Composing complex questions: Multi-*wh* questions and questions with quantifiers[1]

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DiP Colloquium, March 17, 2017
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1. Introduction

- Among the following three readings of complex *wh*-questions, which and which readings should be analyzed uniformly?

(1)	A:	**Which boy** invited which girl?	$Q_{\text{Multi-}wh}$	PL
	B:	Which girl did **every boy** invite?	$Q_{\forall}$	PL
	C:	Which girl did **one of the boys** invite?	$Q_{\exists}$	Choice

  - Option 1: treat AB uniformly.
    Both AB are pair-list (PL) readings that request the full list of boy-inviting-girl pairs.
  - Option 2: treat BC uniformly.
    Both BC involve quantifying-into question (QiQ), intuitively interpreted as:
    'For every/one boy x, which girl did x invite?'

- I argue for option 2 and offer **function**-based approaches to derive the above three readings.

Roadmap
- §2: Why unifying the QiQ readings, not the PL readings?
  - The two PL readings are semantically different
  - The two QiQ readings are syntactically similar
- §3: Individual readings and functional readings
- §4: Function-based approaches to compose the complex questions
- Appendex: FAQs

Note:
The core ideas of this work is independent from the way of composing simple questions. Compositions in §3 and §4 are demonstrated using Hamblin-Karttunen Semantics for the sake of presentation, while myself pursues a categorial approach (see Appendix 5).

[1]This talk is based on Xiang (2016: chap. 5-6), dissertation entitled "Interpreting questions with non-exhaustive answers". Details related to higher-order answers, mention-some readings, and retrieving short answers have been greatly simplified for the sake of presentation. For helpful comments, discussions, and questions, I thank Gennaro Chierchia, Veneeta Dayal, Danny Fox, and C.-T. James Huang. All errors are mine.

2. Why unifying the QiQ readings, not the PL readings?

2.1. The current dominant view

- Previous accounts commonly attempt to unify PL readings, because:

  1: PL readings of $\mathrm{Q}_{\text{Multi-}wh}$ and $\mathrm{Q}_{\forall}$ are intuitively semantically identical. The two PL readings (1A-1B) both request the full list of boy-inviting-girl pairs and both have the following presuppositions (Dayal 2002):

  (2) a. **Domain exhaustivity**: '**Every** boy invited a girl.'
  Every member of the set quantified over by the *wh*/∀-subject is paired with a member of the set quantified over by the *wh*-object.

  b. **Point-wise uniqueness**: 'Each boy invited **at most one** girl.'
  Every member of the set quantified over by the *wh*/∀-subject is paired with no more than one member of the set quantified over by the *wh*-object.

  2: QiQ readings are hard to get compositionally. For example, in Hamblin-Karttunen semantics, where questions are defined as sets of propositions, QiQ suffers type-mismatch.

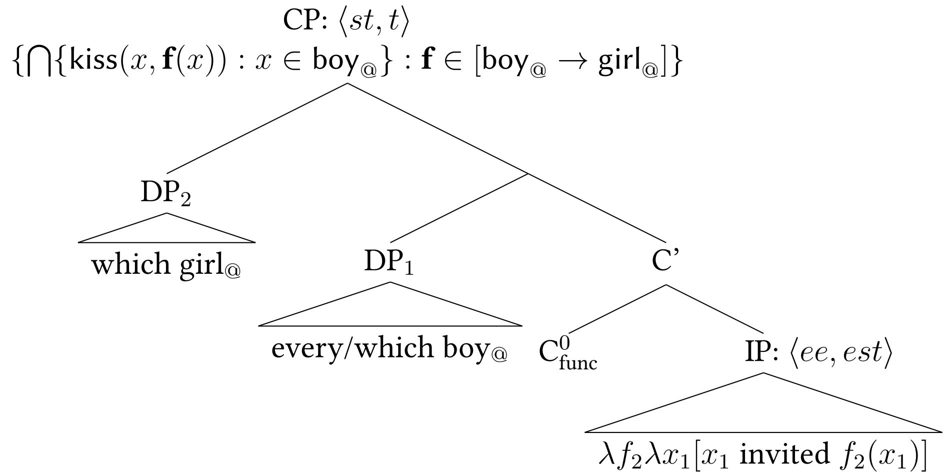
  (3) *[[$_{\langle et,t\rangle}$ every boy] λx [$_{\mathrm{Q}_{\langle st,t\rangle}}$ which girl did x invite?]]

  Many accounts end up claiming that QiQ readings do not form a natural class. (Dayal 1996, Pafel 1999, Fox 2012, a.o.)

- To unify treatments of PL readings, previous accounts either use the same logical form to derive the two PL readings (Engdahl 1980, 1986; Dayal 1996, 2017), or at least give questions with PL readings the same root denotation (Fox 2012).

  – Dayal (1996, 2017): the two PL readings are derived via the same LF:

  (4)



  – Fox (2012): Under PL readings, both questions denote a *family of questions.* Answering a family of questions amounts to answering all the questions in this family.

  (5) $[\![\mathrm{Q}_{\text{multi-}wh}]\!]_{\text{PL}} = [\![\mathrm{Q}_{\forall}]\!]_{\text{PL}} = \{[\![\text{which girl did } x \text{ invite?}]\!] : x \text{ is a boy}\}$

2.2. The two PL readings are semantically different wrt domain exhaustivity

- PL readings of $Q_{\text{Multi-}wh}$ are NOT subject to domain exhaustivity (contra Dayal):

(6) (Context: *100 candidates are competing for 3 jobs.*)
√ "Guess which candidate will get which job."
"Guess which job will every candidate get."

(7) (Context: *4 kids are playing Musical Chairs and are competing for 3 chairs.*)
"Guess which of the 4 kids will sit on which of the 3 chairs."
$\not\rightsquigarrow$ Each of the 4 kids will sit on one of the 3 chairs.

– In a $Q_{\text{multi}-wh}$, the object-*wh* isn't associated with domain exhaustivity either:

(8) (Context: *There are 4 boys and 4 girls in the dancing class. Each boy will be paired with one girl in a dance competition. Only two pairs will be in the finals.*)
"Guess which of the 4 boys will dance with which the 4 girls in the finals."
$\not\rightsquigarrow$ Each boy will dance with some girl in the finals.
$\not\rightsquigarrow$ Each girl will dance with some boy in the finals.

2.3. QiQ readings are syntactically similar

- PL readings of $Q_\forall$ and choice readings of $Q_\exists$ have similar syntactic distributions. They both exhibit subject-object asymmetry (Chierchia 1991, 1993):

(9)	a.	Which candidate did **every student**$_{\text{subj}}$ vote for?	√ pair-list
	b.	Which student voted for **every candidate**$_{\text{obj}}$?	× pair-list
(10)	a.	Which candidate did **one of the students**$_{\text{subj}}$ vote for?	√ choice
	b.	Which student voted for **one of the candidates**$_{\text{obj}}$?	?choice

Interim Summary
– PL readings of $Q_\forall$ and $Q_{\text{Multi-}wh}$ are not semantically identical. PL readings of $Q_\forall$ are subject to domain exhaustivity, while those of $Q_{\text{Multi-}wh}$ are not.
– QiQ readings are subject to similar syntactic constraints. Their distributional patterns uniformly exhibit subject-object asymmetry.
☞ We shall unify the treatment of QiQ readings, not the PL readings.

3. Individual readings and functional readings

- Traditionally, a *wh*-item is defined as an ∃-indefinite quantifying over the extension of its *wh*-complement (Karttunen 1977).

(11) Traditional definition:
a. $[\![\text{which}]\!] = [\![\text{some}]\!] = \lambda A_{\langle e,t\rangle}\lambda P_{\langle e,t\rangle}.\exists\alpha \in A[P(\alpha) = 1]$
b. $[\![\text{which girl}_@]\!] = \lambda P_{\langle e,t\rangle}.\exists\alpha \in \text{girl}_@[P(\alpha) = 1]$

- I argue that the quantification domain of *which*-NP contains not only individuals in ⟦NP⟧ but also **functions to** ⟦NP⟧.[2]

(12) My definition:

a. $[\![\text{which}]\!] = \lambda A_{\langle e,t\rangle} \lambda P_{\langle e,t\rangle}.\exists \alpha \in (A \cup \{\mathbf{f} : \text{Range}(\mathbf{f}) \subseteq A\})[P(\alpha) = 1]$
where $\text{Range}(\mathbf{f}) \subseteq A$ iff $\forall x \in \text{Dom}(\mathbf{f})[\mathbf{f}(x) \in A]$

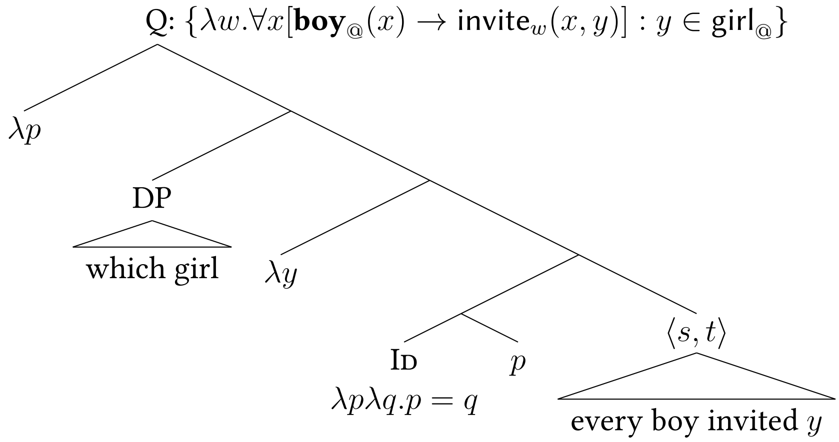
b. $[\![\text{which girl}_@]\!] = \lambda P_{\langle e,t\rangle}.\exists \alpha \in (\mathsf{girl}_@ \cup \{\mathbf{f} : \text{Range}(\mathbf{f}) \subseteq \mathsf{girl}_@\})[P(\alpha) = 1]$

- Whether a *wh*-question takes an individual or functional reading depends on whether the *wh*-trace is individual (x) or functional (**f**).

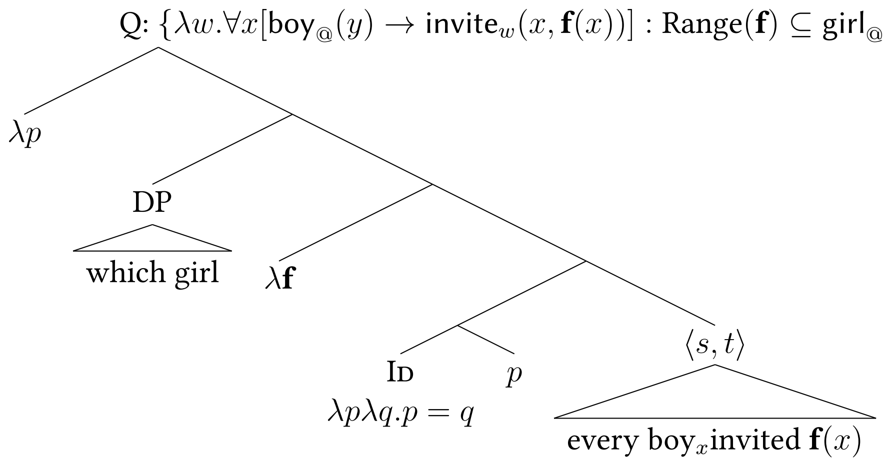
Using GB-transformed LF of Karttunen Semantics (Heim 1995), we have:

(13) "Which girl did every boy invite?"

a. **Individual reading**
'Which girl y is s.t. every boy invited y?' 'Anna'



b. **Functional reading**
'Which function **f** to $\mathsf{girl}_@$ is s.t. every boy x invited $\mathbf{f}(x)$?' 'His girlfriend'



In the functional reading, *wh*-movement leaves a functional trace **f**, whose argument x is locally bound by the non-interrogative quantifier *every boy*$_x$.

[2] In Xiang (2016), I argue that the quantification domain of a *wh*-item could be even richer: if ⟦NP⟧ is closed under sum, then the quantification domain of *which*-NP contains also disjunctions and conjunctions over the items in ⟦NP⟧ (Xiang 2016: §1.7), as well as functions to those disjunctions and conjunction (Xiang 2016: §5.4).

4. Compose complex questions

- In questions with quantifiers, QiQ readings have the same distributional pattern as functional reading (Chierchia 1991, 1993):

(14) a. Which candidate did **every student**$_{\text{subj}}$ vote for? √pair-list, √functional
b. Which student voted for **every candidate**$_{\text{obj}}$? ×pair-list, ×functional

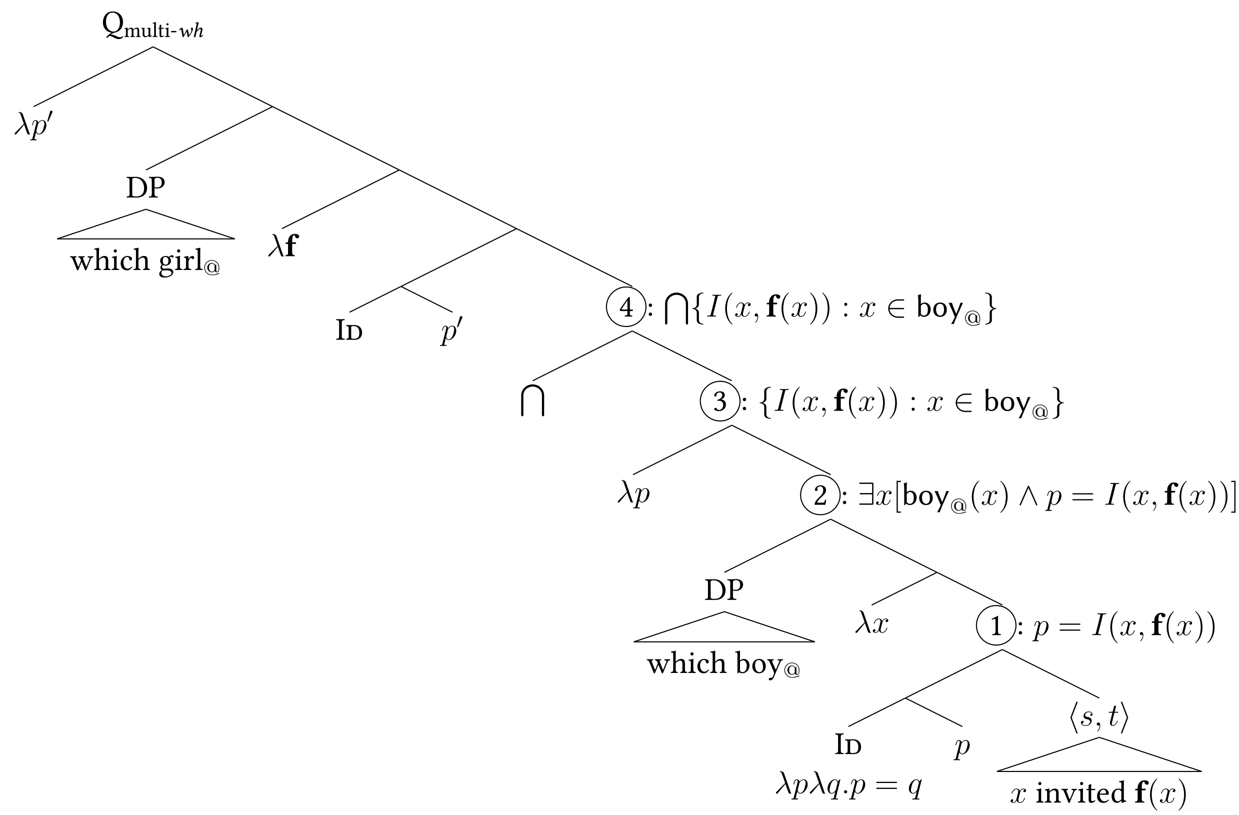
(15) a. Which candidate did **one of the students**$_{\text{subj}}$ vote for? √choice, √functional
b. Which student voted for **one of the candidates**$_{\text{obj}}$? ?choice, ×functional

- I treat the aforementioned list and choice readings as special functional readings:[3]

  the object-*wh* trace is functional, and its argument variable is bound by the *wh*-/∀-/∃-subject.

I. **Pair-list readings of multi-*wh* questions**

(16) Which boy invited which girl?



1. Node ①: the Id-operator creates an equation between its two propositional arguments.
2. Node ②: *which boy* takes movement and existentially quantifies into this equation.
3. Node ③ to ④: extract the set of propositions that satisfy the existentially quantified equation, and then return the conjunction of these propositions, which is then the question nucleus.

... (the rest steps are the same as the basic functional reading)

... Finally, with two boys ab and two girls mj taken into considerations, the Hamblin set is

[3] There've been quite a few studies proposing function-based approaches to derive some or all the list/choice readings. Representatives include: Engdahl (1980, 1986), Groenendijk and Stokhof (1984), Chierchia (1993), and Dayal (1996, 2017).

(17) $[\![\text{Q}_{\text{multi-}wh}]\!] = \{\bigcap\{I(x, \mathbf{f}(x)) : x \in \text{boy}_@\} : \text{Range}(\mathbf{f}) \subseteq \text{girl}_@\}$

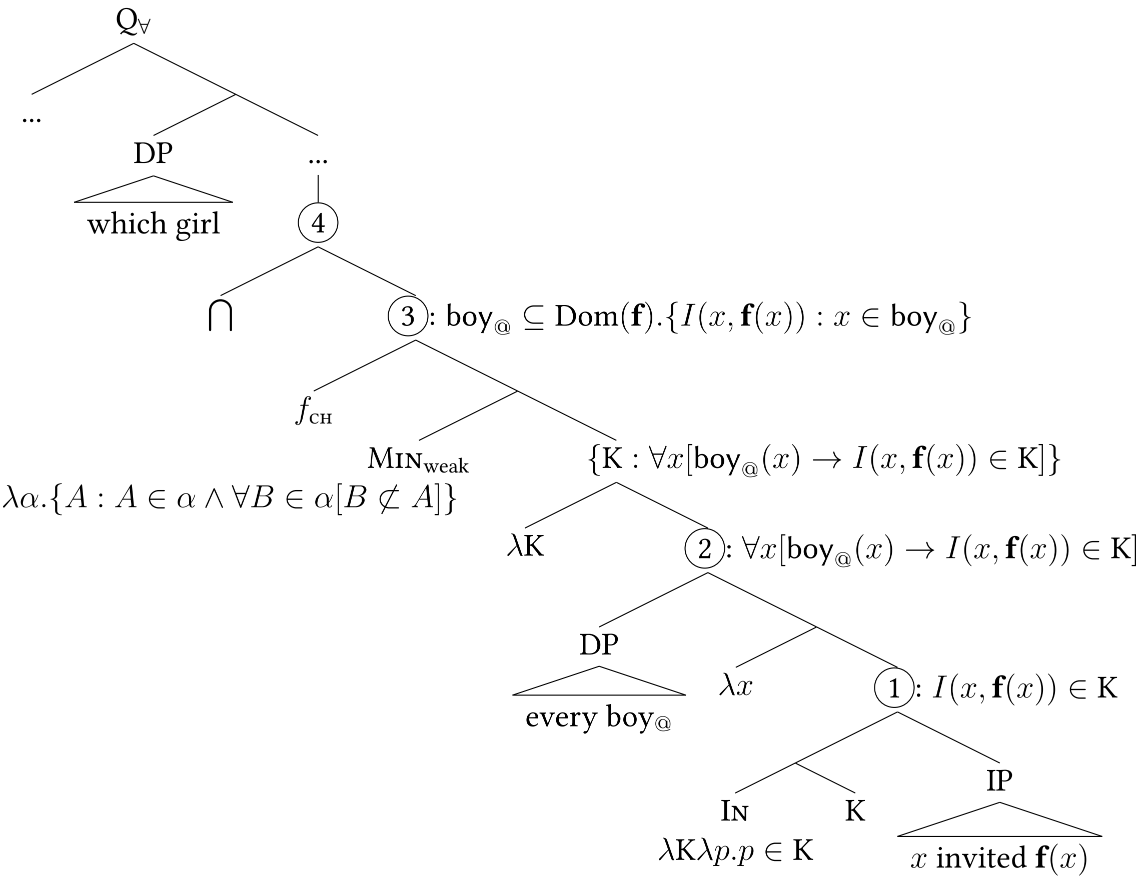
$$= \left\{ \begin{array}{ll} I(a,m) & I(a,m) \wedge I(b,m) \\ I(a,j) & I(a,m) \wedge I(b,j) \\ I(b,m) & I(a,j) \wedge I(b,m) \\ I(b,j) & I(a,j) \wedge I(b,j) \end{array} \right\} \quad \text{based on} \left\{ \begin{array}{ll} [a \to m] & [a \to m, b \to m] \\ [a \to j] & [a \to m, b \to j] \\ [b \to m] & [a \to j, b \to m] \\ [b \to j] & [a \to j, b \to j] \end{array} \right\}$$

Propositions in the Hamblin set can be based on one of the boys or both of the boys:

$\Rightarrow$ **No domain exhaustivity**

II. Pair-list readings of ∀-questions (inspired by Fox 2012)[4]

(18) Which girl did every boy invite?



1. Node (1): the IN-operator creates an membership relation, namely invite$(x, \mathbf{f}(x)) \in$ K.
2. Node (2): *every boy* undergoes QR and universally quantifies into this membership relation. For this denotation to be defined, **f** must be defined for every boy. Note that this quantification doesn't suffer type-mismatch.
3. Node (3): 'a minimal K such that for every boy x: 'x invited $\mathbf{f}(x)$' is in K'.
   Here there is only one minimal K set that satisfies the ∀-quantified membership relation:

[4] The tricks of letting the quantifier quantifies into a membership relation and extracting out the minimal eligible K set have been reached by Fox (2012). The main differences between my proposal and Fox's are: (i) Fox pursues a family-of-question approach for both $\text{Q}_{\text{multi-}wh}$ and $\text{Q}_\forall$, which cannot account for the semantic differences between the PL readings of these two questions; (ii) Fox uses Pafel's MIN-operator, which is too strong and cannot extend to $\text{Q}_\exists$.

(1) $[\![\text{Min}]\!]_{\text{Pafel-Fox}} = \lambda\alpha.\iota A[A \in \alpha \wedge \forall B \in \alpha[A \subseteq B]]$

(19) a. $\{K : \forall x[\text{boy}_@(x) \rightarrow I(x, \mathbf{f}(x)) \in K]\}$
$= \text{boy}_@ \subseteq \text{Dom}(\mathbf{f}).\{K : \{I(x, \mathbf{f}(x)) : x \in \text{boy}_@\} \subseteq K\}$

b. Apply $\textsc{Min}_{\text{weak}}$, return:
$\text{boy}_@ \subseteq \text{Dom}(\mathbf{f}).\{\{I(x, \mathbf{f}(x)) : x \in \text{boy}_@\}\}$

c. Apply f_{ch}, return:
$\text{boy}_@ \subseteq \text{Dom}(\mathbf{f}).\{I(x, \mathbf{f}(x)) : x \in \text{boy}_@\}$

... Finally, with two boys ab and two girls mj taken into considerations, the Hamblin set is:

(20) $[\![Q_\forall]\!] = \{\bigcap\{I(x, \mathbf{f}(x)) : x \in \text{boy}_@\} : \text{Range}(\mathbf{f}) \subseteq \text{girl}_@ \wedge \text{boy}_@ \subseteq \text{Dom}(\mathbf{f})\}$

$$= \left\{ \begin{array}{l} I(a,m) \wedge I(b,m) \\ I(a,m) \wedge I(b,j) \\ I(a,j) \wedge I(b,m) \\ I(a,j) \wedge I(b,j) \end{array} \right\} \quad \text{based on} \quad \left\{ \begin{array}{l} [a \rightarrow m, b \rightarrow m] \\ [a \rightarrow m, b \rightarrow j] \\ [a \rightarrow j, b \rightarrow m] \\ [a \rightarrow j, b \rightarrow j] \end{array} \right\}$$

Propositions in the Hamblin set must be based on both of the boys.

⇒ **Domain exhaustivity**

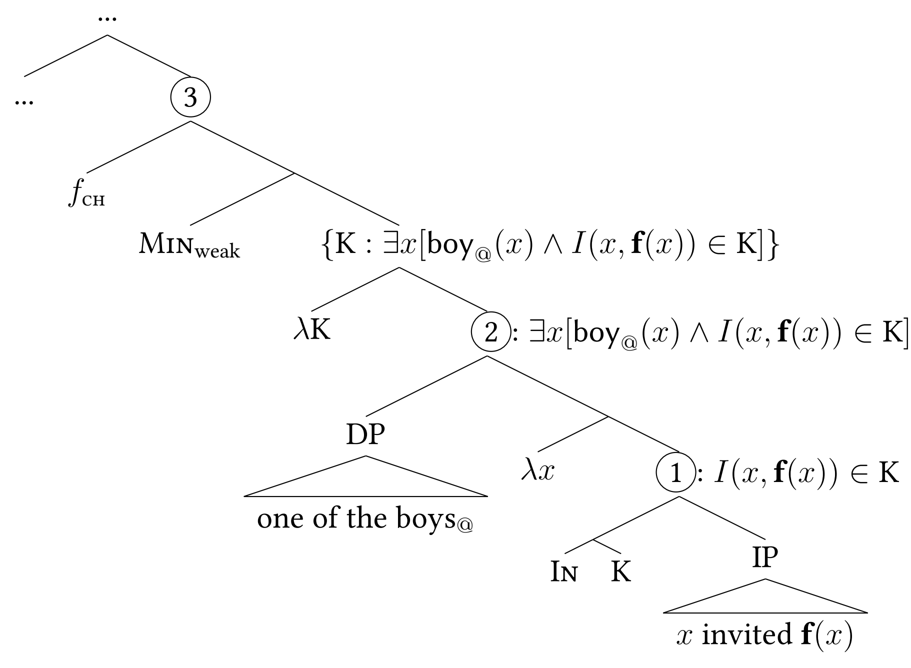
Compare the derivations of the two PL readings:

- In the multi-*wh* question, *which boy* ∃-quantifies into an **identity** relation, while in the ∀-question, *every boy* ∀-quantifies into a **membership** relation.
- At node ③, both derivations return $\{I(x, \mathbf{f}(x)) : x \in \text{boy}_@\}$. But the one in $Q_\forall$ also presupposes that **f** is defined for every boy, yielding a domain exhaustivity effect.

III. Choice readings of $Q_\exists$

The choice reading is derived in exactly the same way as the PL reading of the $Q_\forall$ as in (18): the ∃-subject quantifies into $\text{invite}(x, \mathbf{f}(x)) \in K$, and then extracting one of the minimal eligible K sets. The conjunction of each such minimal K set is a possible question nucleus.

(21) Which girl did one of the boys invite?



In parallel to (19) and (20),

(22) Node ③ has multiple possible denotations, each of which is a singleton proposition set $\{x$ invited $\mathbf{f}(x)\}$ where x is a boy.

a. $\{\text{K} : \exists x[\text{boy}_@(x) \wedge I(x, \mathbf{f}(x)) \in \text{K}]\} = \{\text{K} : \exists x \in \text{boy}_@[\{I(x, \mathbf{f}(x))\} \subseteq \text{K}]\}$

b. Apply $\textsc{Min}_{\text{weak}}$, return:
$\{\{I(x, \mathbf{f}(x))\} : x \in \text{boy}_@\}$

c. Apply f_{ch}, return:
$\{I(x, \mathbf{f}(x))\}$, where $x \in \text{boy}_@$

(23) $[\![\text{Q}_\exists]\!] = \{I(x, \mathbf{f}(x)) : \text{Range}(\mathbf{f}) \subseteq \text{girl}_@\}$, where $x \in \text{boy}_@$
$= \{I(a, \mathbf{f}(a)) : \text{Range}(\mathbf{f}) \subseteq \text{girl}_@\}$, 'which girl did a invite?'
or $= \{I(b, \mathbf{f}(b)) : \text{Range}(\mathbf{f}) \subseteq \text{girl}_@\}$ 'which girl did b invite?'

Compare $\text{Q}_\forall$ and $\text{Q}_\exists$:

- $\text{Q}_\forall$
  - ... doesn't take a choice reading, because: there is **only one** minimal eligible K set that contains all propositions of the form 'boy x invited $\mathbf{f}(x)$',
  - ... takes a PL reading, because: this minimal set is **non-singleton**.
- In contrast, $\text{Q}_\exists$
  - ... takes a choice reading, because: there are **multiple** minimal sets that contain one proposition of the form 'boy x invited $\mathbf{f}(x)$'. Each minimal set yields a possible Q.
  - ... doesn't take a PL reading, because: all the eligible minimal sets are **singletons**.

5. Conclusions

- PL readings of $\text{Q}_{\text{multi-}wh}$ and $\text{Q}_\forall$ are not semantically equivalent and must be treated differently. Only that of $\text{Q}_\forall$ is subject to domain exhaustivity.
- I treat all the list/choice readings as functional readings: the object-*wh* trace is functional, and its argument variable is bound by the *wh*-/∀-/∃-subject.
- This analysis captures the contrast between $\text{Q}_{\text{multi-}wh}$ and $\text{Q}_\forall$ wrt domain exhaustivity, unifies QiQ readings, and manages to keep QiQ as regular quantification.

Appendix: FAQs

1. **Why is it that questions with N-quantifiers do not admit QiQ readings?**

(24) Which girl did no boy invite?
#[slience]

Reply: At node ③, the only minimal set that contains no proposition of the form "boy x invited $\mathbf{f}(x)$' is $\varnothing$. Hence $Q = \{\bigcap \varnothing : x \text{ is a boy}\}$, which is not a proper answer space.

2. **Why matrix questions with numeral-modified quantifiers do not admit PL readings?**

(25) a. Which girl did at least two boys invite?
Andy invited Mary, Billy invited Jenny.
b. Which girl did more than two boys invite?
Andy invited Mary, Billy invited Jenny, Clark invited Helen.

Reply: These numeral-modified quantifiers are ∃-**quantifiers** with numeral-modified restriction (Link 1987). At node ③, each minimal K set is a **singleton set** that contains one proposition of the form "x invited $\mathbf{f}(x)$" where x denotes the sum of a certain number of boys.

(26) a. $[\![\varnothing_\exists \text{ at least two boys}_@]\!] = \lambda f.\exists x[{}^*\text{boy}(x) \wedge \mid x \mid \geq 2 \wedge f(x)]$
b. $[\![\varnothing_\exists \text{ more than two boys}_@]\!] = \lambda f.\exists x[{}^*\text{boy}(x) \wedge \mid x \mid > 2 \wedge f(x)]$

This explanation also extends to cases of definite plurals (*the boys*), proportional phrases (e.g., *all the boys*, *most (of the) boys*), etc.

3. **Why not defining questions with PL readings as families of questions** (as in Hagstrom 1998, Fox 2012, Nicolae 2013, Kotek 2014, a.o.)?

(27) $[\![\text{Q}_{\text{multi-wh}}]\!] = [\![\text{Q}_\forall]\!] = \{\, [\![\text{which girl did } x \text{ invite?}]\!] : x \in \text{boy}_@ \}$

Reply: This approach unavoidably predicts the PL readings of multi-*wh* and ∀-questions semantically equivalent, and thus cannot capture their contrast wrt domain exhaustivity.

We can at most analyze one of the questions with a PL reading as a family of questions. See chapter 5 appendix and §6.3 in Xiang (2016).

4. **How can we account for the following quantificational variability (QV) effects?**

(28) John mostly knows [$_Q$ which girl every boy invited].
... [$_Q$ which boy invited which girl].
$\rightsquigarrow$ Most p [p is a true atomic proposition 'boy x invited girl y'] [John knows p]

Defining questions as sets of conjunctive propositions, we cannot define the domain of *mostly* because conjuncts of a conjunction cannot be recovered. (Lahiri 2002).

Alternatively, I pursue a **category approach** and define question as a λ-abstract. (Xiang 2016: chap. 1)

(29) a. $[\![\text{who did John invite}]\!] = \lambda x[\mathsf{hmn}_@(x) = 1. I(j,x)]$
b. $[\![\text{Q}_{\text{multi-wh}}]\!] = \lambda \mathbf{f}[\text{Range}(\mathbf{f}) \subseteq \mathsf{girl}_@ . \bigcap\{I(x, \mathbf{f}(x)) : x \in \mathsf{boy}_@\}]$
c. $[\![\text{Q}_\forall]\!] = \lambda \mathbf{f}[\text{Range}(\mathbf{f}) \subseteq \mathsf{girl}_@ \wedge \text{Dom}(\mathbf{f}) \supseteq \mathsf{boy}_@ . \bigcap\{I(x, \mathbf{f}(x)) : x \in \mathsf{boy}_@\}]$

The domain of *mostly* is defined based on the atomic parts of functions.[5] For example, let **f** be the complete true short answer of $\text{Q}_{\text{multi-wh}}$, then the QV inference is:

(30) Most $\text{f}'[\text{f}' \in \textsc{At}(\mathbf{f})]$[John knows $[\![\text{Q}_{\text{multi-wh}}]\!](\text{f}')$]

(31) John knows [which boy invited which girl]$_{\textsc{pl}}$.
(Context: *Andy, Billy, and Clark invited only Jenny, Mary, and Sue, respectively; no other boy invited any of the girls.*)

a. $\mathbf{f} = \left\{ \begin{array}{c} a \to m \\ b \to j \\ c \to s \end{array} \right\}$

b. The QV inference:

$$\textsc{Most}\ \text{f}' \left[\text{f}' \in \left\{ \begin{array}{c} \{a \to m\} \\ \{b \to j\} \\ \{c \to s\} \end{array} \right\} \right] \left[\mathsf{know}(j, \bigcap\{\mathsf{invite}(x, \text{f}'(x)) : x \in \mathsf{boy}_@\}) \right]$$

$$= \textsc{Most}\ \text{f}' \left[\text{f}' \in \left\{ \begin{array}{c} \{a \to m\} \\ \{b \to j\} \\ \{c \to s\} \end{array} \right\} \right] \left[\mathsf{know}(j, \mathsf{invite}(x, \text{f}'(x))) \right]$$

(John knows most of the following boy-invite-girl pairs: a invited m, b invited j, and c invited s.)

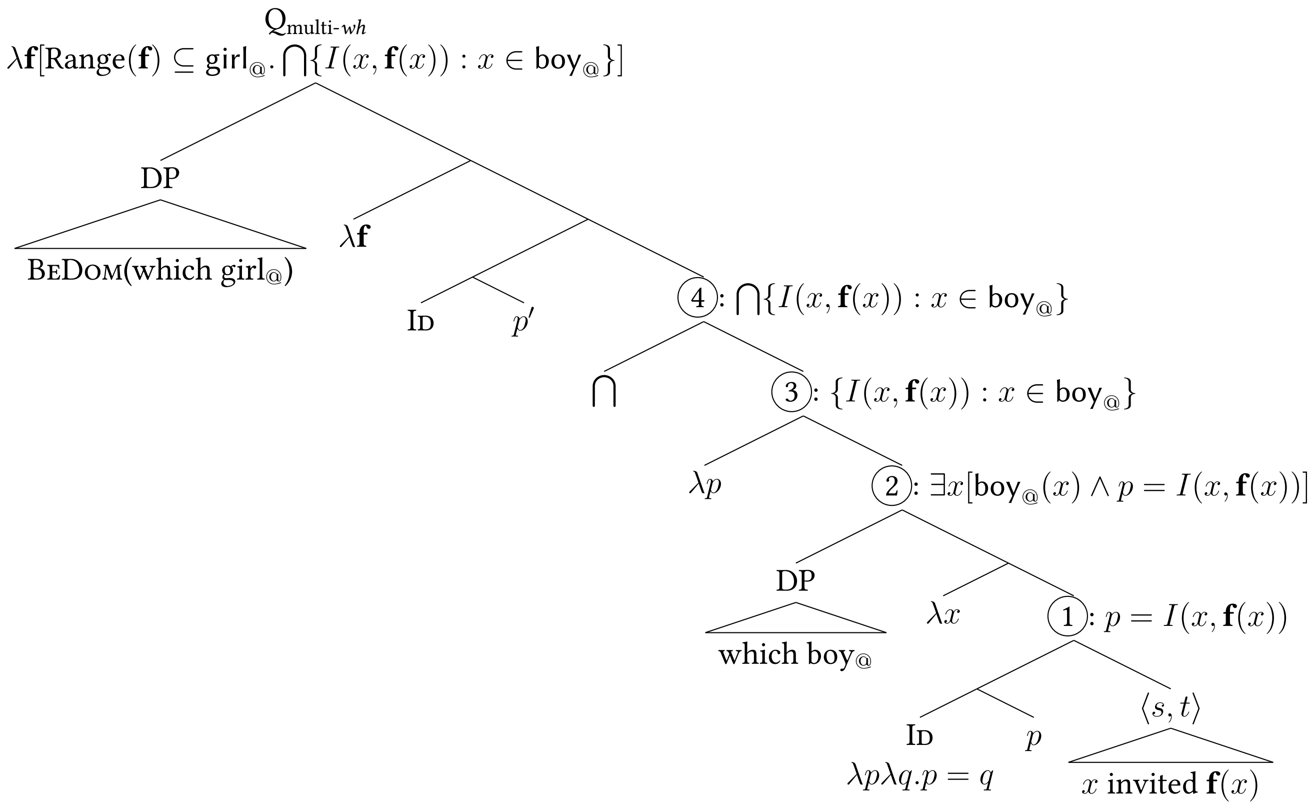
See more details in Xiang (2016: §5.4.4).

[5] Atomic functions and atomic parts of functions:

(1) a. A function **f** is atomic iff $\bigoplus \text{Dom}(\text{f}')$ is atomic.
b. $\textsc{At}(\mathbf{f}) = \{\text{f}' : \text{f}' \subseteq \mathbf{f} \text{ and } \bigoplus \text{Dom}(\text{f}') \text{ is atomic}\}$

5. Composing questions in a hybrid categorial approach

(32) Which boy invited which girl? (Pair-list reading)



(33) Which girl did every boy invite? (Pair-list reading)