Computational Psycholinguistics

Lecture 10: Computational Language Acquisition

Afra Alishahi

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Human Language Acquisition

- Representation of the linguistic knowledge
  - What is innate, what is learnable?
  - How is the knowledge organized in mind and brain?
    - Are there separate areas/levels for representing lexical/syntactic/semantic knowledge?
- Acquisition of the linguistic knowledge
  - What are the processes involved in language learning?
  - Are different types of knowledge acquired in order?

Learnability in Acquisition

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Modularity in Acquisition

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Syntax vs. Semantics

- How is the surface structure (i.e., syntax) linked to the underlying meaning (i.e., semantics)?
  - Alternative 1: syntax is learned independently of semantics
  - Alternative 2: syntax and semantics are learned at the same time
- A suitable case study: verb argument structure
  - The relationship between the semantics of verbs and their syntactic form

Verb Argument Structure

- Knowledge of verb argument structure:
  - *Number* and *type* of arguments that the verb takes
    - *The man built the house*
    - **The man built, *The house built the man*
  - *Semantic roles* that verb arguments receive in an event
    - *She<Agent> broke the window<Theme>, The window<Theme> broke*
    - **She<Agent> broke*
  - *Syntactic realization* of the verb and its arguments
    - *I filled the glass with water*
    - **I filled water into the glass*

General Regularities

- Challenges of argument structure acquisition:
  - Detecting general regularities: young children are aware of a general mapping between syntactic forms and semantic elements

    bunny gorped duck ⇒ causal action?

    kitty blicked down the street ⇒ manner of motion?

  - Learning idiosyncrasies: highly similar verbs (e.g. *load, fill, pour*) have different syntactic behaviour

    *I filled the glass with water, *I filled water into the glass*

    **They loaded the truck with hay, They loaded hay into the truck*

Mapping of Syntax to Semantics

- Semantic Bootstrapping (Pinker, 1984)
  - The syntactic behaviour of a verb is innately determined by the decompositional representation of its meaning
    - *Agent* is 1st argument of CAUSE, *Theme* is 1st argument of GO & BE, *Patient* is 2nd argument of CAUSE.
  - With the innate knowledge of the mapping between semantics and syntax, a child can predict the correct mapping once she knows what a verb means
- It fails to explain recent experimental findings.

Experimental Findings

- Item-based learning:
  - Young children build their linguistic knowledge around individual items
  - Two year olds show little tendency to apply syntactic structures they have already learned to new verbs
  - Tendency to generalize familiar constructions to new forms increases as children grow older

➡ Verb-Island Hypothesis (Tomasello, 1992)

U-shaped Learning Curve

- Observed U-shaped learning curves in children
  - Imitation: an early phase of conservative language use (each verb is used in the constructions it has been seen in before)
  - Generalization: knowledge of general regularities is acquired and applied to new forms
  - Overgeneralization: occasional mis-application of general patterns, which leads to errors
  - Recovery: over time, overgeneralization errors cease to appear in child speech

Imitation & Generalization

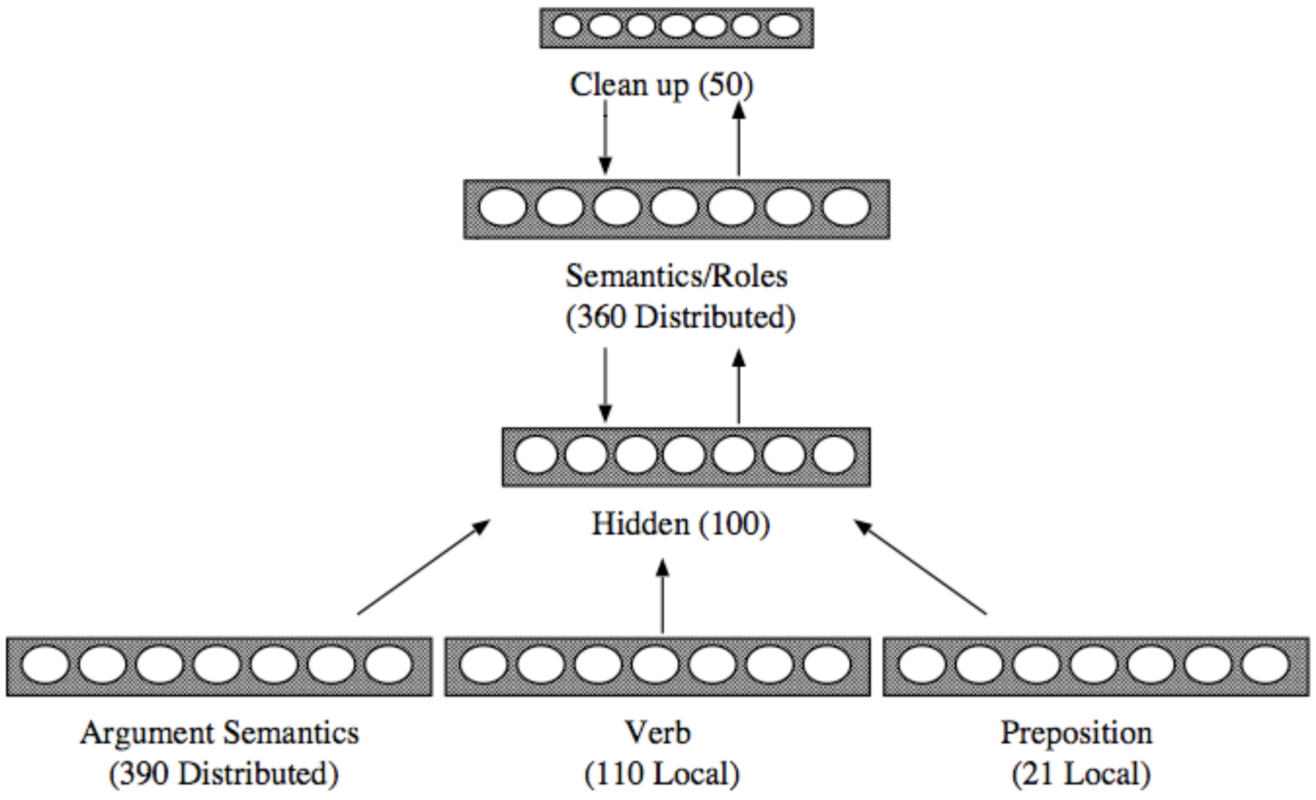
- Akhtar's (1999) experiment
  - 2-4 years old children were taught novel verbs in non-standard English word order (e.g., SOV)

    Look! Bunny duck gorped.

  - In elicited production, 2 and 3-year-olds imitated the observed pattern half the time and "corrected" to the English SVO pattern half the time.
  - 4-year-olds rarely imitated the observed order, almost always correcting to the SVO order

Computational Generalization

- Computational models of learning general regularities from input data
  - Emergence of abstract knowledge from exposure to a number of instances (McClelland & Kawamoto, 1986; Allen 1997)
  - Allen (1997):



Overgeneralization & Recovery

- Overgeneralization errors happen in different domains of language
  - English past-tense: *I goed*
  - Argument structure: *You can drink me the milk*
- Consistent patterns among children:
  - For a given form, errors are few at the early steps
  - Number of errors increase as general patterns emerge
  - After a while errors decrease again

Lack of Negative Evidence

- Negative evidence
  - Information about which strings of words do not belong to language (corrective feedback from parents)
- Marcus (1993): there is no reliable negative evidence available to children
  - Some suggest that, even if corrective feedback is provided, children ignore it.
- Recovery from overgeneralization must occur *without* relying on negative evidence

Recovery Mechanisms

- Many learning mechanisms are suggested as factors in recovery from overgeneralization (Goldberg, 1999; MacWhinney, 2004)
  - Entrenchment, competition, cue construction, ...
- Recently, probabilistic interaction between various factors is suggested as a solution (Onnis et al., 2002; Alishahi & Stevenson, 2008)
  - The frequencies of verbs and general constructions
  - Semantic match between a construction and an event

Productive Generalization

- Children eventually stop overgeneralizing, but productive use of language continues through adulthood:

    The truck rumbled down the hill.

    The fly buzzed into the room.

- Alternative: Construction Grammar (Lakoff 1987, Fillmore et al. 1988, Langacker 1999)
    - In addition to the idiosyncratic meanings associated with individual words or morphemes, meaning may also be *directly* associated with syntactic forms

Construction Grammar

- Argument structure construction (Goldberg, 1995)
  - A mapping between underlying verb-argument relations and the syntax used to express them

$Subj\ V\ Obj\ Obj2 \Leftrightarrow X\ cause\ Y\ receive\ Z$ Example: *Pat faxed Bill the letter.*
$Subj\ V\ Oblique \Leftrightarrow X\ move\ Y$ Example: *The fly buzzed into the room.*

How are Constructions Learned?

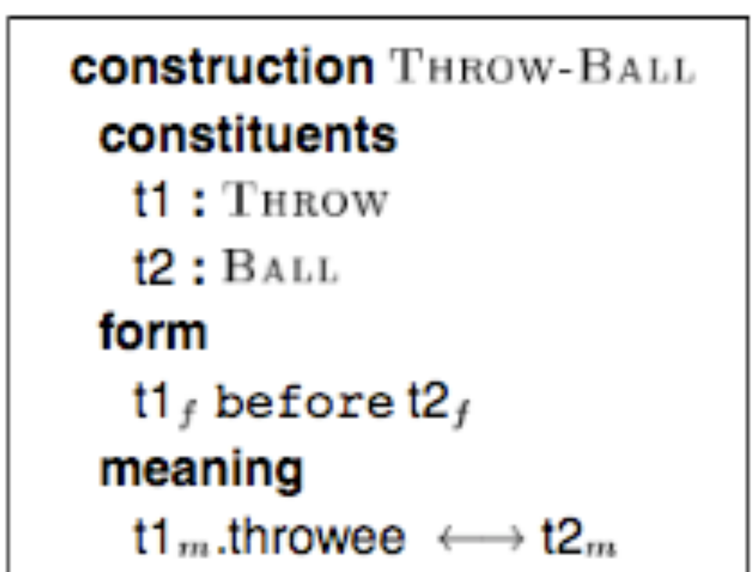
- Tomasello (1991):
  - Argument structure patterns are initially acquired on a verb-by-verb basis
  - Constructions associated with the common syntactic patterns are learned through a process of categorization and generalization over the input.
- Goldberg (1995):
  - Constructional meaning is formed around the meanings of highly frequent *light verbs*
  - E.g., the construction "Subj V Obl" paired with the meaning "X moves Y" corresponds to the light verb *go*

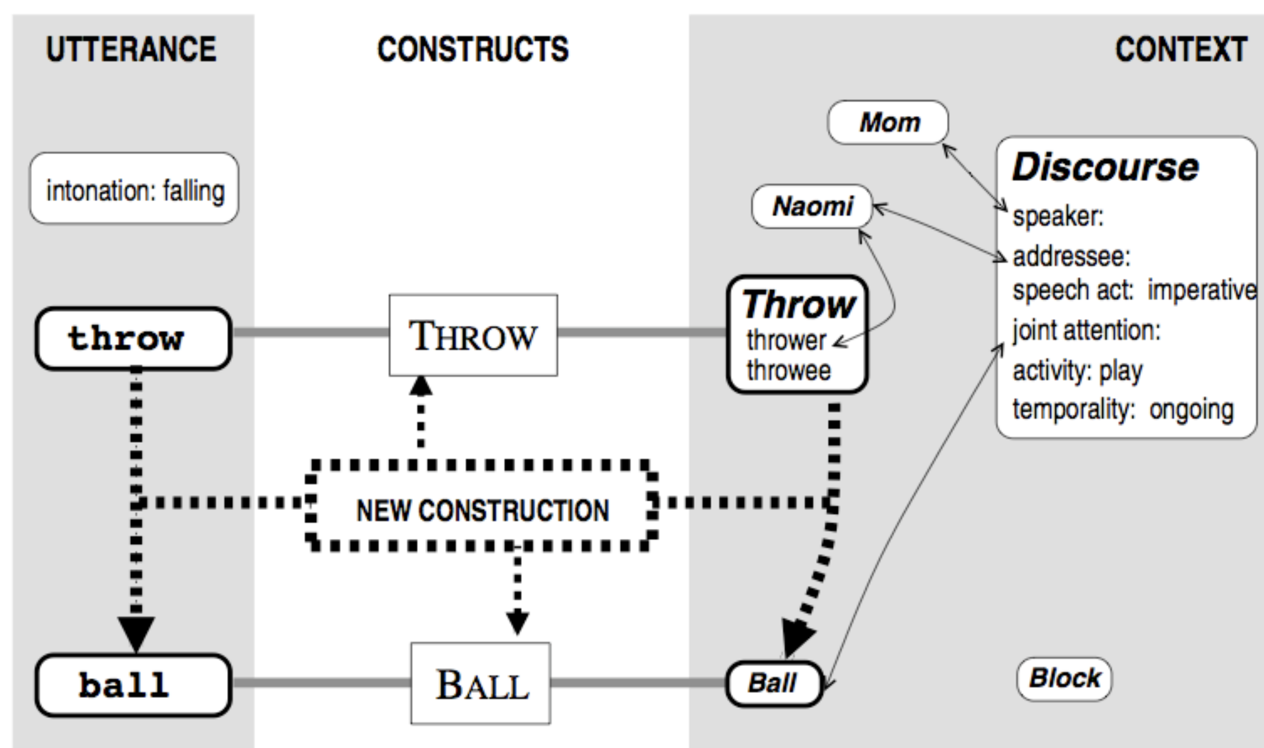
Computational Models of Constructions

- FrameNet (Baker, Fillmore, Low, 1998): a database of lexical constructions (or frames)
- The acquisition of constructions
  - Learning lexical constructions (Chang, 2004)
  - Learning verb meaning from image data (Dominey, 2003; Dominey & Inui, 2004)
  - Learning abstract constructions from verb usage data (Alishahi & Stevenson, 2008)

Chang (2004)

- A model for learning lexical-based multi-word constructions from child-directed data
  - Goal: learn associations between form and meaning relations
  - Learning task: finding the best grammar to fit the observed data





Alishahi & Stevenson (2008)

- A Bayesian, usage-based model of early argument structure acquisition
  - Each verb usage is viewed as a set of features
  - Constructions are viewed as a probability distribution over syntactic and semantic features
  - A Bayesian clustering method detects and groups similar usages to form constructions

Alishahi & Stevenson (2008)

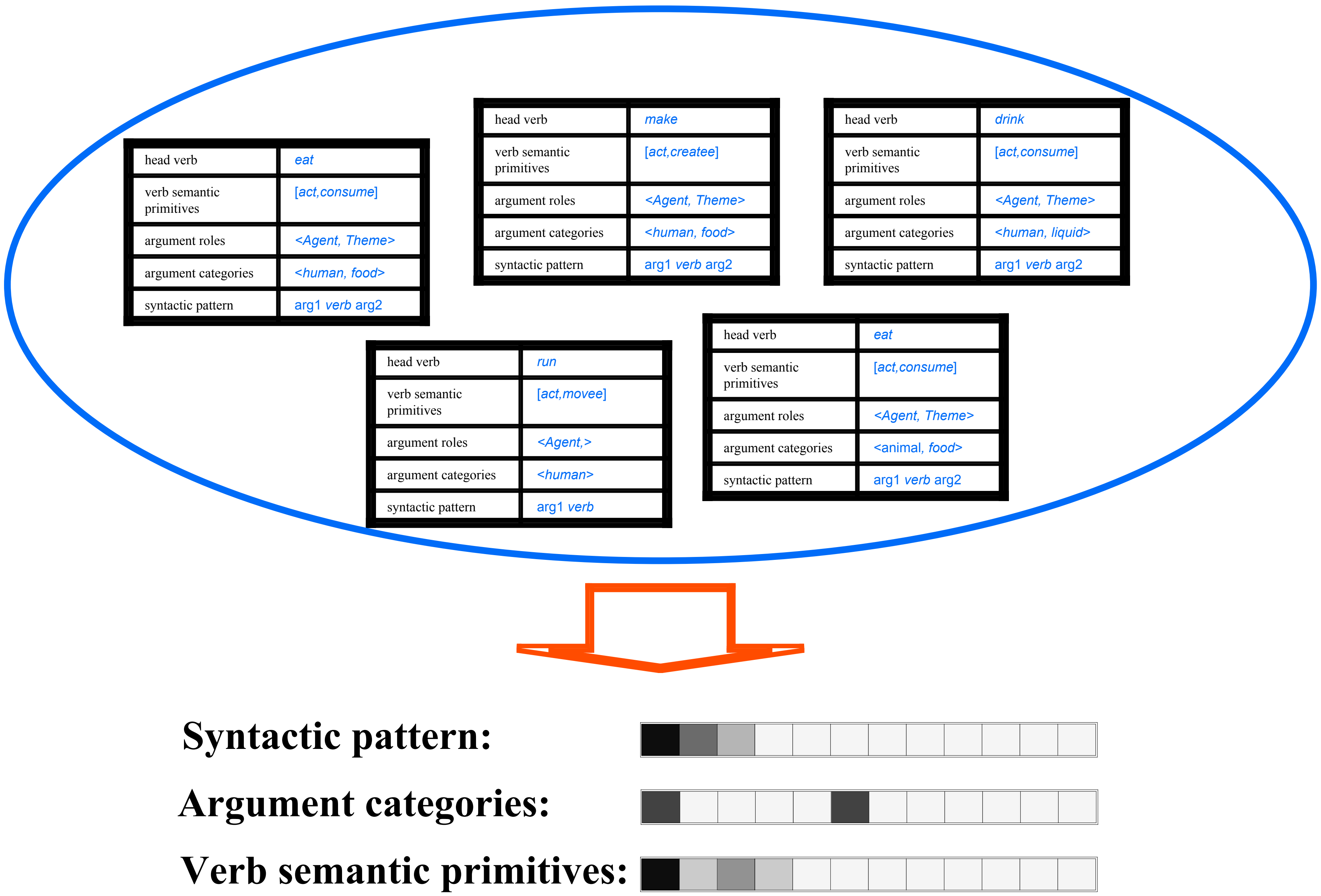
- Verb usages as argument structure frames:

Sara is eating an apple

head verb	*eat*
verb semantic primitives	[*act,consume*]
argument roles	<*Agent, Theme*>
argument categories	<*human, food*>
syntactic pattern	arg1 *verb* arg2

Alishahi & Stevenson (2008)

- Constructions as clusters of similar frames:



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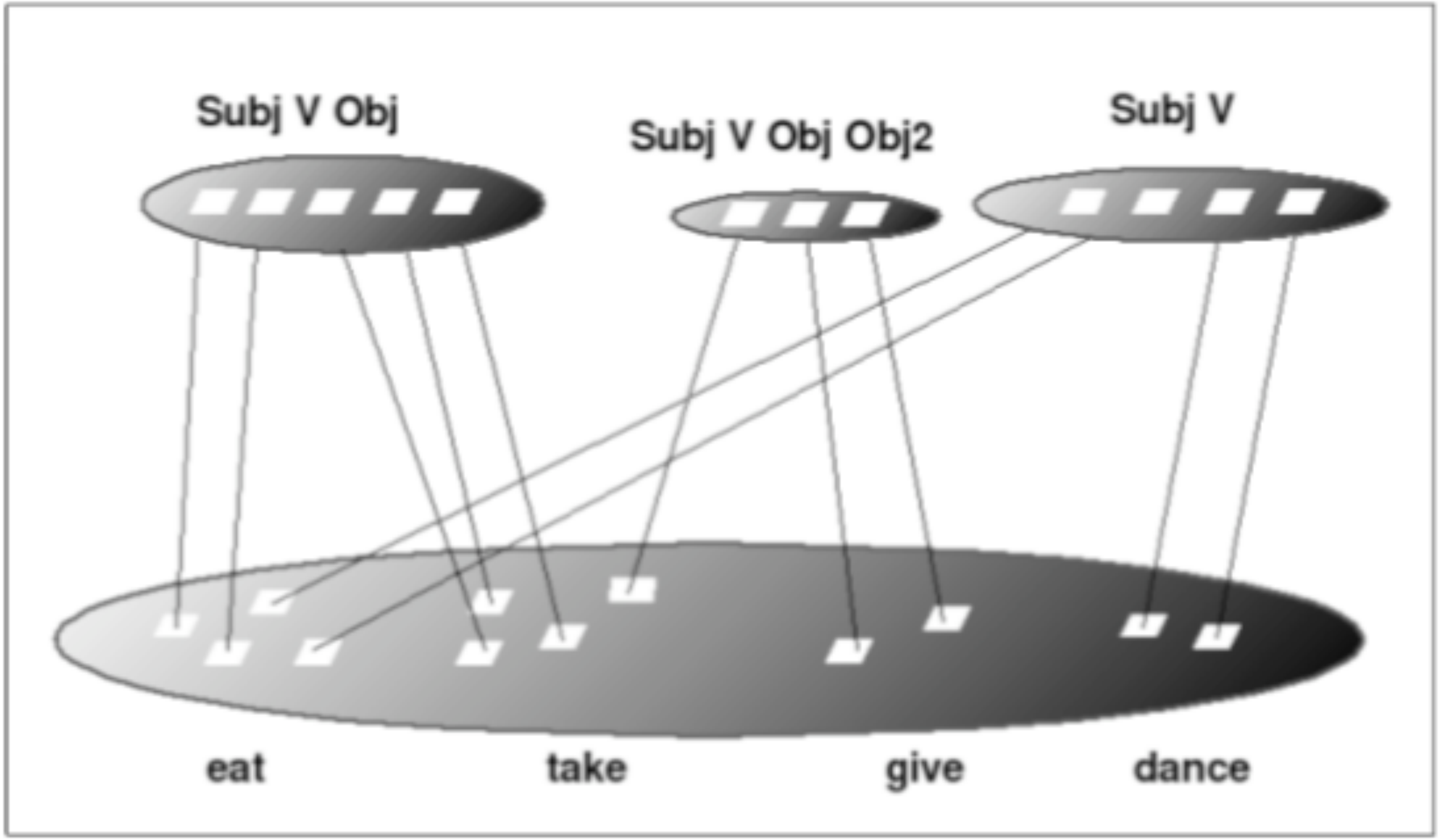
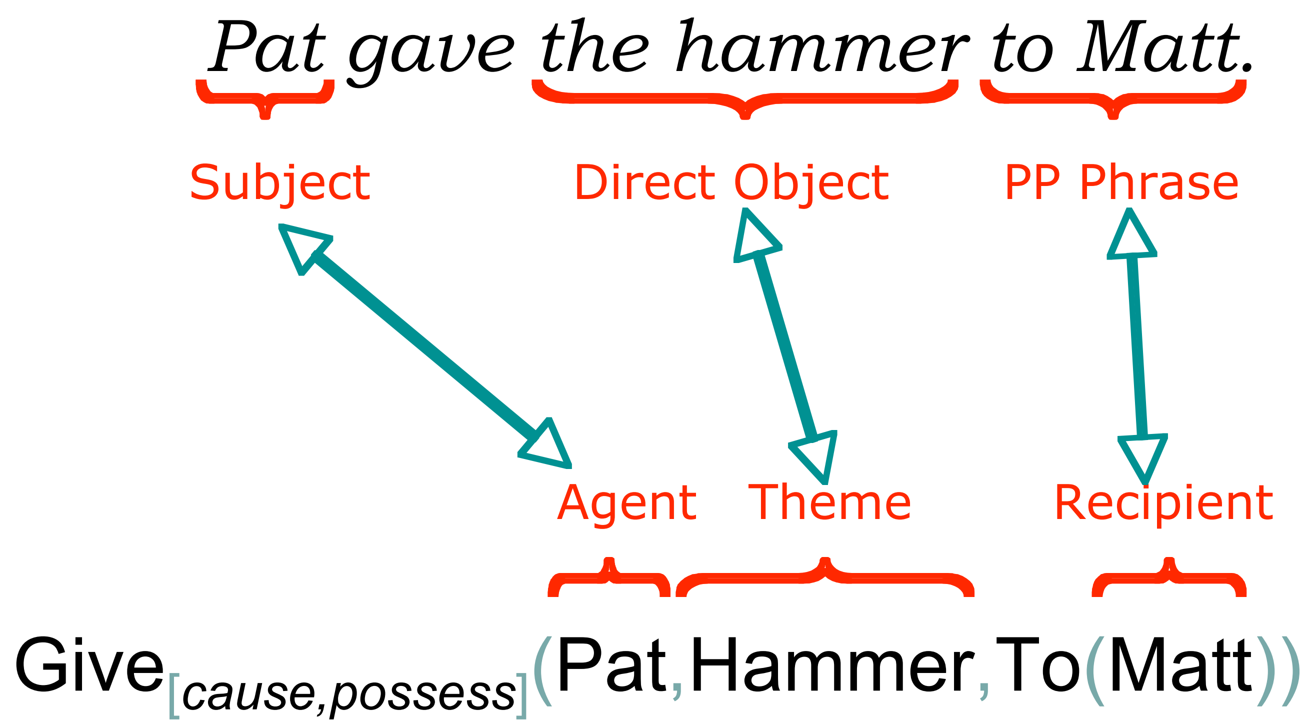


Verb Semantic Roles

- Semantic (thematic) roles, such as Agent, Theme and Instrument, indicate the relations of the participants in an event to the main predicate

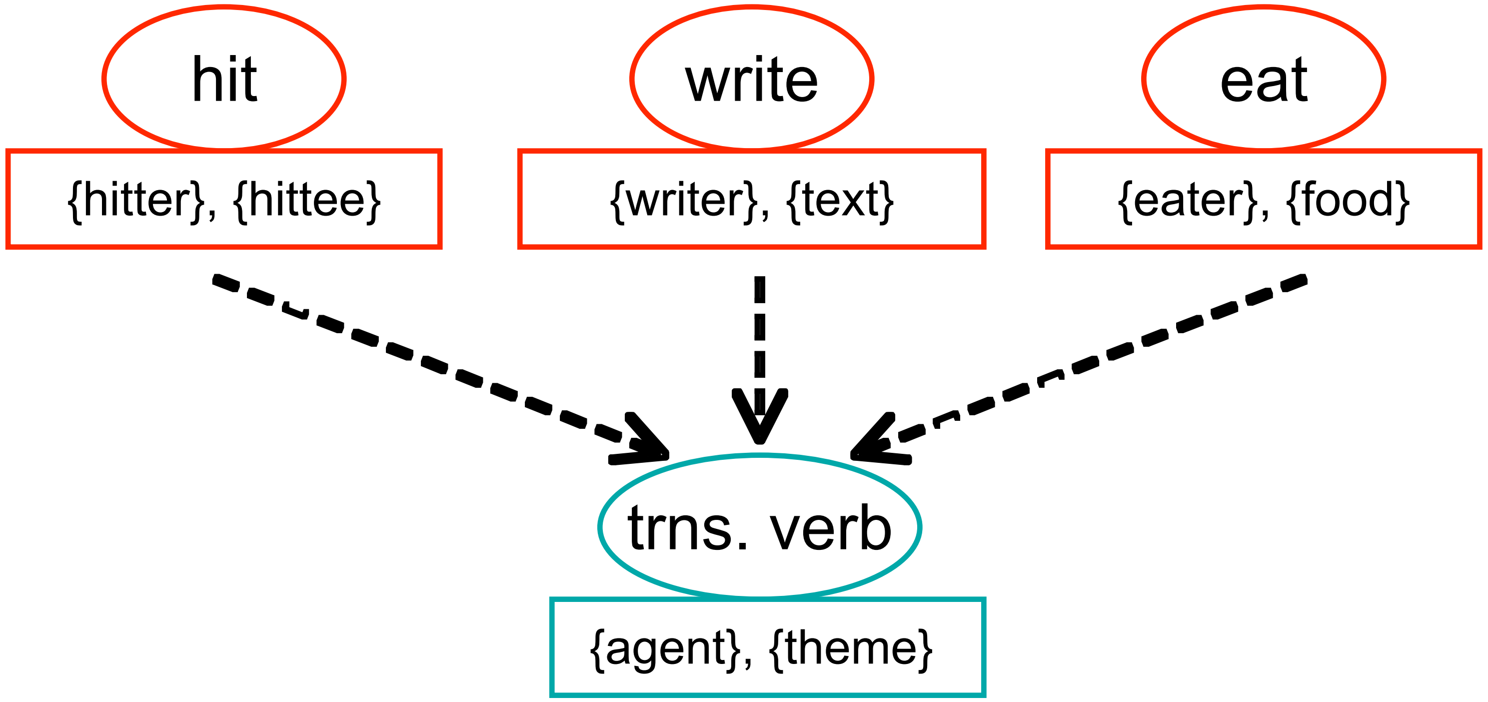


Main Questions

- What is the nature of semantic roles?
  - Traditional view: roles are atomic and universal, such as Agent, Theme, Goal, … (e.g., Jackendoff 1990)
  - Proto-role Hypothesis (Dowty, 1991): roles are a set of properties, such as volitional, affecting, animate
- Where do they come from?
  - Traditional view: roles and their link to syntactic positions are innate (e.g., Pinker 1989)
  - Alternative view: they are gradually learned from verb usages (e.g., Tomasello 2000)

Learnability of Thematic Roles

- Usage-based account: verb-specific roles change to general roles over time



- Experimental evidence confirms that access to general roles such as Agent and Theme is age-dependent (Shayan & Gershkoff-Stow, 2007)

Linking Semantic Roles to Grammatical Functions

- Children are sensitive to the association between semantic roles (e.g. Agent) and grammatical functions (e.g. Subject) from an early age
  - Fisher 1994, 1996; Nation et al., 2003
- Nativist account: innate “linking rules” that map roles to sentence structure enable children to infer associations between role properties and syntactic positions (e.g., Pinker, 1989)

Computational Studies of Roles

- Assignment of general pre-defined roles to sentence constituents
  - E.g., McClelland and Kawamoto (1986), Allen (1997)
- Role learning
  - Learning verb-specific roles from annotated data (Chang 2004)
  - Discovering relational concepts from unstructured examples (Kemp et al., 2006; Doumas et al., 2008)
  - Acquiring semantic profiles for general roles from verb usages (Alishahi & Stevenson, 2008)

Open Questions

- How various aspects of language acquisition interact with each other?
  - Various learning procedures are most likely interleaved (e.g., word leaning and syntax acquisition)
  - Most of the existing models of language acquisition focus on one aspect, and simplify the problem
- How to evaluate the models on realistic data?
  - Large collections of child-directed utterances/speech are available, but no such collection of semantic input