Semantic Theory
week 7 – Event semantics

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A problem with verbs and adjuncts

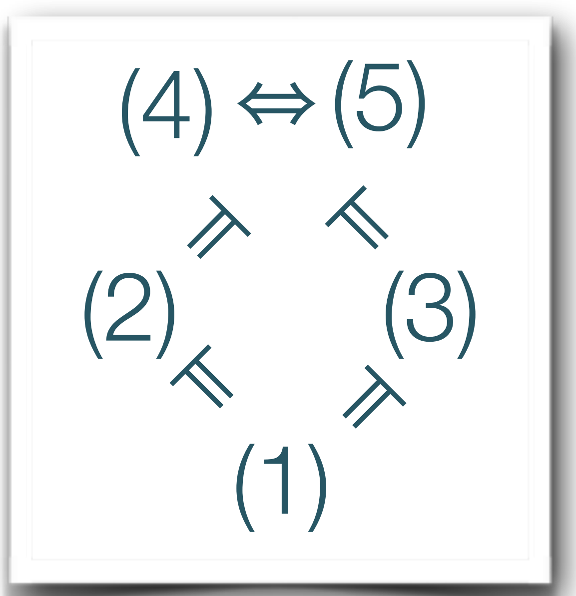
(1) *The gardener killed the baron* ↦ $kill_1(g',b')$ $kill_1 :: \langle e,\langle e,t\rangle\rangle$

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

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

(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* ↦ $kill_5(g',b',p',m')$ $kill_5 :: \ldots$

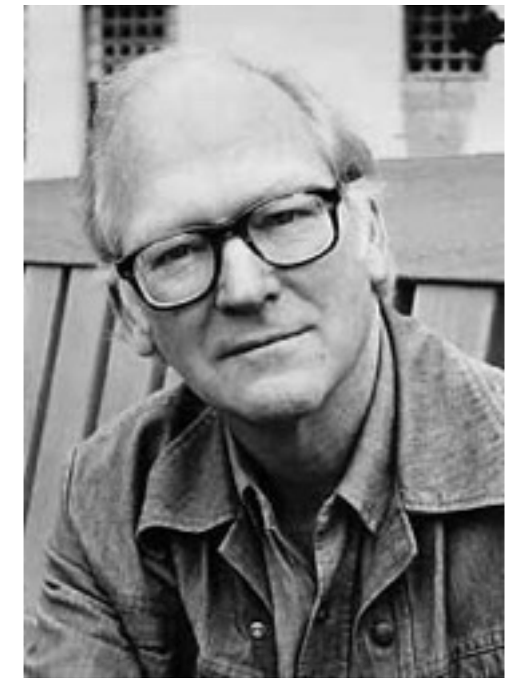


Q: How to explain the systematic logical entailment relations between the different uses of "kill"?

Davidson's solution: verbs introduce events.

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

- kill ↦ λyλxλe(kill'(e,x,y)) :: ⟨e,⟨e,⟨e,t⟩⟩⟩ *arity = n+1*



Sentences denote sets of events:

- λyλxλe(kill'(e,x,y))(b')(g') $\Rightarrow^{\beta}$ λe(kill'(e, g', b')) :: ⟨e,t⟩

Existential closure turns sets of events into truth conditions

- λP∃e(P(e)) :: ⟨⟨e,t⟩,t⟩
- λP∃e(P(e))(λe(kill'(e,g',b'))) $\Rightarrow^{\beta}$ ∃e(kill'(e,g',b')) :: t

Davidson (1967, 1980)

Davisonian events and adjuncts

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

- at midnight $\mapsto$ $\lambda P \lambda e(P(e) \wedge \mathrm{time}(e,m'))$ :: $\langle\langle e,t\rangle,\langle e,t\rangle\rangle$
- in the park $\mapsto$ $\lambda P \lambda e(P(e) \wedge \mathrm{location}(e,p'))$ :: $\langle\langle e,t\rangle,\langle e,t\rangle\rangle$

The gardener killed the baron at midnight in the park

$\mapsto \exists e\, (\mathrm{kill}(e, g', b') \wedge \mathrm{time}(e, m) \wedge \mathrm{location}(e, p'))$

$\Leftrightarrow \exists e\, (\mathrm{kill}(e, g', b') \wedge \mathrm{location}(e, p) \wedge \mathrm{time}(e, m'))$

}

$\vDash \exists e\, (\mathrm{kill}(e, g', b') \wedge \mathrm{time}(e, m'))$

$\vDash \exists e\, (\mathrm{kill}(e, g', b') \wedge \mathrm{location}(e, p'))$

$\vDash \exists e\, (\mathrm{kill}(e, g', b'))$

Compositional derivation of event-semantic representations

the gardener killed the baron

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

α

… at midnight

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

… in the park

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

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

Existential closure

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

Model structures with events

To interpret events, we need enriched *ontological* information

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

A model structure with events is a triple $M = \langle U, E, V \rangle$, 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 $x \in VAR_U$ $VAR_U = \{ x, y, z, \dots , x_1, x_2, \dots \}$ (Object variables)
- $g(e) \in E$ for $e \in VAR_E$ $VAR_E = \{ e, e', e'', \dots, e_1, e_2, \dots \}$ (Event variables)

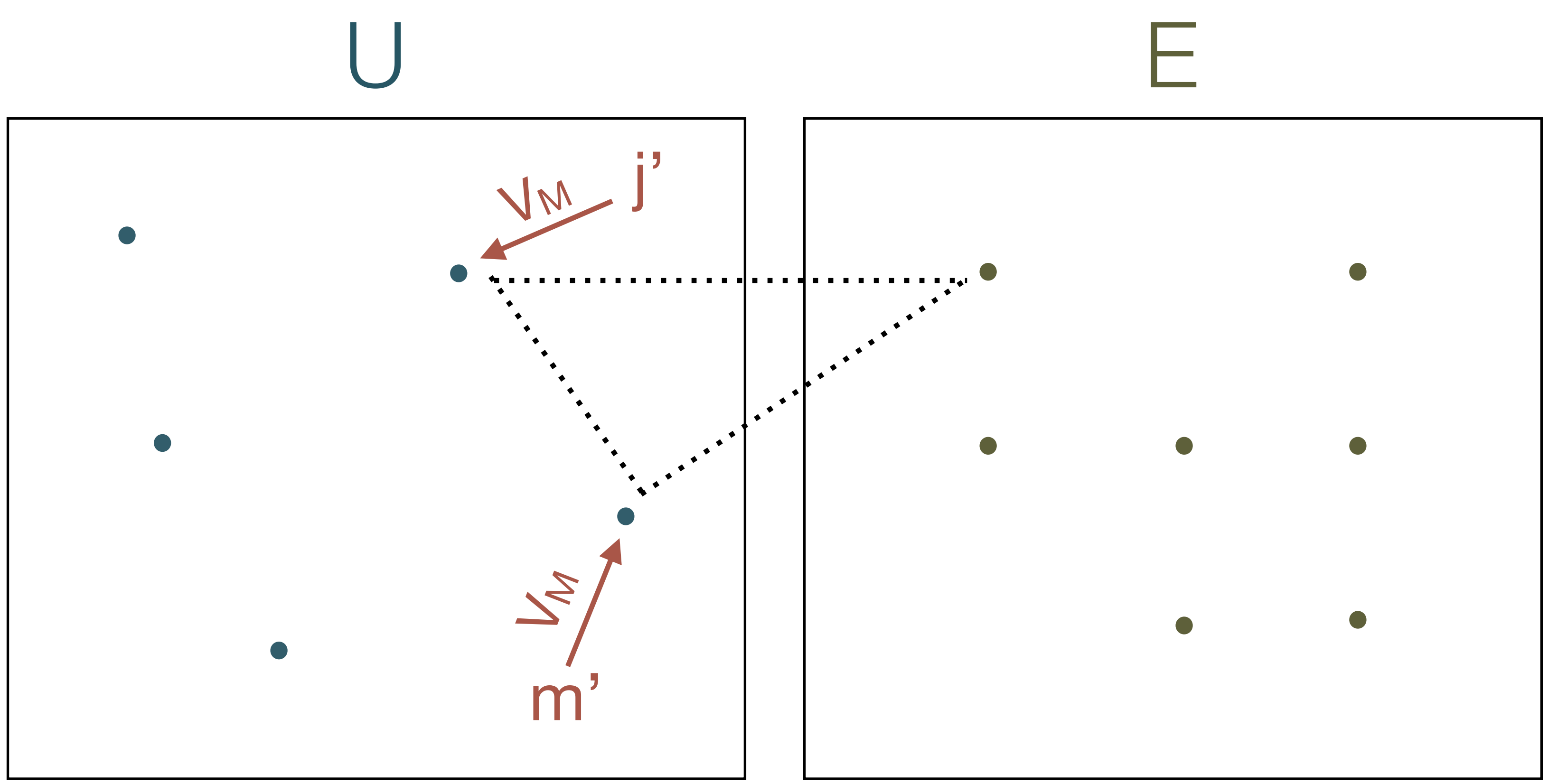
Quantification ranges over sort-specific domains:

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

Interpreting events

John kisses Mary $\mapsto$ ∃e (kiss(e, j', m'))

$[\![$ ∃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 ⟨s, V_M(j'), V_M(m')⟩ ∈ V_M(kiss)



Advantages of Davidsonian events

- ☑ 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⟩⟩

Uniform treatment of 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

- *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 $P\Phi$, $F\Phi$, $H\Phi$, $G\Phi$ are also well-formed formulae.

Φ happened in the past

Φ will happen in the future

Φ has always been the case

Φ is always going to be the case

Classical Tense Logic (cont.)

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

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

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

Temporal Relations and Events

(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 to formalize temporal relations *between events*?

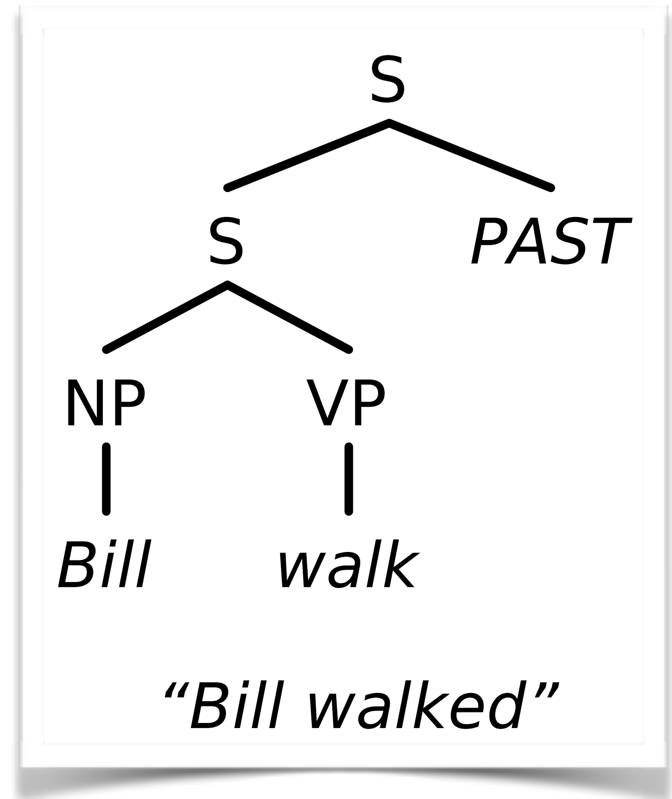
Temporal Event Structure

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
- Overlapping events: e ▪ e' iff neither e < e' nor e' < e

Tense in Semantic Construction

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



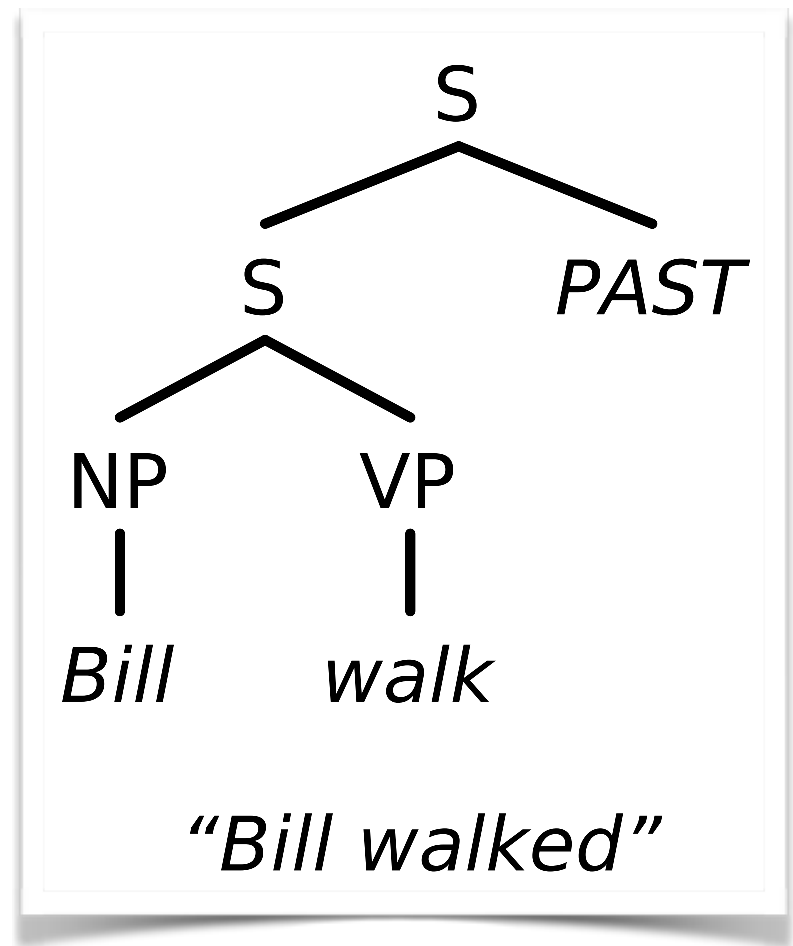
PAST $\mapsto \lambda P.\exists e\, [P(e) \wedge e < e_u] : \langle\langle e, t\rangle, t\rangle$

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

Tense in Semantic Construction

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

- walk $\mapsto$ $\lambda x\ \lambda e\ [walk(e, x)]$
- Bill walk $\mapsto$ $\lambda x\ \lambda e\ [walk(e, x)](b') \Rightarrow^{\beta} \lambda e\ [walk(e, b')]$
- Bill walk PAST
  $\mapsto \lambda E\ \exists e\ [E(e) \wedge e < e_u](\lambda e'\ [walk(e', b)])$
  $\Rightarrow^{\beta} \exists e\ [\lambda e'\ [walk(e', b)](e) \wedge e < e_u]$
  $\Rightarrow^{\beta} \exists e\ [walk(e, b) \wedge e < e_u]$



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Verbal arguments; a related problem?

(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

agent patient instrument

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

$\mapsto \exists e\ [break(e) \wedge agent(e, j) \wedge patient(e, w) \wedge instrument(e, r)]$

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

$\mapsto \exists e\ [break(e) \wedge patient(e, w) \wedge instrument(e, r)]$

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

$\mapsto \exists e\ [break(e) \wedge patient(e, w)]$

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

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

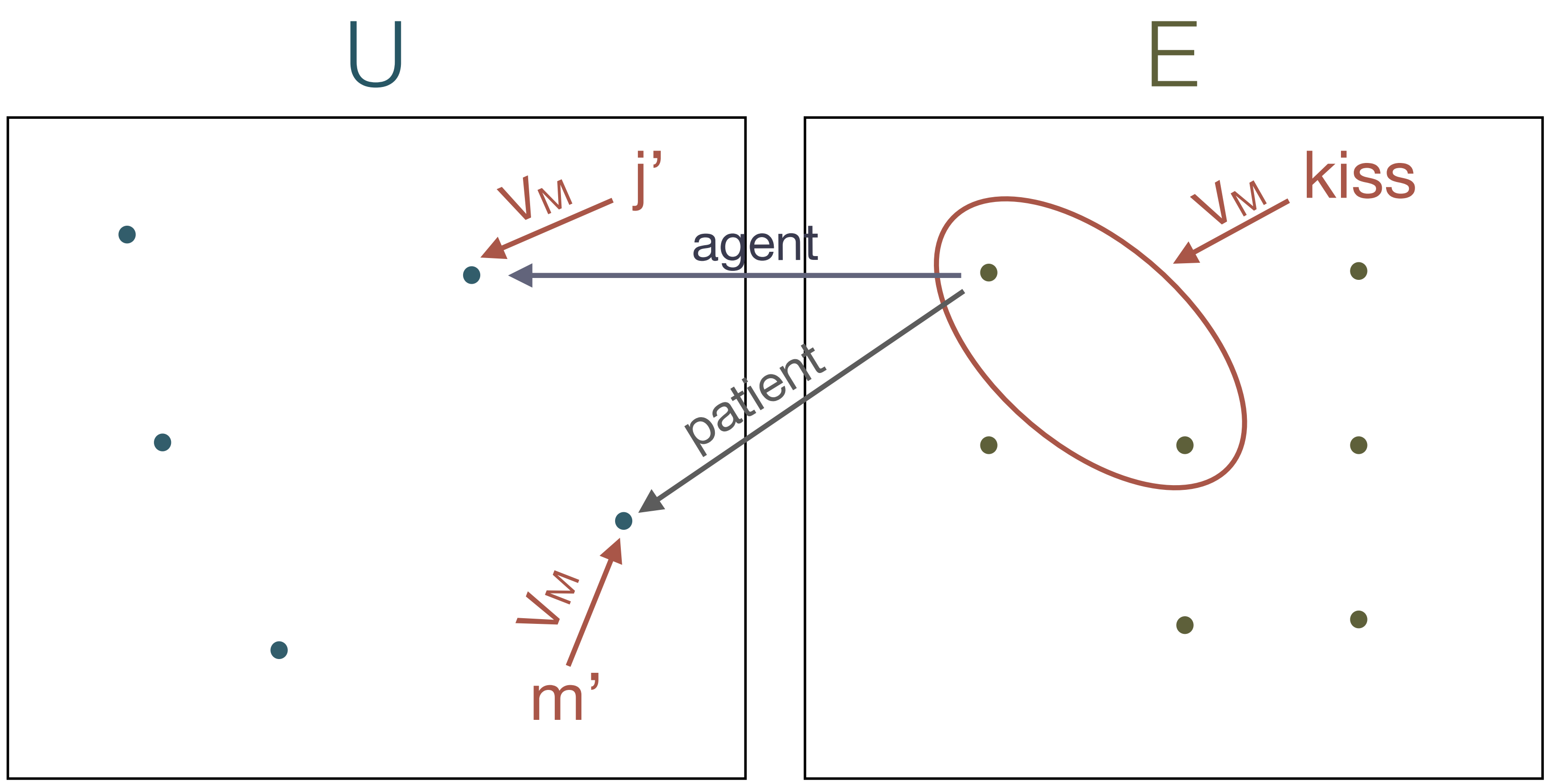
Interpretation of events with thematic roles

John kisses Mary $\mapsto \exists e\,(kiss(e) \wedge agent(e, j') \wedge patient(e,m'))$

$[\![\, \exists e\,(kiss(e) \wedge agent(e, j') \wedge patient(e,m'))\,]\!]^{M,g} = 1$

iff there is an $s \in E$ such that $[\![kiss(e)]\!]^{M,g[e/s]} = 1$ and $[\![\, agent(e, j')]\!]^{M,g[e/s]} = 1$ and $[\![patient(e,m')]\!]^{M,g[e/s]} = 1$

iff there is an $s \in E$ such that $s \in V_M(kiss)$ and $\langle s, V_M(j')\rangle \in V_M(agent)$ and $\langle s, V_M(m')\rangle \in V_M(patient)$



Thematic roles & verbal differences/similarities

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*

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

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… there are some difficult cases:

(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: includes a separate role inventory for every lemma
- FrameNet: “Frame-based” role inventories

Frames are structured schemata representing complex prototypical situations, events, and actions

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

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

Semantic corpora with thematic roles (cont.)

Propbank (Palmer et al. 2005): Annotation of Penn TreeBank with predicate-argument structure.

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

Pred	replace
Arg0	Lufthansa
Arg1	its737s
Arg2	AirbusA320s

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

Pred	substitute
Arg0	Lufthansa
Arg1	AirbusA320s
Arg2	its737s

FrameNet (Baker et al. 1998): A database of frames and a lexicon with frame information

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

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

Frame	REPLACING
Agent	Lufthansa
Old	its737s
New	AirbusA320s