Dependent Event Types

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This talk

I. Davidsonian event semantics

II. Dependent event types

- DETs in simple type theory (Montague's setting)
  - Adequacy: conservativity over Church's simple type theory (*)
- DETs in modern type theories (MTT-semantics)

III. Two applications of DETs

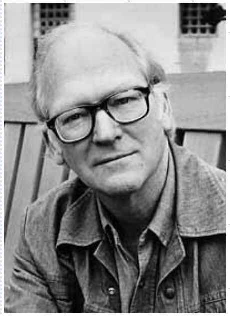
- Event quantification problem and its DET solution
- Selectional restriction in MTT-semantics with DETs (*)

Work based on

- Z. Luo & S. Soloviev. Dependent Event Types. WoLLIC 2017.

But, (*) above are new, not in the above paper.

I. Davidsonian event semantics



- Original motivation: adverbial modifications

  (1) John buttered the toast.

  (2) John buttered the toast with the knife in the kitchen.

  Do we have (2) ⇒ (1)?

  - Cumbersome in MG with meaning postulates (next slide)
  - Davidson (1967): verbs tacitly introduce existentially quantified events, doing away with meaning postulates.

- In neo-Davidsonian notation (1980s) with thematic roles (slide)

  (1′) ∃e:Event. butter(e)
  & agent(e)=john & patient(e)=toast

  (2′) ∃e:Event. butter(e) & with(e,knife) & at(e,kitchen)
  & agent(e)=john & patient(e)=toast

  Obviously, (2′) ⇒ (1′)

MG approaches without events

- (1) John buttered the toast.

  (1″) butter(john,toast), where butter : $\mathbf{e}^2 \rightarrow \mathbf{t}$.

- (2) John buttered the toast with the knife in the kitchen.

  (2″) butter(j,t,k,m), where butter : $\mathbf{e}^4 \rightarrow \mathbf{t}$

  (2‴) kitchen(knife(butter(john)))(toast), where
  butter : $\mathbf{e} \rightarrow \mathbf{e} \rightarrow \mathbf{t}$, knife/kitchen : $(\mathbf{e} \rightarrow \mathbf{t}) \rightarrow (\mathbf{e} \rightarrow \mathbf{t})$

- Both need meaning postulates to get, eg,

  (2″) ⇒ (1″) or (2‴) ⇒ (1″),

  rather ad hoc.

Major thematic relations [edit]

Here is a list of the major thematic relations.[3]

- Agent: deliberately performs the action (e.g., **Bill** ate his soup quietly.).
- **Experiencer**: the entity that receives sensory or emotional input (e.g. **Susan** heard the song. **I** cried.).
- **Stimulus**: Entity that prompts sensory or emotional feeling - not deliberately (e.g. David Peterson detests **onions!**).
- **Theme**: undergoes the action but does not change its state (e.g., We believe in one **God**. I have **two children**. I put **the book** on the table. He gave **the gun** to the police officer.) (Sometimes used interchangeably with patient.)
- Patient: undergoes the action and changes its state (e.g., The falling rocks crushed **the car**.). (Sometimes used interchangeably with theme.)
- **Instrument**: used to carry out the action (e.g., Jamie cut the ribbon **with a pair of scissors**.).
- **Force** or **Natural Cause**: mindlessly performs the action (e.g., **An avalanche** destroyed the ancient temple.).
- **Location**: where the action occurs (e.g., Johnny and Linda played carelessly **in the park**. I'll be **at Julie's house** studying for my test.).
- **Direction** or **Goal**: where the action is directed towards (e.g., The caravan continued on **toward the distant oasis**. He walked **to school**.).
- **Recipient**: a special kind of goal associated with verbs expressing a change in ownership, possession. (E.g., I sent **John** the letter. He gave the book **to her**.)
- **Source** or **Origin**: where the action originated (e.g., The rocket was launched **from Central Command**. She walked **away from him**.).
- **Time**: the time at which the action occurs (e.g., The pitcher struck out nine batters **today**)
- **Beneficiary**: the entity for whose benefit the action occurs (e.g.. I baked **Reggie** a cake. He built a car **for me**. I fight **for the king**.).
- **Manner**: the way in which an action is carried out (e.g., **With great urgency**, Tabitha phoned 911.).
- **Purpose**: the reason for which an action is performed (e.g., Tabitha phoned 911 right away **in order to get some help**.).
- **Cause**: what caused the action to occur in the first place; not *for what*, rather *because of what* (e.g., **Because Clyde was hungry**, he ate the cake.).

Problems in Event-semantics + Montague

- For example, “event quantification problem” (EQP)
- Incompatibility between event semantics and MG.

(1) Nobody talked.

Intended neo-Davidsonian event semantics is (2):

(2) $\neg\exists x{:}\mathbf{e}.\ human(x)\ \&\ \exists v{:}Event.\ talk(v)\ \&\ agent(v,x)$

But the incorrect semantics (3) is also possible – it is well-typed:

(3) $\exists v{:}Event.\ \neg\exists x{:}\mathbf{e}.\ human(x)\ \&\ talk(v)\ \&\ agent(v,x)$

which moves the event quantifier “∃v:Event” in (2) to the left.

Some proposed solutions to EQP

- Many different proposals (only mentioning two below)
  - Purpose: to force scope of event quantifier to be narrower.
- Champollion's quantificational event sem. [2010, 2015]
  - Trick: taking a set E of events as argument, but **talk**(e) …
    - talk : (Event→**t**)→**t** with talk(E) = ∃e:Event. e∈E & **talk**(e)
  - Debatable: intuitive meanings, compositionality & complexity
- Winter-Zwarts [2011] & de Groote [2014]
  - Use Abstract Categorial Grammar (see, eg, [de Groote 01])
    - ACG structure prevents incorrect interpretation.
  - Seemingly coincidental (and what if one does not use ACG?)
- Our proposal: dependent event types (solution to EQP & …)

II. Dependent event types [Luo & Soloviev (WoLLIC17)]

- Dependent event types
  - Refining event structure by (dependent) typing
  - Applications include
    - A solution to EQP
    - Selection restrictions in MTT-semantics with events
- How:

  Refining event structure:

  Event ➔ Evt(a)/Evt(a,p)

  which are event types dependent on thematic roles a/p, called agents/patients, respectively.

DETs and their subtyping relationships

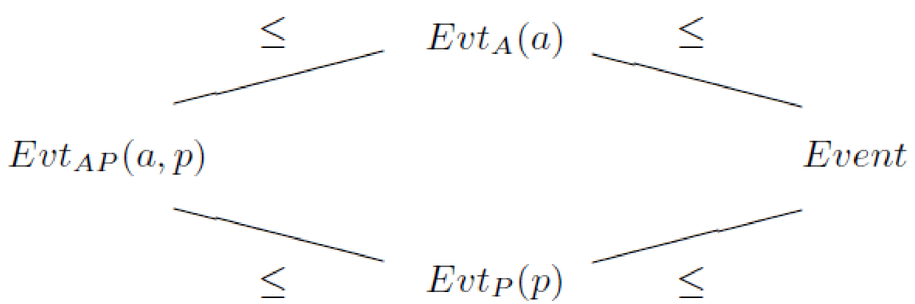
- For a:Agent and p:Patient, consider DETs

  Event, $Evt_A(a)$, $Evt_P(p)$, $Evt_{AP}(a,p)$

- Subsumptive subtyping

$$\frac{a : A \quad A \leq B}{a : B}$$

- Subtyping between DETs (eg, Any event with agent a and patient p is an event with agent a.)



Two systems with DETs

- Extension of Montague's simple TT with DETs
  - C_e extends Church's STT (1940) with DETs
  - Montague's system is familiar for many – hopefully better understanding of DETs.
- Extension of modern type theories with DETs
  - T[E] extends type theory T with DETs (e.g., T = UTT).
  - This shows how DETs work in MTTs.

Dependent event types in Montagovian setting

- Eg. John talked loudly.
  - talk, loud : Event→**t**
  - agent : Event→**e**→**t**
- (neo-)Davidsonian event semantics

$$\exists e : Event.\ talk(e)\ \&\ loud(e)\ \&\ agent(e, j)$$

- Dependent event types in Montagovian setting:

$$\exists e : Evt_A(j).\ talk(e)\ \&\ loud(e)$$

which is well-typed because $Evt_A(j) \leq Event$.

C_e: extending Church's simple TT with DETs

- First, Church's simple type theory (1940)
  - Employed in Montague's semantics (c.f., Gallin 1975)
  - Its rules are presented in the Natural Deduction style as follows.

- Rules for sorts/judgements and λ-calculus

$$\frac{}{\mathbf{e}\ type} \qquad \frac{}{\mathbf{t}\ type} \qquad \frac{}{x : A\ [x : A]} \qquad \frac{}{P\ true\ [P\ true]}$$

$$\frac{A\ type \quad B\ type}{A \to B\ type} \qquad \frac{b : B\ [x : A] \quad x \notin FV(B)}{\lambda x{:}A.b : A \to B} \qquad \frac{f : A \to B \quad a : A}{f(a) : B}$$

Note: the side condition in the λ-rule is there only for DETs.

- Rules for truth of logical formulas

$$\frac{P : \mathbf{t} \quad Q : \mathbf{t}}{P \supset Q : \mathbf{t}} \qquad \frac{Q\ true\ [P\ true]}{P \supset Q\ true} \qquad \frac{P \supset Q\ true \quad P\ true}{Q\ true}$$

$$\frac{A\ type \quad P : \mathbf{t}\ [x : A]}{\forall(A, x.P) : \mathbf{t}} \qquad \frac{P\ true\ [x : A]}{\forall(A, x.P)\ true} \qquad \frac{\forall(A, x.P[x])\ true \quad a : A}{P[a]\ true}$$

- Rule for “conversion” of logical formulas (λ-conversion omitted)

$$\frac{P\ true \quad Q : \mathbf{t}}{Q\ true} \quad (P \simeq Q)$$

Dependent event types in C_e

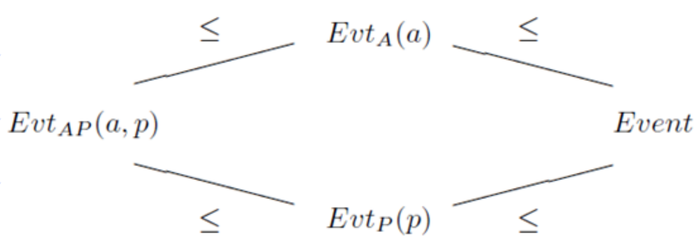
$$\frac{}{Agent\ type} \qquad \frac{}{Patient\ type}$$

$$\frac{}{Event\ type} \qquad \frac{a : Agent}{Evt_A(a)\ type} \qquad \frac{p : Patient}{Evt_P(p)\ type} \qquad \frac{a : Agent \quad p : Patient}{Evt_{AP}(a,p)\ type}$$

$$\frac{a : Agent \quad p : Patient}{Evt_{AP}(a,p) \leq Evt_A(a)} \qquad \frac{a : Agent \quad p : Patient}{Evt_{AP}(a,p) \leq Evt_P(p)} \qquad \frac{a : Agent}{Evt_A(a) \leq Event} \qquad \frac{p : Patient}{Evt_P(p) \leq Event}$$

$$\frac{A\ type}{A \leq A} \qquad \frac{A \leq B \quad B \leq C}{A \leq C} \qquad \frac{A' \leq A \quad B \leq B'}{A \to B \leq A' \to B'}$$

$$\frac{A \simeq B}{A \leq B} \qquad \frac{a : A \quad A \leq B}{a : B}$$

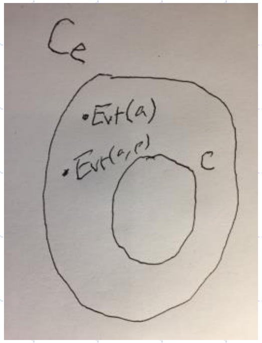


Conservativity (new result)

Background notes

(1) Conservative extension: "J in C and |- J in C_e, then |- J in C."

(2) Logical consistency is preserved by conservative extensions.



<u>Theorem</u>. C_e is a conservative extension over Church's simple type theory.

- <u>Proof</u>.
  - Define R : C_e ➔ C that preserves derivations.
    - R maps Evt(…) to Event and Agent/Patient to **e**.
    - R(t)=t for t∈C.
  - For any C_e-derivation D, R(D) is a C-derivation.

<u>Corollary</u>. C_e is logically consistent.

DET-solution to EQP

(1) Nobody talked.

Neo-Davidsonian in Montague's setting (repeated):

(2) $\neg\exists x{:}\mathbf{e}.\ human(x)\ \&\ \exists v{:}Event.\ talk(v)\ \&\ agent(v,x)$

(3) $\exists v{:}Event.\ \neg\exists x{:}\mathbf{e}.\ human(x)\ \&\ talk(v)\ \&\ agent(v,x)$

The incorrect (3) is well-typed.

Dependent event types in Montague's setting:

(4) $\neg\exists x{:}\mathbf{e}.\ human(x)\ \&\ \exists v{:}Evt_A(x).\ talk(v)$

(#) $\exists v{:}Evt_A(x).\ \neg\exists x{:}\mathbf{e}.\ human(x)\ \&\ talk(v)$

where (#) is ill-typed since the first "x" is outside scope of "$\exists x{:}\mathbf{e}$".

Dependent event types in MTT-semantics

- Let T be any modern type theory (eg, UTT [Luo94]) and E the basic coercions characterizing DET-subtyping. Then, T[E] extends T with DET-subtyping.
- Example of DETs in MTT-semantics

John talked loudly.

$$talk : \Pi h : Human.\ Evt_A(h) \rightarrow Prop.$$

$$loud : Event \rightarrow Prop.$$

$$[\![\text{John talked loudly}]\!] = \exists e : Evt_A(j).\ talk(j,e)\ \&\ loud(e).$$

T[E]: formal presentation in LF

- Constant types/families:
  - $Agent,\ Patient : Type.$
  - $Event : Type,$
    $Evt_A : (Agent)Type,$
    $Evt_P : (Patient)Type$, and
    $Evt_{AP} : (Agent)(Patient)Type.$
- Coercive subtyping in E for DETs:

$$Evt_{AP}(a,p) \leq_{c_1[a,p]} Evt_A(a), \quad Evt_{AP}(a,p) \leq_{c_2[a,p]} Evt_P(p),$$
$$Evt_A(a) \leq_{c_3[a]} Event, \quad Evt_P(p) \leq_{c_4[p]} Event,$$

  where $c_3[a] \circ c_1[a,p] = c_4[p] \circ c_2[a,p]$.
- T[E] has nice properties such as normalisation and consistency if T does (Luo, Soloviev & Xue 2012).

Comparison: a summary (John talked loudly)

- (neo-)Davidsonian event semantics
  - talk, loud : Event→**t** and agent : Event→**e**→**t**.

    $$\exists e : Event.\ talk(e)\ \&\ loud(e)\ \&\ agent(e,j)$$
- Dependent event types in Montagovian setting:
  - talk, loud : Event→**t** and agent : Event→**e**→**t**.

    $$\exists e : Evt_A(j).\ talk(e)\ \&\ loud(e)$$

    which is well-typed because $Evt_A(j) \leq$ Event.
- Dependent event types in MTT-semantics:

  $$talk : \Pi h : Human.\ Evt_A(h) \to Prop.$$

  $$loud : Event \to Prop.$$

  $$[\![\text{John talked loudly}]\!] = \exists e : Evt_A(j).\ talk(j,e)\ \&\ loud(e).$$

  Note: talk's type requires that e have a dependent event type.

III. Selectional restrictions with events

- (#) Tables talk.
  - Montague: $\forall x{:}\mathbf{e}.talk(x)$ – well-typed but false ($talk : \mathbf{e} \rightarrow \mathbf{t}$)
  - MTT-sem: $\forall x{:}Table.talk(x)$ – ill-typed ($talk : Human \rightarrow Prop$)
- What happens when we have events? ($talk : Event \rightarrow \mathbf{t}/Prop$)
  - Montague: $\forall x{:}\mathbf{e}\ \exists v{:}Event.\ talk(v)\ \&\ agent(v)=x$ (well-typed)
  - MTT-sem: $\forall x{:}Table\ \exists v{:}Evt_A(x).\ talk(v)$

    where we have $Table \leq Agent$. (Also well-typed!)

So? There are three approaches to enforce selectional restriction with events:

1. Refining typing for verb phrases (like talk)
2. Refining typing of thematic roles (like agent)
3. Further refining dependent event types by subtyping

- Approach 1: Instead of (neo-Davidsonian) talk : Event→**t**,
  - $talk_h$: Human→Event→Prop (Davidson's original proposal), or
  - $talk_d$: ∏h:Human. $Evt_A(h)$→Prop (dependent typing)

  Then, "Tables talk" is ill-typed – table x is not a human:
  - (#) ∀x:Table ∃v:Event. $talk_h(x,v)$ & agent(v)=x
  - (#) ∀x:Table ∃v:$Evt_A(x)$. $talk_d(x,v)$
- Approach 2: Instead of (neo-Davidsonian) agent:Event→**e**,
  - $agent_h$: Event→Human (with codomain being Human)

  Then, "Tables talk" is ill-typed – table x is not a human:
  - (#) ∀x:Table ∃v:Event. talk(v) & $agent_h(v)$=x

- Approach 3: refined DETs
  - Let $T \leq_c$ Agent. (Consider subtypes of Agent, wlg.)
    - $Evt_A[T] : T \rightarrow Type$
    - $Evt_A[T](a) = Evt_A(c(a))$, for any a : T.
- Examples
  - Men talk.
    - $\forall x{:}Man\ \exists v{:}Evt_A[Human](x).\ talk(v)$ (OK because Man≤Human)
  - Tables talk.
    - (#) $\forall x{:}Table\ \exists v{:}Evt_A[Human](x).\ talk(v)$ (ill-typed - x is not a human.)
  - John picked up and mastered the book.
    - $\exists v{:}Evt_{AP}[Human,P\bullet I](j,b).\ pick\text{-}up(v)\&master(v)$, where $b : Book \leq P\bullet I$.
- Note: this approach is more flexible/powerful.

Related (and some future) work on DETs

- Original idea
  - Came from my treatment of an example in (Asher & Luo 12)
    - Evt(h) to represent collection of events conducted by h : Human.
  - Further prompted by de Groote's talk at LENLS14 (on EQP etc.)
- Other applications of DETs
  - For example, problem with negation in event semantics
- DETs dependent on other parameters
  - Dependency on other thematic roles, say time/location/…
  - Dependency on other kinds of parameters than thematic roles?