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Concealed Questions

(Pre-final version)

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Abstract

Concealed questions (CQs) are determiner phrases that are interpreted as if they were embedded questions. For instance, *Eve's phone number* in *Adam knows Eve's phone number* is interpreted as having the meaning of the question *what Eve's phone number is*. CQs raise two preliminary challenges. First, it is not clear how such cases should be integrated into a uniform analysis of predicates that select for questions, canonically realized by CPs, not DPs. Second, it has to be explained how a definite description, which would normally be used to pick out an entity in the world acquires this question-like meaning. More generally, since it is not obvious how the truth-conditions of CQ-sentences should be computed, this construction raises a challenge for the *principle of compositionality*, according to which the literal meaning of a sentence is a function of the meanings of its parts and of the way they are syntactically combined.

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1. Introduction

When the nominal argument of (certain) question-selecting verbs gives rise to a question-like interpretation, it goes with the name of *concealed question* (henceforth, CQ); some examples and their paraphrases are given below.[1]

(1) a. Mary knows *Joan's phone number*.
b. The X-ray revealed *the gender of the baby*.
c. *Your airline ticket price* depends on when and where you travel.
d. Sam asked me *the outcome of the election*.

(2) a. Mary knows *what Joan's phone number is*.
b. The X-ray revealed *what the gender of the baby was*.
c. *What your airline ticket price is* depends on when and where you travel.
d. Sam asked me *what the outcome of the election was*.

In (2), an embedded question is used to paraphrase the CQs in (1). Does this imply that CQs are, at some level of representation, questions? How do definite descriptions (for

e.g., *Joan's phone number*), which would normally be used to pick out entities in the world (Joan's actual phone number, as in *Bill wrote down Joan's phone number*), combine with question-selecting verbs and end up with the meanings in (2)? What is immediately intriguing about the sentences in (1) is that their meanings do not follow from the meaning of their syntactic components and standard compositionality principles (c.f. Heim and Kratzer 1998; von Fintel and Heim 2011): a question-selecting verb and a definite description can't semantically compose, let alone give rise to the paraphrases in (2). Thus, CQ-constructions reveal that there is either more to the syntax than what it appears (some concealed clausal structure, a position defended by Baker 1968), or that there is more to compositionality than just basic combinatorial rules such as functional application (not a novelty in the semantics literature, -> article 103: Type Shifting). Although the literature on CQs is in disagreement on many aspects of the machinery supposed to deliver the truth-conditions for a variety of CQ-constructions, they all – with the exception of Baker (1968) – converge on the fact that the resolution to the compositionality mismatch must rely on semantic rather than syntactic means. The chapter is structured in the following way. Section 2 discusses some undisputed facts regarding CQs. Section 3 introduces the two main analyses of CQs: the Individual Concept approach and the Question approach, spelling out some compositional details. Section 4 introduces some challenging data for both analyses, currently at the center of debate. Section 5 concludes.

2. Some undisputed facts about CQs

2.1 CQs are intensional objects

The CQs in examples (1a-d) are all definite descriptions (henceforth, *definite CQs*). Definite descriptions are normally used to refer to entities/individuals in the world, as in the examples (3a) and (4a) below. Such *referential* (or extensional) uses allow for substitution of extensionally equivalent expressions. Suppose, for instance, that the exact amount of Sam's debt is $2.000; then, (3a) is equivalent to (3c). Analogously, if the kind of wine she likes the most is Pinot Grigio, (4a) is equivalent to (4c). Another way to put it is that the premises in the (a-b) statements below entail the conclusion in (c) ("⊨" stands for logical entailment).

(3) a. Sam paid *the exact amount of his debt.* *referential*
b. The exact amount of John's debt is $2.000
c. ⊨ Sam paid $2.000

(4) a. John ordered *the kind of wine she likes the most.* *referential*
b. The kind of wine she likes the most is Pinot Grigio.
c. ⊨ John ordered Pinot Grigio.

On the other hand, the very same definite descriptions, when used as CQs, do not allow for substitution of equivalents. Consider (5-6) below: from the truth of the premises (a)-(b), the conclusion in (c) does not follow if we interpret the DP in italics as CQs.

Intuitively, figuring out what the exact amount of Sam's debt is does not entail figuring out what quantity of money Joan won at the lottery last week, despite the fact that the two DPs are co-referential at the actual world/time index. Similarly, remembering what kind of wine she likes the most does not entail remembering what kind of wine someone else likes the most, even if they happen to be the same wine. The lack of entailment in examples like those below has been taken as evidence that CQs are intensional objects.

(5) a. Sam figured out *the exact amount of his debt*. *CQ*
b. The exact amount of Sam's debt is the quantity of money Joan won at the lottery last week.
c. ⊭ Sam figured out the quantity of money Joan won at the lottery last week.

(6) a. John can't remember *the kind of wine she likes the most.* *CQ*
b. The kind of wine she likes most is the kind of wine John likes the most.
c. ⊭ John_i can't remember the kind of wine he_i likes the most.

2.2 Epistemic verbs: CQs vs. *acquaintance* readings

A notable class of CQ-embedding verbs includes *epistemic* verbs, i.e. verbs of mental attitude (*know*, *reveal*, *forget*, *discover*, etc. -> article 8: Attitude Verbs). Both sentences in (7) make a claim about Elsie's beliefs, hence the verb is said to be epistemic.

(7) a. Elsie knows that the capital of Italy is Rome.
b. Elsie knows what the capital of Italy is.

The vast majority of these verbs in English, when allowed to take a nominal, rather than a clausal complement, can have an epistemic (report of mental attitude) as well as a non-epistemic (or referential) interpretation. In such cases, the epistemic reading is our CQ-reading, while the non-epistemic/referential reading often goes by the name of *acquaintance* reading. For instance, (8a) may be used as an attitude report to convey that Elsie has forgotten what the capital of Italy is (CQ-reading), or to convey that she has lost her acquaintance to Rome (e.g. her personal memories) while, possibly, remembering that Rome is the capital of Italy (acquaintance reading). Similarly, (8b) can mean that Erin knows who the current governor of Alaska is, without necessarily being acquainted to the person (CQ-reading), or that she is acquainted with the individual who is the current governor of Alaska (e.g. they are neighbors), without necessarily knowing that this person is the governor of Alaska (acquaintance reading).

(8) a. Elsie has forgotten *the capital of Italy.*
b. Erin knows *the governor of Alaska*.

Since Heim (1979), it is commonly assumed that the ambiguity just described is due – in part – to a lexical ambiguity of the embedding verb.[2] Some CQ-embedding verbs, including *know*, would be systematically ambiguous between an *extensional* (referential) entry, responsible for the acquaintance reading, and an *intensional* (epistemic) entry

responsible for the CQ-reading, which would be analogous to the entry in standard attitude reports with clausal complements. The lexical ambiguity hypothesis is supported by the existence of languages, like German and Italian, which lexically distinguish between acquaintance and CQ-embedding interpretations by having two different verbs corresponding to English *know: wissen* and *kennen* in German; *sapere* and *conoscere* in Italian. When *wissen/sapere* are allowed to occur with a nominal object, the sentence cannot receive an acquaintance reading. This is shown in (9) and (10) below:[3]

(9) *Hans* ***weiß*** *Willis Telefonnumer* (German; *acquaintance)
Hans knows Willis telephone number
'Hans knows (what) the telephone number of Willis (is)'

(10) *Gianni* ***sa*** *la capitale del Congo.* (Italian; *acquaintance)
Gianni knows the capital of-the Congo
'Gianni knows (what) the capital of Congo (is)'

2.3 Some nouns make better CQs than others

Another undisputed fact is that not every referential nominal makes a good CQ; numerals and proper names, for instance, cannot be CQs. Consider (11) and (12) below. Despite the fact that *the exact amount of Sam's debt* refers to a specific amount of money and that *the name of the wine* refers to a proper name, the a-sentences are felicitous, while the b-sentences, replacing the definite descriptions with a numeral and a name, are not.

(11) a. Sam figured out *the exact amount of her debt*.
b. #Sam figured out *$2.000*.

(12) a. The waiter wouldn't tell us *the name of the wine*.
b. #The waiter wouldn't tell us *Pinot Grigio*.

Proper names and numerals are *rigid designators* – nominals whose extension cannot vary across possible indices. Thus, one might think that their *rigidity* is the reason why they are banned from CQ-constructions, which we have established require intensional objects. An explanation along these lines, however, would not explain why (13) is felicitous, despite the fact that it is not metaphysically possible for the square root of 25 to vary across indices.[4] So, the fact that numerals and proper names are rigid does not, by itself, explain why they are not good CQs.

(13) John figured out the square root of 25.

It has long been observed that the typical examples of CQs involve functional nouns, such as *capital*, *price*, *age* etc. (Löbner 1981, Caponigro and Heller 2007, Percus 2014). Unlike common nouns (also known as *sortal*), which denote sets of entities – for e.g., the extension of the noun *table* is the set of all things that are tables – functional nouns, denote sets of pairs of individuals. For instance, the extension of the functional noun *capital* is the set of pairs $\langle x, y \rangle$ such that x is the capital of y. Some have claimed that it is

not just functional nouns, but the larger class of relational nouns that characterizes CQs (Nathan 2006, Barker 2016). In relational nouns, the NP-predicate characterizes a relation rather than a function. Thus, the extension of the relational noun *neighbor* is the set of pairs <*x, y*> such that *x* is a neighbor of *y*. In any case, the main empirical observation is that common nouns make terrible CQs, as shown by the markedness of (14a-b) below.

(14) a. #Sue knows the shoes.
b. #The sommelier wouldn't tell us the wine.

To account for the infelicity of sentences like (14a-b), Nathan (2006) provides a semantic analysis that derives CQs from relational nouns only (see also Barker 2016). However, although it is true that the most natural examples of CQs involve functional (or relational) nouns, grammatically constraining CQs to just this class of nouns does not seem to make correct empirical predictions. In fact, being a functional (or relational) noun is not a necessary and sufficient condition for being a CQ. First, there are several functional nouns that don't work well as CQs. *Nose* for instance could be taken to denote the set of pairs <*x, y*> such that *x* is the nose of *y*; nevertheless the sentence in (15a) below sounds bizarre (setting aside an irrelevant acquaintance readings); same for (15b) with the functional noun *pit*.

(15) a. #Elsie knows *Rajesh's nose*.
b. #Andrea told me *the pit of the fruit*.

Second, Caponigro and Heller (2007) note that as soon as common nouns are modified in some way, by adding a relative clause, a superlative etc., the CQ-reading becomes accessible. Compare, for instance, (16a-b) with (14a-b).

(16) a. Sue knows the shoes that you want to buy.
b. The sommelier wouldn't tell us the best wine on the menu.

The question is: why do these types of nominal modifications affect the availability of CQs? One might be tempted by the following conjecture. Maybe the reason why (16a) is better than (14a) is that the relative clause in (16a) provides an informative property that was missing in (14a). Intuitively, (14a) might be unacceptable because, in normal circumstances, the statement I know of this entity that it is shoes sounds odd and uninformative; it is hard to imagine a situation in which someone might be acquainted with shoes without knowing that they are shoes. By adding a relative clause in (16a), on the other hand, we are contributing an informative property (being the shoes that the addressee intends to buy), thus turning an uninformative statement into an informative one. However, an explanation along these lines wouldn't explain the contrast between (17a) and (17b) below. In this case, knowing what a carburetor is, being able to identify it among other parts of your car, is a much less trivial fact than knowing of a pair of shoes that they are shoes. However, (17a) is as odd as the examples in (14).[5] Therefore, a purely pragmatic explanation of why modification helps with the acceptability of CQ-constructions might not be on the right track.[6]

(17) a. #Fabio knows the carburetor.
b. Fabio knows the best carburetor on the market.

Finally, notice that getting a CQ-reading from common nouns might be hard, but crucially not impossible. Frana (2006) provides the following scenario:[7]

(18) *Context: The guessing game*
Imagine you are involved in the following game: you have been presented with a series of objects: a pair of shoes, a carburetor and a pair of scissors. Your challenge is to look at the objects for 3 minutes and memorize the way they look. After that, you will be shown only little parts of them and you will have to tell what they are. Imagine you were only successful with the shoes. Then, you can report that by saying: "I didn't win. I only knew the shoes".

2.4 CQs are not syntactically questions

The first reference to CQs in the linguistics literature is Baker (1968), who advances the hypothesis that CQs are syntactically base-generated as questions. Under this proposal, the question meaning of the object DP in (19) would follow by saying that the interpretation process applies to structures like (20) before the extra material gets deleted at surface structure.

(19) Kim knows the capital of Italy.
(20) Kim knows [$_{CP}$ ~~what~~ the capital of Italy ~~is~~]

Baker's main piece of evidence in favor of the claim that CQs should be analyzed as elliptic versions of embedded questions comes from the observation that these question-like readings are only found with predicates that select for *wh*-questions. This generalization captures the contrast between epistemic verbs like *know*, *forget* and *reveal* in (21), which syntactically embed *wh*-questions and allow for CQ readings of their DP complements, and epistemic predicates like *believe*, *think* and *deny*, which do neither, as shown in (22).

(21) a. Meg forgot what the capital of Italy is.
a'. Meg forgot the capital of Italy.
b. Kim knows who the governor of California was.
b'. Kim knows the governor of California.
c. John revealed who the winner of the contest was.
c'. John revealed the winner of contest.

(22) a. *Meg believed what the capital of Italy is.
a'. *Meg believed the capital of Italy.
b. *Kim thought who the governor of California was.
b'. *Kim thought the governor of California.
c. *John denied who the winner of the contest was.

c'. *John denied the winner of contest.

However, Baker's question in disguise approach has been abandoned in favor of a semantic version of the question approach, according to which CQs are syntactically DPs that are only semantically equivalent to indirect *wh*-questions. As Baker himself notes, formulating the transformational rule that would derive a CQ from the underlying structure of an indirect *wh*-question without overgeneralizing is not trivial. Baker tentatively proposes the rule in (23), whose application is illustrated in (24).

(23) [NP_1 be wh-PRO] → NP_1

(24) James figured out [[the plane's arrival time]$_1$ be wh-some PRO]

However, this proposal incorrectly predicts the occurrence of proper nouns and pronouns in concealed forms. For instance, from (25a), (23) allows us to incorrectly generate (25b). Similarly, from (26a), we would get (26b) (Baker 1968:90).

(25) a. John wouldn't tell us who Lyndon Johnson is.
b. *John wouldn't tell us Lyndon Johnson.

(26) a. John forgot who she was, but he never forgot her face and manner.
b. #John forgot her, but he never forgot her face and manner.

Secondly, if CQs were base-generated as questions, then it would be reasonable to expect that every question-embedding predicate would be able to select for CQ-complements. Grimshaw (1979), however, shows that CQs are not allowed with just any predicate that takes *wh*-questions. Verbs like *wonder, inquire* and *care* can embed questions but not CQs, as shown in (27) from Grimshaw (1979: 302):

(27) a. I wonder what answer he gave.
a'. *I wonder the answer he gave.
b. John inquired what the number of students in the class was.
b'. *John inquired the number of students in the class.
c. I don't care what height the plants grow to.
c'. *I don't care the height the plants grow to.

To account for the contrasts between (27a'-c') and (21a'-c'), Grimshaw proposes to distinguish between syntactic subcategorization and semantic selection features of the embedding verb. She argues, contra Baker, that CQs are syntactically DPs that are only semantically interpreted as questions (via a translation rule – Grimshaw's *CQ Rule*). She notes that syntactically, CQs behave more like NPs than CPs. They have the internal structure of NPs in that they combine with a determiner and can be modified by an adjective, a PP complement and a relative clause. They also have the distribution of NPs: they occur in object positions, as in most of our examples, but also in subject positions, as in (1c), or (28) below.

(28) *The height of the building* wasn't clear. (Grimshaw, 1979)

Her proposal is that only verbs that syntactically subcategorize for DPs and semantically select questions can embed CQs. Thus, as summarized in (29) below, only verbs of the *know*-class can embed CQs.[8] Verbs in the *believe*-class fail to embed CQs since they semantically do not select for question-type meanings, while verbs in the *wonder*-class fail to embed CQs because they don't subcategorize for DP arguments.[9]

(29)

	Syntactic subcategorization	*Semantic selection*
Know	[**DP**,CP]	[**Question**, Proposition]
Believe	[**DP**,CP]	[Proposition]
Wonder	[CP]	[**Question**]

2.5 CQs have a limited range of meanings

The following examples from Baker (1968) give the illusion that CQs can take up the meaning of a variety of *wh*-questions:

(30) a. Susan found out the place where the meeting was to be held.
b. Fred tried to guess the amount of the stolen money.

(31) a. Susan found out **where** the meeting was to be held.
b. Fred tried to guess **how much** money had been stolen.

However, such flexibility is an illusion. As Nathan (2006) shows, CQs can only have the identity-question meanings ***who*** *X is/was* or ***what*** *X is/was* (and all the examples in (30) can be paraphrased in this way). Other questions, such as *where/when/how much X is*, are not possible meanings for a CQ, even when they are made salient by the context. Consider, for instance, the following examples, from Nathan (2006: 6):

(32) a. Leslie needed directions, so I told her where the capital of Vermont is.
b. #Leslie needed directions, so I told her the capital of Vermont.
c. Leslie was studying for a geography quiz, so I told her the capital of Vermont.

(33) a. Alex wants to be on time, so I told him when the class he should attend is.
b. #Alex wants to be on time, so I told him the class he should attend.
c. Alex wants to learn semantics, so I told him the class he should attend.

It's important to note that the identity-question only generalization discovered by Nathan (2006) constitutes another argument against Baker's question-in-disguise approach. Under this view, it is not clear what would prevent (32b), for instance, from having the underlying representation in (34):

(34) Leslie needed directions, so I told her [where the capital of Vermont is]

One way to explain Nathan's facts under Grimshaw's version of the Question approach would be to say that the CQ-Rule translates DP-CQs into identity questions only. It turns

out, however, that CQs and identity questions are not truth-conditionally equivalent. This has been shown by a brief remark in the literature attributed to Bill Greenberg. Heim (1979) reports a discussion from Greenberg (1977) about the contrast between the CQ-sentence in (35a) and its *wh*-question paraphrase in (35b):[10]

(35) a. John found out the murderer of Smith.
b. John found out who the murderer of Smith was.

Following Greenberg, Heim observes that (35b) has an ambiguity that is absent from its CQ counterpart:

> "[(35b)] cannot only be used to express that John solved the question who murdered Smith, but has a further reading which is perfectly compatible with John's being entirely ignorant about Smith's murder, and which only amounts to the claim that John found out some essential fact or other (e.g. that he was his brother) about the person referred to as "the murderer of Smith". But this is not an available reading for [(35a)], which can only be used in the first-mentioned way."
>
> (Heim, 1979: 53)

The contrast in meaning between (35a) and (35b) shows that not even identity-question paraphrases characterize the meaning of a CQ-sentence correctly.[11] This seems to be a problem for an analysis that assumes CQs to be semantically equivalent to (embedded) identity questions.

However, as pointed out by Nathan (2006), Greenberg's observation does not force us to abandon the narrower claim that CQs denote certain types of identity questions. Frana (2010b, 2017) proposes that the ambiguity found in embedded identity questions of the type *who/what DP is* derives from the fact that the copular clause [$_{IP}$ *DP is* t_i] contained in them can have either a *specificational* or a *predicational* interpretation (in the sense of Higgins, 1973; -> ARTICLE 55: Copular Sentences), whereas CQs are unambiguously specificational.[12]

(36) *Specificational and Predicational readings of embedded identity questions*
A discovered who *the NP* is.
SPEC: *A* discovered which individual is *the NP*. It is *x*.
PRED: *A* discovered something about the person *the NP* refers to. He is $P_{salient}$.

Summing up, the original claim that definite CQs are truth-conditionally equivalent to (embedded) identity questions needs to be further refined by saying that definite CQs are truth-conditionally equivalent to specificational identity questions. Following Frana (2010b, 2017), the lack of ambiguity in CQs can be traced back to the absence of the copula, which in the full-fledged question generates the specificational vs. predicational ambiguity, characteristic of copular sentences.[13] What remains to be addressed is how exactly definite CQs end up with the same meaning of specificational questions; I will turn to this in the following section.

3. Main analyses of CQs

Over the past forty years, several approaches have tackled the compositionality challenge represented by CQs in different ways. The main divide is whether the repair strategy to the compositionality mismatch is introduced as an autonomous type-shifter that targets the CQ itself (*clausal* approaches) or whether the crucial type-shift operation is incorporated in a dedicated lexical entry of the embedding verb (*individual concept* approaches). According to the clausal approaches, inspired by Grimshaw (1979), the denotation of a CQ must be shifted into the denotation of the corresponding identity question (through an especially devised type-shifter). Under this line of approach a sentence like *John knows the capital of Italy* is analyzed along the lines of (37a).[14] Heim (1979) entertains the hypothesis, later developed by Romero (2005, 2010) and Frana (2010a, 2013, 2017), that CQs denote individual concepts (functions from indices to individuals) and that a CQ-sentence should be analyzed along the lines of (37b).

(37) *Main CQ-analyses*

a. **CQs as clausal complements (questions/propositions)**: John knows what the capital of Italy is. (Nathan 2006; Harris 2007; Romero 2007; Aloni 2008; Roelofsen and Aloni 2008; Aloni and Roelofsen 2011; Percus 2014)

b. **CQs as individual concepts**: The value that the individual concept *the capital of Italy* yields at the actual world and at John's belief worlds is the same. (Heim 1979; Romero 2005, 2010; Frana 2010a, 2013, 2017)

As suggested by the informal paraphrases above, both approaches – although conceptually and technically different – produce equivalent truth-conditions for simple CQ-sentences, such as our examples in (1a-d). Thus, it appears that examination of simple CQ-sentences does not discriminate one theory from another, nor does it tell us much about what ingredients are necessary for the proper treatment of CQs. For this reason, in most of the work cited above, the focus has shifted from simple definite CQs to many other kinds of CQ-constructions. Among these, are CQs consisting of indefinite and quantified DPs, and *nested* CQs (CQs modified by a relative clause containing a CQ-gap, as in Heim's (1979) famous example *John knows$_1$ the price that Fred knows$_1$*). I will return to these data in §4. In the remaining of this section I will spell out the compositional details of the individual concept approach and the clausal approach.

3.1 The Individual Concept Approach

The origin of the individual concept approach (henceforth, IC-approach) can be found in Heim (1979)'s pioneering paper on CQs, where she suggests that definite descriptions with CQ-readings, like the underlined DP in (38), may be analyzed on a par with definite descriptions in temporally intensional contexts, like the underlined DP in (39).

(38) Julio knows <u>the temperature in this room</u>.

(39) <u>The temperature in this room</u> is rising.

While in (39), the temporally intensional predicate *is rising* forces us to look at temperature values at earlier and later (temporal) indices, the epistemic verb *know* in (38) forces us to compare temperature values at different (world) indices (the actual world *w* and the worlds according to Julio's beliefs in the actual world at the present time). Given the Montagovian treatment of sentences like (39) in terms of individual concepts (Montague 1974), Heim suggests that an analogous analysis could be given for (38). Let's expand on these premises. The original argument for the introduction of individual concepts is due to Montague's (1974) analysis of the *temperature paradox*, attributed to Barbara Partee (-> ARTICLE 77: The Partee Paradox). Partee's observation is that in contrast to the valid argument in (40), the syllogism in (41) is intuitively invalid: by substitution, the first two sentences appear to lead to the invalid conclusion in (41c).

(40) a. The mayor of Amherst is Ms. Higgins.
b. The mayor of Amherst lives on Main St.
c. Ms. Higgins lives on Main St.

(41) a. The temperature in this room is ninety.
b. The temperature in this room is rising.
c. Ninety is rising.

Montague's account of the contrast between the valid argument in (40) and the (invalid) temperature paradox in (41) has three major components.[15] First, he argues that definite descriptions like *the mayor of Amherst* and *the temperature in this room* do not denote individual entities, but rather individual concepts, i.e. functions from indices (world/time pairs) to entities. These functions, as opposed to the constant functions denoted by proper names like *Ms. Higgins* and *ninety*, can yield different values at different indices. Second, Montague assumes that equative *be*, as in *the temperature is 90* or *the mayor is Ms. Higgins*, expresses extensional identity. Thus, as can be seen in (42a) and (43a) below, the first premise of both arguments does not assert that two ICs are identical, but rather that their extensions are the same at the index of evaluation. Finally, according to Montague, the significant difference between the valid argument in (40) and the temperature paradox lies in the kind of predication involved in the second premise. While in (42b) the extensional predicate **lives on Main Street** applies to the value of the function denoted by *the mayor of Amherst* (**f**) at the index of evaluation, in (43b) the (temporally) intensional predicate **rise** applies to the function denoted by *the temperature in this room* (**f'**), not to its value (intuitively, in order to establish whether the temperature is rising, one needs to look not just at the actual temperature value, but also at the values that the function yields at earlier and later indices):

(42) a. The mayor of Amherst is Ms Higgins.
$f(i_0) = g(i_0)$ *extensional identity*
b. The mayor of Amherst lives on Main Street.
lives-on-MS_{i_0} ($f(i_0)$) *extensional predication*
c. Ms. Higgins lives on Main Street.
lives-on-MS_{i_0} ($g(i_0)$)

(43) a. The temperature in this room is ninety.
f'(i_0) = g'(i_0) *extensional identity*
b. The temperature in this room is rising.
rise$_{i_0}$ (f') *intensional predication*
c. Ninety is rising
rise$_{i_0}$ (g')

It is easy to see that from the truth of (42a-b), the truth of (42c) must follow. The same does not hold for (43). Given that the temperature function that yields 90 at $\mathbf{i_0}$ can be different from the constant function that yields 90 at all indices, (43a-b) can be true even if (43c) is false. Therefore, the paradox is resolved.

In analogy to the temperature paradox, Heim (1979) proposes the following invalid argument involving CQ-readings of the DPs in italics (analogous to the entailments in (5-6)).

(44) a. The capital of Italy is the largest town in Italy.
b. John knows *the capital of Italy*.
c. John knows *the largest town in Italy*. (Heim 1979:54)

The entailment in (44) does not go through if we assume that the DPs in italics are interpreted as CQs. Intuitively, knowing what the capital of Italy is does not entail knowing what the largest town in Italy is, despite the fact that the two DPs are co-referential at the actual world/time index. As Heim points out, the lack of entailment is expected if the CQs in (44) denote individual concepts and *know* can select for individual concepts. On a par with Montague's analysis of the temperature paradox, (44) can be analyzed as in (45). Setting aside the semantic interpretation of *know* for the moment, the failure of entailment can be explained by assuming that equating the value of two concepts at the actual index as in (45a) is not enough to guarantee identity across indices. Therefore, the conclusion in (45c) does not follow from the premises of the argument.

(45) a. The capital of Italy is the largest town in Italy.
f(i_0) = g(i_0) *extensional identity*
b. John knows *the capital of Italy*.
know$_{i_0}$ (f)(john) *intensional predication*
c. John knows *the largest town in Italy*.
know$_{i_0}$ (g)(john)

Building on Heim (1979), Romero (2005) develops a detailed analysis of definite CQs embedded under epistemic *know*. In her view, a parsimonious analysis of CQs follows by assuming that predicates like epistemic *know* are defined cross-categorially to combine both with questions (46) and individual concepts (47) (here $Dox_x(w)$ stands for the set of worlds compatible with what the attitude holder *x* believes in world *w*, i.e. the set of *x*'s doxastic alternatives to *w,* c.f. Hintikka (1969), -> ARTICLE 8: Attitude Verbs).[16]

(46) $[\![know_Q]\!]^w = \lambda Q_{<s,<<s,t>,t>>} \lambda x_e.\ \forall w' \in \mathrm{Dox}_x(w)\ [Q(w') = Q(w)]$

(47) $[\![know_{CQ}]\!]^w = \lambda f_{<s,e>} \lambda x_e.\ \forall w' \in \text{Dox}_x(w)\ [f(w') = f(w)]$

In the case of simple definite CQs, $know_{CQ}$ combines with the intension of the DP, i.e. an individual concept. As shown in (48) below, the intension of *the capital of Italy* is the function mapping possible indices to the capital of Italy at that index (indices normally consist of world/time pairs, but I am ignoring the time parameter here). The truth-conditions for *John knows the capital of Italy* are derived as shown in (49) below.

(48) a. $\lambda w'.\ [\![\textit{the capital of Italy}]\!]^{w'} = \lambda w'.\ \iota x_e$: x is the capital of Italy at w'

b. *the capital of Italy*$_{<s,e>}$

$$\begin{pmatrix} w_0 \rightarrow \text{Rome} \\ w_1 \rightarrow \text{Salerno} \\ w_2 \rightarrow \text{Venice} \\ \ldots \end{pmatrix}$$

(49) $[\![\textit{John knows}_{CQ}\ \textit{the capital of Italy}]\!]^w =$
$\forall w' \in \text{Dox}_{\text{John}}(w)\ [\iota x_e\ [x \text{ is Italy's capital in } w'] = \iota x_e\ [x \text{ is Italy's capital in } w]]$

According to the formula above, the sentence *John knows the capital of Italy* is true in the world of evaluation w iff all of John's belief worlds w' are such that the unique individual that is the capital of Italy in those belief worlds is the unique individual that is the capital of Italy in the actual world (i.e. in each world compatible with John's beliefs in the actual world, the capital of Italy is Rome). These truth-conditions correctly capture the interpretation of the sentence under its CQ-reading without assuming that the definite description denotes a question. The parallel with (specificational) questions (i.e. the crucial type-shift operation) is built into the lexical entry of the embedding predicate.

3.2 The Clausal Approach

Several versions of the clausal approach have been advanced in the literature (Nathan 2006, Harris 2007, Romero 2007, Aloni 2008; Roelofsen and Aloni 2008; Aloni and Roelofsen 2011; Percus 2014), which differ most notably along the following dimensions:[17]

(50) (i) The resulting question denotation denotes a set of worlds vs. a set of propositions.
(ii) The type shifter applies at the DP-level vs. at the noun-level.

Here, I will describe the approach that Nathan (2006: 32-34) tentatively suggests (see also Percus 2014 for a recent implementation of Nathan's original proposal).[18] The proposal is to assume a type-shifter (I will call it the *Q*-shifter) that applies to the intension of the definite DP, i.e. an individual concept, and returns the meaning of a specificational question (in the form of a set of propositions). Like before, we can think of the meaning of a definite description, such as *the capital of Italy*, as contributing a

concept *f* (a function that for every index in the domain of *f* yields the value of *f* at that index). The question meaning in (52), derived by applying the Q-shifter to the intension of the definite description, is the (specificational) question of what value does the concept yield at a given index, for instance *what is$_{SPEC}$ the capital of Italy*?

(51) **Q-shifter** (after Nathan 2006 (6))
$[\![\mathbf{Q}]\!]^w = \lambda f_{<s,e>} \lambda p_{<s,t>} . [\exists x_e . p = \lambda w'. [\underline{f(w') = x}]]$

(52) a. $\lambda p_{<s,t>} . [\exists x_e . p = (\lambda w'. [\![\textit{the capital of Italy}]\!]^{w'} = x)]$
b. {the capital of Italy is Rome, the capital of Italy is Venice, the capital of Italy is Salerno, …}

This denotation can then be fed to a question-selecting lexical entry of the embedding verb, such as (53), and the correct truth-conditions follow, as shown in (54).[19]

(53) $[\![\textit{know}_Q]\!]^w = \lambda Q_{<<s,t>,t>} \lambda x_e. \forall p: (Q(p) \,\&\, p(w)) \Rightarrow \forall w' \in \text{Dox}_x(w): p(w')$

(54) $[\![\textit{John knows}_Q \textit{ Q (the capital of Italy)}]\!]^w =$
$\forall p: ([\exists x_e . p = (\lambda w'. [\![\textit{the capital of Italy}]\!]^{w'} = x)] \,\&\, p(w)) \Rightarrow$
$\forall w' \in \text{Dox}_{\text{John}}(w): p(w')$

According to the formula in (54), *John knows the capital of Italy* is true iff for every proposition *p* of the form 'The capital of Italy is$_{\text{SPEC}}$ *x*' which is true in *w*, *p* is also true in all the worlds compatible with John's beliefs in *w*. In other words, John knows the actual answer to the question *what is$_{SPEC}$ the capital of Italy?* Technically, the main difference with the previous approach is that in this case, the crucial type-shift operation is implemented as an independent type-shifter, instead of being incorporated into the lexical entry of the embedding verb.

4. Beyond simple definite CQs

4.1 Indefinite and Quantified CQs

Frana (2006) discovered that CQs are also possible with indefinites. Some examples are given in (55) below for English, Italian and German respectively.

(55) Lorenzo knows *a number that can be squared*. (Frana 2017)

(56) *Italian "sapere"*
So un posto dove possiamo nasconderci. (Frana 2006)
know$_{(1st, SG)}$ a place where can$_{(1st, PL)}$ hide.
'I know a place where we can hide.'

(57) *German "wissen"*
Maria **weiß** ein Hotel, das noch zwei Zimmer frei hat. (Frana 2006)
Maria knows a hotel that still two rooms free has.
'Maria knows a hotel that still has two rooms available.

The data with indefinite CQs raise a challenge for the semantic mechanism that crafts CQ-meanings from DPs. Both the clausal approach (at least under some versions) and the IC-approach rely on the assumption that the DP/CQ denotes the intension of an individual, i.e. an individual concept. The individual concept is then either type-shifted into a propositional object (clausal approaches), or fed directly to a designated lexical entry of the verb designed to build propositional meanings from individual concepts (IC-approach). However, indefinites do not denote individual concepts. Consider, for instance, (58) in a context where the following rule is assumed: if a student knows a number that can be squared, then the student will pass the test. It is clear that (58) is compatible with a scenario in which there are multiple numbers that can be squared. All that is needed for (58) to be true is that Lorenzo knows *one of them*. Thus, the meaning of the indefinite *a number that can be squared* cannot be analyzed as an individual concept, i.e. as a function from points of reference into the unique number that can be squared at that point of reference, given that at the same point of reference there might be more than one entity that satisfies that description.

(58) Lorenzo knows *a number that can be squared*. Thus, he will pass the test.
CQ: Lorenzo knows of a number that can be squared that it is a number that can be squared. Thus, he will pass the test.

In order to overcome the difficulty presented by indefinite CQs, Frana (2006) proposes a property-based analysis of both definite and indefinite CQs (see also Schwager 2008). Under this line of analysis, CQ-readings are analyzed as *de re* belief ascriptions toward the individual that is in the extension of the CQ at the actual world, to whom the attitude holder ascribes the property denoted by the DP-CQ.[20] Thus, (55) would be analyzed in the following way (informally):

(59) **CQs as properties**: Lorenzo believes *de re* of a number that can be squared that it has the property of being a number that can be squared. (Frana 2006)

However, CQs are not only possible with indefinites and definite descriptions, but also with properly quantified DPs, as shown in (60). When facing quantified CQs, the property approach does not have a clear empirical advantage over its competitors. This is because in a standard type-shifting system, properly quantified DPs do not denote individual concepts, nor properties of individuals; and movement (via QR) of the quantified phrase would still not deliver the right type of argument for an epistemic verb like *know* (c.f. Frana 2013, 2017).

(60) Antonio knows *three/most/every European capital(s)*.

A further complication regarding quantified CQs, first noted by Heim (1979), is that they are often ambiguous. Consider (61) below, for instance. Setting aside the referential reading, according to which the cosmopolitan Clara is acquainted with every existing capital in the world, the sentence can have two distinct CQ-readings. According to one (labeled *pair-list*), the sentence says that for every existing country *x*, Clara knows the answer to the question *What is the capital of x?* According to the other CQ-reading (labeled *set*), the sentence says that for every capital city *x*, Clara knows the answer to the question *Is x a capital?* or *Is x the capital of some country?*[21] The two readings are truth-conditionally different. In fact, it is easy to imagine scenarios that would make the *set* reading true, but the *pair-list* reading false (the reverse does not hold, i.e. the *pair-list* reading entails the *set* reading, but not the other way around). For instance, suppose that Clara's task was to set apart capital cities from regular cities and assume that she completed this task successfully. In this scenario, the set reading of (61) is true, but the pair-list reading could be false, since Clara might not know how to pair each capital to the corresponding country.

(61) Clara knows every capital.
***CQ/Pair-list**:* For every country *x*, Clara knows what the capital of *x* is.
***CQ/Set**:* For every capital city *x*, Clara knows that *x* is a capital.

As first pointed out by Frana (2010a), the ambiguity displayed by (61) is quite systematic; it is found whenever the head noun of the quantified CQ is relational. Further examples are provided in (62a-b) from Heim (1979) and Frana (2013) respectively.

(62) a. The secretary knows every phone number (of the employees in this office).
b. The postman knows every zip code (in Massachusetts).

According to one reading of (62a), the secretary knows for every employee in this office what his/her phone number is (pair-list). However, this is not the only reading available. Imagine that the secretary needs to assign to a new employee a phone number that is not yet taken by any other employee. In this case, she ''needs to know every phone number not in the sense of knowing which number is whose, but merely in the sense of knowing which numbers are somebody's at all'' (Heim 1979). Similarly for (62b). Under one reading, the postman knows for every town in Massachusetts what its zip code is (pair-list). Under the other reading, the postman simply knows for every actual zip code from Massachusetts that it is the zip code of some town in Massachusetts (set). On the other hand, when the head noun of the quantified CQ is lexically non-relational (as in (63a)) or its internal argument has been saturated (as in (63b)), the sentence is more naturally interpreted as having a set reading, examples from Frana (2013).[22]

(63) a. Mara knows every book that Erin read this summer.
CQ/Set: For every book *x* that Erin read this summer (Anna Karenina, Les Misérables, etc.) Mara knows that *x* is a book that Erin read this summer.
b. Bob knows every member of the Italian soccer team.
CQ/Set: For every *x* that is a member of the Italian soccer team (Pirlo, Buffon, etc.) Bob knows that *x* is a member of the Italian soccer team.

With respect to the distribution of the two readings, Frana (2010a and subsequent work) proposes the following generalization:

(64) *Distribution of pair-list and set readings*
Pair-list readings arise with CQs headed by relational nouns whose internal argument has not been saturated (2-place predicate NPs; semantic type <e<e,t>>). *Set* readings arise with CQs headed by nouns that are not – or no longer – relational (1-place predicate NPs; semantic type <e,t>).

Building on Nathan (2006), Frana shows that an Individual Concept (IC) based approach can quite easily account for pair-list readings by allowing QR of the quantified CQ and quantification over *meaningfully sorted* concepts (concepts that are individuated on the basis of the internal argument of the relational noun). Set readings, on the other hand, require further additions in order to be accommodated (see Frana 2013, 2017 for details). See also Aloni and Roelofsen (2011) for a Q-based account of the ambiguity between pair-list and set readings.[23]

4.2 Heim's ambiguity: Q/MQ readings

Heim (1979) discovered that sentences with *nested CQs* (a CQ modified by a relative clause that contains a CQ-gap) are ambiguous. Consider Heim's original example below.

(65) John knows the price that Fred knows. (Heim, 1979)

Imagine a situation in which the price of several objects is at issue; for instance, the price of milk, the price of bread and the price of apples. Imagine that Fred knows only one of these prices; he knows that milk costs 2 dollars per gallon. Under this scenario, (65) has the two readings paraphrased in (66) below, which I will label the question (Q) and the meta-question (MQ) reading.[24]

(66) **Q**: John, like Fred, knows that milk costs $2.00 (per gallon).
MQ: John knows which price Fred knows. It is the price of milk.

On one reading (Q), John and Fred share the same knowledge regarding the value/answer of a particular price concept/question: "what is the price of milk?", though John may know nothing about Fred's mental states. On the other reading (MQ), John knows the answer to the meta-question "which price-question does Fred know the answer to?" In this case, John does not need to know the answer to the price-question "what is the price of milk?". In fact, he may not know how much milk costs; all he needs to know is that Fred knows what it costs. [25]

As Heim points out, despite this intuitive ambiguity, the IC-approach can only account for the first mentioned Q-reading in (66), but not for the MQ-reading. If *the price that Fred knows* denotes an IC, this will be the function that maps a world into the dollar amount corresponding to the price that Fred knows in that world. Applied to the actual

world in our scenario, that value is $2.00. Therefore, for (65) to be true in the actual world, Fred will have to know that the value that the IC *the price that Fred knows* yields when applied to the actual world is $2.00. This is the Q-reading. In order to account for the MQ-reading, Heim argues, we would have to introduce a homonym of *price* that denotes properties of individual concept-concepts, i.e. functions of type <s<s,e>>. We would also have to modify the lexical entry of $know_{CQ}$ so that it can take a function of type <s<s,e>> as its internal argument. However, as Heim points out, this could go on indefinitely, given that examples of higher complexity can always be constructed. The following one is also from Heim (1979).

(67) John knows the price known to Fred that Bill knows.

Heim ends up abandoning the IC-approach and arguing for a pragmatic account of CQs in which the property described by the DP-CQ is contextually determined (however, see Romero 2005, 2010 for arguments against this analysis). Instead, Romero (2005) develops an account of the ambiguity of (65) building on Heim's intuition of using functions of higher type. In her analysis, the DP *the price that Fred knows* denotes not just an individual concept, but an individual concept-concept (semantic type <s<s,e>>). The way Romero derives the two readings is by providing either the extension or the intension of the CQ as the internal argument of a type-flexible $know_{CQ}$ (crucially, the extension would still be an intensional object of semantic type <s,e>), this is schematically illustrated in (69).[26]

(68) *Romero's type-flexible entry for* $know_{CQ}$

$[\![know_{CQ}]\!]^w = \lambda \underline{y}_{\tau}\, \lambda x_e\, \forall w' \in \mathrm{Dox}_x(w)\, [\underline{y}(w') = \underline{y}(w)]$

where τ = <s,e> or <s,<s,e>> or...

(69) **Q**: $[\![know_{CQ}]\!]^w + [\![the\ price\ that\ Fred\ knows_{<s,e>}]\!]^w$

MQ: $[\![know_{CQ}]\!]^w + \lambda w'.\, [\![the\ price\ that\ Fred\ knows_{<s,e>}]\!]^{w'}$

A further important data point comes from Roelofsen and Aloni (2008), who observe that Heim's sentences can have two additional (set-based) readings. To illustrate this four-way ambiguity, consider (70) below. Let's start by assuming that all that Miles knows about world capitals is that Rome is the capital of Italy. Then, depending on whether Clara's knowledge is about 'capital-questions' (Q-readings) or about Miles's knowledge of 'capital-questions' (MQ-readings), we have Heim's Q and MQ-readings in (71).

(70) Clara knows the capital that Miles knows.

(71) **Q:** As for the city *x* and the country *y* of which Miles knows that *x* is the capital of *y*, Clara also knows that *x* is the capital of *y*. (*Clara, like Miles, knows that Rome is the capital of Italy*).

MQ: Clara knows which capital concept/question it is of which Miles knows its value/answer.

(*Clara knows that Miles knows the answer to the question 'what is the capital of Italy?' but she may not know the answer to the question*).

However, as Roelofsen and Aloni point out, Heim and Romero failed to notice the existence of two additional set-based readings.[27] Suppose that all that Miles knows about world capitals is that Rome is the capital of some country (set-based readings). Then, depending on whether Clara's knowledge is about 'capital-questions' (Q-readings) or about Miles's knowledge of 'capital-questions' (MQ-readings), we have the two additional readings below. The scenarios below, from Frana (2017), help getting the two readings intuitively.

(72) *Set/Q scenario:* Miles and Clara are given a list of cities (some of which are capitals and some of which are not). Their task is to indicate for each city in the list whether it is a capital. Miles gives only one correct answer. Clara happens to give exactly the same correct answer.

Set/Q: As for the city *x* of which Miles knows that it is some country's capital, Clara also knows that *x* is some country's capital.
(*Clara, like Miles, knows that Rome is the capital of some country*).

(73) *Set/MQ scenario:* Miles is given a list of cities (some of which are capital, some of which are not). His task is to indicate for each city on the list whether it is a capital. Miles gives only one correct answer (Rome). Later on, Clara is asked a meta-question regarding Miles's performance: which one of these capital-questions did Miles answer correctly? To which she answers correctly.

Set/MQ: Clara knows which city it is of which Miles knows it is a capital.
(*Clara knows that Miles knows that Rome is the capital of some country*).

See Aloni and Roelofsen (2011) and Frana (2017) for accounts of these additional readings.

5. Conclusions

To sum up, in this overview we have surveyed the following facts about CQs: they are nominal arguments of certain question-embedding verbs; they are intensional objects; they can be indefinites and quantified DPs (John knows *a/every European capital*), not just definite descriptions; some classes of nouns are banned from CQs (proper names and unmodified numerals); not every noun makes a good CQ; although some functional and relational nouns make the most naturally sounding examples, not every noun of this kind works as a CQ and generally modification via a relative clause, or a superlative, may turn any noun into an interpretable CQ (*John knows the/every/a book that Sally read this summer*); CQs with quantified DPs can have pair-list and set-readings, which correlate with the type of head noun (2-place NP-predicate vs. 1-place NP-predicate) and, finally,

nested CQs can have Meta Question readings. We have also seen two lines of analyses that craft CQ-meanings from individual concepts. The IC-approach builds a propositional meaning through a designated lexical entry of the embedding predicate. The clausal approach derives the propositional meaning via an independent type-shifter that applies to the intension of the DP (an individual concept) before it combines with the verb. We have seen that both approaches need to be amended when faced with quantified and indefinite CQs, which do not denote individual concepts, and provided several pointers at the most recent literature that addresses these data. To conclude, although there is no resolution in the literature on which approach best addresses all the data we have quickly surveyed, several accounts exist that satisfactorily address the challenges represented by CQ-constructions. Some questions remain open. For instance, the issue of semantic selection (i.e., how to correctly characterize the class of predicates that selects for CQs) has not seen many advances since Grimshaw (1979) (though see Nathan (2006) for an attempt in this direction) and the issue of whether the class of nouns occurring as CQs is regimented by the grammar, and how to explain the impact of nominal modification (see Nathan 2006, Percus 2014 and Barker 2016 on this).

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[1] CQs are cross-linguistically attested; see, for instance, Caponigro and Heller (2007) for Hungarian and Wolof; Caponigro and Polinsky (2011) for Adyghe; Heim (1979) for German; Frana (2006) for Italian and Romero (2005) for Spanish. This overview focuses on English.

[2] And in part to the fact that definite descriptions can contribute their extensions or their intensions, more about this in §3.

[3] At least in Italian, the *sapere/conoscere* split is unique; other CQ-embedding verbs are ambiguous between intensional and extensional interpretations in the same way English *know* is.

[4] Thanks to an anonymous reviewer for offering this example.

[5] Note, moreover, that carburetor is a functional noun (*the carburetor of the car*).

[6] Nathan (2006: 117-120) argues that when a common noun is modified by a relative clause, a CQ-reading is available because the relative clause itself acts as a type-shifter. However, postulating a special entry for relative clauses that implements a type-shifting operation doesn't come free of cost and one should worry about what other consequences in the grammar it might introduce. See also Percus (2014) and Barker (2016) for alternative proposals.

[7] In §4, we will see that that *set* readings of quantified and indefinite CQs follow from head nouns that are sortal. Thus, set readings provide yet another reason why we might not want to restrict CQs to just relational or functional nouns.

[8] Pesetsky (1981) provides an alternative account of the contrast between *know*-type and *wonder*-type verbs. His proposal is that CQs cannot occur as arguments of *wonder*-type verbs because these verbs exhibit *quirky case* (unusual case-marking): *wonder*-type predicates require their objects to have no case at all. Since DPs - but not CPs - must have case, it follows that CPs, but not DPs, can be arguments of these verbs. Thus, Pesetsky's proposal would simplify Grimshaw's proposal by reducing syntactic subcategorization to case requirements. However, see discussion in Nathan (2006:50-52) and Frana (2017: 17-20) for limitations on Pesetsky's proposal.

[9] Although in the examples seen so far verbs of the *believe* class did not allow for DP complements, these verbs do, in fact, take a restricted class of DPs as their complements, e.g. *John believed the story you told him* or *The judge denied the government's motion*.

[10] Some speakers do not like CQs with *find out* and a person-denoting DP-object. However, the contrast can be reproduced by replacing *find out* with *discover*.

[11] See, however, Aloni and Roelofsen (2011: 21-23) for different intuitions regarding Greenberg-style examples.

[12] See Romero (2005) on more parallelisms between CQs and subjects of specificational clauses.

[13] See Percus (2003), Nathan (2006:34) and Frana (2010b) for accounts of the ambiguity of copular questions.

[14] Although different on many levels, I am lumping together (different) question approaches with (different) proposition approaches. In fact, depending on the view taken on the semantics of question (Karttunen-style vs. Groenendijk and Stokhof-style), some question approaches (e.g. Aloni and Roelofsen 2011) are not distinguishable type-wise from proposition-based approaches (Romero 2007, Nathan 2006).

[15] What follows is a simplified version of Montague's original analysis (c.f. Montague 1974:30-31).

[16] Romero (2005) uses a notation with world variables in the metalanguage (2-sorted type theory). For consistency's sake, all the formulas from her paper are translated into the notation at use here.
[17]Aloni and Roelofsen (2011) add another dimension along which different approaches may differ, the perspectival dimension, which they model via Aloni's (2001) *conceptual covers* framework (see also Harris 2007 and Schwager 2008).
[18] Nathan (2006) ends up advocating for a different analysis.
[19] Although the question meaning built in (52) follows a Hamblin-style semantics of questions, the truth-conditions derived in (54) adopt a Karttunen-style semantics, where the basic denotation of a question is a set of propositions which (intuitively) constitute its true answers (c.f. Karttunen 1977 and Article 44: Questions and Interrogatives).
[20] In order to accommodate predicative uses of definite descriptions, it is commonly assumed that the definite undergoes Partee's (1986) type-shifting operation IDENT, which takes an individual and returns the property of being identical to that individual (Article 103: Type Shifting).
[21] The terms *pair-list* and *set* readings were first used by Roelofsen and Aloni (2008) in this sense.
[22] Pair-list readings can result by contextually coercing the noun into being functional. For instance, *member of the Italian soccer team* could be interpreted as a function mapping each member of the team to the role he plays as a member of the team. Under this interpretation of the noun, it is possible to generate a *pair-list* reading according to which Bob knows for each individual what his role in the team is.
[23] Other references on quantified CQs are Romero (2010) for a different IC-based analysis of set readings and Frana (2017) for a comparison between Frana (2013) and Romero (2010).
[24] The two readings are often labeled in the literature **A** (Q-reading) and **B** (MQ-reading).
[25] It is important to stress the fact that the truth-conditional difference between the two readings does not simply depend upon John knowing (or not knowing) about Fred's mental states; the *object* of John's belief is different from one reading to the other. In the Q-reading, he holds a belief about the value of a given concept (a dollar amount; an entity of type e); in the MQ-reading, he holds a belief about the concept itself (the price of milk; a function of type <s,e>).
[26] See also Nathan (2006), Aloni and Roelofsen (2011) and Percus (2014) for alternative accounts of the ambiguity.
[27] This is probably due to the fact that Heim's original example employs an abstract functional noun, such as *price*, for which set readings are very counterintuitive.