

HG2002 Semantics and Pragmatics

Formal Semantics

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Lecture 10

Location:

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

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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:

<i>woman</i>	[FEMALE]	[ADULT]	[HUMAN]	
<i>spinster</i>	[FEMALE]	[ADULT]	[HUMAN]	[UNMARRIED]
<i>bachelor</i>	[MALE]	[ADULT]	[HUMAN]	[UNMARRIED]
<i>wife</i>	[FEMALE]	[ADULT]	[HUMAN]	[MARRIED]

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

<i>woman</i>	[+FEMALE]	[+ADULT]	[+HUMAN]	
<i>spinster</i>	[+FEMALE]	[+ADULT]	[+HUMAN]	[−MARRIED]
<i>bachelor</i>	[−FEMALE]	[+ADULT]	[+HUMAN]	[−MARRIED]
<i>wife</i>	[+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 $\not\subset$ *wife*

- Redundancy Rules

[+HUMAN]	→	[+ANIMATE]	
[+ANIMATE]	→	[+CONCRETE]	
[+MARRIED]	→	[+ADULT]	
[+MARRIED]	→	[+HUMAN]	...

- Predicates with argument structure

parent (of y)(x,y) → [+PARENT](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:

	<i>break</i>	<i>cut</i>	<i>hit</i>	<i>touch</i>
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

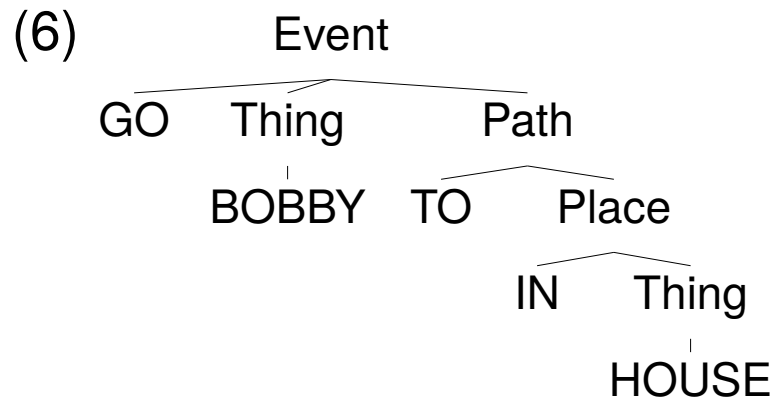
Jackendoff's Lexical Conceptual Structure

- 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

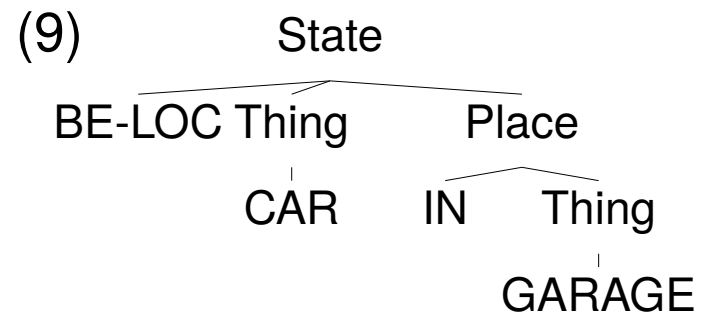
(4) *Bobby went into the house*

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



(7) *The car is in the garage*

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



Things: Boundedness and Internal Structure

- Two components:

Boundedness	Internal Struct.	Type	Example
+b	−i	individuals	<i>a dog/two dogs</i>
+b	+i	groups	<i>a committee</i>
−b	−i	substances	<i>water</i>
−b	+i	aggregates	<i>buses, cattle</i>

- 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 → *bricks*

composed of

$[-b, +i] \rightarrow [+b, -i]$

bricks → *house of bricks*

containing

$[-b, -i] \rightarrow [+b, -i]$

coffee → *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 dog all over the road

Pustejovsky's Generative Lexicon

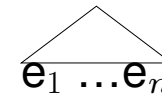
- Each lexical entry can have:
 - ARGUMENT STRUCTURE
 - EVENT STRUCTURE
 - LEXICAL INHERITANCE STRUCTURE
 - QUALIA STRUCTURE:
 - CONSTITUTIVE constituent parts
 - FORMAL relation to other things
 - TELIC purpose
 - AGENTIVE how it is made
- Interpretation is **generated** by combining word meanings
- Events have **complex** structure

State

S
|
e

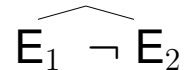
understand, love, be tall

Process

P

e₁ ... e_n

sing, walk, swim

Transition

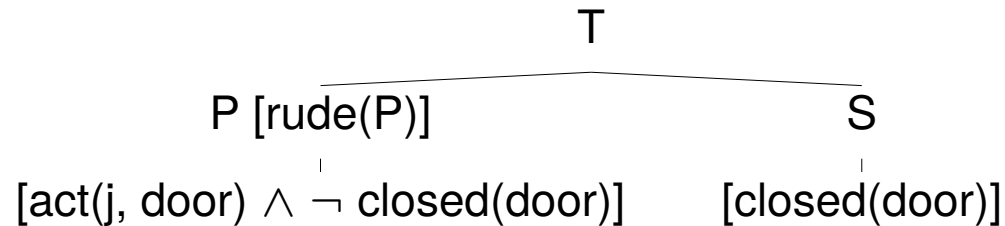
T

E₁ ¬ E₂

open, close, build

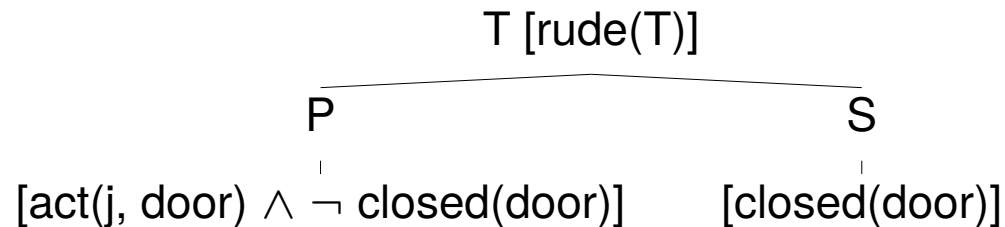
Modifier Ambiguity

(14) *Jamie closed the door rudely*

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



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



Qualia Structure

(17) *fast typist*

- a. a typist who is fast [at running]
- b. a typist who types fast

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

➤ (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

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

➤ antonym

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

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

➤ converse

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

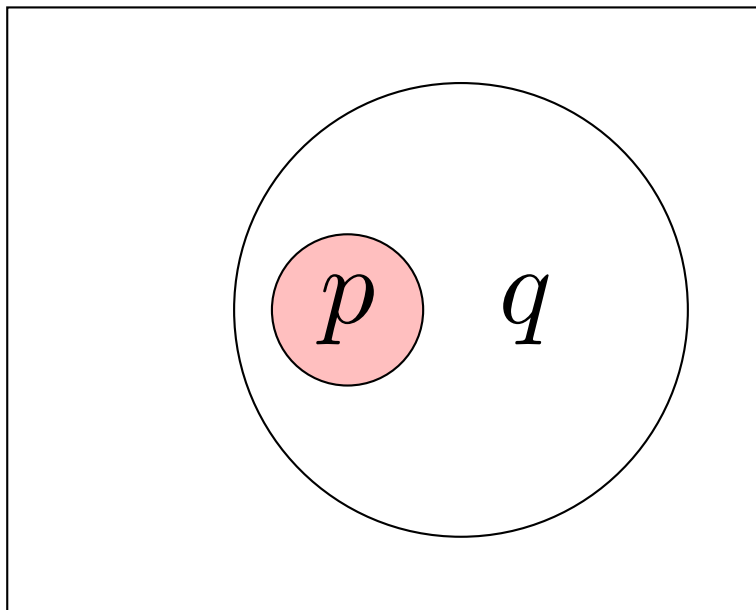
➤ synonym

➤ $\forall x((\text{EGGPLANT}(x) \rightarrow \text{BRINJAL}(x)) \wedge (\text{BRINJAL}(x) \rightarrow \text{EGGPLANT}(x)))$

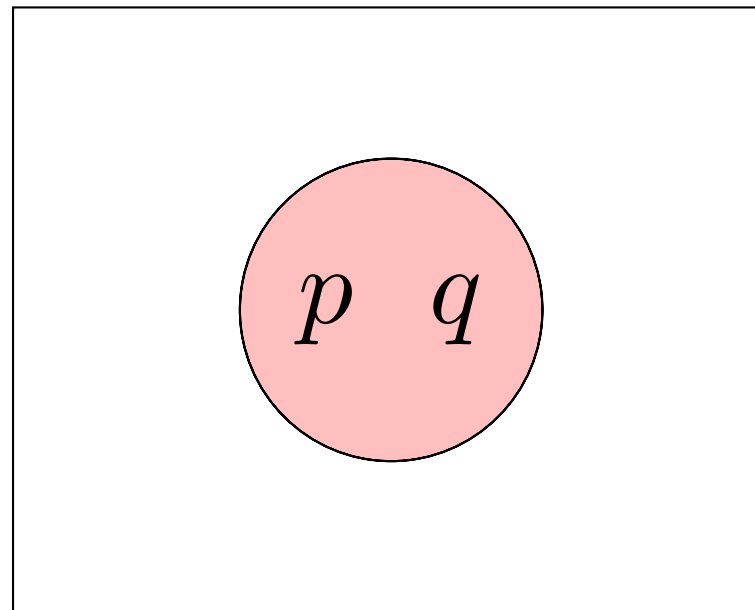
➤ $\forall x(\text{EGGPLANT}(x) \equiv \text{BRINJAL}(x))$

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

$p \subset q$ **hypernym**

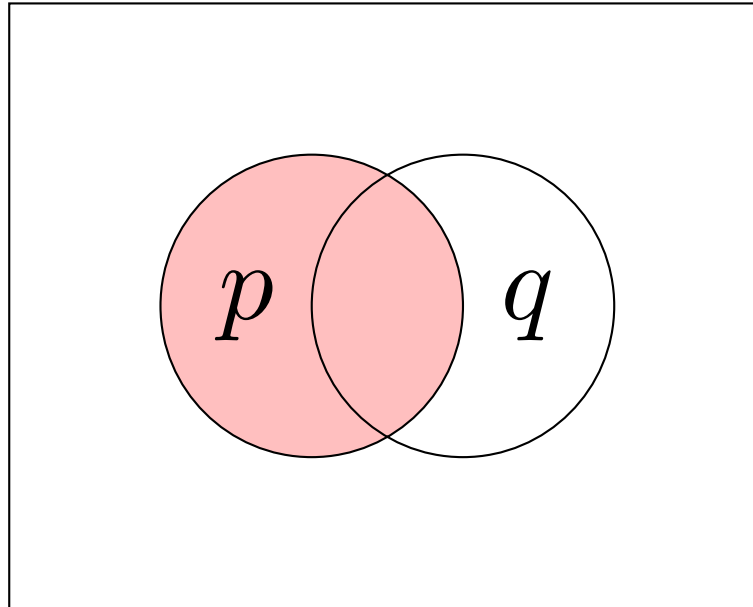


$p \sim q$ **synonym**

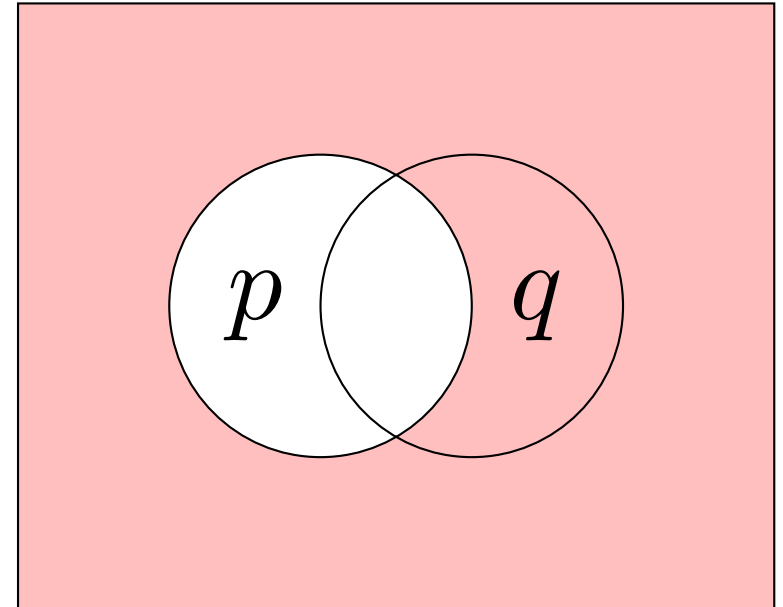


Logical Connectives as Sets (p and $\neg p$)

p

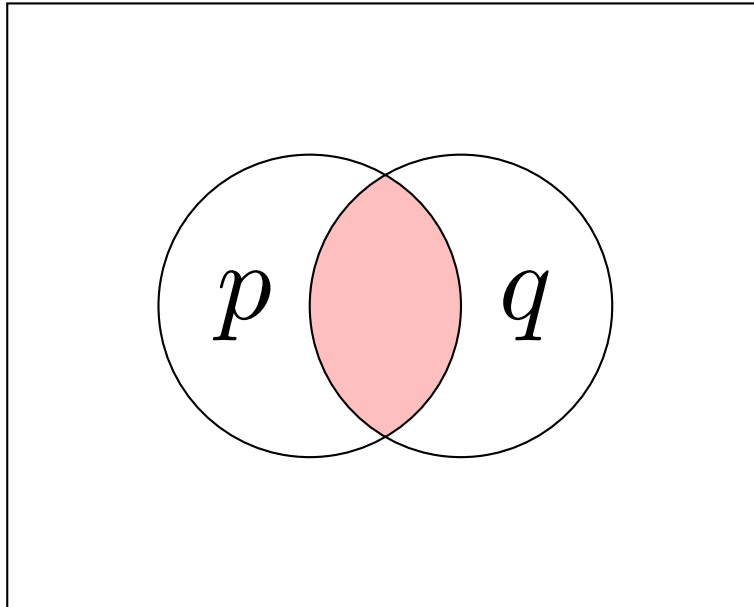


$\neg p$ “not”

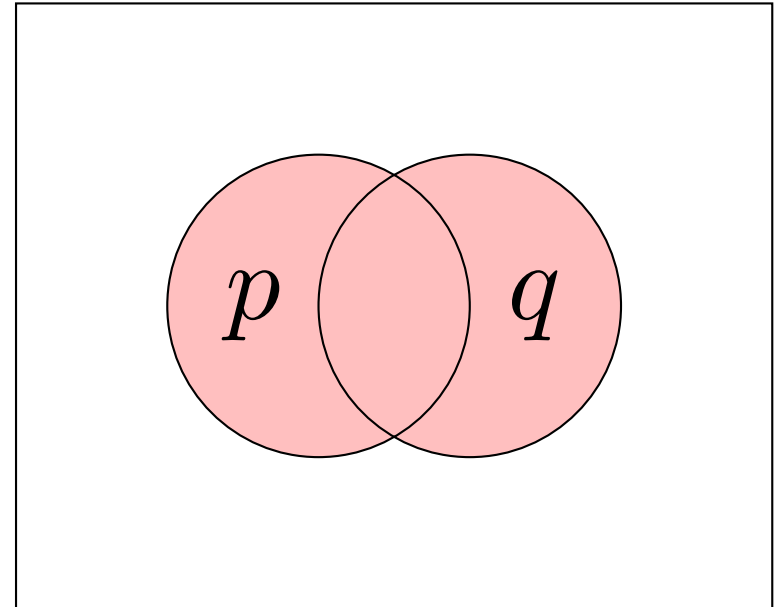


Logical Connectives as Sets ($p \wedge q$ and $p \vee q$)

$p \wedge q$ “and”

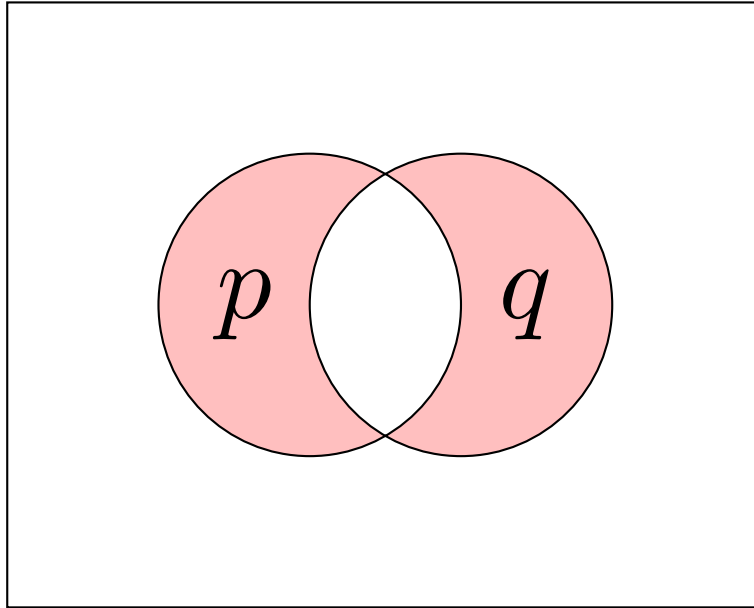


$p \vee q$ “or”

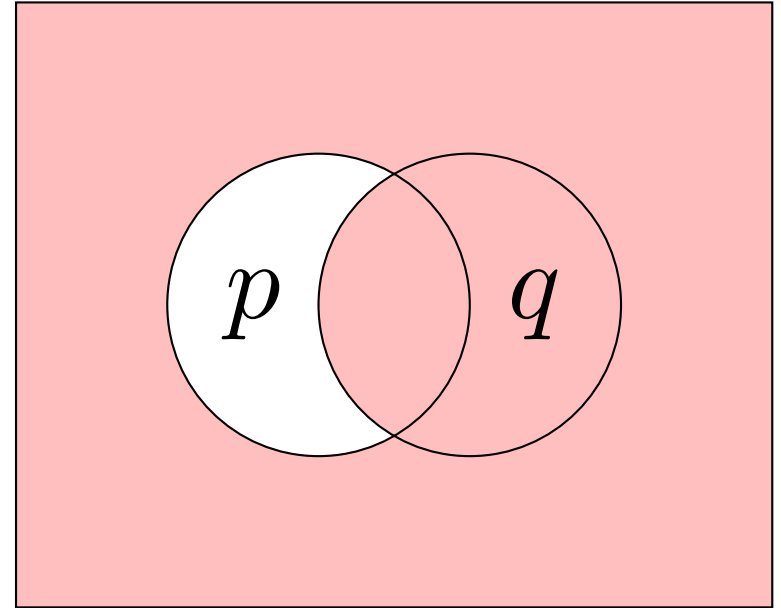


Logical Connectives as Sets ($p \oplus q$ and $p \rightarrow q$)

$p \oplus q$ “exclusive or”



$p \rightarrow q$ “if”



Natural Language Quantifiers and Higher Order Logic

Restricted Quantifiers

- *Most students read a book*
 - $\text{Most}(x)(S(x) \wedge R(x))$
most things are students and most things read books
 - $\text{Most}(x)(S(x) \rightarrow R(x))$
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
 - $(\text{Most } x: S(x)) R(x)$
- Sometimes we need to decompose
 - *everybody* $(\forall x: P(x))$
 - *something* $(\exists x: T(x))$

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 *lan 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 *lan* is part of the set defined by *sings* in the model M_1

➤ Remodel, with sing a property of lan: $i(S)$

$[i(S)]^{M_1} = 1$ 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 *lan* in the model M_1

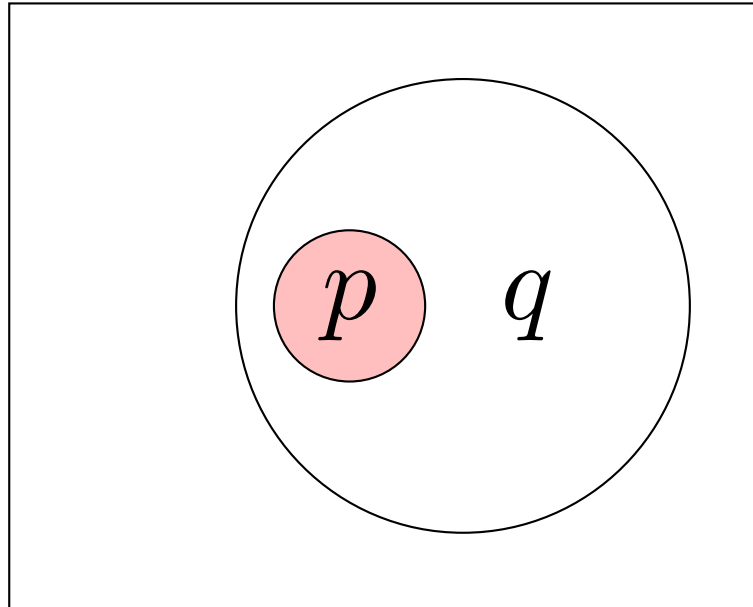
➤ *lan* is a set of sets of properties: **second-order logic**

Generalized Quantifiers

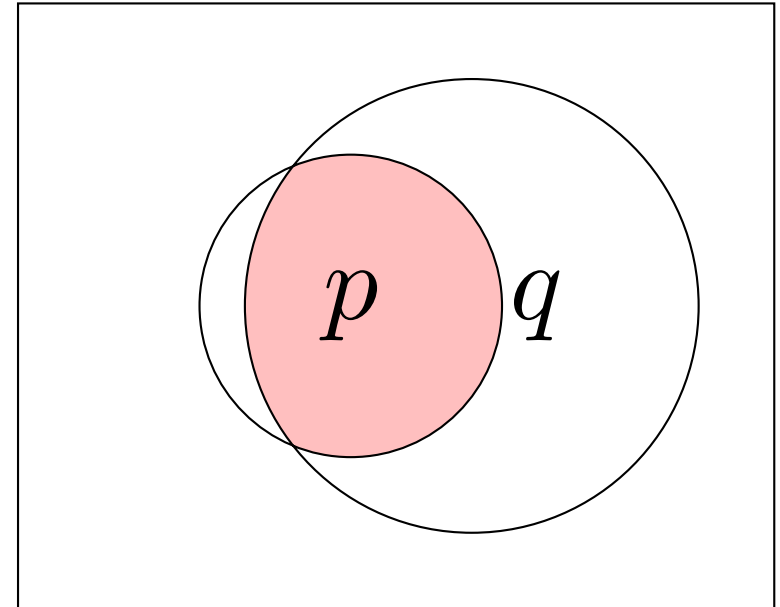
- $Q(A,B)$: *Q A are B*
- $\text{most}(A,B) = 1$ iff $|A \cap B| > |A - B|$
- $\text{all}(A,B) = 1$ iff $A \subseteq B$
- $\text{some}(A,B) = 1$ iff $A \cap B \neq \emptyset$
- $\text{no}(A,B) = 1$ iff $A \cap B = \emptyset$
- $\text{fewer than } x(A,B,X) = 1$ iff $|A \cap B| < |X|$

Generalized Quantifiers: *all*, *most*

all p are q

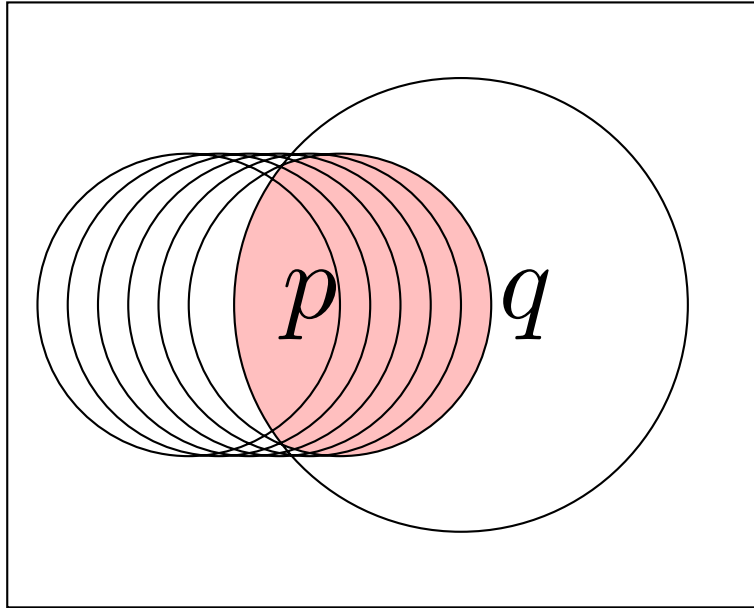


most p are q

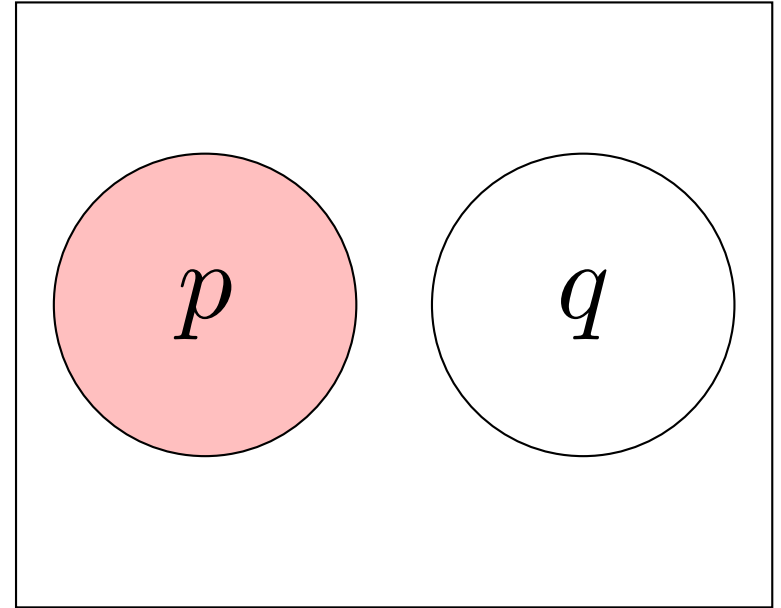


Generalized Quantifiers: some, no

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**
 $\text{det}(A,B) = \text{det}(B,A)$

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

➤ **asymmetrical** (proportional) quantifiers are **strong**
 $\text{det}(A,B) \neq \text{det}(B,A)$

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

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

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 \nRightarrow Kim doesn't eat dessert*

Downward entailment

- (26) 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

- (27) a. *Every student studies semantics* \nRightarrow *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* \nRightarrow *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 rèn hé péngyǒu
I NEG-have any friend
“I don’t have any friends.”
- (31) *我 有 任何 朋友
wǒ yǒu rèn hé 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

➤ $\Diamond\phi = \textit{it is possible that } \phi$

➤ $\Box\phi = \textit{it is necessary that } \phi$

➤ 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
 - $P\phi = \textit{it is permitted that } \phi$
 - $O\phi = \textit{it is obligatorily } \phi$
- 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

- (43) a. *R2D2_i mistrusts itself_i*
b. $M(r,r)$
- (44) a. *Every robot mistrusts itself*
b. $(\forall x: R(x)) M(x,x)$
- (45) a. *Luke bought a robot and it doesn't work*
b. $(\exists x: R(x)) B(l,x) \wedge \neg W(x)$
- (46) a. *Every robot went to Naboo. ?It met Jar Jar.*
b. $(\forall x: R(x)) W(x,n); M(x,j)$ unbound
- (47) a. *A robot went to Naboo. It met Jar Jar.*
b. $(\exists x: R(x)) W(x,n); M(x,j)$???
- 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

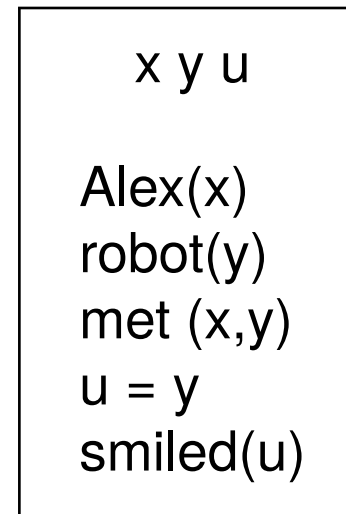
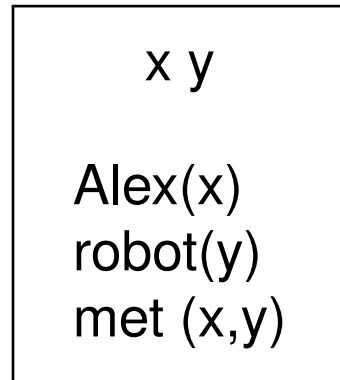
- (49) a. *If R2D2_i owns a ship it is rich*
b. $(\exists x (S(x) \wedge O(r,x))) \rightarrow R(x)$
- (50) a. *If a robot owns a ship it races it*
b. $*(\exists x \exists y (R(x) \wedge S(y) \wedge O(x,y))) \rightarrow R(x,y)$
c. $\forall x \forall y ((R(x) \wedge S(y) \wedge O(x,y)) \rightarrow R(x,y)$
 \exists needs to become \forall
- (51) *Every farmer who owns a donkey beats it*

Discourse Representation Theory

➤ Build up Discourse Representation Structures

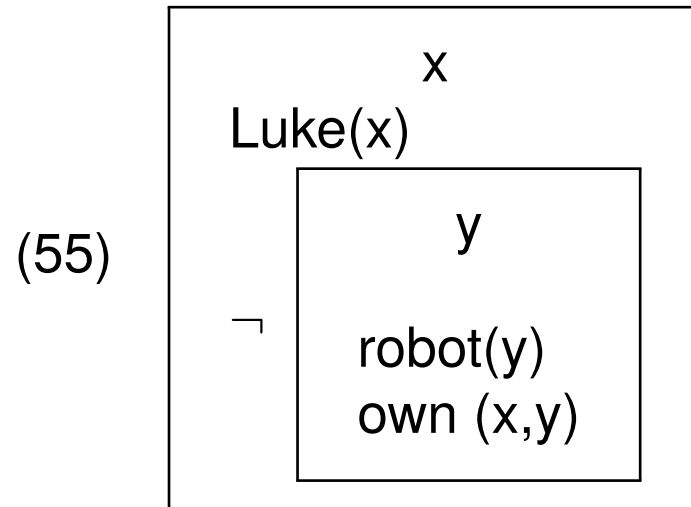
- (52) a. *Alex met a robot_i*
b. *It_i smiled*

(53)



Negative Contexts

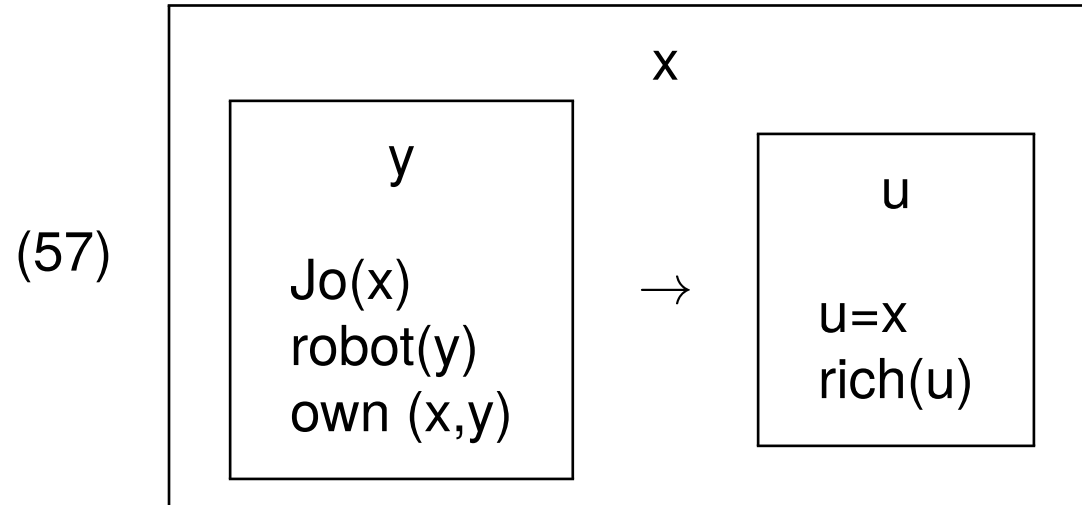
(54) a. *Luke does not own a robot*



- 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*

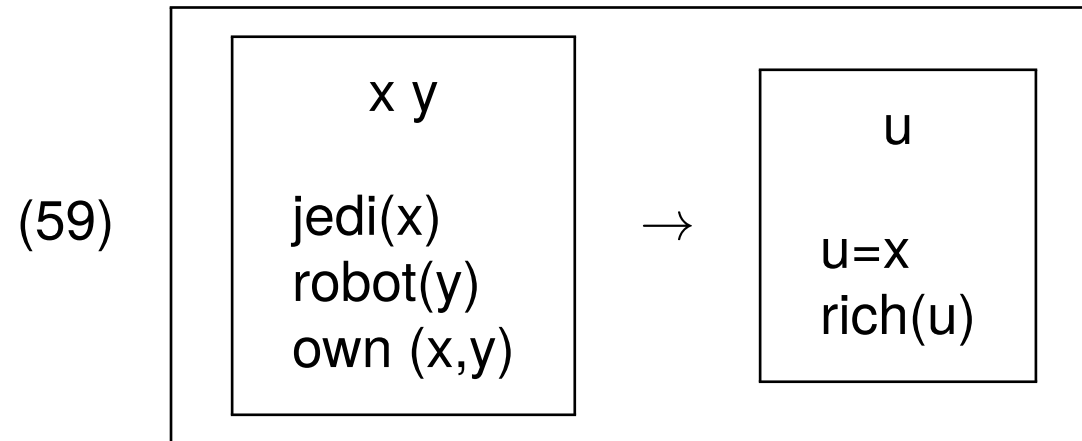


➤ The contained DRS is **subordinate**

➤ indefinite NPs in the antecedent are accessible in the consequent

More Conditionals

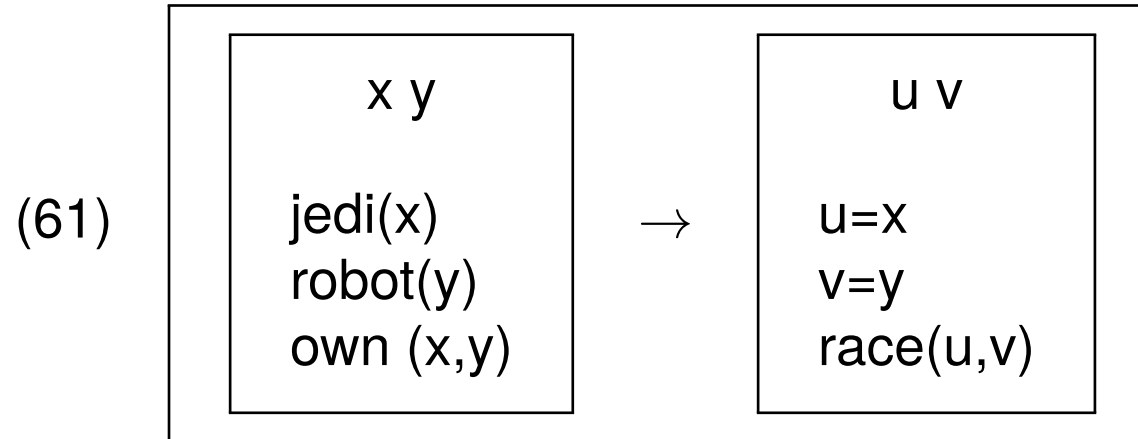
(58) a. *If a Jedi owns a robot then they are rich*



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

More Conditionals

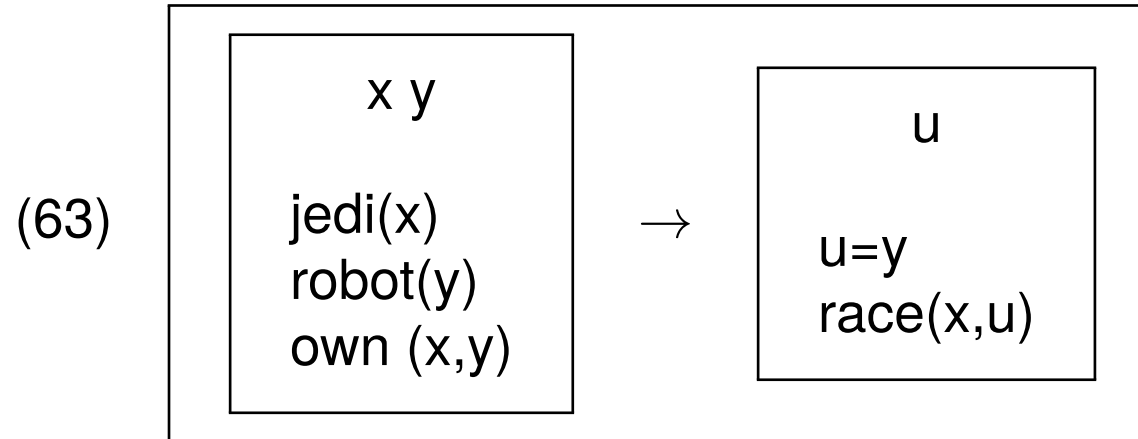
(60) a. *If a Jedi owns a robot then they race it*



- 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*



- 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.