

100 Things You Always Wanted to Know about Semantics & Pragmatics But Were Afraid to Ask*

Emily M. Bender
University of Washington

based on joint work with Alex Lascarides
University of Edinburgh

ACL 2018
15 July 2018
Melbourne

*for fear of being told 1,000 more

Goals

- Mine:
 - Give you a sense of linguistic semantics and pragmatics
 - Help you make more effective meaning-sensitive natural language technology
 - Intermediate goal on the way to writing a book ;-)
- Yours:
 - What do you hope to get from this tutorial?
 - What meaning-sensitive NLT are you working on?
 - For what languages?

Outline

- Introduction: What is meaning?
- Lexical semantics
- Semantics of phrases
- Meaning beyond the sentence
- Presupposition and implicature
- Resources
- Wrap-up

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Why semantics and pragmatics?

- Understanding semantics and pragmatics is beneficial for building scalable NLP systems



- How do strings of words relate to speaker intent?
- General purpose NLU requires modeling that which is general across language

- Knowledge of semantics and pragmatics can inform the design of NLP systems for understanding and generation



- Mapping between surface forms and intent representations

What is meaning?

In part: Validity or truth conditions



All cats are mortal

Euler is a cat

Euler is mortal

$$\forall x (cat(x) \rightarrow mortal(x))$$
$$cat(e)$$

$$mortal(e)$$

- Some words (e.g. *all*, *if*, *must*) map to special logical constants
- Others map to non-logical constants
- Interpretation of logical formulae (LF) is compositional as is (generally) the translation of natural language expressions to LFs
- Validity is relevant for inference and thus RTE, QA, IE

What is meaning?

In part: Validity or truth conditions



All
Eu
—
Eu

$l(x))$

- Some v
- Others
- Interpre
- translat
- Validity



) the

What is meaning?

Not just validity or truth conditions

- Constructing meaning representations also requires commonsense reasoning:

John can open Bill's safe.

... He knows the combination.

... He should change the combination (Hobbs 1979)



- World knowledge: safes have combinations => the combination is the combination to Bill's safe.
- World knowledge: knowing the combination allows you to open it + coherence (second clause explains first) => He is John
- World knowledge: changing combination solves security breach + coherence (first clause explains second) => He is Bill

Meaning derived from form is different from meaning derived from context of use

- Meaning level 1: Semantics derived from form: What is constant about the meaning of a sentence across different occasions of use

A: Is it raining?

B: Yes.

Meaning derived from form is different from meaning derived from context of use

- Meaning level 2: What a speaker publicly commits to by virtue of using a particular form in a particular context

A: Is it raining?

B: Yes.

A: It's perfectly dry outside. You're lying.

B: #I didn't say it's raining.

Meaning derived from form is different from meaning derived from context of use

- Meaning level 3: Inferences about a speaker's private cognitive states, but which the speaker hasn't publicly committed to

A: Is it raining?

B: Yes.

A: Oh, so you do think I should take my umbrella.

B: I didn't say that.

Meaning derived from form is different from meaning derived from context of use

- Meaning level 1: Semantics derived from form: What is constant about the meaning of a sentence across different occasions of use
- Meaning level 2: What a speaker publicly commits to by virtue of using a particular form in a particular context
- Meaning level 3: Inferences about a speaker's private cognitive states, but which the speaker hasn't publicly committed to



(Lascarides & Asher 2009, Asher & Lascarides 2013)

Locutionary/illocutionary/perlocutionary acts (Austin 1962, Searle 1969)

- Locutionary: The act of saying something meaningful, e.g. *Smoking is bad for your health.*
- Illocutionary: An act performed by performing a locutionary act
 - Direct: Assertion that smoking is bad for your health
 - Indirect: Warning not to smoke
- Perlocutionary: An act which changes the cognitive state of the interlocutor (e.g. causes them to adopt the intention to stop smoking)



NB: This cross-cuts 3-way distinction from previous slide

Speech acts are also relational, i.e. properties of pairs of utterances



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- DAMSL (Core and Allen 1997) tagset includes tags for forward & backward looking functions: e.g. ‘tag question’, ‘answer’
 - Coherence-based models of discourse (Hobbs 1979, Asher & Lascarides 2003) attach all utterances via two-place *coherence relations*: e.g. ‘explanation’, ‘result’, ‘contrast’
 - Coherence relations are also anaphoric (Webber et al 2003, A&L 2003), as the first argument of the relational speech act has to be identified in the preceding discourse.

Linguistic meaning also includes emotional content

- External to ‘propositional content’ discussed above
- Expressions of speaker attitude towards propositions such as with evaluative adverbs: *Fortunately, it is not too cold outside.*
- Expressions of speaker feelings towards referents: *That damn cat*
- Expressions of speaker emotional state via prosodic variation in the speech signal

Linguistic meaning also includes emotional content

- Six properties of expressive content (Potts 2007)
 - i. independent of truth conditional semantics
 - ii. non-displaceable (always pertains to current situation)
 - iii. perspective dependent, usually the speaker's perspective
 - iv. nigh-impossible to paraphrase with strictly non-expressive terms
 - v. like performatives: the mere act of uttering them is the act that constitutes their effect
 - vi. repeating expressives is informative rather than redundant

Linguistic meaning also includes emotional content

- In many languages, expressives can be morphemes
- Diminutives and augmentatives cross-linguistically both come to carry positive and negative expressive content (Ponsonnet ip)

Jid'iu-pe-taiti-a=wekwana mida yawe=chidi
peel-COMPASS-A3-PFV-PST=3PL 2SG husband=DIM

‘[The frogs] peeled you entirely, my poor husband.’ [tna] (Ottaviano 1980)

tii-kaik-pa-a
take-AUG-INDIC-3SG.3SG

‘The nasty one takes him.’ [kal] (Tersis 2008)



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- Expressions of speaker emotional state via prosodic variation in the speech signal
 - => Related to, but not the same as, sentiment lexicons (e.g. MPQA subjectivity lexicon (Wilson et al 2005))

Linguistic form also conveys social meaning

- Dedicated words or morphemes that carry information about politeness or formality: English *please*, French *tu* v. *vous*, Japanese honorifics:

本 を もらった。

Hon wo morat-ta.

Book ACC receive.SHON:±-PST.AHON:—

本 を もらいました。

Hon wo morai-masi-ta.

Book ACC receive.SHON:±-AHON:+-PST

‘(I) received a book.’ [jpn]

Linguistic form also conveys social meaning

- Dedicated words or morphemes that carry information about politeness or formality: English *please*, French *tu* v. *vous*, Japanese honorifics:

本 を いただいた。

Hon wo itadai-ta.

Book ACC receive.SHON:—-PST.AHON:—

本 を いただきました。

Hon wo itadaki-masi-ta.

Book ACC receive.SHON:—-AHON:+-PST

‘(I) received a book.’ [jpn]

Linguistic form also conveys social meaning

- Dedicated words or morphemes that carry information about politeness or formality: English *please*, French *tu* v. *vous*, Japanese honorifics.
- More commonly, parts of the linguistic system become imbued with associations with groups of people or their associated traits (Labov 1966, Lavandera 1978, Campbell-Kibler 2010).
 - Differing pronunciations, pitch, speech rates, pairs of near-synonyms, stylistic choices
- Such forms are available as a resource speakers use to construct personae and social situations (Eckert 2001)



There is ambiguity at many levels

- Phonetic: *wreck a nice beach*
- POS: *A man walked in. / Sailors man the decks.*
- Word sense: *mogul* (mound of snow, Chinese emperor)
- Attachment: *I saw a kid with a telescope.*
- Scope (quantifiers): *Kim didn't buy a car.*
- Scope (presuppositions): *Kim believes Sandy's motorcycle is red, even though Sandy never bought nor received a motorcycle.*
- Speech act: *Have you emptied the dishwasher? / Is that a question or a request?*



In face-to-face conversation, people use both verbal and non-verbal actions to convey meaning



- Deixis: *Put this in the dishwasher.*

- Non-verbal antecedents to relational speech acts (here, correction):

B is putting an unprotected vase in a cardboard box

A: Bubblewrapping fragile objects protects them in transit.

- Facial expressions: e.g. raised eyebrows can indicate surprise at or even denial of a previous utterance
- Depicting gestures

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- Non-verbal antecedent

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correction):

board box

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(Loehr 2004)

Linguistic meaning and non-linguistic perception interact in complex ways

- Interpretation requires a representation of non-linguistic objects, including time (*now, tomorrow*), place (*here, there*), speaker & hearer (*I, you*).

- But also very specific details of the physical context:

Gesturing to a poster of Florence
That's a beautiful city.

- Linguistic meaning affects interpretation of non-linguistic environment:

Nodding at scratch on the wall

My daughter Rose has been sent to her room. vs.
I tried to move furniture today.



Linguistic meaning and non-linguistic perception interact in complex ways

- Linguistic meaning affects interpretation of non-linguistic environment... which in turn affects interpretation of further linguistic meaning.



Nodding at scratch on the wall

My daughter Rose has been sent to her room.

I was cooking dinner.

- Without the nod to the scratch on the wall, the two events would be interpreted as overlapping.
- With it (and its interpretation), cooking dinner overlaps with the scratch being made, and the punishment is later.

Summary: Levels of meaning and ambiguity

- Inferences about speakers' private states
- A speaker's public commitments
 - Follow from the assumption that discourse is coherent, which affects both identifying coherence relations and resolution of anaphora.
- Semantics derived from form
 - Semantics derived from form underspecifies aspects of meaning such as scope of quantifiers, word sense ambiguities, semantic relation between nouns in a compound. These are determined by the context of use.

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Lexical semantics is often represented with opaque predicate symbols

- Or: The meaning of life is \wedge life'
- These opaque symbols miss/gloss over a lot of information (commonsense knowledge, ontological information, distributional semantics)
- One key thing that is captured: *arity* of relations — how many arguments does each take?



Lexical semantics: Overview

- Lexical semantics includes many aspects of meaning:
 - Semantic roles—not just the number of arguments, but the specific relationship they bear to the predicate
 - Word sense—fine-grained distinctions in meaning between different uses of the same form / shared meanings between different forms
 - Connotation—what word choice conveys beyond truth-conditional semantics
- What we call lexical semantics sometimes attaches to collections of words ('multi-word expressions') rather than single words

Some words are unambiguous; others have many senses



- WordNet (Miller et al 1990) lists one sense for *daffodil*, 49+2 (verb+noun) for *make*, and (14+2) for *ride*, of which here is a selection:
 - a. ride over, along, or through
 - b. sit and travel on the back of animal, usually while controlling its motions
 - c. be carried or travel on or in a vehicle
 - d. be contingent on
 - e. harass with persistent criticism or carping
 - f. keep partially engaged by slightly depressing a pedal with the foot
 - g. continue undisturbed and without interference
 - h. move like a floating object

Some ambiguity is shared across languages, but not all



- Open Multilingual WordNet (Bond and Paik, 2012) lists the Japanese word 乗る in senses 1-3 for *ride*, but not the others. Conversely, there eight senses for 乗る, including 5 not shared with *ride*:
 - a. の後ろに乗る ('get up on the back of')
 - b. 特定の種類の輸送または特定のルートによって旅行するか、進行する ('travel or go by means of a certain kind of transportation, or a certain route')
 - c. 持つまたは取れるように設計された ('be designed to hold or take')
 - d. 電車、バス、船、航空機など) に乗り込む ('get on board of (trains, buses, ships, aircraft, etc.)')
 - e. 必要な設備により、執行あるいは実行のために準備し供給する ('prepare and supply with the necessary equipment for execution or performance')
 - f. 乗り込んだ状態になる ('go on board')

Polysemy v. homonymy

- Sets of word senses can be classified according to how they relate to each other:
 - Polysemy — productive word sense relations
 - Homonymy — other sets of word senses
- Speakers can & do create new senses as they talk
 - Sometimes exploiting established polysemy patterns (Pustejovsky 1995)
 - Sometimes idiosyncratically (Garrod and Anderson 1987)



Constructional polysemy and sense extension

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- Constructional polysemy: related senses that cohabit the same lexical entry
 - Physical object v. abstract content: *book, magazine, newspaper, leaflet*
- Sense extension: regular ways of deriving new word senses given a member of a class

- Animal v. meat of that animal: *crocodile, kangaroo, emu, snail*

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- Test to distinguish these: co-predication

That book on the shelf is about syntax.

Cambridge is in the South East and voted Conservative.

#Mr. Pickwick took his hat and his leave.

#That porg was happy and tasty.

Structured lexical meaning representations support the analysis of constructional polysemy

- Qualia structure (Pustejovsky 1991)

$$\left[\begin{array}{l} \mathbf{book} \\ \text{argstr} : \left[\begin{array}{l} \text{arg1} : \mathbf{x:ind} \\ \text{arg2} : \mathbf{y:abstr} \end{array} \right] \\ \text{qualia} : \left[\begin{array}{l} \text{agentive} : \mathbf{write(e,z,y)} \\ \text{telic} : \mathbf{read(e,z,y)} \end{array} \right] \end{array} \right]$$

- Models which senses appear in which contexts. E.g. *enjoy* takes NP complement but characterizes an event

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Kim enjoyed the book.

Stephen King enjoyed the book.

- Lexicalized: #*Kim enjoyed the doorstep*.

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Homonymy

- Homonymy involves unrelated word senses
- Can't use copredication/zeugma test to distinguish, because sense extensions (=polysemy) also fail this test
- Might be tempted to use etymology, but that's not reliable either:
 - River + financial institution sense are actually etymologically related (Lyons 1995:28): Italian Renaissance bankers used to sit on riverbanks to conduct business!
- Even though the distinction is hard to operationalize, it's still valuable to know about what kind of sense variation is out there in the lexicon



Predictable word senses also arise from derivational morphology



- Nominalization:

Most prominent argument: The *nominator* was thorough.

Undergoer-like argument: The *nominee* was controversial.

Result of action: The *confirmation* of the nominee sparked protests.

Event itself: The *confirmation* of the nominee took several weeks.

- Morphological causative:

田中 が 山田 に 本 を 読まさせた。

Tanaka ga Yamada ni hon wo yoma-sase-ta.

Tanaka NOM Yamada DAT book ACC read-CAUS-PST

‘Tanaka made Yamada read a book.’ [jpn]

Predicted word senses can be blocked by high frequency words

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- Lexical rules for sense extension are semi-productive

Porg is a delicacy in Ahch-To.

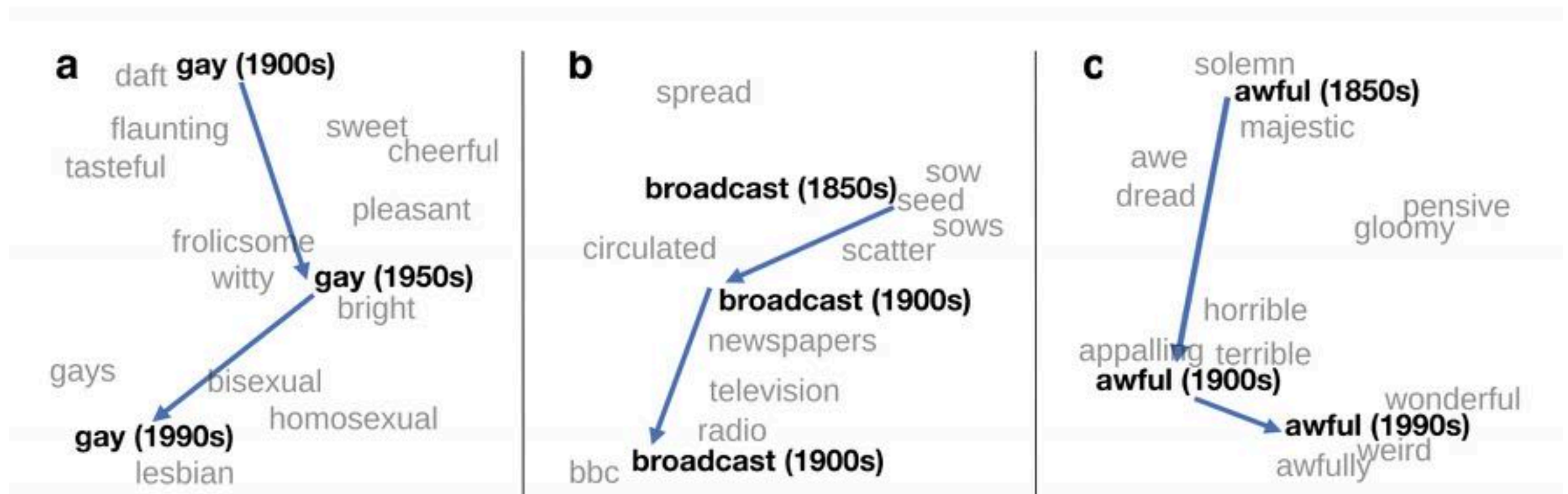
#I ate cow stew.

#Would you like a pig kebab?

- Blocking depends on frequency, so low-frequency words can co-exist with derived forms with the same meaning: *coney*, *rabbit*
- Dependence on frequency makes productivity/blocking a property of language and how it's used (Briscoe and Copestake 1999)
- Can be unblocked: *stealer of hearts* (Bauer 1983:87-88)

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Word senses can change over time



(Hamilton et al 2016:1490)

Word senses can change over time

- Patterns of change (Traugott and Dasher 2001, Bréal 1900, Jeffers and Lehiste 1979):
 - Metaphor: *broadcast* < to cast seeds out
 - Narrowing: *skyline* < any horizon
 - Generalization: *hoover*, *kleenex*, *xerox*
 - Pejoration: *stink* < OE *stincan* 'to smell'



Words can change senses over time

- Semantic change is heavily influenced by culture
- ex: Gender roles and associated power imbalances lead to prevalence of pejoration in terms denoting women and girls (McConnell-Ginet 1984)

buddy v. sissy

master v. mistress

hussy < housewife

- Higher frequency words change senses more slowly and more polysemous words change more quickly (Hamilton et al 2016)

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You shall know the meaning of a word by the company it keeps!

(Firth 1957, paraphrasing Wittgenstein)

- So far, looking at word sense from the point of view of the lexicographer's problem
 - Word senses are things that words have & can change over time
 - Task is to identify and describe them
- Alternative view: Word senses derive instead from how words are deployed by speakers carrying out communicative intents
 - No clear boundaries between word senses
- Harris 1954: Distributional analysis can at least establish similarity of meaning



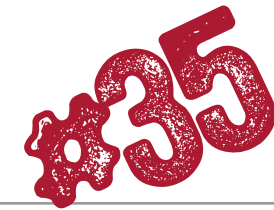
Vector space representations are a practical implementation of this idea

- If parameters are word counts for same-paragraph or same-document words: vector represents topical similarity (Clark 2015)
- If parameters involve a much smaller context window: synonymy
- Vectors can be sensitive to linguistic structure: certain POS, based on lemmas, including grammatical relations
- Most common similarity metric: cosine measure

$$\begin{aligned} \text{sim}(\vec{w}_1, \vec{w}_2) &= \frac{\vec{w}_1 \cdot \vec{w}_2}{|\vec{w}_1| \cdot |\vec{w}_2|} \\ &= \frac{\vec{w}_1 \cdot \vec{w}_2}{\sum_i (w_{1i})^2 \sum_i (w_{2i})^2} \\ &= \text{cosine}(\vec{w}_1, \vec{w}_2) \end{aligned}$$



Vector space representations pick up human biases from their training texts



- Speer (2017) case study: Star ratings for Mexican restaurants systematically underpredicted by sentiment analysis system
 - Because it included word embeddings trained on open-domain text
- One solution: debiasing word embeddings (e.g., Bolukbasi et al 2016)
- Complimentary alternative: foreground characteristics of training data to facilitate reasoning about when attitudes learned by the system may be harmful (Anonymous 2018)

Vector space representations are complementary to formal semantic ones



- Formal semantics uses set-theoretic representations, useful for inference
- But relies on symbolic generalizations to capture similarity between words
- Distributional/vector-space representations capture a notion of similarity missing in formal models
- Vector-space models handle novel word senses more gracefully
- Compositionality of vector-space representations is as yet unsolved
- Combination of vector-space & compositional representations will be valuable

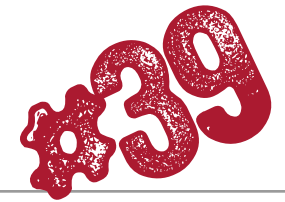
Word senses can be added through metaphor, shifting in unbounded but not arbitrary ways

- *I have always despised politics. But I have climbed to the top of that greasy pole.*
- French *sortir* ('to go out, come out'), unlike *partir* ('to go, leave'), requires that the goal be in a neighborhood near to the source, explaining *partir*/**sortir de la guerre* 'leave the war'
- Capturing general relationships among salient attributes of the denotation of words in the source and target domains enhances performance in metaphor classification (Bulat et al 2017, see also Lakoff and Johnson 1980)
- Metaphorical meanings can also become conventionalized, e.g. metaphor of time as a resource (*time is running out, you have plenty of time*)

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Words can have surprising nonce uses through meaning transfer and metonymy



- Meaning transfer is the linguistic process by which a property or relation denoting term takes on a new sense just in case there is some salient connection (Nunberg, 2004)

We are parked out back.

I am parked out back and have been waiting for 15 minutes.

*I am parked out back and may not start.

Ringo squeezed himself into a narrow space.

Yeats did not like to hear himself read in an English accent.

The ham sandwich and salad at table 7 is getting impatient.

- If this phenomenon is common in training texts, it will introduce noise into distributional semantic models

Words can also carry (defeasible) information about interpretation of dropped arguments

Have you eaten? → a meal

I drank all night. → alcohol

Kim will bake tomorrow afternoon.

→ a flour-based product

- Defeasible:

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Kirk has some symptoms of diabetes.

For instance, he drinks all the time.

- Lexically specific:

Kim sipped.

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Relational predicates



- Many words are best understood as denoting relations between arguments

- Verbs:

[Kim] bet [Sandy] [\$5]
[to three donuts] [that Chris would win].

- Subordinators:

Kim left because Sandy stayed.

- Nouns:

Kim's cousin arrived.

Pat denied the rumor that Chris cheated.

Intrinsic arguments



- In relational nouns (*cousin*, *rumor*) one of the arguments is denoted by the noun itself
- Similarly, non-relational nouns (*cat*) are one place relations
- Verbs also have such an intrinsic argument: the event (or eventuality) described by the verb
- Some words don't represent semantic predicates or arguments at all:



It bothers Kim that Sandy left.

Semantic roles

- Semantic arguments are differentiated by their role with respect to the predicate
- Within a predicate, semantic roles are usually (but not always) quite distinct

Kim saw Sandy.

Kim kissed Sandy.

Kim resembled Sandy.



- Syntax plays an important role in indicating which semantic roles which constituents play and with respect to which predicates
- ... but it is not the case that syntactic roles such as 'subject' or 'object' map consistently onto semantic roles.

Semantic roles can be analyzed at varying degrees of granularity



-
- Attempts to find a single, compact, comprehensive set of semantic roles date back to Pāṇini (6th century BCE) (Dowty 1989), but have never succeeded
 - FrameNet (Baker et al 1998): Frame specific Frame Elements, organized into a hierarchy
 - PropBank (Palmer et al 2005); ERG (Flickinger 2000, 2011): Bland, re-used semantic role names with predicate-specific interpretation
 - VerbNet (Palmer et al 2017): Practical middle ground, with a hierarchy that maps between general LIRICS roles and specific FEs.

Further point of variation: Direction of dependencies

Kim met Sandy today in the garden at dusk with a lantern.

- The ERG treats *today*, *in*, *at*, and *with* as predicates which each take the meeting event as an argument
- In PropBank they are ARG-M dependents of *met*.
- In FrameNet they are non-core Frame Elements of the frame evoked by *met*.
- => Understanding these properties of a semantic-role labeling scheme is important to understanding how make use of the labels it provides.



When an argument is not overtly expressed, the semantic predicate still carries a role for it

- Constructional null instantiation (Baker et al 1998; Fillmore and Petruck 2003)

The cake was eaten.

Eat the cake!

Kim tried to eat the cake.

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- Lexically licensed definite and indefinite null instantiation (Fillmore 1986)

I ate.

*I devoured.

Kim already told Sandy.

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When an argument is not overtly expressed, the semantic predicate still carries a role for it

- Systematic definite null instantiation



Comí pizza.
eat.PST-1SG pizza

‘I ate pizza.’ [spa]

あげた。
Age-ta.
Give-PST

‘They gave it to them.’ [jpn]

Multiword expressions straddle the boundary between lexical and compositional semantics

- Speakers know roughly as many MWEs as single words (Jackendoff 1997)
- Idiosyncrasy may be syntactic, semantic, or just statistical (Sag et al 2002)

Long time no see.

Kim kicked the bucket.

telephone booth (US)/telephone box (UK)/#telephone closet

- See also “four part idioms” in Chinese and Japanese

瓜 田 李 下

guā tián lǐ xià

melon field plum under

‘Avoid situations where you
might be suspected of wrongdoing’ [cmn]



Collocations are dependent on word form and not just word senses

- Collocation: a sequence of two or more words that appear together with greater frequency than their individual frequencies would predict
- Specific to word forms, and not meanings

emotional baggage

strong tea

make progress

do homework

center divider

in my opinion

from my point of view

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- Collocation: a sequence of two or more words that appear together with greater frequency than their individual frequencies would predict
- Specific to word forms, and not meanings

emotional baggage

?emotional luggage

strong tea

?powerful tea

make progress

?do progress

do homework

?make homework

center divider

?middle separator

in my opinion

?from my opinion

from my point of view

?in my point of view

Collocations are often less ambiguous than the words taken in isolation

- *Heavy* has 27 senses in WordNet (Miller et al 1990), but in collocations it is unambiguous:

heavy smoker → ‘prodigious’
heavy sleeper → ‘deep and complete’

- A special case of a more general phenomenon:
 - Words are often less ambiguous in their linguistic context than they are in isolation of any context, thanks to knowledge about preferred linguistic forms and preferred meanings



MWEs share many sense-related properties with single words

- Can have sense ambiguity: *pick up, put up, make out*
- Like derivational morphology, there are patterns for creating new ones: completive *up* -> *eat up, drink up, finish up, google up*
- A given MWE's sense can drift from what the derivational patterns would predict: *pull up* ('drive and park')

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MWEs vary in their compositionality and in their syntactic flexibility (maybe correlated)



- *kick the bucket, saw logs v. pull strings, skeletons in the closet*

Kim kicked the bucket. ('Kim died')

Kim sawed logs all night. ('Kim snored all night.')

The bucket was kicked by Kim. (unidiomatic reading only)

The logs were sawed by Kim. (unidiomatic reading only)

Some strings are harder to pull than others.

His closets would be easy to find skeletons in.

(Nunberg, Sag & Wasow 1994)

Compositional semantics is about working out who did what to whom, where, when, how and why

- The translation of natural language strings to logical forms
- Who did what to whom: Predicate + arguments
- Where, when, how, why: Predicate symbols that take events as arguments

Kim met Sandy today in the garden at dusk with a lantern.

$$\text{Kim}(x) \wedge \text{meet}(e, x, y) \wedge \text{Sandy}(y)$$
$$\wedge \text{temp_loc}(e, t) \wedge \text{today}(t)$$
$$\wedge \text{in}(e, g) \wedge \text{garden}(g)$$
$$\wedge \text{at}(e, d) \wedge \text{dusk}(d)$$
$$\wedge \text{with}(e, l) \wedge \text{lantern}(l)$$


Some entailment can be modeled by ‘wedge elimination’



Kim met Sandy today in the garden at dusk with a lantern.

$$\begin{aligned} & \text{Kim}(x) \wedge \text{meet}(e,x,y) \wedge \text{Sandy}(y) \\ & \wedge \text{temp_loc}(e,t) \wedge \text{today}(t) \\ & \wedge \text{in}(e,g) \wedge \text{garden}(g) \\ & \wedge \text{at}(e,d) \wedge \text{dusk}(d) \\ & \wedge \text{with}(e,l) \wedge \text{lantern}(l) \end{aligned}$$

One-to-many mappings

- String to syntax: One to many

The astronomer saw the kid with the telescope.

- Syntax to LF: One to many

Every dog chased some cat.

- LF to string: One to many

Kim gave Sandy a book. / Kim gave a book to Sandy.

- <string, LF> to syntax: One to many

I will go to school tomorrow.



Quantifiers can be modeled as relations between sets & NL determiners as quantifiers



- *A dog barks*: Intersection of set of dogs & set of barkers is non-empty
- *Every dog barks*: Set of dogs is a subset of the set of barkers

$a_M(X, Y)$	\longleftrightarrow	$X \cap Y \neq \emptyset$
$every_M(X, Y)$	\longleftrightarrow	$X \subseteq Y$
more than 2 $_M(X, Y)$	\longleftrightarrow	$ X \cap Y \geq 2$
neither $_M(X, Y)$	\longleftrightarrow	$ X = 2$ and $X \cap Y = \emptyset$
more than half $_M(X, Y)$	\longleftrightarrow	$ X \cap Y > \frac{ X }{2}$
only $_M(X, Y)$	\longleftrightarrow	$X \cap Y \neq \emptyset$ and $(M \setminus X) \cap Y = \emptyset$ ¹
all but one $_M(X, Y)$	\longleftrightarrow	$ X \cap Y = X - 1$ and $ X \cap (M \setminus Y) = 1$

(See Westerståhl 1989)

Scope of quantifiers is not fixed by syntax but scope of other scopal operators is

- Every student read some book

$$\forall(x, \text{student}(x), \exists(y, \text{book}(y), \text{read}(x, y)))$$
$$\exists(y, \text{book}(y), \forall(x, \text{student}(x), \text{read}(x, y)))$$

- Every student probably didn't read some book

$$\forall(x, \text{student}(x), \exists(y, \text{book}(y), \text{probably}(\text{not}(\text{read}(x, y)))))$$
$$\forall(x, \text{student}(x), \text{probably}(\text{not}(\exists(y, \text{book}(y), \text{read}(x, y)))))$$
$$\exists(y, \text{book}(y), \forall(x, \text{student}(x), \text{probably}(\text{not}(\text{read}(x, y)))))$$
$$\exists(y, \text{book}(y), \text{probably}(\text{not}(\forall(x, \text{student}(x), \text{read}(x, y)))))$$

$$*\forall(x, \text{student}(x), \text{not}(\text{probably}(\exists(y, \text{book}(y), \text{read}(x, y)))))$$



Scope is more or less relevant depending on the task

- IR doesn't care about negation
- IE does
- Sentiment analysis does even more
- MT doesn't care about quantifier scope

Scope is more or less relevant depending on the task



- Pronoun resolution can require information about relative scope

A person gets run over on Princes Street every day.
He's getting really pissed off about it.

- *A person* is available as an antecedent for *he* only if *a* takes wide scope over *every*.
- Also important in question answering & dialogue systems:
Do all the students in NLP101 get a mark above 70%?
Please give me all hotels with at least one 5-star review.
- Both queries require a narrow scope interpretation of the existential quantifier

Beyond PAS, compositional semantics includes other grammaticized concepts

- Time: tense, aspect

ngi-sa-phek-a
SC1SG-PERS-cook-FV

‘I still cook’ [ssw] (Nichols 2011:35)



- Evidentials: source of information, degree of certainty

waly-marsh-ma-’-yuu
NEG=win+DUAL-NEG-1SG-VISUAL

‘They didn’t win (i.e. they lost), I saw it.’ [mrc] (Aikhenvald, 2006:96)

- Politeness

本 を いただきました。
Hon wo itadaki-masi-ta.
Book ACC receive.SHON:—AHON:+-PST

‘(I) received a book.’ [jpn]

Crosslinguistic
variation

Tense encodes the relationship between speech time, event time, and reference time.

- Reference time is determined anaphorically: *I left the oven on!*

present (*Kim leaves*): E, R, S

simple past (*Kim left*): $E, R \prec S$

past perfect (*Kim had left*): $E \prec R \prec S$

simple future (*Kim will leave*): $S \prec E, R$

present perfect (*Kim has left*): $E \prec R, S$

present future (*Kim leaves next week*): $S, R \prec E$

future perfect (*Kim will have left*): $S \prec E \prec R$



(Reichenbach 1947)

Aspect: the description of the internal temporal properties of the event and how it's viewed

- Situation aspect/Aktionsart: Internal structural properties of an event (Vendler 1957)
 - State: *I like semantics.*
 - Activity: *I am studying semantics. I am reading.*
 - Accomplishment: *I read three books.*
 - Achievement: *I found the solution.*
- A linguistic fact, and not a fact about the world. What exactly does *find* lexicalize?



Aspect: the description of the internal temporal properties of the event and how it's viewed

- Major distinction:

- Perfective — an event viewed as completed

I ate the apple before they arrived.



- Imperfective — an event viewed as on-going

I was eating the apple when they arrived.

- Further categories: progressive, persistive, inceptive, habitual, ...
- Some languages (e.g. Mandarin) primarily or only grammaticize aspect, others (e.g. English) primarily or only tense



Grammaticalized politeness can help with reference resolution

- Japanese doesn't show person/number/gender via verbal agreement nor via pronouns (which mostly aren't used)
- Politeness markers can be an important source of info for reference resolution of dropped arguments

本 を いただきました。

Hon wo itadaki-masi-ta.

Book ACC receive.SHON:--AHON:+-PST

‘(I) received a book.’ [jpn]



Information status describes relationship of referents to the common ground







Type id <	Referential <	Uniq. id. <	Familiar <	Activated <	In focus
<i>a N</i>	indefinite <i>this N</i>	<i>the N</i>	<i>that N</i>	<i>that, this</i> <i>this N</i>	<i>it</i>

(Prince 1981, Gundel et al 1993)

- Choice of determiner
- Presence/absence of case marking (e.g. accusative in Turkish, Persian)
- Specific morphology (e.g. Scandinavian)

Information structure distinguishes what the speaker presents as given v. new

- *It must have been Kim who wrote this.*
- What's expressed as given might not be mutually known (can be accommodated) 
- What's expressed as new had better be new: *Who voted for Sandy? #Kim voted for SANDY.* 
- Main distinctions are topic/focus aka theme/rheme aka ...
 - Cross-cutting distinction: contrast (Molnár 2002, Krifka 2008) 
- Marked by: position of constituent, special constructions, special morphology, particles, intonation (Song 2017) 

Information structure can interact with truth conditions



Information structure can interact with truth conditions



Dogs must be carried on this escalator

1. You can ride this escalator only if you are carrying a dog
2. If you are riding this escalator with a dog, then carry it.
3. You can't carry your dog on any escalator other than this one.

1. Dogs_H* must be carried on this escalator ._{LL}%
2. Dogs_{L+H}* _{LH}% must be carried_H on this escalator._{LL}%
3. Dogs_{L+H}*_{LH}% must be carried_{L+H}*_{LH}% on this_H escalator ._{LL}%

(Halliday 1970, Partee 1991)

Outline

- Introduction: What is meaning?
- Lexical semantics
- Semantics of phrases
- **Meaning beyond the sentence**
- Presupposition and implicature
- Resources
- Wrap-up

Understanding meaning in discourse involves updating some representation of what's been said

- Compositional semantics is just the first step (Hobbs 1979)

John took a train from Paris to Istanbul.
He has family there.

- *He* = John; *there* = Istanbul; his family is there now & was when he went; second sentence *explains* the first
- Discourse update: A function $R(D1:n)$, applied to minimal discourse units Dn
- Relies on structured connections between discourse units



Understanding meaning in discourse involves updating some representation of what's been said

- Some points of variation in theories of discourse update
 - Monotonic (Kamp & Reyle 1993) or not (e.g. Asher & Lascarides 2003)
 - Size of the discourse units: whole sentences (Kamp & Reyle 1993), sentence fragments (Poesio & Traum 1998), single words (Kempson et al 2000)
 - A single logic for updating both discourse & the cognitive state of the participants (Sperber & Wilson 1986) or two related ones (Asher & Lascarides 2003)
 - Update has access to syntax & semantics of whole discourse (Kempson et al 2000) or just semantics (Kamp & Reyle 1993, Asher & Lascarides 2003)



Discourse is structured by coherence relations between the contents of discourse segments

- (A) One plaintiff was passed over for promotion three times.
- (B) Another didn't get a raise for five years.
- (C) A third plaintiff was given a lower wage compared to males who were doing the same work.
- (D) But the jury didn't believe this.

- Possible antecedents of *this*?

(Asher 1993)

Discourse is structured by coherence relations between the contents of discourse segments

Three plaintiffs make three claims that they are ill-treated

Elaboration

(A)

Continuation

(B)

Continuation

(C)

- Possible antecedent of *this*: Must be in same discourse segment or in one to which its discourse segment is coherently related

Discourse is structured by coherence relations between the contents of discourse segments

Three plaintiffs make three claims that they are ill-treated

Elaboration

(A)

Continuation

(B)

Continuation

(C)

- Discourse relations can be coordinating (like *Continuation*) or subordinating (like *Elaboration*)
- Arguments of discourse relations can be explicit in the discourse, or accommodated from what's implicit

Discourse is structured by coherence relations between the contents of discourse segments

Three plaintiffs make three claims that they are ill-treated

Elaboration

(A)	—————	(B)	—————	(C)
	<i>Continuation</i>		<i>Continuation</i>	

- Only discourse segments on the “right frontier” are accessible as arguments for further coherence relations
- Here: whole thing, just (C), or just the implicit common thread of (A)-(C)

Discourse is structured by coherence relations between the contents of discourse segments

Three plaintiffs make three claims that they are ill-treated

Elaboration

(A)

Continuation

(B)

Continuation

(C)

- Possible antecedents of *this*?

Not just what's said, but how affects possible coherence relations

- (A) One plaintiff was passed over for promotion three times.
- (B) Another didn't get a raise for five years.
- (C) A third plaintiff was given a lower wage compared to males who were doing the same work.
- (D) In summary, three plaintiffs made three claims.
- (E) But the jury didn't believe this.

- Possible antecedents of *this*?

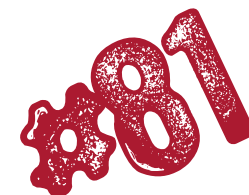


Discourse is too open-ended to assume a priori knowledge of possible signals

- Recent work attempts to model discourse understanding based on game theory (e.g. Wang et al 2016)
- Given signal, what must the speaker's intended message have been?

So, the deal is that I pay you three hundred and sixty-two pounds now plus you don't pay any rent next time you land on any of my greens, my yellows—excluding Leicester Square—or on Park Lane, unless I've built a hotel on it, unless you mortgage something. (BBC4 *Cabin Pressure*)

- Adapting game theory to handle open-ended sets of possible messages and open ended ways of expressing each is an open problem



Reference resolution is more than just finding nouns that are antecedents to pronouns



- Simple pronouns: *A woman walked in. She sat down.*
- Strict v. sloppy readings: *John rode his motorcycle and Alex did too.*
- Bridging: *My car broke down. The engine blew up.*
- Non-noun antecedent: *Who came to the party? Kim. // Where are you going? To buy some milk.*

Reference resolution is more than just finding nouns that are antecedents to pronouns

- Unexpressed antecedent: *I ate well last night. The salmon was delicious.*
- Resolving unexpressed arguments: *What happened to the cake?*

食べた。

Tabē-ta.

eat-PST

‘I ate it.’ [jpn]

- Antecedent is event: *Kim kicked Sandy. It hurt.*
- Antecedent is proposition: *Pat said that Kim kicked Sandy. But Chris didn’t believe it.*



Reference resolution is critical for discourse processing

- MT: Need antecedent to resolve PNG on pronouns
- QA/IE: Need antecedent to know who did what to whom
- Dialogue systems: Cross-turn coref critical for multiturn dialogues
- ...

Coreference is constrained by grammatical factors (hard constraints)

- Person/number/gender

You have a Rover. He is lucky (He \neq you)

John has a Rover. It is red/*They are red.

John has a Rover. He is attractive (He \neq the Rover)

- Binding theory

John bought him a Rover (He \neq John)

He claims that he sold John a Rover (He \neq John)



Coreference is constrained by grammatical factors (soft constraints)

- Recency

John has a Rover. Bill has a Ford.

Mary likes to drive it. (it=Ford)

- Grammatical function: subject > object > oblique-position (Grosz et al., 1995)

John went to the car dealers with Bill.

He bought a Rover. (He=John).

John and Bill went to the car dealers.

He bought a Rover. (He=??)

Coreference is constrained by grammatical factors (soft constraints)

- Repeated mention

John needed a new car.

He decided he wanted something sporty.

Bill went to the car dealers with him.

He bought an MG. (He=John)

- Parallelism (Stevenson et al., 1995)

John telephoned Bill.

He forgot to lock the house. (He=John)

John criticized Bill.

He forgot to lock the house. (He=Bill)



Reference resolution depends on logical form (and which specific LF)

- Formal semantic representations, derived from syntax, are not eliminable (e.g. Partee 1984)

A man walked. He talked.

It's not the case that every man didn't walk. #He talked.

Exactly one of the ten balls is not in the bag.

It's under the sofa.

Exactly nine of the ten balls are in the bag.

#It's under the sofa.



Solutions: DRT (Kamp & Reyle 1993),
dynamic logic (Groenendijk and Stokhof 1991)

Reference resolution depends on discourse structure

John had a great evening last night.
He had a lovely meal.
He ate salmon.
He devoured lots of cheese.
He won a dancing competition.
#It was a beautiful pink.



(Asher & Lascarides 2003)

Reference resolution depends on discourse structure

John had a lovely evening

Elaboration

He had a
great meal

He won a
dancing competition

Narration

Elaboration

He ate salmon

He devoured cheese

Narration

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Utterances entail things and presuppose things

- Kim's cousin took an aspirin
 - Someone took an aspirin — ENTAILED
 - Kim has a cousin — PRESUPPOSED
 - There's someone called Kim — PRESUPPOSED



Tests for entailment v. presupposition

- Presuppositions project from embedding contexts that entailments do not:

It's not the case that Kim's cousin took an aspirin.

I believe that Kim's cousin took an aspirin.

It's possible that Kim's cousin took an aspirin.

If the bathroom cabinet door is open,
then Kim's cousin took an aspirin.



- Apply carefully, though: presuppositions can be cancelled or filtered (Gazdar 1979)

If Kim has a cousin, then Kim's cousin took an aspirin.

It's not the case that Kim's cousin took an
aspirin—Kim hasn't got a cousin.

Presupposition triggers are bits of linguistic form — and they are heterogenous

- Lexical items: *know, regret, forget, manage (to), lie*
- Proper names, definite descriptions, possessives: *Kim, the cat, Kim's cousin*
- Iterative adverbs: *also, again, too*
- Ordinals: *second, third*
- Domain of quantification: *all the kids are happy*
- Focus: *wh-* questions, *it* clefts, focal stress



Some linguistic contexts pass presuppositions up, others don't, and with others it depends



- Holes pass them up:

Kim doesn't know it's raining.

I doubt Kim knows it's raining.

- Plugs stop them from projecting:

Sara says she knows it's raining.

- With filters, it depends:

If Sara is married, her husband is bald.

If Sara lives in Paris, her husband is bald.

- Structure provided by compositional semantics is key in all three cases.

(Karttunen 1973)

Conversational implicatures are calculable from what is said

- If an utterance appears to violate one of the Gricean maxims, hearer can reason on the basis of the assumption that the speaker is actually being cooperative

Maxim of Quality: Do not say what you believe to be false; do not say that for which you lack adequate evidence.

Maxim of Quantity: Make your contribution as informative as is required (for the current purposes of the conversation); do not make it *more* informative than is required.

Maxim of Relation: Be relevant.

Maxim of Manner: Avoid obscurity of expression; avoid ambiguity; be brief; be orderly.

(Grice 1975)

Conversational implicatures are calculable from what is said

A: Did the students pass the exam?

B: Some of them did.

A: I'm out of gas.

B: There's a gas station around the corner.

A: Are you coming out tonight?

B: I have to work.

Grandma fell and broke her leg.



Conversational implicatures are cancellable

A: Did the students pass the exam?

B: Some of them did; in fact all of them did.

A: I'm out of gas.

B: There's a gas station around the corner, but it's closed.

A: Are you coming out tonight?

B: I have to work, but I'll come out anyway.

Grandma fell and broke her leg, but not in that order.



Agreement and denial can be implicated



- Implicated denial (Schlöder & Fernandez 2015, Walker 1996):

A: We're all mad, aren't we?	$\forall x.M(x)$
B: Well, some of us.	$\exists x.M(x)$
\rightsquigarrow <i>Not all of us</i>	$\rightsquigarrow \neg \forall x.M(x)$

A: He's brilliant and imaginative.

B: He's imaginative

- Implicated agreement (Sacks et al 1974):

Mark (to Karen and Sharon): Karen 'n' I're having a fight,
after she went out with Keith and not me.

Karen (to Mark and Sharon): Wul Mark, you never asked me out.

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Lexical resources: Sense, semantic roles

- English WordNet: Synsets (sets of forms that share a meaning) linked by lexical relations: hypernymy, meronymy, troponymy, antonymy (Miller 1990)
 - <https://wordnet.princeton.edu/>
- Open Multilingual WordNet: WordNets for 34 languages, all linked to the Princeton English WordNet (Bond and Paik 2002)
 - <http://compling.hss.ntu.edu.sg/omw/>



Lexical resources: Sense, semantic roles



- FrameNet (English): 1,200 semantic frames, with frame elements, linked to annotated data and word senses (Baker et al 1998)
 - <https://framenet.icsi.berkeley.edu/fndrupal/>
- Multilingual FrameNet: <https://framenet.icsi.berkeley.edu/fndrupal/node/5549>
- VerbNet (English): Extends Levin's (1993) verb classes, includes semantic role annotation, and links to FrameNet and WordNet (Kipper et al 2008)

Resources for sentence-level semantic information

- PropBank: Predicate-argument relations on top of English PTB trees (Palmer et al 2005)
 - Other languages: Hindi (Palmer et al 2009), Chinese (Xue & Palmer 2009), Arabic (Zaghouani et al 2010), Finnish (Haverinen et al 2015), Portuguese (Duran et al 2012), Basque (Aldezabal et al 2010), Turkish
- NomBank: like PropBank, but for argument-taking nouns (Meyers et al 2004)
- OntoNotes: PropBank + word sense + links to ontology + coreference (Hovy et al 2006)



Resources for sentence-level semantic information

- Redwoods: grammar-derived, hand-disambiguated Minimal Recursion Semantics representations for English (Oepen et al 2002, Flickinger et al 2017)
 - Other languages: Japanese (Bond et al 2004), Spanish (Marimon 2015)
- AMR Bank: non-compositional semantic representations for English, with predicate argument structure + word sense and coref
 - Other languages: Chinese (Xue et al 2014), Czech (Xue et al 2014)



Parsers that produce semantic representations

- English Resource Grammar (Flickinger 2000, 2011): HPSG + MRS
- Jacy grammar of Japanese (Siegel et al 2016): HPSG + MRS
- Boxer (Bos 2015): CCG + DRS for English
- + parsers trained on treebanks



Corpora annotated with discourse information

- Penn Discourse Treebank (English, Chinese): explicit and implicit discourse connectives (Miltsakaki et al 2004, Xue et al 2005)
- RST Treebank (English, Spanish, Basque): Rhetorical Structure Theory discourse relations (Carlson et al 2001, Irukieta et al 2015)
- ANNODIS (French): rhetorical relations and topical chains (Afantenos et al 2012)



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Wrap up

- What was something surprising that came up today?
- What are you most confident you'll remember?
- How might you apply something you learned today?

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