

Semantic Theory

Week 4 – Event semantics

Noortje Venhuizen
Harm Brouwer

Universität des Saarlandes

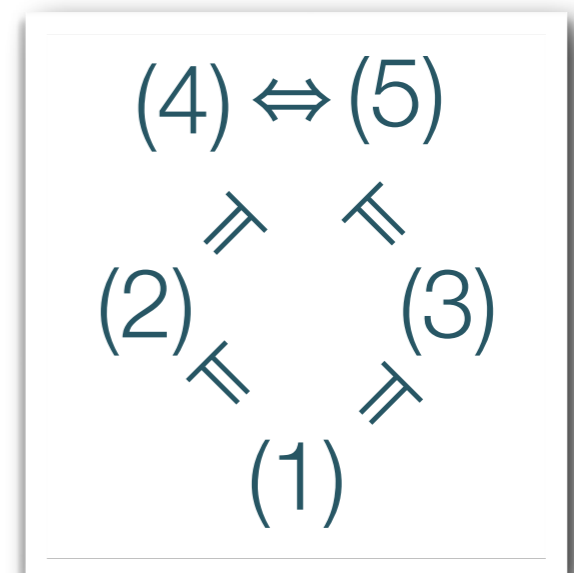
Summer 2021

A problem with verbs and adjuncts

- (1) *The gardener killed the baron* $\mapsto \text{kill}_1(g',b')$ $\text{kill}_1 :: \langle e, \langle e, t \rangle \rangle$
- (2) *The gardener killed the baron in the park* $\mapsto \text{kill}_2(g',b',p')$ $\text{kill}_2 :: \langle e, \langle e, \langle e, t \rangle \rangle$
- (3) *The gardener killed the baron at midnight* $\mapsto \text{kill}_3(g',b',m')$ $\text{kill}_3 :: \langle e, \langle e, \langle e, t \rangle \rangle$
- (4) *The gardener killed the baron at midnight in the park* $\mapsto \text{kill}_4(g',b',m',p')$ $\text{kill}_4 :: \dots$
- (5) *The gardener killed the baron in the park at midnight* $\mapsto \text{kill}_5(g',b',p',m')$ $\text{kill}_5 :: \dots$

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 introduce events.

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

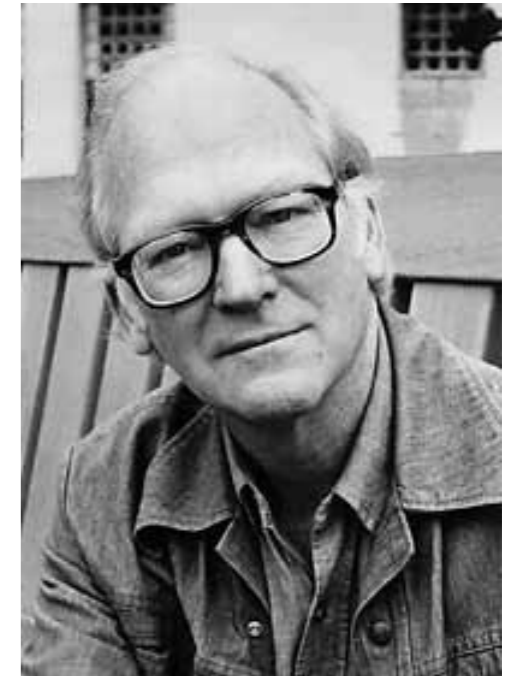
- $\text{kill} \mapsto \lambda y \lambda x \lambda e (\text{kill}'(e, x, y)) :: \langle e, \langle e, \langle e, t \rangle \rangle \rangle$ *arity = n+1*

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

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



Davidson (1967, 1980)

Davisonian events and adjuncts

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

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

The gardener killed the baron at midnight in the park

$$\begin{array}{l} \mapsto \exists e (\text{kill}(e, g', b') \wedge \text{time}(e, m) \wedge \text{location}(e, p')) \\ \Leftrightarrow \exists e (\text{kill}(e, g', b') \wedge \text{location}(e, p) \wedge \text{time}(e, m')) \end{array} \left. \vphantom{\begin{array}{l} \mapsto \\ \Leftrightarrow \end{array}} \right\} \begin{array}{l} \models \exists e (\text{kill}(e, g', b') \wedge \text{time}(e, m')) \\ \models \exists e (\text{kill}(e, g', b') \wedge \text{location}(e, p)) \\ \models \exists e (\text{kill}(e, g', b')) \end{array}$$

Compositional derivation of event-semantic representations

the gardener killed the baron

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

... 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 $\mathbf{M} = \langle \mathbf{U}, \mathbf{E}, \mathbf{V} \rangle$, where

- U is a set of “standard individuals” or “objects”
- E is a set of events
- $U \cap E = \emptyset$,
- 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 $x \in \text{VAR}_U$ $\text{VAR}_U = \{ x, y, z, \dots, x_1, x_2, \dots \}$ (Object variables)
- $g(e) \in E$ for $e \in \text{VAR}_E$ $\text{VAR}_E = \{ e, e', e'', \dots, e_1, e_2, \dots \}$ (Event variables)

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

Quantification ranges over sort-specific domains:

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

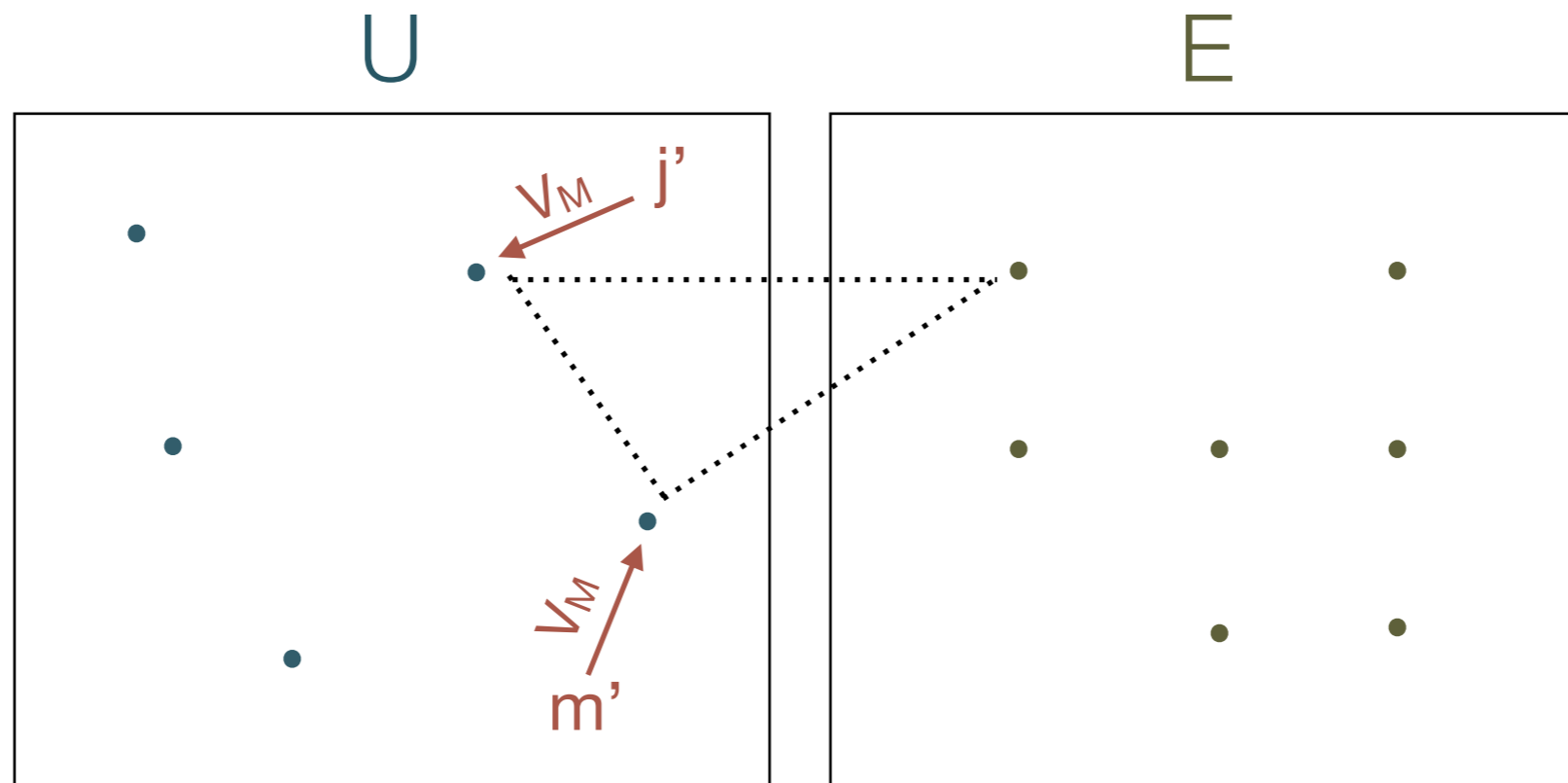
Interpreting events

John kisses Mary $\mapsto \exists e (\text{kiss}(e, j', m'))$

$\llbracket \exists e (\text{kiss}(e, j', m')) \rrbracket^{M,g} = 1$

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

iff there is an $s \in E$ such that $\langle s, V_M(j'), V_M(m') \rangle \in V_M(\text{kiss})$



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*

$\mapsto \exists e \exists x (\text{see}(e, b', x) \wedge \text{elephant}(x))$

$\text{see} :: \langle e, \langle e, \langle e, t \rangle \rangle$

(2) *Bill saw an accident*

$\mapsto \exists e \exists e' (\text{see}(e, b, e') \wedge \text{accident}(e'))$

$\text{see} :: \langle e, \langle e, \langle e, t \rangle \rangle$

(3) *Bill saw the children play*

$\mapsto \exists e \exists e' (\text{see}(e, b, e') \wedge \text{play}(e', \text{the-children}))$

$\text{see} :: \langle e, \langle e, \langle e, t \rangle \rangle$

Uniform treatment of adjuncts and post-nominal modifiers

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

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

(1) *The murder in the park...*

$\mapsto \lambda F \lambda e [F(e) \wedge \text{location}(e, \text{park})] (\lambda e_1 [\text{murder}(e_1)])$

(2) *The fountain in the park*

$\mapsto \lambda F \lambda x [F(x) \wedge \text{location}(x, \text{park})] (\lambda y [\text{fountain}(y)])$

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

Classical Tense Logic

- *John walks* $\text{walk}(\text{john})$
- *John walked* $P(\text{walk}(\text{john}))$
- *John will walk* $F(\text{walk}(\text{john}))$

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 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 (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
- $U \cap T = \emptyset$
- $<$ 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

$\llbracket P\Phi \rrbracket^{M, t, g} = 1$ iff there is a $t' < t$ such that $\llbracket \Phi \rrbracket^{M, t', g} = 1$

$\llbracket F\Phi \rrbracket^{M, t, g} = 1$ iff there is a $t' > t$ such that $\llbracket \Phi \rrbracket^{M, t', g} = 1$

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

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

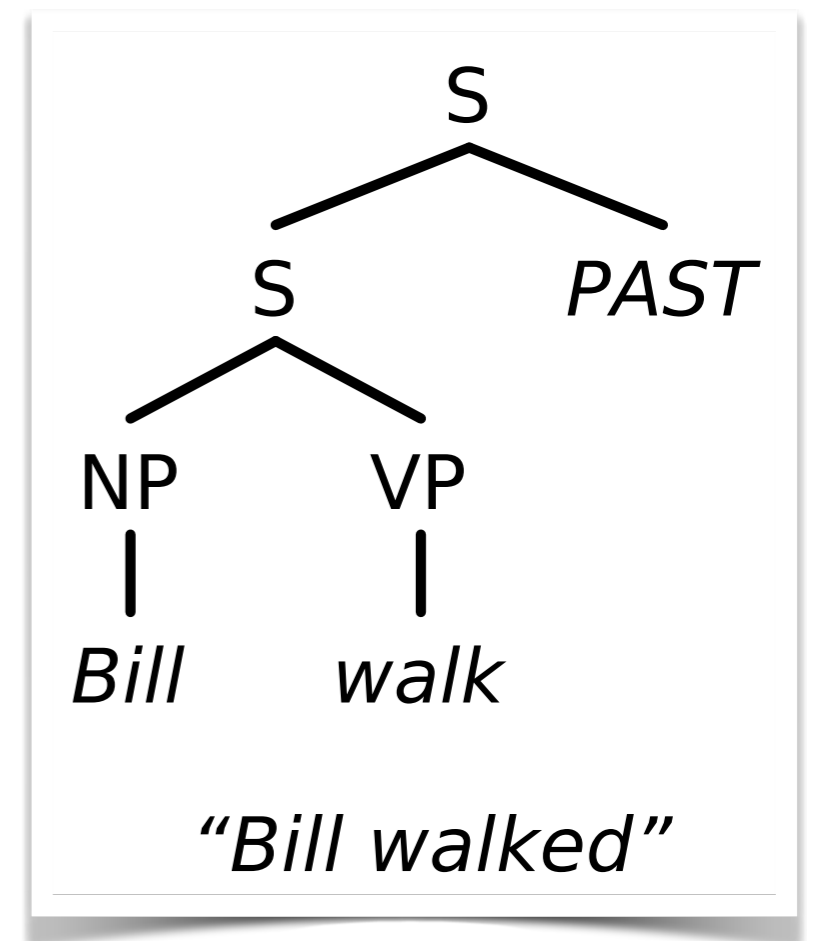
- $U \cap E = \emptyset$,
- $< \subseteq E \times E$ is an asymmetric relation (temporal precedence)
- $e_u \in E$ is the utterance event
- V is an interpretation function like in standard FOL
- Notation for overlapping events: $e \cdot e'$ iff neither $e < e'$ nor $e' < e$

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

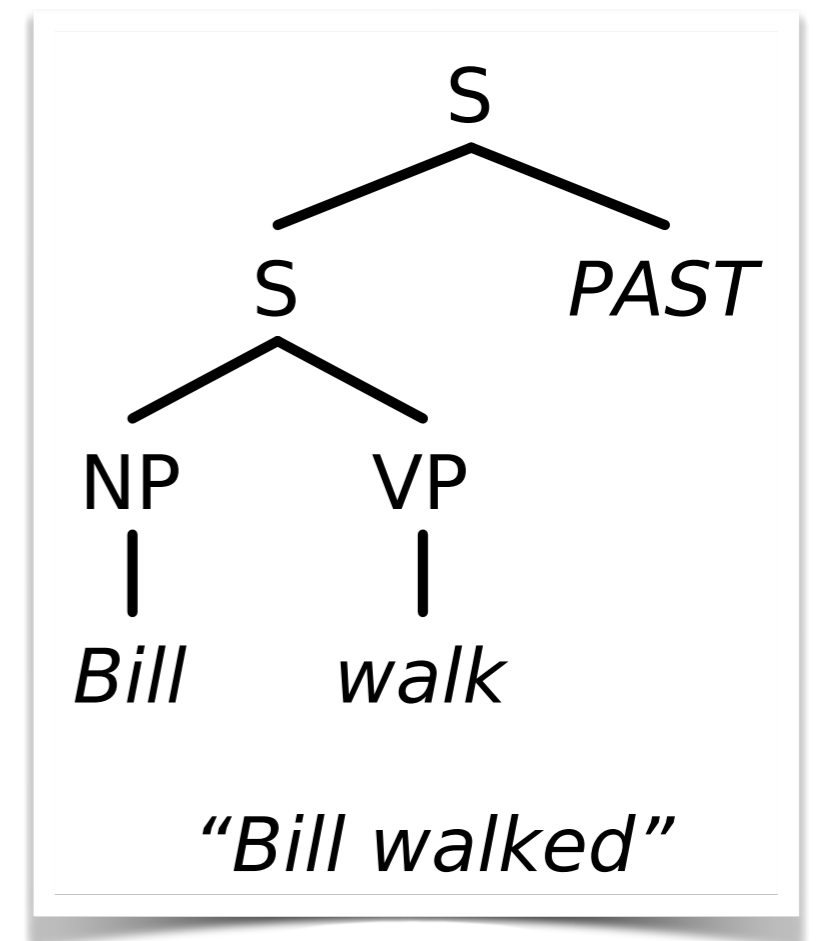
PRES $\mapsto \lambda P.\exists e [P(e) \wedge e \cdot e_u] : \langle \langle e, t \rangle, t \rangle$



Tense in Semantic Construction (cont.)

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

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



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

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:

$$\exists e(\text{break}_3(e, j, w, r)) \not\models \exists e(\text{break}_2(e, r, w)) \not\models \exists e(\text{break}_1(e, w))$$

Semantic/Thematic roles

agent

patient

instrument

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

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

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

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

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

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

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.

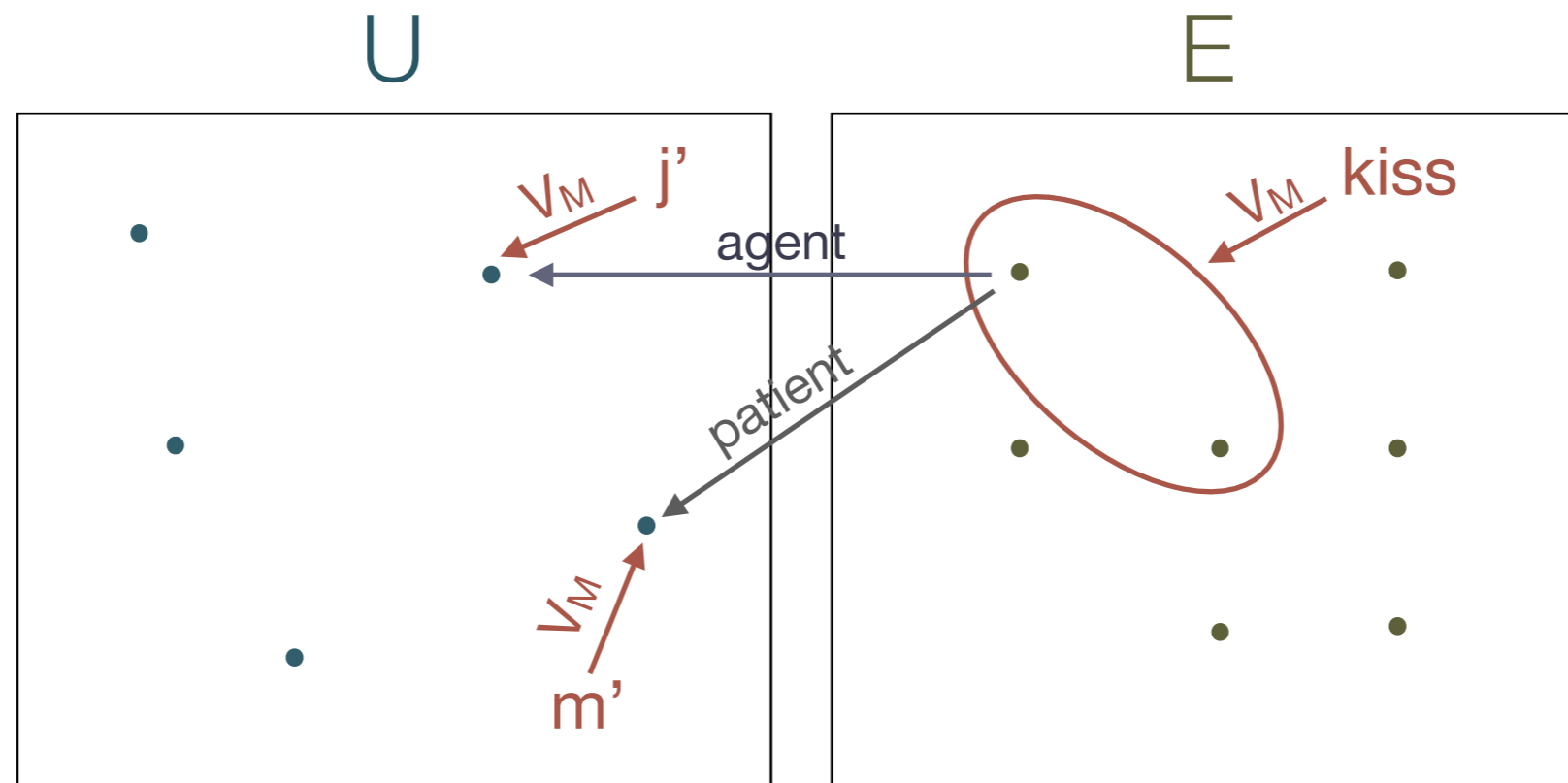
Interpretation of events with thematic roles

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

$\llbracket \exists e (\text{kiss}(e) \wedge \text{agent}(e, j') \wedge \text{patient}(e, m')) \rrbracket^{M,g} = 1$

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

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



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

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... 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) *[Agent Lufthansa] is replacing* *Frame: REPLACING* *[Old its 737s] [New with Airbus A320s]*
- (2) *[Agent Lufthansa] is substituting* *Frame: REPLACING* *[New Airbus A320s] [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]

(2) [Arg0 Lufthansa] is substituting
[Arg1 Airbus A320s] [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

(3) [Agent Lufthansa] is replacing_{Frame: REPLACING}
[Old its 737s] [New with Airbus A320s]

(4) [Agent Lufthansa] is substituting_{Frame: REPLACING}
[New Airbus A320s] [Old for its 737s]

Frame	REPLACING
Agent	Lufthansa
Old	its737s
New	AirbusA320s

Advantages of Davidsonian events

- ☑ Intuitive representation and semantic construction for adjuncts
- ☑ Uniform treatment of verb complements
- ☑ Uniform treatment of adjuncts and post-nominal modifiers
- ☑ 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/>