Negation, modality, events, and truthmaker semantics

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Overview of the course

- Day 1: Davidsonian event semantics, problems with negation.
- Day 2: Situation semantics, negation as a modality.
- Day 3: Negative events in compositional semantics.
- Day 4: Event semantics as exact truthmaker semantics.
- Day 5: Propositions as sets of events, and negative individuals.

Day 4

Recap from Day 3

- *Neg* is a function from sets of events to sets of events.
- The Principle of Negation: P contains an actual event iff $Neg(P)$ doesn't.
- Given this assumption, the desirable linguistic properties of negation follow.
- The negative events obtained through *Neg* can be used to model negative perception reports.
- The Principle of Negation can be modalized to a possible worlds setting in which negation interacts as expected with modals and attitude verbs.
- But the Principle of Negation is a stipulation at this point.

Today's contents

- Leakage.
- Events as exact truthmakers.
- Bilateral truthmaker semantics.
- Unilateral truthmaker semantics based on exclusion.
- Proof of the Principle of Negation.

Persistency and leakage

- Situation semantics treats ordinary lexical predicates like *rain* as persistent.
- If it rains in s_1, and s_1 is a part of s_2, it rains in s_2.
- This means that an intersective semantics for conjunction is appropriate: it rains and snows in s just in case it rains in s and snows in s.

Event predicates are not persistent

- Some early theorists suggested that ordinary event predicates are persistent too (Lasersohn 1992).
- But the consensus today is that this is not the case – unlike situation semantics.
- We want to avoid **leakage**: an event predicate that allows extraneous material into the event (Bayer 1997).
- The problem can be illustrated with nondistributive adverbials (see Eckardt 1998: Chapters 4 and 5 and Schein 1993):

(1)
a. In 30 minutes, Alma put each ball into a box.
b. From 2-4pm, Bertha took a nap and watered the tulips.
c. Unharmoniously, every organ student sustained a note on the Wurlitzer.

Why leakage is bad

(2) From 2-4pm, Bertha took a nap and watered the tulips.

- This is true iff there are a napping event e_1 and a watering event e_2 and their sum $e_1 \sqcup e_2$ lasted from 2-4pm.
- Suppose that *Bertha took a nap* was persistent (i.e., leakage).
- Then it would hold not only of e_1 but also of $e_1 \sqcup e_2$.
- Then it would follow that *From 2-4pm, Bertha took a nap*.
- To block this entailment, we assume that *Bertha took a nap* does not apply to $e_1 \sqcup e_2$.
- So we assume that it is not persistent.
- Similarly for *Bertha watered the tulips*.

The entries for situation semantics don't work for events

For comparison: Conjunction in situation semantics

$[\![p \wedge q]\!] = \{s \mid s \in [\![p]\!] \text{ and } s \in [\![q]\!]\}$

- For event predicates that are not persistent, this won't work

(3) a. Bertha took a nap and watered the tulips.
b. The sphere rotated quickly and heated up slowly.

- Neither of these sentences ascribes two properties to the same event.
- In the previous example, *Bertha took a nap* holds of e_1 and *Bertha watered the tulips* holds of e_2. Neither holds of $e_1 \sqcup e_2$.
- If these are the only events in play, there is no event of which both predicates hold.

Event semantics and truthmaker semantics

- Various scholars have pointed out the connection between event semantics and truthmaker semantics (Fernando 2015, Kratzer 2021).
- This provides a good starting point for thinking about one of these frameworks if you are familiar with the other.

Truthmaker semantics

- Truthmaker semantics has been developed mainly by logicians and philosophers, who have been in the business of providing new model theories for various sentential logics and new analyses of philosophical concepts like subject matter, logical subtraction, and ground (van Fraassen 1969, Fine 2014, 2016, 2017a,b,c, Yablo 2014, Jago 2020).
- There has also been an increasing interest in linguistic applications of this framework (Yablo 2016, 2017, Fine 2017c, Moltmann 2020, 2021).
- 'Truthmaker semantics' is best regarded as an umbrella term. We discuss systems of 'recursive' truthmaking, but will not have time to discuss the 'reductive' approach in Yablo 2014 on which truthmakers are minimal models.

Truthmakers are devoid of extraneous material

- In Fine's "exact" truthmaker semantics, truthmakers are partial states that must be wholly relevant to the truth of the statements they make true (no leakage).
- The partiality distinguishes truthmaker semantics from traditional possible worlds semantics whose verifying states are complete.
- The exact verification sets this system apart from situation semantics, where the truthmakers (situations) can be inexact, i.e. contain extraneous material as well (Kratzer 2021).

Truthmaker semantics is silent on what truthmakers are

- In Fine's abstract algebraic approach, the exact nature of the truthmakers (called "states") is largely left open.

  [T]he term 'state' is a mere term of art and need not be a state in any intuitive sense of the term. Thus facts or events or even ordinary individuals could, in principle, be taken to be states, as long as they are capable of being endowed with the relevant mereological structure and can be properly regarded as verifiers. (Fine 2017c)

- This makes truthmaker semantics a good fit for integration with various linguistic frameworks that supply these truthmakers (e.g., Moltmann 2020).

Models for exact truthmaker semantics

- A model for possible worlds semantics tells us which propositional letters are true at which possible worlds.
- For situation semantics, it tells us which propositional letters are true in which situations.
- For exact truthmaker semantics, it tells us which letters are verified by which truthmakers (and in bilateral versions, also which ones are falsified by which falsemakers).
- It is helpful to think of these truthmakers as events.

Example

$M(rain) = \{e_1, e_2, e_1 \sqcup e_2\}, M(snow) = \{e_3\}, M(sleet) = \{\}$

- We can impose various constraints – e.g., requiring that all propositional letters have truthmakers.

Exact truthmaker semantics: Conjunction

Conjunction in exact truthmaker semantics

$$[\![p \wedge q]\!] = \{e \mid \exists e_1 \in [\![p]\!] \exists e_2 \in [\![q]\!].\ e = e_1 \sqcup e_2\}$$

- The signature of truthmaker semantics is the clause for conjunction.
- Linguists know this as the "collective" or "non-boolean" theory of conjunction (Krifka 1990a, Lasersohn 1995, Heycock & Zamparelli 2005).
- This is a pointwise version of collective conjunction a la Link (1983). Link was primarily concerned with individual conjunctions.
- It maintains the exact-verification character of the verifiers of the conjuncts.

For comparison: Conjunction in situation semantics

$$[\![p \wedge q]\!] = \{s \mid s \in [\![p]\!] \text{ and } s \in [\![q]\!]\}$$

Exact truthmaker semantics: Disjunction

Disjunction in exact truthmaker semantics – noninclusive version

$[\![p \vee q]\!] = \{e \mid e \in [\![p]\!] \text{ or } e \in [\![q]\!]\}$

Disjunction in exact truthmaker semantics – inclusive version

$[\![p \vee q]\!] = \{e \mid e \in [\![p]\!] \text{ or } e \in [\![q]\!] \text{ or } e \in [\![p \wedge q]\!]\}$

- There are two variants for the clause for disjunction.
- A truthmaker for either disjunct also verifies the disjunction.
- This is similar to alternative and inquisitive semantics.
- The inclusive semantics adds the truthmakers for the conjunction as well.

For comparison: Disjunction in situation semantics

$[\![p \vee q]\!] = \{s \mid s \in [\![p]\!] \text{ or } s \in [\![q]\!]\}$

The American Plan versus the Australian Plan

- Two approaches to negation (Meyer & Martin 1986):
- On the **American Plan**, we use a bilateral system (separate truth and falsity conditions).
- On the **Australian Plan**, we use a primitive relation between truthmakers.
- Let's look at the American Plan first.
- We associate each propositional letter with verifiers and falsifiers.
- The connectives then need to be extended with rules to propagate falsifiers.
- For conjunction and disjunction, these rules are set up to honor De Morgan laws.

Conjunction in bilateral truthmaker semantics

Conjunction: verifiers (as before)

$$[\![p \wedge q]\!]_+ = \{e \mid \exists e_1 \in [\![p]\!]_+ \exists e_2 \in [\![q]\!]_+.\ e = e_1 \sqcup e_2\}$$

Conjunction: falsifiers (new)

$$[\![p \wedge q]\!]_- = \{e \mid e \in [\![p]\!]_- \text{ or } e \in [\![q]\!]_-\}$$

This is just the noninclusive clause for disjunction. One could just as well use the inclusive clause.

Disjunction in bilateral truthmaker semantics

Disjunction: verifiers (as before)

$[\![p \vee q]\!]_+ = \{e \mid e \in [\![p]\!]_+ \text{ or } e \in [\![q]\!]_+\}$

This is just the noninclusive clause for disjunction, again just for concreteness.

Disjunction: falsifiers (new)

$[\![p \vee q]\!]_- = \{e \mid \exists e_1 \in [\![p]\!]_- \exists e_2 \in [\![q]\!]_-.\ e = e_1 \sqcup e_2\}$

This is the clause for conjunction.

Negation in bilateral truthmaker semantics

Negation: verifiers

$[\![\neg p]\!]_+ = [\![p]\!]_-$

Negation: falsifiers

$[\![\neg p]\!]_- = [\![p]\!]_+$

- Bilateral truthmaker semantics uses verifiers and falsifiers. Negation flips between these.

Negation in unilateral truthmaker semantics

- Now let's look at the Australian Plan.
- On this plan we don't use bilateral semantics, so we only have verifiers.
- We keep the clauses for conjunction and disjunction from before.
- For negation, we need to add more structure to our models.
- Recall the compatibility negation from orthologic:

Compatibility negation (reminder)

$s_1 \in [\![\neg p]\!]$ iff for every s_2 such that $s_1 C s_2$, p is false in s_2.
Equivalently: ... iff for every s_2 where p is true, $s_1 \perp s_2$.

- So we need to add a C or (equivalently) a $\perp$ relation to our models.

Adding an exclusion relation

- Let's try to reuse $\perp$ from Goldblatt (1974) and Dunn (1993).
- That notion is upwards persistent on both sides: if $s_1 \perp s_2$ and $s_2 \sqsubseteq s_3$ and $s_1 \sqsubseteq s_4$ then also $s_3 \perp s_4$.
- This gives us only a "slippery" handle on our negative events:

Compatibility negation (reminder)

$s_1 \in [\![\neg p]\!]$ iff for every s_2 such that $s_1 C s_2$, p is false in s_2.
Equivalently: ...iff for every s_2 where p is true, $s_1 \perp s_2$.

If we use the upwards persistent $\perp$, then $\neg p$ is persistent even if p is not: we get leakage.

$\perp$ as exclusion between events

- Let's redefine $\perp$ so that it matches the following intuitive gloss: If $e_1 \perp e_2$, then event e_1's occurring is wholly relevant to event e_2's not occurring and vice versa.
- The rest of this presentation is novel work by Champollion and Bernard.
- This is inspired by the unilateral negation in Fine (2017a).
- However, that negation is upwards persistent on its second argument and so the "and vice versa" part of the intuitive gloss does not apply.

Our $\perp$ is exact, Dunn's "$\perp$" is inexact

- Our $\perp$ looks similar to the "$\perp$" relation in (Dunn 1993). Is it the same?
- No. The two relate in much the same way that events relate to situations.
- Let's say that two events "conflict" just in case a part of one excludes a part of the other:

Definition: Conflict

$$e_1 \mathrel{\tilde{\perp}} e_2 \stackrel{\text{def}}{=} \exists f_1 \exists f_2 .\ f_1 \sqsubseteq e_1 \wedge f_2 \sqsubseteq e_2 \wedge f_1 \perp f_2$$

- Dunn's "$\perp$" is much more like our $\tilde{\perp}$ than like our $\perp$.

Possible and impossible events

- Let's distinguish between possible and impossible events.
- Possible events are events that do not self-conflict.

Definition: Possibility

$\textsc{Poss}(e) \stackrel{\text{def}}{=} \neg(e \perp e)$
(An event is possible iff it does not conflict with itself.)

- Two (or more) events are called (in)compossible just in case their sum is (im)possible.

Possible worlds are maximal possible events

- Possible worlds can be defined as possible events that contain every event with which they are compossible (cf. Plantinga 1978, Kratzer 1989).
- One such event is then designated as the actual world.

Definition: Possible world

$\textsc{World}(e) \stackrel{\text{def}}{=} \textsc{Poss}(e) \wedge \forall e'.\ [e \sqsubset e' \rightarrow \neg \textsc{Poss}(e')]$

(A possible world is a possible event that is not a proper part of any possible event.)

Constraining $\perp$

- We place various constraints on $\perp$; we will assume that:
  - it is symmetric;
  - it is cumulative;
  - if two events are possible but their sum is not, they conflict;
  - every possible event is part of a possible world;
  - every impossible event conflicts with every possible world.

Axiom: Symmetry of Exclusion

$$\forall e_1 \forall e_2.\ [e_1 \perp e_2 \rightarrow e_2 \perp e_1]$$

Constraining $\perp$

- We place various constraints on $\perp$; we will assume that:
  - it is symmetric;
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  - every possible event is part of a possible world;
  - every impossible event conflicts with every possible world.

Axiom: Cumulativity of Exclusion

$\forall e_1 \forall e_2 \forall f_1 \forall f_2. \, (e_1 \perp f_1 \wedge e_2 \perp f_2) \rightarrow e_1 \sqcup e_2 \perp f_1 \sqcup f_2$

Constraining $\perp$

- We place various constraints on $\perp$; we will assume that:
  - it is symmetric;
  - it is cumulative;
  - if two events are possible but their sum is not, they conflict;
  - every possible event is part of a possible world;
  - every impossible event conflicts with every possible world.

Axiom: Rashōmon

$$\forall e_1 \forall e_2.\ [[\textsc{Poss}(e_1) \wedge \textsc{Poss}(e_2) \wedge \neg e_1 \not\perp e_2] \rightarrow \textsc{Poss}(e_1 \sqcup e_2)]$$

Constraining $\perp$

- We place various constraints on $\perp$; we will assume that:
  - it is symmetric;
  - it is cumulative;
  - if two events are possible but their sum is not, they conflict;
  - every possible event is part of a possible world;
  - every impossible event conflicts with every possible world.

Axiom: Cosmopolitanism

$$\forall e_1.\ [\textsc{Poss}(e_1) \rightarrow \exists e_2.\ [\textsc{World}(e_2) \wedge e_1 \sqsubseteq e_2]]$$

Constraining $\perp$

- We place various constraints on $\perp$; we will assume that:
  - it is symmetric;
  - it is cumulative;
  - if two events are possible but their sum is not, they conflict;
  - every possible event is part of a possible world;
  - every impossible event conflicts with every possible world.

Axiom: Harmony

$\forall e.\ [\neg \textsc{Poss}(e) \rightarrow \forall w.\ \textsc{World}(w) \rightarrow w \perp e]$

E-frames

(4) **Definition: E-frame**

An E-frame is a quadruple $\langle E, \sqsubseteq, \perp, w_0 \rangle$ where:

a. E, the *event space*, is a set (understood as the set of events, including possible worlds);

b. $\sqsubseteq$, the *parthood relation*, is a binary relation over E such that $\langle E, \sqsubseteq \rangle$ is a complete lattice;

c. $\perp$, the *exclusion relation*, is a binary relation over E which satisfies Symmetry, Cumulativity, Cosmopolitanism, Harmony, and Rashōmon;

d. w_0, the *designated world*, is a possible world contained in E (understood as the actual world).

Some aspects of complete lattices

The sum (or join) operation

- Any set of events S has a least upper bound: $\sqcup S$.
- Intuitively, $\sqcup S$ is the sum of the information contained in each $e \in S$.
- Special notation for two elements: $e_1 \sqcup e_2 \stackrel{\text{def}}{=} \sqcup\{e_1, e_2\}$
- Full event: $\blacksquare \stackrel{\text{def}}{=} \sqcup E$; $\forall e.\ e \sqsubseteq \blacksquare$

The product (or meet) operation

- Any set of events S has a greatest lower bound: $\sqcap S$.
- Intuitively, $\sqcap S$ is the information shared by all $e \in S$.
- Special notation for two elements: $e_1 \sqcap e_2 \stackrel{\text{def}}{=} \sqcap\{e_1, e_2\}$
- Null event: $\square \stackrel{\text{def}}{=} \sqcap E$; $\forall e.\ \square \sqsubseteq e$

Defining *Neg* in terms of $\perp$

Intuitively, we construct a precluder for a set of events P by "knocking out" (excluding a part of) every event in P and summing up the events that do the knocking out.

Definition: Preclusion

An event e precludes a set of events P just in case there is a function f from events to events such that for all $e' \in P$, $f(e')$ excludes ($\perp$) some part of e', and $e = \bigsqcup\{f(e') \mid e' \in P\}$.

A negated predicate denotes the set of all of its precluders:

Definition: *Neg*

$$Neg(P) \stackrel{\text{def}}{=} \{e \mid e \text{ precludes } P\}$$

The Principle of Negation is now a theorem

- This vantage point provides conceptual clarity on negative events.
- Various proofs and concepts from truthmaker semantics carry over, sometimes in modified form.
- In particular, the Principle of Negation (an axiom in Bernard & Champollion 2018) is now a theorem.

Principle of Negation

$$\forall P.\ [\exists e \in P.\ actual(e)] \leftrightarrow \neg[\exists e \in Neg(P).\ actual(e)]$$

Proof sketch of the Principle of Negation

Principle of Negation

$\forall P.\ [\exists e \in P.\ \mathit{actual}(e)] \leftrightarrow \neg[\exists e \in \mathit{Neg}(P).\ \mathit{actual}(e)]$

- We interpret being actual as being part of the designated actual world, and we show the result for any possible world w.
- $\rightarrow$ ("No Gluts") If w contains some $e \in P$: any $e' \in \mathit{Neg}(P)$ precludes P and thus e is excluded by some part of e'; hence $e \sqcup e'$ is impossible and thus not part of w; So e' is not part of w.
- $\leftarrow$ ("No Gaps") First: w conflicts with any event it does not contain. Then, if w contains no event in P: for any $e_i \in P$, w has some part that excludes something in e; let f map each e_i to this part; $\bigsqcup\{f(e_i) \mid e_i \in P\}$ precludes P, is part of w, and is in $\mathit{Neg}(P)$.

A natural fit for the collective theory of conjunction

- Recall that the collective theory of conjunction translates *and* as pointwise mereological sum (Krifka 1990b, Lasersohn 1995, Heycock & Zamparelli 2005, cf. Champollion 2016):

(5) $[\![\text{and}]\!] \stackrel{\text{def}}{=} \lambda P_2 \lambda P_1 \lambda e.\ \exists e_1 \exists e_2.\ e = e_1 \sqcup e_2 \wedge P_1(e_1) \wedge P_2(e_2)$

- We now have a natural treatment of sentences involving negated VP conjunctions (e.g., *DP does not drink and drive*) as event predicates.

A complete set of propositional connectives

- Disjunction can be interpreted as union as usual.
- This means we now have a complete set of propositional connectives for event semantics.
- If desired, this can be generalized as in Partee & Rooth (1983).

(6) $[\![\text{or}]\!] \stackrel{\text{def}}{=} \lambda P_2 \lambda P_1 \lambda e.\ P_1(e) \vee P_2(e)$

(7) $[\![\text{not}]\!] \stackrel{\text{def}}{=} \lambda P \lambda e.\ e \in \mathit{Neg}(P)$

(8) $[\![\text{and}]\!] \stackrel{\text{def}}{=} \lambda P_2 \lambda P_1 \lambda e.\ \exists e_1 \exists e_2.\ e = e_1 \sqcup e_2 \wedge P_1(e_1) \wedge P_2(e_2)$

Day 4: Summary

- Exact truthmaker semantics is a natural fit for event semantics.
- In bilateral truthmaker semantics, negation flips verifiers and falsifiers.
- In unilateral truthmaker semantics, we use a compatibility negation.
- Because event predicates are not persistent, we cannot use the Goldblatt-Dunn compatibility negation.
- However, a variant of the unilateral negation in Fine (2017a) fits the bill.
- The resulting theory is a natural fit for the collective theory of conjunction.
- The Principle of Negation is now a theorem.

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