortunately, this might avoid the infinite hierarchy in the case of the boundedness formula; but we cannot be certain that there is no other sentence in our logical language giving rise to a similar structure. Hence, we need to find a more general definition for EXH, one that is independent of the existence of maximal states.

In particular, we would like to be able to cope with sentences whose denotation has the structure (very roughly) sketched in Figure 17: there is not only one infinite state hierarchy, but there are two separate ones. This denotation might be thought of as an infinite variant of the familiar  example. In analogy to exhaustifying  , we would like to obtain a state set with three distinct “blocks” as the result of applying EXH to this example: roughly, one “block” for each of the two hierarchies respectively and one for their intersection. The preliminary exhaustivity operator is not up to this task: it would simply pool together the worlds from both hierarchies, since they all share the common trait of not being contained in any alternative. The condition that all worlds in the same partition block need to fulfil thus has to be stronger than being contained in exactly the same alternatives—those worlds also need to agree on the “very large”, but non-maximal states they are contained in.

Hence, we generalise the concept of alternatives to the setting in which there are no maximal states. Under this generalised notion, an alternative in a sentence meaning X is no longer a maximal *state* (since, again, these are not guaranteed to exist), but rather a maximal *set* of states in X that is closed under finite union:

(165) Generalised definition of alternatives:

$$\textsc{alt}_{\text{gen}} = \lambda X_T.\lambda A_T.\left(\begin{array}{l} A \subseteq X \wedge \forall p,q \in A : (p \cup q \in A) \\ \wedge \neg\exists B \subseteq X : (A \subsetneq B \wedge \forall p,q \in B : p \cup q \in B) \end{array}\right)$$

If the denotation X has maximal states, $\textsc{alt}_{\text{gen}}$ boils down to exactly the set of these maximal states: for every $A \in \textsc{alt}_{\text{gen}}$, $\bigcup A$ is a maximal state, and vice versa, for every maximal state p, it is the case that $\wp(p) \in \textsc{alt}_{\text{gen}}$.

Under this notion of alternatives, two alternatives are mutually exclusive if their unions are disjoint:

(166) Let $A, B \in \textsc{alt}_{\text{gen}}$. A and B are mutually exclusive iff $\bigcup A \cap \bigcup B = \emptyset$.

What we expect from the exhaustivity operator is the same as before: we need EXH to strengthen a sentence meaning X in such a way that the alternatives in the resulting sentence meaning $\textsc{exh}(X)$ are mutually exclusive. If X is the denotation of a *wh*-question about a property P, for example, this means that all worlds in an alternative A from $\textsc{exh}(X)$ agree in which individuals have property P and which do not. A definition of EXH that delivers this objective is the following (where A^* is the pseudo-complement of A: $A^* = \wp(\overline{\bigcup A})$; see Section 2.1.2).

(167) Second revision of exhaustivity operator:

$$\textsc{exh} = \lambda X_T.\lambda p_{\langle s,t\rangle}.X(p) \wedge \forall A \in \textsc{alt}_{\text{gen}}(X) : p \in A \vee p \in A^*$$

Recall the perspective we had taken on strongly exhaustive *wh*-questions: they can be viewed as a conjunction of polar questions, one for each individual in the domain. What we demand of a strongly exhaustive answer is then that it resolves each one of those polar questions. This is exactly the requirement formulated in (167): to be contained in the exhaustified sentence denotation, a state p has to be informative enough to—either affirmatively ($p \in A$) or negatively ($p \in A^*$)—answer every polar “subquestion” of X. Since $A \cap A^* = \emptyset$, it will never be the case that both $p \in A$ and $p \in A^*$.

Owing to the generalised notion of alternatives, (167) also works for sentence meanings without maximal states. Returning to the denotation in Figure 17, the new exhaustivity operator will partition the state set into exactly three (generalised) alternatives: two of them consisting of states that are contained in only one of the two hierarchies from the original state set respectively and one consisting of states that are contained in both hierarchies from the original state set.

Note that the generalised notion of alternatives proposed in this appendix is not adopted in the rest of the thesis. In principle, it should be possible to do so. Since this would require a reformulation of many of the existing lexical entries, however, lifting $\mathsf{Inq}^{\lambda}_{\mathsf{B}}$ to a more general setting is left for future work.

B The intensional theory of types

B.1 Syntax

We start by defining the set of types $\mathbf{T}$. It is the smallest set such that:

(i) $e, s, t \in \mathbf{T}$

(ii) If $\sigma, \tau \in \mathbf{T}$, then $\langle \sigma, \tau \rangle \in \mathbf{T}$.

For each type σ, the vocabulary of intensional type theory contains the infinite set $\mathrm{VAR}_\sigma^{\mathscr{L}}$ of variables of type σ and the (possibly empty) set $\mathrm{CON}_\sigma^{\mathscr{L}}$ of constants of type σ.

Based on this, we can define the syntax of an intensional, type-theoretical language $\mathscr{L}$. By $\mathrm{WE}_\sigma^{\mathscr{L}}$, we refer to the set of all well-formed expressions of type σ in $\mathscr{L}$. Under this terminology, formulas are the elements of $\mathrm{WE}_t^{\mathscr{L}}$.

(i) If $\alpha \in \mathrm{VAR}_\sigma^{\mathscr{L}}$, or $\alpha \in \mathrm{CON}_\sigma^{\mathscr{L}}$, then $\alpha \in \mathrm{WE}_\sigma^{\mathscr{L}}$.

(ii) If $\alpha \in \mathrm{WE}_{\langle \sigma,\tau \rangle}^{\mathscr{L}}$ and $\beta \in \mathrm{WE}_\sigma^{\mathscr{L}}$, then $(\alpha(\beta)) \in \mathrm{WE}_\tau^{\mathscr{L}}$.

(iii) If $\varphi, \psi \in \mathrm{WE}_t^{\mathscr{L}}$, then $\neg\varphi, (\varphi \wedge \psi), (\varphi \vee \psi)$ and $(\varphi \rightarrow \psi) \in \mathrm{WE}_t^{\mathscr{L}}$.

(iv) If $\varphi \in \mathrm{WE}_t^{\mathscr{L}}$ and $v \in \mathrm{VAR}_\sigma^{\mathscr{L}}$, then $\forall v \varphi, \exists v \varphi \in \mathrm{WE}_t^{\mathscr{L}}$.

(v) If $\alpha \in \mathrm{WE}_\sigma^{\mathscr{L}}$ and $\beta \in \mathrm{WE}_\sigma^{\mathscr{L}}$, then $(\alpha = \beta) \in \mathrm{WE}_t^{\mathscr{L}}$.

(vi) If $\alpha \in \mathrm{WE}_\sigma^{\mathscr{L}}$ and $v \in \mathrm{VAR}_\tau^{\mathscr{L}}$, then $\lambda v \alpha \in \mathrm{WE}_{\langle \tau,\sigma \rangle}^{\mathscr{L}}$.

(vii) For any σ, all elements of $\mathrm{WE}_\sigma^{\mathscr{L}}$ are constructed in a finite number of steps using (i)–(vi).

B.2 Semantics

Here, we start by specifying domains of interpretation for the different types. A domain $\boldsymbol{D}_{\sigma,D,W}$ for type σ is defined based on a set of possible worlds W and a domain of individuals D.

(i) $\boldsymbol{D}_{e,D,W} = D$

(ii) $\boldsymbol{D}_{s,D,W} = W$

(iii) $\boldsymbol{D}_{t,D,W} = \{1, 0\}$

(iv) $\boldsymbol{D}_{\langle\sigma,\tau\rangle,D,W} = \{f \mid f : \boldsymbol{D}_{\sigma,D,W} \rightarrow \boldsymbol{D}_{\tau,D,W}\} =: \boldsymbol{D}_{\sigma,D,W}^{\boldsymbol{D}_{\tau,D,W}}$

A model $\mathscr{M} = (D, W, I)$ for an intensional type-theoretical language $\mathscr{L}$ consists of a non-empty domain D, a non-empty set of possible worlds W and an interpretation function I (a function mapping expressions from $\mathrm{CON}_\sigma^{\mathscr{L}}$ to objects in $\boldsymbol{D}_\sigma$). The extension $[\![\alpha]\!]_{\mathscr{M},w,g}$ of an expression α is defined relative to such a model, a possible world $w \in W$ and an assignment function g (a function mapping variables from $\mathrm{VAR}_\sigma^{\mathscr{L}}$ to objects in D_σ). In the below setup, all worlds share a common domain.

(i) If $\alpha \in \mathrm{CON}_\sigma^{\mathscr{L}}$, then $[\![\alpha]\!]_{\mathscr{M},w,g} = I(\alpha)$.
If $\alpha \in \mathrm{VAR}_\sigma^{\mathscr{L}}$, then $[\![\alpha]\!]_{\mathscr{M},w,g} = g(\alpha)$.

(ii) If $\alpha \in \mathrm{WE}_{\langle\sigma,\beta\rangle}^{\mathscr{L}}$ and $\beta \in \mathrm{WE}_\sigma^{\mathscr{L}}$, then $[\![\alpha(\beta)]\!]_{\mathscr{M},w,g} = [\![\alpha]\!]_{\mathscr{M},w,g}([\![\beta]\!]_{\mathscr{M},w,g})$.

(iii) If $\varphi, \psi \in \mathrm{WE}_t^{\mathscr{L}}$, then:
$[\![\neg\varphi]\!]_{\mathscr{M},w,g} = 1$ iff $[\![\varphi]\!]_{\mathscr{M},w,g} = 0$.
$[\![\varphi \wedge \psi]\!]_{\mathscr{M},w,g} = 1$ iff $[\![\varphi]\!]_{\mathscr{M},w,g} = [\![\psi]\!]_{\mathscr{M},w,g} = 1$.
$[\![\varphi \vee \psi]\!]_{\mathscr{M},w,g} = 1$ iff $[\![\varphi]\!]_{\mathscr{M},w,g} = 1$ or $[\![\psi]\!]_{\mathscr{M},w,g} = 1$.
$[\![\varphi \rightarrow \psi]\!]_{\mathscr{M},w,g} = 0$ iff $[\![\varphi]\!]_{\mathscr{M},w,g} = 1$ and $[\![\psi]\!]_{\mathscr{M},w,g} = 0$.

(iv) If $\varphi \in \mathrm{WE}_t^{\mathscr{L}}$ and $v \in \mathrm{VAR}_\sigma^{\mathscr{L}}$ where $\sigma \neq s$, then:
$[\![\forall v\varphi]\!]_{\mathscr{M},w,g} = 1$ iff for all $\mathbf{d} \in \mathbf{D}_\sigma$: $[\![\varphi]\!]_{\mathscr{M},w,g[v/\mathbf{d}]} = 1$.
$[\![\exists v\varphi]\!]_{\mathscr{M},w,g} = 1$ iff for some $\mathbf{d} \in \mathbf{D}_\sigma$: $[\![\varphi]\!]_{\mathscr{M},w,g[v/\mathbf{d}]} = 1$.

(v) If $\varphi \in \mathrm{WE}_t^{\mathscr{L}}$ and $v \in \mathrm{VAR}_s^{\mathscr{L}}$, then:
$[\![\forall v\varphi]\!]_{\mathscr{M},w,g} = 1$ iff for all $w' \in W$: $[\![\varphi]\!]_{\mathscr{M},w',g} = 1$.
$[\![\exists v\varphi]\!]_{\mathscr{M},w,g} = 1$ iff for some $w' \in W$: $[\![\varphi]\!]_{\mathscr{M},w',g} = 1$.

(vi) If $\alpha \in \mathrm{WE}_\sigma^{\mathscr{L}}$ and $v \in \mathrm{VAR}_\tau^{\mathscr{L}}$, then $[\![\lambda v\alpha]\!]_{\mathscr{M},w,g}$ is that function $h \in \boldsymbol{D}_\sigma^{\boldsymbol{D}_\tau}$ such that for all $\mathbf{d} \in \boldsymbol{D}_\tau : h(\mathbf{d}) = [\![\alpha]\!]_{\mathscr{M},w,g[v/\mathbf{d}]}$.

(vii) If $\alpha \in \mathrm{WE}_\sigma^{\mathscr{L}}$ and $v \in \mathrm{VAR}_s^{\mathscr{L}}$, then $[\![\lambda v\alpha]\!]_{\mathscr{M},w,g}$ is that function $h \in \boldsymbol{D}_\sigma^W$ such that for all $w' \in W : h(w') = [\![\alpha]\!]_{\mathscr{M},w',g}$.

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