# HG2002 Semantics and Pragmatics

# Formal Semantics

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Lecture 10

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# 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

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

# 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 <u>broke</u> the window* ↔ *The window <u>broke</u>*

  also *the window <u>is broken</u>* (state)

- **Middle construction** alternation:

  *Kim <u>cut</u> the bread* ↔ *The bread <u>cut</u> easily*

- **Conative** alternation:

  *Kim <u>hit</u> the door* ↔ *Kim <u>hit</u> at the door*

- **Body-part possessor ascension** alternation:

  *Kim <u>cut</u> Sandy's arm* ↔ *Kim* <u>cut Sandy on the arm</u>

# 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, ...*}

# 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 |

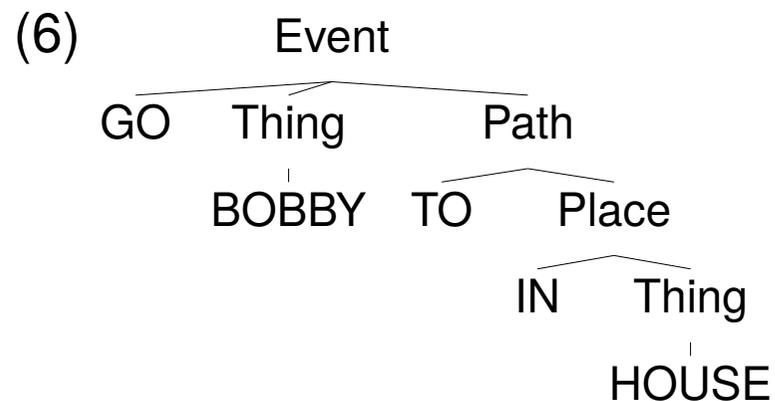# Jackendoff's Lexical Conceptual Structure

➤ 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
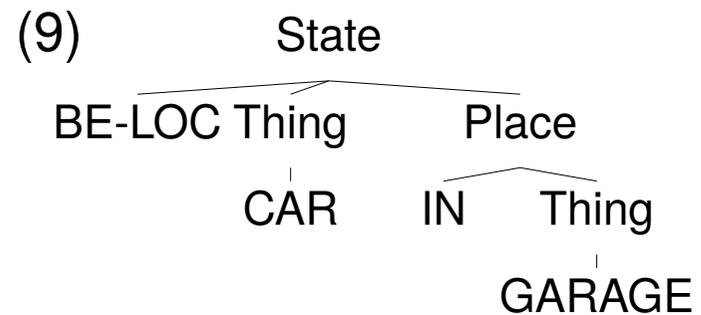
(4) *Bobby went into the house*

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

(6)
```
                Event
        ┌─────────┼─────────┐
       GO       Thing      Path
                 │        ┌──┴───┐
               BOBBY     TO    Place
                              ┌──┴──┐
                             IN    Thing
                                    │
                                  HOUSE
```

(7) *The car is in the garage*

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

(9)
```
                State
        ┌─────────┼─────────┐
    BE-LOC      Thing      Place
                 │        ┌──┴───┐
                CAR      IN    Thing
                                │
                              GARAGE
```

# 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 [±b, ±i]).

*sleep* [−b], *cough* [+b], *eat* [±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] → [−b, +i] | *brick → bricks* |
| **composed of** | [−b, +i] → [+b, −i] | *bricks → house of bricks* |
| **containing** | [−b, −i] → [+b, −i] | *coffee → a cup of coffee/a coffee* |

➢ Excluding

| | | |
|---|---|---|
| **element** | [−b,+i] → [+b, −i] | *grain of rice* |
| **partitive** | [−b, ±i] → [+b, −i] | *top of the mountain*, *one of the* |
| **universal grinder** | [+b, −i] → [−b, −i] | *There's <u>dog</u> all over the road* |

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See Bond (2005) for an extension to Japanese and computational implementation.                    13

# 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
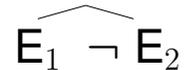
➤ Events have **complex** structure
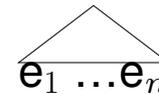
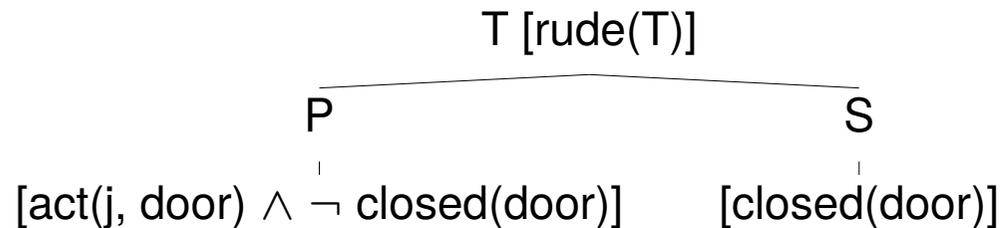| **State** | **Process** | **Transition** |
|:---:|:---:|:---:|
| S | P | T |
| $\mid$ | | |
| e | $e_1 \dots e_n$ | $E_1 \ \neg \ E_2$ |
| *understand, love, be tall* | *sing, walk, swim* | *open, close, build* |

# 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) ∧ ¬ closed(door)]          [closed(door)]
```
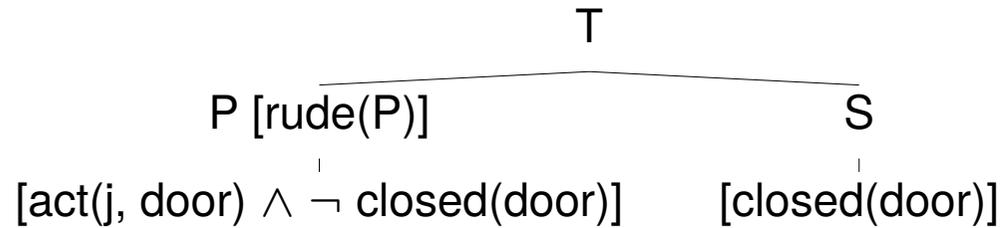
(16)  *It was rude of Jamie to close the door*

```
                           T [rude(T)]
               _____|_____
          P                             S
          |                             |
  [act(j, door) ∧ ¬ closed(door)]   [closed(door)]
```

# Qualia Structure

(17)  *fast typist*

      a.  a typist who is fast [at running]

      b.  a typist who types fast

(18)  *Joan baked the potato*

➤ typist $\begin{bmatrix} \text{ARGSTR} & \begin{bmatrix} \text{ARG}1 & \texttt{x:typist} \end{bmatrix} \\ \\ \text{QUALIA} & \begin{bmatrix} \text{FORMAL} & \begin{bmatrix} \texttt{x} \, [ \, \subset \, \texttt{person} \, ] \end{bmatrix} \\ \\ \text{TELIC} & \begin{bmatrix} \texttt{type(e,x)} \end{bmatrix} \end{bmatrix} \end{bmatrix}$

➤ (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**

  ➤ $\forall x(\text{DOG}(x) \rightarrow \text{ANIMAL}(x))$

➤ **antonym**

  ➤ $\forall x(\text{DEAD}(x) \rightarrow \neg\text{ALIVE}(x))$
  ? $\forall x(\text{ALIVE}(x) \rightarrow \neg\text{DEAD}(x))$

➤ **converse**

  ➤ $\forall x \forall y(\text{PARENT}(x,y) \rightarrow \text{CHILD}(y,x))$

➤ **synonym**

  ➤ $\forall x((\text{EGGPLANT}(x) \rightarrow \text{BRINJAL}(x)) \wedge (\text{BRINJAL}(x) \rightarrow \text{EGG-PLANT}(x)))$
  ➤ $\forall x(\text{EGGPLANT}(x) \equiv \text{BRINJAL}(x))$

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These are relations on predicates, not words

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

$p \subset q$ hypernym
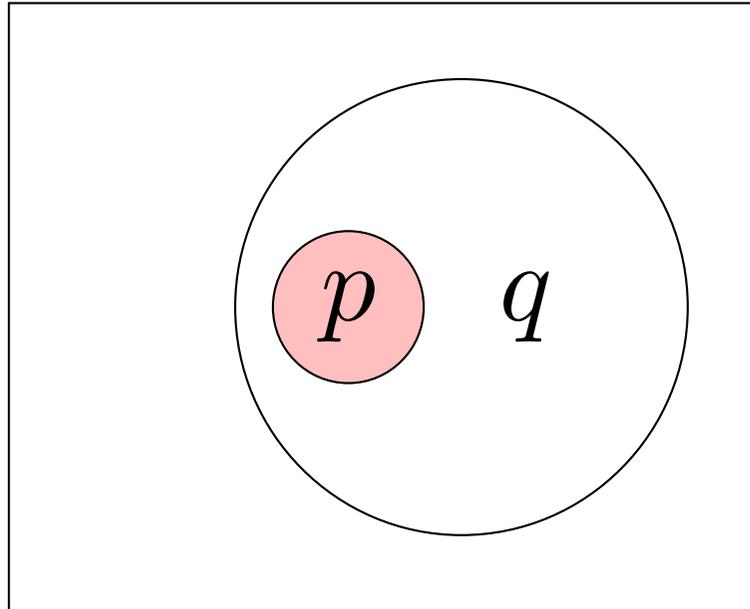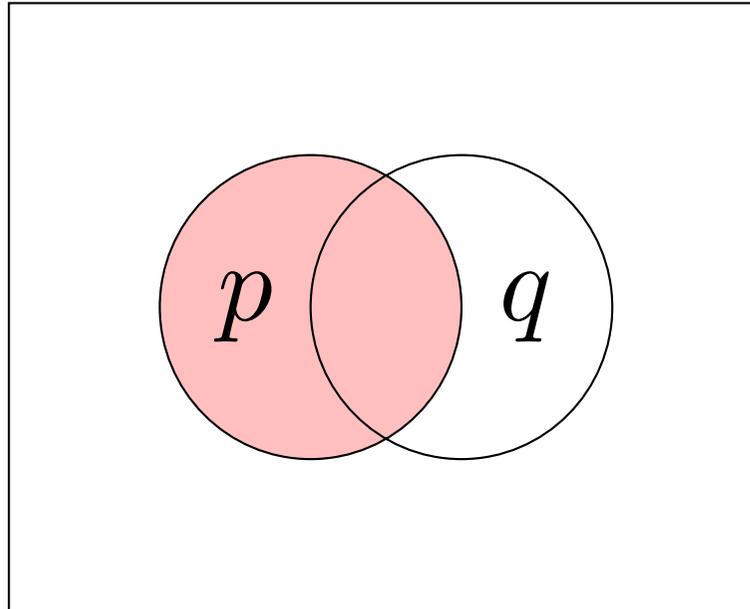
$p \sim q$ synonym
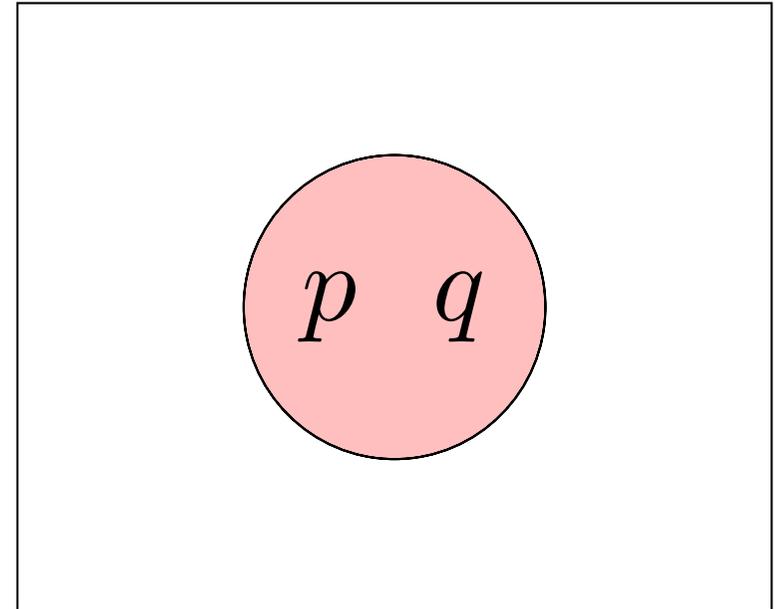
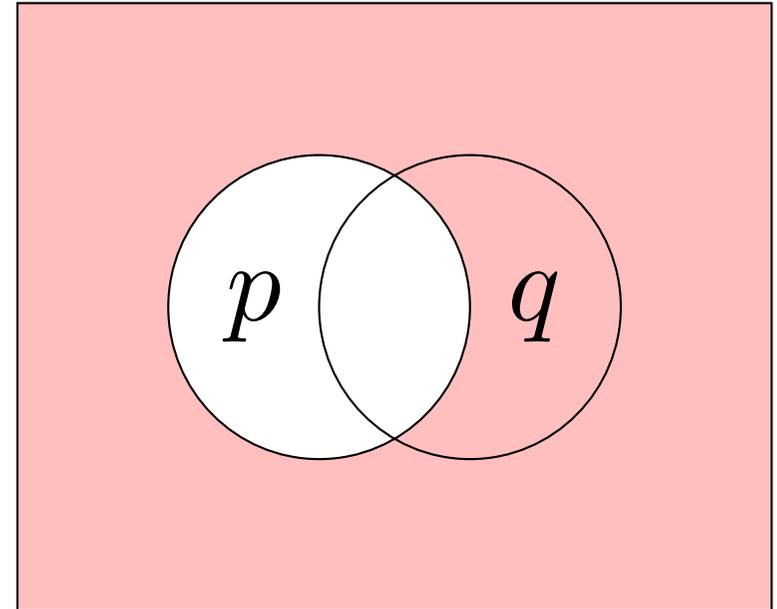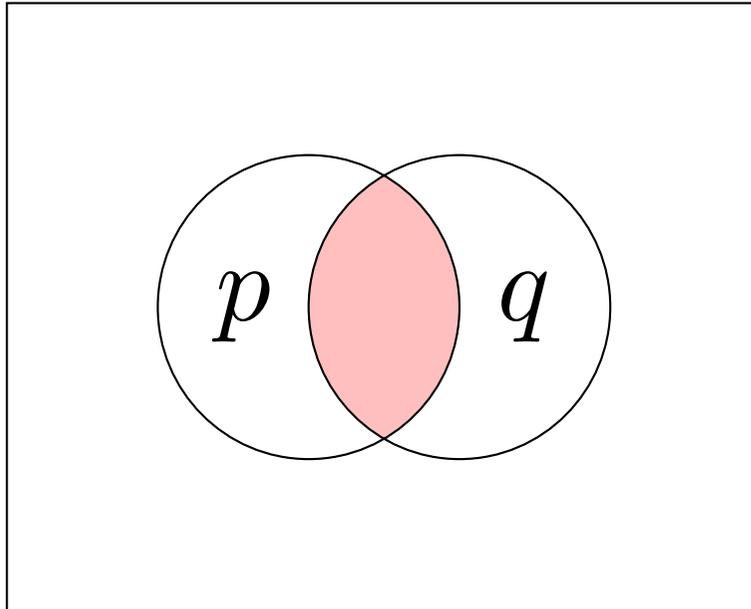# Logical Connectives as Graphs ($p$ and $\neg p$)

$p$                                                        $\neg p$ "not"

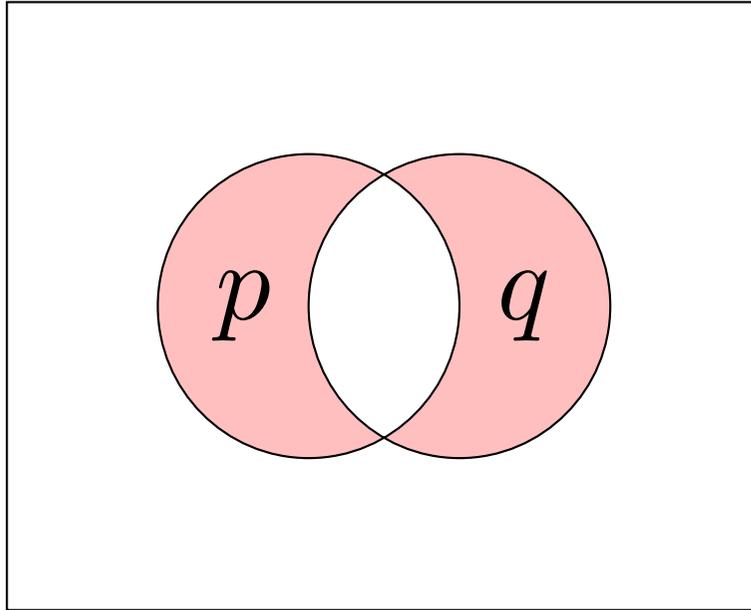# Logical Connectives as Graphs ($p \wedge q$ and $p \vee q$)
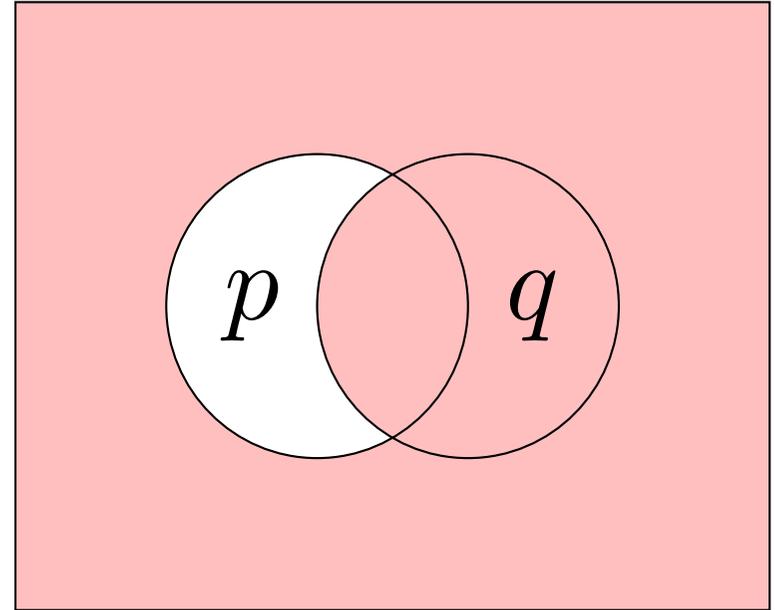
$p \wedge q$ "and" $\qquad\qquad\qquad\qquad$ $p \vee q$ "or"
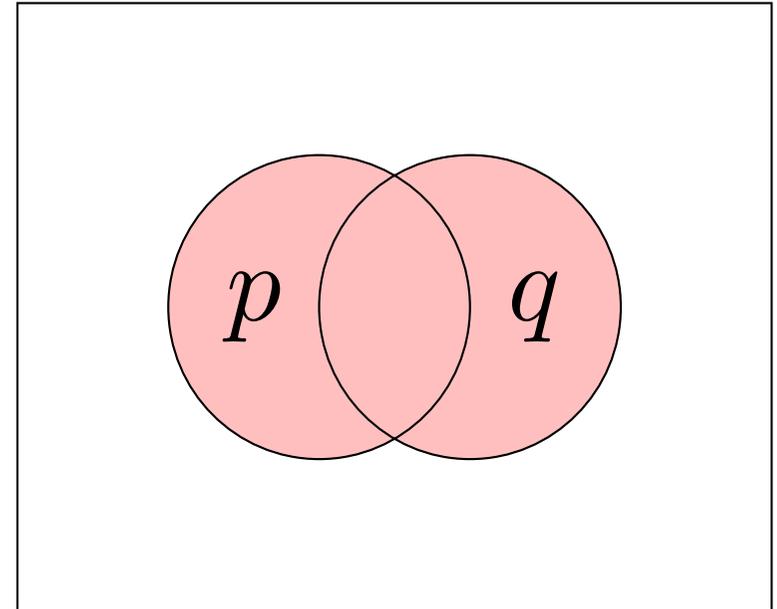
# **Logical Connectives as Graphs ($p \oplus q$ and $p \to q$)**

$p \oplus q$ "exclusive or"

$p \to q$ "if"

# Natural Language Quantifiers and Higher Order Logic

# Restricted Quantifiers

➤ *Most students read a book*

   ➤ Most(x)(S(x) ∧ R(x))
   *most things are students and most things read books*
   ➤ Most(x)(S(x) → R(x))
   *most things are such that, if they are students, they read books*

➤ We need to restrict the quantification

   ➤ (Most x: S(x)) R(x)

➤ Sometimes we need to decompose

   ➤ *everybody* (∀x: P(x))
   ➤ *something* (∃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 $M_1$
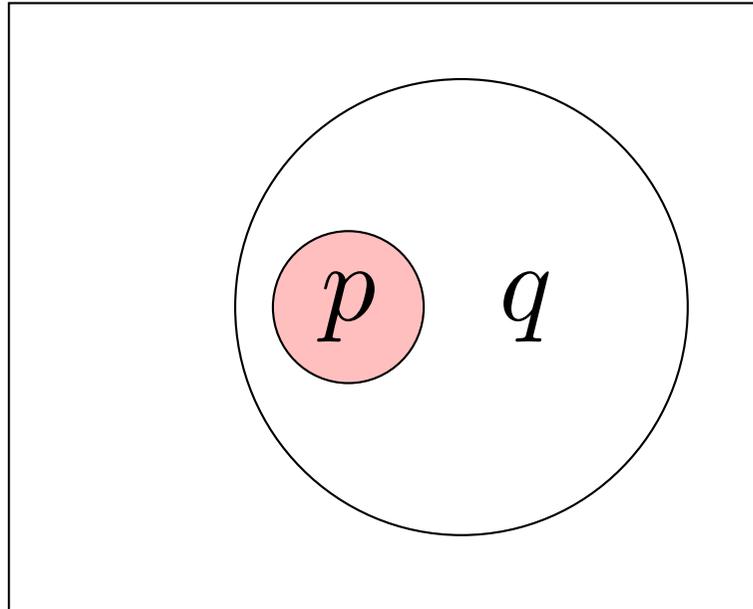
➤ *Ian* is a set of sets of properties: **second-order logic**

# 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 $|A \cap B| < |X|$

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Q: Try to define `many`

# Generalized Quantifiers: all, most



all $p$ are $q$                                most $p$ are $q$
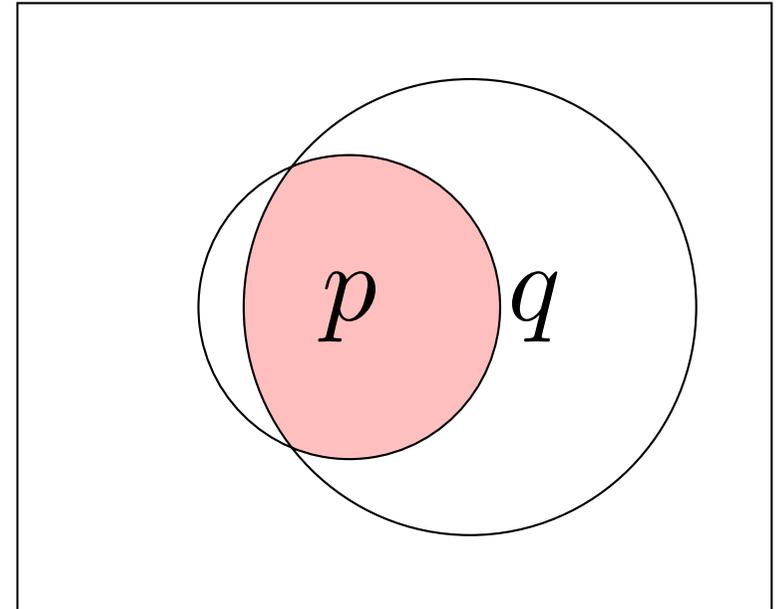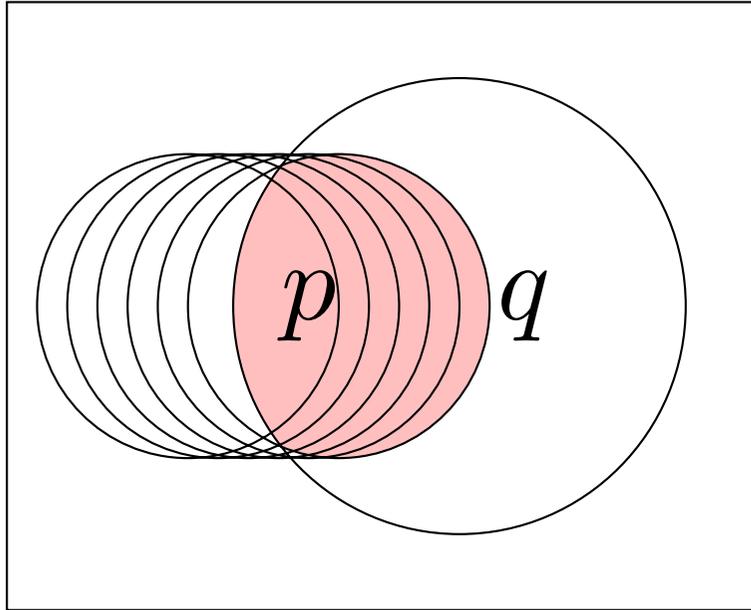
# Generalized Quantifiers: some, no

some $p$ are $q$

no $p$ are $q$
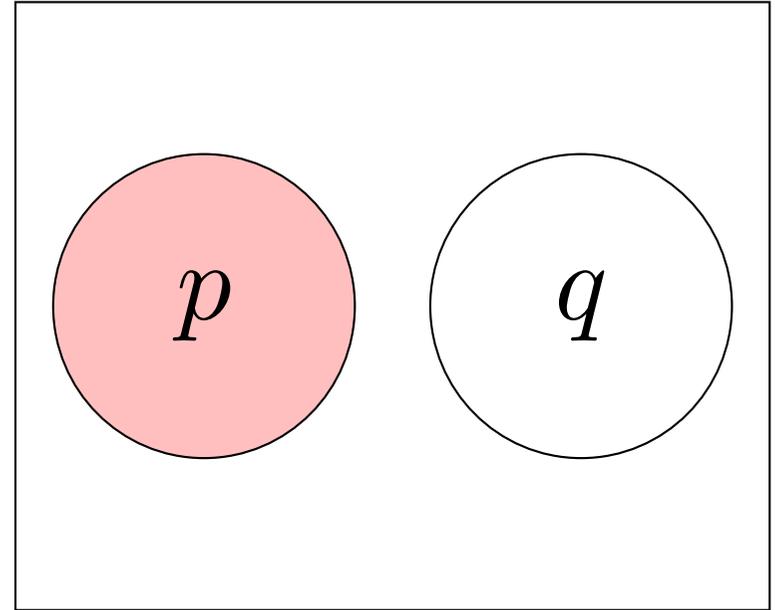
# Strong/Weak Quantifiers

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

    a.   *There is a̲ fox in the henhouse*

    b.   *There are two̲ foxes in the henhouse*

    c.   *\*There is every̲ fox in the henhouse*

    d.   *\*There are both̲ foxes in the henhouse*

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

  (20)   *3 lecturers are Australian = 3 Australians are lecturers*

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

  (21)   *most lecturers are Australian $\neq$ most Australians are lectures*

# Negative Polarity Items (NPI)

➢ Some words in English mainly appear in negative environments

   (22)  a.  *Kim doesn't ever eat dessert*

         b.  **Kim does ever eat dessert*

   (23)  a.  *Kim hasn't eaten dessert yet*

         b.  **Kim has eaten dessert yet*

   (24)  a.  *Few people have eaten dessert yet*

         b.  **Many people have eaten dessert yet*

   (25)  a.  *Rarely does Kim ever eat dessert*

         b.  **Often does Kim ever eat dessert*

➢ Not just negation, but also some quantifiers

# 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

(26)  a.  *Kim doesn't eat dessert $\Rightarrow$ Kim doesn't eat hot dessert*
       b.  *Kim doesn't eat hot dessert $\nRightarrow$ Kim doesn't eat dessert*

       **Downward entailment**

(27)  a.  *Kim eats some desserts $\nRightarrow$ 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

(28)  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)**

(29)  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)**

(30)    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!

(31)   我 没有     任何 朋友
      wǒ méi-yǒu  rènhé péngyǒu
      I    NEG-have any    friend

"I don't have any friends."

(32)   * 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

(33)  *I know that $p$*

(34)  *I am absolutely certain that $p$*

(35)  *I am almost certain that $p$*

(36)  *I believe that $p$*

(37)  *I am pretty certain that $p$*

     *...*

(38)  *Possibly $p$*

     *...*

(39)  *It is very unlikely that $p$*

(40)  *It is almost impossible that $p$*

(41)  *It is impossible that $p$*

(42)  *It is not the case that $p$*

(43)  *I am absolutely certain that not-$p$*

# Modal Logics

➤ Add two modal operators for epistemic modality

> ➤ $\diamond\phi = $ *it is possible that* $\phi$
> ➤ $\square\phi = $ *it is necessary that* $\phi$

➤ Define them in terms of **possible worlds**

> ➤ $\diamond\phi$: true in at least one world
> ➤ $\square\phi$: 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

➤ $P\phi =$ *it is permitted that* $\phi$
➤ $O\phi =$ *it is obligatorily* $\phi$

➤ Define them in terms of **possible worlds**

➤ $P\phi$: true in at least one legal or morally ideal world
➤ $O\phi$: true in all legal or morally ideal worlds

# Dynamic Approaches to Discourse

# Anaphora

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

     b.  M(r,r)

(45)  a.  *Every robot mistrusts itself*

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

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

     b.  ($\exists$x: R(x)) B(l,x) $\wedge$ ¬W(x)

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

     b.  ($\forall$x: R(x)) W(x,n); M(x,j)  <span style="color:red">unbound</span>

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

     b.  ($\exists$x: R(x)) W(x,n); M(x,j)  <span style="color:red">???</span>

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

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

indefinite nominals scope can still be limited

# Donkey Sentences

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

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

(51)    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 $\forall$

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

# Discourse Representation Theory

➢ Build up Discourse Representation Structures

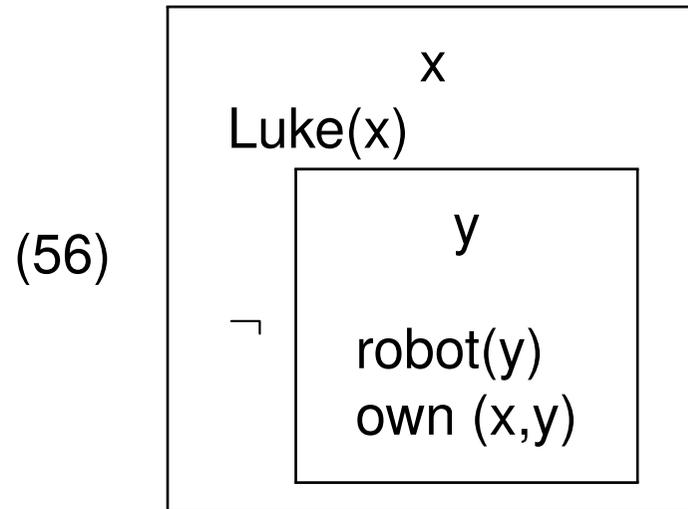(53)   a.   *Alex met a robot$_i$*

   b.   *It$_i$ smiled*

(54)

| 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

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

(56)

$$
\neg
\begin{array}{|l|}
\hline
x \\
Luke(x) \\
\neg
\begin{array}{|l|}
\hline
y \\
\\
robot(y) \\
own\ (x,y) \\
\hline
\end{array} \\
\hline
\end{array}
$$

➤ The contained DRS is **subordinate**

   ➤ indefinite NPs in negated subordinate structures are inaccessible

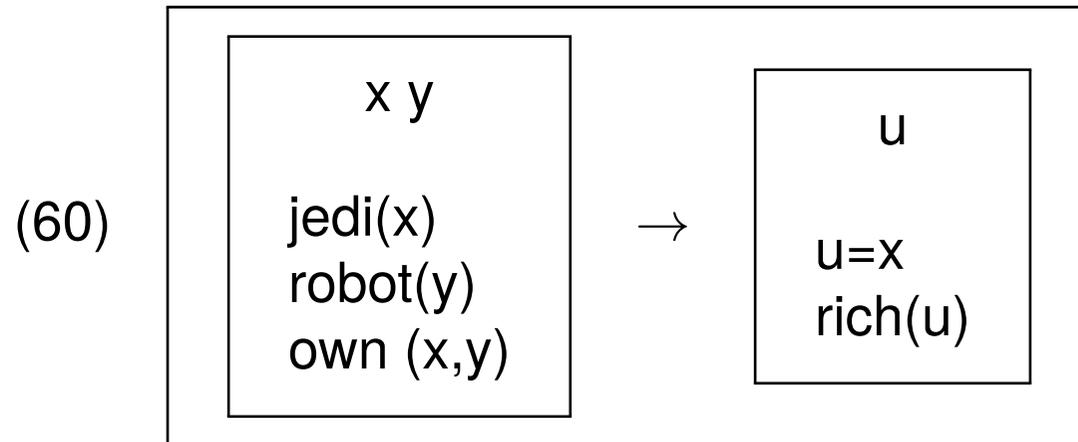   ➤ names (constants) are always accessible

# Conditionals

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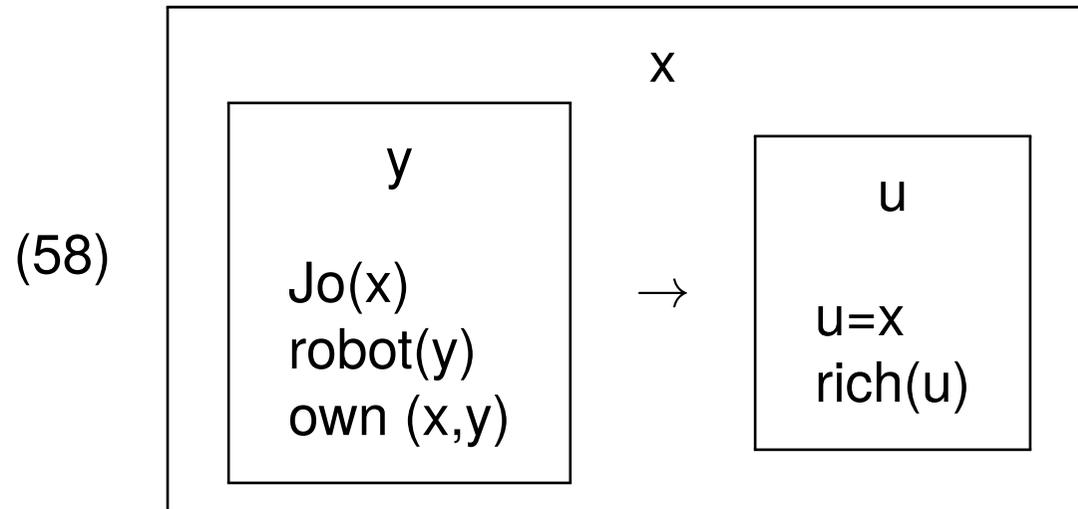
(58)

$$
\boxed{\;x\quad\boxed{\begin{array}{c} y \\[4pt] \text{Jo(x)} \\ \text{robot(y)} \\ \text{own (x,y)} \end{array}}\;\rightarrow\;\boxed{\begin{array}{c} u \\[4pt] \text{u=x} \\ \text{rich(u)} \end{array}}\;}
$$

➤ The contained DRS is **subordinate**

  ➤ indefinite NPs in the antecedent are accessible in the consequent

# More Conditionals

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

(60)

$$
\boxed{\;\boxed{\begin{array}{l} x\ y \\[4pt] jedi(x) \\ robot(y) \\ own\ (x,y) \end{array}} \;\rightarrow\; \boxed{\begin{array}{l} u \\[4pt] u{=}x \\ rich(u) \end{array}}\;}
$$

➢ The contained DRS is **subordinate**

 ➢ indefinite NPs in the antecedent are accessible in the consequent

# More Conditionals

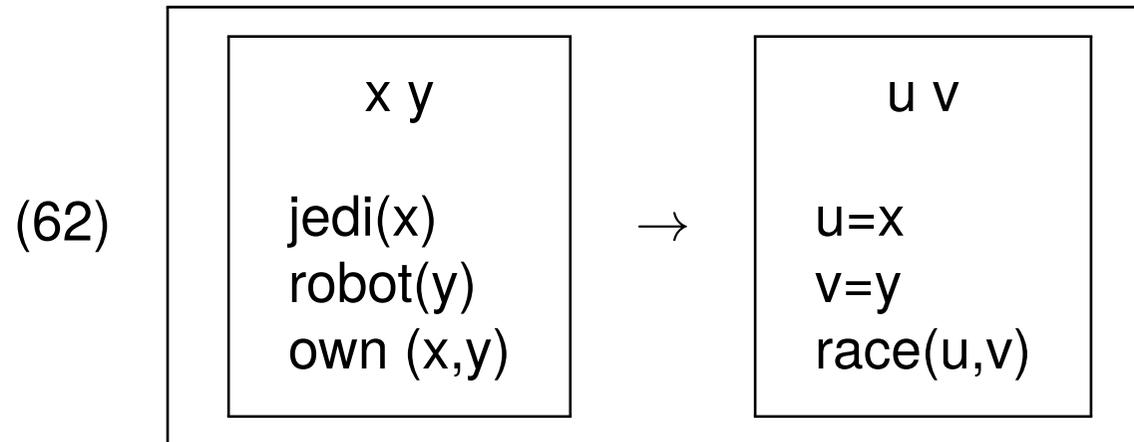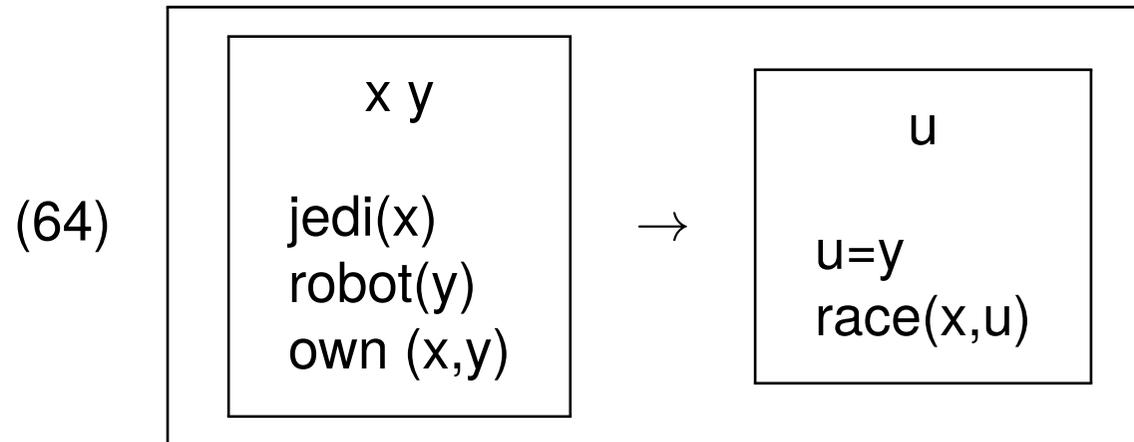(61)   a.   *If a Jedi owns a robot then they race it*

(62)

$$
\boxed{
\begin{array}{|c|}
\hline
x\ y \\
\\
jedi(x) \\
robot(y) \\
own\ (x,y) \\
\hline
\end{array}
\ \rightarrow\
\begin{array}{|c|}
\hline
u\ v \\
\\
u=x \\
v=y \\
race(u,v) \\
\hline
\end{array}
}
$$

➤ The contained DRS is **subordinate**

  ➤ indefinite NPs in the antecedent are accessible in the consequent

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

(64)

$$
\boxed{\;\boxed{\begin{array}{l} x\ y \\[4pt] jedi(x) \\ robot(y) \\ own\ (x,y) \end{array}} \quad \rightarrow \quad \boxed{\begin{array}{l} u \\[4pt] u{=}y \\ race(x,u) \end{array}}\;}
$$

➢ 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.