Concealed questions under cover

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Consider the following situation. In front of you lie two face-down cards. One is the Ace of Hearts, the other is the Ace of Spades, but you don't know which is which. You are playing the following game. You have to choose one card: if you choose the Ace of Spades, you win 10 euros, if you choose the Ace of Hearts, you lose 10 euros. Consider now the following sentence:

(1)   You know which card is the winning card.

Is this sentence true or false in this situation? On the one hand, the sentence is true. You know that the Ace of Spades is the winning card, so you know which card is the winning card. On the other hand, however, as far as you know, this card on the left might be the winning card, or that one on the right. So you do not know which card is the winning card. Intuitively, there are two different ways in which the cards can be identified in this situation: by their position (the card on the left, the card on the right) or by their suit (the Ace of Hearts, the Ace of Spades). Which of these identification methods is adopted seems to affect our evaluation of sentence (1). If identification by suit is adopted, (1) is true. But, if demonstrative identification is used, the sentence is false.

This example illustrates the central idea I wish to defend in this article. Different methods of identification are operative in different conversational circumstances and our evaluation of fragments of discourse, in particular *knowing-wh* constructions, may vary relative to these methods. In a number of previous works, I proposed a formalization of this old insight in a possible world semantics (Aloni 2000, 2001, 2002, 2005a-b). The main idea consisted in representing methods of identification by what I called *conceptual covers* (sets of concepts satisfying a number of natural constraints) and relativizing interpretation to a contextual parameter selecting different conceptual covers on different occasions. The main goal of the present article is to apply these ideas to a more recent puzzle concerning the interpretation of so-called concealed questions (Heim 1979). A concealed question is a noun

phrase naturally read as an identity question. As an illustration, consider the italicized nouns in the following examples:

(2) a. John knows *the price of milk.*
     b. ≡ John knows what the price of milk is.

(3) a. Mary found out *the murderer of Smith.*
     b. ≡ Mary found out who the murderer of Smith is.

(4) a. Ann told me *the time of the meeting.*
     b. ≡ Ann told me what the time of the meeting is.

In her classic article, Heim (1979) observed that there is an ambiguity in sentences like the following:

(5) John knows the capital that Fred knows.
     a. [Reading A] John knows the same capital that Fred knows
     b. [Reading B] John knows what capital Fred knows

Suppose Fred knows the capital of Italy. Then on reading A the sentence entails that also John knows the capital of Italy. On reading B, instead, (5) lacks this entailment. It only follows that John knows that Fred knows what the capital of Italy is. John himself may lack this knowledge.

Of the promising existing approaches to concealed questions (e.g. Romero 2005, Nathan 2005, Frana 2006), Romero (2005) is the only one who provides a detailed account of Heim's ambiguity. Her solution, however, has a cost: it requires an undesirable cross-categorial account of the embedding verb *know* which can take complements of types (s, e), $(s, (s, e))$, $(s, (s, (s, e)))$, ... In this article I will show that by adopting conceptual covers we can perspicuously represent the two readings of (5) without type inflation. The idea of using conceptual covers in the representation of concealed questions has been recently defended in Harris (2007) and Schwager (2007). The account I wish to present here is very close in spirit to these two previous approaches, although technically it is quite different, in particular in its solution to Heim's puzzle.

As a starting point I will assume Groenendijk & Stokhof's (henceforth G&S) (1984) account of questions and knowledge-*wh*. The next section briefly introduces their analysis. Section 2 introduces the notion of a conceptual cover and employs it in the interpretation of (embedded) questions. Section 3 and 4 extend this analysis to concealed questions. Section 5 concludes the article and describes future lines of research.

1 G&S on questions and knowledge

In this section I will briefly introduce Groenendijk and Stokhof's (1984) analysis of questions and knowledge-*wh* ascriptions.

In G&S theory, the meaning of a question is identified with the set of meanings of all its possible exhaustive answers. More formally, interrogative sentences are represented by formulae of predicate logic preceded by a question operator, ?, and a sequence $\vec{x}$ of k variables. Sentences are evaluated with respect to models $M = \langle D, W, I \rangle$ consisting of a set D of individuals, a set W of possible worlds and a world dependent interpretation function I for the non-logical fragment of the language.

A classical interpretation is assumed for indicative sentences. The denotation of an indicative in a model M, relative to a world w and an assignment function g is a truth value: $[\![\phi]\!]_{M,w,g} \in \{0, 1\}$.

Interrogatives are analyzed in terms of their possible answers. The denotation of an interrogative in a given world is the proposition expressing the exhaustive (or complete) true answer to the question in that world.

Definition 1 [Questions]

$$[\![?\vec{x}\phi]\!]_{M,w,g} = \{v \in W \mid \forall \vec{d} \in D^k : [\![\phi]\!]_{M,v,g[\vec{x}/\vec{d}]} = [\![\phi]\!]_{M,w,g[\vec{x}/\vec{d}]}\}$$

An interrogative $?\vec{x}\phi$ collects the worlds v in which the set of sequences of individuals satisfying ϕ is the same as in the evaluation world w. If $\vec{x}$ is empty, $?\vec{x}\phi$ denotes in w the set of the worlds v in which ϕ has the same truth value as in w. For example, a polar question $?p$ denotes in w the proposition *that p*, if p is true in w, and the proposition *that not p* otherwise. As for who-questions, suppose a and b are the only two individuals in the extension of P in w, then the proposition *that a and b are the only P* is the denotation of $?xPx$ in w, that is the set of worlds v such that $I_v(P) = I_w(P) = \{a, b\}$.

While indicatives express propositions, interrogatives determine *partitions* of the logical space. I will write $[\![\phi]\!]_M$ to denote the meaning of a closed sentence ϕ with respect to M, identified with the set of all possible denotations of ϕ in M. While the meaning of an indicative corresponds to a set of worlds, i.e. a proposition, the meaning of an interrogative is identified with the set of meanings of all its possible complete answers. Since the latter is a set of mutually exclusive propositions the union of which exhausts the set of worlds, we say that questions partition the logical space. Partitions can be perspicuously visualized in diagrams.

p
$\neg p$

λw [nobody is P in w]
λw [d_1 is the only P in w]
λw [d_2 is the only P in w]
$\lambda w[d_1$ & d_2 are the only P in w]
...
λw[all $d \in D$ are P in w]

In the first diagram, the polar question $?p$ divides the set of worlds in two alternatives, the alternative in which p is true and the alternative in which p is false. In the second diagram, the single-constituent question $?xPx$ divides the set of worlds in as many alternatives as there are possible denotations of the predicate P within M. Intuitively, two worlds belong to the same block in the partition determined by a question if their differences are irrelevant to the issue raised by the question.

To express knowledge-*wh*, we extend the language with a knowledge operator K_a selecting questions as complements. A sentence like 'a knows-*wh* ϕ' will translate as $K_a(?\vec{x}\phi)$. A model for the extended language is a quadruple (D, W, Bel, I), where D, W, and I are as above and Bel is a function mapping individual-world pairs (a, w) into a subset of W. Intuitively $Bel(a, w)$ represents the belief state of a in w. The semantics of the knowledge operator K_a is specified in the following clause:

Definition 2 [Knowledge-*wh*] $[\![K_a(?\vec{x}\phi)]\!]_{M,w,g} = 1$ iff $Bel(a, w) \subseteq [\![?\vec{x}\phi]\!]_{M,w,g}$

$K_a Q$ is true in w iff a's belief state is contained in the denotation of Q in w. Since Q's denotation in a world is equivalent to Q's true exhaustive answer in that world, $K_a Q$ is true iff a believes the true exhaustive answer to Q.

Consider now our initial sentence (1), here rewritten as (6)-a:

(6)   a.   You know which card is the winning card.
       b. $K_a(?x\ \phi)$

Given the standard method of individuating objects adopted in the G&S analysis, the embedded question will determine the following partition:

(7)   {that d_1 is the winning card, that d_2 is the winning card, ...}

Sentence (6) is true in w iff you believe the only proposition in this partition that is true in w, i.e. the unique true exhaustive answer to the embedded question in w. As we have observed in the introduction, however, our evaluation of (6) (and of what counts as a good answer to its embedded question)

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depends on the adopted method of identification. Clearly, Groenendijk and Stokhof's standard treatment fails to account for this dependence.

An even more serious problem arises with the following sentences:

(8) a. Which card is which?
     b. $?xy.\ x = y$

(9) a. You don't know which card is which.
     b. $\neg K_a(?xy.\ x = y)$

It's easy to see that, since in each world each individual d is identical to itself, (8) is vacuous on Groenendijk and Stokhof's account and (9) is predicted to entail that your belief state is inconsistent. Both predictions clashes with our intuitions about these examples. The analysis presented in the following section will solve these problems by introducing the notion of a conceptual cover.

2 Questions under Cover

In this section, I present a refinement of the G&S semantics in which different ways of identifying objects are represented and made available within one single model. Identification methods are formalized by conceptual covers. Conceptual covers are sets of individual concepts which represent different ways of perceiving one and the same domain. Questions are relativized to conceptual covers. What counts as an answer to a wh-question depends on which conceptualizations of the universe of discourse are assumed in the specific circumstances of the utterance.

2.1 Conceptual Covers

Consider again the card situation discussed at the beginning of the article. In front of you lie two face-down cards. One is the Ace of Spades, the other is the Ace of Hearts. You don't know which is which. There are two different ways of identifying the two cards in this scenario: by their position on the table (the card on the left, the card on the right) and by their suit (the Ace of Spades, the Ace of Hearts). These two identification methods are typical examples of what the notion of a conceptual cover is meant to formalize.

A conceptual cover is a set of individual concepts which satisfies the following condition: in each world, each individual constitutes the instantiation of one and only one concept. More formally:

Definition 3 [Conceptual covers] Given a set of possible worlds W and a universe of individuals D, a *conceptual cover* CC based on (W, D) is a set of functions $W \rightarrow D$ such that:

$$\forall w \in W : \ \forall d \in D : \ \exists! c \in CC : c(w) = d$$

Conceptual covers are sets of concepts which exhaustively and exclusively cover the domain of individuals. In a conceptual cover, each individual is identified by means of at least one concept in each world (*existence*), but in no world is an individual counted twice (*uniqueness*). In a conceptual cover, each individual in the universe of discourse is identified in a determinate way, and different conceptual covers constitute different ways of conceiving of one and the same domain.

Illustration   Consider again the card situation discussed above. To formalize this situation, we just need to distinguish two possibilities. The following diagram visualizes such a simple model:

$$w_1 \mapsto \heartsuit \quad \spadesuit$$
$$w_2 \mapsto \spadesuit \quad \heartsuit$$

The domain D consists of two individuals $\heartsuit$ and $\spadesuit$. The set of worlds W consists of w_1 and w_2. As illustrated in the diagram, either $\heartsuit$ is the card on the left (w_1); or $\heartsuit$ is the card on the right (in w_2).

There are only two possible conceptual covers definable over such a model, namely the set A which identifies the cards by their position on the table and the set B which identifies the cards by their suit:

$$A = \{\lambda w[left]_w, \lambda w[right]_w\}$$

$$B = \{\lambda w[Spades]_w, \lambda w[Hearts]_w\}$$

Set A contains the concepts *the card on the left* and *the card on the right*; set B the concepts *the Ace of Spades* and *the Ace of Hearts*. They stand for two different ways of conceiving one and the same domain. C below is an example of a set of concepts which is not a conceptual cover:

$$C = \{\lambda w[left]_w, \lambda w[Hearts]_w\}$$

Formally, C is not a cover because it violates both the existential condition (no concept identifies $\spadesuit$ in w_1) and the uniqueness condition ($\heartsuit$ is counted twice in w_1). Intuitively, C is ruled out because it does not provide a proper perspective over the universe of individuals. That C is inadequate is not due to properties of its individual elements, but to their combination. Although the two concepts *the card on the left* and *the Ace of Hearts* can both be salient, they cannot be regarded as standing for the two cards in D. If taken together, the two concepts do not constitute an adequate way of looking at our domain.

2.2   Quantification Under Cover

I propose to relativize interpretation to contextually selected conceptual covers.

I add a special index $n \in N$ to the variables in the language. These indices range over conceptual covers. A model for this richer language is a five-tuple (D, W, I, Bel, C) where D, W, I and Bel are as above and C is a set of conceptual covers based on (W, D). A *conceptual perspective* $\wp$ in M is a function from N to C. Sentences are interpreted with respect to assignments under a perspective. An *assignment under a perspective* $g_\wp$ is a function mapping variables x_n to concepts in $\wp(n)$, rather than individuals in D. Quantification under conceptual cover is defined as follows:

Definition 4 [Quantification under conceptual cover]

$$\llbracket \exists x_n \phi \rrbracket_{M,w,g_\wp} = 1 \ \ \text{iff} \ \ \exists c \in \wp(n) : \llbracket \phi \rrbracket_{M,w,g_\wp[x_n/c]} = 1$$

On this account, variables range over elements of a conceptual cover, rather than over individuals *simpliciter*. The denotation of a variable in a world, however, will always be an individual, and never a concept.

Definition 5 [The denotation of variables] $\llbracket x_n \rrbracket_{M,w,g_\wp} = (g_\wp(x_n))(w)$

The denotation $\llbracket x_n \rrbracket_{M,w,g_\wp}$ of a variable x_n with respect to a model M, a world w and an assignment under a perspective $g_\wp$ is the individual $(g_\wp(x_n))(w)$, i.e. the value of concept $g_\wp(x_n)$ in world w. On this account, then, variables do not refers to concepts, but to individuals. They do refer, however, in a non rigid way: different individuals can be their value in different worlds. To avoid the well-known problems that arise when we treat variables as non-rigid designators,[1] we put restrictions on their possible trans-world values via the notion of a conceptual perspective.

Quantification under conceptual cover is neither bare quantification over individuals, nor quantification over ways of specifying these individuals, rather it is quantification over individuals under a perspective. Relativization to a perspective $\wp$ will only affect the interpretation of variables occurring free in an intensional context, and our evaluation of constituent questions. In this system, questions involve quantification over elements of $\wp$-selected conceptualizations. In case of multi-constituent questions, different variables can be assigned different conceptualizations. (By $\vec{x_n}$ I mean the sequence $x_{1_{n_1}}, \ldots, x_{k_{n_k}}$. By $\wp(\vec{n})$ I mean the product $\prod_{i \in k}(\wp(n_i))$. And by $\vec{c}(w)$ I mean the sequence $c_1(w), \ldots, c_k(w)$.)

Definition 6 [Questions under Cover]

$$\llbracket ?\vec{x_n}\phi \rrbracket_{M,w,g_\wp} = \{v \mid \forall \vec{c} \in \wp(\vec{n}) : \llbracket \phi \rrbracket_{M,w,g_\wp[\vec{x_n}/\vec{c}]} = \llbracket \phi \rrbracket_{M,v,g_\wp[\vec{x_n}/\vec{c}]}\}$$

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[1] As an illustration of these problems consider the validity of the exportation from 'Ralph believes that there is a spy' to 'There is someone Ralph believes to be a spy' (Kaplan 1969, p. 220) and the solution proposed in Aloni (2005a-b).

The idea formalized by this definition is that by interpreting an interrogative sentence one quantifies over tuples of elements of possibly distinct conceptual covers rather than directly over tuples of individuals in D. If analyzed in this way, a question like $?x_n P x_n$ groups together the worlds in which the denotation of P is identified by means of the same set of elements of the conceptual cover selected for n. A multi-constituent question like $?x_n y_m R x_n y_m$ groups together those worlds in which the pairs (d_1, d_2) in the denotation of R are identified by means of the same pairs of concepts (c_1, c_2), where c_1 and c_2 can be elements of two different conceptualizations. The following diagram visualizes the partition determined by $?x_n P x_n$ under a perspective $\wp$ such that $\wp(n) = \{c_1, c_2, \dots\}$.

λw [no $c_i(w)$ is P in w]
λw [$c_1(w)$ is the only P in w]
λw [$c_2(w)$ is the only P in w]
λw [$c_1(w)$ & $c_2(w)$ are the only P in w]
$\dots$
λw[all $c_i(w)$ are P in w]

Due to the definition of conceptual covers, in the first block of this partition no individual in D is P; in the fourth block exactly two individuals in D are P; and in the last block all individuals in D are P.

Illustration Consider again the card situation described above. In front of you lie two face-down cards. One is the Ace of Hearts, the other is the Ace of Spades. You don't know which is which. Furthermore, assume that one of the cards is the winning card, but you don't know which one. We can model this situation as follows (the dot indicates the winning card):

$$
\begin{array}{rcll}
w_1 & \mapsto & \heartsuit & \spadesuit^\bullet \\
w_2 & \mapsto & \spadesuit & \heartsuit^\bullet \\
w_3 & \mapsto & \heartsuit^\bullet & \spadesuit \\
w_4 & \mapsto & \spadesuit^\bullet & \heartsuit
\end{array}
$$

Our model now contains four worlds, representing the possibilities which are compatible with the described situation. Now consider two possible conceptual perspectives: $\wp$ and $\wp'$. The former assigns to the index of the variable x_n the cover that identifies the cards by means of their position on the table, $\wp'(n)$ identifies the cards by their suits:
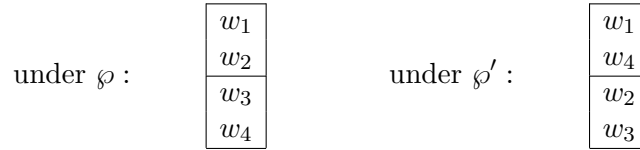
(10)   a. $\wp(n) = \{\lambda w[left]_w, \lambda w[right]_w\}$;

      b. $\wp'(n) = \{\lambda w[Spades]_w, \lambda w[Hearts]_w\}$.

Consider the following interrogative sentence:

(11)   a.   Which is the winning card?
          b. $?x_n.\ x_n = \iota y_n P y_n$

Example (11) structures the set of worlds in two different ways depending on which perspective is assumed:

$$\text{under } \wp: \quad \begin{array}{|c|} \hline w_1 \\ w_2 \\ \hline w_3 \\ w_4 \\ \hline \end{array} \qquad \text{under } \wp': \quad \begin{array}{|c|} \hline w_1 \\ w_4 \\ \hline w_2 \\ w_3 \\ \hline \end{array}$$

Under $\wp$, (11) disconnects those worlds in which the winning card occupies a different position. Under $\wp'$, it groups together those possibilities in which the winning card is of the same suit. In other words, in the first case, the relevant distinction is whether the left card or the right card is the winning card; in the second case the question expressed is whether Spades is winning, or Hearts. Since different partitions are determined under different perspectives, we can account for the fact that different answers are required in different contexts. For instance, (12) counts as an answer to (11) only under $\wp'$:

(12)   The Ace of Spades is the winning card.

Consider now the situation described at the beginning of this article. You know that the Ace of Spades is the winning card, but you don't know whether it is the card on the left or that on the right. In this situation your belief state corresponds to the set: $\{w_1, w_4\}$. Sentence (13) is then correctly predicted to be true under $\wp'$, but false under $\wp$.

(13)   a.   You know which card is the winning card.
          b. $K_a(?x_n.\ x_n = \iota y_n P y_n)$

    Finally, consider again the following sentences:

(14)   a.   Which card is which?
          b. $?x_n y_m.\ x_n = y_m$

(15)   a.   You don't know which card is which.
          b. $\neg K_a(?x_n y_m.\ x_n = y_m)$

As we saw, in standard theories, (14) and (15) are wrongly predicted to be vacuous and to entail that your belief state is inconsistent, respectively.

On our account, instead, since different *wh*-phrases in a multi-constituent question can range over different sets of concepts, (14) can be significant and (15) can fail to entail inconsistence. To see this, assume $\wp$ assigns different covers to n and m, for example:

(16) a. $\wp(n) = \{\lambda w[left]_w, \lambda w[right]_w\}$;
      b. $\wp(m) = \{\lambda w[Spades]_w, \lambda w[Hearts]_w\}$.

If interpreted under such perspective, (14) groups together those worlds that supply the same mapping from one cover to the other, and is not vacuous in our model. The determined partition is depicted in the following diagram:

$$\text{under } \wp : \quad \boxed{\begin{array}{c} w_1 \\ w_3 \\ \hline w_2 \\ w_4 \end{array}}$$
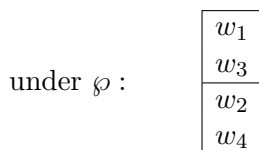
The question divides the set of worlds in two blocks: $\{w_1, w_3\}$ and $\{w_2, w_4\}$. The first alternative corresponds to the possible answer (17), the second to the possible answer (18):

(17) The Ace of Hearts is the card on the left and the Ace of Spades is the card on the right.

(18) The Ace of Hearts is the card on the right and the Ace of Spades is the card on the left.

If your belief's state is specified as above, i.e. $\{w_1, w_4\}$, then (15) would be true in w_1 without entailing inconsistency.

   In the following section we will use this analysis of knowing-*wh* to explain our interpretation of concealed questions.

3   Concealed Questions under Cover

In this section I propose an analysis of Concealed Questions (henceforth CQs) defining a type-shifting operator mapping nominals into identity questions. The latter are then interpreted relative to a conceptual perspective as explained in the previous section.

   As we saw in the introduction, CQs are nominals naturally read as identity questions. As an example, consider the italicized part in (19):

(19) a. John knows *the capital of Italy.*
      b. John knows what the capital of Italy is.

Example (19)-a is ambiguous between an epistemic CQ-reading exemplified in (19)-b and an acquaintance reading in which the italicized nominal is not

a CQ.[2] Only on this second reading, substitution of identicals is allowed:

(20)   Mary knows the capital of Italy.

      a.   Acquaintance: $\Rightarrow$ She knows$_{AC}$ Rome

      b.   CQ-reading: $\not\Rightarrow$ She knows$_{CQ}$ Rome

In this article we will only be concerned with CQ-readings of these sentences. A detailed analysis is proposed in the following section.

3.1 The proposal

On this account, CQs are syntactically nominals, but semantically questions. Their interpretation crucially involves the application of a type-shifting operator $\uparrow_n$ which transforms an entity denoting expression α into the identity question $?x_n.\ x_n = \alpha$ (who$_n$/what$_n$ is α?).[3]

Definition 7 [The type-shift rule] $\uparrow_n \alpha \ =_{\text{def}} ?x_n.\ x_n = \alpha$

The type-shift rule $\uparrow_n$ applies to avoid the type mismatch otherwise arising from the application of a question embedding verb like *know* to an entity denoting expression. The value of n in $\uparrow_n$ is pragmatically supplied. The resulting identity question is interpreted relative to a conceptual perspective as explained in the previous section.

    Analyses of CQs are normally grouped in three classes (see Heim 1979, and Romero 2006 for a detailed evaluation): pragmatic theories (e.g. Frana 2006), individual concept theories (e.g. Romero 2005), and propositional theories (e.g. Nathan 2005). The present account, technically, can seen as a combination of all three approaches. Since question denotations are propositions we share the positive sides of the proposition theory in that no special notion of knowledge-CQ must be posited, standard knowledge-*wh* will suffice. On the other hand, identity questions are here interpreted with respect to contextually selected sets of concepts allowing us to account for (a) for the contextual dependence of CQs as in the pragmatic approach and (b) the intuition formalized in the individual concept approach that their interpretation requires comparing values assigned in different worlds.

Illustrations   A sentence like (20), on its CQ-reading, receives on this account the following representation:

(21)   a.   John knows the capital of Italy.

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[2]Languages like German or Italian use different lexical items for the two readings: *wissen* and *kennen* in German (Heim 1979); *sapere* and *conoscere* in Italian (Frana 2007). When *wissen* and *sapere* take a nominal argument, only the CQ reading is available.

[3]Cf. Harris (2007, chapter 4) which presents psycholinguistic evidence that is broadly compatible with a view of concealed questions that involves a shift of interpretation.

b. $K_j(\uparrow_m \iota x_n P x_n)$ $(= K_j(?y_m.\ y_m = \iota x_n P x_n))$

When a question embedding verb like *know* applies to an entity denoting expression like *the capital of Italy*, the type-shift rule $\uparrow_m$ must apply to avoid type mismatch. The resulting sentence is then interpreted according to the analysis of knowing-*wh* under cover given in the previous section.

(22) $\llbracket K_j(?y_m.\ y_m = \iota x_n P x_n) \rrbracket^{w,g_\wp} = 1$ iff $Bel(j,w) \subseteq \llbracket ?y_m.\ y_m = \iota x_n P x_n \rrbracket^{w,g_\wp}$

The intended meaning is obtained if m is mapped to the following cover representing identification by name:

(23) $\wp(m) = \{\lambda w[\text{Berlin}]_w, \lambda w[\text{Rome}]_w, \lambda w[\text{Paris}]_w, ...\}$

The value $\wp(n)$ assigned to n is irrelevant in this case, because x_n does not occur free in an intensional context. By an economy principle, we can then assume $\wp(n) = \wp(m)$.

Assuming the question semantics introduced in the previous section, the embedded question $?y_m.\ y_m = \iota x_n P x_n$ denotes in w the proposition that Rome is the capital of Italy, if in w Rome is indeed the capital of Italy. Sentence (21) then is true in w iff John believes in w this true proposition.

Since no shift of cover is necessary for this example, the same interpretation would have obtained if we had assumed the classical G&S theory. In the following example, instead, conceptual covers play a more crucial role.

Example (24) illustrates the case of a quantified CQ. Quantified CQs are typically problematic for an individual concept account. On the present theory, they can be perspicuously analyzed as follows (where $\Box$ is a universal modal operator, i.e. $\Box\phi$ is true in a world, iff ϕ is true in all worlds).

(24)   a.   John knows all European capitals.
        b. $\forall x_n(\Box P x_n \to K_j(\uparrow_m x_n))$

(24)-b can be roughly paraphrased as *for each European capital John knows it*. The most natural resolution for n and m here is the following:

(25)   a. $\wp(n) = \{$*the capital of Germany, the capital of Italy*, ... $\}$
        b. $\wp(m) = \{$*Berlin, Rome*, ... $\}$

The sentence is then predicted to be true iff John knows the true exhaustive answer to the question $?y_m.\ x_n = y_m$ (What$_m$ is x_n?) for each $x_n \in \wp(n)$, that is:

(26)   a.   What is the capital of Germany?
        b.   What is the capital of Italy?
        c.   ...

This prediction is intuitively correct. Note that contrary to the previous example, the quantified case crucially requires a shift in perspective, n and m cannot be assigned the same value here, otherwise the quantified questions would be trivialized.

In the following section, we discuss Heim's ambiguity where conceptual covers again play an essential role.

3.2   Heim's ambiguity

As we saw in the introduction, Heim (1979) describes two readings for sentences like (27), normally labeled as reading A and reading B.

(27)   John knows the capital that Fred knows.
      a.   [Reading A] John knows the same capital that Fred knows
      b.   [Reading B] John knows what capital Fred knows

The representation of this ambiguity is a challenge for most approaches to CQs. Romero (2005) was the first to provide a detailed account. In Romero's analysis, CQs denote individual concepts. Reading A is obtained by letting *know* apply to the extension of the description 'the capital that Fred knows', an object of type (s, e). Reading B is obtained by letting *know* apply to the intension of the description 'the capital that Fred knows', an object of type $(s, (s, e))$. Suppose Fred only knows the capital of Germany, then the extension of 'the capital that Fred knows' will be the concept *the capital of Germany*, its intension will be the 'meta-concept' *the capital that Fred knows*. Only reading A then is correctly predicted to entail that John knows the capital of Germany. Reading B only entails that John knows what capital Fred knows. Although Romero's analysis captures the two readings of our sentence, it does it on a high cost: a cross-categorial account of *know* is needed which can take complements of types (s, e), $(s, (s, e))$, $(s, (s, (s, e)))$, ... In what follows I will show that this type inflation can be avoided if we use quantification under conceptual covers.

In our framework, Heim's ambiguity can be represented as follows:

(28)   John knows the capital Fred knows.
      a.   Reading A: $\exists y_n (y_n = \iota x_n (P x_n \wedge K_f(\uparrow_m x_n)) \wedge K_j(\uparrow_m y_n))$
      b.   Reading B: $K_j(\uparrow_n \iota x_n (P x_n \wedge K_f(\uparrow_m x_n)))$

Reading A can be paraphrased as saying that there is a unique capital that Fred knows and John knows it too under the same conceptual perspective. Reading B simply asserts that John knows the answer to the question 'What is the capital that Fred knows?'.

Heim's intended meanings are captured by assuming the following resolution for the indices n and m:

(29)　　a.　$\wp(n)=\{$*the capital of Germany, the capital of Italy, …*$\}$
　　　　b.　$\wp(m)=\{$*Berlin, Rome, …*$\}$

On this resolution, on reading A, both Fred and John can identify one and the same capital in $\wp(n)$ by name. On reading B, instead, only Fred has this knowledge. John can only give a descriptive answer to the question 'What is the capital that Fred knows?'.

Illustration　　As an illustration consider the following situation:

(30)　　a.　In w_1, Berlin is the capital of Germany and Paris is the capital of France. Fred knows that Berlin is the capital of Germany, but doesn't know the capital of France.
　　　　b.　In w_2, Paris is the capital of Germany and Fred knows that Paris is the capital of Germany, but doesn't know the capital of France.
　　　　c.　In w_3, Berlin is the capital of Germany and Paris is the capital of France. Fred knows that Paris is the capital of France, but doesn't know the capital of Germany.

Suppose $Bel(j, w_1) = \{w_1, w_2\}$, that is, John believes in w_1 that Fred knows the capital of Germany, but he himself wonders whether it is Berlin or Paris. Intuitively this is a situation in which reading A is false in and reading B is true.

Suppose now instead $Bel(j, w_1) = \{w_1, w_3\}$. In w_1, John knows all the capitals, but he doesn't know which capital Fred knows: Fred might know Berlin, or he might know Paris. In this case, intuitively, reading A is true and reading B is false.

Let us call these two cases M_1 and M_2:

(31)　　a.　M_1: $Bel_1(j, w_1) = \{w_1, w_2\} \mapsto$ reading A is false in w_1 and reading B is true.
　　　　b.　M_2: $Bel_2(j, w_1) = \{w_1, w_3\} \mapsto$ reading A is true in w_1 and reading B is false.

In what follows I will show that these are indeed our predictions given the representations in (28).

First of all, let us consider the concepts relevant in these situations. Let b, p and r stand for the individuals Berlin, Paris, and Rome respectively. Let **g**, **f**, **i** be the concepts *the capital of Germany, the capital of France* and *the capital of Italy* respectively. The following table represents the values of these concepts in the relevant worlds. To fully represent Fred's belief, we consider for each world w_i also a world w_i' and assume $Bel(f, w_i) = \{w_i, w_i'\}$.

(32)

	g	**f**	**i**
w_1	b	p	r
w'_1	b	r	p
w_2	p	b	r
w'_2	p	r	b
w_3	b	p	r
w'_3	r	p	b

Let us consider now the description 'the capital Fred knows'.

(33)   a.   The capital Fred knows.
           b. $\iota x_n(Px_n \wedge K_f(\uparrow_m x_n))$

As above, we assume that $\wp(n)$ is the descriptive cover {*the capital of Germany, the capital of France, the capital of Italy*}. Whereas $\wp(m)$ is the cover {*Berlin, Paris, Rome*} representing identification by name, which in this model corresponds to the rigid cover $RC = \{\lambda w\, d \mid d \in D\}$.

It's easy to see that under this conceptual perspective, (33) corresponds to the concept **k** getting the values listed in (34).

(34)

	k
w_1	b
w'_1	b
w_2	p
w'_2	p
w_3	p
w'_3	p

As an illustration of the working of this semantics, we show in details the case of w_1. Let us assume the following treatment of iota terms:

(35) $[\![\iota x_n \phi]\!]_{M,w,g_\wp} = c(w)$, if $\exists! c \in \wp(n) : [\![\phi]\!]_{M,w,g_\wp[x/c]} = 1$, undefined otherwise.

Recall that $\wp(n)$ is the descriptive cover. We want to show that there is only one concept c in this cover that satisfies the clause in (36), and that its value in w_1 is b, as illustrated in table (34):

(36) $[\![Px_n \wedge K_f(\uparrow_m x_n)]\!]_{M,w_1,g_\wp[x_n/c]} = 1$

In this logic, (36) holds iff the following holds:

(37) $c(w_1) \in I_{w_1}(P)$ & $Bel(f, w_1) \subseteq [\![?y_m.\ x_n = y_m]\!]_{M,w_1,g_\wp[x_n/c]}$

$Bel(f, w_1)$ is $\{w_1, w'_1\}$ by definition of the model. The following table gives us the denotation of $?y_m.\ x_n = y_m$ (what is x_n?) in w_1 for each possible values for x_n.

(38)   a. $x_n \rightarrow$ *the capital of Germany* $\mapsto \{w_1, w_1', w_3\}$
        b. $x_n \rightarrow$ *the capital of France* $\mapsto \{w_1, w_3, w_3'\}$
        c. $x_n \rightarrow$ *the capital of Italy* $\mapsto \{w_1, w_2, w_3\}$

The set in (38)-a corresponds to the denotation in w_1 of the question *What is the capital of Germany?* and contains all worlds in which the capital of Germany is identified by the same name as in w_1, i.e. as Berlin. The set in (38)-b corresponds to the denotation in w_1 of the question *What is the capital of France?* and contains all worlds in which the capital of France is identified by the same name as in w_1, i.e. as Paris. And so on. Of these three sets, only the one in (38)-a contains $Bel(f, w_1)$. Therefore, there is a unique concept satisfying the clause in (37), namely *the capital of Germany*, and its value in w_1 is indeed b, Berlin.   □

Consider now reading A, represented by (39).

(39) $\exists y_n(y_n = \iota x_n(Px_n \wedge K_f(\uparrow_m x_n)) \wedge K_j(\uparrow_m y_n))$

Example (39) is true in w_1 iff there is a concept c in the descriptive cover $\wp(n)$ s.t. (i) $c(w_1)$ is equivalent to the value of the concept *the capital Fred knows* in w_1, i.e. $c(w_1) = b$ and (ii) John knows how to map c into the naming cover $\wp(m)$, i.e. there is a concept c' in $\wp(m)$ s.t. in each world v in John's belief state c and c' have the same value. Consider now the two models M_1 and M_2 in (31). In both models, the only concept in $\wp(n)$ satisfying the first condition is *the capital of Germany*. It is easy to see, however, that the second condition is only satisfied in M_2, where $Bel_2(j, w_1) = \{w_1, w_3\}$ is a state where c, the capital of Germany, is identified as Berlin. In M_1, instead, which formalizes a situation in which John wonders whether the capital of Germany is Berlin or Paris, the sentence is false. $Bel_1(j, w_1) = \{w_1, w_2\}$ is a state where the capital of Germany cannot be identified.

Consider now Reading B, represented by (40).

(40) $K_j(\uparrow_n \iota x_n(Px_n \wedge K_f(\uparrow_m x_n)))$

Sentence (40) states that John knows the true exhaustive answer to the following question:

(41)   a.   What is the capital Fred knows?
       b. $?y_n.\ y_n = \iota x_n(Px_n \wedge K_f(\uparrow_m x_n))$

Consider the partition determined by this question in both our models M_1 and M_2:

(42)

w_1	w_1'
w_2	w_2'
w_3	w_3'

In the first block of this partition, Fred knows the capital of Germany. In the second block, he knows the capital of France. Reading B states that John knows the true exhaustive answer to this question, i.e. that his belief state is contained in one and only one block in this partition. Consider now again the characterization of John's belief state in w_1 in our two models in (31): $Bel_1(j, w_1) = \{w_1, w_2\}$ in M_1, and $Bel_2(j, w_1) = \{w_1, w_3\}$ in M_2. Sentence (42) is then true in w_1 given M_1, but false in w_1 given M_2.

Aside: an alternative pragmatic account In a logic assuming quantification under conceptual cover, a *de dicto* sentence always has an equivalent *de re* representation. This holds also for our *de dicto* rendering of reading B in (40). This means then that in the present system we have an alternative way of representing Heim's ambiguity solely in terms of different index resolutions. Our ambiguous sentence could receive one and only one *de re* representation as in (43).

(43)   a.   John knows the capital that Fred knows.
        b. $\exists y_0(y_0 = \iota x_1(Px_1 \wedge K_f(\uparrow_2 x_1)) \wedge K_j(\uparrow_3 y_0))$

The readings A and B would then be obtained by assuming the resolutions in (44) and (45) respectively:

(44)   Reading A:

        a. $0, 1$ → *the capital of Germany, the capital of Italy,* ...
        b. $2, 3$ → *Berlin, Rome,* ...

(45)   Reading B:

        a. 0 must include *the capital that Fred knows*;
        b. $1, 3$ → *the capital of Germany, the capital of Italy,* ...
        c. 2 → *Berlin, Rome,* ...

   Note however, that a *de re* representation of reading B is more costly than our *de dicto* alternative in (40) in that it involves a third conceptual cover as value of $\wp(0)$, a cover containing the concept *the capital Fred knows*.

   A purely pragmatic account of Heim's ambiguity along these lines has been proposed by Schwager (2007), although her formalization is quite different from the one I present here. In order to fully evaluate a structural or a pragmatic account, we probably will need to have a closer look at various disambiguated variants of (43):

(46)   a.   John knows the capital Fred does.
        b.   John knows the same capital Fred knows.
        c.   John knows the capital Fred knows too.

Example (46)-a is from Harris (2007). Examples (46)-b and c are attributed to Irene Heim in Schwager (2007). In all three cases in (46) only reading A

survives. A structural account to the ambiguity might be better equipped to account for these facts than a purely pragmatic account. A full analysis however must be left to another occasion.

4   Two observations and their exceptions

Section 2 of the present article accounted for the variability of interpretation of questions and their answers by relativizing their evaluation to contextually selected method of identification. The previous section applied the same theory to the case of concealed questions. Greenberg (1977), however, observed that CQ interpretations are typically not ambiguous in the way their question paraphrases are. Consider the following CQ with its question paraphrase:

(47)   a.   Officer Hopkins found out the murderer of Smith.
        b.   Officer Hopkins found out who the murderer of Smith was.

Both (47)-a and (47)-b can be interpreted as (48)-a, but, as Greenberg observed, only the full embedded question version (47)-b enjoys also reading (48)-b, where an identifying property or fact is enough to resolve the embedded question.

(48)   a.   Officer Hopkins resolved the question of who murdered Smith by identifying the individual.
        b.   Officer Hopkins resolved the question of who murdered Smith by finding out some essential facts (e.g. that he was his brother) about the individual denoted by *the murderer of Smith*.

To capture this fact about CQs, in most existing analyses, sentence (47)-a is interpreted as requiring that one and the same individual is the murderer of Smith in each world in Officer Hopkins' belief state. This is the standard way of modeling identification. For a term t to be identified by a subject a, t has to denote one and the same individual in all of a's doxastic alternatives (Hintikka 1969).

In this framework, we could follow the same strategy and account for Greenberg's observation by fixing as value of n, in our type-shift operation $\uparrow_n$, the rigid cover $RC = \{\lambda w\, d \mid d \in D\}$. Note that if we adopted $\uparrow_{RC}$, still conceptual covers could play a crucial role to account for quantified CQs like those in (24), which, as we saw, involved quantification under a perspective. We will not follow this strategy though and in the following paragraphs I will briefly explain why.

First of all, if we assumed $\uparrow_{RC}$, we would lose our perspicuous representation Heim's ambiguity. Reading B of a sentence like *John knows the capital Fred knows* typically involves identification by the non-rigid cover {*the capital of Germany, the capital of Italy,...*}. Indeed all previous theo-

ries that define identification in terms of rigidity fail to account for reading B of Heim's sentence.

Secondly, as various double vision or mistaken identity puzzles show, identification is always relative to a perspective (e.g. Quine's (1953, 1956) *Tully/Cicero* or *Ortcutt* situations, but also our initial card scenario). An analysis of identification in terms of rigidity would fail to account for these situations. As an illustration involving a CQ, consider the following example from Schwager (2007, p. 3):

(49)   **scenario** John gives you a name and address of Dr. Maria Bloom (the individual DMB) who is indeed a doctor who can help you. That same night, John and DMB happen to be at the same party and she is introduced to him as 'Mary'. They start chatting and, since she is a spare-time semanticist, she starts explaining to him some classical puzzles of mistaken identity. John is very fascinated and ends up thinking she must be some sort of philosopher (or maybe, philologist?), but certainly not a doctor.

Intuitively both (50)-a and (50)-b can be understood as true in the given scenario.

(50)   a.   John knows a doctor who can help you.
        b.   John thinks his interlocutor is not a doctor.

As Schwager observes, on a rigid account of CQs (e.g. Frana 2006 and Nathan 2005), (50)-a entails that there is one and the same individual, DMB, who is a doctor who can help you in all of John's doxastic alternatives. But then since DMB is also John's interlocutor, (50)-b is incorrectly predicted to be false in this situation by these theories.

Schwager's theory, instead, which uses conceptual covers, avoids this problem, as well as the present analysis. On these two accounts, identification by name and demonstrative identification can be represented by two different conceptual covers. For example, the rigid cover RC can be used for demonstrative identification, and the non-rigid cover $NC = \{\lambda w[\text{Maria Bloom}]_w,... \}$ for naming (in an epistemic setting it is most natural to treat names as non-rigid designators, cf. Hintikka 1975). Sentence (50)-a then, naturally interpreted under naming, can be compatible with (50)-b, interpreted under demonstrative identification. But then adopting $\uparrow_{RC}$ would not be adequate to account for this situation.

To capture Schwager's mistaken identity example, but, at the same time, account for Greenberg's observation, we could then assume $\uparrow_{RC/NC}$, rather then $\uparrow_{RC}$. CQs would then require identification by ostension or by name. Identifications by description would be ruled out in this account, in accordance to Greenberg's observation. Reading B of Heim's example would have then to be explained on a different level (e.g. as in Romero 2005).

Harris (2007), however, discusses various examples of CQs involving identification by description, rather than acquaintance or naming, showing that given the right context many exceptions to Greenberg's observation can be found. Here is one of his convincing examples (Harris 2007, p. 18):

(51)   **scenario** John is a statistician researching management trends in professional or academic organizations. He discovers that the person elected president of the LSA is always the person who has published the most articles in *Language* the year before. Perhaps this fact is merely an odd anomaly. Perhaps it is stated as such in the by-laws of the organization. In any event, interpreting (a) as (b) is perfectly felicitous in this situation:
    a.   John predicted/guessed/recalled the president of LSA.
    b.   John predicted/guessed/recalled it is the linguist with the most articles published in *Language*.

Examples like (51) constituted the main motivation for our choice to leave the resolution of n to pragmatics in our definition of $\uparrow_n$. Romero (2005, 2006), however, discusses a potential problem arising for such a pragmatic approach. On a pragmatic account, when placed in the right context, we should be able to interpret *Rome* in (52) as a concealed question. But, as Romero observed, 'this is contrary to fact: no matter how much one plays with the context, (52) does not have a CQ reading' [Romero, 2006, example (12)].

(52)   #John knows$_{CQ}$ Rome.

To further support her argument Romero also mentions that in languages like Spanish in which, contrary to English, epistemic *know* and acquaintance *know* are lexically distinct the epistemic, or CQ, version of (52) is simply ungrammatical:

(53)   a. #Juan sabe Roma.
    b.   'John knows$_{CQ}$ Rome'

The following example however shows that again given the right context exceptions to Romero's observation can be found.[4] Suppose you are given the list of world capitals in (54) and you are asked to say which state each city is the capital of:

(54)   Rome, Naypyidaw, Mbabane, Ouagadougou.

In this situation I could say in Italian:

(55)   a.   So solo Roma.

---

[4]Other examples of this type have been brought to my attention by Paul Dekker (p.c.).

       b.   'I know$_{\text{CQ}}$ only Rome'

Italian *sapere*, like Spanish *saber* only has the CQ reading (cf. footnote 2). Example (55) then shows that given the right context even proper names could have a CQ interpretation, an exception to Romero's observation.

This last example, again, can only be tackled if we let the value of n in $\uparrow_n$ be pragmatically supplied, as has been proposed in the previous section. Of course, still, CQs are ordinarily interpreted as requiring identification by name, and cases like (55) are very marginal. A theory of how covers are contextually selected is urgently needed to account for these facts, but unfortunately such a theory must be left to another occasion (see Aloni 2005b, and Schwager 2007 for a first attempt).

5 Conclusion

A domain of individuals can be observed from many different angles. The first part of this article presented a theory in which these different ways of identifying objects are represented and their impact on our interpretation of (embedded) questions is accounted for.

In the second part, the same theory has been used to account for the meaning of concealed questions. In this proposal, the interpretation of a concealed question results from the application of a type-shifting operation mapping an individual denoting expression into an identity question interpreted relative to a contextually selected identification method.

The most urgent question that needs to be addressed now is how different identification methods are selected on different occasions. Another issue that deserves further investigation concerns the disappearance of reading B in elliptical or other variants of Heim's sentences (see examples in (46)). Other empirical properties of CQs that have not been discussed yet include their link with relational nouns, and the fact that not all question-embedding verbs can embed concealed questions contrary to what the present analysis predicts (Mary knows/# wonders the capital of Italy). But again, an explanation of these facts must be left to another occasion.

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