Semantic Theory

Lexical Semantics I

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What do content words really mean?

- *John loves Mary*
- *Mary kicked John*
- *Bill is coughing*

- *Bill travelled to Paris*
- *Bill's travel started in Paris*

- *Bill saw an elephant*
- *Bill saw an accident*

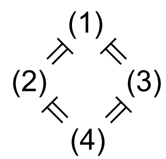
Davidson's problem

Interpretation of adjunct constructions:

(1) *The gardener killed the baron at midnight in the park*
$\Rightarrow kill_4(g, b, m, p)$
(2) *The gardener killed the baron at midnight*
$\Rightarrow kill_3(g, b, m)$
(3) *The gardener killed the baron in the park*
$\Rightarrow kill_2(g, b, p)$
(4) *The gardener killed the baron*
$\Rightarrow kill_1(g, b)$

Davidson's Problem

- Problem: How can the systematic logical entailment relations between the different uses of *kill* be explained?



- Naïve FOL interpretation does not solve the problem:
  - $kill_4(g, b, m, p) \not\models kill_3(g, b, m)$
  - $kill_3(g, b, m) \not\models kill_1(g, b)$
  - etc.

An Interpretation Alternative

- Determine the maximum arity n of the predicate.
- Take n to be the arity of the predicate.
- Bind syntactically empty argument positions with existential quantifier.

  (1) ⇒ kill(g, b, m, p)
  (2) ⇒ ∃y kill(g, b, m, y)
  (3) ⇒ ∃x kill(g, b, x, p)
  (4) ⇒ ∃x∃y kill(g, b, x, y)

- Problem: What is the maximum arity of a predicate?
  The gardener killed the baron at midnight in the park under cover of absolute darkness with a gun …

Davidson's Proposal

- Standard FOL-Semantics: two-place verbs denote sets of pairs of individuals.
- Davidson: Verbs denote events.
- Verbs expressing events have an additional event argument, which is not realised at linguistic surface:

  $\lambda y \lambda x \lambda e.\ kill(e,x,y)$
- In general, n-place event verbs are represented by relations of arity n+1.
- Adjuncts express two-place relations between events and the respective "circumstantial information" (a time, a location, ...)
- The event variable is existentially bound:

  The gardener killed the baron at midnight in the park

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

Davidson's Proposal

- Semantic representation of verbs using events allows an arbitrary number of adjuncts.

- Since adjunct information is attached through conjunction, entailment the entailment problem is trivially solved:

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

$\models \quad \exists e[\ kill(e,g,b) \wedge time(e, m)\ ]$

$\models \quad \exists e[\ kill(e,g,b)\ ]$

Extending model structure with events

- Enriching model structures with ontological information - in the traditional Aristotelian sense of ontology: The area of philosophy identifying and describing the basic "categories of being and their relations".

- We assume two disjoint classes, or kinds, or sorts of individuals:
  - A set of "standard individuals" or "objects" U
  - A set of events E

- A model structure is defined as

  M = (U, E, V),
  with $U \cap E = \emptyset$,
  V interpretation function like in standard FOL

Sorted logic

- We assume a separate inventory of variables for each sort of individuals:
  - (Standard) Object variables: Var_U = x, y, z, ..., x_1, x_2, ...
  - Event variables: Var_E = e, e', e'', ..., , e_1, e_2, ...
- Variable assignment functions g assign object and event variables individuals of the respective sort-specific domain:
  - $g(x) \in U$ for $x \in Var_U$
  - $g(e) \in E$ for $e \in Var_E$
- Quantification ranges over sort-specific domains:
  - $[[\exists x\ \Phi]]^{M,g} = 1$ iff there is an $a \in U$ s.t. $[[\ \Phi\ ]]^{M,g[x/a]} = 1$
  - $[[\exists e\ \Phi]]^{M,g} = 1$ iff there is an $a \in E$ s.t. $[[\ \Phi\ ]]^{M,g[e/a]} = 1$

Why event semantics is attractive

- Events as "first-class citizens" enable a natural interpretation of verbs and nominal event predicates.
- Natural representation of adjunct information
- Uniform treatment of NPs and infinitive constructions as verb complements
- Intuitive semantic construction for adjuncts
- Uniform treatment of noun modifiers (adjectives, post-nominal PPs) and adjuncts
- Plausible integration of tense

Uniform treatment of verb complements

- *Bill saw an elephant.*
  $\exists e \exists x\ [\ see(e, b, x) \wedge elephant(x)]$
- *Bill saw an accident.*
  $\exists e \exists e'\ [\ see(e, b, e') \wedge accident(e')]$
- *Bill saw the children play*
  $\exists e \exists e'\ [\ see(e, b, e') \wedge play(e', the\text{-}children)]$

Adjuncts as modifiers

- Treatment of adjuncts as predicate modifiers, in analogy to attributive adjectives: type ((e,t),(e,t)):
- Adjectives modify a predicate over standard objects, encoded as a common noun:
  - Representation of the intersective adjective *red:*
    red $\Rightarrow \lambda F \lambda x[F(x) \wedge red^*(x)]$,
    modifying, e.g., $\lambda x[book(x)]$
- Adjuncts modify event predicates, encoded as a sentence (more precise description follows):
  - *at midnight* $\Rightarrow \lambda E \lambda e[E(e) \wedge time(e, midnight)]$,
    modifying, e.g., $\lambda e[it\_rains(e)]$

Compositional derivation of event-semantic representations

- *kill* ⇒ $\lambda y \lambda x \lambda e.\text{kill}(e,x,y) : (e,(e,(e,t)))$
- *baron* ⇒ $b : e$
- *gardener* ⇒ $g : e$
- *at midnight* ⇒ $\lambda E \lambda e[E(e) \wedge \text{time}(e, \text{midnight})] : ((e,t),(e,t))$
- *in the park* ⇒ $\lambda E \lambda e[E(e) \wedge \text{location}(e, \text{park})] : ((e,t),(e,t))$

$\lambda y \lambda x \lambda e.\text{kill}(e,x,y)$ g b

$\lambda E \lambda e[E(e) \wedge \text{time}(e, \text{midnight})]$ $\lambda e.\text{kill}(e, g, b) : (e,t)$

$\lambda E \lambda e[E(e) \wedge \text{location}(e, \text{park})$ $\lambda e[\text{kill}(e, g, b) \wedge \text{time}(e, \text{midnight})] : (e,t)$

$\lambda e[\text{kill}(e, g, b) \wedge \text{time}(e, \text{midnight}) \wedge \text{location}(e, \text{park})] : (e,t)$

Existential closure: ———

$\exists e[\text{kill}(e, g, b) \wedge \text{time}(e, \text{midnight}) \wedge \text{location}(e, \text{park})] : t$

Adjuncts and modifiers, continued

Uniform semantic representation for adjuncts and post-nominal modifiers:

in the park ⇒ $\lambda F \lambda x[F(x) \wedge \text{location}(x, \text{park})]$

- Local adjunct:
  [[The gardener killed the baron] in the park]
  ⇒ $\lambda E \lambda e[E(e) \wedge \text{location}(e, \text{park})](\lambda e.\text{kill}(e, g, b))$
  ⇔ $\lambda e[\text{kill}(e, g, b) \wedge \text{location}(e, \text{park})]$
- Post-nominal modifier of event noun:
  The [[murder] in the park]
  ⇒ $\lambda E \lambda e[E(e) \wedge \text{location}(e, \text{park})](\lambda e.\text{murder}(e))$
  ⇔ $\lambda e[\text{murder}(e) \wedge \text{location}(e, \text{park})]$
- Post-nominal modifier of standard noun:
  The [[pavillon] in the park]
  ⇒ $\lambda F \lambda x[F(x) \wedge \text{location}(x, \text{park})](\lambda y.\text{pavillon}(y))$
  ⇔ $\lambda x[\text{pavillon}(x) \wedge \text{location}(x, \text{park})]$

Tense

- Tensed sentences:
  John walked
  John is walking
  John will walk
- Representation of tense in conventional tense logic:
  walk(john)
  P*walk(john)*
  F*walk(john)*

Tense Logic

- Model structure: $M = \langle U, T, <, V \rangle$
  - $U \cap T = \varnothing$
  - $<$ a linear ordering on T
  - V a value assignment function, which assigns to every non-logical constant α a function from T to appropriate denotations of α
- Interpretation of tense operators:
  $[\![PA]\!]^{M,t} = 1$ iff $[\![A]\!]^{M,t'} = 1$ for at least one $t' < t$
  $[\![FA]\!]^{M,t} = 1$ iff $[\![A]\!]^{M,t'} = 1$ for at least one $t' > t$

Temporal Event Structure

- A model structure with events and temporal precedence is defined as

  M = (U, E , <, e_u, V),
  with U∩E = ∅,
  < ⊆ E×E an asymmetric relation (temporal precedence)
  e_u∈E the utterance event
  V an interpretation function like in standard FOL, with
  D_e = U∪E

- Overlapping events:

  e o e' iff neither *e < e'* *nor e' < e*

Temporal Event Structure II

- An alternative model structure with points and intervals of time:

  M = (U, E , T, <, t_u, *tl*, V),
  with U, E, and T mutually disjoint,
  < a linear ordering on T
  t_u∈T is the utterance time
  tl a function from E to intervals of T
  V an interpretation function like in standard FOL

- Precedence of events:

  e < e' iff for all t ∈ *tl*(e), t'∈ *tl*(e'): t < t'

- Overlapping events:

  e o e' iff *tl*(e) ∩ *tl*(e') ≠ ∅

Tense in Semantic Construction

- Tense is encoded in the verb inflection.
- There are reasons to give stem and inflection of the verb distinct syntactic representations, where inflection is represented as an abstract tense operator commanding the untensed rest of the sentence:

  Bill walked : $[_S [_S \text{Bill} [_{VP} \text{walk}]] \text{PAST}]$

- Semantic representation of tense operators expresses temporal location of reported event w.r.to utterance event:

  PAST ⇒ $\lambda E \exists e(E(e) \wedge e < e_u)$: ((e,t),t)
  PRES ⇒ $\lambda E \exists e(E(e) \wedge e \text{ o } e_u)$: ((e,t),t)

- Standard function application effects integration of temporal information and binding of the event variable:

$$\frac{\lambda E \exists e(E(e) \wedge e < e_u) \qquad \lambda e.\text{walk}(e, b)}{\exists e[\text{walk}(e, b) \wedge e < e_u]}$$

Stative and non-stative verbs

- *Mary kicked John* : "there is a kicking event, in which Mary and John are involved"
- *John knew the answer:* "there is a knowing event, in which John and the answer are involved" (?)
- There are verbs expressing states and verbs expressing events (which we call non-stative for the time being)
  - States: *know, believe, have, desire, love*
  - Events: *run, walk, kick, kill, build a house*
- Only non-stative verbs come with an extra argument:
  - kick(e, x, y)
  - know(x, y)