Semantic Theory
Week 7 – Event semantics

Noortje Venhuizen

Universität des Saarlandes

Summer 2018

A problem with verbs and adjuncts

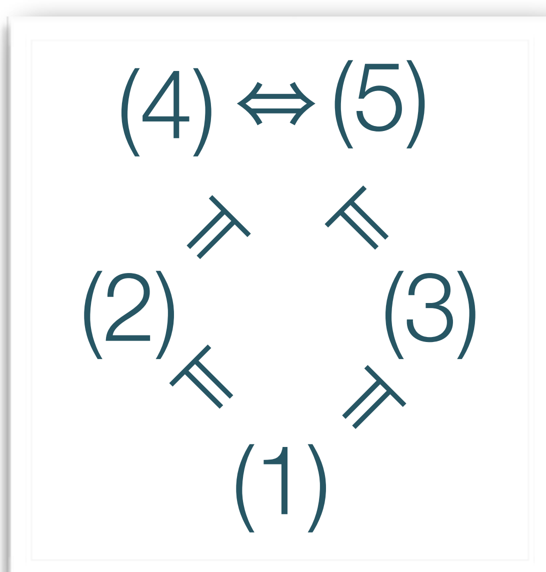
(1) *The gardener killed the baron* $\mapsto$ $kill_1(g',b')$ $kill_1 :: \langle e,\langle e,t\rangle\rangle$

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

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

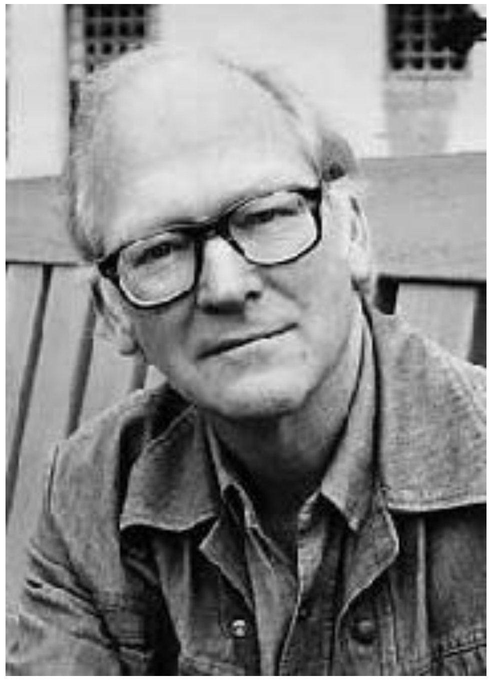
(4) *The gardener killed the baron at midnight in the park* $\mapsto$ $kill_4(g',b',m',p')$ $kill_4 :: \ldots$

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



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 $\mapsto$ $\lambda y \lambda x \lambda e(\text{kill'}(e,x,y))$ :: $\langle e,\langle e,\langle e,t\rangle\rangle\rangle$ *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 $\mapsto$ $\lambda P \lambda e(P(e) \wedge \mathrm{time}(e,m'))$ :: $\langle\langle e,t\rangle,\langle e,t\rangle\rangle$
- 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

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

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

α

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

… 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)

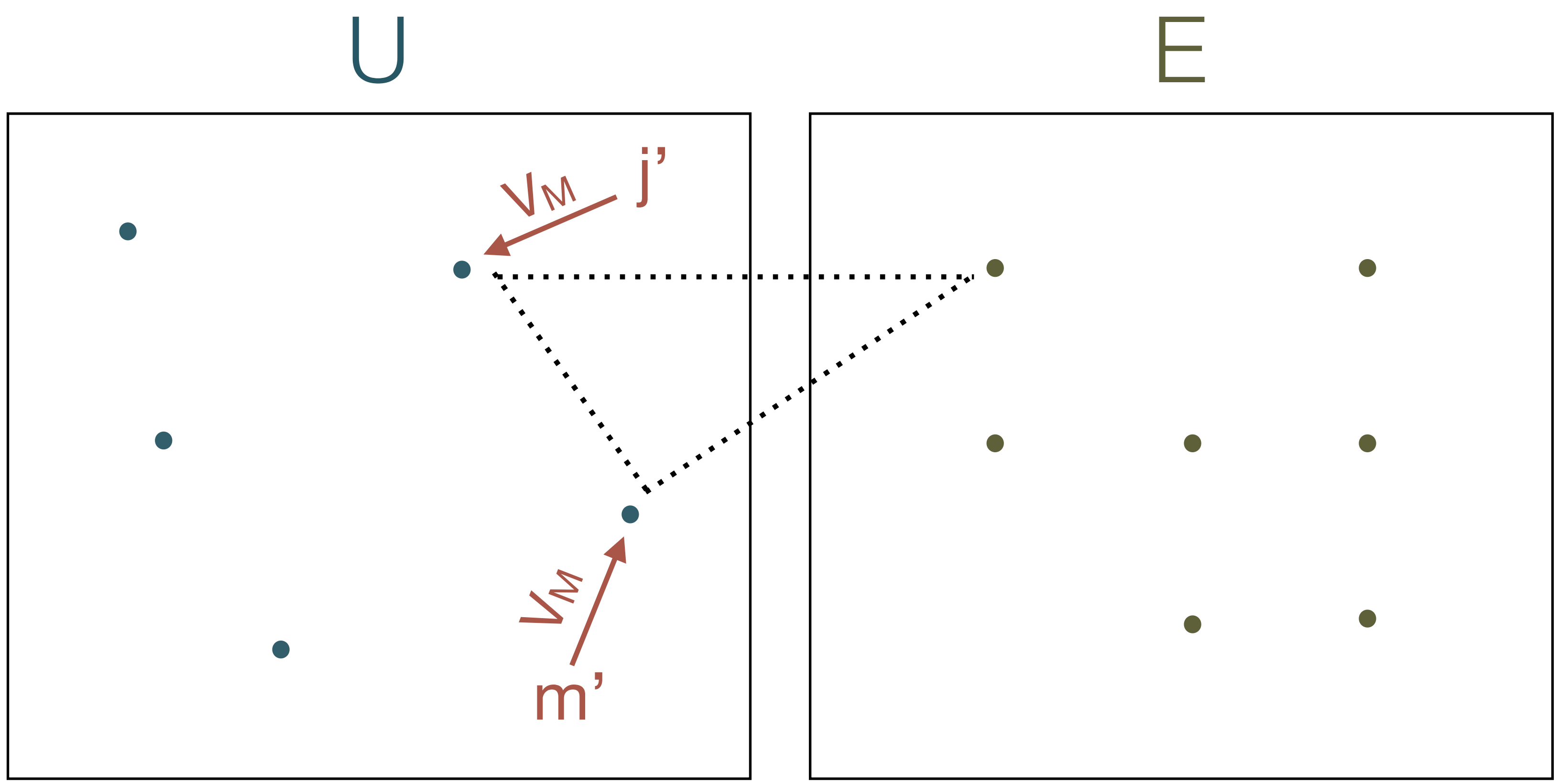
Quantification ranges over sort-specific domains:

- $[\![\exists x\, \Phi]\!]^{M,g} = 1$ 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 $\mapsto$ $\exists e\ (kiss(e, j', m'))$

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



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 :: $\langle e,\langle e,\langle e,t\rangle\rangle$

(2) *Bill saw an accident*

$\mapsto \exists e\ \exists e'\ (\text{see}(e, b, e') \wedge \text{accident}(e'))$ see :: $\langle e,\langle e,\langle e,t\rangle\rangle$

(3) *Bill saw the children play*

$\mapsto \exists e\ \exists e'\ (\text{see}(e, b, e') \wedge \text{play}(e', \text{the-children}))$ 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 ↦ $\lambda F\ \lambda x\ [\ F(x) \wedge red^*(x)\ ]$ $\langle\langle e,t\rangle,\langle e,t\rangle\rangle$
- 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 ….

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

Advantages of Davidsonian events

- [x] Intuitive representation and semantic construction for adjuncts
- [x] Uniform treatment of verb complements
- [x] 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* walk(john)
- *John walked* P(walk(john))
- *John will walk* F(walk(john))

Φ has always been the case

Φ is always going to be the case

Syntax like in first-order logic, plus

- if Φ is a well-formed formula, then PΦ, FΦ, HΦ, GΦ are also well-formed formulae.

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
- $U \cap T = \varnothing$
- $<$ 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*?

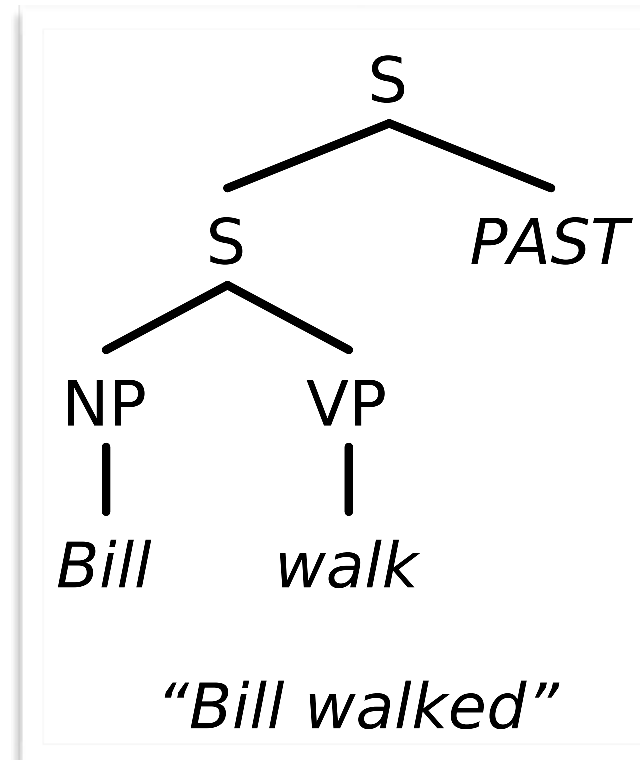
Temporal Event Structure

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: $e \cdot e'$ 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.



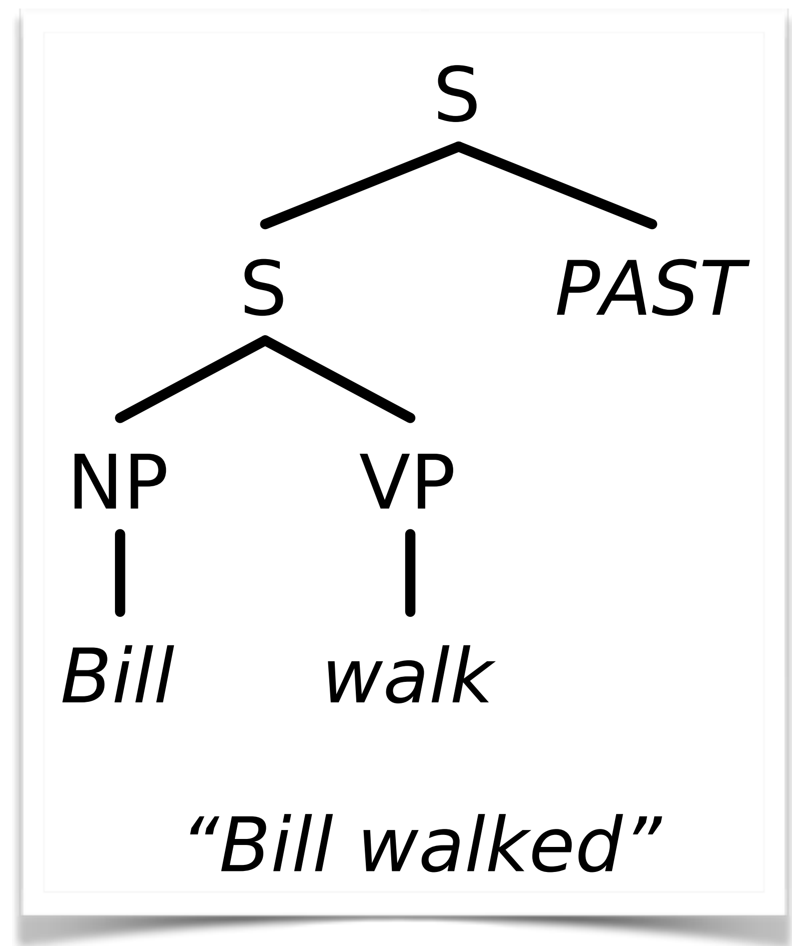
PAST $\mapsto \lambda P.\exists e\ [P(e) \wedge e < e_u] : \langle\langle e, t\rangle, t\rangle$

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



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?

(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.*

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

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

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

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

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

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.

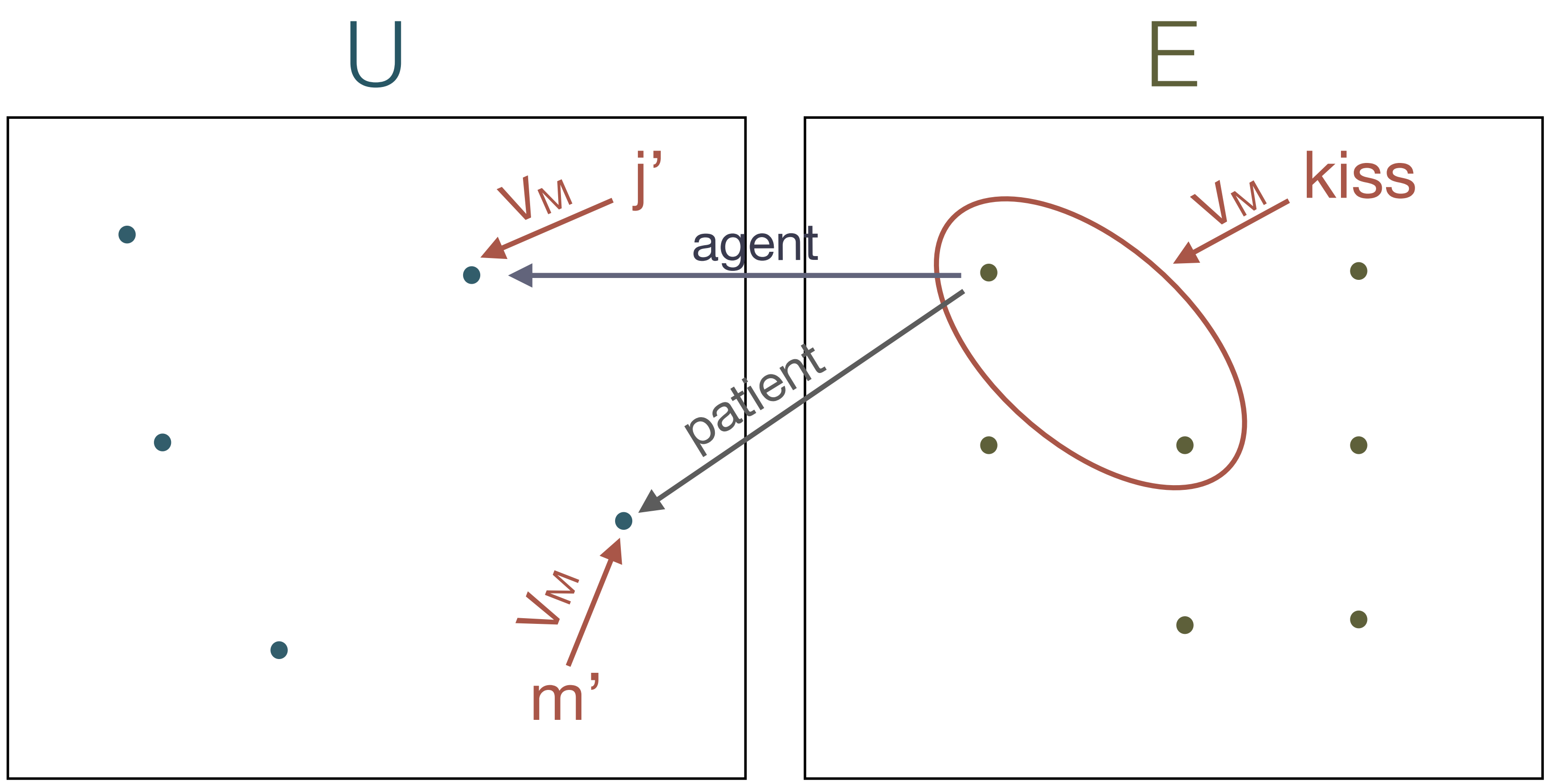
Interpretation of events with thematic roles

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*

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

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]

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

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

… but how does it combine with other semantic constructs?

A problem with events and quantification

John kissed Mary

$\mapsto \lambda P.P(j') \; [\; \lambda P.P(m')(\lambda y \lambda x \lambda e\, [kiss(e) \wedge agent(e,x) \wedge patient(e,y)])\;]$

$\Rightarrow^{\beta}\; \lambda e\, [kiss(e) \wedge agent(e,j') \wedge patient(e,m')]$

$\Rightarrow^{\text{E-CLOS}}\; \exists e\, [kiss(e) \wedge agent(e,j') \wedge patient(e,m')]$

John kissed every girl

$\mapsto \lambda P.P(j') \; [\; \lambda P.\forall x(girl'(x) \rightarrow P(x))(\lambda y \lambda x \lambda e\, [kiss(e) \wedge agent(e,x) \wedge patient(e,y)])\;]$

$\Rightarrow^{\beta}\; \lambda e\, [\forall x(girl'(x) \rightarrow kiss(e) \wedge agent(e,j') \wedge patient(e,x)]$

$\Rightarrow^{\text{E-CLOS}}\; \exists e\, [\forall x(girl'(x) \rightarrow kiss(e) \wedge agent(e,j') \wedge patient(e,x)]$

Two solutions to the event quantification problem

Solution I

Interpret sentences as generalized quantifiers over events: $\langle\langle e,t\rangle,t\rangle$ instead of $\langle e,t\rangle$ (E-CLOS part of lexical semantics) (Champollion, 2010; 2015)

kiss $\mapsto \lambda F_{\langle v,t\rangle}.\exists e\,(\mathrm{kiss}(e) \wedge F(e)) :: \langle\langle v,t\rangle,t\rangle \quad \approx \{\, F \mid F \cap \mathrm{KISS} \neq \varnothing \}$

separate type for events!

Solution II

Introduce separate types for regular NPs and quantified NPs, and restrict existential closure to regular NPs (Winter & Zwarts, 2011; de Groote & Winter, 2014)

john $\mapsto j :: e$

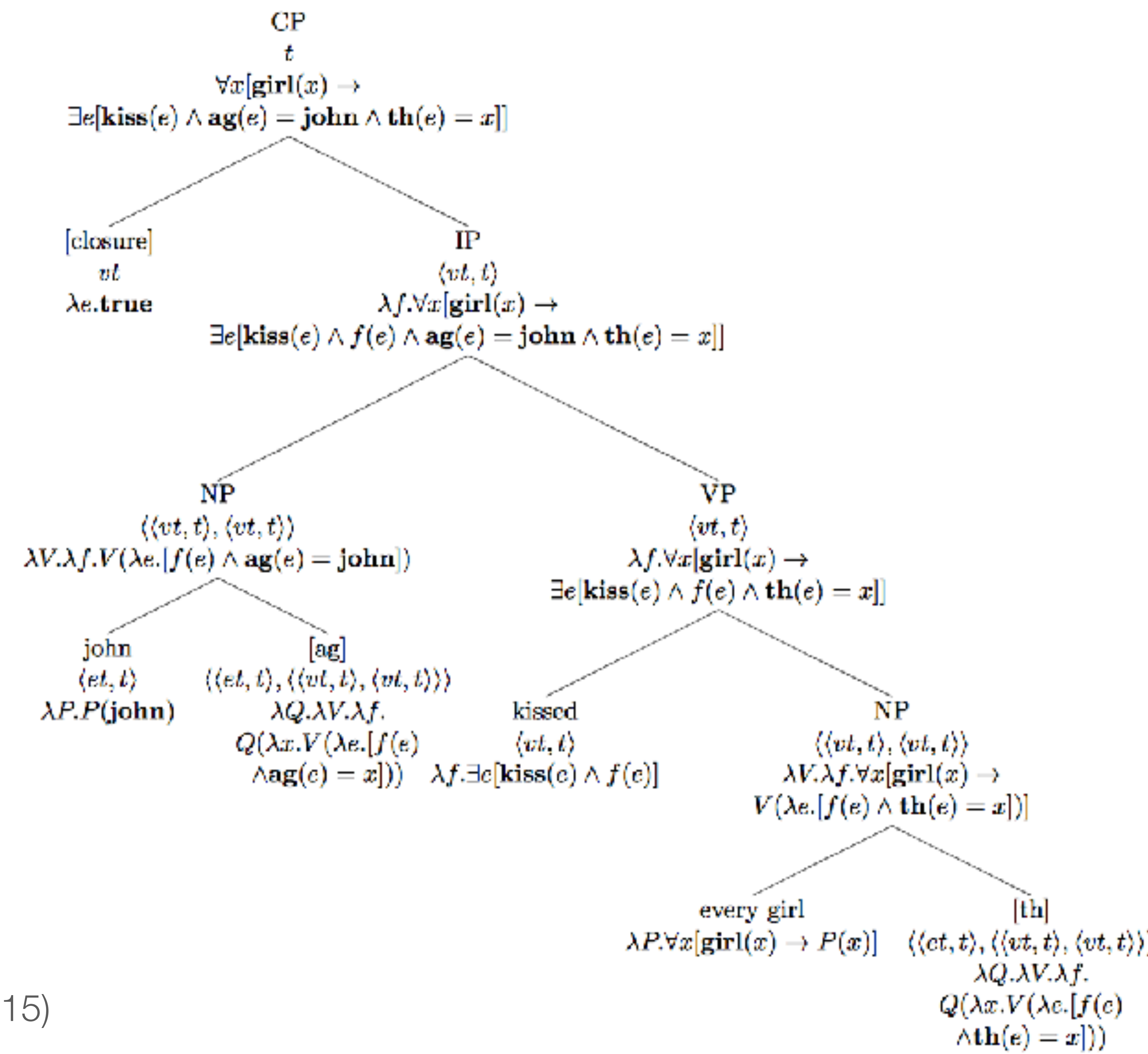
every girl $\mapsto \lambda P \lambda Q.\forall x(\mathrm{girl}(x) \rightarrow Q(x)) :: \langle\langle e,t\rangle,\langle\langle e,t\rangle,t\rangle\rangle$

kiss $\mapsto \lambda x \lambda y \lambda e.\mathrm{kiss}(e,x,y) :: \langle e,\langle e,\langle v,t\rangle\rangle\rangle$

e-clos $\mapsto \lambda P.\exists e(P(e)) :: \langle\langle v,t\rangle,t\rangle$

separate type for events!

Solution I: Sentences as GQs over events



(Champollion, 2010; 2015)

Solution II: Type-restriction for existential closure

$$\dfrac{\vdash \textsc{every} : N \to (NP \to S) \to S \qquad \vdash \textsc{girl} : N}{\vdash \textsc{every girl} : (NP \to S) \to S}\ (1)$$

$$\dfrac{\dfrac{\vdash \textsc{kissed} : NP \to NP \to V \qquad x : NP \vdash x : NP}{x : NP \vdash \textsc{kissed}\ x : NP \to V} \qquad \vdash \textsc{john} : NP}{x : NP \vdash \textsc{kissed}\ x\ \textsc{john} : V}\ (2)$$

$$\dfrac{\dfrac{\vdash \textsc{e-clos} : V \to S \qquad \begin{array}{c} \vdots\ (2) \\ x : NP \vdash \textsc{kissed}\ x\ \textsc{john} : V \end{array}}{x : NP \vdash \textsc{e-clos}\,(\textsc{kissed}\ x\ \textsc{john}) : S}}{\vdash \lambda x.\ \textsc{e-clos}\,(\textsc{kissed}\ x\ \textsc{john}) : NP \to S}\ (3)$$

$$\dfrac{\begin{array}{c} \vdots\ (1) \\ \vdash \textsc{every girl} : (NP \to S) \to S \end{array} \qquad \begin{array}{c} \vdots\ (3) \\ \vdash \lambda x.\ \textsc{e-clos}\,(\textsc{kissed}\ x\ \textsc{john}) : NP \to S \end{array}}{\vdash \textsc{every girl}\,(\lambda x.\ \textsc{e-clos}\,(\textsc{kissed}\ x\ \textsc{john})) : S}$$

(Winter & Zwarts, 2011; de Groote & Winter, 2014)

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/