Higher-order readings of WH-questions

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Abstract In most cases, a WH-question expects an answer that names an entity in the set denoted by the extension of the WH-complement. However, evidence from questions with necessity modals and questions with collective predicates shows that sometimes a WH-question must be interpreted with a higher-order reading, in which this question expects an answer naming a generalized quantifier.

This paper investigates the distribution and the compositional derivation of these higher-order readings. First, I argue that the generalized quantifiers that can serve as direct answers to WH-questions are subject to two constraints — Positiveness and Homogeneity. Next, on the distribution of higher-order readings, I find that questions in which the WH-complement is singular-marked or numeral-modified can be responded by elided disjunctions but not conjunctions. I further present two ways to account for this disjunction-conjunction asymmetry. In the uniform account, these questions admit disjunctions because disjunctions (but not conjunctions) may satisfy the atomicity requirement of singular-marking and the cardinality requirement of numeral-modification. In the reconstruction-based account, the WH-complement is syntactically reconstructed, which gives rise to local uniqueness and yields a contradiction for conjunctive answers.

Keywords: *wh*-words, questions, higher-order readings, quantifiers, Boolean coordinations, number-marking, uniqueness, collectivity, reconstruction

1. Introduction

A WH-question (with *who*, *what*, or *which*-NP) expects an answer that names either an entity in the set denoted by the WH-complement or a generalized quantifier (GQ) ranging over of a subset of this set. This requirement is especially robustly seen with short answers of questions. For example in (1), the speaker uttering the short answer (1a) is committed to that the mentioned individual is a math professor (Jacobson 2016). Moreover, this inference projects over quantification: the most prominent reading of the disjunction (1b) yields that both mentioned individuals are math professors.[1]

(1) Which math professor left the party at midnight?

a. Andy. $\rightsquigarrow$ *Andy is a math professor.*

b. Andy or Billy. $\rightsquigarrow$ *Andy and Billy are math professors.*

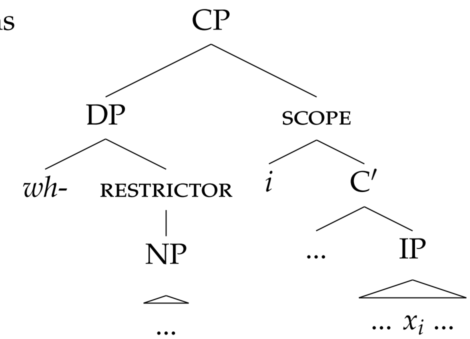
To capture this question-answer relation, it is commonly assumed that WH-phrases are functions (e.g. existential ($\exists$-)quantifiers or domain restrictors) over first-order predicates, and that the domain for quantification or abstraction is the set denoted by the extension of the WH-complement. An LF schema for WH-questions is given in (2): the WH-phrase binds an *e*-type variable inside the question-nucleus (namely, IP) and assigns this variable with a value in the extension of the NP-complement.

[1] Elided disjunctions are scopally ambiguous relative to this commitment, as described in (i). This paper considers only the reading (ia). The other reading can be derived by accommodating the presupposition locally.

(i) a. *Andy and Billy are math professors, and one of them left the party at midnight.*

b. *Either Andy or Billy is math professor who left the party at midnight.*

(2) LF schema of WH-questions



In this view, the root denotation of a WH-question is either a one-place function defined for values in the extension of the NP-complement (as assumed in categorial approaches and structured meaning approaches) or a set of propositions naming such values (as assumed in propositional approaches such as Hamblin-Karttunen Semantics, Partition Semantics, and Inquisitive Semantics). For convenience in describing the relation between WH-phrases and WH-questions in meaning, the following presentation follows categorial approaches to question composition (Hausser and Zaefferer 1979; Hausser 1983; a.o.). The core idea of this paper, however, is independent from the assumptions of categorial approaches on defining and composing questions.

Categorial approaches define questions as functions and WH-phrases as function domain restrictors. In (3), for example, in forming the question *which student came?*, the WH-phrase *which student* applies to a first-order function defined for any individuals and returns a more restrictive first-order function that is only defined for atomic students. I henceforth call this functional denotation of a question a "Q-function" and the domain of a Q-function a "Q-domain".

(3) a. $[\![\textit{which student}]\!] = \lambda P_{et} \lambda x_e \colon \textsf{student}(x).P(x)$
    b. $[\![\textit{which student came?}]\!] = [\![\textit{which student}]\!]([\![\textit{came}]\!]) = \lambda x_e \colon \textsf{student}(x).\textsf{came}(x)$

Treating short answers as bare nominals, categorial approaches regard the relation between matrix questions and short answers as a simple function-argument relation — the Q-function serves as a function for an entity-denoting answer and an argument for a GQ-denoting answer. For example, in (4a), applying the Q-function denoted by the question to an individual denoted by the short answer yields that this individual came and the presupposition that this individual is a student. In (4b), in contrast, since the disjunctive answer has a complex type ($\langle et, t \rangle$), the question-answer relation is flip-flopped into an argument-function relation. Applying the Boolean disjunction $a^{\Uparrow} \cup b^{\Uparrow}$ (i.e., the union of two Montagovian individuals, see definitions in footnote 2) to the Q-function yields the presupposition that both of the disjoined individuals a and b are students.

(4) a. Combining w. entity-denoting answers
    $[\![\text{WH-Q}]\!]([\![\textit{Andy}]\!])$
    $= (\lambda x_e \colon \textsf{student}(x).\textsf{came}(x))(a)$
    $= \textsf{student}(a).\textsf{came}(a)$

    b. Combining w. GQ-denoting answers
    $[\![\textit{Andy or Billy}]\!]([\![\text{WH-Q}]\!])$
    $= (a^{\Uparrow} \cup b^{\Uparrow})(\lambda x_e \colon \textsf{student}(x).\textsf{came}(x))$
    $= \textsf{student}(a) \wedge \textsf{student}(b).\textsf{came}(a) \vee \textsf{came}(b)$

The above discussion considers **first-order readings** of WH-questions. In a first-order reading, the Q-function is a first-order function. However, as first observed by Spector (2007, 2008), in some cases a WH-question can only be properly addressed by an answer that specifies a GQ. For example in

(5), the elided disjunction in the answer is interpreted under the scope of the necessity modal *have to*. Spector argues that to obtain this narrow scope reading, *which books* should bind a higher-order trace (of type $\langle et, t \rangle$) across the necessity modal, so that a disjunction can be semantically reconstructed to a scopal position under the modal.

(5) a. Which books does John have to read?
b. The French novels or the Russian novels. The choice is up to him. $\Box \gg$ *or*

Examples like (5) show that questions can also have **higher-order readings**, in which the Q-functions take GQs as arguments. This paper investigates into those higher-order readings.

The rest of this paper is organized as follows. Section 2 presents evidence for cases where a question must be interpreted with a higher-order reading, drawn on data about questions with modals or collective predicates. Section 3 argues that the higher-order meanings involved in a Q-domain are subject to two constraints — Positiveness and Homogeneity. Sections 4 and 5 investigate the compositional derivation of two types of higher-order readings and explain their distributional constraints. Section 6 concludes.

2. Evidence for higher-order readings

Saying that a question has a first-order reading yields two predictions regarding to its GQ-naming answers. First, the named GQ must be interpreted with wide scope relative to the scopal expressions in the question nucleus. Second, the answer space (viz., the Hamblin set) of this question consists of only propositions denoted by the entity-naming answers. If an answer names a GQ, the proposition denoted by this answer is not in the answer space of this question, and the named GQ is not in the Q-domain; instead, those answers are derived by applying additional Boolean operations to propositions in the answer space.

This section presents counterexamples to both predictions, showing that first-order readings are insufficient. First, evidence from questions with necessity modals (e.g., *which books does John have to read?*) shows that sometime the Q-domain of a question must Boolean disjunctions and existential quantifiers (§2.1). Second, evidence from questions with collective predicates (e.g. *which children formed one team?*) shows that sometimes the Q-domain of a question must contain Boolean conjunctions and universal quantifiers (§2.2). Finally, combinations of these two diagnostics rule in the Boolean coordinations of the aforementioned GQs (§2.3).

2.1. Non-reducibility: Evidence for disjunctions and existential quantifiers

In general, to completely address a question, one must provide the strongest true answer (Dayal 1996). Hence, for an answer to be possibly complete, there must be a world in which this answer is the strongest true answer. As seen in (6), in responding to a basic WH-question, a disjunctive answer is always partial/incomplete — whenever the disjunctive answer is true, it is asymmetrically entailed by another true answer, namely, one of its disjuncts.

(6) a. Which books did John read?
b. The French novels or the Russian novels.

However, Spector (2007, 2008) observes that disjunctions can completely address WH-questions where the nucleus has a necessity modal (called "$\Box$-questions" henceforth). For example in (7), the elided disjunction is scopally ambiguous. If the disjunction takes scope over the necessity modal *have to*, the disjunctive answer has a partial answer reading. Alternatively, if interpreted under the scope of the modal, the elided disjunction can also be regarded as a complete specification of John's reading obligation — there is not any specific book that John has to read, his only reading obligation is to choose between the French novels and the Russian novels. This narrow scope complete answer reading is also observed with existential quantifiers, as seen in (8).

(7) a. Which books does John have to read?
   b. The French novels or the Russian novels.
      i. 'John has to read F or R, I do not know which exactly.' (Partial: *or* $\gg \Box$)
      ii. 'John has to read F or R, and the choice is up to him.' (Complete: $\Box \gg$ *or*)

(8) a. Which books does John have to read?
   b. At least two books by Balzac.
      i. 'There are at least two books by Balzac that John has to read, I don't know what they are.' (Partial: $\exists \gg \Box$)
      ii. 'John has to read at least two books by Balzac, which two (or more) to read is up to his own choice.' (Complete: $\Box \gg \exists$)

To obtain the complete answer reading (7b-ii), the elided disjunctive answer must be treated as a GQ (i.e., the union of two Montagovian individuals $f^{\Uparrow} \cup r^{\Uparrow}$)[2] and be reconstructed to a position under the necessity modal. Thus, Spector (2007) concludes that the question (7a) is ambiguous between a high reading and a low reading where "high" and "low" mean that the scope of the disjunction is wide and narrow relative to the modal, respectively. To highlight the contrast between these two readings with respect to the types of the Q-functions, I instead call the two readings the **first-order reading** and the **higher-order reading**, respectively. As paraphrased in (9), the first-order reading expects answers that specify an entity, while the higher-order reading expects answers that specify a GQ.

[2] Disjunctions over set-denoting expressions are standardly treated as **unions** '$\cup$'. This idea follows a more general schema defined in Partee and Rooth 1983. Since entities are not sets, to be disjoined, they have to be first type-shifted into GQs of a conjoinable type $\langle et, t \rangle$ via Montague-lift. Hence, in a coordination of two definite DPs, *or* combines with two Montagovian individuals and returns their union (Keenan and Faltz 1984: Part 1A).

(i) For any meaning α of type τ, the Montague-lifted meaning is $\alpha^{\Uparrow}$ (of type $\langle\langle \tau, t\rangle, t\rangle$) such that $\alpha^{\Uparrow} =_{\text{df}} \lambda m_{\langle \tau, t\rangle}.m(\alpha)$.

The conjunctive *and* is commonly treated ambiguously as either an **intersection** operator '$\cap$' (for combining sets) or a **summation** operator '$\oplus$' (for combining entities) (Link 1983; Hoeksema 1988; among others).

(ii) a. For any non-empty set A such that $A \subseteq D_e$,
   $\bigoplus A =_{\text{df}} \iota x : \forall y[y \in A \to y \leq x] \wedge \forall z[z \leq x \to \exists z'[z' \in A \wedge z \circ z']]$ where $z \circ z' =_{\text{df}} \exists m[m \leq z \wedge m \leq z']$
   (For any non-empty set A, the sum of A is the unique x such that every member of A is a part of x and that every part of x overlaps with a member of A.)
   b. For any two entities x and y, $x \oplus y =_{\text{df}} \bigoplus\{x, y\}$

Another approach is to assign the conjunctive *and* a single meaning but ascribe the ambiguity to covert operations. For example, Winter (2001) and Champollion (2016b) treat *and* unambiguously an intersection operation and use covert type-shifting operations to derive the collective reading.

(9) Which books does John have to read?

a. First-order reading: 'For which book(s) x is such that John has to read x?'

b. Higher-order reading: 'For which a GQ π over books is such that John has to read π?'

Spector assumes that the higher-order reading involves **semantic reconstruction** (Cresti 1995; Rullmann 1995): the WH-phrase binds a higher-order trace π (of type $\langle et, t\rangle$) across the necessity modal. Adapting this analysis to the categorial approach, I propose the LFs and Q-functions for the two readings as follows. (The Q-domain assumed for the higher-order reading is subject to revision. '$\textsc{smlo}(\pi)$' stands for the **smallest live-on set** of π.[3] For now, I just assume that the Q-domain is the set of GQs ranging over a set of books.) Observe that, for the higher-order reading, the GQ-denoting answer is interpreted at whatever scopal position that the higher-order *wh*-trace π has.

(10) First-order reading

a. LF: [which-books λx [have-to [John read x_e]]]

b. $[\![\textsc{wh}\text{-Q}]\!] = \lambda x_e\colon \textsf{books}_w(x).\Box[\lambda w.\textsf{read}_w(j,x)]$

c. $[\![F\ or\ R]\!]([\![\textsc{wh}\text{-Q}]\!]) = (f^{\Uparrow} \cup r^{\Uparrow})(\lambda x\colon \textsf{books}_w(x).\Box[\lambda w.\textsf{read}_w(j,x)])$
$= \textsf{books}_w(f) \wedge \textsf{books}_w(r).\Box[\lambda w.\textsf{read}_w(j,f)] \cup \Box[\lambda w.\textsf{read}_w(j,r)]$

(11) Higher-order reading

a. LF: [which-books $\lambda\pi$ [have-to [$\pi_{\langle et,t\rangle}$ λx [John read x_e]]]]

b. $[\![\textsc{wh}\text{-Q}]\!] = \lambda\pi_{\langle et,t\rangle} : \textsc{smlo}(\pi) \subseteq \textsf{books}.\Box[\lambda w.\pi(\lambda x_e.\textsf{read}_w(j,x))]$ (To be revised)

c. $[\![\textsc{wh}\text{-Q}]\!]([\![F\ or\ R]\!]) = (\lambda\pi_{\langle et,t\rangle} : \textsc{smlo}(\pi) \subseteq \textsf{books}.\Box[\lambda w.\pi(\lambda x.\textsf{read}_w(j,x))])(f^{\Uparrow} \cup r^{\Uparrow})$
$= \textsc{smlo}(f^{\Uparrow} \cup r^{\Uparrow}) \subseteq \textsf{books}.\Box[\lambda w.(f^{\Uparrow} \cup r^{\Uparrow})(\lambda x.\textsf{read}_w(j,x))]$
$= \{f, r\} \subseteq \textsf{books}.\Box[\lambda w.\textsf{read}_w(j,f) \vee \textsf{read}_w(j,r)]$

$\Box$-questions are useful in validating the existence of Boolean disjunctions in a Q-domain because the answer space of a $\Box$-question is not closed under disjunction.

(12) A proposition set Q is **closed under disjunction** iff for any two propositions p and q, if both p and q are members of Q, then the disjunction $p \vee q$ is also a member of Q.

The following figures illustrate the answer space of a plain episodic question and that of a $\Box$-question. Arrows indicate entailments. $f(x)$ abbreviates for the proposition *John read x*.

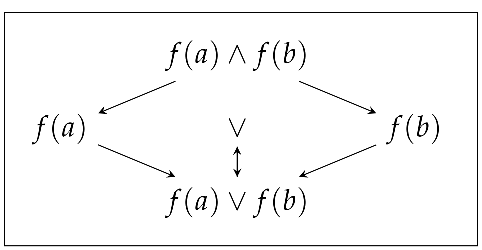


Figure 1: Answer space for 'what did John read?'

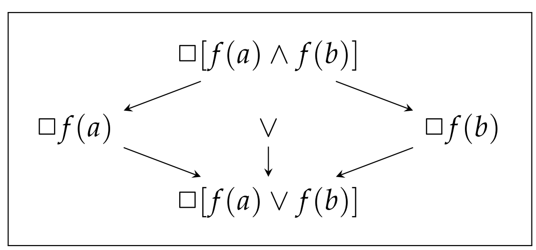


Figure 2: Answer space for 'what does John have to read?'

[3] For any π of type $\langle \tau t, t\rangle$ and any set A of type $\langle \tau, t\rangle$, we say that π **lives on** A iff for every B: $\pi(B) \Leftrightarrow \pi(B \cap A)$ (Barwise and Cooper 1981), and that π **ranges over** A iff A is the smallest live-on set (SMLO) of this GQ (Szabolcsi 1997). For example, the smallest live-on set of *some/every/no student* is the set of atomic students. These notions will be crucial for later discussions on defining what types of GQs should and should not be ruled into a Q-domain (see section 3).

In Figure 1, the disjunctive answer $f(a) \vee f(b)$ is semantically equivalent to the disjunction of the two individual answers $f(a)$ and $f(b)$. Hence, the disjunctive answer can never be the strongest true answer of the question — whenever the disjunctive answer is true, there will be another true answer, $f(a)$ or $f(b)$, asymmetrically entailing it. In contrast, in Figure 2, the disjunctive answer $\Box[f(a) \vee f(b)]$ can be the strongest true answer since it is semantically weaker than the disjunction of the two individual answers. If John's only reading obligation is to choose between a and b, the individual answers are false, and the disjunctive answer is the unique true answer and hence the strongest true answer.

More generally, $\Box$-questions may yield Q-functions that are not reducible relative to disjunctions and $\exists$-quantifiers. The following defines reducibility, where '$\bullet$' stands for the combinatory operation between the function θ and a GQ:

(13) A function θ is **reducible** relative to a GQ π iff $\theta \bullet \pi \equiv \pi(\lambda x.\theta \bullet x^{\Uparrow})$.

The same as $\Box$-questions, the following questions ((14) and (15) are taken from Spector (2007)), with a word expressing universal quantification, also have readings where the Q-function is non-reducible relative to disjunctions or to $\exists$-quantifiers.

(14) Attitude verbs
  a. Which books did John *demand* that we read?
  b. Which books is John *certain* that Mary read?
  c. Which books does John *expect* Mary to read?

(15) Modals
  a. Which books is it *sufficient* to read?
  b. Which books is John *required* to read?

(16) Quantifiers
  a. Which books did *all* of the students read?
  b. Which books does John *always*/*usually* read?

2.2. Stubborn collectivity: Evidence for conjunctions and universal quantifiers

Spector (2007, 2008) and Fox (2013) have assumed that a Q-domain may contain Boolean conjunctions, but they have not provided empirical evidence for this assumption. Clearly, Spector's non-reducibility diagnostic does not extend to Boolean conjunctions — the Q-functions of $\Box$-questions as well as those discussed in (14) to (16) are reducible relative to Boolean conjunctions. Compare:

(17) a. $[\lambda\pi.\textsf{J has to read } \pi](\textsf{f}^{\Uparrow} \cup \textsf{r}^{\Uparrow}) \neq \textsf{J has to read f} \vee \textsf{J has to read r}$
  b. $[\lambda\pi.\textsf{J has to read } \pi](\textsf{f}^{\Uparrow} \cap \textsf{r}^{\Uparrow}) = \textsf{J has to read f} \wedge \textsf{J has to read r}$

This section introduces a diagnostic for ruling in Boolean conjunctions proposed in Xiang (2016: §1.6). This diagnostic draws on the fact that questions with a stubbornly collective predicate (e.g., *formed a team*, *co-authored two papers*) may have answers naming Boolean conjunctions, and especially that stubborn collectivity in these questions does not trigger uniqueness.

First, to see what is stubborn collectivity, observe that the phrasal predicate *formed a/one team* admits a collective reading but not a covered/ (non-atomic) distributive reading. The sentence (18a) cannot be truthfully uttered in the given context, because it admits only a collective reading and this reading is false in the given scenario. In contrast, the plural counterpart *formed teams* admits a covered/ (non-atomic) distributive reading and thus (18b) can be truthfully uttered.

(18) (w: *The children abcd formed exactly two teams in total:* $a + b$ *formed one, and* $c + d$ *formed one.*)
   a. # The children formed a/one team.
   b. $\surd$ The children formed teams.

Note that the falsehood of (18a) is not improved even if the context has explicitly separated the four children into two pairs, as seen in (19).

(19) [Yesterday, the pair *ab* competed against the pair *cd*.] Today, the children (all) formed a team. ($^{\text{OK}}$collective, $^{\#}$non-atomic distributive, $^{\#}$atomic distributive)

Hence, I say that *formed a team* is "stubbornly collective", in contrast to other collective predicates (e.g., *lift the piano*) that admit also covered/distributive readings. Stubborn collectivity is widely observed with quantized phrasal predicates of the form "V + counting noun", such as *formed one committee* and *co-authored two papers*.[4]

Second, for the absence of uniqueness effects, compare the sentences in (20a-b) in the same discourse. The declarative-embedding sentence (20a) suffers a presupposition failure, because the factive verb *know* embeds a false collective declarative. However, the sentence (20b), where *know* embeds the interrogative counterpart of this collective declarative, does not suffer a presupposition failure. Moreover, intuitively, (20b) implies that John knows precisely the component members of all the teams formed by the considered children, which is a conjunctive inference.

(20) (w: *The children abcd formed exactly two teams in total:* $a + b$ *formed one, and* $c + d$ *formed one.*)
   a. # John knows [that **the children** formed a team].
   b. $\surd$ John knows [**which children** formed a team].
   c. $\leadsto$ *John knows that* $a + b$ *formed a team* <u>*and*</u> $c + d$ *formed a team.*

The conjunctive inference (20c) is quite surprising — where does the conjunctive closure come from? Clearly, no matter how we analyze collectivity, this conjunctive closure cannot come from the predicate *formed a team* or anywhere within the question nucleus, otherwise the embedded clause in (20a) would admit a non-atomic distributive/ covered reading and (20a) would be felicitous. In contrast, I argue that this conjunctive closure is provided by the WH-phrase: the WH-phrase quantifies over a set of higher-order meanings including the Boolean conjunction $(a \oplus b)^{\Uparrow} \cap (c \oplus d)^{\Uparrow}$.

(21) Which children formed a team?
   Higher-order reading: 'For which GQ π over children is such that π formed a team?'
   a. [which-children $\lambda\pi$ [$_{\text{IP}}$ $\pi_{\langle et,t\rangle}$ λx [$_{\text{VP}}$ x_e formed a team]]]

[4] A predicate P is **quantized** iff whenever P holds for x, P does not hold for any proper subpart of x (Krifka 1997). Formally: $\forall x \forall y[P(x) \wedge P(y) \rightarrow [x \leq y \rightarrow x = y]]$. Defining predicates as sets of events, Champollion (2016a) argues that distributive readings are not available with quantized predicates because the extension of a quantized verbal phrase is not closed under sum formation.

b. $[\![\text{WH-Q}]\!] = \lambda\pi_{\langle et,t\rangle} : \textsc{smlo}(\pi) \subseteq \textit{children}.\lambda w[\pi(\lambda x.\textit{f.a.team}_w(x))]$

c. $[\![\text{WH-Q}]\!]((a \oplus b)^{\Uparrow} \cap (c \oplus d)^{\Uparrow})$
$= \{a \oplus b, c \oplus d\} \subseteq \textit{children}.\lambda w[\textit{f.a.team}_w(a \oplus b) \wedge \textit{f.a.team}_w(c \oplus d)]$

One might suggest to ascribe the conjunctive closure to an operator outside the question denotation, such as Heim's (1994) answerhood-operator. As schematized in (22), this operator contains a $\bigcap$-closure, it applies to an evaluation world w and a Hamblin set Q and returns the conjunction of all the propositions in Q that are true in w.

(22) a. $\textsc{Ans}\text{-H}(w)(Q) = \bigcap\{p \mid w \in p \in Q\}$

b. $\bigcap\{\lambda w.\textit{f.a.team}_w(a \oplus b), \lambda w.\textit{f.a.team}_w(c \oplus d)\} = \lambda w.\textit{f.a.team}_w(a \oplus b) \wedge \textit{f.a.team}_w(c \oplus d)$

However, this definition of answerhood cannot capture the contrast in (23). The question-embedding sentence (23b) is infelicitous because the embedded numeral-modified question (viz., the question in which the WH-complement is numeral-modified) has a uniqueness presupposition which contradicts the context.

(23) (w: *The children abcd formed two teams in total: $a + b$ formed one, and $c + d$ formed one.*)

a. √ John knows [**which children** formed a team].

b. # John knows [**which two children** formed a team].
$\rightsquigarrow$ *Only two of the children formed any team.*

Uniqueness presuppositions in WH-questions are standardly explained by "Dayal's presupposition" — a question is defined only if it has a strongest true answer (Dayal 1996). For a question with a Hamblin set Q, its strongest true answer is the true proposition in Q entailing all the true propositions in Q. In the rest of this section, I argue that the contrast between (23a-b) is due to the following: in (23a), the embedded simple plural-marked question has a strongest true answer in the given discourse, while in (23b), the embedded numeral-modified question does not.

Dayal's presupposition was originally motivated to explain the uniqueness requirement of singular-marked WH-questions (i.e., questions in which the WH-complement is singular-marked). In Srivastav 1991, she observes that a singular-marked WH-question can have only one true answer. For illustration, compare the examples in (24). The continuation in (24a) is infelicitous because the singular-marked question has a uniqueness presupposition that only one of the children came, which is inconsistent with the second clause. By contrast, this inconsistency disappears if the singular WH-phrase *which child* is replaced with a plural phrase *which children* or a bare *wh*-word *who*, as in (24b-c).

(24) a. "Which child came? # I heard that many children did."

b. "Which children came? I heard that many children did."

c. "[Among the children,] who came? I heard that many children did."

To capture the uniqueness presuppositions of singular-marked questions, Dayal (1996) defines a presuppositional answerhood-operator that checks the existence of the strongest true answer, as schematized in (25). Applying this ANS-D-operator returns the unique strongest of the propositions in Q true in w and presupposes the existence of this strongest true proposition.

(25) $\textsc{Ans-D}(w)(Q) = \exists p[w \in p \in Q \wedge \forall q[w \in q \in Q \rightarrow p \subseteq q]].$
$\iota p[w \in p \in Q \wedge \forall q[w \in q \in Q \rightarrow p \subseteq q]]$
($\textsc{Ans-D}(w)(Q)$ is defined only if the set of answers in Q that are true in w has a strongest member; when defined, $\textsc{Ans-D}(w)(Q)$ returns this unique strongest true answer.)

Adopting the ontology of individuals by Sharvy (1980) and Link (1983), Dayal assumes that the Hamblin set of a singular-marked WH-question is smaller than the one of its plural-marked counterpart. The ontology of individuals assumes that both singular and plural nouns denote sets of entities (of type $\langle e, t \rangle$). In particular, a singular noun denotes a set of atomic elements, while a plural noun denotes a set consisting of both atomic and sum elements.[5] If sums are defined in terms of part-hood relation ($\leq$) as in footnote 2, the ontology of individuals can be represented as in Figure 3. Letters *abc* each denotes an atomic child. Lines indicate *part of* relations from the bottom to the top. For example, atomic entities a and b are parts of their sum $a \oplus b$.

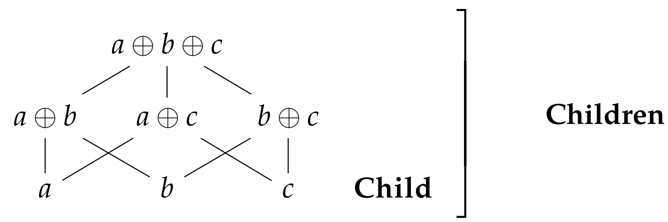


Figure 3: Ontology of individuals (Sharvy 1980, Link 1983)

Accordingly, as illustrated in (26), the former Hamblin set includes only propositions naming an atomic child, while the latter also includes propositions naming a sum of children. Q_w stands for the set of propositions in Q that are true in w, namely, the Karttunen set in w. As a consequence, under a discourse where both Andy and Bill came, (26b) has a strongest true answer $\lambda w.\mathsf{came}_w(a \oplus b)$ while (26a) does not. Then employing $\textsc{Ans-D}$ in (26a) gives rise to a presupposition failure. To avoid this presupposition failure, (26a) can only be felicitously used in a world where only one of the children came, which therefore explains its uniqueness requirement.

(26) (w: *Among the considered children, only Andy and Billy came.*)
   a. Which child came?
      i. $Q = \{\lambda w.\mathsf{came}_w(x) \mid x \in \mathsf{child}\}$
      ii. $Q_w = \{\lambda w.\mathsf{came}_w(a), \lambda w.\mathsf{came}_w(b)\}$
      iii. $\textsc{Ans-D}(w)(Q)$ is undefined
   b. Which children came?
      i. $Q = \{\lambda w.\mathsf{came}_w(x) \mid x \in \mathsf{children}\}$
      ii. $Q_w = \{\lambda w.\mathsf{came}_w(a), \lambda w.\mathsf{came}_w(b), \lambda w.\mathsf{came}_w(a \oplus b)\}$
      iii. $\textsc{Ans-D}(w)(Q) = \lambda w.\mathsf{came}_w(a \oplus b)$

[5]The view of treating plurals as sets ranging over not only sums but also atomic elements is called the "inclusive" theory of plurality (Sauerland et al. 2005, among others), as opposed to the "exclusive" theory which defines plurals as denoting sets consisting of only non-atomic elements. Whether plurals are treated inclusive or exclusive is not crucial in this paper. The following presentation follows the inclusive theory.

It is also straightforward to see that, to account for the uniqueness presupposition, the Q-domain yielded by a singular-marked WH-phrase must exclude Boolean conjunctions such as $a^{\Uparrow} \cap b^{\Uparrow}$. Otherwise, the singular-marked question (26a) would admit conjunctive answers like $\lambda w.\textsf{came}_w(a) \wedge \textsf{came}_w(b)$ and would not be subject to uniqueness, contra fact.[6]

Numeral-modified questions (viz., questions in which the WH-complement is numeral-modified) also have a uniqueness presupposition. For example, the numeral-modified question in (27a) implies that only two of the children came, and the one in (27b) implies that only two or three of the children came. Both inferences contradict each of their follow-up clauses.

(27) a. 'Which two children came? # I heard that three children did.'
b. 'Which two or three children came? # I heard that five children did.'

Dayal's account of uniqueness easily extends to numeral-modified questions. As seen in (28), for a question of the form "which *n* children came?" where *n* is a bare numeral and is read as 'exactly *n*', Dayal's presupposition is satisfied only if exactly *n* children came. If the number of children who came is smaller than *n*, this question has no true answer (viz., $Q_w = \emptyset$); if the number of the children who came is larger than *n*, the question does not have a strongest true answer.

(28) (w: *Among the considered children, only Andy, Billy, and Clark came.*)
Which two children came?
a. $Q = \{\lambda w.\textsf{came}_w(x) \mid x \in \textsf{2-children}\}$
b. $Q_w = \{\lambda w.\textsf{came}_w(a \oplus b), \lambda w.\textsf{came}_w(a \oplus c), \lambda w.\textsf{came}_w(b \oplus c)\}$
c. ANS-D$(w)(Q)$ is undefined

Crucially, the same as in a singular-marked WH-question, the Q-domain of a numeral-modified WH-question has no Boolean conjunction; otherwise, (28) would have a strongest true answer based on $(a \oplus b)^{\Uparrow} \cap (c \oplus d)^{\Uparrow} \cap (b \oplus c)^{\Uparrow}$.

Return to the contrast of question-embeddings in (23), repeated below:

(29) (w: *The children abcd formed two teams in total: $a+b$ formed one, and $c+d$ formed one.*)
a. $\surd$ John knows [**which children** formed a team].
b. # John knows [**which two children** formed a team].
$\rightsquigarrow$ *Only two of the children formed any team.*

[6]Drawing on facts from Spanish *quién* 'who.SG' which is singular-marked but does not trigger uniqueness (Maldonado 2017), Elliott et al. (2018) by contrast propose that *quién*-questions admit also higher-order readings, in which the yielded Q-domain ranges over a set of Boolean conjunctions over atomic elements. Alonso-Ovalle and Rouillard (2019) argue against this view, drawn on facts of questions with a collective predicate. As seen in (i), *quién* 'who.SG' can be used to combine with a stubbornly collective predicate *formó un grupo* 'formed.SG a group', and the formed question expects to specify the component members of one or more groups.

(i) Quién formó un grupo?
who.SG formed.SG a group
'Who formed a group?'

a. Los estudiantes.
the students

b. Los estudiantes y los profesores.
the students and the professors.

The felicity of answer (ib) shows that the *quién*-question admits answers naming Boolean conjunctions over non-atomic elements. Hence, Alonso-Ovalle & Rouillard conclude that *quién* 'who.SG' is number-neutral in meaning and is semantically ambiguous — it ranges over either the set of atomic and non-atomic individuals or a set of Boolean conjunctions and disjunctions.

The contrast is explained if we assume that the Q-domain of a basic plural-marked question contains Boolean conjunctions, while that of a numeral-modified question does not. More specifically, in (29a), the Q-domain yielded by *which children* includes Boolean conjunctions and hence the embedded question *which children formed a team* admits conjunctive answers. In the given scenario, the Boolean conjunction $(a \oplus b)^{\Uparrow} \cap (c \oplus d)^{\Uparrow}$ yields the strongest true answer. In contrast, the Q-domain yielded by *which two children* consists of only pluralities denoting sums of two children (such as $a \oplus b$ and $c \oplus d$), and hence the embedded question in (29b) has two true answers, namely, $\lambda w.\textsf{f.a.team}_w(a \oplus b)$ and $\lambda w.\textsf{f.a.team}_w(c \oplus d)$, neither of which counts as the strongest true answer. In conclusion, (29b) is infelicitous because the embedded question does not satisfy Dayal's presupposition, and this presupposition failure projects over the factive predicate *know*.

2.3. Evidence for Boolean compounds

Previous sections provide two diagnostics for simple GQs. The diagnostic based on non-reducibility validates the existence of Boolean disjunctions and existential GQs in a Q-domain. The diagnostic based on stubbornly collectivity provides evidence for Boolean conjunctions and universal GQs. Combining these two diagnostics, the following shows that a Q-domain also contains Boolean coordination compounds of GQs.

Assume that the 8 students enrolled in a class are separated into four pairs by year and major. As part of the course requirement, each pair of students have to co-present one paper this or next week. Moreover, the instructor requires the presentations in each week to be given by students from the same department.

junior linguists:	$\{a_1, b_1\}$	junior philosophers:	$\{a_2, b_2\}$
senior linguists:	$\{c_1, d_1\}$	senior philosophers:	$\{c_2, d_2\}$

With the above background, consider the following conversation:

(30) a. Guest: "[In your class,] which students have to present a paper together this week?"
b. Instructor: "The two junior linguists and the two senior linguists, OR, the two junior philosophers and the two senior philosophers."

The question from the guest involves a necessity modal *have to* and a stubbornly collective predicate *present a paper together*. The answer provided by the instructor can be unpacked as follows: the disjunctive answer conveys in general a free choice inference as in (31a), and the choices are specified as in (31b-c). ('p.a.p.t.' is abbreviated for 'present a paper together'.)

(31) a. *The presentations this week have to be given by either the linguists or the philosophers. They can be given by the linguists, and can be given by the philosophers.*
b. *If the presentations are given by the linguists, $a_1 \oplus b_1$ will p.a.p.t., and $c_1 \oplus d_1$ will p.a.p.t..*
c. *If the presentations are given by the philosophers, $a_2 \oplus b_2$ will p.a.p.t., and $c_2 \oplus d_2$ will p.a.p.t..*

To get the free choice inference (31a), the disjunction must be interpreted under the scope of the necessity modal. Further, since the predicate *present a paper together* is stubbornly collective, to derive the conjunctive inferences in (31b-c), each disjunct/choice must be understood as naming a Boolean conjunction over two pairs of students. In sum, the strongest true answer of the question is an inference with the following scopal pattern: $\Box \gg$ *or* $\gg$ *and* $\gg$ *a paper*. To get this scopal pattern, the LF of this question should involve a higher-order *wh*-trace in between the necessity modal and the collective predicate, as in (32). Instructor's answer should be read as naming a Boolean disjunction over two Boolean conjunctions, namely, $((a_1 \oplus b_1)^{\Uparrow} \cap (c_1 \oplus d_1)^{\Uparrow}) \cup ((a_2 \oplus b_2)^{\Uparrow} \cap (c_2 \oplus d_2)^{\Uparrow})$.

(32) [which-students $\lambda\pi$ [$_{\text{IP}}$ have to [$\pi_{\langle et,t\rangle}$ λx [$_{\text{VP}}$ x_e present a paper together]]]]

2.4. Interim summary

To sum up, this section provides two diagnostics for ruling in higher-order meanings into a Q-domain. The first diagnostic is based on narrow scope readings of GQ-naming answers to questions in which the Q-function is non-reducible relative to the named GQs. Results of this diagnostic rule in Boolean disjunctions and a class of existential GQs. The second diagnostic is based on the absence of uniqueness effects in questions with a stubbornly collective predicate. This diagnostic rules in Boolean conjunctions and universal GQs. In addition, combining these two diagnostics, I have also shown that a Q-domain contains also Boolean coordinations of GQs.

3. Constraints on the Q-domain

Evidence from the previous section has shown that the Q-domain of a *wh*-question may contain Boolean disjunctions, conjunctions, a class of existential GQs, universal GQs, and their Boolean coordinations. One might wonder whether we can make the following generalization:

> The Q-domain yielded by a WH-phrase consists of all GQs ranging over a subset of the extension of the WH-complement and the Boolean combinations of these GQs.

In this section, I will show that this generalization is too strong. Spector (2007, 2008) gives some counterexamples to this generalization and argues that the GQs in a Q-domain must be **increasing**. Extending Spector's diagnostic to non-monotonic GQs, I show that the increasing-ness requirement is too strong. Instead, I argue that whether a higher-order meaning can be ruled into a Q-domain is determined by its **positiveness** and **homogeneity**.

3.1. The Completeness Test and The Increasing-ness Constraint

Whether a meaning is included in the Q-domain of a question can be examined by the **Completeness Test**, as generalized in (33). This test draws on a deductive relation between attitudes held towards a question and attitudes held towards the answers of this question: the question-embedding sentence *x knows Q* implies that x knows the complete true answer of Q. The complete answer of a question is the strongest true proposition in the Hamblin set of this question (Dayal 1996); hence, if a proposition p is true but is not entailed by the complete true answer of Q, p is not in the Hamblin set of Q.[7]

[7] Here I consider only questions with at most one complete true answer, which is the strongest true answer. For mention-some questions which can have multiple complete true answers, see Fox (2013) and Xiang (2016: chapter 2-3).

(33) **The Completeness Test** (generalized from Spector (2008))
For any proposition p that names a short answer x to a question Q: if *x knows Q* does not entail *x knows p*, then: p is not in the Hamblin set of Q, and x is not in the Q-domain of Q.

Consider (34) for an illustration of the simplest case. In the given context, the true answers of the question *who came* include positive propositions like *Andy and Billy came*, negative propositions like *Cindy did not come*, and their Boolean coordinations such as *Andy and Billy came but Cindy did not*. However, the question-embedding sentence (34) being true only requires the belief-holder Sue to know the positive answers; it does not require her to know the negative answers. This asymmetry suggests that the Q-domain of the embedded question includes *Andy and Billy* (interpreted either as a sum $a \oplus b$ or a GQ $\lambda P.P(a) \wedge P(b)$), but not the negative GQ *not Cindy* ($\lambda P.\neg P(c)$) or the conjunctive compound which involves a negative conjunct *Andy and Billy but not Cindy* ($\lambda P.P(a \oplus b) \wedge \neg P(c)$).

(34) (*w: Among the relevant individuals, Andy and Billy came, but Cindy did not.*)
Sue knows who came.
  a. $\rightsquigarrow$ *Sue knows that Andy and Billy came.*
  b. $\not\rightsquigarrow$ *Sue knows that Cindy did not come.*

For embeddings of $\Box$-questions, consider the truth conditions of the sentence (35b) under the context described in (35a). Strikingly, (35b) implies that Sue knows John's reading obligation (a-i), but not that she knows (a-ii); Sue can be ignorant about whether John should read any books by Betty.[8]

(35) a. Context: John's reading obligations include the following:
(i) he must read at least two books by Anne; (ii) he must read no book by Betty.
  b. Sue knows which books John must read.
$\rightsquigarrow$ *Sue knows (a-i).*
$\not\rightsquigarrow$ *Sue knows (a-ii).*

Given this contrast, Spector (2008) proposes that the GQs involved in a Q-domain must be increasing:[9] 'x knows Q' implies that x knows the complete/strongest true answer of Q; therefore, that Sue can be ignorant about the requirement (a-ii) excludes the decreasing GQ *no book by Betty* and the non-monotonic GQ-coordination *at least two books by Anne and no book by Betty* from the Q-domain. The higher-order reading is then paraphrased as follows: 'for which increasing GQ π over books, it is the case that John has to read π?'[10]

[8]Surprisingly, in contrast to (35b), the following two sentences with a concealed question or a definite description do imply that Sue knows all of John's reading obligations list in (35a).

(i) a. Sue knows what John's reading obligations are.
  b. Sue knows John's reading obligations.

[9]Monotonicity of GQs is defined as follows:

(i) For any π of type $\langle et, t\rangle$, π is ...
  a. *increasing* iff $\pi(A) \Rightarrow \pi(B)$ for any sets of entities A and B such that $A \subseteq B$;
  b. *decreasing* iff $\pi(A) \Leftarrow \pi(B)$ for any sets of entities A and B such that $A \subseteq B$;
  c. *non-monotonic* iff π is neither increasing nor decreasing.

[10]The Completeness Test in (i) considers two more cases that involve GQ-disjunctions (underlined). This test further

3.2. The Positiveness Constraint

The following example extends the Completeness Test to a broader range of GQs. The game requirements list in (36aa) each name a GQ over a set of cards. Among those GQs, (i-ii) are increasing, (iii-iv) are decreasing, and (v) is non-monotonic. Intuitively, the question-embedding sentence (36b) implies that Sue knows about not only (i-ii) but also (v). In particular, for the condition about her knowledge towards (v), it is insufficient if Sue knows that John has to play at least two hearts but does not know that he cannot play more than two hearts. Spector's Increasing-ness Constraint incorrectly rules out the non-monotonic GQ *exactly two hearts* and fails to predict that (36b) implies that Sue knows the requirement (v). More generally, any monotonicity-based constraint would face a dilemma — we want to rule out non-monotonic GQ-coordinations while not excluding simplex non-monotonic GQs.

(36) a. Context: John is playing a board game. This game requires him to play ...
  i. {at least three, more than two} red spades;
  ii. every black spade except the smallest one in his hand;
  iii. {at most three, less than four} black diamonds;
  iv. no red diamond except largest one in his hand;
  v. exactly two hearts;

b. Sue knows which cards John must play.
$\rightsquigarrow$ *Sue knows that John must play (a-i), (a-ii), (a-v).*
$\not\rightsquigarrow$ *Sue knows that John must play (a-iii)/(a-iv).*

In contrast to Spector (2008), I propose that whether a simplex or complex GQ should be ruled into a Q-domain is determined by its "positiveness", not its monotonicity. A GQ being positive means that the meaning of this GQ ensures existence with respect to its smallest live-on set. For example, *at least two books* and *exactly two books*, while having different monotonicity patterns, both entail *some books* and are thus positive. By contrast, the decreasing quantifier *at most two books* does not entail *some books* and is thus not positive. A formal definition is given in (37b). $\textsf{\textit{some}}(\textsc{smlo}(\pi))$ stands for the GQ derived by applying the basic existential determiner $\textsf{\textit{some}}$ to the smallest live-on set of π. (For the definition of live-on sets, see footnote 3.)

(37) **The Positiveness Constraint**

a. GQs in the Q-domain of a WH-question must be positive.

b. For any π of type $\langle et, t\rangle$, π is positive iff $\pi \subseteq \textsf{\textit{some}}(\textsc{smlo}(\pi))$.

confirms that non-monotonic Boolean disjunctions must be excluded from the Q-domain of the embedded question.

(i) a. John's reading obligations for the summer consist of the following:
  i. John has to read <u>no leisure book or more than two math books</u>. (In other words, John has to read more than two math books if he reads any leisure book.)
  ii. John has to read <u>none or all of the Harry Potter books</u>, (because Harry Potter books must be rented in a bundle, and his mom would blame him for wasting money if he rents the entire book series but only reads some of them.)

b. Sue knows which books John has to read in the summer. $\not\rightsquigarrow$ *Sue knows (a-i)/(a-ii).*

Table 1 compares monotonicity and positiveness for a list of GQs that range over a set of books. (a and b are two distinct atomic books). Observe that increasing GQs are all positive, decreasing ($\downarrow_{\text{MON}}$) GQs are all non-positive, and non-monotonic (N.M.) GQs can be positive or non-positive.

Generalized quantifier π	SMLO(π)	Increasing?	Positive?
$a^{\Uparrow}$	$\{a\}$	Yes	Yes
$a^{\Uparrow} \cap b^{\Uparrow}$, $a^{\Uparrow} \cup b^{\Uparrow}$	$\{a, b\}$	Yes	Yes
{at least, more than} two books	*books*	Yes	Yes
every book except a	*book* $- \{a\}$	Yes	Yes
{at most, less than} two books	*books*	No ($\downarrow_{\text{MON}}$)	No
no book except a	*book* $- \{a\}$	No ($\downarrow_{\text{MON}}$)	No
exactly two books	*books*	No (N.M.)	Yes
two to ten books	*books*	No (N.M.)	Yes
less than three or more than ten books	*books*	No (N.M.)	No

Table 1: Increasing-ness/monotonicity versus positiveness

3.3. The Homogeneity Constraint

Table 1 has considered only coordinations over Montagovian individuals and GQs of the simplex form 'Det+NP'. Benjamin Spector (pers. comm.) points out that, however, positiveness does not exclude the unwanted non-monotonic GQ-coordinations such as *every article and no book*. Calling this GQ-conjunction π and representing it as $\{E \mid A \subseteq E \wedge B \cap E = \emptyset\}$, we have SMLO$(\pi) = A \cup B$ and $\pi \subseteq \mathtt{some}(A \cup B)$.[11] Benjamin Spector further points out that any GQ π can be semantically decomposed into the conjunction $\pi^+ \cap \pi^-$, where π^+ is the logically strongest increasing GQ entailed π, and π^- is the logically strongest decreasing GQ entailed by π.

(38) **Decomposing a GQ**
For any π of type $\langle et, t \rangle$, $\pi = \pi^+ \cap \pi^-$ where $\pi^+ =_{\text{df}} \{P \mid \exists P' \subseteq P[\pi(P')]\}$, and $\pi^- =_{\text{df}} \{P \mid \exists P' \supseteq P[\pi(P')]\}$

In particular, if π is monotonic, then one of the retrieved strongest GQ is trivial: π is increasing iff $\pi^- = D_{\langle e,t \rangle}$, and π is decreasing iff $\pi^+ = D_{\langle e,t \rangle}$. The smallest live-on set of the trivial GQ $D_{\langle e,t \rangle}$ is D_e. Hence, to exclude non-monotonic GQ-coordinations (e.g., *every article and no book*) while keeping

[11] The following explains why $A \cup B$ is the smallest live-on set of π. First, (i-a) shows that $A \cup B$ is a live-on set of π: replacing E with $E \cap (A \cup B)$ does not change the set being defined. Next, (i-b) shows that $A \cup B$ is the smallest live-on set: for any a, replacing E with $E \cap (A \cup B - \{a\})$ in the set description makes no change to the set being defined iff $a \notin A \cup B$.

(i) $\pi = \{E \mid A \subseteq E \wedge B \cap E = \emptyset\}$

a. $\{E \mid [A \subseteq (E \cap (A \cup B))] \wedge [B \cap (E \cap (A \cup B)) = \emptyset]\}$
$= \{E \mid [A \subseteq E \wedge A \subseteq (A \cup B)] \wedge [(B \cap (A \cup B)) \cap E = \emptyset]\}$
$= \pi$

b. $\{E \mid [A \subseteq (E \cap ((A \cup B) - \{a\}))] \wedge [B \cap (E \cap ((A \cup B) - \{a\})) = \emptyset]\}$
$= \{E \mid [A \subseteq E \wedge A \subseteq (A \cup B - \{a\})] \wedge [(B \cap ((A \cup B) - \{a\})) \cap E = \emptyset]\}$
$= \{E \mid [A \subseteq E \wedge A \subseteq (A \cup B) \wedge a \notin A] \wedge [(B - \{a\}) \cap E = \emptyset]\}$
$= \pi$ iff $a \notin A$ and $a \notin B$

simplex non-monotonic GQs (e.g., *exactly two books*), we just need to exclude the non-monotonic πs from which the retrieved π^+ and π^- range over different sets. For example, *exactly two books* is not excluded since it would be decomposed into two GQs ranging over the same set books (i.e., *at least two books* and *no more than two books*). I call GQs satisfying this condition as being "homogenous" and propose that the higher-order meanings involved in the Q-domain of a question is also subject to homogeneity.

(39) **The Homogeneity Constraint**

a. GQs in the Q-domain of a WH-question must be homogenous.

b. For any π of type $\langle et, t\rangle$, π is homogenous iff π is monotonic or $\textsc{smlo}(\pi^+) = \textsc{smlo}(\pi^-)$.

Table 2 compares positiveness and homogeneity. Observe that the complex non-monotonic GQ *every A and no B* is positive but not homogenous. Out of this complex GQ, the strongest increasing GQ ranges over A, while the strongest increasing GQ ranges over B.

GQ π	SMLO(π)	SMLO(π^+)	SMLO(π^-)	Positive?	Homogenous?
at least two B	B	B	D_e	Yes	Yes
exactly two B	B	B	B	Yes	Yes
every A and no B	$A \cup B$	A	B	Yes	No

Table 2: Positiveness versus homogeneity

3.4. Interim summary

In summary, the Q-domain yielded by the phrase '*wh*-A' in a higher-order reading, if any, is the set consisting of the positive homogenous GQs ranging over a subset of A. I write this set as ${}^{\mathrm{H}}A$.

(40) ${}^{\mathrm{H}}A = \{\pi_{\langle et,t\rangle} \mid \textsc{smlo}(\pi) \subseteq A \wedge \pi \text{ is positive} \wedge \pi \text{ is homogenous}\}$, where

a. π is positive iff $\pi \subseteq \mathit{some}(\textsc{smlo}(\pi))$;

b. π is homogenous iff π is monotonic or $\textsc{smlo}(\pi^+) = \textsc{smlo}(\pi^-)$.

It is unclear where the positiveness and homogeneity constraints come from. They could be in the lexicon of a type-shifting operator, presupposed by the higher-order *wh*-trace, or constraints on semantic reconstruction. For now, I just treat 'H' as a syntactically presented operator asserting positiveness and homogeneity. (For distributional constraints of this operator, see section 4.) Then, the first-order/higher-order ambiguity of a WH-question can be attributed to the absence/presence of the H-shifter within the WH-phrase. As exemplified in (41), in the LF for the higher-order reading, a H-shifter is applied to the WH-complement, shifting the restrictor of the *wh*-determiner from a set of entities to a set of positive homogenous GQs, and then the WH-phrase binds a higher-order trace π across the modal verb.

(41) Which books does John have to read?

a. **First-order reading**
[which-books λx [have-to [John read x_e]]]
$[\![\text{WH-Q}]\!] = \lambda x_e\colon x \in \mathit{books}_w.\Box\lambda w.\mathit{read}_w(j, x)$

b. **Higher-order reading** ($\Box \gg \pi$) (Revised from (11))
[which-$^{\mathrm{H}}$books $\lambda\pi$ [have-to [$\pi_{\langle et,t\rangle}$ λx [John read x_e]]]]
$[\![\text{WH-Q}]\!] = \lambda\pi_{\langle et,t\rangle} : \pi \in {}^{\mathrm{H}}\textit{books}_w . \Box\lambda w.\pi(\lambda x.\textit{read}_w(j, x))$

4. Distributing 'conjunction-admitting' higher-order readings

As discussed in section 2.2, uniqueness effects in WH-questions show that higher-order readings are unavailable in questions where the WH-complement is singular-marked or numeral-modified. Aforementioned examples are collected in the following:

(42) a. Which child came? $\rightsquigarrow$ *Exactly one of the children came.*
b. Which two children came? $\rightsquigarrow$ *Only two of the children came.*
c. Which two children formed a team? $\rightsquigarrow$ *Only two of the children formed any team.*

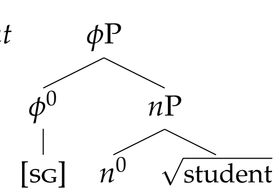
According to Dayal (1996), the singular-marked question (42a) presupposes uniqueness because its strongest true answer exists only when it has exactly one true answer. This analysis also extends to the numeral-modified questions (42b-c), as argued in section 2.2 and Xiang 2016. Adopting this analysis of uniqueness, I have concluded that these questions cannot take answers that name Boolean conjunctions, and further that these questions do not have higher-order readings.

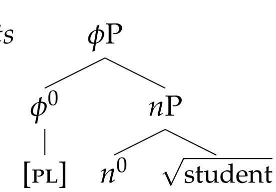
Strikingly, in contrast to a numeral-modifier, a PP-modifier does not block higher-order readings. Compare the following two sentences for example. Although *students (that are) in a group of two* is semantically similar to *two student*, the embedded question in (44), where the WH-complement is modified by a PP or a relative clause does not presuppose uniqueness, and the question-embedding sentence can be naturally followed by an answer sentence that names a Boolean conjunction. This contrast suggests that the availability of higher-order reading is sensitive to the internal structure of the WH-complement.

(43) I know which **two students** presented a paper together,
a. ... the two boys.
b. # ... the two boys and the two girls.

(44) I know which **students (that are) in a group of two** presented a paper together,
a. ... the two boys.
b. ... the two boys and the two girls.

To account for the above distributional constraints, I propose that the H-shifter (i.e., the operator that turns a set of entities into a set of GQs) is applied locally to the nP within the WH-complement and argue that the application of H is blocked in singular-marked nouns and numeral-modified nouns due to conflicts in meaning and types. First of all, I assume the following structure for a singular/plural bare noun:

(45) a. *student*


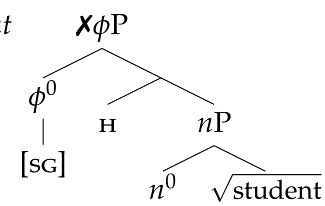
b. *students*


At the right bottom of each tree, n^0 combines with the root $\sqrt{\text{student}}$ and returns a projection nP which denotes a set with a complete join semi-lattice structure (Harbour 2014). For example, with three atomic students abc, $[\![n\text{P}]\!] = \{a, b, c, a \oplus b, a \oplus c, b \oplus c, a \oplus b \oplus c\}$. The number feature [SG]/[PL] is evaluated at ϕ^0. Following Sauerland (2003), I treat [PL] semantically vacuous while [SG] a predicate modifier asserting (or presupposing) atomicity.

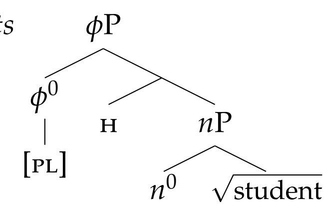
(46) a. $[\![[\text{PL}]]\!] = \lambda P_{\langle e,t\rangle} \lambda x_e . P(x)$
b. $[\![[\text{SG}]]\!] = \lambda P_{\langle e,t\rangle} \lambda x_e . \text{ATOM}(x) \wedge P(x)$
c. $[\![[\text{PL}](n\text{P})]\!] = [\![n\text{P}]\!] = \{a, b, c, a \oplus b, a \oplus c, b \oplus c, a \oplus b \oplus c\}$
d. $[\![[\text{SG}](n\text{P})]\!] = \{a, b, c\}$

The above assumptions straightforwardly explain why the H-shifter cannot be used in singular nouns. In (47a), applying the H-shifter to nP returns a set of GQs and GQ-compounds, which are all non-atomic and are conflicting with the atomicity requirement of [SG]. Hence, the H-shifter cannot be applied in a singular-marked WH-question because it would yield an empty Q-domain. In contrast, H-shifter can be freely used in simple plural-marked and number-neutral WH-questions because in these questions the [PL] feature carried by ϕ^0 is semantically vacuous.[12]

(47) a. *student*

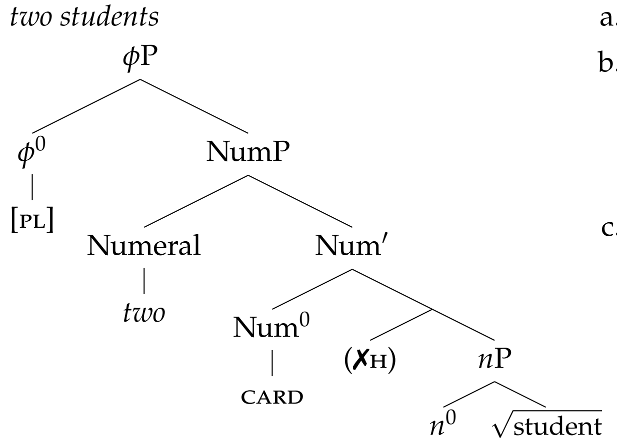


b. *students*



Next, consider numeral-modified NPs. Following Scontras (2014), I place cardinal numeral-modifiers at [Spec, NumP] and assume that Num^0 is located between n^0 and ϕ^0 and is occupied by a cardinality predicate CARD. As defined in (48a), CARD takes a predicate P and a numeral n and returns the set of individuals in P each of which is constituted of exactly-n atoms. These assumptions automatically explain why the H-shifter cannot be used in a numeral-modified NP: the CARD-predicate at Num^0 checks the cardinality of the elements in the set it combines with and hence it cannot combine with a set of GQs.

(48) *two students*

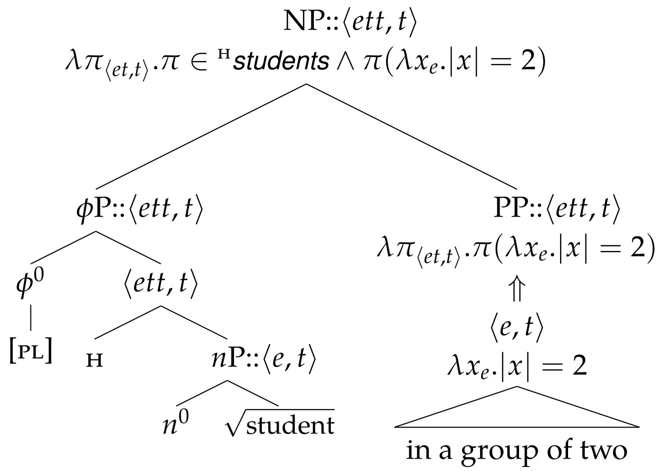


a. $[\![\text{CARD}]\!] = \lambda P \lambda n \lambda x . P(x) \wedge |x| = n$
b. Without the H-shifter
$[\![\text{Num}']\!] = \lambda n \lambda x . \textit{students}(x) \wedge |x| = n$
$[\![\text{NumP}]\!] = \lambda x . \textit{students}(x) \wedge |x| = 2$
$= \{a \oplus b, b \oplus c, a \oplus c\}$
c. With the H-shifter
$[\![\text{Num}']\!]$ is undefined (or Num′ has type-mismatch)

[12] This claim holds regardless of whether plurals are treated inclusively or exclusively. One can also treat [PL] as a predicate restrictor that asserts/presupposes non-atomicity or anti-presupposes atomicity. See also footnote 5.

In contrast to numeral-modifiers, PP-modifiers are adjoined to the entire NP/ϕP. Hence, the H-shifter can be used in the modified NP without causing a type-mismatch. As illustrated in (49), all we need is applying argument-lifting to the PP-modifier and shifting it into a set of GQs. Then, the lifted PP composes with the higher-order ϕP standardly via Predicate Modification. This analysis also extends to NPs modified with relative clauses.

(49) *students in a group of two*



5. The 'conjunction-rejecting' higher-order reading

5.1. The puzzles

In section 2.2, based on stubborn collectivity and uniqueness effects, I showed that WH-questions with a singular-marked or numeral-modified WH-complement do not admit answers naming Boolean conjunctions. I further concluded in section 4 that these questions do not have higher-order readings and explained this distributional constraint. The explanation attributed the unavailability of higher-order readings to that applying the H-shifter yields semantic consequences that conflict with the atomicity requirement of singular nouns and the cardinality requirement of numerals.

Surprisingly, however, in responding to a $\Box$-question where the WH-phrase is singular-marked or numeral-modified, narrow scope disjunctions are not as bad as conjunctions. This contrast is witnessed in (50) and (51).[13]

(50) I know which book John has to read,

a. # ... Book A and Book B.

b. ? ... Book A or Book B. (#*or* $\gg \Box$, ?$\Box \gg$ *or*)

(51) I know which two books John has to read ...

a. ?? ... the two French books and the two Russian books.

b. ? ... the two French books or the two Russian books. (#*or* $\gg \Box$, ?$\Box \gg$ *or*)

[13]The conjunctive continuation in (51a) is intuitively more acceptable than the conjunctive continuation in (50a), as pointed out by Gennaro Chierchia (p.c.). One possibility for the improvement in (51a) is that the numeral *two* can be reconstructed to the nucleus, which yields a simple plural-marked question roughly read as 'which books are two books that John have to read?'

Narrow scope readings of elided disjunctions are even more readily available in discourse. In (52), the disjunction in the answer is interpreted under the scope of *should*, conveying a free choice inference that the questioner is free to use any one of the two mentioned textbooks. By the diagnostic of non-reducibility in section 2.1, that the disjunctive answer admits a narrow scope reading suggests that here the $\Box$-question admits higher-order answers, which conflicts with the aforementioned generalization that singular-marked questions do not have higher-order readings.

(52) Which textbook should I use for this class?
Heim&Kratzer or *Meaning&Grammar*, the choice is up to you.

A similar fact is observed in questions with possibility modal (called $\Diamond$-questions henceforth). $\Diamond$-questions are known to be ambiguous between mention-some (MS-)readings and mention-all (MA-)readings (Groenendijk and Stokhof 1984; for an extensive discussion on what is 'mention-some', see Xiang 2016: chapter2). As exemplified in (53), if interpreted with a MS-reading, the $\Diamond$-question can be naturally addressed by an answer that specifies only one feasible option; while in MA-readings, the $\Diamond$-question requires the addressee to exhaustively list out all the feasible options. Crucially, MA-answers of $\Diamond$-questions can have either an elided conjunctive form, as in (53b), or an elided disjunctive form read as free choice, as in (53c). While having different forms, both of the MA-answers convey the same conjunctive inference that we can use *Heim&Kratzer* for this class <u>and</u> we can use *Meaning and Grammar* for this class.

(53) What can we use [as a textbook] for this class?
a. *Heim&Kratzer*. MS
b. *Heim&Kratzer* and *Meaning and Grammar*. Conjunctive MA
c. *Heim&Kratzer* or *Meaning and Grammar*. Disjunctive MA

In Xiang (2016), I propose that MS-readings are higher-order readings: in the LF of a $\Diamond$-question with a MS-reading, the WH-phrase binds a higher-order trace across the $\Diamond$-modal. In responding to the MS/MA ambiguity of $\Diamond$-questions, I argue that MA-readings arise as long as one of the following conditions is met: (i) the higher-order *wh*-trace takes wide scope, or (ii) this trace is associated with an operator with a meaning akin to the Mandarin free choice licensing particle *dou*. In particular, condition (i) yields conjunctive MA, and condition (ii) yields disjunctive MA. I will give more details of this analysis in section 5.3.2.

It is commonly believed that MS-readings and multi-choice readings are unavailable in singular-marked $\Diamond$-questions because these questions presuppose uniqueness (Fox 2013; Xiang 2016: chapter 3). The infelicity of the continuations in (54) supports this view: the continuations name multiple choices of textbooks, while the preceding question-embedding sentence implies that there is only one feasible choice.

(54) I know which textbook we can use for this class, ...
a. # ... *Heim&Kratzer* and *Meaning and Grammar*.
b. ? ... *Heim&Kratzer* or *Meaning and Grammar*.

However, Hirsch and Schwarz (2019) novelly observe that the matrix singular-marked $\Diamond$-question in (55) does admit a multi-choice reading. They argue that the singular WH-phrase triggers uniqueness but the uniqueness presupposition can be accommodated under the scope of the modal verb *could*. The question can be read as 'for which x, it is the case that x is the unique letter missing in *fo_m*?'.

(55) Which letter could be missing in *fo_m*? (Hirsch and Schwarz 2019)

  a. (The missing letter could be) *a*.

  b. The missing letter could be *a* and the missing letter could be *r*.

Note that in example (55), the multi-choice answer (55b) is not a direct answer. As seen in (56a-b), in the form congruent with the question or in the form of a short answer, the conjunctive answers are greatly degraded. In contrast, the multi-choice inference can be felicitously expressed in the form of an elided free choice disjunction, as in (56c). The same pattern is seen with numeral-modified WH-questions, as shown in (57).

(56) Which letter could be missing in *fo_m*?

  a. ?? *a* could be missing in *fo_m* and *r* could be missing in *fo_m*.

  b. # *a* and *r*.

  c. *a* or *r*. (Both are possible.)

(57) Which two letters could be missing in *f_ _m*?

  a. Letters *oa* or letters *or*.

  b. ?? Letters *oa* and letters *or*.

For a direct comparison with the number-neutral $\diamond$-question (53), I re-illustrate Hirsch and Schwarz's (2019) idea in (58). According to Hirsch and Schwarz, the uniqueness inference triggered by the singular WH-phrase *which textbook* can be interpreted globally or locally. The global uniqueness reading says that there is only one textbook that we can use for this class and the questioner asks to specify this book. The local uniqueness reading says that we will only use one textbook for this class and the questioner asks to list out one option, as in a MS-reading, or all the options, as in a MA-reading. In contrast to the numeral-neutral question in (53) where an elided MA-answer can be either a conjunction or a disjunction, here an elided MA-answer must be a disjunction, as seen in (53a-b). The disjunction/conjunction contrast is also seen with the universal free choice item *any book*, which is argued to be existential in lexicon (Chierchia 2006, 2013), and the basic universal quantifier *every book*.

(58) Which textbook can I use for this class?

  a. *Heim&Kratzer* or *Meaning and Grammar*. Disjunctive MA

  b. # *Heim&Kratzer* and *Meaning and Grammar*. Conjunctive MA

  c. Any book that teaches compositionality.

  d. # Every book that teaches compositionality.

To sum up, first, singular-marked and numeral-modified $\diamond$-questions admit multi-choice readings if uniqueness is interpreted locally. Second, their multi-choice answers must be expressed as free choice disjunctions, not as conjunctions.

In addition to WH-questions, Gentile and Schwarz (2018) make a similar observation with *how many*-questions. First, the same as singular-marked and numeral-modified WH-questions, *how* *many*-questions presuppose uniqueness. For example, the question in (59) cannot be felicitously responded by a multi-choice answer expressed by a conjunction of two cardinal numerals. Given that the predicate of this question (viz., *solved this problem together*) is stubbornly collective, Gentile and Schwarz conjecture from the uniqueness effect that the Q-domain of this question does not include Boolean conjunctions over numerals.

(59) How many students solved this problem together?
#Two and three.
(Intended: 'Two students solved this problem together, and (another) three students solved this problem together.')

Further, Gentile and Schwarz observe that $\diamond$-modals can obviate violations of uniqueness in *how many*-questions. For example, the question in (60) admits multi-choice answers like (60a-b) and does not seem to presuppose uniqueness. In analogy to (56-58), I add that the multi-choice answer cannot be expressed by an elided conjunction, as shown in (60c).

(60) How many students are allowed to solve this problem together?
a. Two are OK and three are OK.
b. Two or three.
c. # Two and three.

Two puzzles arise from the above observations. First, why singular-marked or numeral-modified $\Box/\diamond$-questions admit disjunctive answers but not conjunctive answers? Second, why this 'conjunction-rejecting' higher-order reading is available despite that the WH-phrase is singular-marked or numeral-modified, in contrast to the 'conjunction-admitting' higher-order reading discussed in section 4?

The following sections provide two approaches to derive the 'conjunction-rejecting' higher-order reading and explain its distributional constraints. One approach treats the 'conjunction-rejecting' reading the very same reading as the regular higher-order reading but gives a weaker semantics to singular and numeral-modified nouns. The other approach assumes that the derivation of this reading involves reconstructing the WH-complement to the question nucleus and interpreting uniqueness locally. Both approaches can well explain the puzzles.

5.2. A uniform approach

The first approach treats the 'conjunction-rejecting' higher-order uniformly as the 'conjunction-admitting' higher-order reading. The core idea of this approach comes from a personal communication with Manuel Križ. To derive these two higher-order readings uniformly, all we need is to allow some of the Boolean disjunctions to be atomic or cardinal, just like entities.

In the following definitions, the (a)-condition on minimal witness sets ensures the atomic/cardinal GQ to be a Boolean disjunction, an existential quantifier, or a Montagovian individual. In comparison, if π is a universal quantifier or a Boolean conjunction, its minimal witness set is not singleton; if π is a decreasing quantifier, its minimal witness set is the empty set.[14]

(61) A GQ π is atomic iff

[14] Witness sets are defined in terms of the living-on property as follows (Barwise and Cooper 1981):

a. the minimal witness sets of π are all singleton sets;

b. every member in the smallest live-on set of π is atomic.

(62) A GQ π has the cardinality n iff

a. the minimal witness sets of π are all singleton sets;

b. every member in the smallest live-on set of π has the cardinality n.

Based on the above assumptions, I re-define the singular feature [SG] and the cardinality predicate CARD as polymorphic restrictors in (64). '$\textsc{mws}(A, x)$' is read as 'A is a minimal witness set of x'.

(63) Old definitions

a. $[\![[\textsc{sg}]]\!] = \lambda P_{\langle e,t\rangle}\lambda x_e.P(x) \wedge \textsc{Atom}(x)$

b. $[\![\textsc{card}]\!] = \lambda P\lambda n\lambda x.P(x) \wedge |x| = n$

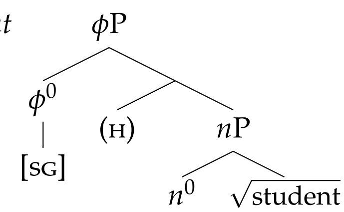
(64) New definitions

a. $[\![[\textsc{sg}]]\!] = \lambda P\lambda x.\begin{cases} P(x) \wedge \textsc{Atom}(x) & \text{if } P \subseteq D_e \\ P(x) \wedge \forall A[\textsc{mws}(A, x) \rightarrow |A| = 1] \wedge \forall y \in \textsc{smlo}(x)[\textsc{Atom}(y)] & \text{if } P \subseteq D_{\langle et,t\rangle} \end{cases}$

b. $[\![\textsc{card}]\!] = \lambda P\lambda n\lambda x.\begin{cases} P(x) \wedge |x| = n & \text{if } P \subseteq D_e \\ P(x) \wedge \forall A[\textsc{mws}(A, x) \rightarrow |A| = 1] \wedge \forall y \in \textsc{smlo}(x)[|y| = n] & \text{if } P \subseteq D_{\langle et,t\rangle} \end{cases}$

With the revised definitions, the H-shifter can be used regularly in singular nouns and numeral-modified nouns. In a discourse with three students *abc*, the singular noun *student* and the numeral-modified noun *two students* are interpreted as follows. The conjunction-rejecting reading is then derived in the exactly same way as the conjunction-admitting readings.

(65) *student*



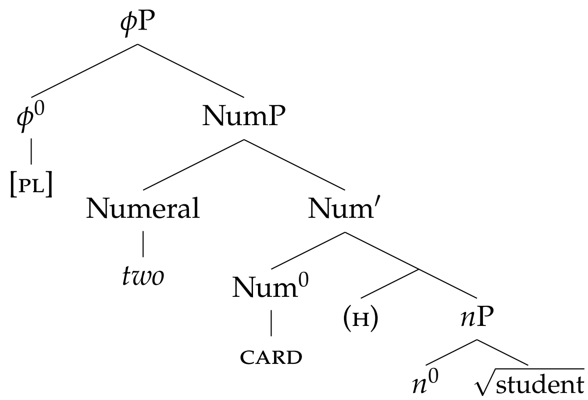
a. Without H: $[\![\phi\text{P}]\!] = \{a, b, c\}$

b. With H: $[\![\phi\text{P}]\!] = \{a^{\Uparrow}, b^{\Uparrow}, c^{\Uparrow}, a^{\Uparrow} \cup b^{\Uparrow}, a^{\Uparrow} \cup c^{\Uparrow}, a^{\Uparrow} \cup c^{\Uparrow}, a^{\Uparrow} \cup b^{\Uparrow} \cup c^{\Uparrow}\}$
$= \{\bigcup A \mid A \subseteq \{x^{\Uparrow} \mid x \in \{a, b, c\}\}$

(i) if a GQ π lives on a set B, then A is a **witness set** of π iff $A \subseteq B$ and $\pi(A)$.

For example, given a discourse domain including three students *abc*, the universal quantifier *every student* has a unique minimal witness set $\{a, b, c\}$, while the singular existential quantifier *some student* has three minimal witness sets $\{a\}$, $\{b\}$, and $\{c\}$, each of which consists of one atomic student.

(66) *two students*



a. Without H: $[\![\phi\text{P}]\!] = [\![\text{NumP}]\!] = \{a \oplus b, b \oplus c, a \oplus c\}$

b. With H:

$$[\![\phi\text{P}]\!] = [\![\text{NumP}]\!] = \left\{ \begin{array}{ccc} (a \oplus b)^{\Uparrow}, & (b \oplus c)^{\Uparrow}, & (a \oplus c)^{\Uparrow} \\ (a \oplus b)^{\Uparrow} \cup (b \oplus c)^{\Uparrow}, & (a \oplus b)^{\Uparrow} \cup (a \oplus c)^{\Uparrow}, & (a \oplus b)^{\Uparrow} \cup (a \oplus c)^{\Uparrow} \\ & (a \oplus b)^{\Uparrow} \cup (b \oplus c)^{\Uparrow} \cup (a \oplus c)^{\Uparrow} & \end{array} \right\}$$
$$= \{\bigcup A \mid A \subseteq \{x^{\Uparrow} \mid x \in \{a \oplus b, b \oplus c, a \oplus c\}\}$$

5.3. A reconstruction-based approach

This section proposes a reconstruction-based approach to deriving the conjunction-rejecting higher-order readings. I will first discuss the derivational procedure and consequences of reconstructing a singular WH-complement to the nucleus, and explain why singular-marked and numeral-modified □-questions admit narrow scope disjunctive answers. Then I will extend this analysis to ◇-questions and explain the contrast between disjunctive and conjunctive MA-answers.

5.3.1. □-questions

Let us start with a singular-marked □-question. (67) provides the rough LF structures and the yielded Q-functions for first-order and higher-order readings with local uniqueness. In both LF structures, the WH-complement *book* is reconstructed to a position in the nucleus c-commanded by the □-modal. The reconstruction has two consequences. First, it leaves a semantically unmarked variable D as the restrictor of the WH-phrase, which can be type-lifted freely by the H-shifter without causing a type-mismatch or a violation to atomicity. Thus, a higher-order reading arises if the H-shifter is applied to the D variable and if the WH-phrase binds a higher-order trace, as in (67b). Second, uniqueness is evaluated at whichever scopal position that the reconstructed noun adjoins to. In both (67a-b), uniqueness takes scope below the □-modal.[15]

[15]Luis Alonso-Ovalle (pers. comm.) points out that the assumed local uniqueness inference might be too strong for □-questions. For example, the question-answer in (i) can be felicitously uttered in a context where it is taken for granted that to win the game, one needs a group of two cards and also other cards.

(i) Which two cards do you need to win the game?
The two red aces or the two black aces.

I argue that the local uniqueness inference in (i) is assessed dynamically relative to a local context, namely, the context where the player has a bunch of cards in hand and only needs two more cards to close the game.

(67) Which book does John have to read?

a. First-order reading ($\Box \gg \iota$)

'For which entity x_e, it has to be the case that x is the book that John read?'

i. $[_{\text{CP}}$ which$_D$ λx $\Box$ $[x$ is the book John read$]]$

ii. $[\![\text{WH-}Q]\!] = \lambda x_e : x \in D.\Box\lambda w[x = \iota y[\textit{book}_w(y) \wedge \textit{read}_w(y)]]$

b. Higher-order reading ($\Box \gg \pi \gg \iota$)

'For which $\pi_{\langle et,t\rangle}$, it has to be the case that π is the book that John read?'

i. $[_{\text{CP}}$ which$_{^{\text{H}}D}$ $\lambda\pi$ $\Box$ $[\pi_{\langle et,t\rangle}$ $\lambda x.$ x_e is the book John read$]]$

ii. $[\![\text{WH-}Q]\!] = \lambda\pi_{\langle et,t\rangle} : \pi \in {}^{\text{H}}D.\Box\lambda w[\pi(\lambda x_e.x = \iota y[\textit{book}_w(y) \wedge \textit{read}_w(j, y)])]$

The following trees illustrate the two LF structures in more details. The syntactic reconstruction of the WH-complement is realized in three steps. First, a copy of *which book* is interpreted within the nucleus. As assumed in categorial approaches, *which book John read* denotes a one-place predicate. Second and third, THE-insertion introduces uniqueness, and variable insertion introduces a variable bound by the WH-phrase.[16] In particular, in the LF (69) for the higher-order reading, the same as what is assumed for conjunction-admitting higher-order readings, here the *wh*-restrictor (viz., the domain variable D) is type-raised by a H-shifter, and the WH-phrase binds a higher-order trace π across the $\Box$-modal.

(68) LF with reconstruction for the first-order reading ($\Box \gg \iota$)

[16] I assume a locality constraint that the variable introduced by variable insertion has to be the variable directly bound by the WH-phrase. With this assumption, in the LF for the higher-order reading, variable insertion introduces a higher-order variable π; it cannot be as follows where it introduces an individual variable x bound by the higher-order *wh*-trace:

(i) * [*wh*P $\lambda\pi_{\langle et,t\rangle}$ [have to [π λx_e [$\underline{\lambda y.x = y}$ [THE [which book John read]]]]]

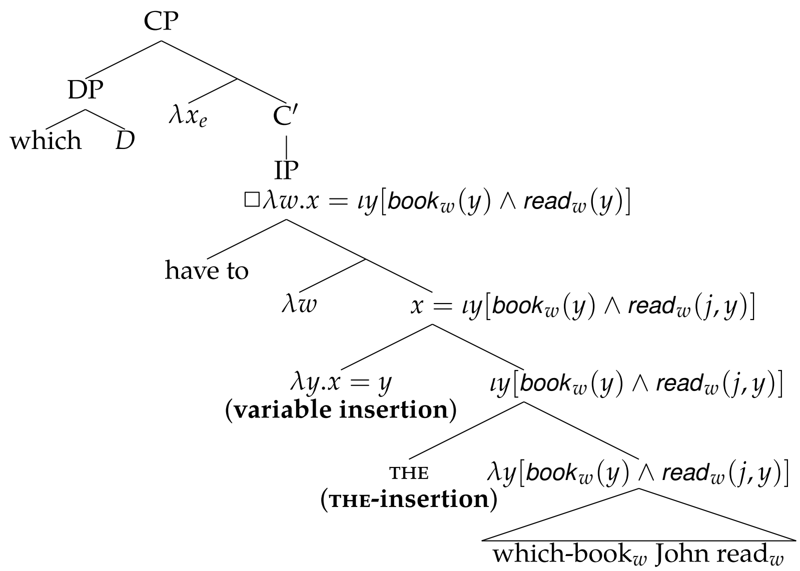
This constraint avoids unattested split scope readings of conjunctive answers to questions with an existential quantifier. Observe that the question in (ii) cannot be felicitously responded by a conjunction. The infelicity of the conjunctive answer suggests that this answer cannot be interpreted with a split scope reading as follows: 'for a math problem x_1, Andy is the unique student who solved x_1, and for a math problem x_2, Billy is the unique student who solved x_2' (*and* $\gg \exists \gg \iota$). The unavailability of this reading requests to rule out the LF in (iib) where the existential quantifier *a math problem* takes scope between the higher-order trace π and the inserted THE.

(ii) Which student solved a math problem?
\# Andy and Billy. (*and* $\gg \iota \gg \exists$)

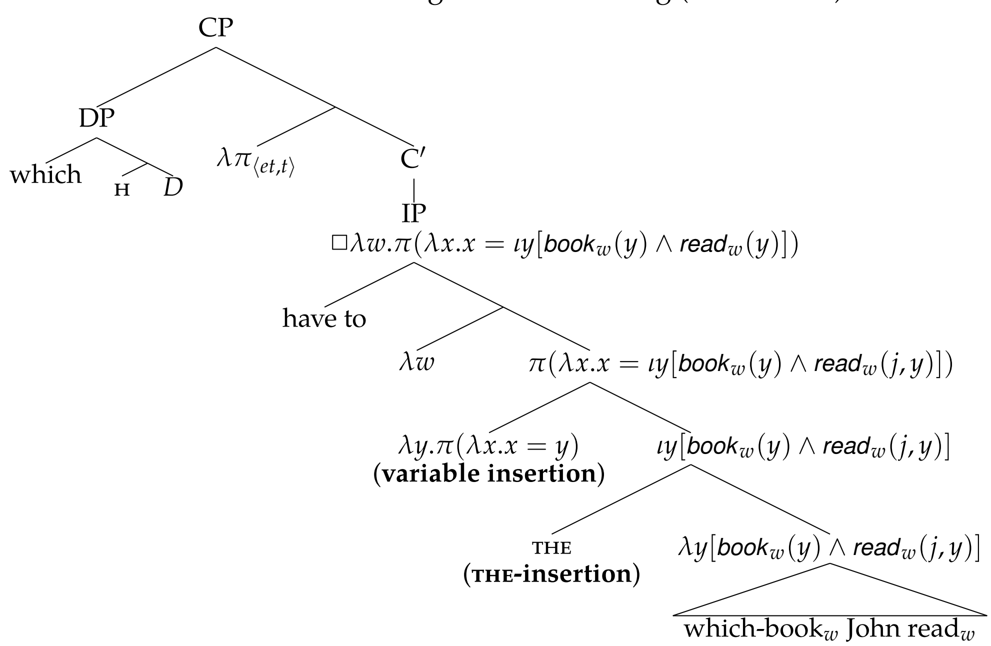
a. [*wh*P $\lambda\pi_{\langle et,t\rangle}$ [$\underline{\lambda y.\pi(\lambda x.x = y)}$ [THE [which student solved a math problem]]]]

b. * [*wh*P $\lambda\pi_{\langle et,t\rangle}$ [π λx_e [[a math problem] λz [$\underline{\lambda y.x = y}$ [THE [which student solved z]]]]]]

One might have concerns with the assumed syntax for reconstruction. The assumed THE-insertion and variable insertion, on the one hand, are similar to the operations of determiner replacement and variable insertion used in trace conversion (Fox 2002) especially backward trace conversion (Erlewine 2014). On the other hand, in trace conversion, THE-insertion and determiner replacement are locally applied to the moved DP (e.g. *which book*), while in my proposal, THE-insertion and variable insertion apply to a larger constituent 'DP+VP' (e.g., *which book John read*). I admit that the assumed syntax for reconstruction is unconventional, but this is not necessarily a problem for considering (69) as the structure that derives the 'conjunction-rejecting' reading. As seen in section 5.1, this reading itself is a bit unnatural. It is much harder to get than the conjunction-admitting reading, especially in question-embeddings (see (50-51) and (54)). Thus, it is likely that the derivation of this reading requires abnormal operations, and it is possible that the structure used for deriving this reading is not the real LF of the considered question.



(69) LF with reconstruction for the higher-order reading ($\Box \gg \pi \gg \iota$)



The above derivation predicts that the higher-order trace π immediately scopes over uniqueness. This prediction explains why a question in this reading rejects conjunctive answers: if π is a Boolean conjunction, combining π with a predicate of uniqueness yields a contradiction. As shown in (70b), unless Book A and B are the same book, combining the Q-function with the conjunction $a^{\Uparrow} \cap b^{\Uparrow}$ yields a contradiction.

(70) Which book does John have to read?
$[\![\text{WH-Q}]\!] = \lambda\pi_{\langle et,t\rangle} : \pi \in {}^{\text{H}}D.\Box\lambda w[\pi(\lambda x_e.x = \iota y[\textit{book}_w(y) \wedge \textit{read}_w(j, y)])]$

a. Book A or Book B.
$[\![\text{WH-Q}]\!](a^{\Uparrow} \cup b^{\Uparrow}) = \Box\lambda w[[a = \iota y[\textit{book}_w(y) \wedge \textit{read}_w(j, y)]] \vee [b = \iota y[\textit{book}_w(y) \wedge \textit{read}_w(j, y)]]]$
(It has to be the case that the unique book that John read is Book A or that that the unique book he read is Book B.)

b. # Book A and Book B.
$[\![\text{WH-Q}]\!](a^{\Uparrow} \cap b^{\Uparrow}) = \Box\lambda w[[a = \iota y[\mathit{book}_w(y) \wedge \mathit{read}_w(j,y)]] \wedge [b = \iota y[\mathit{book}_w(y) \wedge \mathit{read}_w(j,y)]]]$
(#It has to be the case that the unique book that John read is Book A and that the unique book he read is Book B.)

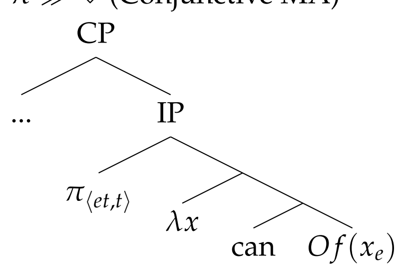
5.3.2. $\Diamond$-questions

The MA-answer of a question is the true answer that entails all the true answers to this question. In Xiang 2016: chapter 2, I argue that for a $\Diamond$-question, the MA-reading expecting conjunctive answers and the MA-reading expecting disjunctive answers are derived via different LF structures.

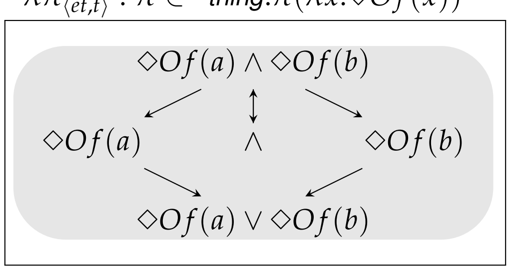
Conjunctive MA In the conjunctive MA-reading, the WH-phrase binds a higher-order trace which takes scope above the $\Diamond$-modal. The following considers the interpretations of a number-neutral $\Diamond$-question in cases where the higher-order *wh*-trace (π) takes scope below and above the $\Diamond$-modal. For each case, (71a/b) illustrates the structure of its question nucleus and the yielded Q-function and answer space. In both structures, a local O-operator ($\approx$ *only*) is associated with the individual trace x.[17] The illustration of each answer space considers only the propositions derived by applying the Q-function to the conjunction $a^{\Uparrow} \cap b^{\Uparrow}$, the Montagovian individuals $a^{\Uparrow}$ and $b^{\Uparrow}$, and the disjunction $a^{\Uparrow} \cup b^{\Uparrow}$. f stands for the predicate *use as a textbook for this class*; for example, $\Diamond Of(a)$ is read as 'Book A can be used as the only textbook for this class.' Arrows indicate entailment relations among the propositional answers, and shades mark the answers that are true in the described world.

(71) (*w: Book A and Book B each can be used as the only textbook for this class; no other book can be used as a textbook for this class.*)
What can we use [as a textbook] for this class? Book A and Book B.

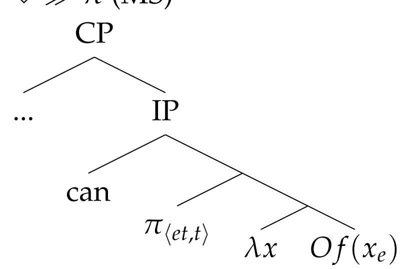
a. $\pi \gg \Diamond$ (Conjunctive MA)



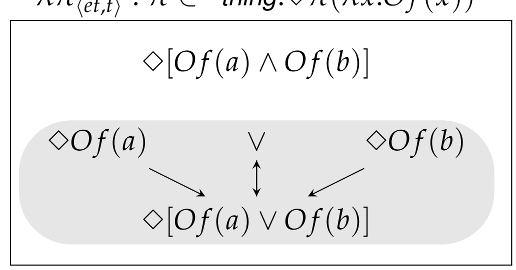
$\lambda\pi_{\langle et,t\rangle} : \pi \in {}^{\mathrm{H}}\mathit{thing}.\pi(\lambda x.\Diamond Of(x))$



b. $\Diamond \gg \pi$ (MS)



$\lambda\pi_{\langle et,t\rangle} : \pi \in {}^{\mathrm{H}}\mathit{thing}.\Diamond\pi(\lambda x.Of(x))$



[17] In Xiang (2016: chapter 2), I argue that an LF with narrow scope π yields a MS-reading. The local O-operator is assumed for predicting the facts that MS-answers are always mention-one answers, and that any answer that names one feasible option is a possible MS-answer. These issues are beyond the scope of this paper.

As seen in (71a), if the *wh*-trace π scopes above the $\diamond$-modal, the conjunctive answer derived by combining the Q-function with the Boolean conjunction $a^{\Uparrow} \cap b^{\Uparrow}$ entails all the true answers, and thus it is the complete answer to the $\diamond$-question. This conjunctive answer is read as 'it is possible that we use Book A as the only textbook for this class, and it is possible that we use Book B as the only textbook for this class.' In contrast, as seen in (71b), if π scopes under the $\diamond$-modal, the inference derived based on $a^{\Uparrow} \cap b^{\Uparrow}$ is a contradiction (and therefore is not shaded), read as '# it is possible that we use Book A as the only textbook for this class and Book B as the only textbook for this class.' In short, the take-away point is that conjunctive MA answers are available only if the LF of the $\diamond$-question has the '$\pi \gg \diamond$' scopal pattern.

Next, consider the singular-marked $\diamond$-question in (72). Again, the puzzle is that multi-choice answers of this question cannot have a conjunctive form. As assumed in section 5.3.1, the derivation of the higher-order reading of a singular-marked question involves reconstructing the WH-complement. Reconstructing the singular noun *book* and letting the higher-order *wh*-trace π take scope above the $\diamond$-modal yield the following scopal pattern: $\pi \gg \iota \gg \diamond$. As shown in (72b), unless A and B are the same book, combining the derived higher-order Q-function with the Boolean conjunction $a^{\Uparrow} \cap b^{\Uparrow}$ yields a contradiction.

(72) Which book can we use [as a textbook] for this class? # Book A and Book B.
  a. $[\![\text{WH-Q}]\!] = \lambda \pi_{\langle et,t \rangle} : \pi \in {}^{\text{H}}D.\lambda w[\pi(\lambda x_e.x = \iota y[\textsf{book}_w(y) \wedge \diamond_w f(y)])]$
  b. $[\![\text{WH-Q}]\!](a^{\Uparrow} \cap b^{\Uparrow}) = \lambda w[[a = \iota y[\textsf{book}_w(y) \wedge \diamond_w Of(y)]] \wedge [b = \iota y[\textsf{book}_w(y) \wedge \diamond_w Of(y)]]]$
  (#*a* is the unique book that we can use as the only textbook for this class, and *b* is the unique book that we can use the only textbook for this class.)

Disjunctive MA In contrast, disjunctive MA arises if the higher-order *wh*-trace is associated with an DOU-operator, regardless of whether this trace scopes below or above the $\diamond$-modal (Xiang 2016: chapter 2). The DOU-operator is the covert counterpart of the Mandarin particle *dou*. This particle has many different uses. In $\diamond$-questions, associating *dou* with a WH-phrase blocks the MS-reading, as seen in (73a); in $\diamond$-declaratives, associating *dou* with a pre-verbal disjunction yields a free choice (FC) inference, as shown in (73b). (For other uses of *dou* and a unified analysis, see Xiang 2016: chapter 7 and Xiang To appear.) It is thus appealing to unify the derivation of free choice disjunction in $\diamond$-declaratives and the derivation of disjunctive MA-readings of $\diamond$-questions.

(73) a. **Dou** [shei] keyi jiao jichu hanyu?
  DOU who can teach Intro Chinese
  'Who can teach Intro Chinese?' (MA only)
  b. [Yuehan huozhe Mali] **dou** keyi jiao jichu hanyu
  John or Mary DOU can teach intro Chinese
  Intended: 'Both John and Mary can teach Intro Chinese.'

I define *dou* as a pre-exhaustification exhaustifier over sub-alternatives. As schematized in (74), *dou* affirms its propositional argument and negates the exhaustification of each of the sub-alternatives of its propositional argument (Xiang 2016: chapter 7; Xiang To appear). The alternations in function of *dou* come from minimal variations with the semantics of sub-alternatives (details omitted). In particular, for a disjunctive sentence of the form $\diamond(\phi \vee \psi)$ or the form $\diamond\phi \vee \diamond\psi$, the sub-alternatives are $\Diamond\phi$ and $\Diamond\psi$. The covert DOU is semantically identical to *dou* except that it does not presuppose non-vacuity. With this semantics, applying *dou*/DOU to a disjunctive sentence yields a universal free choice inference.

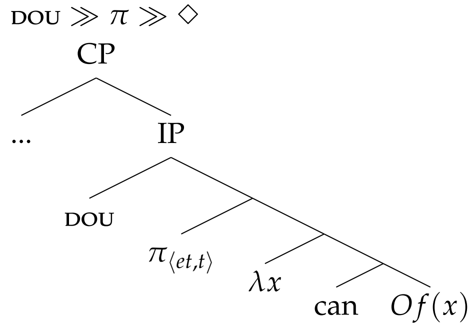
(74) $[\![dou_C]\!] = \lambda p \lambda w : \exists q \in \textsc{Sub}(p, C).p(w) = 1 \wedge \forall q \in \textsc{Sub}(p, C)[O_C(q)(w) = 0]$
(For any proposition p and world w, $[\![dou_C]\!](p)(w)$ is defined only if C contains a sub-alternative of p. When defined, $[\![dou_C]\!](p)(w)$ asserts that p is true in w, and that for any q that is a sub-alternative of p, the exhaustification of q is false in w.)

(75) $[\![\textsc{dou}_C]\!] = \lambda p \lambda w : p(w) = 1 \wedge \forall q \in \textsc{Sub}(p, C)[O_C(q)(w) = 0]$

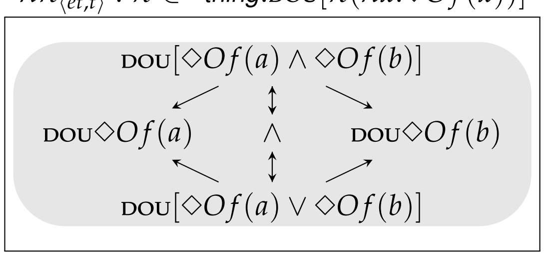
The following illustrates two possible structures of the question nucleus for the disjunctive MA-readings as well as the Q-function and answer space yielded by each structure. In both structures, a covert DOU-operator is presented at the left edge of the question nucleus and is associated with the higher-order trace π. The two structures differ only with respect to the scopal pattern between π and the $\Diamond$-modal. As computed in (77), no matter whether π scopes above or below $\Diamond$-modal, DOU strengthens the disjunctive answer into a free choice statement that is semantically equivalent to the conjunction of the two individual answers.

(76) (*w: Book A and Book B each can be used as the only textbook for this class; no other book can be used as a textbook for this class.*)
What can we use [as a textbook] for this class? Book A or Book B.

a. DOU $\gg \pi \gg \Diamond$

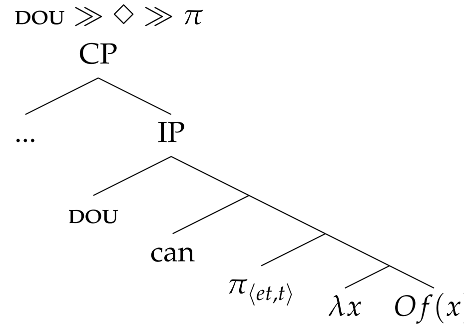


$\lambda\pi_{\langle et,t\rangle} : \pi \in {}^{\text{H}}\textit{thing}.\textsc{dou}[\pi(\lambda x.\Diamond Of(x))]$

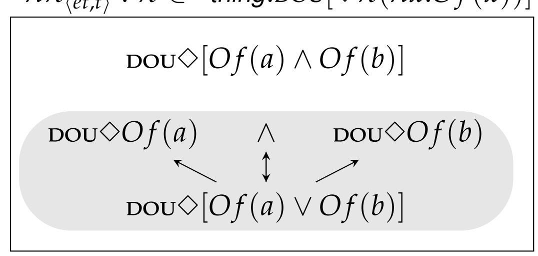


With DOU ($\pi \gg \Diamond$): disjunctive/conjunctive MA

b. DOU $\gg \Diamond \gg \pi$



$\lambda\pi_{\langle et,t\rangle} : \pi \in {}^{\text{H}}\textit{thing}.\textsc{dou}[\Diamond\pi(\lambda x.Of(x))]$



With DOU ($\Diamond \gg \pi$): disjunctive MA

(77) a. If $\pi \gg \Diamond$

$$\begin{aligned}
&\textsc{dou}[\Diamond Of(a) \vee \Diamond Of(b)]\\
&= [\Diamond Of(a) \vee \Diamond Of(b)] \wedge \neg O\Diamond Of(a) \wedge \neg O\Diamond Of(b)\\
&= [\Diamond Of(a) \vee \Diamond Of(b)] \wedge [\Diamond Of(a) \rightarrow \Diamond Of(b)] \wedge [\Diamond Of(b) \rightarrow \Diamond Of(a)]\\
&= [\Diamond Of(a) \vee \Diamond Of(b)] \wedge [\Diamond Of(a) \leftrightarrow \Diamond Of(b)]\\
&= \Diamond Of(a) \wedge \Diamond Of(b)
\end{aligned}$$

b. If $\Diamond \gg \pi$
$\textsc{dou}\Diamond[Of(a) \vee Of(b)]$
$= \Diamond[Of(a) \vee Of(b)] \wedge \neg O\Diamond Of(a) \wedge \neg O\Diamond Of(b)$
$= \Diamond[Of(a) \vee Of(b)] \wedge [\Diamond Of(a) \to \Diamond Of(b)] \wedge [\Diamond Of(b) \to \Diamond Of(a)]$
$= \Diamond[Of(a) \vee Of(b)] \wedge [\Diamond Of(a) \leftrightarrow \Diamond Of(b)]$
$= \Diamond Of(a) \wedge \Diamond Of(b)$

Next, return to singular-marked $\Diamond$-questions. Recall that, while rejecting conjunctive answers, singular-marked $\Diamond$-questions admit elided disjunctions as their MA-answers. The following considers the two possibilities where a covert DOU-operator is presented in the nucleus and is associated with a higher-order trace. For the numeral-neutral question in (76), the Q-functions yielded by the two possible LFs have the same output (i.e., free choice statements) when combining with a Boolean disjunction. In the singular-marked question, however, whether π takes scope below or above the $\Diamond$-modal yields a crucial difference with respect to the interpretation of the disjunctive answer. If π takes wide scope, as seen in (78a), the derived free choice inference is a contradiction, just like the case of the wide scope conjunctive answer in (72). In contrast, as seen in (78b), if π takes a narrow scope relative to the $\Diamond$-modal, the derived free choice inference is not contradictory and is a desired MA-answer.

(78) Which book can we use [as a textbook] for this class? Book A or Book B.

a. If $\pi \gg \iota \gg \Diamond$:
$[\![\textsc{wh}\text{-Q}]\!] = \lambda \pi_{\langle et,t \rangle} : \pi \in {}^{H}D.\textsc{dou}[\lambda w.\pi(\lambda x_e.x = \iota y[\mathsf{book}_w(y) \wedge \Diamond_w Of(y)])]$
$[\![\textsc{wh}\text{-Q}]\!](a^{\Uparrow} \cup b^{\Uparrow})$
$= \textsc{dou}[\lambda w.[(a^{\Uparrow} \cup b^{\Uparrow})(\lambda x_e.x = \iota y[\mathsf{book}_w(y) \wedge \Diamond_w Of(y)])]]$
$= \textsc{dou}[\lambda w[[a = \iota y[\mathsf{book}_w(y) \vee \Diamond_w Of(y)]] \wedge [b = \iota y[\mathsf{book}_w(y) \wedge \Diamond_w Of(y)]]]]$
$= \lambda w[[a = \iota y[\mathsf{book}_w(y) \wedge \Diamond_w Of(y)]] \wedge [b = \iota y[\mathsf{book}_w(y) \wedge \Diamond_w Of(y)]]]$
(#*a* is the unique book that we can use as the only textbook for this class, and *b* is the unique book that we can use as the only textbook for this class.)

b. If $\Diamond \gg \pi \gg \iota$:
$[\![\textsc{wh}\text{-Q}]\!] = \lambda \pi_{\langle et,t \rangle} : \pi \in {}^{H}D.\textsc{dou}\Diamond[\lambda w.\pi(\lambda x_e.x = \iota y[\mathsf{book}_w(y) \wedge Of_w(y)])]$
$[\![\textsc{wh}\text{-Q}]\!](a^{\Uparrow} \cup b^{\Uparrow})$
$= \textsc{dou}\Diamond[\lambda w.(a^{\Uparrow} \cup b^{\Uparrow})(\lambda x_e.x = \iota y[\mathsf{book}_w(y) \wedge Of_w(y)])]$
$= \Diamond\lambda w[a = \iota y[\mathsf{book}_w(y) \wedge Of_w(y)]] \cap \Diamond\lambda w[b = \iota y[\mathsf{book}_w(y) \wedge Of_w(y)]]$
(*a* can be the unique book that we use as the only textbook for this class, and *b* can be the unique book that we use as the only textbook for this class.)

To sum up, in responding to a number-neutral $\Diamond$-question, a disjunction can serve as its MA-answer regardless of whether this disjunction is interpreted below or above the $\Diamond$-modal. However, in responding to a singular-marked $\Diamond$-question, a disjunction can have a MA-answer reading but must be interpreted with a narrow scope.

5.4. Comparing the two approaches

Both the uniform approach and the reconstruction approach can properly derive and account for the distributional constraints of the 'conjunction-rejecting' reading.

First, both approaches explain why singular-marked and numeral-modified questions admit 'conjunction-rejecting' higher-order readings. In the uniform approach, since disjunctions can be singular/cardinal, the atomicity/cardinality restrictor in the WH-complement does not block the application of the H-shifter, allowing the Q-domain of a singular-marked/numeral-modified question to range over a set of Boolean disjunctions (and Montagovian individuals). In the reconstruction approach, the atomicity/cardinality restrictor in the WH-complement can block the application of the H-shifter, but this blocking effect disappears once the WH-complement is reconstructed to the question nucleus.

Second, both approaches explain why questions in these readings reject conjunctive answers. In the uniform approach, Boolean conjunctions are not atomic or cardinal, and hence are ruled out immediately by the atomicity/cardinality restrictor within the WH-complement. In the reconstruction approach, conjunctive answers are not acceptable because conjoining two uniqueness inferences yields a contradiction.

Last, both approaches capture the local uniqueness effects. In the uniform approach, disjunctions that are considered singular range over a set of atomic entities, and likewise, disjunctions having the cardinality n range over a set of entities each of which has the cardinality n. In the reconstruction approach, reconstruction involves THE-assertion which introduces uniqueness.

These two approaches, however, are not notational equivalence of each other. First, they attribute the deviance of conjunctive answers to different reasons and thus can make different predictions in some cases. In the reconstruction approach, disjunctive answers are acceptable because disjoining two uniqueness inference does not yield a contradiction. However, the computation in (78a) shows an exception: if disjunctions are interpreted as wide scope free choice, they would yield contradictions the same as conjunctions. In contrast, the uniform approach does not predict disjunctions to be deviant in any case. Unfortunately, it is very hard to check the predictions with real data. Second, the uniform approach derives the 'conjunction-rejecting' reading in the very same way as the 'conjunction-admitting' reading, while the reconstruction approach uses a salvaging strategy. As such, on the one hand, the uniform approach is technically neater, and on the other hand, the reconstruction approach predicts the general difficulty in interpreting singular-marked and numeral-modified questions with higher-order readings.

6. Conclusion

This paper investigates the higher-order readings of WH-questions. First, drawing on evidence from questions with necessity modals or collective predicates, I showed that sometimes a WH-question can only be completely addressed by a GQ and must be interpreted with a higher-order reading. Next, I argued that the GQs that can serve as complete answers of questions are subject to two constraints — positiveness and homogeneity. Incorporating these constraints into the meaning of a H-shifter, I proposed that higher-order readings arise if the H-shifter converts the *wh*-restrictor into a set of higher-order meanings and if the WH-phrase binds a higher-order trace. Accordingly, higher-order readings are unavailable if the application of the H-shifter is blocked, either by the atomicity constraint of the singular feature [SG] in singular nouns, or by the cardinality constraint of numerals in numeral-modified nouns.

Further, there arose a puzzle that singular-marked and numeral-modified questions admit and only admit disjunctive answers. I provided two explanations to this distribution. In the uniform approach, these questions admit disjunctions because disjunctions (but not conjunctions) may satisfy the atomicity/cardinality requirement. In the reconstruction approach, the WH-complement is reconstructed, which gives rise to local uniqueness and yields contradictions for conjunctive answers.

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