HG2002 Semantics and Pragmatics

Formal Semantics

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Lecture 10

https://bond-lab.github.io/Semantics-and-Pragmatics/

Overview

- Revision: Components
- Quantifiers and Higher Order Logic
- Modality
- (Dynamic Approaches to Discourse)
- Next Lecture: Chapter 11 — Cognitive Semantics

Revision:
Componential Analysis

Break word meaning into its components

- components allow a compact description
- interact with morphology/syntax
- form part of our cognitive architecture
- For example:

woman	[FEMALE]	[ADULT]	[HUMAN]	
spinster	[FEMALE]	[ADULT]	[HUMAN]	[UNMARRIED]
bachelor	[MALE]	[ADULT]	[HUMAN]	[UNMARRIED]
wife	[FEMALE]	[ADULT]	[HUMAN]	[MARRIED]

- We can make things more economical (fewer components):

woman	[+FEMALE]	[+ADULT]	[+HUMAN]	
spinster	[+FEMALE]	[+ADULT]	[+HUMAN]	[−MARRIED]
bachelor	[−FEMALE]	[+ADULT]	[+HUMAN]	[−MARRIED]
wife	[+FEMALE]	[+ADULT]	[+HUMAN]	[+MARRIED]

Defining Relations using Components

- **hyponymy**: P is a hyponym of Q if all the components of Q are also in P.
  spinster $\subset$ ***woman***; ***wife*** $\subset$ ***woman***

- **incompatibility**: P is incompatible with Q if they share some components but differ in one or more **contrasting** components
  spinster $\not\approx$ ***wife***

- Redundancy Rules

  $$\begin{array}{lll} [+\text{HUMAN}] & \rightarrow & [+\text{ANIMATE}] \\ [+\text{ANIMATE}] & \rightarrow & [+\text{CONCRETE}] \\ [+\text{MARRIED}] & \rightarrow & [+\text{ADULT}] \\ [+\text{MARRIED}] & \rightarrow & [+\text{HUMAN}] \quad \ldots \end{array}$$

- Predicates with argument structure
  parent (of y)($\underline{x}$,y) $\rightarrow$[+PARENT]($\underline{x}$,y)

Katz's Semantic Theory

- Semantic rules must be recursive to deal with infinite meaning
- Semantic rules interact with syntactic rule to build up meaning **compositionally**
  - A **dictionary** pairs lexical items with semantic representations
    - (**semantic markers**) are the links that bind lexical items together in lexical relations
    - [**distinguishers**] serve to identify this particular lexical item

      this information is not relevant to syntax
  - **projection rules** show how meaning is built up
    - Information is passed up the tree and collected at the top.
    - **Selectional restrictions** help to reduce ambiguity and limit the possible readings

Verb Classification

- We can investigate the meaning of a verb by looking at its grammatical behavior

  (1) Consider the following transitive verbs

  a. *Margaret cut the bread*

  b. *Janet broke the vase*

  c. *Terry touched the cat*

  d. *Carla hit the door*

- These do not all allow the same argument structure alternations

Diathesis Alternations

- **Causative/inchoative** alternation:
  Kim broke the window ↔ *The window broke*
  also *the window is broken* (state)
- **Middle construction** alternation:
  Kim cut the bread ↔ *The bread cut easily*
- **Conative** alternation:
  Kim hit the door ↔ *Kim hit at the door*
- **Body-part possessor ascension** alternation:
  Kim cut Sandy's arm ↔ *Kim* cut Sandy on the arm

Diathesis Alternations and Verb Classes

- A verb's (in)compatibility with different alternations is a strong predictor of its lexical semantics:

	break	***cut***	***hit***	***touch***
Causative	YES	NO	NO	NO
Middle	YES	YES	NO	NO
Conative	NO	YES	YES	NO
Body-part	NO	YES	YES	YES

  break = {*break, chip, crack, crash, crush, ...*}
  cut = {*chip, clip, cut, hack, hew, saw, ...*}
  hit = {*bang, bash, batter, beat, bump, ...*}
  touch = {*caress, graze, kiss, lick, nudge, ...*}

break	CAUSE, CHANGE
cut	CAUSE, CHANGE, CONTACT, MOTION
hit	CONTACT, MOTION
touch	CONTACT

Cognitive Semantics

➢ Major semantic components of Motion:

- **Figure**: object moving or located with respect to the **ground**
- **Ground**: reference object
- **Motion**: the presence of movement of location in the event
- **Path**: the course followed or site occupied by the Figure
- **Manner**: the type of motion

(2)	*Kim*	*swam*	*away*	*from the crocodile*
	Figure	Manner	Path	Ground

(3)	*The banana*	*hung*	*from*	*the tree*
	Figure	Manner	Path	Ground

➢ These are lexicalized differently in different languages.

Language (Family)	Verb Conflation Pattern
Romance, Semitic, Polynesian, …	Path + fact-of-Motion
Indo-European (– Romance), Chinese	Manner/Cause + fact-of-Motion
Navajo, Atsuwegei, …	Figure + fact-of-Motion

Jackendoff's Lexical Conceptual Structure

- An attempt to explain how we think
- **Mentalist Postulate**

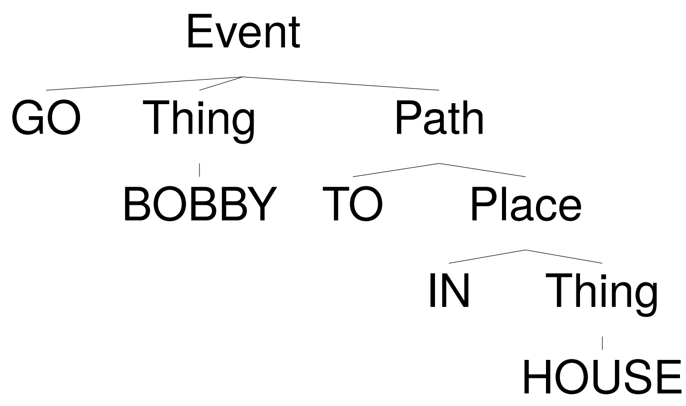
  Meaning in natural language is an information structure that is mentally encoded by human beings
- Universal Semantic Categories
  - **Event**
  - **State**
  - **Material Thing/Object**
  - **Path**
  - **Place**
  - **Property**

Motion as a tree

(4) *Bobby went into the house*

(5) “Bobby traverses a path that terminates at the interior of the house”

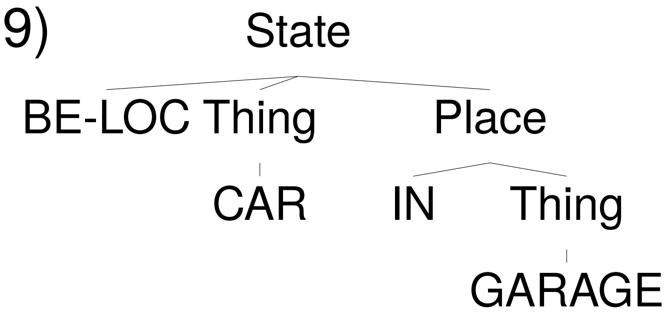
(6)



(7) *The car is in the garage*

(8) “The car is in the state located in the interior of the garage”

(9)



Things: Boundedness and Internal Structure

- Two components:

Boundedness	Internal Struct.	Type	Example
$+$b	$-$i	**individuals**	*a dog*/*two dogs*
$+$b	$+$i	**groups**	*a committee*
$-$b	$-$i	**substance**s	*water*
$-$b	$+$i	**aggregates**	*buses, cattle*

- This can be extended to verb aspect (the verb event is also [$\pm$b, $\pm$i]).
  sleep [$-$b], ***cough*** [$+$b], ***eat*** [$\pm$b]

  (10) Bill ate two hot dogs in two hours.

  (11) *Bill ate hot dogs in two hours.

  (12) #Bill ate two hot dogs for two hours.

  (13) Bill ate hot dogs for two hours.

Conversion: Boundedness and Internal Structure

- Including

plural	[+b, –i] $\rightarrow$ [–b, +i]	*brick* $\rightarrow$ *bricks*
composed of	[–b, +i] $\rightarrow$ [+b, –i]	*bricks* $\rightarrow$ *house of bricks*
containing	[–b, –i] $\rightarrow$ [+b, –i]	*coffee* $\rightarrow$ *a cup of coffee/a coffee*

- Excluding

element	[–b,+i] $\rightarrow$ [+b, –i]	*grain of rice*
partitive	[–b, $\pm$i] $\rightarrow$ [+b, –i]	*top of the mountain*, *one of the*
universal grinder	[+b, –i] $\rightarrow$ [–b, –i]	*There's <u>dog</u> all over the road*

See Bond (2005) for an extension to Japanese and computational implementation.

Pustejovsky's Generative Lexicon

- Each lexical entry can have:

  ARGUMENT STRUCTURE

  EVENT STRUCTURE

  LEXICAL INHERITANCE STRUCTURE

  QUALIA STRUCTURE:

CONSTITUTIVE	constituent parts
FORMAL	relation to other things
TELIC	purpose
AGENTIVE	how it is made

- Interpretation is **generated** by combing word meanings
- Events have **complex** structure

State	**Process**	**Transition**
S	P	T
e	$e_1 \ldots e_n$	$E_1 \neg E_2$
understand, love, be tall	***sing, walk, swim***	***open, close, build***

Modifier Ambiguity

(14) *Jamie closed the door rudely*

(15) *Jamie closed the door in a rude way [with his foot]*

T

P [rude(P)]　　　　S

[act(j, door) $\wedge \neg$ closed(door)]　　　　[closed(door)]

(16) *It was rude of Jamie to close the door*

T [rude(T)]

P　　　　S

[act(j, door) $\wedge \neg$ closed(door)]　　　　[closed(door)]

Qualia Structure

(17) *fast typist*

a. a typist who is fast [at running]

b. a typist who types fast

➢ typist

$$\left[\begin{array}{ll} \text{ARGSTR} & \left[\text{ARG1} \quad \texttt{x:typist}\right] \\ \text{QUALIA} & \left[\begin{array}{ll} \text{FORMAL} & \left[\texttt{x}\ [\subset \texttt{person}\ ]\right] \\ \text{TELIC} & \left[\texttt{type(e,x)}\right] \end{array}\right] \end{array}\right]$$

➢ (17a) *fast* modifies x

➢ (17b) *fast* modifies e

Summary

- Meaning can be broken up into units smaller than words: **components**
  - These can be combined to make larger meanings
  - At least some of them influence syntax
  - They may be psychologically real

- Problems with Components of Meaning
  - Primitives are no different from necessary and sufficient conditions
    it is impossible to agree on the definitions
    but they allow us to state generalizations better
  - Psycho-linguistic evidence is weak
  - It is just **markerese**
  - There is no **grounding**

Word Meaning: Meaning Postulates

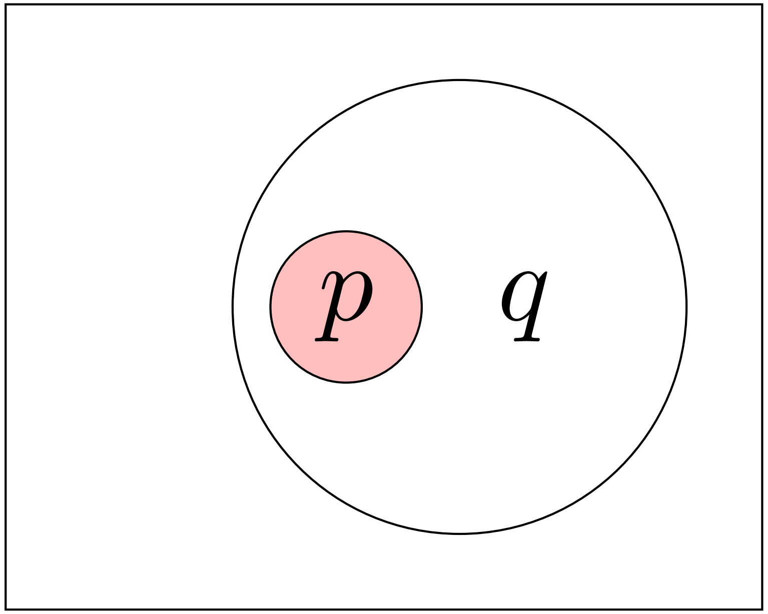
Defining Relations using Logic

- **hyponymy**
  - $\forall$x(DOG(x) $\rightarrow$ ANIMAL(x))
- **synonym**
  - $\forall$x((EGGPLANT(x) $\rightarrow$ BRINJAL(x)) $\wedge$ (BRINJAL(x) $\rightarrow$ EGG-PLANT(x)))
  - $\forall$x(EGGPLANT(x) $\equiv$ BRINJAL(x))

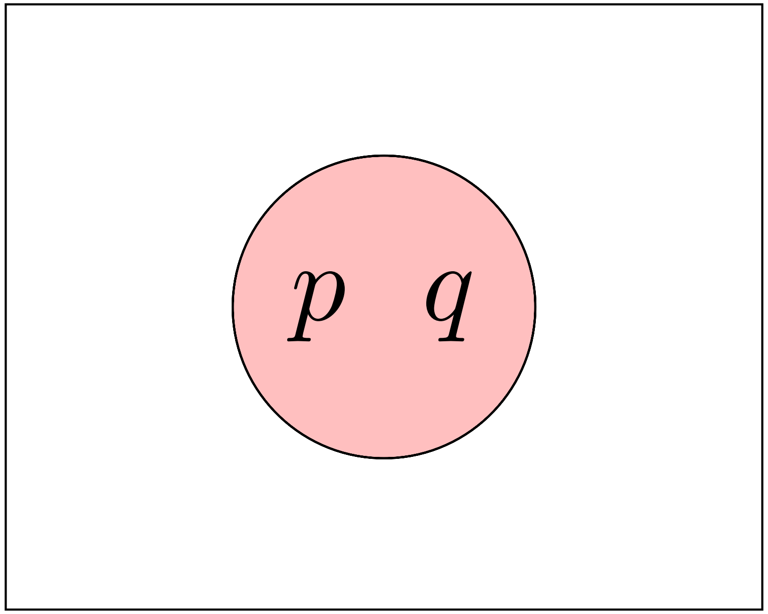
- **antonym**
  - $\forall x(\text{DEAD}(x) \rightarrow \neg\text{ALIVE}(x))$;
  + $\forall x(\text{ALIVE}(x) \rightarrow \neg\text{DEAD}(x))$
- **converse**
  - $\forall x \forall y(\text{PARENT}(x,y) \rightarrow \text{CHILD}(y,x))$;
    $\forall x \forall y(\text{PARENT}(x,y) \rightarrow \neg\ \text{CHILD}(x,y))$
  - $\forall x \forall y(\text{CHILD}(y,x) \rightarrow \text{PARENT}(x,y))$
    $\forall x \forall y(\text{CHILD}(y,x) \rightarrow \neg\ \text{PARENT}(y,x))$

Semantic Relations as Sets ($p \subset q$ and $p \sim q$)

$p \subset q$ **hypernym**

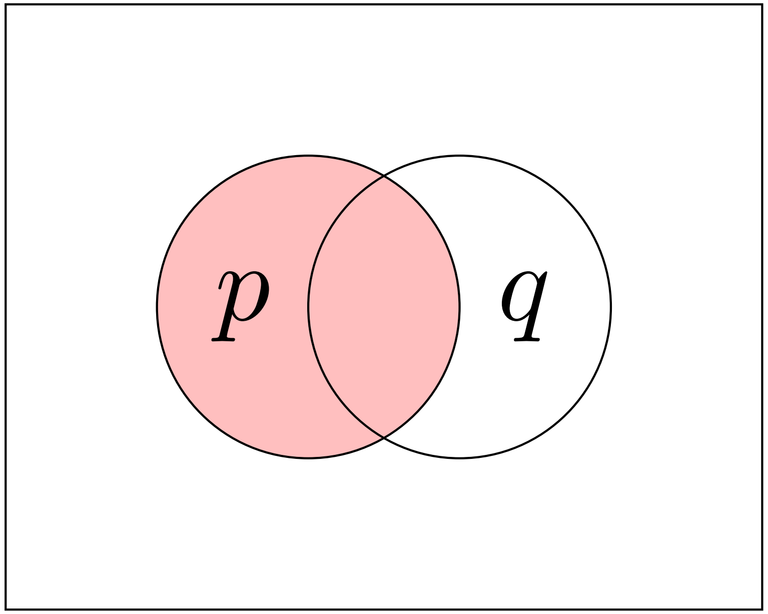


$p \sim q$ **synonym**

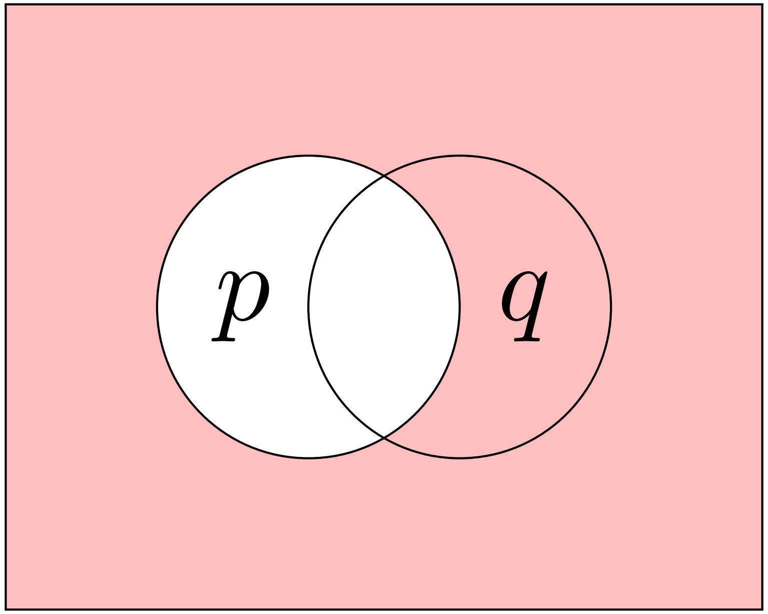


Logical Connectives as Sets (p and $\neg p$)

p

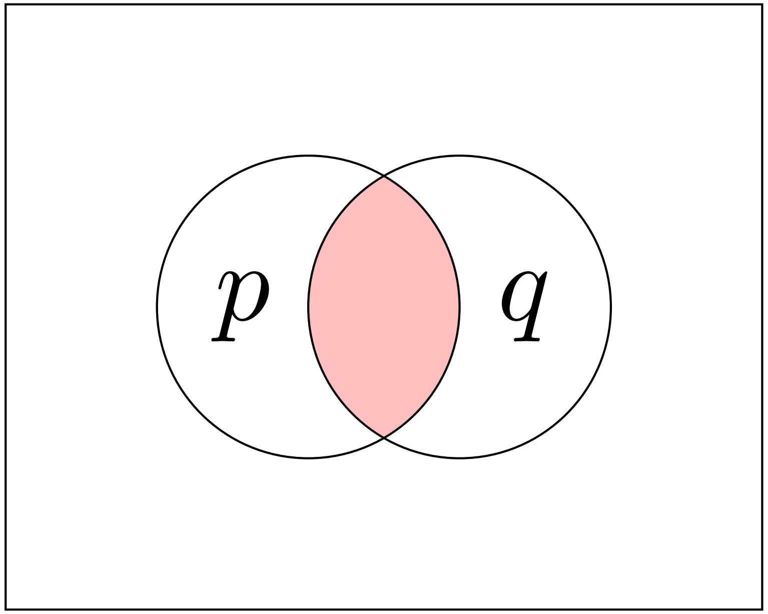


$\neg p$ "not"

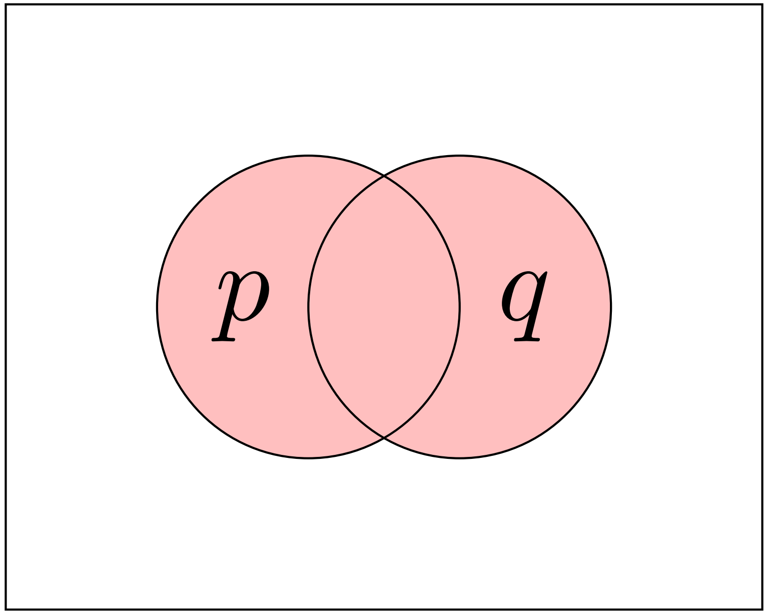


Logical Connectives as Sets ($p \wedge q$ and $p \vee q$)

$p \wedge q$ "and"

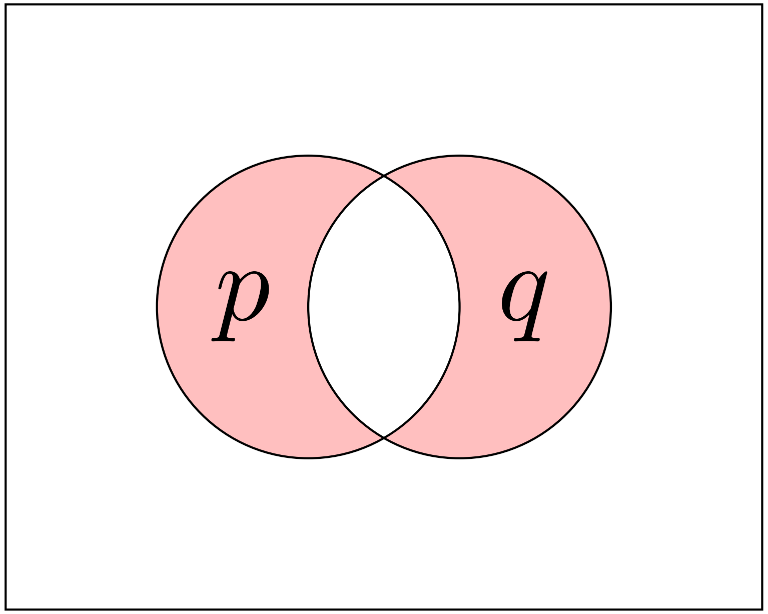


$p \vee q$ "or"

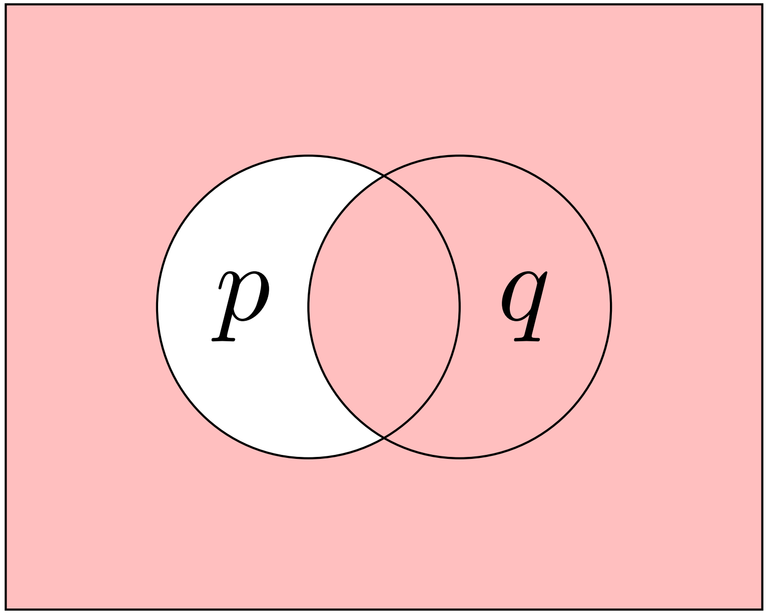


Logical Connectives as Sets ($p \oplus q$ and $p \rightarrow q$)

$p \oplus q$ "exclusive or"



$p \rightarrow q$ "if"



Natural Language Quantifiers and Higher Order Logic

Restricted Quantifiers

- *Most students read a book*
  - $\text{Most(x)(S(x)} \wedge \text{R(x))}$
    most things are students and most things read books
  - $\text{Most(x)(S(x)} \rightarrow \text{R(x))}$
    most things are such that, if they are students, they read books
    but also true for all things that are not students!
- We need to restrict the quantification
  - (Most x: S(x)) R(x)
- Sometimes we need to decompose
  - *everybody* $(\forall \text{x: P(x)})$
  - *something* $(\exists \text{x: T(x)})$

Higher Order Logic

- First-order logic over individuals
- Second-order logic also quantifies over sets
- Third-order logic also quantifies over sets of sets
- Fourth-order logic also quantifies over sets of sets of sets

…

Higher Order Logic

- Recall *Ian sings*
  - $[S(i)]^{M_1}$ = 1 iff $[i]^{M_1} \in [S]^{M_1}$
    The sentence is true if and only if the extension of *Ian* is part of the set defined by *sings* in the model M_1
  - Remodel, with sing a property of Ian: i(S)
    $[i(S)]^{M_1}$ = 1 iff $[S]^{M_1} \in [i]^{M_1}$
    The sentence is true if and only if the denotation of the verb phrase *sings* is part of the extension of *Ian* in the model M_1
- *Ian* is a set of sets of properties: **second-order logic**

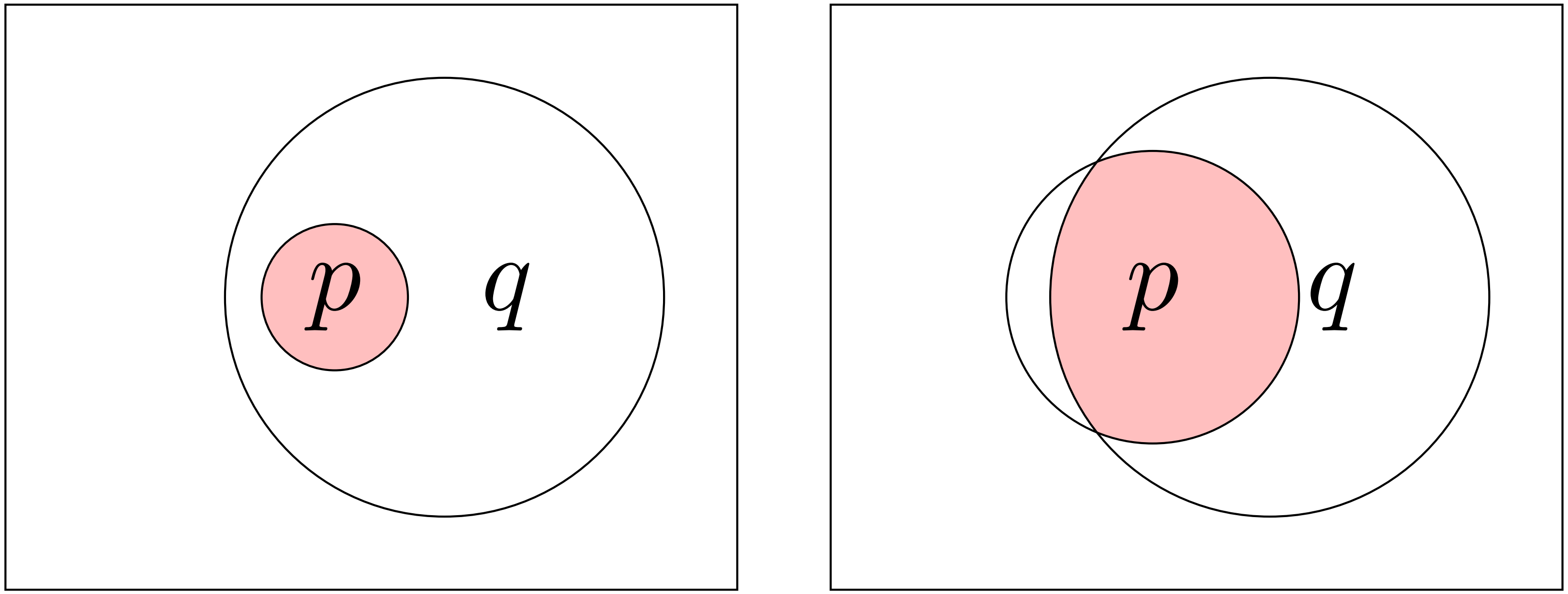
Generalized Quantifiers

- Q(A,B): *Q A are B*
- `most(A,B)` = 1 iff $|A \cap B| > |A - B|$
- `all(A,B)` = 1 iff $A \subseteq B$
- `some(A,B)` = 1 iff $A \cap B \neq \emptyset$
- `no(A,B)` = 1 iff $A \cap B = \emptyset$
- `fewer than x(A,B,X)` =1 iff $|A \cap B| < |X|$

Q: Try to define `many`

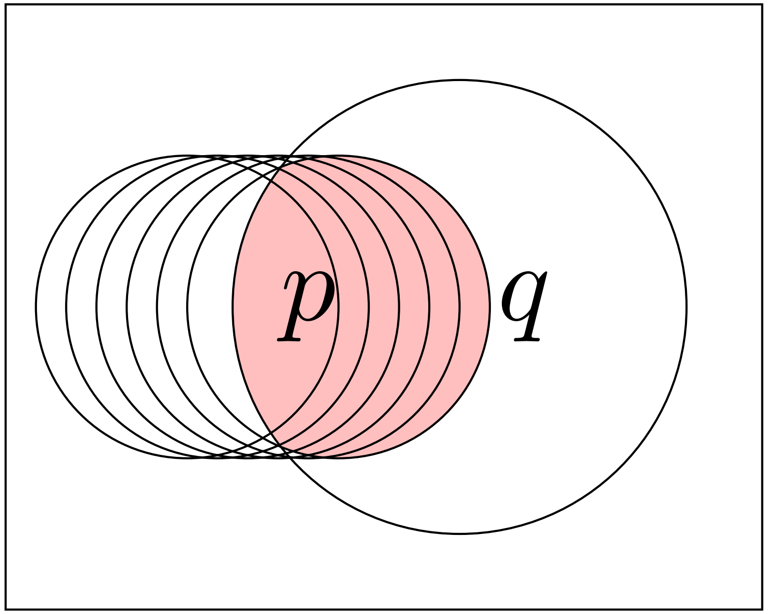
Generalized Quantifiers: `all`, `most`

all p are q most p are q

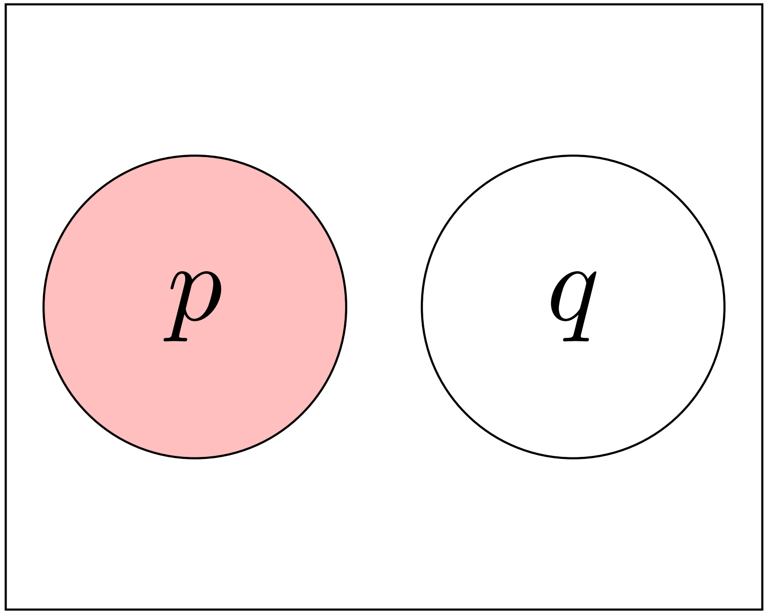


Generalized Quantifiers: `some`, `no`

some p are q



no p are q



Strong/Weak Quantifiers

(18) only **weak** quantifiers can occur in existential *there* sentences

a. *There is a fox in the henhouse*

b. *There are two foxes in the henhouse*

c. **There is every fox in the henhouse*

d. **There are both foxes in the henhouse*

- **symmetrical** (cardinal) quantifiers are **weak**
  det(A,B) = det(B,A)

(19) *3 lecturers are Australian* = *3 Australians are lecturers*

- **asymmetrical** (proportional) quantifiers are **strong**
  det(A,B) $\neq$ det(B,A)

(20) *most lecturers are Australian* $\neq$ *most Australians are lecturers*

Q: Come up with some more strong and weak quantifiers

Negative Polarity Items (NPI)

- Some words in English mainly appear in negative environments

(21) a. *Kim doesn't ever eat dessert*
b. **Kim does ever eat dessert*

(22) a. *Kim hasn't eaten dessert yet*
b. **Kim has eaten dessert yet*

(23) a. *Few people have eaten dessert yet*
b. **Many people have eaten dessert yet*

(24) a. *Rarely does Kim ever eat dessert*
b. **Often does Kim ever eat dessert*

- Not just negation, but also some quantifiers

Q: Come up with some NPIs and environments

Monotonicity

- Some quantifiers control entailment between sets and subsets
  - **Upward entailment** goes from a subset to a set
  - **Downward entailment** goes from a set to a subset

(25) a. *Kim doesn't eat dessert* $\Rightarrow$ *Kim doesn't eat hot dessert*

b. *Kim doesn't eat hot dessert* $\not\Rightarrow$ *Kim doesn't eat dessert*

Downward entailment

(26) a. *Kim eats some desserts* $\not\Rightarrow$ *Kim eats hot desserts*

b. *Kim eats some hot desserts* $\Rightarrow$ *Kim eats some desserts*

Upward entailment

- Negative Polarity Items are licensed by downward entailing expressions

Left and Right Monotonicity

➢ The monotonicity may depend on the position

(27) a. *Every student studies semantics* $\not\Rightarrow$ *Every student studies formal semantics*

b. *Every student studies formal semantics* $\Rightarrow$ *Every student studies semantics*

Upward entailment (right argument)

(28) a. *Every student studies semantics* $\Rightarrow$ *Every linguistics student studies semantics*

b. *Every linguistic student studies semantics* $\not\Rightarrow$ *Every student studies semantics*

Downward entailment (left argument)

(29) a. *Every student who has ever studied semantics loves it*

b. **Every student who has studied semantics ever loves it*

c. *Few students who have ever studied semantics dislike it*

d. *Few students who have studied semantics ever dislike it*

➢ Formal models of quantification can be used to make predictions about seemingly unrelated phenomena

In other languages too!

(30) 我 没有 任何 朋友
wǒ méi-yǒu rènhé péngyǒu
I NEG-have any friend
"I don't have any friends."

(31) * 我 有 任何 朋友
wǒ yǒu rènhé péngyǒu
I have any friend
*"I have any friends."

Modality

Modality as a scale of Implicatures

(32) *I know that* p

(33) *I am absolutely certain that* p

(34) *I am almost certain that* p

(35) *I believe that* p

(36) *I am pretty certain that* p

. . .

(37) *Possibly* p

. . .

(38) *It is very unlikely that* p

(39) *It is almost impossible that* p

(40) *It is impossible that* p

(41) *It is not the case that* p

(42) *I am absolutely certain that not-*p

Modal Logics

- Add two modal operators for epistemic modality
  - $\diamond\phi$ = *it is possible that* ϕ
  - $\Box\phi$ = *it is necessary that* ϕ
- Define them in terms of **possible worlds**
  - $\diamond\phi$: true in at least one world
  - $\Box\phi$: true in all worlds
- $M = \{W, U, F\}$: the model now has three parts

  W set of possible worlds
  U domain of individuals (universe)
  F denotation assignment function

Deontic Modality

- Add two modal operators for deontic modality
  - Pϕ = *it is permitted that* ϕ
  - Oϕ = *it is obligatorily* ϕ
- Define them in terms of **possible worlds**
  - Pϕ: true in at least one legal or morally ideal world
  - Oϕ: true in all legal or morally ideal worlds

Dynamic Approaches to Discourse

Anaphora

(43) a. *R2D2$_i$ mistrusts itself$_i$*

b. M(r,r)

(44) a. *Every robot mistrusts itself*

b. $(\forall x\text{: } R(x))\ M(x,x)$

(45) a. *Luke bought a robot and it doesn't work*

b. $(\exists x\text{: } R(x))\ B(l,x) \wedge \neg W(x)$

(46) a. *Every robot went to Naboo. ?It met Jar Jar.*

b. $(\forall x\text{: } R(x))\ W(x,n); M(x,j)$ unbound

(47) a. *A robot went to Naboo. It met Jar Jar.*

b. $(\exists x\text{: } R(x))\ W(x,n); M(x,j)$???

indefinite nominals exist beyond the sentence: **discourse referents**

(48) a. *Luke didn't buy a robot. ?It met Jar Jar.*

indefinite nominals scope can still be limited

Donkey Sentences

(49) a. *If R2D2$_i$ owns a ship it is rich*

b. $(\exists x\ (S(x) \wedge O(r,x))) \rightarrow R(x)$

(50) a. *If a robot owns a ship it races it*

b. *$(\exists x \exists y\ (R(x) \wedge S(y) \wedge O(x,y))) \rightarrow R(x,y)$

c. $\forall x \forall y\ ((R(x) \wedge S(y) \wedge O(x,y)) \rightarrow R(x,y)$

$\exists$ needs to become $\forall$

(51) *Every farmer who owns a donkey beats it*

Discourse Representation Theory

➢ Build up Discourse Representation Structures

(52) a. *Alex met a robot*$_i$

b. *It*$_i$ *smiled*

(53)

x y
Alex(x) robot(y) met (x,y)

x y u
Alex(x) robot(y) met (x,y) u = y smiled(u)

Negative Contexts

(54) a. *Luke does not own a robot*

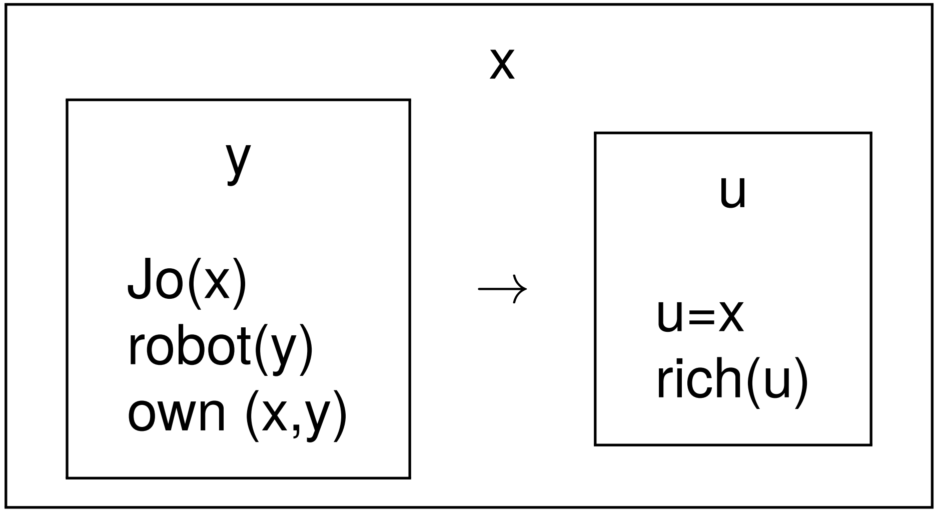
(55)

x
Luke(x)
¬ [y ; robot(y), own (x,y)]

- The contained DRS is **subordinate**
  - indefinite NPs in negated subordinate structures are inaccessible
  - names (constants) are always accessible

Conditionals

(56) a. *If Jo owns a robot then they are rich*

(57) 

- The contained DRS is **subordinate**
  - indefinite NPs in the antecedent are accessible in the consequent

More Conditionals

(58) a. *If a Jedi owns a robot then they are rich*

(59)

x y jedi(x) robot(y) own (x,y)	$\rightarrow$	u u=x rich(u)

- The contained DRS is **subordinate**
  - indefinite NPs in the antecedent are accessible in the consequent

More Conditionals

(60) a. *If a Jedi owns a robot then they race it*

(61)

x y		u v
jedi(x) robot(y) own (x,y)	$\rightarrow$	u=x v=y race(u,v)

- The contained DRS is **subordinate**
  - indefinite NPs in the antecedent are accessible in the consequent

More Conditionals

(62) a. *Every Jedi who owns a robot races it*

(63)

x y		u
jedi(x) robot(y) own (x,y)	$\rightarrow$	u=y race(x,u)

- The contained DRS is **subordinate**
  - Universal Quantifiers copy the variable across the conditional

Discourse Representation Theory

- Explains how reference occurs across clauses and sentences
  - Distinguishes between names and indefinite NPS
  - Distinguishes between positive assertions, negative sentences, conditional sentences, universally quantified sentences
  - Is useful for modeling the incremental update of knowledge in a conversation

Acknowledgments and References

- Video *Regency Disco* from that Mitchel and Webb Look Episode 3.3, which was first broadcast on Thursday 25th June 2009.