Semantic Theory

Week 5: Event Semantics

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A problem with verbs and adjuncts

(1) *The gardener killed the baron* ↦ $kill_1(g', b')$ $kill_1 :: \langle e, \langle e, t \rangle \rangle$

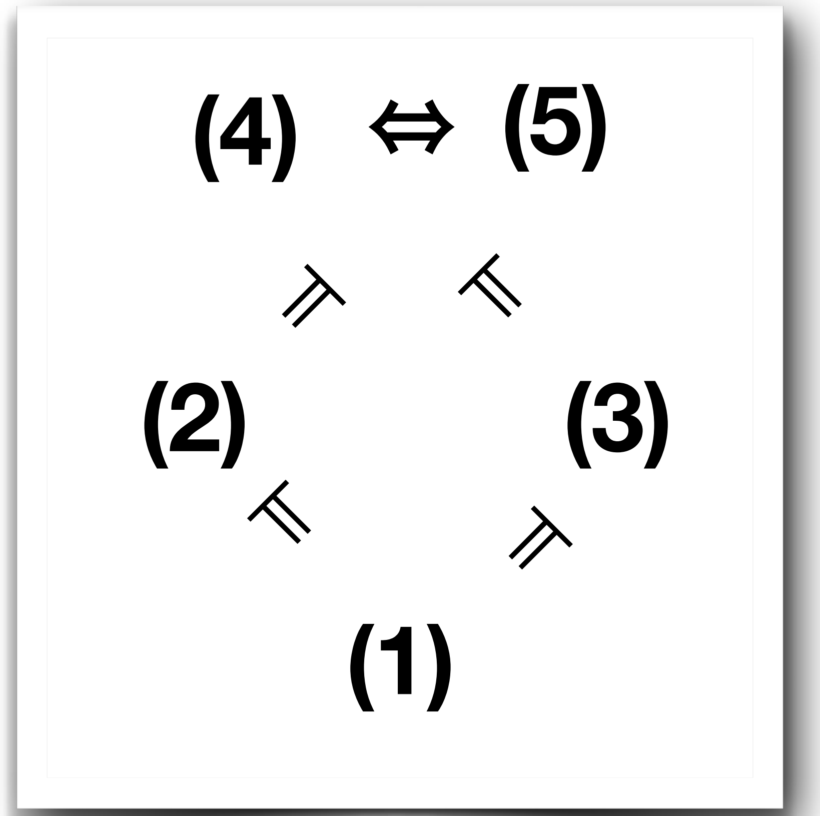
(2) *The gardener killed the baron in the park* ↦ $kill_2(g', b', p')$ $kill_2 :: \langle e, \langle e, \langle e, t \rangle \rangle \rangle$

(3) *The gardener killed the baron at midnight* ↦ $kill_3(g', b', m')$ $kill_3 :: \langle e, \langle e, \langle e, t \rangle \rangle \rangle$

(4) *The gardener killed the baron at midnight in the park* ↦ $kill_4(g', b', m', p')$ $kill_4 :: \ldots$

(5) *The gardener killed the baron in the park at midnight* ↦ $kill_5(g', b', p', m')$ $kill_5 :: \ldots$

Q: How to explain the systematic logical entailment relations between the different uses of "kill"?



NB. We use the FOL syntax for predicates here, i.e., "kill(x,y)" — which is equivalent to the type theoretic expression "kill(y)(x)"

Davidson's solution

Verbs as event-denoting expressions

Verbs expressing events have an additional event argument, which is not realised at linguistic surface:

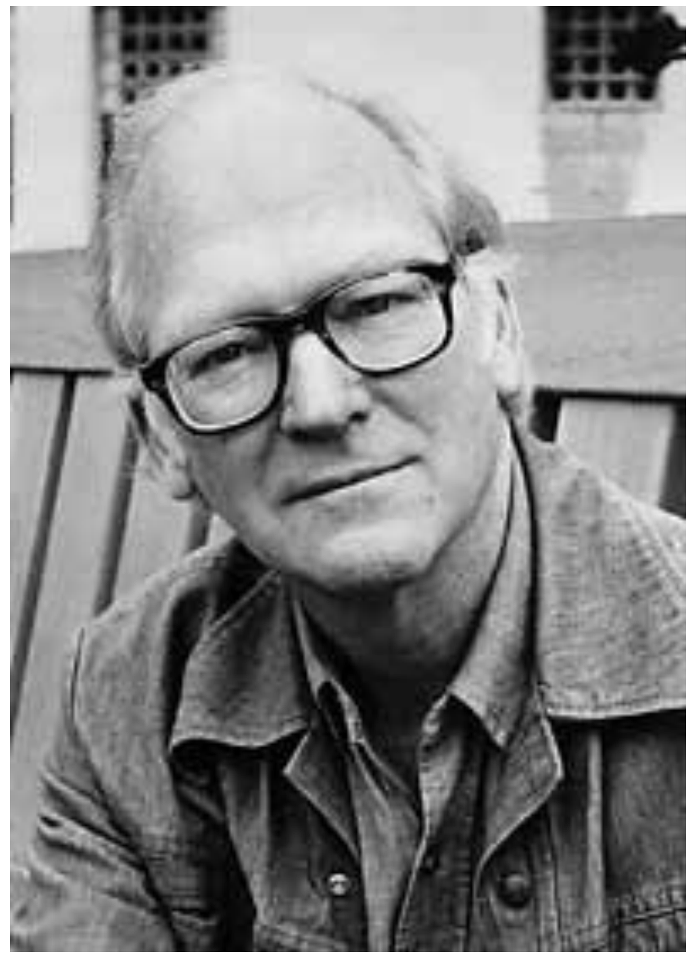
- kill $\mapsto$ $\lambda y \lambda x \lambda e(\text{kill'}(e,x,y)) :: \langle e,\langle e,\langle e,t\rangle\rangle\rangle$ **arity = n+1**

Sentences denote sets of events:

- $\lambda y \lambda x \lambda e(\text{kill'}(e,x,y))(b')(g') \Rightarrow^{\beta} \lambda e(\text{kill'}(e, g', b')) :: \langle e,t\rangle$

Existential closure turns sets of events into truth conditions

- $\lambda P \exists e(P(e)) :: \langle\langle e,t\rangle,t\rangle$
- $\lambda P \exists e(P(e))(\lambda e_1(\text{kill'}(e_1,g',b'))) \Rightarrow^{\beta} \exists e(\text{kill'}(e,g',b')) :: t$



Donald Davidson (1917–2003)

Davisonian events and adjuncts

Adjuncts express two-place relations between events and the respective "circumstantial information": time, location, …

- at midnight $\mapsto$ λPλe(P(e) ∧ time(e,m')) :: ⟨⟨e,t⟩,⟨e,t⟩⟩
- in the park $\mapsto$ λPλe(P(e) ∧ location(e,p')) :: ⟨⟨e,t⟩,⟨e,t⟩⟩

The gardener killed the baron at midnight in the park

$\mapsto$ ∃e (kill(e, g', b') ∧ time(e, m) ∧ location(e, p'))

⇔ ∃e (kill(e, g', b') ∧ location(e, p) ∧ time(e, m'))

} ⊨ ∃e (kill(e, g', b') ∧ time(e, m'))
⊨ ∃e (kill(e, g', b') ∧ location(e, p'))
⊨ ∃e (kill(e, g', b'))

Compositional derivation of event-semantic representations

the gardener killed the baron

$$\lambda x_e \lambda y_e \lambda e_e[\, kill(e, y, x)\,](b')(g') \Rightarrow^{\beta} \lambda e\, [\, kill(e, g', b')\,]$$

… at midnight

α

$$\lambda F_{\langle e,t\rangle} \lambda e_e\, [\, F(e) \wedge time(e, m')\,](\lambda e_1\, [\, kill(e_1, g', b')\,]) \Rightarrow^{\beta} \lambda e\, [\, kill(e, g, b) \wedge time(e,m')\,]$$

… in the park

α

$$\lambda F_{\langle e,t\rangle} \lambda e_e\, [F(e) \wedge location(e, p')]\, (\lambda e_2\, [kill(e_2, g', b') \wedge time(e_2, m')]) \Rightarrow^{\beta}$$

$$\lambda e\, [kill(e, g', b') \wedge time(e, m') \wedge location(e, p')\,]$$

Existential closure

$$\lambda P_{\langle e,t\rangle} \exists e(P(e))(\lambda e'(K \wedge T \wedge L) \Rightarrow^{\beta} \exists e\, [\, kill(e, g', b') \wedge time(e, m') \wedge location(e, p')\,]$$

Model structures with events

Enriched ontological structures

Ontology: The area of philosophy identifying and describing the basic "categories of being" and their relations.

A model structure with events is a triple **M = ⟨U, E, V⟩**, where

- U is a set of "standard individuals" or "objects"
- E is a set of events
- $U \cap E = \varnothing$,
- V is an interpretation function like in first order logic

Sorted (first-order) logic

A variable assignment g assigns individuals (of the correct sort-specific domain) to variables:

- $g(x) \in U$ for $x \in VAR_U$ $VAR_U = \{ x, y, z, \ldots, x_1, x_2, \ldots \}$ (Object variables)
- $g(e) \in E$ for $e \in VAR_E$ $VAR_E = \{ e, e', e'', \ldots, e_1, e_2, \ldots \}$ (Event variables)

NB. variables from VAR_U and VAR_E are all of type e (in the formalisation used here)

Quantification ranges over sort-specific domains:

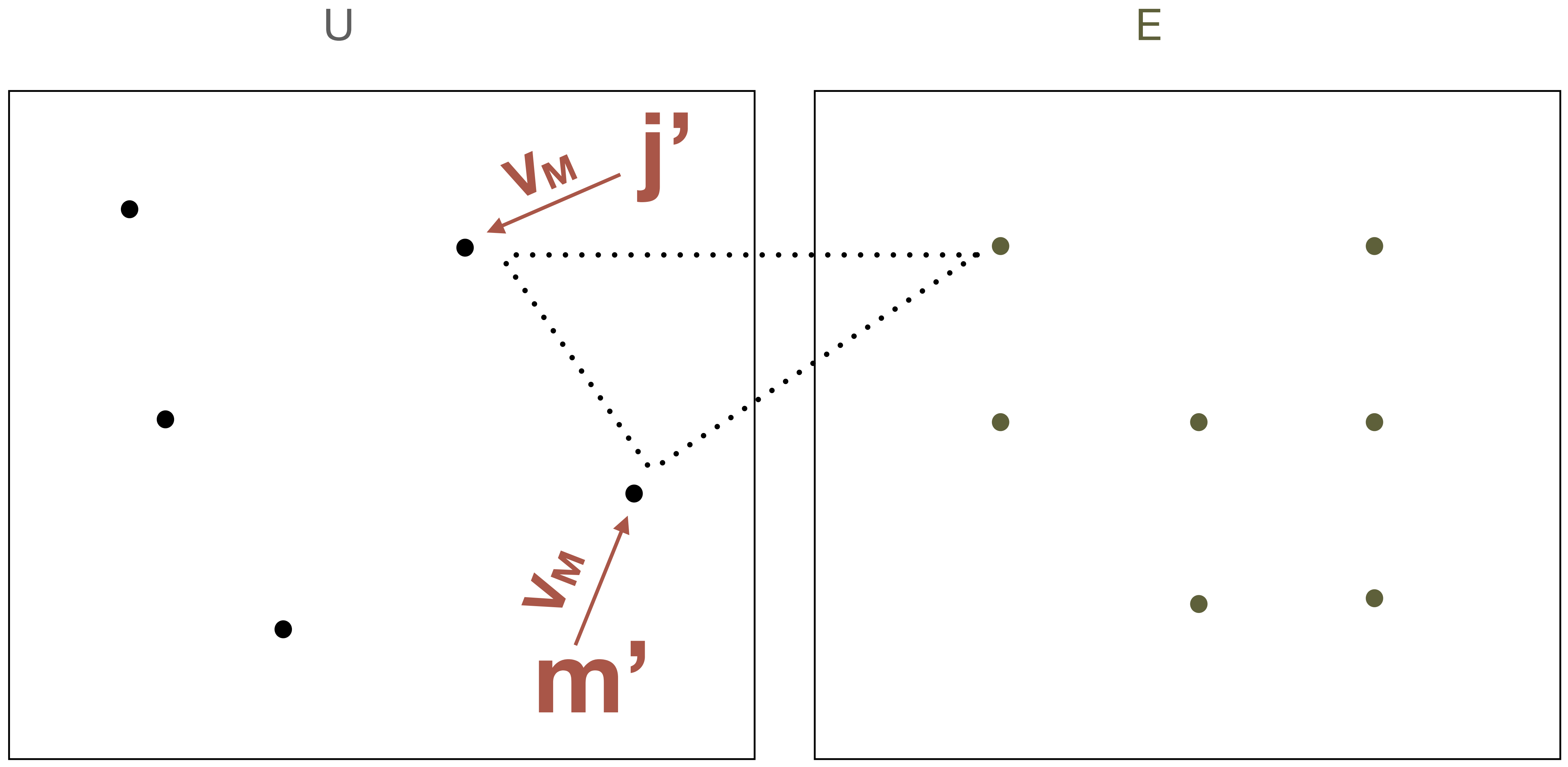
- $[\![\exists x\, \Phi]\!]^{M,g} = 1$ iff there is some $d \in U$ such that $[\![\Phi]\!]^{M,g[x/d]} = 1$
- $[\![\exists e\, \Phi]\!]^{M,g} = 1$ iff there is some $s \in E$ such that $[\![\Phi]\!]^{M,g[e/s]} = 1$
- (universal quantification analogous)

Interpreting events

Example

John kisses Mary ↦ ∃e (kiss(e, j', m'))

$[\![\exists e\ (kiss(e, j', m'))\ ]\!]^{M,g} = 1$
iff there is an s ∈ E such that $[\![\ kiss(e, j', m')\ ]\!]^{M,g[e/s]} = 1$
iff there is an s ∈ E such that $\langle s, V_M(j'), V_M(m') \rangle \in V_M(kiss)$



Advantages of Davidsonian events

- [x] Intuitive representation and semantic construction for adjuncts
- [ ] Uniform treatment of verb complements
- [ ] Uniform treatment of adjuncts and post-nominal modifiers
- [ ] Coherent treatment of tense information
- [ ] Highly compatible with analysis of semantic roles

Uniform treatment of verb complements

(1) *Bill saw an elephant*

$\mapsto \exists e\ \exists x\ (\text{see}(e, b', x) \wedge \text{elephant}(x))$ **see :: ⟨e,⟨e,⟨e,t⟩⟩**

(2) *Bill saw an accident*

$\mapsto \exists e\ \exists e'\ (\text{see}(e, b, e') \wedge \text{accident}(e'))$ **see :: ⟨e,⟨e,⟨e,t⟩⟩**

(3) *Bill saw the children play*

$\mapsto \exists e\ \exists e'\ (\text{see}(e, b, e') \wedge \text{play}(e', \text{the-children}))$ **see :: ⟨e,⟨e,⟨e,t⟩⟩**

Adjuncts and post-nominal modifiers

Treatment of adjuncts as predicate modifiers, analogous to attributive adjectives:

- red ↦ $\lambda F\, \lambda x\, [\, F(x) \wedge red^*(x)\,]$ $\langle\langle e,t\rangle,\langle e,t\rangle\rangle$
- in the park ↦ $\lambda F\, \lambda e\, [\, F(e) \wedge location(e, park)\,]$ $\langle\langle e,t\rangle,\langle e,t\rangle\rangle$

(1) *The murder in the park…*

↦ $\lambda F \lambda e[F(e) \wedge location(e, park)]\ (\lambda e_1\ [murder(e_1)])$

(2) The fountain in the park ….

↦ $\lambda F \lambda x[F(x) \wedge location(x, park)]\ (\lambda y\ [fountain(y)])$

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Classical Tense Logic

Prior's tense logic

- *John walks* walk(john)
- *John walked* P(walk(john))
- *John will walk* F(walk(john))

Syntax like in first-order logic, plus

- if Φ is a well-formed formula, then PΦ, FΦ, HΦ, GΦ are also well-formed formulae such that:
  - P ≡ ¬H¬
  - F ≡ ¬G¬

Φ has always been the case

Φ is always going to be the case

Φ happened in the past

Φ will happen in the future

Classical Tense Logic

Model structures with tense information

Tense model structures are quadruples $M = \langle U, T, <, V \rangle$ where

- U is a non-empty set of individuals (the "universe")
- T is a non-empty sets of points in time
- $U \cap T = \varnothing$
- $<$ is a linear order on T
- V is a value assignment function, which assigns to every non-logical constant α a function from T to appropriate denotations of α

$[\![P\Phi]\!]^{M, t, g} = 1$ *iff* there is a $t' < t$ such that $[\![\Phi]\!]^{M, t', g} = 1$

$[\![F\Phi]\!]^{M, t, g} = 1$ *iff* there is a $t' > t$ such that $[\![\Phi]\!]^{M, t', g} = 1$

Temporal Relations and Events

Observation: Event structure is inherently related to temporal structure.

(1) *The door opened, and Mary entered the room.*

(2) *John arrived. Then Mary left.*

(3) *Mary left, before John arrived.*

(4) *John arrived. Mary had left already.*

Q: How can we extend event-based models with a notion of *temporal order between events*?

Temporal Event Structure

Ordered universe of events

A model structure with events *and* temporal precedence is defined as:
$M = \langle U, E, <, e_u, V \rangle$, where

- $U \cap E = \varnothing$,
- $< \subseteq E \times E$ is an asymmetric relation (temporal precedence)
- $e_u \in E$ is the utterance event
- V is an interpretation function like in standard FOL
- Notation for overlapping events: $e \cdot e'$ iff neither $e < e'$ nor $e' < e$

Tense in Semantic Construction

- We can represent tense inflection as an abstract tense operator reflecting the temporal location of the reported event relative to the utterance event.

PAST $\mapsto \lambda P.\exists e\,[P(e) \wedge e < e_u] : \langle\langle e, t\rangle, t\rangle$

PRES $\mapsto \lambda P.\exists e\,[P(e) \wedge e \circ e_u] : \langle\langle e, t\rangle, t\rangle$

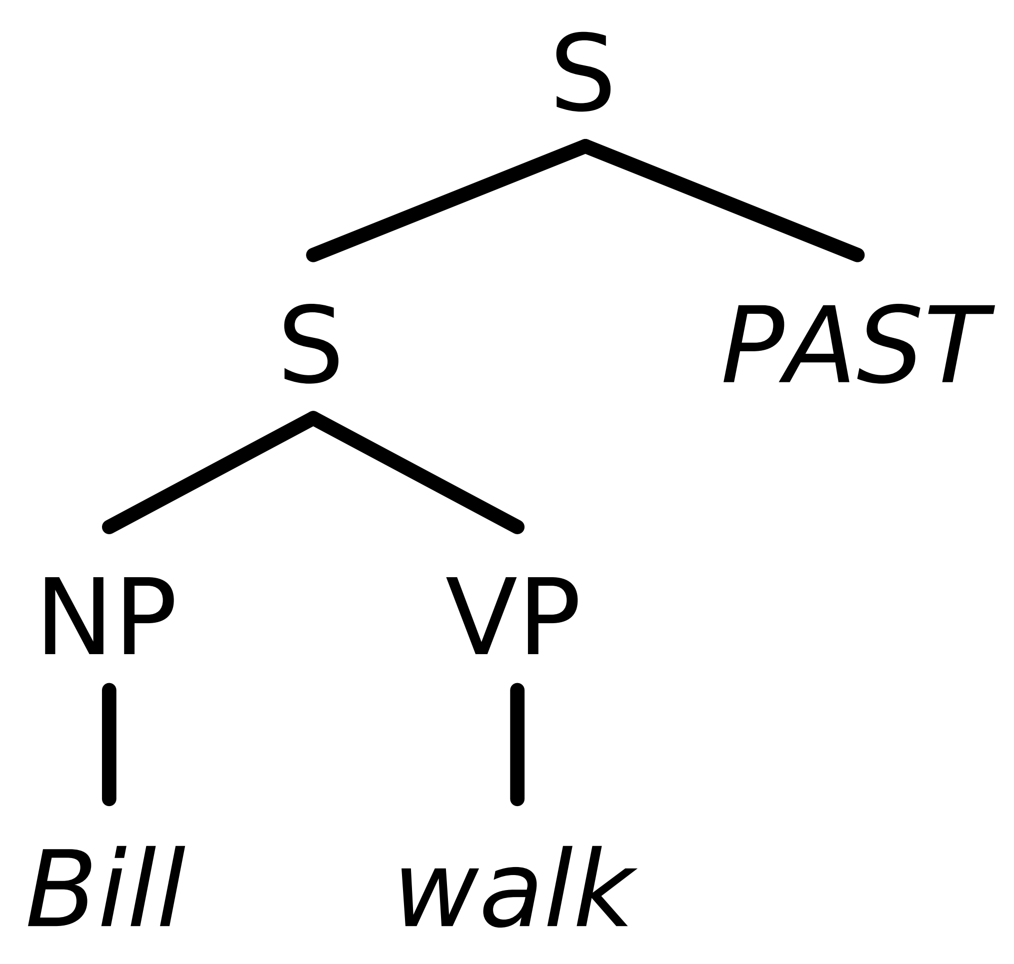
- Standard function application results in integration of temporal information and binding of the event variable (i.e., replacing E-CLOS):

Bill walk $\mapsto \lambda x\, \lambda e\,[walk(e, x)](b') \Rightarrow^{\beta} \lambda e\,[walk(e, b')]$

PAST (Bill walk) $\mapsto \lambda E\, \exists e\,[E(e) \wedge e < e_u](\lambda e'\,[walk(e', b)])$

$\Rightarrow^{\beta} \exists e\,[\lambda e'\,[walk(e', b)](e) \wedge e < e_u]$

$\Rightarrow^{\beta} \exists e\,[walk(e, b) \wedge e < e_u]$



"Bill walked"

Advantages of Davidsonian events

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Verbal arguments

A related problem?

Verbal arguments with the same semantic "role" may syntactically appear in different positions.

(1) *John* ***broke*** *the window with a rock.*

(2) *A rock* ***broke*** *the window.*

(3) *The window* ***broke****.*

… and we're back to the same entailment issue:

$\exists e(break_3(e, j, w, r)) \not\models \exists e(break_2(e, r, w)) \not\models \exists e(break_1(e, w))$

Semantic/Thematic roles

(1) *John* ***broke*** *the window with a rock.* (agent, patient, instrument)

↦ ∃e [break(e) ∧ agent(e, j) ∧ patient(e, w) ∧ instrument(e, r)]

(2) *A rock* ***broke*** *the window.*

↦ ∃e [break(e) ∧ patient(e, w) ∧ instrument(e, r)]

(3) *The window* ***broke****.*

↦ ∃e [break(e) ∧ patient(e, w)]

In standard FOL & Type Theory: Thematic roles are implicitly represented by the canonical order of the arguments

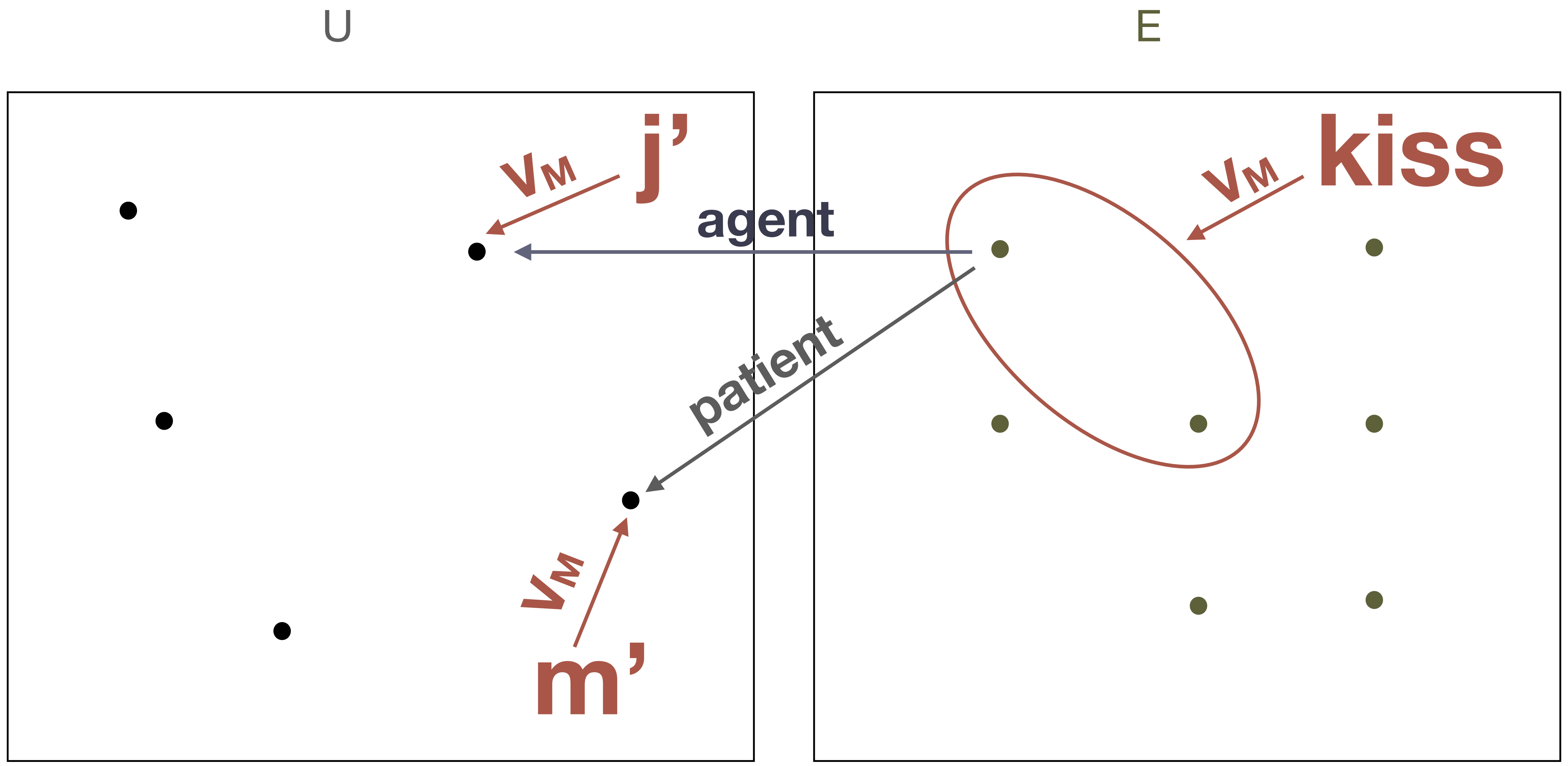
In Neo-Davidsonian event semantics: Thematic roles are two-place relations between the event denoted by the verb, and an argument role filler.

Interpreting thematic roles

Example using event model

John kisses Mary ↦ ∃e (kiss(e) ∧ agent(e, j’) ∧ patient(e,m’))

$[\![$ ∃e (kiss(e) ∧ agent(e, j’) ∧ patient(e,m’)) $]\!]^{M,g}$ = 1
iff there is an s ∈ E s.t. $[\![$kiss(e)$]\!]^{M,g[e/s]}$ = 1 and $[\![$ agent(e, j’)$]\!]^{M,g[e/s]}$ = 1 and $[\![$patient(e,m’)$]\!]^{M,g[e/s]}$ = 1
iff there is an s ∈ E s.t. s ∈ V_M(kiss) and ⟨s,V_M(j’)⟩ ∈ V_M(agent) and ⟨s,V_M(m’)⟩ ∈ V_M(patient)



Verbal differences and similarities

Patterns for thematic roles

Different verbs allow different thematic role configurations

(1) *a.* *John **broke** the window with a rock* — **agent, patient, instrument**
b. *John **smiled** at Mary* — **agent, recipient**

(2) a. *The window **broke*** — **allows inanimate subject**
b. **The bread **cut*** — **does not allow inanimate subject**

Thematic roles capture equivalences and entailment relations between different predicates

(3) a. *Mary **gave** Peter the book*
b. *Peter **received** the book from Mary*

$\forall e[\text{give}(e) \leftrightarrow \text{receive}(e)] \models (3a) \leftrightarrow (3b)$

Determining the role inventory

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, Patient, Theme, Recipient, Instrument, Source, Goal, Beneficiary, Experiencer

But what about the following examples?

(1) *Lufthansa is replacing its 737s with Airbus 320*

(2) *John sold the car to Bill for 3,000€*

(3) *Bill bought the car from John for 3,000€*

Semantic corpora with thematic roles

PropBank and FrameNet

PropBank (Palmer et al. 2005): Annotation of Penn TreeBank with **predicate-argument structure**; separate role inventory for every lemma

(1) [$_{\text{Arg0}}$ Lufthansa] is **replacing** [$_{\text{Arg1}}$ its 737s] [$_{\text{Arg2}}$ with Airbus A320s]

(2) [$_{\text{Arg0}}$ Lufthansa] is **substituting** [$_{\text{Arg1}}$ Airbus A320s] [$_{\text{Arg2}}$ for its 737s]

Pred	replace
Arg0	Lufthansa
Arg1	its737s
Arg2	AirbusA320s

Pred	substitute
Arg0	Lufthansa
Arg1	AirbusA320s
Arg2	its737s

FrameNet (Baker et al. 1998): A database of **frames** and a lexicon with frame information; a frame is a structured schema representing complex prototypical situations, events, and actions

(3) [$_{\text{Agent}}$ Lufthansa] is **replacing**$_{\text{Frame: REPLACING}}$ [$_{\text{Old}}$ its 737s] [$_{\text{New}}$ with Airbus A320s]

(4) [$_{\text{Agent}}$ Lufthansa] is **substituting**$_{\text{Frame: REPLACING}}$ [$_{\text{New}}$ Airbus A320s] [$_{\text{Old}}$ for its 737s]

Frame	REPLACING
Agent	Lufthansa
Old	its737s
New	AirbusA320s

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- ☑ Intuitive representation and semantic construction for adjuncts
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- ☑ Plausible treatment of tense information
- ☑ Compatible with analysis of semantic roles

Reading Material & Links

- **Overview paper:** Lasersohn (2012) Event-Based Semantics: https://semanticsarchive.net/Archive/jFhNWM2M/eventbasedsemantics.pdf
- **PropBank:** http://propbank.github.io/
- **FrameNet:** https://framenet.icsi.berkeley.edu/fndrupal/