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February 5, 2019

Categorial Approaches

1. Overview

- **Categorial approaches** (also called **functional approaches**) define questions as functions from "short answers" (i.e., the missing information of open propositions) to propositions (or truth values). **Structured meaning approaches**, which define questions as function-domain pairs, are also variants of categorial approaches.
- Categorial approaches are originally motivated to capture the relation between questions and short answers semantically. They are also motivated/used to analyze free relatives (Caponigro 2003, 2004), quantificational variability effects (Xiang 2016, 2018).
- Categorial approaches have difficulties in composing multi-*wh* questions and question coordinations.

2. Basics of categorial approaches

- The origin of these approaches dates back to Cohen (1929). Representatives using lambda calculus are Hausser and Zaefferer (1979), Hausser (1983), and among others. This class doesn't follow a particular framework; we will focus on the essence of categorial approaches.

2.1. *Wh*-questions

- Recall: A *wh*-question can be responded directly by either a short answer or a full answer.

(1) Who came?
  a. Jenny. (short answer)
  b. Jenny came. (full answer)

It remains controversial whether short answers in discourse are bare nominal or covertly clausal.

- If they are covertly clausal, then short answers shall be treated as propositions/sentences, and are derived from full answers syntactically by ellipsis (Merchant 2004).

(2) a. Who did Bozo invite to the party?
  [$_{\text{FP}}$ Who [$_{\text{C}'}$ did [$_{\text{IP}}$ Bozo invite t_1 to the party]]
 b. Claribel.
  [$_{\text{FP}}$ Claribel$_1$ [$_{\text{F}'}$ E^0 [$_{\text{IP}}$ ~~Bozo invite t_1 to the party~~]]

- If they are bare nominal, then they can be interpreted differently from the corresponding full answers, and there should be a way to derive the nominal meaning of a short answer from a question semantically.

(3) Which mathematics professor left the party at midnight? (Jacobson 2016: ex. 14)
  a. Jill. $\rightsquigarrow$ *Jill is a mathematics professor.*
  b. Jill left the party at midnight. $\not\rightsquigarrow$ *Jill is a mathematics professor.*

- Core assumptions of categorial approaches
  - Short answer is the primary way of responding to questions. Short answers of *wh*-questions are **bare nominal**, not covertly clausal.
  - The question-answer relation is in natural a **function-argument relation**. The root denotation of a *wh*-question is a **function/ λ-abstract** that takes the denotation of a short answer (e.g., an entity) as an argument and returns the denotation of the corresponding full answer (viz., a proposition/sentence).

    (4) Single-*wh* questions
      a. $[\![\text{who came}]\!] = \lambda x : \mathsf{hmn}(x).\mathsf{came}(x)$
      b. $[\![\text{who came}]\!]([\![\text{Jenny}]\!]) = (\lambda x : \mathsf{hmn}(x).\mathsf{came}(x))(j) = \mathsf{came}(j)$

    (5) Multi-*wh* questions (w. single-pair readings)
      a. $[\![\text{who bought what}]\!] = \lambda x \lambda y : \mathsf{hmn}(x) \wedge \mathsf{thing}(y).\mathsf{bought}(x, y)$
      b. $[\![\text{who sent what to where}]\!] = \lambda x \lambda y \lambda z : \mathsf{hmn}(x) \wedge \mathsf{thing}(y) \wedge \mathsf{place}(z).\mathsf{sent}(x, y, z)]$

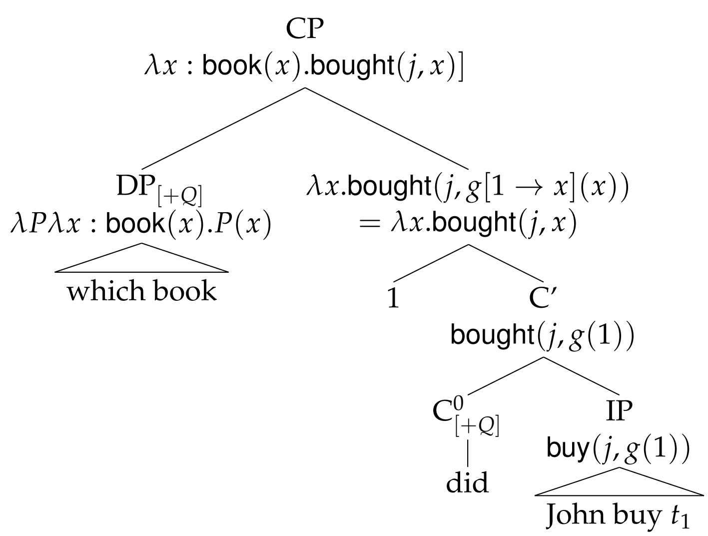
  - The *wh*-determiner denotes the λ-*operator*; *wh*-words/phrases denote restrictions of functions.

    (6) a. $[\![\text{wh-}]\!] = \lambda R \lambda P \lambda x : R(x).P(x)$
      b. $[\![\text{who}]\!] = \lambda P \lambda x : \mathsf{hmn}(x).P(x)$
      c. $[\![\text{what}]\!] = \lambda P \lambda x : \mathsf{thing}(x).P(x)$
      d. $[\![\text{which student}]\!] = \lambda P \lambda x : \mathsf{student}(x).P(x)$

- Composing single-*wh* questions

  The *wh*-phrase moves to [Spec, CP] and combines with the remnant via Functional Application.

  (7) Which book did John buy?



- **Discussion:** Try to derive the following denotation for a multi-*wh* question compositionally. What difficulties do you encounter?

  (8) $[\![\text{who bought what}]\!] = \lambda x \lambda y : \mathsf{hmn}(x) \wedge \mathsf{thing}(y).\mathsf{bought}(x, y)$

2.2. Alternative questions and polar questions

- **Alternative questions** are very similar to *wh*-questions; they can be replied by "short answers" (the minimal disjuncts) and full answers.

(9) Did Mary invite Andy or Billy?
  a. Andy.
  b. She invited Andy.

(10) a. LF: $[_{\text{CP}}$ $[_{\text{DP}}$ Andy or Billy] 1 $[_{\text{C}'}$ did $[_{\text{IP}}$ Mary invited t_1]]]
  b. Interpretation: $\lambda x : x \in \{a, b\}.\mathsf{invited}(m, x)$

The contrast between short and full answers of *wh*-questions in (3) is also seen in alternative questions:

(11) Did Mary invite Andy or Billy?
  a. # Cindy.
  b. She invited Cindy.

- **Basic polar questions** The words *yes* and *no* can be regarded as short answers to basic polar questions.

(12) Did Jenny come?
  Yes/No, (she did/didn't).

Yes and *No* are defined as functions from propositions to truth values. As such, a basic polar question denotes an abstract over such functions.

(13) a. LF: $[_{\text{CP}}$ $\text{OP}_{Y/N}$ $[_{\text{C}'}$ did $[_{\text{IP}}$ Jenny come]]]
  b. $[\![\text{Did Jenny come?}]\!] = \lambda f : f \in \{\lambda p.{}^{\vee}p, \lambda p.\neg{}^{\vee}p\}.f({}^{\wedge}\mathsf{came}(j))$
  c. $[\![\text{yes}]\!] = \lambda p.{}^{\vee}p$
  d. $[\![\text{no}]\!] = \lambda p.\neg{}^{\vee}p$

- Krifka (2001): Unlike basic polar questions, **polar alternative questions** can't be responded by a single word *yes*/*no*. Compare (12) with the following:

(14) Did Jenny come or not?
  Yes/No, ??(she did/didn't).

(15) Did Jenny come, or didn't she come?
  Yes/No, # (she did/didn't).

This contrast between basic polar questions and polar alternative questions is not predicted by Hamblin-Karttunen Semantics: Hamblin-Karttunen Semantics predicts these questions to have the very same denotation.

In contrast, categorial approaches capture this contrast — short answers of basic alternative questions are functions from propositions to truth values, while "short answers" of polar alternative questions are full sentences.

(16) a. LF: $[_{\text{CP}}$ __ $[[_{\text{C}'}$ did $[_{\text{IP}}$ Jenny come]] or $[_{\text{C}'}$ didn't $[_{\text{IP}}$ she come]]$]_1$ t_1]
  b. $[\![\text{Did Jenny come or didn't she come?}]\!] = \lambda p : p \in \{{}^{\wedge}\mathsf{came}(j), {}^{\wedge}\neg\mathsf{came}(j)\}.{}^{\vee}p$

3. Structured meaning approaches

- Structured meaning approaches are variants of categorial approaches. Representatives include: Von Stechow and Ede Zimmermann (1984); Stechow (1990); Ginzburg (1992); Ginzburg and Sag (2000); Krifka (2001).
- Questions denote ordered pairs $\langle Q, D\rangle$:
  - Q: the function-like denotation of a question as assumed by categorial approaches
  - D: the domain restriction, a set consisting of the possible short answers to this question

(17) a. $[\![\text{Which student came?}]\!] = \langle \lambda x.\mathsf{came}(x), \mathsf{student}\rangle$
b. $[\![\text{Do you want tea or coffee?}]\!] = \langle \lambda x.\mathsf{want}(\mathsf{you}, x), \{\mathsf{tea}, \mathsf{coffee}\}\rangle$
c. $[\![\text{Did Jenny come?}]\!] = \langle \lambda f[f({}^\wedge\mathsf{came}(j))], \{\lambda p.{}^\vee p, \lambda p.\neg{}^\vee p\}\rangle$
d. $[\![\text{Did Jenny come or not?}]\!] = \langle \lambda p.{}^\vee p, \{{}^\wedge\mathsf{came}(j), {}^\wedge\neg\mathsf{came}(j)\}\rangle$

- Structured meaning approaches are especially well-suited for treating **question-answer congruence**: both questions and declaratives lend themselves to a structured meaning analysis. A declarative is analyzed as a pair $\langle B, F\rangle$ (B: background, F: focus). Applying the background to the focus yields standard propositional semantics.

(18) — Who invited Mary? — JENny$_F$ invited Mary.
a. $[\![\text{Who invited Mary?}]\!] = \langle \lambda x.\mathsf{invite}(x, m), \mathsf{hmn}\rangle$
b. $[\![\text{JENny}_F \text{ invited Mary}]\!] = \langle \lambda x.\mathsf{invite}(x, m), j\rangle$
c. $B(F) = \mathsf{invited}(j, m)$

(19) — Who did Jenny invite? — Jenny invited MAry$_F$.
a. $[\![\text{Who did Jenny invite?}]\!] = \langle \lambda x.\mathsf{invite}(j, x), \mathsf{hmn}\rangle$
b. $[\![\text{Jenny invited MAry}_F]\!] = \langle \lambda x.\mathsf{invited}(j, x), m\rangle$
c. $B(F) = \mathsf{invited}(j, m)$

(20) **Criterion for congruent question-answer pairs**
For any Q(uestion)-A(nswer) pair where $[\![\text{Q}]\!] = \langle Q, D\rangle$ and $[\![\text{A}]\!] = \langle B, F\rangle$:
the Q-A pair is congruent only if $Q = B$ and $F \in D$.

Discussion: Explain why the following answers are inappropriate:

(21) Who did Mary see?
a. MAry$_F$ saw Jenny.
b. Mary saw [*The Game of Throne*]$_F$.

4. More arguments for categorial approaches (Xiang 2018)

4.1. Caponigro's generalization on questions and free relatives (FRs)

- The meaning of a *wh*-FR systematically equals to the nominal meaning of a/the complete true short answer of the corresponding *wh*-question.

(22) a. John ate what Mary cooked for him. ⇝ *John ate* ***everything*** *that Mary cooked for him.*
  b. John went to where he could get help. ⇝ *John went to* ***some*** *place where he could get help.*

The similarities between *wh*-FRs and *wh*-questions in form and meaning make it appealing to treat these two constructions uniformly. Options are:

(a) Option I (b) Option II

- **Caponigro's Generalization** (Caponigro 2003, 2004): If a language uses the *wh*-strategy to form both questions and FRs, the *wh*-words found in FRs are always a **subset** of those found in questions.[1]

(23) Spanish *qué* 'what'
  a. Pregunté **qué**/ lo-que cocinaste.
   asked.1SG what/ the.N.S-COMP cooked.2SG
   'I asked what you cooked.'
  b. Comí ***qué**/ lo-que cocinaste.
   ate.1SG *what/ the.N.S-COMP cooked.2SG
   'I ate what you cooked.'

(24) Estonian *millal* 'when'
  a. Ma ksisin sult, [$_{Q}$ **millal** Maria saabus].
   I asked you when Maria arrived
   'I asked you when Maria arrived.'
  b. * Ma lahkusin (siis), [$_{FR}$ **millal** Maria saabus]
   I left then when Maria arrived.
   'I left when Maria arrived.'

(25) English *who*
  a. I will marry [$_{FR}$ who you choose].
  b. I don't know [$_{Q}$ who couldn't sleep enough].
  c. ?? [$_{FR}$ Who couldn't sleep enough] felt tired the following morning.

Prediction: *Wh*-FRs are formed out of *wh*-questions (Option II). (Chierchia and Caponigro 2013)

☞ The nominal meaning of a short answer must be derivable from the root denotation of a question.

[1] This generalization was firstly made based on 28 languages from Indo-European, Finno-Ugric, and Semitic families. It also extends to Tlingit and Haida (Cable 2005), Nieves Mixtec and Melchor Ocampo Mixtec (Caponigro et al. 2013), and Chuj (Kotek and Erlewine 2018).

4.2. Quantificational variability effects

- Indirect questions with quantity adverbials (e.g., *mostly, for the most part, to a large extent*) are subject to **quantificational variability (QV)** effects. (Berman 1991; Lahiri 1991, 2002; Cremers 2016; Beck and Sharvit 2002)

(26) Jenny mostly knows [$_Q$ who came].
$\rightsquigarrow$ MOST x [x came] [J knows that x came]

Typically, the domain restriction of the quantity adverbial can be formed by **atomic short answers** or **atomic propositional answers** of the embedded question. (Lahiri 1991, 2002; Cremers 2016)

(26′) (w: *Among the four considered individuals abcd, abc came but d didn't.*)

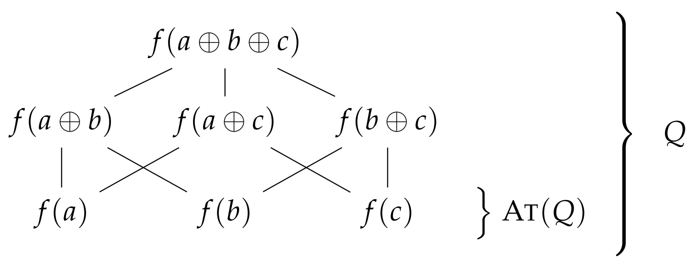
a. ✓ MOST x [x is an $\underbrace{\text{atomic true short answer of Q}}_{\{a,b,c\}}$] [J knows that x came]

b. ✓ MOST p [p is an $\underbrace{\text{atomic true propositional answer of Q}}_{\{\hat{}\mathsf{came}(a),\hat{}\mathsf{came}(b),\hat{}\mathsf{came}(c)\}}$] [J knows p]

Atomic propositional answers are those that only entail themselves:

(27) $\textsc{At}(Q) = \{p : p \in Q \land \forall q \in Q[p \subseteq q \rightarrow q = p]\}$

E.g. the answer space (Hamblin set) of *who came*, where $f = \mathsf{came}$:



- **A challenging case to proposition-based accounts: questions with a non-divisive predicate**

(28) A predicate P is **divisive** iff $\forall x[P(x) \rightarrow \forall y \leq x[y \in \textsc{dom}(P) \rightarrow P(y)]]$.

If the predicate of the embedded question is **non-divisive**, this domain restriction cannot be recovered based propositional answers (Schwarz 1994).

(29) Jenny mostly knows [$_Q$ which professors formed the committee].
$\rightsquigarrow$ 'For most of the professors in the committee, Jenny knows that they were in the committee.'
(w: *The committee was formed by three professors abc*.)

a. ✓ MOST x [x is $\underbrace{\text{an atomic subpart of the true short answer of Q}}_{\textsc{At}(a\oplus b\oplus c)=\{a,b,c\}}$] [J knows that x was in the committee]

b. ✗ MOST p [p is $\underbrace{\text{an atomic true propositional answer of Q}}_{\{\hat{}\mathsf{f.t.comm.}(a \oplus b \oplus c)\}}$] [J knows p]

Prediction: Short answers must be derivable from the denotation of an embedded question.

A salvaging strategy and its problems

Williams (2000) argues to salvage the proposition-based account by interpreting the embedded question with a **sub-divisive reading**, obtained based on a collective lexicon of the *wh*-determiner.

(30) Jenny knows which professors formed the committee.
$\approx$ 'Jenny knows which prof(s) x is s.t. x is **part of** the group of profs who formed the committee.'

a. $[\![\text{which}]\!] = \lambda A \lambda P.\{\lambda w.\exists y \in A[y \geq x \wedge P_w(y)] \mid x \in A\}$

b. $[\![\text{which profs}_@ \text{ f.t.c.}]\!] = \{\lambda w.\exists y[{}^*\text{prof}_@(y) \wedge y \geq x \wedge \text{f.t.c.}_w(y)] \mid x \in {}^*\text{prof}_@\}$
({x is part of a group of profs who formed the committee: x is prof(s)})

But, this sub-divisive reading is not observed in the corresponding matrix question. Compare:

(31) a. Who is part of the professors who formed the committee, for example?
b. Which professors formed the committee, # for example?

The partiality marker *for example* presupposes the existence of an incomplete true answers, and thus cannot be used in questions with only one true answer.

(32) a. Which student came, # for example?
b. Is it raining, # for example?
c. Zhiyou shei lai -le, # ju-ge lizi? *Mandarin*
only who come -PERF give-CL example
Intended: 'Which people x is such that **only** x came, # for example?'

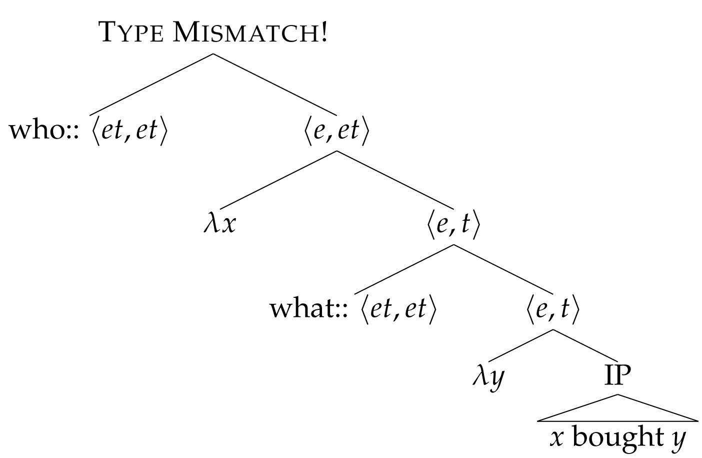
The infelicity of using *for example* in (31b) suggests that *which profs formed a committee* admits only a collective reading, under which this question can have only one true answer. Conversely, if it admits a sub-distributive reading, the use of *for example* in (31b) would be felicitous, contra fact.

5. Problems of categorial approaches

5.1. Composing multi-*wh* questions

- **The problem**: the composition of a multi-*wh* question (w. single-pair readings) suffers type mismatch.

(33) Who bought what?



- **A solution** (Xiang 2016, 2018)

The domain of a function-like question denotation is the extension of the *wh*-complement. Defining the *wh*-phrase (*wh*P) as an $\exists$-quantifier, we can extract out this domain by applying a BE-shifter to *wh*P.

(34) a. $[\![\text{which student}_@]\!] = \lambda f_{\langle e,t\rangle}.\exists x \in \mathsf{student}_@[f(x)]$

b. $\text{BE} = \lambda \mathcal{P}_{\langle \tau t,t\rangle} \lambda x_\tau [\mathcal{P}(\lambda y.y = x)]$ (Partee 1986)

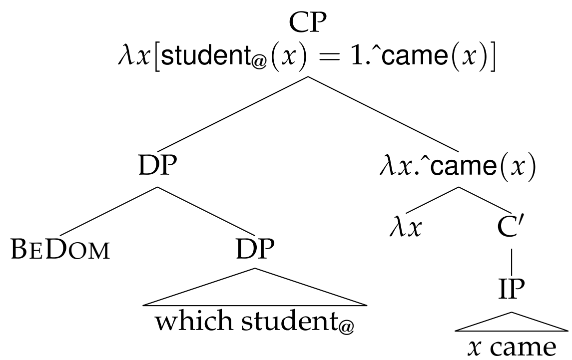
c. $\text{BE}([\![\text{which student}_@]\!]) = \mathsf{student}_@$

To incorporate $\text{BE}(wh\text{P})$ into the question denotation, Xiang coins a covert **BEDOM-operator**, which converts the *wh*P into a **domain restrictor**.

(35) $\text{BEDOM}(\mathcal{P}) = \lambda\theta_\tau.\iota P_\tau[[\text{Dom}(P) = \text{Dom}(\theta) \cap \text{BE}(\mathcal{P})] \wedge \forall\alpha \in \text{Dom}(P)[P(\alpha) = \theta(\alpha)]]$
(For any function θ, restrict the domain of θ with $\text{BE}(\mathcal{P})$.)

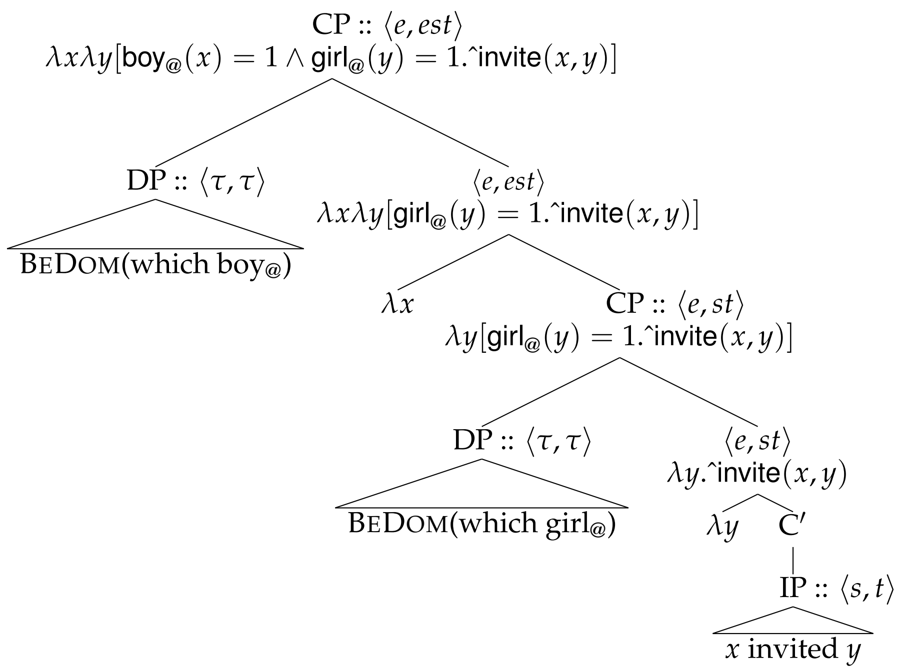
Moving BEDOM(*wh*P) to [Spec, CP] yields a partial property only defined for individuals in BE(*wh*P).

(36) Which student came?



$\text{BEDOM}(\mathcal{P})$ is polymorphic (of type $\langle\tau,\tau\rangle$). Hence, composing multi-*wh* doesn't suffer type-mismatch.

(37) Which boy invited which girl? (Single-pair reading)



- **Discussion:** Xiang defines *wh*Ps as existential quantifiers. If *wh*Ps are defined as function restrictions (as in traditional categorial approaches), how should the BEDOM-operator be defined?

5.2. Coordinations of questions

- Conjunction and disjunction are standardly defined as **meet** $\sqcap$ and **join** $\sqcup$, which operate on meanings of the same **conjoinable type**. (Partee and Rooth 1983, Groenendijk and Stokhof 1989)

(38) **Conjoinable types**
a. t is a conjoinable type;
b. if τ is a conjoinable type, then for any type σ: $\langle\sigma,\tau\rangle$ is a conjoinable type.

(39) $$A' \sqcap B' = \begin{cases} A' \wedge B' & \text{if } A' \text{ and } B' \text{ are of type } t \\ \lambda x[A'(x) \sqcap B'(x)] & \text{if } A' \text{ and } B' \text{ are of some other conjoinable type} \\ \text{undefined} & \text{otherwise} \end{cases}$$
(Join is defined analogously.)

(40) Examples:
a. jump and run — $\text{jump}_{\langle e,t\rangle} \sqcap \text{run}_{\langle e,t\rangle}$
b. * jump and look for — $\#\text{jump}_{\langle e,t\rangle} \sqcap \text{look-for}_{\langle e,et\rangle}$
c. Jenny and every student — $\text{LIFT}(\text{Jenny})_{\langle et,t\rangle} \sqcap \text{every student}_{\langle et,t\rangle}$
d. * Jenny and student — $\#\text{LIFT}(\text{Jenny})_{\langle et,t\rangle} \sqcap \text{student}_{\langle e,t\rangle}$
$\#\text{Jenny}_{e} \sqcap \text{student}_{\langle e,t\rangle}$

- **The problem**: Questions can be coordinated and embedded under the same attitude predicate. But categorial approaches assign them different semantic types.

(41) Jenny knows [[who came]$_{\langle e,t\rangle}$ **and/or** [who bought what]$_{\langle e,et\rangle}$]

Note that, even if the coordinated questions are of the same conjoinable type, traditional categorial approaches do not predict the correct reading.

(42) Jenny knows [$_{\langle e,t\rangle}$ who voted for Andy] and [$_{\langle e,t\rangle}$ who voted for Billy].
(Predicted reading: # 'Jenny knows who voted for both Andy and Billy.')

(43) $[\![\text{who voted for Andy}]\!] \sqcap [\![\text{who voted for Billy}]\!]$
$= (\lambda x[\text{vote-for}(x,a)]) \sqcap (\lambda x[\text{vote-for}(x,b)])$
$= \lambda x[\text{vote-for}(x,a) \wedge \text{vote-for}(x,b)]$
$= [\![\text{who voted for Andy and Billy}]\!]$ — Incorrect!

NB: While treating questions uniformly as of type $\langle st,t\rangle$, Hamblin-Karttunen Semantics also has imperfections in analyzing question coordinations — the conjunction of two questions cannot be the intersection of the Hamblin sets of the two questions:

(44) $[\![\text{who left and who stayed}[\![= [\![\text{who left}]\!] \cap [\![\text{who stayed}]\!] = \emptyset$ — Incorrect!

Hence, Hamblin-Karttunen Semantics has to define the conjunctive as point-wise intersection.

(45) $[\![\text{Q}_1 \text{ and } \text{Q}_2]\!] = \{p \cap q \mid p \in [\![\text{Q}_1]\!] \wedge q \in [\![\text{Q}_2]\!]\}$

Inquisitive Semantics (a variant of Alternative Semantics) restores the basic intersection semantics of conjunction (see Ciardelli et al. 2013, Ciardelli and Roelofsen 2015, and Ciardelli et al. To appear).

- **A "solution"** (Krifka 2001; Xiang 2016, 2018): Embeddings of question coordinations can be reduced into coordinations of question-embeddings. We can thus define conjunction and disjunction across different types of questions, and even across questions and *that*-clauses.

(46) Jenny knows [who came **and** who bought what]
= [Jenny knows who came] **and** [Jenny knows who bought what]

(47) **Type-lifting of Boolean structures** (based on Keenan and Faltz 1985)
Let A' and B' be the meanings of two constructions A and B, then we have:

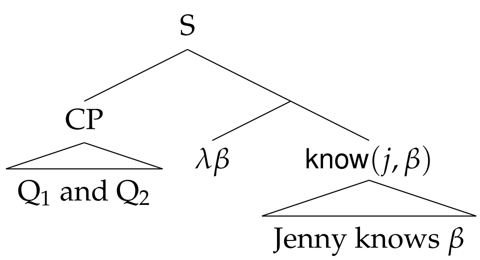
a. $[\![A \text{ and } B]\!] = \lambda P.P(A') \wedge P(B')$

b. $[\![A \text{ or } B]\!] = \lambda P.P(A') \wedge P(B')$

c. $[\![\text{not } A]\!] = \lambda P.\neg P(A')$

Question coordinations are GQs. When embedded, a question coordination undertakes QR and moves to the left edge of the matrix clause.[2]

(48) Jenny knows [[$_{Q_1}$ who came] and [$_{Q_2}$ who bought what]].



$$\begin{aligned}[\![\text{S}]\!] &= (\lambda\alpha.[\alpha(Q_1') \wedge \alpha(Q_2')])(\lambda\beta.\text{know}(j,\beta)) \\ &= (\lambda\beta.\text{know}(j,\beta))(Q_1') \wedge (\lambda\beta.\text{know}(j,\beta))(Q_2') \\ &= \text{know}(j, Q_1') \wedge \text{know}(j, Q_2') \\ &= \text{know}(j, \lambda x.\hat{}\text{came}(x)) \wedge \text{know}(j, \lambda x \lambda y.\hat{}\text{bought}(x,y))\end{aligned}$$

(Jenny knows who came, and she knows who bought what.)

– Evidence for the reductive view (Xiang 2016, 2018):

Evidence 1: [Q_1 and Q_2] > surprise
Conjunctions of questions under **non-divisive** predicates admit only wide scope readings.

(49) a. John is **surprised** that [Mary went to Boston] and [Sue went to Chicago]. (He expected them to go to the same city.)
$\not\rightsquigarrow$ John is surprised that Mary went to Boston.

b. John is **surprised** at [who went to Boston] and [who went to Chicago].
$\rightsquigarrow$ John is surprised at who went to Boston.

Evidence 2: [Q_1 or Q_2] > know
In (50b), John needs to know the complete true answer of one of the questions, not just the disjunction of the complete true answers of the two questions.

Mary invite ...	*a*	*b*	*a or b (or both)*
Fact	Yes	Yes	Yes
John's belief	?	?	Yes

[2]A technical problem: the sister node of the question coordination cannot have a fixed semantic type; the function denoted by this node should be able to take both Q_1' (of type $\langle e, st\rangle$) and Q_2' (of type $\langle e, est\rangle$) as arguments, yielding conflicting requirements on the type of the abstracted variable β. One solution is to assume that the abstracted variable β has a *sum type*, a type that can be one of multiple possible options. For example, if D_a is conceived as the set of items of type a and D_b as the set of items of type b, then $D_{a|b}$ is the set of items of type $a|b$, or equivalently, $D_a \cup D_b$. Accordingly, in (48), the β variable is of the sum type $\langle e, st\rangle | \langle e, est\rangle$, and then the embedding-predicate *know* is a polymorphic function of the type $\langle\langle e, st\rangle | \langle e, est\rangle, et\rangle$. Thank Danny Fox, Floris Roelofsen, Simon Charlow, and Manuel Križ for discussions.

(50) a. John knows that Mary invited *a* or *b* (or both). TRUE

b. John knows [whether Mary invited *a*] **or** [whether Mary invited *b*]. FALSE

– *A challenge to the reductive view*: The disjunction of questions seems can freely take scope above or below an **intensional predicate** (e.g. *wonder*, *investigate*). (Groenendijk and Stokhof 1989)

(51) Peter wonders [$_{Q1}$whom Jenny loves] or [$_{Q2}$whom Mary loves].

a. 'The speaker knows that Peter wants to know the answer to Q1 or the answer to Q2, but she is unsure to which question this answer is.' (Wide scope reading)

b. 'Peter will be satisfied as long as he gets the answer to Q1 or the answer to Q2, regardless of which one.' (Narrow scope reading)

Xiang's reply: Decompose *wonder* into *wants to know*. The narrow scope reading arises when disjunction scopes in between *want* and *know*.

(52) a. [[Q_1 or Q_2] $\lambda\beta$ [Peter wants to know β]] (Wide scope reading)

b. [Peter wants [[Q_1 or Q_2] $\lambda\beta$ [to know β]]] (Narrow scope reading)

6. Compare Hamblin-Karttunen Semantics and categorial approaches

- **Discussion**: Are the denotations of (53a-b) equivalent under Hamblin/Karttunen Semantics? What about under categorial approaches?

(53) a. Did [John come or MAry]$_F$ come?$_{\text{ALT-Q}}$

b. [Among John and Mary,] which person came?

Discussion: Can we derive a Hamblin set based on a lambda abstract? What about retrieving a lambda abstract out of the corresponding Hamblin set?

- Categorial approaches versus Hamblin-Karttunen Semantics

	Categorial	Hamblin-Karttunen
Retrieving the question nucleus	Yes	No
Getting short answers	Yes	No
Getting full answers	Yes	Yes
Uniform semantic type	No	Yes: $\langle st, t\rangle$
Question coordinations	No	No
Type-driven *wh*-movement	Yes	No

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