HG2002 Semantics and Pragmatics

Formal Semantics

Lee Junwen
Division of Linguistics and Multilingual Studies
ljunwen@ntu.edu.sg

Lecture 10
Location: HSS Auditorium

Overview

- Revision: Components
- Quantifiers and Higher Order Logic
- Intensionality
- Next Lecture: Chapter 11 — Cognitive Semantics

Revision: Componential Analysis

Break word meaning into its components

- How do we distinguish between words?
  - *woman* vs *girl: woman* is an adult; *girl* is not.
  - *woman* vs *wife: wife* is a married person; *woman* may not be.
  - *bachelor* vs *wife: bachelor* is a male and unmarried person; *wife* is a female and married person.
  - Differences are formalised as components in their meaning:

woman	[FEMALE]	[ADULT]	[HUMAN]	
girl	[FEMALE]	[CHILD]	[HUMAN]	
bachelor	[MALE]	[ADULT]	[HUMAN]	[UNMARRIED]
wife	[FEMALE]	[ADULT]	[HUMAN]	[MARRIED]

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

woman	[+FEMALE]	[+ADULT]	[+HUMAN]	
girl	[+FEMALE]	[−ADULT]	[+HUMAN]	
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.
  wife $\subset$ ***woman***

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

- Redundancy Rules

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

Katz's Semantic Theory

- How do word meanings combine in a sentence?
  - Semantic rules interact with syntactic rules to build up meaning **compositionally**
    - **projection rules** govern how information is passed up the tree and collected at the top.
  - 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 ➢ not relevant to syntax
    - **Selectional restrictions** help to reduce ambiguity and limit the possible readings

Verb Classification

- Besides distinguishing between individual words, different word *classes* may also be distinguished.
- **Evidence for different verb classes:** Different verbs are felicitous in different argument structure 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

- Four meaning components distinguish between the verb classes:

break = CAUSE, CHANGE
Examples: {*break, chip, crack, crash, crush, ...*}

cut = CAUSE, CHANGE, CONTACT, MOTION
Examples: {*chip, clip, cut, hack, hew, saw, ...*}

hit = CONTACT, MOTION
Examples: {*bang, bash, batter, beat, bump, ...*}

touch = CONTACT
Examples: {*caress, graze, kiss, lick, nudge, ...*}

Levin (1993)

Cognitive Semantics

- Besides within-language meaning taxonomies, there are also cross-linguistic taxonomies.
  - Different languages conflate different 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

(1)	*Kim*	*swam*	*away from*	*the crocodile*
	Figure	Manner	Path	Ground
(2)	*The banana*	*hung*	*from*	*the tree*
	Figure	Manner	Path	Ground

Cognitive Semantics

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    - **Manner**: the type of motion

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

Talmy (1975, 1983, 1985, 2000)

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

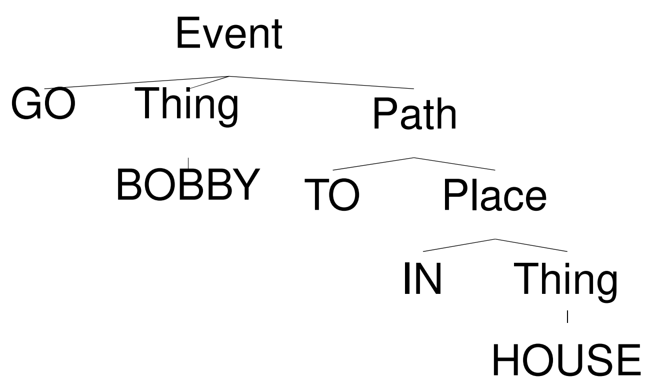
- Universal Semantic Categories
  - **Event**
  - **State**
  - **Material Thing/Object**
  - **Path**
  - **Place**
  - **Property**

Motion as a tree

(3) *Bobby went into the house*

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

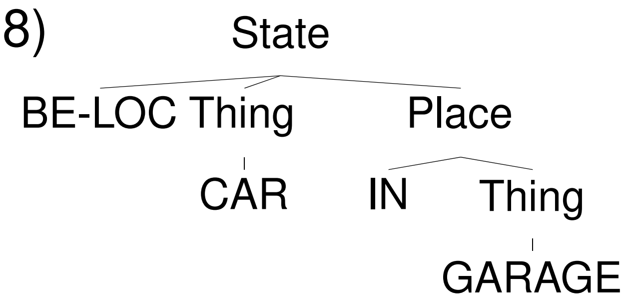
(5)



(6) *The car is in the garage*

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

(8)



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]

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

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

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

(12) 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*

- Extracting

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*

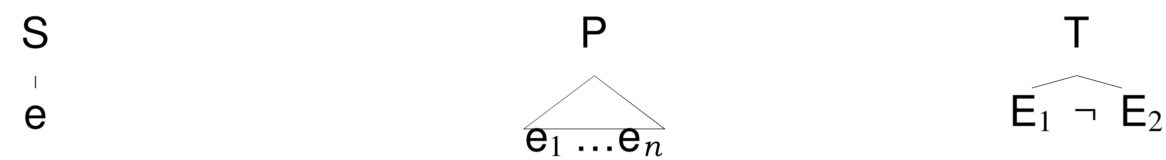
Pustejovsky's Generative Lexicon

- 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	**Process**	**Transition**



understand, love, be tall	***sing, walk, swim***	***open, close, build***

Qualia Structure

(13) *fast typist*

a. a typist who is fast [at running]

b. a typist who types fast

➢ typist $\begin{bmatrix} \text{ARGSTR} & \begin{bmatrix} \text{ARG1} & \mathtt{x{:}typist} \end{bmatrix} \\ \text{QUALIA} & \begin{bmatrix} \text{FORMAL} & \begin{bmatrix} \mathtt{x}\ [\subset \mathtt{person}\ ] \end{bmatrix} \\ \text{TELIC} & \begin{bmatrix} \mathtt{type(e,x)} \end{bmatrix} \end{bmatrix} \end{bmatrix}$

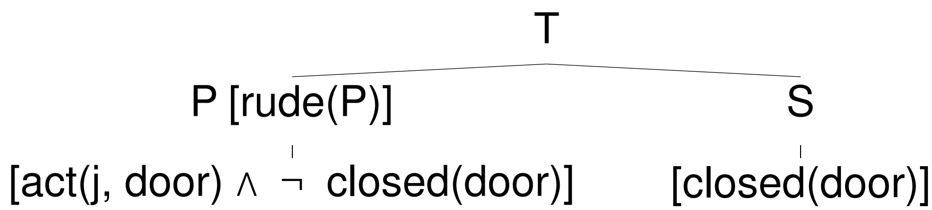
➢ (13a) *fast* modifies x

➢ (13b) *fast* modifies e

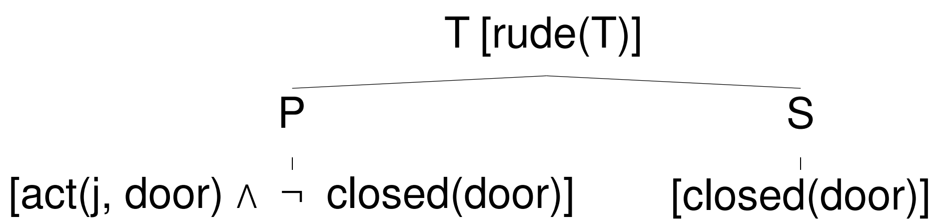
Modifier Ambiguity

(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*



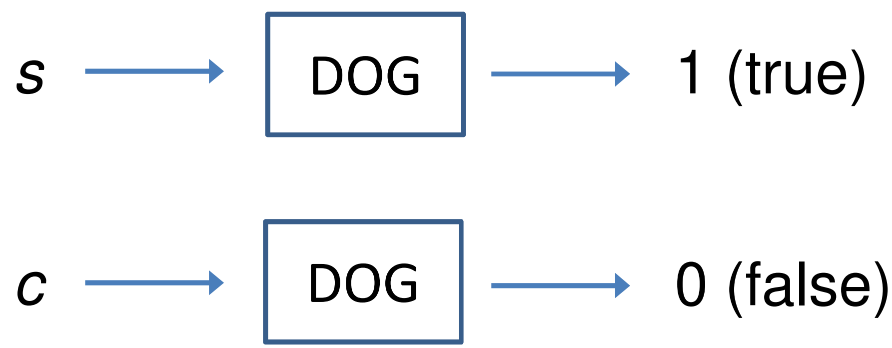
Summary

- 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**

Formal Semantics: Set Theory

Basic Components of Formal Semantics

- **Individuals**
  - Constants: Snoopy – *s;* Charlie Brown – *c;* Lucy – *l*
  - Variables: *x, y*
- **Properties/Predicates**
  - Sets of individuals: DOG(*x*); CHILD(*y*)
- One can also see properties/predicates as functions:



Basic Components of Formal Semantics

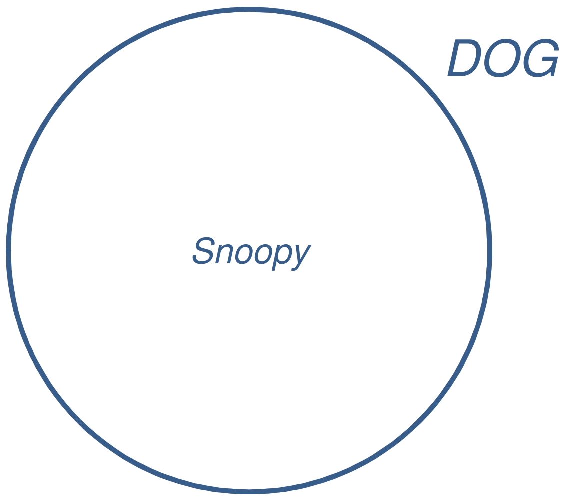
- **Model:** $M = \langle U, F \rangle$
  - **Domain (**U(niverse)**):** Represents the individuals and representations in a situation *v.*
    - {Snoopy, Charlie Brown, Lucy}
  - **Denotation assignment** / **Naming function (**F(unction)**)**: Maps the logical symbols to the items in the model.
    - $F(s)$ = {Snoopy}
    - $F(c)$ = {Charlie Brown}
    - $F(l)$ = {Lucy}
    - $F(DOG)$ = {Snoopy}
    - $F(CHILDREN)$ = {Charlie Brown, Lucy}

Basic Components of Formal Semantics

- Individuals and properties are known as **types**
  - Biggest mistake in writing formal semantics: **type mismatch**
  - Why is LOVE(DOG) bad?
    - Functions can only take in a specific type and return another specific type, e.g. properties only take in individuals and returns truth values.

A Model of the world

- A model of what the world is like in terms of set relations
  - (1) Snoopy is a dog:

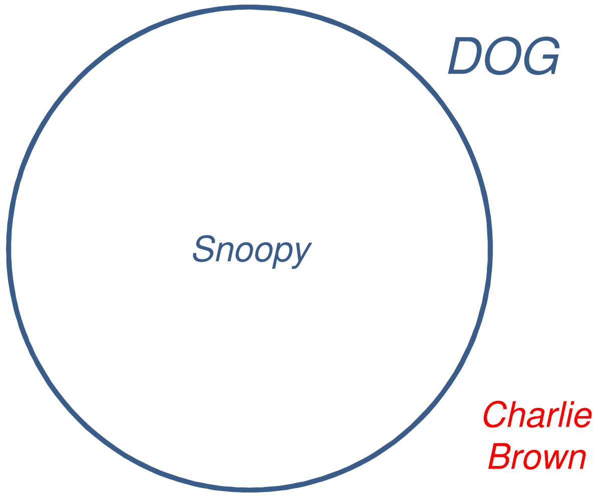


set inclusion

- DOG(s) = 1

A Model of the world

- A model of what the world is like in terms of set relations
  - (2) Charlie Brown is **not** a dog:

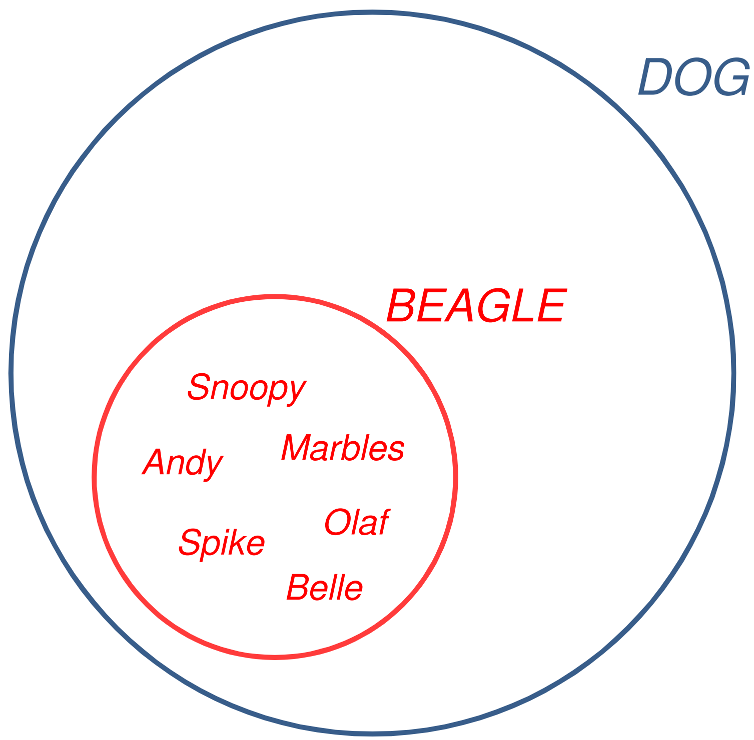


set exclusion

- DOG(c) = 0
- $\neg$DOG(c) = 1

A Model of the world

- Semantic relations in terms of set relations
  - (3) **All** beagles are dogs:

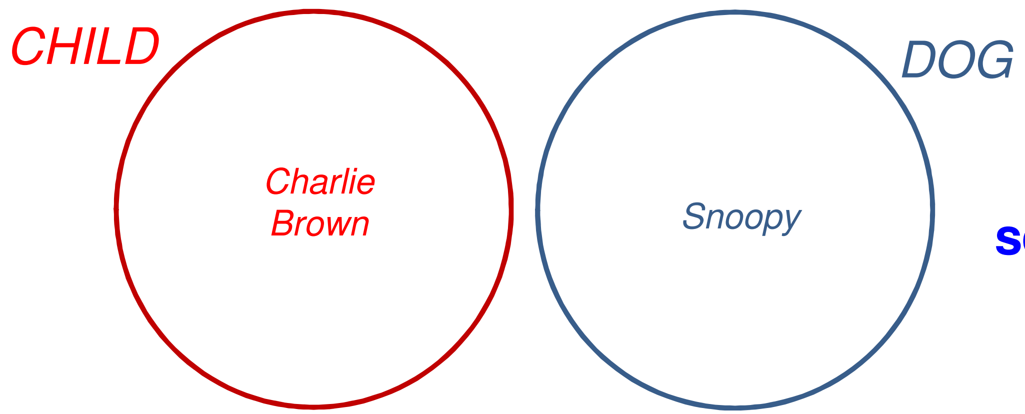


set inclusion

- $\forall x(\text{BEAGLE}(x) \rightarrow \text{DOG}(x))$
- $\text{BEAGLE} \subset \text{DOG}$
- **hyponymy**

A Model of the world

- Semantic relations in terms of set relations
  - (4) A dog is **not** a child:

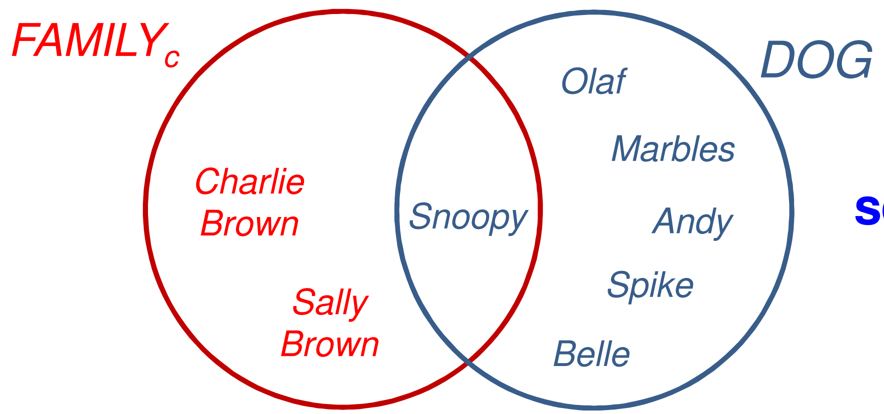


set (non-)intersection

- DOG ∩ CHILD = ∅

A Model of the world

- Logical connectives in terms of set relations
  - (5) Snoopy is a dog **and** is one of Charlie Brown's family:

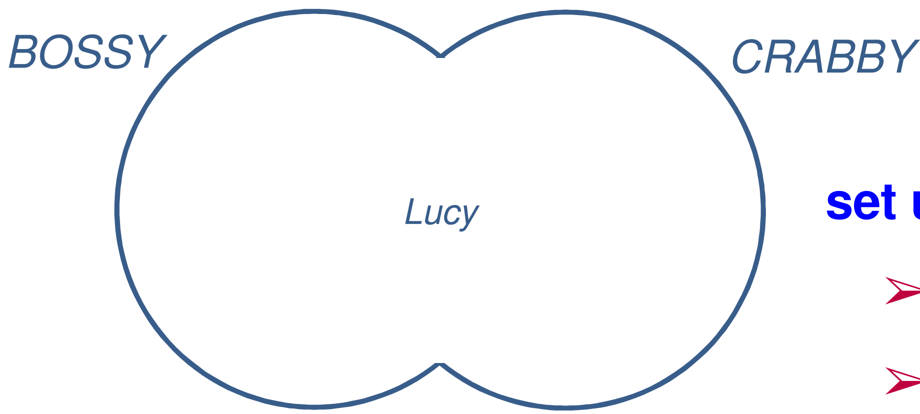


set intersection

- $DOG(s) \wedge FAMILY_c(s)$
- $DOG \cap FAMILY_c$

A Model of the world

- Logical connectives in terms of set relations
  - (6) Lucy is bossy **or** crabby (or both):

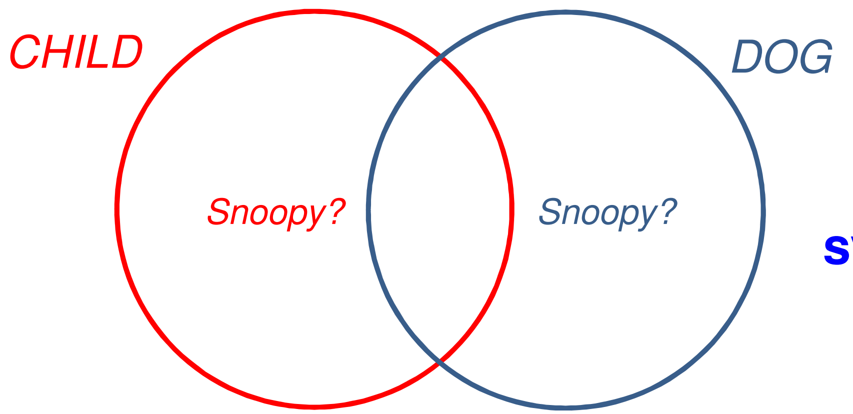


set union

- BOSSY(*l*) ∨ CRABBY(*l*)
- BOSSY ∪ CRABBY

A Model of the world

- Logical connectives in terms of set relations
  - (7) Snoopy is a dog **or** he is a child (but not both):

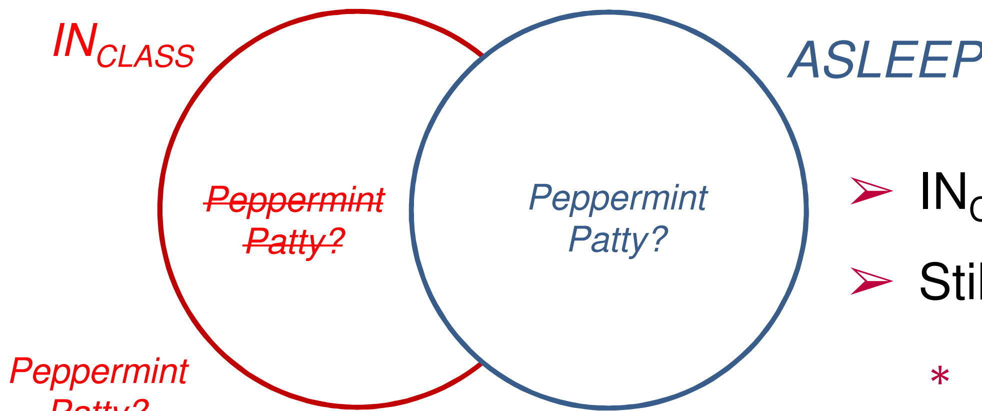


symmetric difference

- DOG(s) $\oplus$ CHILD(s)

A Model of the world

- Logical connectives in terms of set relations
  - (8) **If** Peppermint Patty is in class, she is asleep:



- $\mathrm{IN}_{\mathrm{CLASS}}(p) \rightarrow \mathrm{ASLEEP}(p)$
- Still true if:
  * $\neg\mathrm{IN}_{\mathrm{CLASS}}(p) \wedge \mathrm{ASLEEP}(p)$
  * $\neg\mathrm{IN}_{\mathrm{CLASS}}(p) \wedge \neg\mathrm{ASLEEP}(p)$
- Only place *p* cannot be: $\mathrm{IN}_{\mathrm{CLASS}}(p) \wedge \neg\mathrm{ASLEEP}(p)$

Defining Lexical 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**
  - $\forall x((\text{EGGPLANT}(x) \rightarrow \text{BRINJAL}(x)) \wedge (\text{BRINJAL}(x) \rightarrow \text{EGGPLANT}(x)))$
  - $\forall x(\text{EGGPLANT}(x) \equiv \text{BRINJAL}(x))$

Natural Language Quantifiers and Higher Order Logic

Restricted Quantifiers

- How to translate: (9) Most children love Snoopy?
  - Most(x)(C(x) $\wedge$ L(x,s))
    ☒ *most* x *are children and most* x *love Snoopy*
  - Most(x)(C(x) $\rightarrow$ L(x,s))
    ☒ *most* x *are such that, if they are children, they love Snoopy*

    ∗ If there are 20 individuals/*x*'s in our model,
    a. 10 *x* are not children and do not love Snoopy
    b. 4 *x* are children and love Snoopy
    c. 6 *x* are children and do not love Snoopy

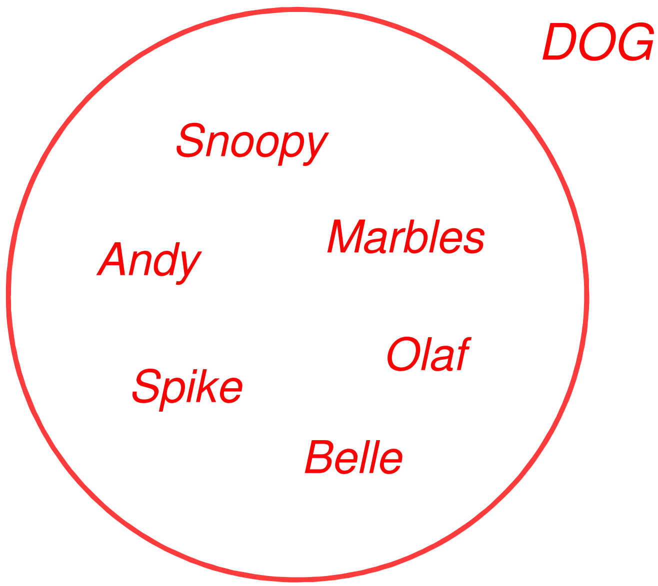
    Material implication is true for (a) and (b), i.e. 14 out of 20 *x*'s, so the statement is correct.
    ➢ But only 4 out of 10 children love Snoopy!

Restricted Quantifiers

- We need to restrict the quantification
  - (Most x: S(x)) R(x)
- Semantics of *most*
  - `most(A,B)` = 1 iff | A ∩ B | > | A – B |
  - **In function terms:** *most* takes a set A and a set B and returns 1 iff the cardinality of the set intersection of A and B (the number of individuals that are in the set of both A and B) is greater than the cardinality of the set of individuals that are in A and not in B.
  - OR: $most_A$ takes a set B and returns 1 iff the cardinality of the set intersection of A and B (the number of individuals that are in the set of both A and B) is greater than the cardinality of the set of individuals that are in A and not in B.

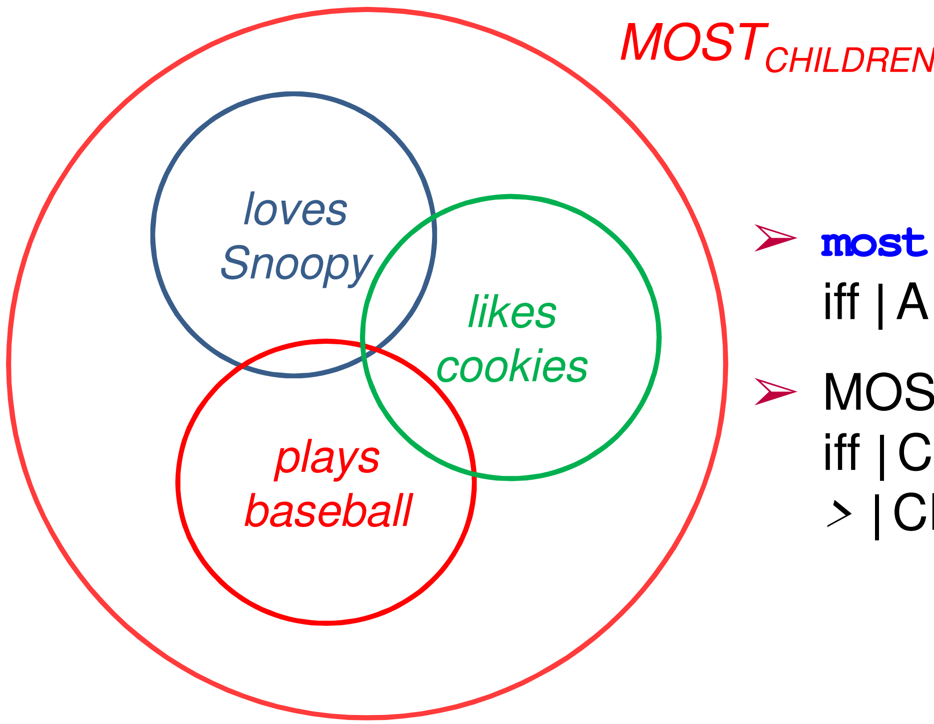
Higher Order Logic

- Functions taking individuals as arguments: **First-order logic**
  - DOG(x): Set of individuals x such that DOG(x) = 1



Higher Order Logic

- Functions taking sets as arguments: **Second-order logic**
  - $\text{MOST}_{\text{CHILDREN}}(\text{P}(x))$: Set of (sets of individuals $\text{P}(x)$) such that $\text{MOST}_{\text{CHILDREN}}(\text{P}(x)) = 1$



- **`most (A,B)`** = 1 iff $|A \cap B| > |A - B|$
- $\text{MOST}_{\text{CHILDREN}}(\text{P}(x)) = 1$ iff $|\text{CHILDREN} \cap \text{P}| > |\text{CHILDREN} - \text{P}|$

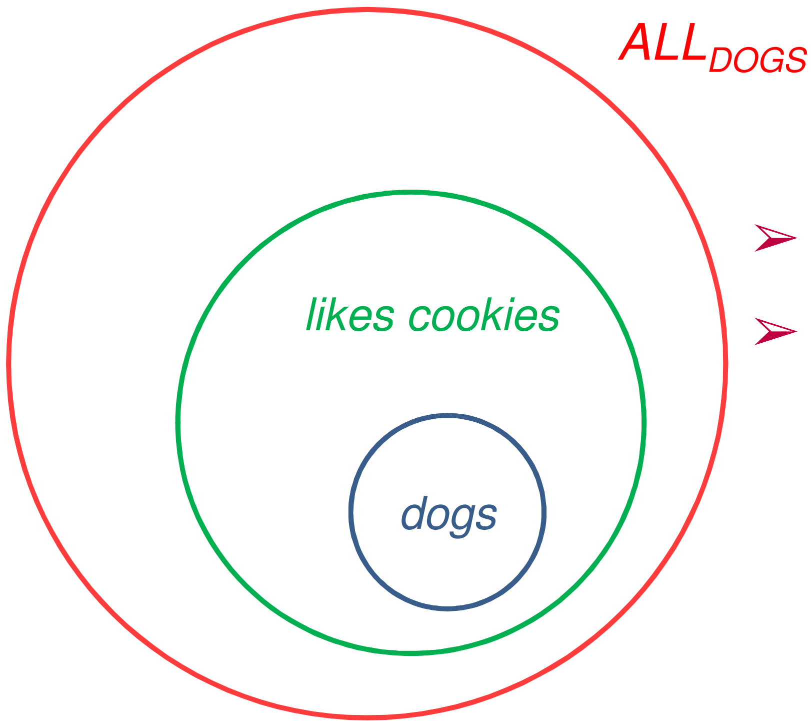
Other Generalized Quantifiers

- 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**

Other Generalized Quantifiers

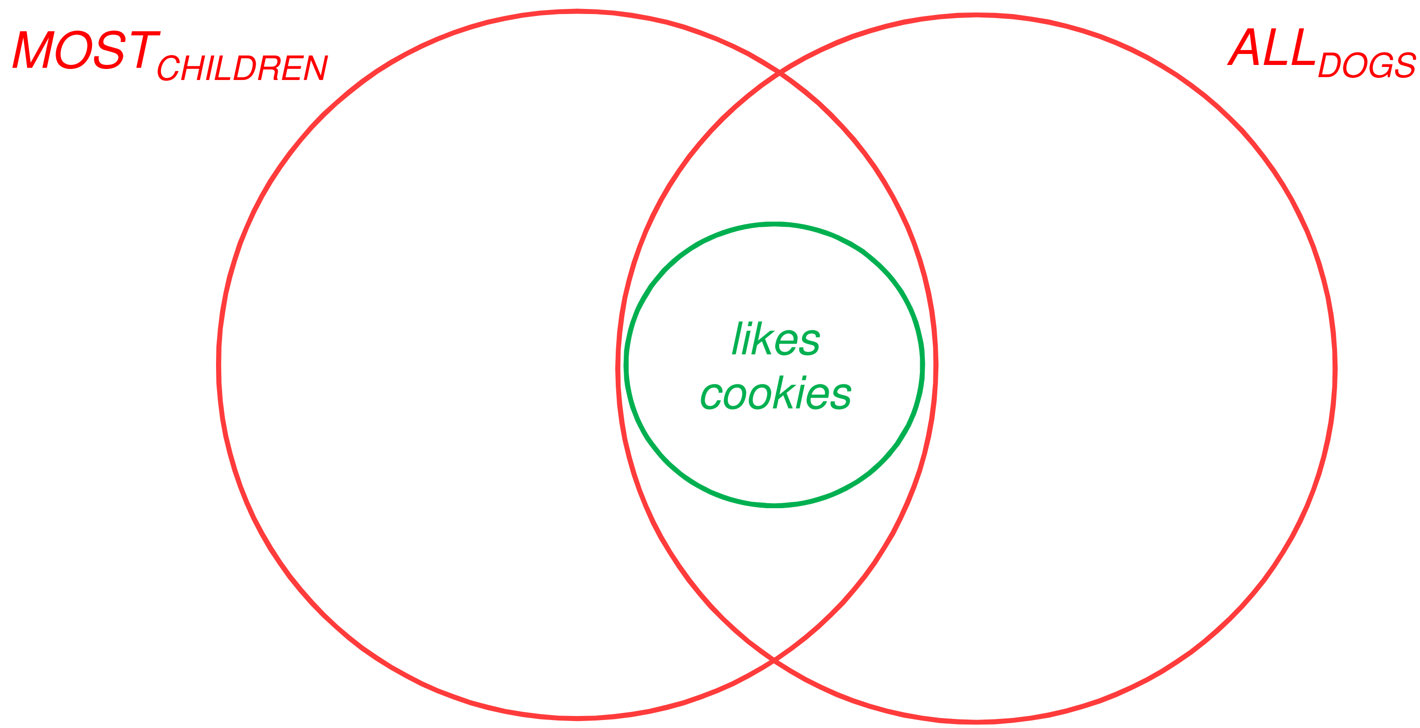
- (10) **All** dogs like cookies.
  - $\text{ALL}_{\text{DOGS}}(\text{P}(x))$*:* Set of (sets of individuals $\text{P}(x)$) such that $\text{DOG} \subseteq \text{P}$



- `all(A,B)` = 1 iff $A \subseteq B$
- $\text{ALL}_{\text{DOGS}}(\text{P}(x)) = 1$ iff $\text{DOG} \subseteq \text{P}$

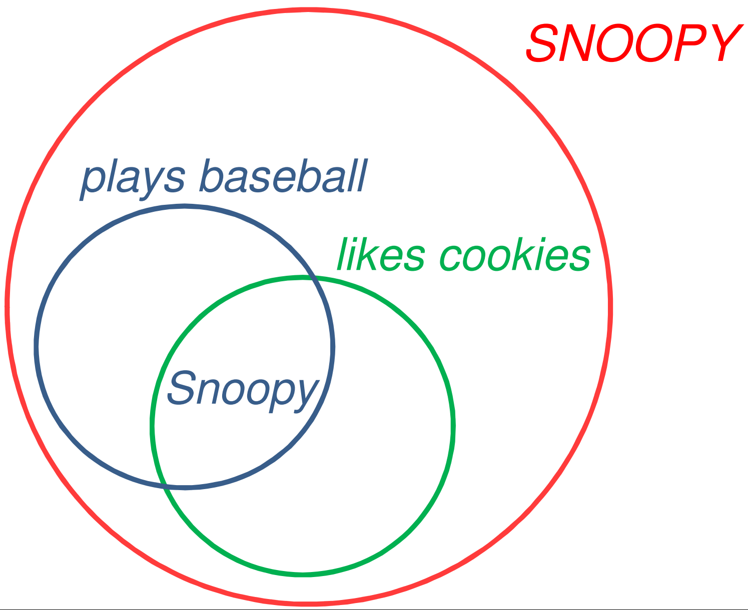
Other Generalized Quantifiers

- (11) **All** dogs and **most** children like cookies.
  - $LIKE_{COOKIES} \in ALL_{DOGS} \cap MOST_{CHILDREN}$



Other Generalized Quantifiers

- **What about:** (13) Snoopy and most children like cookies.
  - Like "most children", "Snoopy" is an NP.
    - ∗ "Snoopy" should have the same semantic type as "most children".
- **Solution:** "Snoopy" is a set of sets of individuals as well:
  - SNOOPY(P(x)) is the set of (sets of individuals P(x)) such that P(s) = 1



Strong/Weak Quantifiers

- **Observation:** only **weak** quantifiers can occur in existential *there* sentences.

  (14) a. *There is a bird on the doghouse.*
  b. *There are two birds on the doghouse.*
  c. **There is every birds on the doghouse.*
  d. **There are both birds on the doghouse.*

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

  (15) *three children are baseball players*
  = *three baseball players are children*

- **asymmetrical** (proportional) quantifiers are **strong:** det(A,B) ≠ det(B,A)

  (16) *most children are baseball players*
  ≠ *most baseball players are children*

Q: Come up with some more strong and weak quantifiers

Negative Polarity Items (NPI)

➢ **Observation:** Some words in English only appear in negative environments:

(17) a. *Charlie Brown doesn't ever kick the football.*
b. **Charlie Brown does ever kick the football.*

(18) a. *Charlie Brown hasn't kicked the football yet.*
b. ** Charlie Brown has kicked the football yet.*

(19) a. *Few people have hit a homerun yet.*
b. **Many people have hit a homerun yet.*

(20) a. *Rarely does Charlie Brown ever hit a homerun.*
b. **Often does Charlie Brown ever hit a homerun.*

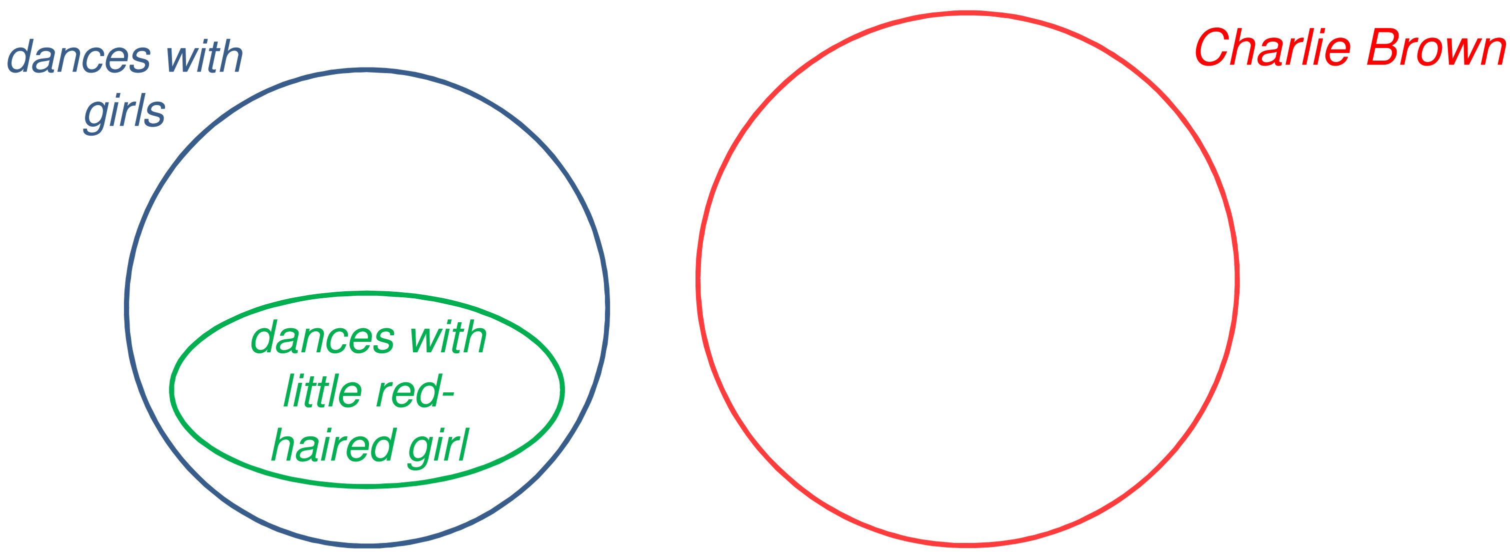
➢ Not just negation, but also some quantifiers

Q: Come up with some NPIs and environments

Monotonicity

- Some quantifiers control entailment between sets and subsets
  - **Downward entailment:**
    P is true of a set ⊢ P is true of a subset

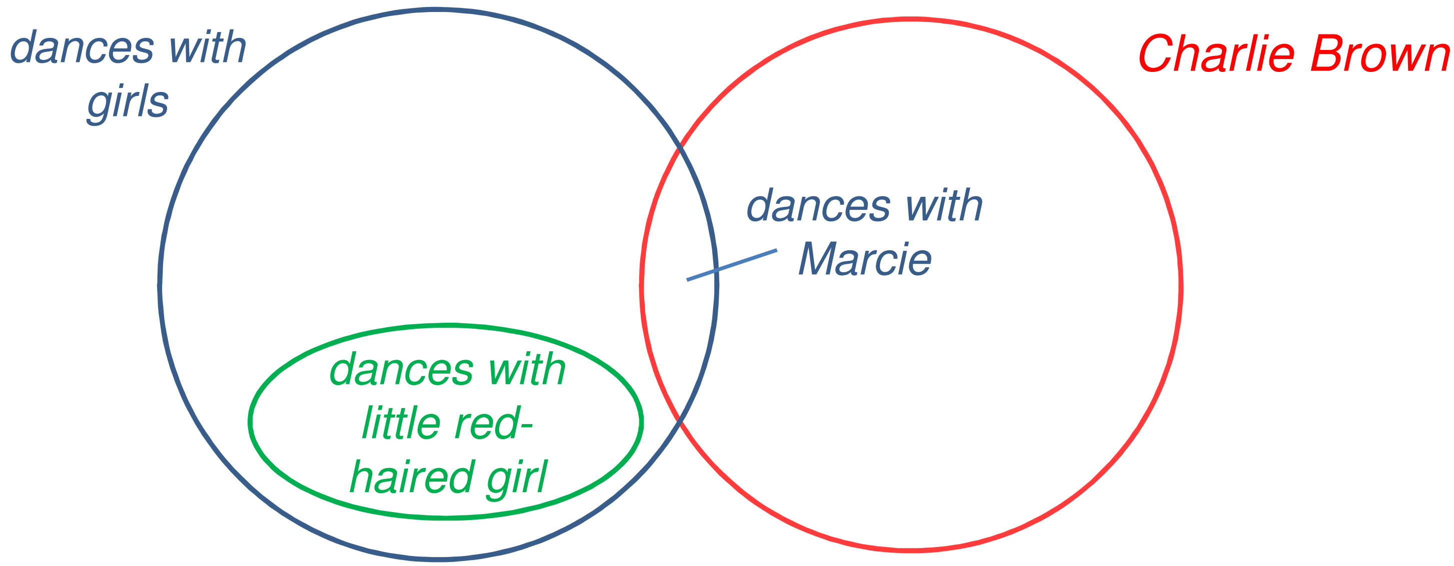
(21) a. Charlie Brown doesn't dance with girls.
⊢ Charlie Brown doesn't dance with the little red-haired girl.



Monotonicity

- Some quantifiers control entailment between sets and subsets
  - **Downward entailment:**
    P is true of a set $\vdash$ P is true of a subset

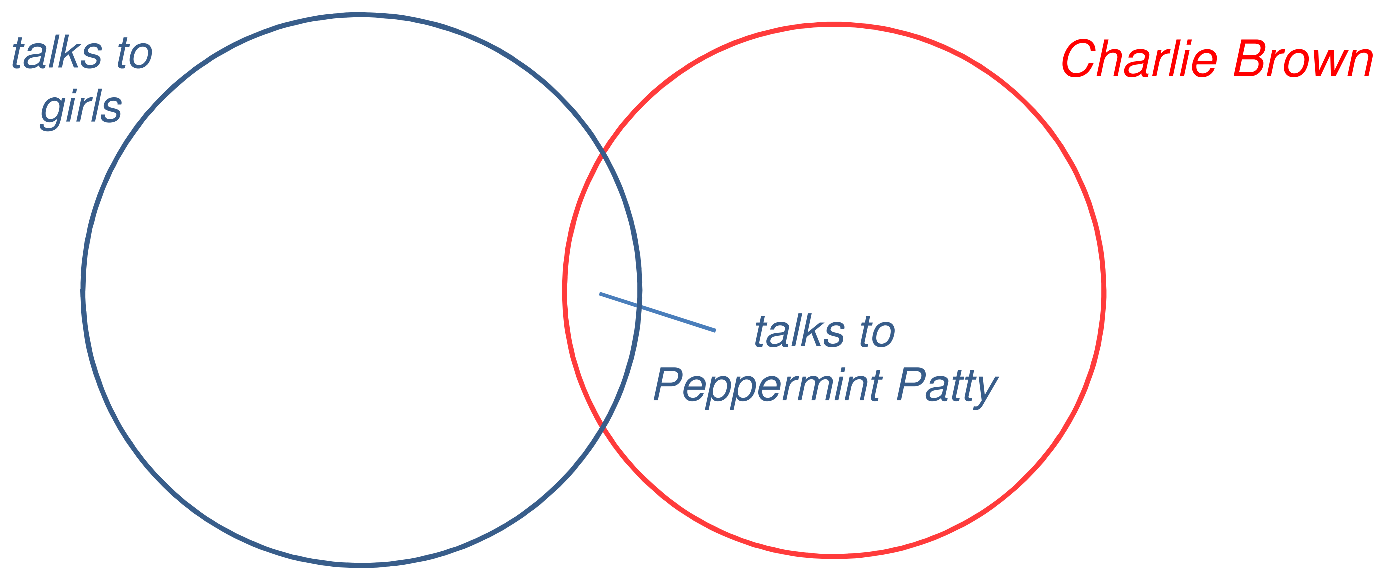
    (21) b. Charlie Brown doesn't dance with the little red-haired girl.
    $\nvdash$ Charlie Brown doesn't dance with girls.



Monotonicity

- Some quantifiers control entailment between sets and subsets
  - **Upward entailment:**
    P is true of a subset ⊢ P is true of a set

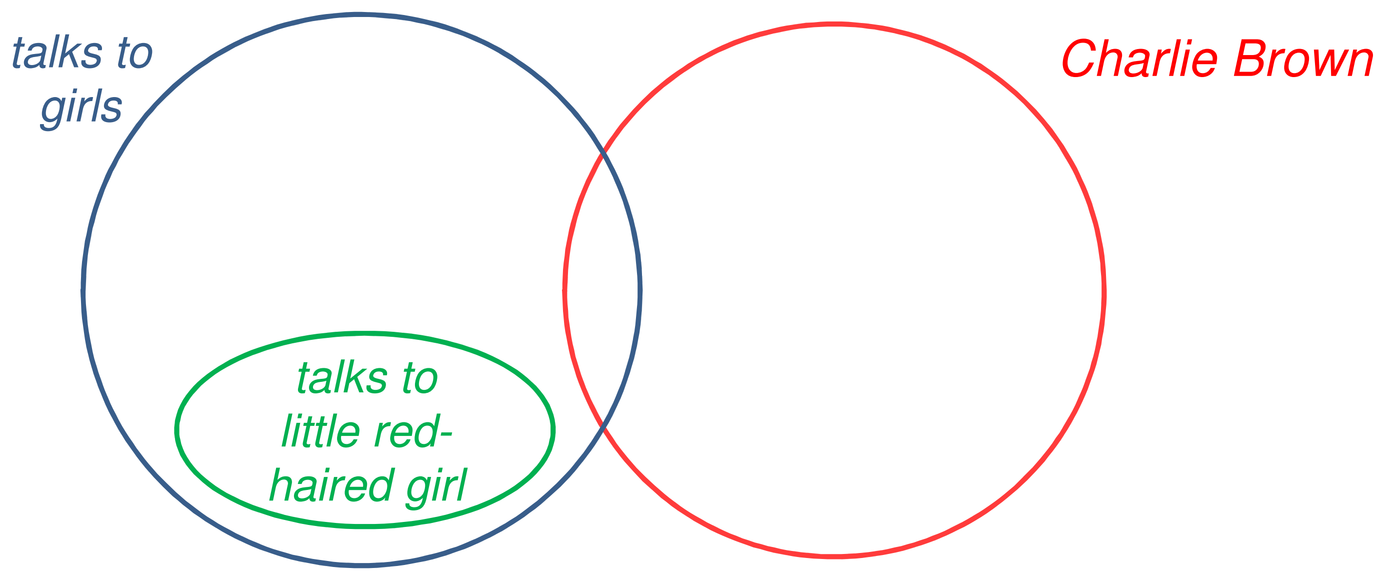
(22) a. Charlie Brown talks to Peppermint Patty.
⊢ Charlie Brown talks to some girls.



Monotonicity

- Some quantifiers control entailment between sets and subsets
  - **Upward entailment:**
    P is true of a subset ⊢ P is true of a set

(22) b. Charlie Brown talks to some girls.
⊬ Charlie Brown talks to the little red-haired girl.



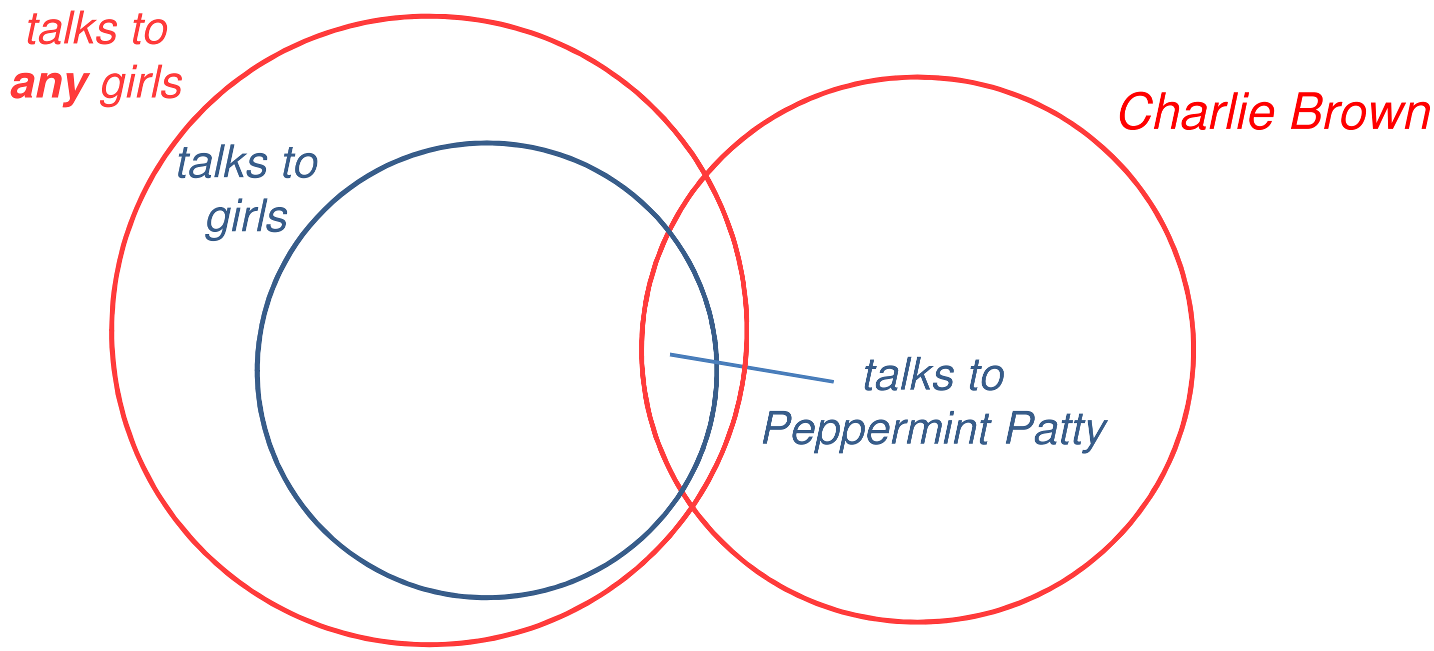
Monotonicity

- Negative Polarity Items are licensed by downward entailing expressions – **Why?**
  - Kadmon & Landman (1993) on *any:*
    - *any* (and other NPIs) are *domain wideners.*
      - Includes individuals that are usually not considered as part of the domain
    - Domain wideners result in a **stronger** statement only in downward entailing contexts.

Monotonicity

➢ **Upward entailment:** P is true of a subset ⊢ P is true of a set

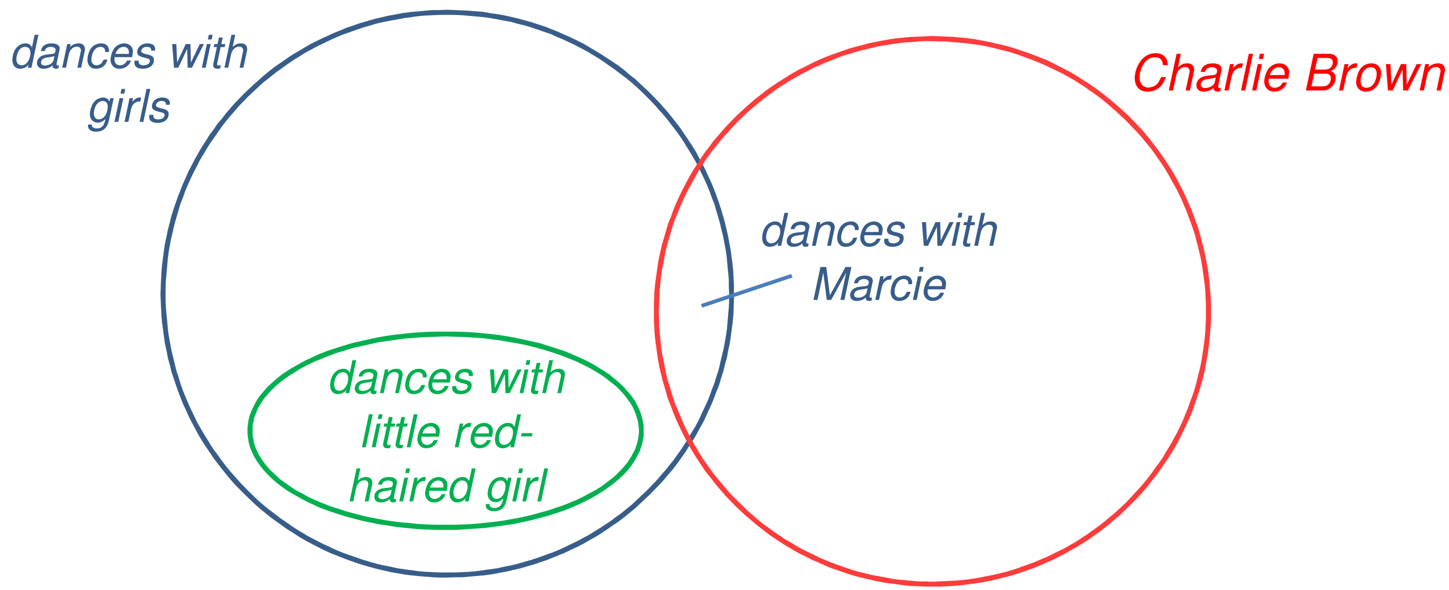
(22) a. Charlie Brown talks to Peppermint Patty. (**TRUE**)
⊢ Charlie Brown talks to some girls. (**TRUE**)
⊢ Charlie Brown talks to any girls. (still **TRUE**)
(**No new information**)



Monotonicity

➢ **Downward entailment:** P is true of a set ⊢ P is true of a subset

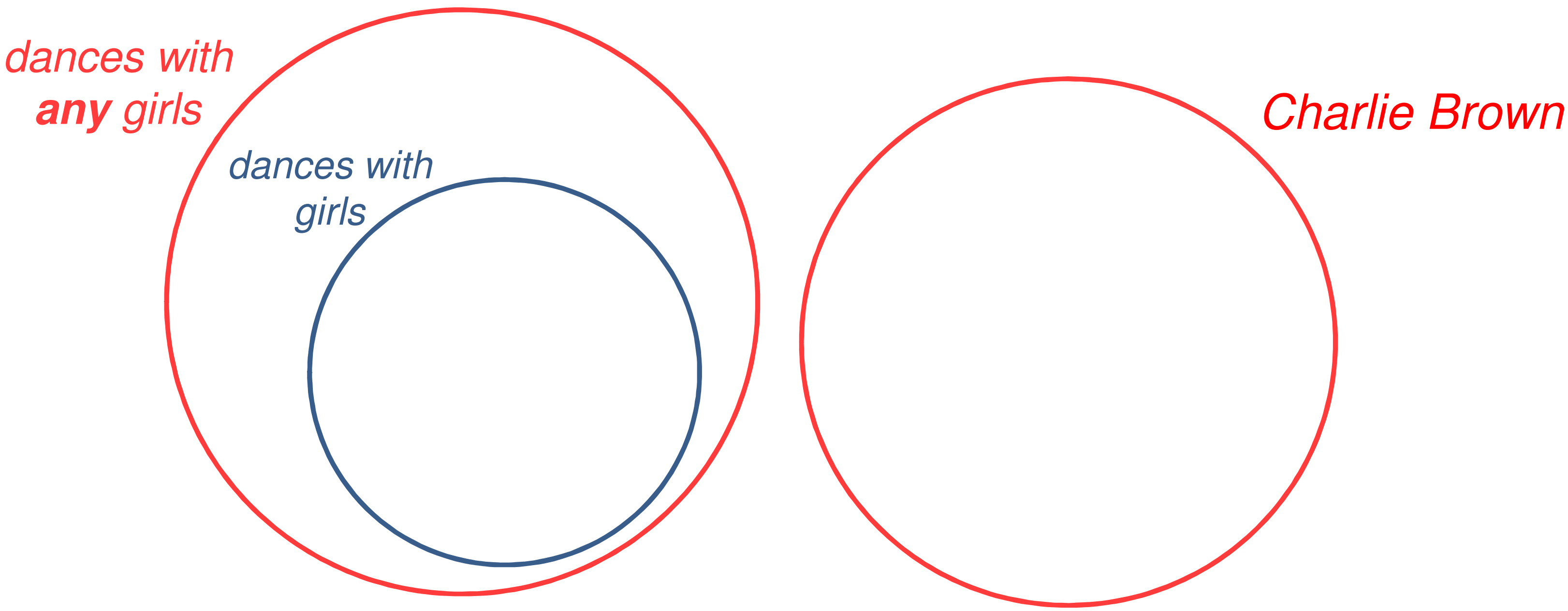
(21) b. Charlie Brown doesn't dance with the little red-haired girl. (**TRUE**)
⊬ Charlie Brown doesn't dance with girls. (**?**)



Monotonicity

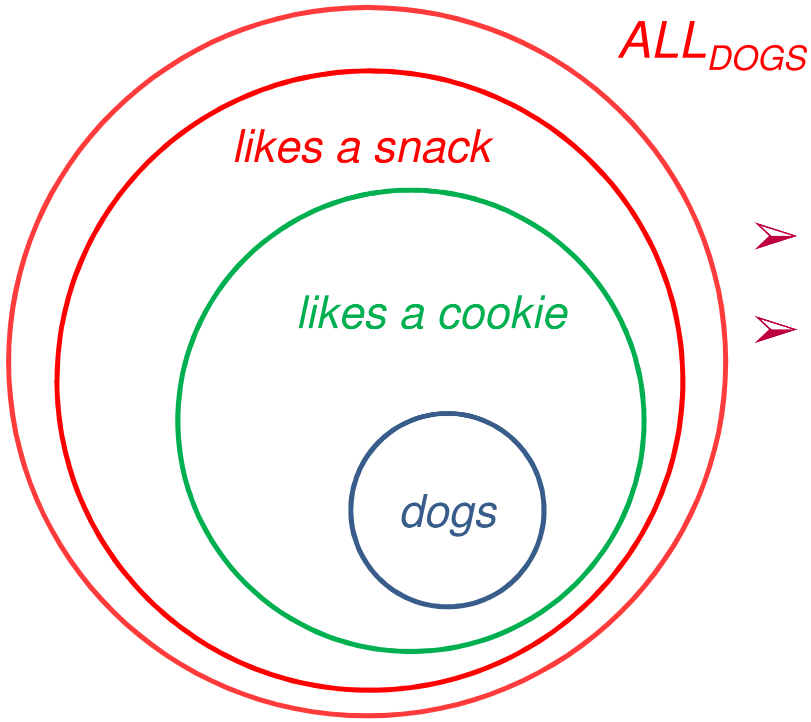
➢ **Downward entailment:** P is true of a set ⊢ P is true of a subset

(21) c. Charlie Brown doesn't dance with **any** girls. (**TRUE**)
(**New information**)
⊢ Charlie Brown doesn't dance with girls. (**TRUE**)



Left and Right Monotonicity

- The quantifier and the position affects entailment patterns
  - (23) **Every** dog likes a cookie.
    ⊢ **Every** dog likes a snack.
    Upward entailment (right argument)



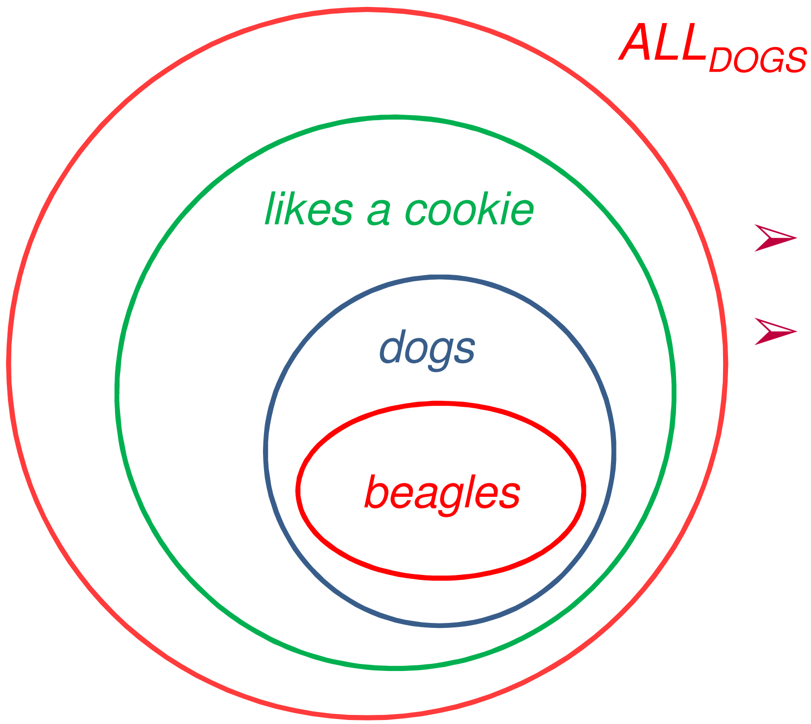
- **`all(A,B)`** = 1 iff $A \subseteq B$
- $ALL_{DOGS}(P(x)) = 1$ iff $DOG \subseteq P$

Left and Right Monotonicity

- The quantifier and the position affects entailment patterns
  - (23) **Every** dog likes a cookie.

    ⊢ **Every** beagle likes a cookie.

    Downward entailment (left argument)



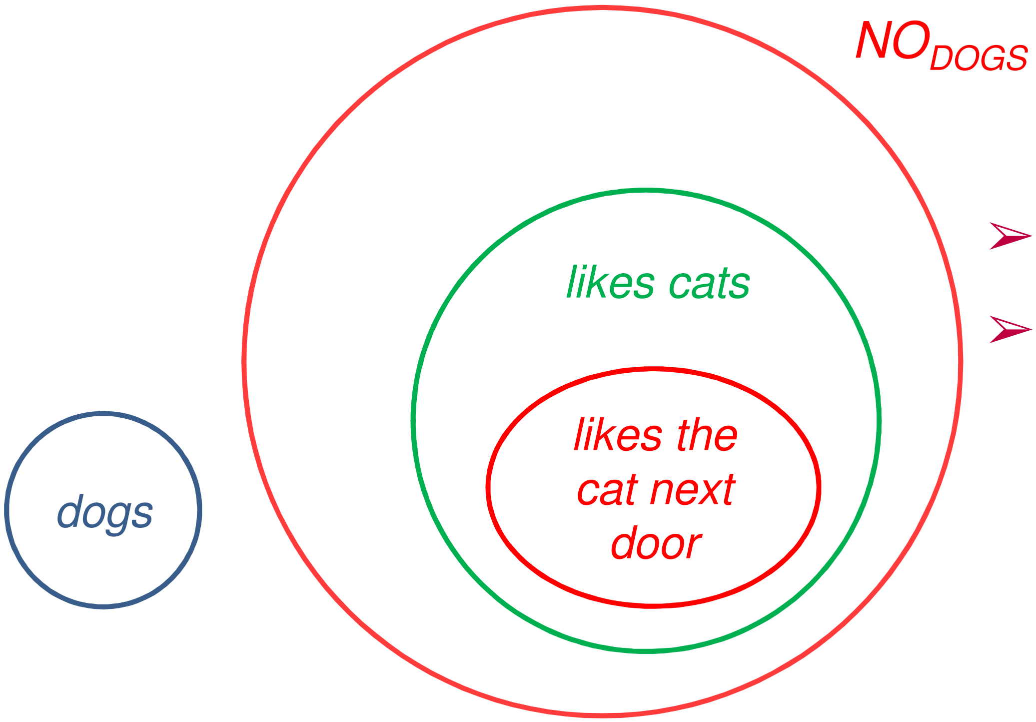
- `all(A,B)` = 1 iff A ⊆ B
- $\text{ALL}_{\text{DOGS}}(\text{P}(x)) = 1$ iff DOG ⊆ P

Left and Right Monotonicity

- The quantifier and the position affects entailment patterns
  - (24) **No** dog likes cats.

    $\vdash$ **No** dog likes the cat next door.

    Downward entailment (right argument)



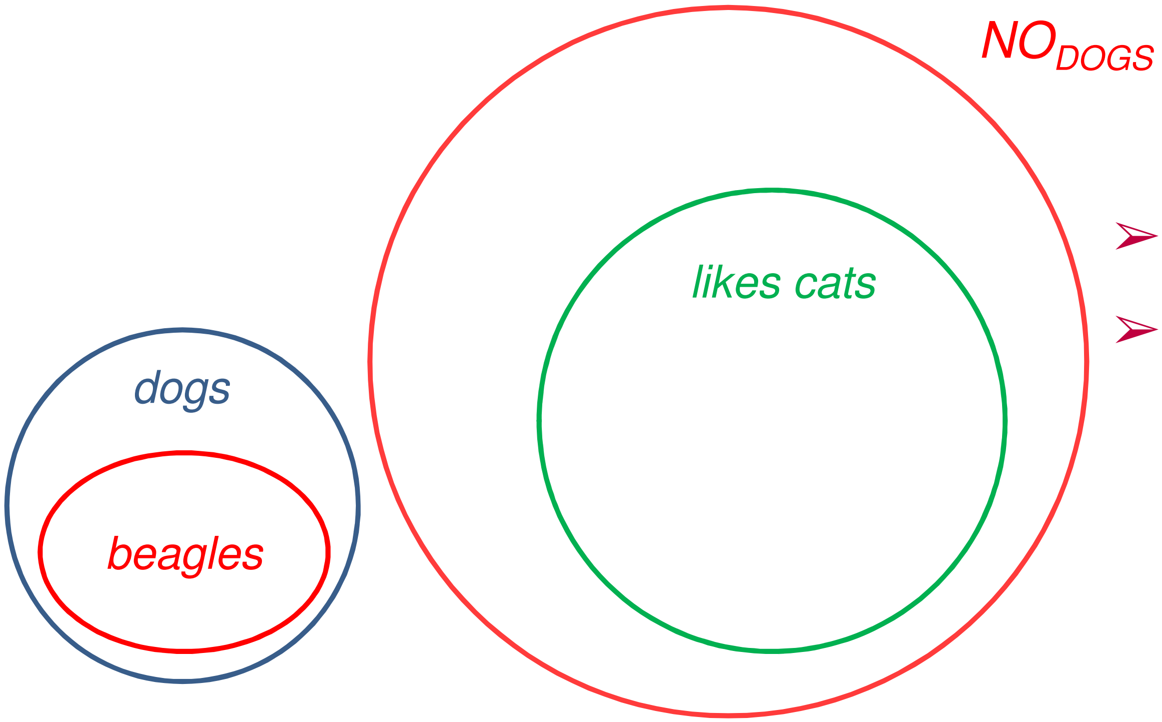
- **no(A,B)** = 1 iff $A \cap B = \emptyset$
- $NO_{DOGS}(P(x)) = 1$ iff $DOG \cap P = \emptyset$

Left and Right Monotonicity

- The quantifier and the position affects entailment patterns
  - (24) **No** dog likes cats.

    $\vdash$ **No** beagle likes cats.

    Downward entailment (left argument)



- **no(A,B)** = 1 iff $A \cap B = \emptyset$
- $NO_{DOGS}(P(x)) = 1$ iff $DOG \cap P = \emptyset$

(25)
a. ***Every*** *dog who has ever owned a supper dish likes a cookie.*
b. ****Every*** *dog who has owned a supper dish ever likes a cookie.*
c. ***No*** *dog who has ever been terrorised by a cat likes them.*
d. ***No*** *dog who has been terrorised by a cat ever likes them.*

➢ Under this account, the interpretation of NPIs involves both **semantics** and **pragmatics**.

Q: Make up your own example (up or down, left or right)

In other languages too!

(26) 我 没有 任何 朋友
wo mei-you renhe pengyou
I neg-have any friend
"I don't have any friends."

(27) * 我 有 任何 朋友
wo you renhe pengyou
I have any friend
*"I have any friends."

Intensionality

Intension vs Extension

- **Extension of a predicate:** The individuals referred to in the actual world (or another world under evaluation).
  - Extension of CHILD = {Charlie Brown, Lucy, Peppermint Patty}
  - Extension of $\text{PLAYER}_{\text{BASEBALL}}$ = {Charlie Brown, Lucy, Peppermint Patty}

- Does this mean that the meaning of CHILD is equivalent to $\text{PLAYER}_{\text{BASEBALL}}$?

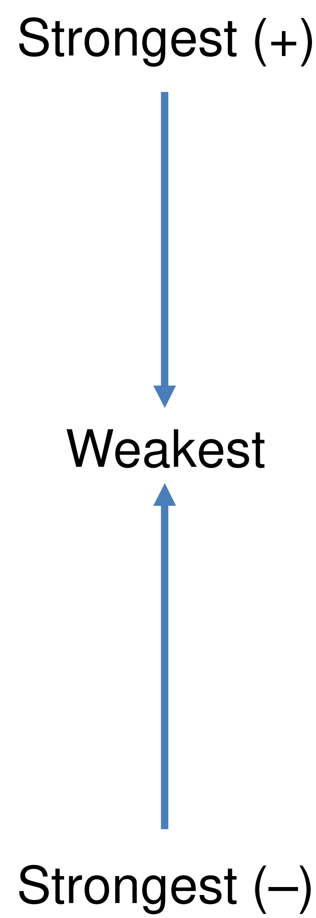
Intension vs Extension

- **Intension of a predicate:** The mapping between **possible worlds** and sets of individuals.
  - The **senses** of CHILD and $\text{PLAYER}_{\text{BASEBALL}}$ are different, so they will have different extensions in different possible worlds.
    - * Extension of CHILD in w_1 = {Charlie Brown, Lucy, Peppermint Patty}
    - * Extension of $\text{PLAYER}_{\text{BASEBALL}}$ in w_1 = {Charlie Brown, Snoopy, Peppermint Patty}
    - * It just so happens that in one specific world, the extensions are the same. ➢ Extensions may change across worlds, but intensions (sense) stays the same!

- We can add *W* (the set of possible worlds) to the model *M:*
  - $M = \{W, U, F\}$

Modality as a scale of Implicatures

(28) *I know that p*
(29) *I am absolutely certain that p*
(30) *I am almost certain that p*
(31) *I believe that p*
(32) *I am pretty certain that p*
. . .
(33) *Possibly p*
. . .
(34) *It is very unlikely that p*
(35) *It is almost impossible that p*
(36) *It is impossible that p*
(37) *It is not the case that p*
(38) *I am absolutely certain that not-p*



Allan (1986): incomplete

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**
  - **Weakest:** It is *possible* that ϕ; ϕ *might* be true
    * $\Diamond\phi = \phi$ is true in **at least one** possible world that is compatible with what the speaker observes
  - **Strongest:** It is necessary that ϕ; ϕ *must* be true
    * $\Box\phi = \phi$ is true in **all** possible worlds that are compatible with what the speaker observes

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

Summary

- A model-theoretic semantics evaluates truth based on a *model:*
  - **Meaning** is formalised as **functions** that take one element of the model (individuals, sets of individuals, etc,) and return other elements (in this class, truth values).
  - For the most part, the approach is **compositional:** meaning of words combine in a systematic way to form a meaning of the entire sentence.
    - Certain phenomena (behaviour of quantifiers in existential *there*-sentences, felicity of NPIs) can be explained by how the semantics combine ➢ Unacceptable sentences are a result of semantic combinations that do not make sense semantically or pragmatically.
- **Current research:** Discourse phenomena can also be accounted for with a model by adding more components to it.
  - Speaker's/Addressee's belief states, evidence, etc.

Acknowledgments and References

- Slides are adapted from Francis Bond's HG2002 slides on formal semantics.