

# Semantic Theory

## Lecture 13 – Lexical Semantics IV

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## Davidsonian Event Semantics

(1) *The gardener killed the baron at midnight in the park*  
 $\Rightarrow \text{kill}_4(g, b, m, p)$

(2) *The gardener killed the baron at midnight*  
 $\Rightarrow \text{kill}_3(g, b, m)$

(3) *The gardener killed the baron in the park*  
 $\Rightarrow \text{kill}_2(g, b, p)$

(4) *The gardener killed the baron*  
 $\Rightarrow \text{kill}_1(g, b)$

■ **Davidson's solution:**  
 $\exists e[\text{kill}'(e, g, b) \wedge \text{time}(e, m) \wedge \text{location}(e, p)]$

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## A Related Problem?

(1) a. *John broke the window with a rock*  
b. *A rock broke the window*  
c. *The window broke*

$\text{break}_3(\mathbf{j}, \mathbf{w}, \mathbf{r}) \models \text{break}_2(\mathbf{r}, \mathbf{w}) \models \text{break}_1(\mathbf{w})$

(2) a. *John flew Bill with the plane to Frankfurt*  
b. *John flew by plane to Frankfurt*  
c. *The plane flew to Frankfurt*

$\text{fly}_4(\mathbf{x}, \mathbf{y}, \mathbf{z}, \mathbf{u}) \models \text{fly}_3(\mathbf{z}, \mathbf{y}, \mathbf{u}) \models \text{fly}_2(\mathbf{y}, \mathbf{u})$

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## A Related Problem?

- The number of overtly realized arguments can vary, but there is a maximum verb-specific set of arguments.
- The arguments under consideration are (typically) realized as complements, not as free adjuncts.
- One syntactic complement type can bind different „argument positions“ – one argument position can be realized through different complement types.
- More precisely: The same **argument grid** of the verb can be realized through **different syntactic patterns**.
- The relation between predicate-argument structure and possible syntactic realizations is **verb-specific**.

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## Syntactic Alternations are Verb-specific

- (1) a. *John broke the window*  
b. *The window broke*
- (2) a. *Margaret cut the bread*  
b. *\*The bread cut*
- (3) a. *The butcher cuts the meat*  
b. *The meat cuts easily*
- (4) a. *Joan knew the answer*  
b. *\*The answer knows easily*

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## Beth Levin's Verb Classes

<i>Margeret cut the bread</i>	<b>Middle alternation</b>
<i>Janet broke the vase</i>	<i>The bread cuts easily</i>
<i>Terry touched the cat</i>	<i>Crystal vases break easily</i>
<i>Carla hit the door</i>	<i>*Cats touch easily</i>
	<i>*Doors hit easily</i>
<b>Conative alternation</b>	<b>Body-part possessor ascension alternation</b>
<i>Margeret cut at the bread</i>	<i>Margeret cut Bill on the arm</i>
<i>*Janet broke at the vase</i>	<i>*Janet broke Bill on the finger</i>
<i>*Terry touched at the cat</i>	<i>Terry touched Bill on the shoulder</i>
<i>Carla hit at the door</i>	<i>Carla hit Bill on the back</i>

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## Beth Levin's Verb Classes

- Different verbs are subject to different alternation patterns.
- Verbs sharing their alternation patterns form semantic classes.
  - Cut verbs: *cut, saw, scrape, scratch, ...*
  - Break verbs: *break, split, tear, ...*

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## Modeling Syntactic Alternations 1<sup>st</sup> attempt

(1) *John broke the window with a rock*  
⇒  $\text{break}(j, w, r)$

(2) *A rock broke the window*  
⇒  $\exists x \text{break}(x, w, r)$

(3) *The window broke*  
⇒  $\exists x \exists y \text{break}(x, w, y)$

Express the semantic relation between different syntactic realizations through

- canonical argument ordering
- existential binding of unfilled argument positions

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## Semantic Roles

- The key for modeling this kind of phenomena is the notion of a **semantic role** (introduced by Charles Fillmore in the late sixties).
- Terminology:
  - “deep cases” (in contrast to “surface cases” of syntax)
  - “thematic roles”
  - “semantic roles”
- Examples:
  - (1) [*John*]<sub>ag</sub> *broke* [*the window*]<sub>pat</sub> [*with a rock*]<sub>inst</sub>
  - (2) [*A rock*]<sub>inst</sub> *broke* [*the window*]<sub>pat</sub>
  - (3) [*The window*]<sub>pat</sub> *broke*

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## What are Thematic Roles?

- Fillmore: understanding a verb (or any other predicate) means to know the situation type or conceptual schema associated with or evoked by it.
- Part of the situation type or conceptual schema are typical participants, persons or objects that play a specific role in the event or action expressed by the predicate.
- In standard logical terms, these participants are just the logical arguments of the predicate.
- Thematic roles are indices expressing the specific contribution of the participants to the situation, or their semantic status of the arguments with respect to the described conceptual schema.

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## Roles and Predicate Logic

- In standard FOL, the relation of the members of the argument set to the predicate in a predicate-argument structure can be expressed by their (canonical) order:
  - First argument position is filled by the agent
  - second by the patient, etc.
- For instance:
  - $\text{break}(j, w, r)$
  - $\exists x \text{break}(x, w, r)$
  - $\exists x \exists y \text{break}(x, w, y)$

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## Roles and Predicate Logic

- We can use role indices to explicitly mark the status of the argument positions:
  - $\text{break}(j_{\text{ag}}, w_{\text{pat}}, r_{\text{inst}})$
- Equivalently, we can encode arguments as feature structures:
  - $\text{break}([\text{ag}: j; \text{pat}: w; \text{inst}: r])$

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## Roles and Predicate Logic

- **Alternative option:** Treat complements analogously to adjuncts in Davidsonian Semantics.
- Thematic roles are two-place relations between the event denoted by the verb, and an argument role filler.
- The event verb itself is just a one-place predicate taking an event as argument.
- For instance:
  - (1) *John broke the window with a rock*  
 $\Rightarrow \exists e [\text{break}(e) \wedge \text{ag}(e, j) \wedge \text{pat}(e, w) \wedge \text{inst}(e, r)]$
  - (2) *The gardener killed the baron at midnight in the park*  
 $\Rightarrow \exists e [\text{kill}(e) \wedge \text{ag}(e, g) \wedge \text{pat}(e, b) \wedge \text{time}(e, m) \wedge \text{loc}(e, p)]$

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## What are roles good for?

- (1) *John broke the window with a rock*  
 $\Rightarrow \exists e [\text{break}(e) \wedge \text{ag}(e, j) \wedge \text{pat}(e, w) \wedge \text{inst}(e, r)]$
  - (2) *A rock broke the window*  
 $\Rightarrow \exists e [\text{break}(e) \wedge \text{pat}(e, w) \wedge \text{inst}(e, r)]$
  - (3) *The window broke*  
 $\Rightarrow \exists e [\text{break}(e) \wedge \text{pat}(e, w)]$
- (1)  $\models$  (2)  $\models$  (3)
  - Thematic roles capture syntactic verb alternations: equivalent uses with different realization of “the same” semantic argument positions.

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## Selectional Preferences

- Thematic roles allow for a more appropriate description of selectional preferences / constraints.
- For instance ...
  - The subject of break is either animate or solid object or breakable object
  - The agent of break is animate
  - Generalization: Agent is animate

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## Modeling cross-lexical relations

- (1) a. John **likes** Mary  
b. Mary **pleases** John
- (2) a. Mary **gave** Peter the book  
b. Peter **received** the book from Mary
- (3) a. The gardener **killed** the baron  
b. The baron **died**

Role semantics does not only relate different uses of the same predicate, but relates different predicates, which describe the same situation type.

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## Modeling cross-lexical relations

- Thematic roles capture equivalences and entailment relations between different predicates with different syntactic realization patterns:

(1) Mary gave Peter the book  
 $\Rightarrow \exists e [give(e) \wedge ag(e,m) \wedge pat(e,b) \wedge rec(e,p)]$

(2) Peter received the book from Mary  
 $\Rightarrow \exists e [receive(e) \wedge ag(e,m) \wedge pat(e,b) \wedge rec(e,p)]$
- $\forall e [give(e) \leftrightarrow receive(e)] \models (1) \leftrightarrow (2)$

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## Roles in Semantic Construction

- How do we get from a surface sentence to its role-semantic representation?
  - $give \Rightarrow \lambda y \lambda z \lambda x \lambda e [give(e) \wedge ag(e,x) \wedge pat(e,y) \wedge rec(e,z)]$
  - $receive \Rightarrow \lambda z \lambda x \lambda y \lambda e [receive(e) \wedge ag(e,x) \wedge pat(e,y) \wedge rec(e,z)]$
- Not a good idea. We should exploit role information for composition.
- Two tasks:
  - **Role Linking:** How can syntactic relations between verb and arguments be mapped to thematic roles?
  - **Semantic Construction:** How can we integrate role information in type-logical semantics?

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## Role Linking

- Part of the linking process is regular. For instance:
  - An overt agent always becomes subject.
  - If there is no overt agent, the instrument becomes subject.
  - If there is neither agent or instrument, the theme becomes subject.
- Linguistic grammar theories try to describe role linking as a systematic process, which is part of the grammar, working, e.g., with “obliqueness hierarchies”.
- Problem: Linking has really unsystematic and idiosyncratic aspects.

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## Semantic Composition

Use role information to drive semantic composition:

- Index  $\lambda$ -variables with role labels.
- Index complements with role labels.
- Impose identity of role indices as an additional condition on conversion.
- Then do away with the ordering of the variables in the  $\lambda$ -prefix: It's not needed anymore.

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## Order-free $\lambda$ -Abstraction

- $\text{give} \Rightarrow \lambda\{x_{\text{ag}}, y_{\text{pat}}, z_{\text{rec}}, e_{\text{ref}}\}.\text{give}(e) \wedge \text{ag}(e, x) \wedge \text{pat}(e, y) \wedge \text{rec}(e, z)$
- $\text{receive} \Rightarrow \lambda\{x_{\text{ag}}, y_{\text{pat}}, z_{\text{rec}}, e_{\text{ref}}\}.\text{receive}(e) \wedge \text{ag}(e, x) \wedge \text{pat}(e, y) \wedge \text{rec}(e, z)$
- **Application:**  
 $\text{give}'(\text{the-book}'_{\text{pat}})(\text{mary}'_{\text{rec}})(\text{john}'_{\text{ag}})$
- **$\beta$ -reduction:**  
 $[\lambda X.\alpha](\beta_r) \Leftrightarrow \lambda(X-\{x_r\}).[\beta/x]\alpha$ , if  $x_r \in X$ .
- **Additional clause:**  
 $\lambda\emptyset.\alpha \Leftrightarrow \alpha$

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## Order-free $\lambda$ -Abstraction

- Note: The result of the application is independent of the order in which the arguments occur.
- Generalization: Simultaneous application and reduction:
- $[\lambda X.\alpha](\{\beta_{i1}, \dots, \beta_{in}\}) \Leftrightarrow \lambda(X-\{x_{i1}, \dots, x_{in}\}).[\beta_{i1}/x_{i1}, \dots, \beta_{in}/x_{in}]\alpha$   
if  $\{x_{i1}, \dots, x_{in}\} \subseteq X$ .

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## What is the appropriate role inventory?

- According to Fillmore (1968), thematic roles form a small, closed, and universally applicable inventory conceptual argument types.
  - A typical role inventory might consist of the roles: Agent, Theme (Patient, Object), Recipient, Instrument, Source, Goal, Beneficiary, Experiencer.
- But: A closed inventory of 8 or 12 or even 20 roles is not sufficient to describe the wealth of predicate-argument relations.

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## Possible Answers

- Use a separate role inventory for every lemma (PropBank).
- Frame-based role inventories (C. Fillmore, FrameNet)

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## Frame Semantics

- Structured schemata representing complex prototypical situations, events, and actions are the basic inventory for the conceptual modelling of the world. These are called frames.
- Frames are „evoked“ by NL expressions, typically content words (also called **frame-evoking elements** or **target words**).
- Thematic roles are neither universal nor lemma-specific: Role specifications have local validity for the target words of a frame (therefore also called **frame elements**).

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## FrameNet

- (1) [*Agent Lufthansa*] is replacing<sub>Frame: REPLACING</sub> [*Old its 737s*]  
[*New with Airbus A320s*]
- (2) [*Agent Lufthansa*] is substituting<sub>Frame: REPLACING</sub>  
[*New Airbus A320s*] [*Old for its 737s*]
- (3) [*Frame REPLACING*]  
[*Agent Lufthansa*  
*Old its737s*  
*New AirbusA320s*]

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## An Example

- (1) Airbus sells five A380 planes to China Southern for 220 million Euro
- (2) China Southern buys five A380 planes from Airbus for 220 million Euro
- (3) Airbus arranged with China Southern for the sale of five A380 planes at a price of 220 million Euro
- (4) Five A380 planes will go for 220 million Euro to China Southern

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## An Example

Common frame-semantic Analysis:

- Frame: COMMERCIAL\_TRANSACTION
- SELLER: Airbus
- BUYER: China Southern
- GOODS: five A380 planes
- PRICE: 220 million Euro

Event-Semantic representation:

- $\exists e$  [COMMERCIAL\_TRANSACTION( $e$ )  
 $\wedge$  seller( $e$ , Airbus)  $\wedge$  buyer( $e$ , C.S.)  
 $\wedge$  goods ( $e$ , 5\_A380)  $\wedge$  price ( $e$ , 220m€) ]

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## The Berkeley FrameNet Database

- The FrameNet database consists of:
- A data-base of frames with
  - Descriptions of frames with inventory of Roles/Frame elements and associated lemmas
  - Frame-to-Frame Relations
- A lexicon with
  - Frame information
  - Grammatical realisation options (underspecified role linking information)
  - Annotations of example sentences (from BNC) for all usage variants of words

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## Example Frames

- Frame: REQUEST
  - Frame Elements: SPEAKER, ADDRESSEE, MESSAGE, MEDIUM, ...
  - Lexical Units: *appeal.n, ask.v, beg.v, beseech.v, call.v, command.n, command.v, demand.n, demand.v, entreat.v, entreaty.n, implore.v, invite.v, order.n, order.v, petition.n, plea.n, plead.v, request.n, request.v, suggestion.n, summon.v, tell.v, urge.v*
- Frame: COMMERCE
  - Frame Elements: BUYER, SELLER, GOODS, ...
  - Lexical Units: *auction.v, retail.v, retailer.n, sale.n, sell.v, vend.v, vendor.n*

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# PropBank

- PropBank: Annotation of Penn TreeBank with predicate-argument structure. Verbs come with individual roles.
- Generalisation over alternation patterns of (senses of) single verbs (the break case).
- No generalisation across lexeme boundaries (the give/receive case).
- Efficient annotation process, high inter-annotator agreement

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## PropBank Example

- (1) *[Arg0 Lufthansa] is replacing [Arg1 its 737s] [Arg2 with Airbus A320s]*
- (2) *[Arg0 Lufthansa] is substituting [Arg1 Airbus A320s] [Arg3 for its 737s]*
- |                          |
|--------------------------|
| <i>[Pred substitute]</i> |
| <i>Arg0 Lufthansa</i>    |
| <i>Arg1 AirbusA320s</i>  |
| <i>Arg3 its737s</i>      |
- |                         |
|-------------------------|
| <i>[Pred replace]</i>   |
| <i>Arg0 Lufthansa</i>   |
| <i>Arg1 its737s</i>     |
| <i>Arg2 AirbusA320s</i> |

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## PropBank and FrameNet

- (1) *[Arg0 Lufthansa] is replacing [Arg1 its 737s] [Arg2 with Airbus A320s]*
- (2) *[Arg0 Lufthansa] is substituting [Arg1 Airbus A320s] [Arg3 for its 737s]*
- |                          |
|--------------------------|
| <i>[Pred substitute]</i> |
| <i>Arg0 Lufthansa</i>    |
| <i>Arg1 AirbusA320s</i>  |
| <i>Arg3 its737s</i>      |
- |                         |
|-------------------------|
| <i>[Pred replace]</i>   |
| <i>Arg0 Lufthansa</i>   |
| <i>Arg1 its737s</i>     |
| <i>Arg2 AirbusA320s</i> |
- (3) *[Agent Lufthansa] is replacing<sub>Frame: REPLACING</sub> [Old its 737s] [New with Airbus A320s]*
- (4) *[Agent Lufthansa] is substituting<sub>Frame: REPLACING</sub> [New Airbus A320s] [Old for its 737s]*
- |                          |
|--------------------------|
| <i>[Frame REPLACING]</i> |
| <i>Agent Lufthansa</i>   |
| <i>Old its737s</i>       |
| <i>New AirbusA320s</i>   |

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