It is argued, contra Beck and Rullmann (1999), and with Heim (1994), that the sources of strongly exhaustive interpretations and ‘de dicto’ interpretations of wh-complements of veridical question-embedding verbs are one and the same. Beck and Rullmann’s theory is shown to predict certain ‘de dicto’ readings which do not exist, while a particular rendition of Heim’s theory is shown to constrain the generation of ‘de dicto’ readings in the correct way.

1. **Introduction**

This paper observes, based on intuitions regarding sentences with various question-embedding verbs, that non-veridical question-embedding verbs support distinct ‘de re’ and ‘de dicto’ readings of their embedded wh-questions, while veridical question-embedding verbs\(^1\) support such distinct readings only if they are lexically marked as strongly exhaustive. I show that this observation is accounted for by Heim (1994), where it is implied that ‘de dicto’ readings of complements of veridical verbs have the same source as strongly exhaustive readings. I further show that the observation is not accounted for by Beck and Rullmann (1999), where it is argued that Strong Exhaustivity and ‘de dicto’ readings always have distinct sources.

\(^{1}\) By ‘veridical question-embedding verb’ I mean, roughly, “a question-embedding verb whose semantics requires the truth of the answer to the embedded question in the world(s) where the local clause containing the verb is evaluated.” By ‘non-veridical question-embedding verb’ I mean “a question-embedding verb whose semantics does not require the truth of the answer to the embedded question . . .”. This use of the term ‘(non-)veridical’ should not be confused with the use made in, for example, Giannakidou (1999). I refrain from using the alternative term ‘(non-)factive’, because it is usually used in the literature to refer to verbs that take declarative complements. So, for example, *tell* is non-factive when it takes a declarative complement, and veridical when it takes an interrogative complement (cf. Lahiri 2002).
2. THE PROBLEM OF STRONG EXHAUSTIVITY AND ‘DE DICTO’ READINGS

Karttunen’s (1977) sets-of-propositions approach to constituent questions was criticized by Groenendijk and Stokhof (1982, 1984; henceforth G&S) as not being fine-grained enough. In particular, G&S showed that Karttunen’s theory couldn’t account for Strong Exhaustivity of *wh*-questions on the one hand, and for ‘de dicto’ readings of *which*-questions on the other hand. Heim (1994) notes with respect to Strong Exhaustivity that whereas G&S’s own theory makes the right predictions for verbs such as *know*, it predicts truth conditions that are too strong for verbs such as *surprise*, for which Karttunen’s theory makes the right predictions. Heim’s own proposal can be seen as an attempt to preserve the good insights of both approaches. In this section we examine Karttunen’s theory and G&S’s criticism of it. Section 3 discusses G&S’s proposal and Heim’s response to both Karttunen and G&S.

The term Strong Exhaustivity refers to the kind of inference illustrated in (1), where (1a,b) lead to (1c):

1. a. John knows who left.
   b. Mary and Sally left, Fred and John didn’t leave.
   ⇒ c. John knows that Mary and Sally left and that Fred and John didn’t leave.

G&S argue that this inference is intuitively valid. That is to say, if (1a) is true, John must be able to successfully divide the domain of relevant individuals into two groups: leavers and non-leavers (assuming he concedes that everyone in the domain exists). ‘Divide successfully’ means that John identifies the set of actual leavers as leavers and the set of actual non-leavers as non-leavers. G&S also argue that Karttunen’s theory doesn’t account for this inference. It accounts only for Weak Exhaustivity, exhibited by the following intuitively valid inference:

2. a. John knows who left.
   b. Mary and Sally left.
   ⇒ c. John knows that Mary and Sally left

Let us see why.

In my presentation, I refer to Karttunen’s analysis as the H/K (Hamblin/Karttunen) analysis, even though my presentation here is not entirely faithful to either Karttunen or Hamblin (1973). For one thing, in a Hamblin analysis interrogatives denote sets of possible answers, and in a Karttunen analysis they denote sets of true answers. I go by the former approach. In addition, I depart from traditional Montagovian semantics by having world variables in the object language.
H/K analysis, an interrogative clause denotes a function from possible worlds to sets of possible answers relative to a domain of relevant individuals. Accordingly, the denotations of *who left* and *which students left* are as in (3) (v and v′ are world indices, i is an individual index, and j is a proposition index; D is the domain of relevant individuals supplied by the context and W is the set of all possible worlds):³

\[
[[\text{CP}_t \lambda v [\text{IP}_t \lambda i [\text{IP}_i \lambda v'[t, i, left_v]]]]]_{\text{H/K}}^P = \text{the function f such that: (a) Dom(f) = W; (b) for all w in W, f(w)}
\]

\[
= \{p: \text{there is an } x \in D \text{ such that } p = \{w' \in W: x \text{ left in } w'\}\}
\]

Following von Stechow (1996) and others, we may assume that the complementizer \(C_j^H/K\) contributes a function from propositions to truth values (\(\lambda q[p = q]\)). It takes as its argument the proposition denoted by the “higher” IP. The wh-phrase is interpreted as a “classical” indefinite (i.e., a set of sets). It takes as its argument the property derived by abstracting over the ‘i’ index at the C’-level. The ‘j’ index (contributed by the complementizer) is abstracted over at the “lower” CP-level. The world variable of the wh-phrase is abstracted over after that.

To account for the validity of the inference in (2) (Weak Exhaustivity) in the spirit of H/K, we assume the following semantics for *know* (BEL(a)(w) is the set of possible worlds compatible with what a believes in w):

\[
(4) \text{ For any question intension (i.e., function from W to D_{\alpha,\beta,\gamma}) Q, possible world w, and individual a, } \]

\[
\text{BEL}(a)(w) \subseteq \cap\{p: p \in Q(w) \text{ and } w \in p\}; \text{ and}
\]

\[
\text{If } \{p: p \in Q(w) \text{ and } w \in p\} = \emptyset,
\]

\[
\text{BEL}(a)(w) \subseteq \{w' \in W: \{p: p \in Q(w') \text{ and } w' \in p\} = \emptyset\}
\]

In other words, if a question has indeed a true answer, to know this question is to believe the conjunction of the true answers to it. Accordingly, if Mary and Sally indeed left, then, *John knows who left* entails that he believes Mary and Sally left (\(\#\@\) = Act – the actual world):

³ My overt abstractors (i.e., the “lambdas”) are essentially like Heim and Kratzer’s (1998) movement indices, but in my system, abstractors over world variables and proposition variables are base-generated, whereas abstractors over individual variables are created as a result of movement (cf. Percus 2000).
And indeed, as G&S claim, the H/K approach cannot account for the inference in (1). John is not required by this approach to successfully divide the domain into leavers and non-leavers. He is only required to believe of the actual leavers that they left. In other words, this approach does not account for the fact that if John knows who left is true, then so is John knows who didn’t leave.

G&S’s second criticism has to do with ‘de dicto’ readings of which-questions. They argue that if Mary and Sally are the students who left, and John knows that they left but he doesn’t know that they are students, then there is a sense in which John knows which students left is true, but there is also a sense in which it is false. They locate the ambiguity in the interpretation of the which-phrase. On the ‘de re’ interpretation of the which-phrase, the sentence is true, but on its ‘de dicto’ interpretation, the sentence is false. So if we point at students Mary and Sally and ask John “Did these individuals leave?”, he would correctly say “Yes.” In this sense, John knows which students left is true. But if we ask him “Which students left?”, he may say “I don’t know” or “Fred and Sam” (if he happens to falsely believe of Fred and Sam that they are students who left). In that sense, John knows which students left is false. G&S observe that the H/K semantics only accounts for the former fact:

(6) \[ [\text{John knows}_D \text{ which students } C^D \text{ left}]^P = 1 \]
iff \( \text{BEL(John)}(\text{Act}) \subseteq \cap \{p: p \in [\text{who } C^D \text{ left}]^P(\text{Act}) \text{ and } \text{Act} \in p\} \)
iff \( \text{BEL(John)}(\text{Act}) \subseteq \{w \in W: \text{Mary and Sally left in } w\} \)

Under the H/K analysis, the relevant leavers are students in the actual world, but not necessarily in the worlds compatible with what John believes. So the fact that John knows which students left has a false reading, in the scenario described above, remains unexplained.

Does John knows which students left intuitively entail John knows which students didn’t leave? The answer is Yes only when the which-phrase is interpreted ‘de re’. That is to say, if we say John knows which students left with a ‘de re’ meaning in mind, we require John to be able to successfully divide the set of actual students into leavers and non-leavers (without necessarily implying that he is aware of their student status). It
does intuitively follow, then, that John knows which of the actual students didn’t leave. However, if we utter the same sentence with a ‘de dicto’ meaning in mind, we require John to be able to identify the set of actual student leavers as student leavers and to identify all the others as non–student-leavers. Within the latter set, he is not required to make any distinctions (e.g., he doesn’t need to know who is a non-student or who is a non-leaver). So it does not intuitively follow, in this case, that he knows which individuals are students who didn’t leave. The judgments are subtle, but I believe that this description of the facts is correct.

Notice, in this connection, that when we say that John knows who left entails John knows who didn’t leave, this holds only if who is interpreted ‘de re’. So if we say John knows who left without implying that he is aware of the person status of the leavers, we imply that John can successfully divide the set of relevant persons into leavers and non-leavers. If we have a ‘de dicto’ meaning in mind, he need not know which individuals are persons who didn’t leave (he need only know who is a non–person-leaver). For simplicity (and because we normally know who is a person and who is not), I treat all who-questions as ‘de re’ questions and all which-questions as ambiguous, but the reader should bear in mind that who-questions are, potentially, just as ambiguous.

The next section briefly outlines G&S’s solution to the problems they observed, and Heim’s response to this solution.


G&S show that if we abandon the view that the basic denotation of an interrogative is that of a function from worlds to sets of propositions, and instead adopt their view that it is a function from worlds to propositions, we solve both the problem of Strong Exhaustivity and the problem of ‘de dicto’ readings of which-questions. The interpretation of who left and the two interpretations of which students left (‘de re’ and ‘de dicto’) in the spirit of G&S are these:

\[
\text{[[}_C^\text{CR} \lambda v [_{_{_C^\text{CR}}} [\lambda \nu'''[\text{who}]]C^_{G&S} \{_{_{_C^\text{I}}} \lambda \nu \nu' \lambda i[t, \text{left}, i]\}]_{_{_{_C^\text{CR}}}}} = \text{the function } f \text{ such that: (a) } \text{Dom}(f) = W; \text{ (b) For all } w \in W, f(w) = \{w' \in W; \{x \in D; x \text{ left in } w\} = \{x \in D; x \text{ left in } w'\}\}
\]

\[
\text{[[}_C^\text{CR} \lambda v [_{_{_C^\text{CR}}} [\lambda \nu'''[\text{which students}]]C^_{G&S} \{_{_{_C^\text{I}}} \lambda \nu \nu' \lambda i[t, \text{left}, i]\}]_{_{_{_C^\text{CR}}}}} = \text{the function } f \text{ such that: (a) } \text{Dom}(f) = W; \text{ (b) For all } w \in W, f(w) = \{w' \in W; \{x \in D; x \text{ is a student in } w\} = \{x \in D; x \text{ is a student in } w'\}\}
\]

(‘de re’)
\[
\llbracket [\lambda v [\lambda v'[\text{which students}_v]] \ C_v^{\text{G\&S}} [\nu \lambda v'[\exists t \ (\text{left}_t)]]]]^D =
\]
the function \(f\) such that: (a) \(\text{Dom}(f) = W\); (b) For all \(w\) in \(W\), \(f(w) = \{w' \in W: \{x \in D: x \text{ is a student in } w \text{ and } x \text{ left in } w\} = \{x \in D: x \text{ is a student in } w' \text{ and } x \text{ left in } w'\}\) (*de dicto*)

To derive these interpretations compositionally, let us assume that the complementizer \(C_v^{\text{G\&S}}\) takes two property arguments and one world argument \((\lambda P \lambda P'[\exists v (P(v) \cap P'(v') = P(v') \cap P'(v'))]\)). The two property arguments are supplied by the IP and the wh-phrase (assume that wh-phrases denote properties). The ‘de re’ reading of \text{which students left} is obtained if the world argument of \text{which students} matches the world index of the complementizer, and the ‘de dicto’ reading is obtained if the world argument of \text{which students} is bound by the closest lambda operator.

Assume now the following semantics for \text{know}:

(8) For any question intension (i.e., function from \(W\) to \(D_{\text{s,t}}\)) \(P\), individual \(a\), and possible world \(w\), \(\llbracket \text{know}_{\text{G\&S}}(w)(P)(a) = 1 \text{ iff } \text{BEL}(a)(w) \subseteq P(w)\).

Strong Exhaustivity is now accounted for. That is to say, inferences of the (1)-variety are predicted:

(9) \(\llbracket \text{John knows}_{\text{G\&S}} \lambda v'[\text{who}_v \ C_v^{\text{G\&S}} \text{left}]^D = 1 \text{ iff } \text{BEL}(\text{John})(\text{Act}) \subseteq \{w \in W: \{x \in D: x \text{ left in } \text{Act}\} = \{x \in D: x \text{ left in } w\}\}

For \text{John knows who left} to be true it is not enough that John believe of the actual leavers that they left. He has to be capable of successfully dividing the domain into leavers and non-leavers (in the event that some non-leaver doesn’t exist for John, he still has to believe that no one besides the actual leavers left). If \text{John knows which students left} is interpreted ‘de re’, John has to be capable of successfully dividing the set of actual students into leavers and non-leavers (without necessarily being aware of their student status). This is also accounted for:

(10) \(\llbracket \text{John knows}_{\text{G\&S}} \lambda v'[\lambda v'[\text{which students}_v]] \ C_v^{\text{G\&S}} \text{left}]^D = 1 \text{ iff } \text{BEL}(\text{John})(\text{Act}) \subseteq \{w \in W: \{x \in D: x \text{ is a student in } \text{Act and } x \text{ left in } \text{Act}\} = \{x \in D: x \text{ is a student in } \text{Act and } x \text{ left in } w\}\)

\(^4\) This is different from G\&S’s compositional derivation, but the differences are not relevant to the issues under discussion.
The ‘de dicto’ reading of John knows which students left is now also accounted for. For the sentence to be true on its ‘de dicto’ reading, John must be able to successfully divide the domain into student leavers and non–student-leavers. He need not be able to divide the latter group any further (in particular, he need not distinguish between leavers who are not students and students who are not leavers):

\[
\text{BEL(John)(Act) } \subseteq \{ w \in W : \{ x \in D : x \text{ is a student in Act and } x \text{ left in Act} \} = \{ x \in D : x \text{ is a student in w and x left in w} \}\]
\]

Thus, it seems that the assumption that the basic denotation of an interrogative clause is a function from worlds to propositions has two obvious advantages over the assumption that it is a function from possible worlds to sets of propositions.

In Heim (1994), it is argued that the G&S semantics does not make the right predictions for all question-taking verbs. In particular, while Heim agrees that know induces Strong Exhaustivity (i.e., inferences of the (1)-variety), she expresses serious doubts that this is also true of surprise (cf. Berman 1991; Lahiri 1991). That surprise is not strongly exhaustive is illustrated by the well-formedness of the following example:

\[
\text{It surprised Bill who came to the party, but it didn’t surprise him who didn’t come.}
\]

This can be uttered felicitously if Jack and Jill came to the party, and Bill didn’t expect them to but came to realize that they did. As for Robert and Sue, who didn’t actually come, Bill had no expectations at all regarding their coming or not coming to the party and learned that they didn’t. It turns out that in this case it is precisely the H/K semantics, and crucially not the G&S semantics, that makes the right predictions. Assume that surprise has the simplified H/K semantics in (13), and the simplified G&S semantics in (14). NONEXP(a) is the complement set of the set of worlds compatible with a’s expectations, Q is a H/K question intension, and P is a G&S question intension.

\[
\text{NONEXP(a)}(w) = \{ p : p \in Q(w) \text{ and } w \in p\}
\]

\[
\text{NONEXP(a)}(w) = \{ p : p \in P(w)\}
\]

\[
\text{NONEXP(a)}(w) = \{ p : p \in Q(w) \text{ and } w \in p\}
\]

\[
\text{NONEXP(a)}(w) = \{ p : p \in P(w)\}
\]

\[
\text{NONEXP(a)}(w) = \{ p : p \in Q(w) \text{ and } w \in p\}
\]

\[
\text{NONEXP(a)}(w) = \{ p : p \in P(w)\}
\]

The “real” semantics for surprise probably involves ranking among worlds compatible with the subject’s expectations.
Thus, we obtain the truth conditions for \textit{It surprised John who came} and \textit{It didn’t surprise John who didn’t come} H/K-style as in (15) and G&S-style as in (16):\footnote{One might be tempted to account for the semantics of \textit{surprise} by claiming that it takes exclamative complements. While this may be plausible in certain cases, I don’t think it is in the examples we are discussing, where the complement of \textit{surprise} seems to be a genuine semantic question (see Lahiri (1991) and Huddleston (1993) for further discussion).}

\begin{enumerate}[a.]
\item \textit{It surprised}\textsubscript{H/K} John who \textit{C}\textsubscript{H/K} came\textsubscript{H/K} = 1 iff NONEXP(John)\textsubscript{A} \sqcap \{p: \text{there is an } x \in D \text{ such that } p = \{w \in W: x \text{ came in } w\} \text{ and } \text{Act} \in p\}\textsubscript{A} \tag{15a} \\
\item \textit{It didn’t surprise}\textsubscript{H/K} John who \textit{C}\textsubscript{H/K} didn’t come\textsubscript{H/K} = 1 iff NONEXP(John)(\text{Act}) \not\sqcap \{p: \text{there is an } x \in D \text{ such that } p = \{w \in W: x \text{ didn’t come in } w\} \text{ and } \text{Act} \in p\}\textsubscript{A} \tag{15b}
\end{enumerate}

\begin{enumerate}[a.]
\item \textit{It surprised}\textsubscript{G&S} John who \textit{C}\textsubscript{G&S} came\textsubscript{G&S} = 1 iff NONEXP(John)\textsubscript{A} \{w \in W: \{x \in D: x \text{ came in } \text{Act}\} = \{x \in D: x \text{ came in } w\}\textsubscript{A}\} \tag{16a} \\
\item \textit{It didn’t surprise}\textsubscript{G&S} John who \textit{C}\textsubscript{G&S} didn’t come\textsubscript{G&S} = 1 iff NONEXP(John)(\text{Act}) \not\{w \in W: \{x \in D: x \text{ didn’t come in } \text{Act}\} = \{x \in D: x \text{ didn’t come in } w\}\textsubscript{A}\} \tag{16b}
\end{enumerate}

(15a, b) are not contradictory; but (16a, b) are, at least whenever everyone in D exists both in Act and in the worlds compatible with John’s expectations in Act.

Given this, Heim proposes a theory that aims to preserve the good implications of H/K (that some verbs are weakly exhaustive) and of G&S (that some verbs are strongly exhaustive) in the following way. Let us define two Answerhood operators, weak and strong, which apply to a H/K question intension.\footnote{Heim uses ‘Ans1’ for ANS-weak, and ‘Ans2’ for ANS-strong. I follow Sharvit and Beck (2001), who renamed the operators for convenience. In addition, Heim treats the basic question intension as the set of true answers, but this difference is irrelevant to the current discussion.}

\begin{align*}
\text{ANS-weak}(Q)(w) &= \cap \{p: p \in Q(w) \text{ and } w \in p\} \\
\text{ANS-strong}(Q)(w) &= \{w' \in W: \text{ANS-weak}(Q)(w) = \text{ANS-weak}(Q)(w')\}
\end{align*}

The lexical semantics of each question-embedding verb will decide which operator is relevant for that verb. In particular, the semantics of \textit{know} refers to ANS-strong, and the semantics of \textit{surprise} refers to ANS-weak.

Let us now be slightly more precise about the semantics of \textit{surprise}, and assume that the world argument also encodes temporality:
As Heim shows (see Heim (1994) for the formal proof), since ANS-strong effectively replicates the results of G&S (but see section 4), we predict that John knows who left entails that John knows who didn’t leave, as desired:

\[
[\text{John knows}_w \text{ who left}_W] = 1 \text{ iff } \text{BEL(John)}(\text{Act}) \subseteq \{w \in W : \cap\{p: \text{there is an } x \in D \text{ such that } p = \{w' \in W: x \text{ left in } w'\} \text{ and } w \in p\} \cap \{p: \text{there is an } x \in D \text{ such that } p = \{w' \in W: x \text{ left in } w'\} \text{ and } \text{Act} \in p\}\}.
\]

Thus, John is correctly required to be able to successfully divide the domain into leavers and non-leavers. Notice that Heim assumes that for any two distinct individuals there is a world where one leaves and the other doesn’t. This assumption will be shown to be crucial in the next section. Turning to surprise, we get the following “weak” – H/K-style – interpretation for
\[
[\text{It surprised}_w \text{ who left}_W] = 1 \text{ iff for any relevant past world } w' \in W \text{ before Act, NONEXP(John)(w') } \supseteq \{p: \text{there is an } x \in D \text{ such that } p = \{w' \in W : x \text{ left in } w'\} \text{ and Act } \in p\} \text{, and for any relevant future world } w'' \in W \text{ at or after Act, BEL(John)(w'') } \subseteq \{p: \text{there is an } x \in D \text{ such that } p = \{w' \in W : x \text{ left in } w'\} \text{ and } \text{Act} \in p\}.
\]

This is a “weak” interpretation because John can be surprised by the leavers and unsurprised by the non-leavers.

In addition, the ‘de re’/‘de dicto’ ambiguity of John knows which students left is also predicted. If we interpret the wh-phrase ‘de re’ (i.e., if we coindex students with the world index of the embedding predicate), we will get the ‘de re’ reading by applying ANS-strong to the ‘de re’ H/K question intension. If we interpret it ‘de dicto’, we will get the ‘de dicto’ reading by applying ANS-strong to the ‘de dicto’ H/K question intension:

---

8 Heim, who like Karttunen doesn’t assume explicit world variables in the object language (with free indexing of world arguments of nouns), would probably generate ‘de re’ readings by moving the wh-restriction above the embedding verb and interpreting it as a set. This difference between Heim’s (1994) system and mine is immaterial to the current discussion.
(21) 

‘de re’: \( \text{[John knows } \lambda v \ldots \text{ which students left]} \)\(^P\) = 1 
iff \( \text{BEL(John)(Act)} \subseteq \text{ANS-strong([} \lambda v \ldots \text{ which students left]} \)\(^P\))(Act) 
iff \( \text{BEL(John)(Act)} \subseteq \{ w \in W: \cap \{ p: \text{there is an } x \in D \text{ such that } x \text{ is a student in Act and } p = \{ w' \in W: x \text{ left in } w' \} \text{ and } w \in p \} = \cap \{ p: \text{there is an } x \in D \text{ such that } x \text{ is a student in Act and } p = \{ w' \in W: x \text{ left in } w' \} \text{ and } Act \in p \} \} \)

‘de dicto’: \( \text{[John knows } \lambda v \ldots \text{ which students left]} \)\(^D\) = 1 
iff \( \text{BEL(John)(Act)} \subseteq \text{ANS-strong([} \lambda v \ldots \text{ which students left]} \)\(^D\))(Act) 
iff \( \text{BEL(John)(Act)} \subseteq \{ w \in W: \cap \{ p: \text{there is an } x \in D \text{ such that } x \text{ is a student in Act and } p = \{ w' \in W: x \text{ left in } w' \} \text{ and } w \in p \} = \cap \{ p: \text{there is an } x \in D \text{ such that } x \text{ is a student in Act and } p = \{ w' \in W: x \text{ left in } w' \} \text{ and } Act \in p \} \} \)

Under the ‘de dicto’ reading, ‘x’ has to be a student in the worlds compatible with what John believes. Thus, we preserve the good insights from both theories.

Notice that Heim’s proposal makes an additional prediction – one that she herself doesn’t explicitly acknowledge: weakly exhaustive veridical verbs (e.g., surprise) do not give rise to ‘de dicto’ readings. This prediction is made as follows: since ANS-strong is the source of both Strong Exhaustivity (i.e. inferences of the (1)-variety) and of ‘de dicto’ readings in veridical environments (e.g., (21)), any veridical verb whose semantics does not make reference to ANS-strong exhibits neither Strong Exhaustivity nor a ‘de dicto’ interpretation. For example:

(22) \( \text{[It surprised}_w \text{ John } \lambda v \ldots \text{ which students left]} \)\(^P\) = 1 
iff for any relevant past world w in W before Act, NONEXP(John)(w) \( \supseteq \) ANS-weak([\( \lambda v \ldots \text{ which students left]} \)\(^P\))(Act), and for any relevant future world w’ in W after Act, BEL(John)(w’) \( \subseteq \) ANS-weak([\( \lambda v \ldots \text{ which students left]} \)\(^P\))(Act).

Since surprise is both veridical and weakly exhaustive, its semantics “wants” the value of ANS-weak in the actual world (not the value of ANS-strong, and not the value of ANS-weak in some world other than the actual world). The value of ANS-weak in the actual world is the same whether we apply it to the ‘de re’ version of which students left or to its ‘de dicto’ version. In (22), that value is \( \cap \{ p: \text{there is an } x \in D \text{ such that } x \text{ is a student in Act and } p = \{ w \in W: x \text{ left in } w \} \text{ and } Act \in p \} \), where ‘x’ is required to
be a student in the actual world. This means that we obtain a ‘de re’ reading regardless of how students is indexed.

I will argue in section 5 that this additional prediction of Heim’s is supported by speakers’ intuitions. Veridical weakly exhaustive verbs do not support genuine ‘de dicto’ readings of which-questions. But let us first look at Beck and Rullmann’s response to Heim.


Beck and Rullmann (henceforth, B&R) claim that Strong Exhaustivity and ‘de dicto’ readings of which-questions – regardless of what kind of verb they are embedded under – do not have the same source. This is incompatible with what is implied by Heim, namely, that Strong Exhaustivity has the same source as ‘de dicto’ readings of which-questions in veridical environments.

B&R agree with Heim that the grammar provides both ANS-weak and ANS-strong, and that certain verbs go with (or tend to go with) one whereas other verbs go with the other. So they agree with her that ANS-strong is the source of Strong Exhaustivity (i.e., inferences of the (1)-variety). However, they argue that ANS-strong is never the source of ‘de dicto’ readings. To account for the ‘de dicto’/‘de re’ distinction, they adopt an idea that goes back to Hamblin (1973), according to which the noun part of the which-phrase is reconstructed in its base position at LF. Combined with the assumption that world arguments of nouns are freely indexed, this gives us different interpretations, ‘de re’ and ‘de dicto’, for which students left:9

\[
\begin{align*}
\text{‘de re’}: & \quad \lambda v [\ldots \text{which}_i C \lambda v' [\pi e_i \text{students}_i \text{left}_i]]] = \\
& \text{the function } f \text{ such that: (a) } \text{Dom}(f) = W; (b) \text{ For all } w \in W, \\
& f(w) = \{p: \text{ there is an } x \in D \text{ such that } p = \{w' \in W: x \text{ is a student in } w \text{ and } x \text{ left in } w'\}\}
\end{align*}
\]

\[
\begin{align*}
\text{‘de dicto’}: & \quad \lambda v [\ldots \text{which}_i C \lambda v' [\pi e_i \text{students}_i \text{left}_i]]] = \\
& \text{the function } f \text{ such that: (a) } \text{Dom}(f) = W; (b) \text{ For all } w \in W, \\
& f(w) = \{p: \text{ there is an } x \in D \text{ such that } p = \{w' \in W: x \text{ is a student in } w' \text{ and } x \text{ left in } w'\}\}
\end{align*}
\]

---

9 In Rullmann and Beck (1998), an alternative analysis is proposed, according to which the which-phrase is a reconstructed definite description. Although the two analyses are different in several crucial respects, they are the same in all respects relevant to the issues at hand.
Here, students is interpreted as part of the proposition. So when applying ANS-weak to a question intension, we will get different values depending on how students is indexed:

\[
\text{ANS-weak(} \lambda v[. \text{ which } C \lambda v' [\text{IP } e_i \text{ students}_i \text{ left}_i])] \text{p)}(\text{Act}) = \cap \{p: \text{there is an } x \in D \text{ such that } p = \{w \in W: x \text{ is a student in } \text{Act} \text{ and } x \text{ left in } w \} \text{ and } \text{Act} \in p\}
\]

The prediction is, then, that any question-embedding verb – be it veridical or non-veridical, weakly or strongly exhaustive – gives rise to ‘de dicto’ readings.

One can find in B&R two reasons to support the total separation of Strong Exhaustivity and ‘de dicto’ readings: the first is implicit, and concerns the general architecture of the grammar, and the second is explicit, and relates to what B&R believe Strong Exhaustivity to be actually “about”.

The first reason has to do with the fact that Heim’s proposal replicates G&S’s predictions regarding the ‘de dicto’ readings of, say, which students left only under the assumption that for any two distinct individuals there is a world in which one leaves and the other doesn’t (the reader is once again referred to Heim (1994) for the formal proof). For many predicates (e.g., leave), this assumption seems plausible. But for a certain class of predicates, this assumption can’t be made. The predicate live with one’s actual spouse is an example of the latter kind. Consider (25):

\[
(25) \text{John knows which students live with their actual spouses.}
\]

Suppose Bill and Sue are married to each other and are the only students who live with their actual spouses. Since the ‘live-with’ relation is symmetric, \{w \in W: \text{Bill lives in } w \text{ with his actual spouse}\} \text{ and } \{w \in W: \text{Sue lives in } w \text{ with her actual spouse}\} \text{ are identical propositions. (25) is intuitively false on its ‘de dicto’ reading, if John is pretty well informed but for the following detail: while he correctly believes that Bill is a student, he believes that Sue is not (in other words, according to him, Bill is the only student who lives with his/her actual spouse). It turns out that G&S’s analysis predicts this, but Heim’s does not. Let us start with G&S:}

\[
(26) \text{G&S’s prediction: } \text{BEL(John)(Act)} \subseteq \{w \in W: \{x \in D: x \text{ is a student in } w \text{ and } x \text{ lives in } w \text{ with } x \text{’s spouse in } \text{Act}\} = \{x \in D: x \text{ is a student in } \text{Act} \text{ and } x \text{ lives in } \text{Act with } x \text{’s spouse in } \text{Act}\}\}
\]
Given that John believes of Sue that she is not a student, \( \{ x \in D : x \text{ is a student in } w \text{ and } x \text{ lives in } w \text{ with } x\text{'s spouse in } Act \} \) contains only Bill in the members of BEL(John)(Act), but since both Bill and Sue are actual students, \( \{ x \in D : x \text{ is a student in } Act \text{ and } x \text{ lives in } Act \text{ with } x\text{'s spouse in } Act \} = \{ \text{Bill, Sue} \} \). So the two sets in (26) are not identical, and the sentence is correctly predicted to be false. Turning to Heim’s analysis, here is what it predicts:

\[
(27) \quad \text{Heim’s prediction: } \text{BEL(John)(Act)} \subseteq \{ w \in W : \cap \{ p : \text{there is an } x \in D \text{ such that } x \text{ is a student in } w \text{ and } p = \{ w' \in W : x \text{ lives in } w' \text{ with } x\text{'s spouse in } Act \} \text{ and } w \in p \} \}
\]

For any \( w \) in BEL(John)(Act), \( \cap \{ p : \text{there is an } x \in D \text{ such that } x \text{ is a student in } w \text{ and } p = \{ w' \in W : x \text{ lives in } w' \text{ with } x\text{'s spouse in } Act \} \text{ and } w \in p \} \) is identical to \( \cap \{ p : \text{there is an } x \in D \text{ such that } x \text{ is a student in } Act \text{ and } p = \{ w' \in W : x \text{ lives in } w' \text{ with } x\text{'s spouse in } Act \} \text{ and } Act \in p \} \), because ‘Bill lives with his actual spouse’ and ‘Sue lives with her actual spouse’ are identical propositions.

Such examples seem to favor the G&S analysis. But given that the set-of-propositions approach to interrogatives does a better job of distinguishing between know-type verbs and surprise-type verbs in terms of Strong Exhaustivity, Heim proposes not to go back to the G&S analysis, but rather to assume that the basic denotation of an interrogative is a set of structured propositions. Details aside, this will amount to placing the following requirement on John’s belief worlds in (25) (LIVE is the property of living with one’s actual spouse; ‘gx’ is a contextually supplied suitable individual concept which implies acquaintance between John and ‘x’ in Act, cf. Cresswell and von Stechow 1982):

\[
(28) \quad \text{BEL(John)(Act)} \subseteq \{ w \in W : \{ \langle x, P \rangle : P = \text{LIVE} \text{ and } x = g_x(Act) \text{ and } g_x(w) \text{ is a student in } w \text{ and } P(g_x(w))(w) = 1 \} = \{ \langle x, P \rangle : P = \text{LIVE} \text{ and } x = g_x(Act) \text{ and } x \text{ is a student in } Act \text{ and } P(x)(Act) = 1 \} \}
\]

This requirement correctly predicts John knows which students live with their actual spouses to be false in the situation described above, because for any belief world of John’s, the first set is \{ \langle Bill, LIVE \rangle \} and the second set is \{ \langle Bill, LIVE \rangle, \langle Sue, LIVE \rangle \}.

B&R show that the assumption that ‘de dicto’ readings arise via reconstruction of the wh-phrase, rather than via ANS-strong, has the virtue of
fully replicating G&S’s results, even with predicates of the *live with one’s actual spouse* -class (a formal proof is provided in Beck and Rullmann 1999):

\[(29) \text{B&R prediction: } \text{BEL(John)}(\text{Act}) \subseteq \{w \in W: \cap \{p: \text{there is an } x \in D \text{ such that } p = \{w' \in W: x \text{ is a student in } w' \text{ and } x \text{ lives in } w' \text{ with } x's \text{ spouse in } \text{Act}\} \text{ and } w \in p\} = \cap \{p: \text{there is an } x \in D \text{ such that } p = \{w' \in W: x \text{ is a student in } w' \text{ and } x \text{ lives in } w' \text{ with } x's \text{ spouse in } \text{Act}\} \text{ and } \text{Act} \in p\}\}

Given that in the scenario described above, John believes of Sue that she is not a student, the two sets of propositions are not the same for any belief world of John’s, and *John knows which students live with their actual spouses* is correctly predicted to be false.

I think B&R are right in trying to avoid recourse to structured propositions. However, as pointed out to me by an anonymous *NALS* reviewer, neither G&S nor B&R solve the real problem. If Bill and Sue are actual spouses, *Bill lives with his actual spouse* and *Sue lives with her actual spouse* intuitively express different things, but according to standard semantics they denote the same proposition. B&R, by replicating G&S’s predictions, deal with this problem in wh-questions by making ‘Bill is a student who lives with his actual spouse’ and ‘Sue is a student who lives with her actual spouse’, which are not identical propositions, the propositions relevant for the interpretation of *which students live with their actual spouses*. But the problem resurfaces in a scenario similar to the one described above, with one difference. Suppose that, as before, John believes Bill is the only student who lives with his/her actual spouse (when, in fact, Bill and Sue are the students who live with their actual spouses). But this time, the reason for his false belief is not that he fails to attribute to Sue the property of being a student (he correctly believes that she is a student), but that he fails to attribute to her the property of living with one’s actual spouse. If we can indeed imagine John in such a state of mind, *John knows which students live with their actual spouses* comes out false. The point is that a straightforward application of the G&S/B&R analysis cannot account for this. Moreover, whether we can legitimately view examples with predicates of the *live with one’s actual spouse* -class as representatives of everyday English is not clear to begin with. My conclusion is that these examples do not provide evidence either for or against B&R’s approach. (From now on I refrain from discussing such examples, and I do not use structured propositions in my semantic representations.)

The second reason found in B&R for the total separation of Strong Exhaustivity and ‘de dicto’ readings concerns the behavior of the non-
veridical agree (on). B&R argue that this verb is non-exhaustive, and yet it gives rise to ‘de dicto’ readings. Consider (30):

(30) John and Mary agree on which students left.

Sentence (30) is perfectly acceptable in a situation where John and Mary mistakenly believe that Professors Smith, Jones, and Brown are the students. B&R’s point is that although (30) has a ‘de dicto’ interpretation, neither it nor (31) have any interpretation that can be sensibly characterized as either weakly or strongly exhaustive:

(31) John and Mary agree on who left.

This is because, they say, agree on is a non-veridical verb, whose semantics does not “care” about the answer that is true in the actual world. ANS-strong and ANS-weak refer to actual true answers. They conclude that agree on is a non-exhaustive verb that gives rise to ‘de dicto’ readings. Hence, exhaustivity, and this includes Strong Exhaustivity, is totally independent of the availability of ‘de dicto’ readings.

I think this argumentation is misguided, and in the next section I explain why, both from a conceptual and an empirical point of view. I argue that agree on is a strongly exhaustive non-veridical verb that supports ‘de dicto’ readings. This shows that veridicality has nothing to do with exhaustivity. I also argue that weakly exhaustive veridical surprise does not support ‘de dicto’ readings. This shows that in complements of veridical verbs, the availability of ‘de dicto’ readings is linked to Strong Exhaustivity, and that it is a mistake to completely separate the sources of the two. These claims are in accordance with Heim (1994).

5. My Response to B&R

5.1. Exhaustivity Is Not Tied to Actual Answers

Before I explain my objections to B&R’s theory, let me say in what ways I agree with them. One of their main claims is that exhaustivity should be viewed as a flexible notion, influenced both by the lexical properties of the embedding verbs as well as by contextual factors. Such flexibility is indeed afforded by Heim’s ANS-weak and ANS-strong operators, and not afforded by G&S, who effectively require all verbs to be strongly exhaustive. B&R’s arguments in favor of flexible exhaustivity are, for the most part, convincing (the reader is referred to their paper for details). Moreover, I think flexible exhaustivity is further supported by the fact that strongly exhaustive verbs such as know sometimes allow weakly exhaustive inter-
pretations. For example, many speakers find the following sentence perfectly acceptable in certain contexts:

(32) I know who was admitted to the program, but I have no idea who wasn’t admitted.

This is never true of surprise, however. It seems that if a verb is lexically marked as strongly exhaustive, it can also have a weakly exhaustive semantics. But the reverse is not true: if a verb is lexically marked as weakly exhaustive, this is the only reading it can have. The following examples support this claim:

(33) John doesn’t REALLY know who left. For example, he doesn’t know that Sally didn’t leave.

(34) It didn’t REALLY surprise Bill who cheated on the exam. #For example, it didn’t surprise him that Mary didn’t cheat.

The acceptability of (33) is due to the fact that know has a strongly exhaustive semantics. The second sentence is an explication of the first: the strongly exhaustive interpretation of know requires John to be able to say about each relevant individual whether or not s/he left. Since the first sentence denies that, the second sentence makes sense. On the other hand, the oddity of the second sentence in (34) comes from the fact that surprise is strictly weakly exhaustive. Denying that whoever cheated surprised Bill cannot mean that there is one non-cheater about whom Bill isn’t surprised. The difference between the two verbs can be captured as in (35), where the semantics of know makes reference either to ANS-strong or to ANS-weak, but the semantics of surprise strictly makes reference to ANS-weak:

(35) a. \[\text{[know-weak]}(w)(Q)(a) = 1 \text{ iff } \text{BEL}(a)(w) \subseteq \text{ANS-weak}(Q)(w),\]
and if \(\text{ANS-weak}(Q)(w) = W\), \(\text{BEL}(a)(w) \subseteq \text{ANS-strong}(Q)(w)\).

b. \[\text{[know-strong]}(w)(Q)(a) = 1 \text{ if } \text{BEL}(a)(w) \subseteq \text{ANS-strong}(Q)(w).\]

c. \[\text{[surprise]}(w)(Q)(a) = 1 \text{ iff for any relevant past world } w' \in W \text{ before } w,\]
\[\text{NONEXP}(a)(w') \supseteq \text{ANS-weak}(Q)(w),\]
and for any relevant future world \(w'' \in W \text{ at or after } w, \text{BEL}(a)(w'') \subseteq \text{ANS-weak}(Q)(w).\)

The flexible approach to exhaustivity which B&R embrace goes well with the idea that know can have weakly exhaustive readings. But I think B&R take the flexibility idea too far when they say that exhaustivity and ‘de dicto’
readings should be completely separated. As we saw above, they argue that *agree on* is a non-exhaustive verb that supports ‘de dicto’ readings. While I agree with B&R that the semantics of *agree on* doesn’t refer to actual true answers, I disagree with them that it is non-exhaustive. Moreover, I think it is strongly exhaustive.

Unlike B&R, I do not think that exhaustivity is about actual true answers. One could restrict exhaustivity in such a way if one wanted to, using a principle such as this:

\[(36) \text{ For any question-embedding verb } V, \text{ NP, interrogative } \alpha, \text{ and world } w, \llbracket NP V \alpha \rrbracket(w) \text{ is defined in terms of ANS-strong/weak only if } V \text{ is veridical.} \]

But I don’t see what insights into our intuitions are to be gained from such a principle. In particular, I disagree with B&R’s claim that there is no sensible way to characterize any reading of, say, (30) and (31) as strongly exhaustive, just because *agree on* is a non-veridical verb (see Lahiri (2002) for a similar point regarding *certain*). Veridicality is not a prerequisite for exhaustivity. Consider the relevant example again:

\[(37) \text{ John and Mary agree on who left.} \]

This sentence has a reading according to which John and Mary have the same three sets in mind: the first set consists of those individuals who left (according to John and Mary’s beliefs), the second set consists of those individuals who didn’t leave (according to John and Mary’s beliefs), and the third set consists of those individuals regarding which they have no opinion. In other words, there is a subset of the domain that John and Mary divide into the same sets of leavers and non-leavers. This should remind us of the strongly exhaustive nature of *know*. If you know who left, you can point at the individuals who left and at those who didn’t leave. If we were to say that *know* is strongly exhaustive and *agree on* is non-exhaustive, we would miss the observation that, despite the fact that the former is veridical and the latter is not, their meanings have in common the property we just described. I suggest, therefore, that a verb is strongly exhaustive if its semantics makes reference to ANS-strong. Both *know* and *agree on* make reference to ANS-strong in their semantics.

The puzzling fact about B&R’s discussion of *agree on* is that the semantics that they propose does, in fact, predict the strongly exhaustive reading (A is a plurality of individuals):
\[\text{agree on}^{B&R}(Q)(w)(A) = 1 \text{ iff (a) for all } x \text{ in } A, \text{ for all } p \text{ in } Q(w), \text{ if } x \text{ believes in } w \text{ that } p \text{ is true, then for any } y \text{ in } A, y \text{ believes in } w \text{ that } p \text{ is true; and (b) for all } x \text{ in } A, \text{ for all } p \text{ in } Q(w), \text{ if } x \text{ believes in } w \text{ that } p \text{ is false, then for any } y \text{ in } A, y \text{ believes in } w \text{ that } p \text{ is false.}\]

\[(Recall \text{ that for } B&R, Q(w) \text{ is a set of propositions with the “reconstructed” wh-phrase. For example, the extension of which students left is } \{p: \text{ there is an } x \text{ in } D \text{ such that } p = \{w' \in W: x \text{ is a student in } w/w' \text{ and } x \text{ left in } w'\}\}. B&R \text{ do not acknowledge that the semantics they propose for agree on is a strongly exhaustive semantics. But it is! We can rewrite this semantics using ANS-strong, as follows. (Remember that we do not assume reconstruction of the wh-phrase. For us, the extension of which students left in } w \text{ is } \{p: \text{there is an } x \text{ in } D \text{ such that student}(w)(x) \& p = \{w' \in W: x \text{ left in } w'\}\}).\]

\[\text{[Agree on – strong]}^{\text{ANS}}(w)(Q)(A) = 1 \text{ iff the following holds. Let } f \text{ be the function such that: (i) } \text{Dom}(f) \text{ is the powerset of } D, \text{ (ii) } f(D) = Q, \text{ and (iii) there is a pair of properties } \langle P_1, P_2 \rangle \text{ such that for all } X \text{ in } \text{Dom}(f), f(X) \text{ is the function } f' \text{ such that } \text{Dom}(f') = W, \text{ and for all } w' \text{ in } W, f'(w') = \{p: \text{there is an } x \text{ in } X \text{ such that } P_1(x)(w') = 1 \text{ and } p = \{w'' \in W: P_2(x)(w'') = 1\}\}. \text{ Then there is a set } D', D' \subseteq D, \text{ such that:}\]

\[\text{a. there is a world } w' \text{ such that for all } x \text{ in } A, \text{BEL}(x)(w) \subseteq \text{ANS}(f(D'))(w'); \text{ and}\]

\[\text{b. there is no } D'', D' \subset D'' \subseteq D, \text{ such that for some } y \text{ in } A \text{ there is a world } w'' \text{ such that } \text{BEL}(y)(w) \subseteq \text{ANS}(f(D''))(w'').\]

Let us illustrate how the semantics of agree on – strong works for John and Mary agree on who left. The function that corresponds to f is this:

\[f: \text{Dom}(f) \text{ is the powerset of } D, \text{ and for all } X \text{ in } \text{Dom}(f), f(X) = \text{the function } f' \text{ such that } \text{Dom}(f') = W, \text{ and for all } w \text{ in } W, f'(w) = \{p: \text{there is an } x \text{ in } X \text{ such that } p = \{w' \in W: x \text{ left in } w'\}\}.\]

Suppose we ask John and Mary individually to divide the domain into those who left and those who didn’t leave. D’, in this case, is the largest subset of the domain which John and Mary carve into the same two sets of leavers.
and non-leavers, and neither one of them has an opinion about any individual in D-D′.

What about the strong ‘de dicto’ reading of *John and Mary agree on which students left?* The function that corresponds to f is this:

\[
(41) f: \text{Dom}(f) \text{ is the powerset of } D, \text{ and for all } X \in \text{Dom}(f), f(X) = \text{the function } f' \text{ such that } \text{Dom}(f') = W, \text{ and for all } w \in W, f'(w) = \{p: \text{there is an } x \in X \text{ such that } x \text{ is a student in } w \text{ and } p = \{w' \in W: x \text{ left in } w'\}\}.
\]

Suppose John and Mary are mistaken about who is a student and who is not. D′ is the largest subset of the domain which they carve into the same two sets of student-leavers and non–student-leavers, and neither one of them has an opinion about any individual in D-D′.

Now, *agree on*, like *know*, probably also has a weakly exhaustive semantics, which we can formulate as follows.

\[
(42) [\text{agree on – weak}]^p_w(Q)(A) = 1 \text{ iff there is a world } w' \text{ such that for all } x \in A, \text{BEL}(x)(w) \subseteq \text{ANS-weak}(Q)(w') \text{ and } \text{ANS-weak}(Q)(w') \neq W, \text{ and there is no } w'' \text{ such that } \text{ANS-weak}(Q)(w'') \subset \text{ANS-weak}(Q)(w'), \text{ and for some } y \in A, \text{BEL}(y)(w) \subseteq \text{ANS-weak}(Q)(w'').
\]

The weakly exhaustive meaning of *John and Mary agree on who left* requires John and Mary to divide the domain into the same two sets: leavers and others. John and Mary need not make the same distinctions within the second set. For example, John may think that Fred didn’t leave, while Mary might have no opinion about Fred.

Support for the claim that *agree on* has, indeed, a strongly exhaustive semantics comes from the acceptability of the following discourse, which resembles the acceptability of the discourse in (33) (with strongly exhaustive *know*) and contrasts with the oddity of the discourse in (34) (with the weakly exhaustive *surprise*):

\[
(43) \text{Bill and Mary do not REALLY agree on who cheated on the exam. For example, Mary thinks that Bob didn’t cheat and Bill has no opinion about Bob.}
\]

The acceptability of (43) is accounted for only if we assume that *agree on* indeed has a reading which is strongly exhaustive. If it didn’t, denying that Bill and Mary agree on who cheated could only mean that one of them thinks of someone that he cheated and the other thinks the opposite or has no opinion of that person.

I would like to stress again that B&R make the same prediction.
problem is that they don’t acknowledge that the semantics they attribute to *agree on* is strongly exhaustive. And since they don’t acknowledge this, they are led to the erroneous conclusion that Strong Exhaustivity has nothing to do with the availability of ‘de dicto’ readings. This brings me to my next point.

5.2. ANS-Strong as the Source of ‘De Dicto’ Readings in Veridical Environments

I argue that in complements of veridical question-embedding verbs, the presence of ANS-strong is a prerequisite for the availability of ‘de dicto’ readings, as implied by Heim (1994). In other words, a question-embedding verb supports ‘de dicto’ readings only if at least one of the following holds: (a) it is non-veridical; (b) it has a strongly exhaustive semantics. Evidence for this claim comes from the fact that *know* and *agree on* (which are both strongly exhaustive) support ‘de dicto’ readings of *which*-questions, but *surprise* (which is veridical but weakly exhaustive) does not. Let us convince ourselves of this.

We have been saying all along that *John knows which students left*, where *students* is read ‘de re’, is a reading distinct from *John knows which students left*, where *students* is read ‘de dicto’. We have been taking this for granted. In practice, when one argues that two “readings” are independent of each other, one has to show that neither reading entails the other. If this cannot be shown, it can always be argued that the grammar produces only one reading (and what seems to be a distinct reading is simply a reflection of different possible circumstances which can make the first reading true). A familiar example is *Every man loves a woman*. Since the “reading” where *a woman* has wide scope entails the “reading” where it has narrow scope, over the years there have been proposals according to which only the latter reading is provided by the grammar. Let us therefore see whether there is indeed justification for the claim that the ‘de re’ and ‘de dicto’ readings of *which*-questions are independent of each other.

Let us start with *know*. Since its semantics refers to ANS-strong, we predict *John knows which students left* to have distinct ‘de re’ and ‘de dicto’ readings (see (21)). In Scenario I below, the sentence is true on its weak ‘de re’ reading and false on it strong ‘de dicto’ reading. The latter claim is confirmed by the acceptability of the discourse in (45):

(44) Scenario I. Student Mary and student Sally left. John knows that they are students and that they left. Fred, a non-student, also left. John knows that Fred left, and thinks he is a student.
John doesn’t REALLY know which students left. Indeed, he knows that Mary and Sally are students who left, but he also thinks that Fred is a student who left.

It is a little harder to show that the ‘de dicto’ readings do not entail the ‘de re’ readings. In fact, know being a veridical verb, all we can show is that a ‘de dicto’ reading does not entail the strongly exhaustive ‘de re’ reading. To see this, consider Scenario II below:

Scenario II. Student Mary and student Sally left. Student Bill didn’t leave. John believes that Mary and Sally are the students who left. John doesn’t know that Bill didn’t leave.

The strong ‘de dicto’ reading of John knows which students left is true, because John can successfully divide the relevant domain into student leavers ({Mary, Sally}) and non–student-leavers ({Bill}). However, the strong ‘de re’ reading of the same sentence is false. This is because John is incapable of successfully dividing the set of actual students into leavers and non-leavers (he doesn’t know that Bill didn’t leave). In fact, we can report John’s state of knowledge by uttering the following:

John doesn’t REALLY know which students left, because Bill is one student who didn’t leave and John doesn’t know that Bill didn’t leave.

This proves that the (strong) ‘de re’ and ‘de dicto’ readings are, in fact, distinct readings. Notice that a weak interpretation of John knows which students left does not distinguish between ‘de re’ and ‘de dicto’ readings. Crucially, no scenario can be constructed where a ‘de dicto’ reading is true and the weak ‘de re’ reading is false. So if John knows of the actual students who left that they are students who left, the sentence is simply true.

Let us move on to the non-veridical agree on, and evaluate John and Mary agree on which students left. We will now see that because agree on is non-veridical, it doesn’t matter whether we assign the sentence a weak or a strong interpretation – in both cases we will get distinct ‘de re’ and ‘de dicto’ readings. This is because the semantics of this verb does not “want” the value of ANS-weak/strong in the actual world (see (39) and (42)). Let us look at some scenarios:

Scenario III. Fred, Marcia, Kate and Sally are the students. John and Mary do not know this. John and Mary both believe that Fred and Marcia left and that Kate and Sally didn’t. They also think that Ron and Don are the students. John thinks that Ron left but Mary doesn’t.
Since John and Mary are capable of dividing the set of actual students into the same two sets of leavers (\{Fred, Marcia\}) and non-leavers (\{Kate, Sally\}), John and Mary agree on which students left is true on its strong ‘de re’ interpretation. Since they have different beliefs regarding Ron, the strong and weak ‘de dicto’ readings are false.

(49) Scenario IV. John and Mary mistakenly believe that Ron, Don, and Mac are the students. They both believe that Ron and Don left and Mac didn’t. In fact, Fred and Marcia are the students. John thinks that Marcia left and Fred didn’t, and Mary believes that Fred left and Marcia didn’t.

Since John and Mary describe the same individuals as “student leavers” (\{Ron, Don\}) and “non–student-leavers” (\{Mac, Fred, Marcia\}), John and Mary agree on which students left is true in its strong ‘de dicto’ sense. However, since they disagree regarding Fred and Marcia – the actual students – the sentence is false on its strong and weak ‘de re’ interpretations.

(50) Scenario V. Fred, Marcia, Kate and Sally are the students. John and Mary do not know this. John and Mary both believe that Fred and Marcia left. John thinks Kate and Sally didn’t leave and Mary has no opinion of Kate. They also think that Ron and Don are the students. John thinks that Ron left but Mary doesn’t.

Since John and Mary describe the same subset of the set of actual students as “leavers”, the sentence is true in its weak ‘de re’ sense. Since they have different sets in mind when they think of “student leavers” (because they have different opinions regarding Ron), the sentence is false in its ‘de dicto’ sense.

(51) Scenario VI. John and Mary mistakenly believe that Ron, Don, and Mac are the students. They both believe that Ron and Don left. John thinks Mac didn’t leave and Mary has no opinion about Mac. In fact, Fred and Marcia are the students. John thinks that Marcia left and Fred didn’t, and Mary believes that Fred left and Marcia didn’t.

Since John and Mary call the same individuals “student leavers,” the sentence is true in its weak ‘de dicto’ sense. However, since they do not call the same subset of the student domain “leavers,” the sentence is false in its ‘de re’ sense.

Thus, we have shown that strongly exhaustive verbs, veridical and non-veridical, distinguish between ‘de re’ and ‘de dicto’ readings of embedded
questions. Now we need to show that veridical verbs that have a strictly weakly exhaustive meaning do not support genuine ‘de dicto’ readings. Consider the following example, evaluated in Scenario VII.

(52) It surprised John which students left.

(53) Scenario VII. Student Mary and student Sally, the only students, left. John is surprised that Mary and Sally left, but he doesn’t know that they are students.

The ‘de re’ reading of (52) is true. Now, if we point at Mary and Sally and ask John, “Did you expect the students to leave?”, he would probably say, “Are these guys students?” But notice the oddity of the following discourse:

(54) # It didn’t REALLY surprise John which students left. Indeed, he didn’t expect Mary and Sally – the students who left – to leave, but he wasn’t aware that they are students.

If (52) had a genuine ‘de dicto’ reading, this discourse would be fine.11

In addition, no scenario can be constructed where the ‘de dicto’ “reading” would be true and the ‘de re’ “reading” false. In the following scenario, (52) is simply true.

(55) Scenario VIII. Student Mary and student Sally left. Student Bill didn’t leave. John knows that Mary and Sally are students and he is surprised that they left. He is not surprised that Bill didn’t leave, because he didn’t expect him to leave.

If we ask John, “Did you expect these students to leave?”, pointing at Mary and Sally, he will say, “No.” If we point at Mary, Sally and Bill – the set of actual students – and ask John which of these individuals he didn’t expect to leave, he will say, “This one and that one,” pointing to Mary and Sally. Either way, (52) is intuitively true. This is further confirmed by the oddity of (56):

(56) # It didn’t REALLY surprise John which students left, because, for example, it didn’t surprise him that Bill DIDN’T leave, and Bill is a student.

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11 A word of caution is in order. In a scenario where Mary is the best student, she left, and John didn’t expect her to leave but did expect the best student to leave (unaware of the fact that Mary is the best student), there is indeed a sense in which (52) is false. But here the embedded question involves quantification over “natural” functions. If we add to Scenario VII the information that John expected the best student and the tallest student to leave, but neither Mary nor Sally fit either of these descriptions, (54) still comes out odd.
Sentence (56) would be fine if *surprise* had a strongly exhaustive meaning, but it doesn’t.

It seems, then, that the prediction made by Heim’s (1994) theory is correct. The verb *surprise* refers exclusively to ANS-weak in its semantics, and ANS-weak does not distinguish between ‘de dicto’ and ‘de re’ interpretations of a *which*-question. Since *surprise* “wants” the output of ANS-weak in the actual world, we necessarily get a ‘de re’ reading. Conclusion: The grammar does not produce two distinct readings for *It surprised Bill which students left*. If it did, we should be able to construct a scenario where the ‘de dicto’ reading is true and the ‘de re’ reading false. But we can’t.

How, then, do we account for the fact that Bill may or may not be aware of the student status of the leavers? This is simply because *It surprised Bill which students left* may be true if Bill is accidentally aware of the student status of the leavers. There is no need to posit two different readings to account for this.

Going back to B&R, since they deny the relationship between Strong Exhaustivity and ‘de dicto’ readings and claim that the availability of ‘de dicto’ readings is explained by reconstruction, they would predict, incorrectly, that *surprise* does distinguish between the two readings. Applying ANS-weak to the complement of *surprise* in, say, *It surprised John which students cheated*, may yield two different outputs, depending on how *students* is indexed. Thus, *surprise* is incorrectly predicted by B&R to support genuine ‘de dicto’ readings.

Are there other predicates that behave like *surprise*? As B&R show, *predict (n% correctly)* is weakly exhaustive. This is supported by the following example (their (81)):

(57) I was better at predicting who would show up than I was at predicting who wouldn’t show up.

The weakly exhaustive nature of *predict* (or *predict n% correctly*) is further supported by the following example:

(58) John did not predict 100% correctly who would be admitted. #For example, Bill wasn’t admitted and John didn’t predict that.

The oddity of the second sentence in (58) comes from the fact that to deny that John predicted 100% correctly who would be admitted simply means that for one of the actual admittees, John didn’t make the right prediction. But it does not mean that for one of the non-admittees John didn’t
make the right prediction. The latter would hold if predict n% correctly did in fact have a strongly exhaustive semantics.

And as predicted by Heim’s theory, like surprise, this predicate doesn’t distinguish between ‘de re’ and ‘de dicto’ readings of which-phrases. For example, John predicted 100% correctly which students would present a paper at the workshop can be true whether John is aware of the student status of the presenters or not, but the grammar doesn’t generate two distinct readings. There is only a ‘de re’ reading. Consider now the following scenario.

(59) Scenario IX. Bill, Fred and Mary are the students. John said Bill and Fred would present a paper and they did. John didn’t know and didn’t say that Bill and Fred are students.

As in the surprise case, John can be accidentally aware of the student status of the presenters, but this, in and of itself, does not justify positing a distinct ‘de dicto’ reading, as is confirmed by the oddity of the following discourse:

(60) # John didn’t REALLY predict (100% correctly) which students would present. He did say that Bill and Fred would present, but he didn’t say, or know, that they’re students.

6. A NOTE ON CHOICE FUNCTIONS AND RECONSTRUCTION

The analysis defended here comes at a certain cost. In recent years, it has become quite common in the literature to analyze questions with in situ wh-phrases without moving the wh-phrase at LF, and by invoking quantification over choice functions. The following is an example:

(61) a. Who saw which man?
   b. \{ p: \text{there is an } x \in D \text{ and a choice function } f \text{ s.t. } p = \{ w \in W: x \text{ saw } f([\text{man}]^p(w/@)) \text{ in } w \} \}

The arguments for using choice functions are compelling and also well known, and I will not repeat them here (see especially Reinhart (1997) for a very useful discussion). Suffice it to say that syntactically, the choice function analysis goes well with the idea that covert wh-movement is as restricted as overt wh-movement (because in situ wh-phrases can appear inside islands). The problem is, as can be seen from (61) (where the world argument of the in situ wh-expression may be bound or free), that we end up predicting weakly exhaustive veridical verbs to give rise to ‘de dicto’ readings. We saw this when we examined B&R’s reconstruc-
tion approach to the ‘de re’/‘de dicto’ distinction, which suffers from the same problem. This means that the choice function approach is incompatible with the claims made here regarding ‘de dicto’ readings, because Heim’s (1994) analysis seems to require wh-movement to Spec,CP at LF.

I think this should lead us to one of the following conclusions: (a) covert wh-movement is not restricted, at least not in the same way overt wh-movement is, and wh-phrases are always interpreted in Spec,CP; (b) covert wh-movement is restricted, and we have yet to find an alternative explanation for the observed correlation between Strong Exhaustivity and the availability of genuine ‘de dicto’ readings in veridical environments. Otherwise, we would have to accept that the grammar generates unattested ‘de dicto’ readings for weakly exhaustive veridical question-embedding predicates.

7. Conclusion

I have made two points regarding exhaustivity. First, it is not “about” actual true answers. One could, of course, restrict exhaustivity in such a way if one wanted, but it is hard to see what insights into our intuitions would be gained by doing so. On the contrary, it seems that we would be missing important similarities between certain veridical and non-veridical verbs if we were to view exhaustivity in this way. Secondly, Strong Exhaustivity correlates with ‘de dicto’ readings in complements of veridical question-embedding verbs. This is expected under Heim’s (1994) analysis, and supported by our intuitive judgments regarding various question-embedding verbs. It seems to me that if B&R still want to contest Heim’s theory, they should do so by challenging the predictions it makes regarding weakly exhaustive veridical verbs, and not by claiming that verbs such as agree on are non-exhaustive.

It is worth pointing out that all verbs examined here belong to one of the following three classes: (a) veridical strongly exhaustive (know); (b) veridical weakly exhaustive (surprise); (c) non-veridical strongly exhaustive (agree on). We have not come across verbs that are non-veridical weakly exhaustive. I do not know whether such verbs exist or not – certainly nothing I have said precludes this possibility. If they don’t – this seems like an

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12 Interrogatives such as ‘which unicorn does John want to date’ (see Rullmann and Beck 1998), which is not about actual unicorns, seem to pose a problem for the non-reconstruction approach. Advocates of Heim (1994) may deal with this by positing a hidden modal in the ‘which’-phrase, yielding the following interpretation: {p: there is an x s.t. for all w, if ‹Act, w› ∈ C, x is a unicorn in w, and p = that John wants to date x}. C is constrained by the context. Usually, C is {‹w1, w2›: w2 ∈ BEL(John)(w1)}. Here, it is {‹w1, w2›: w2 ∈ BEL(John)(w1)}.
accidental gap. If such verbs do exist, the prediction is that they do support ‘de dicto’ readings, since their semantics would require the truth of ANS-weak in some world other than the actual world (just like the semantics of agree on – weak in (42)).

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