Causal models are (not) about events

Elitzur Bar-Asher Siegal
Hebrew University
Yale University

Prerna Nadathur
The Ohio State University

COCOA

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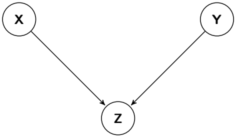
Two kinds of events

What are events in a causal model?

1. What are the relata of a causal model & what is their linguistic role?



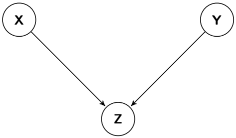
2. What is the relationship between (linguistically-familiar) events/eventualities and causal models?

$$[\![walk]\!] = \lambda w \lambda t \lambda x \lambda e.\texttt{walk}(e) \wedge \texttt{AGENT}(e, x)$$

Our focus: question 2

A straw man: ‘events’ in causal models

Causal model:
DAG + a function indicating how the value of a node depends on the values of its immediate ancestors.



Val(X)	Val(Y)	Val(Z)
0	0	0
1	0	1
0	1	1
1	1	0

- *Terminological NB:* nodes are **events** in the statistical sense
- shorthand for deterministic models: **propositional variable**

  Z ∼ whether or not the door is open:

  Val(Z) = 0 ∼ “The door is not open”
  Val(Z) = 1 ∼ ”The door is open”
  Val(Z) = u ∼ “The state is *undetermined*”
- linguistic events are not coextensive with node-events

Causal models are (not) about events

General caveat:
Causal models are a language-independent cognitive device, the means for encoding & reasoning about causation

Claims: linguistic events have a close relationship with causal models

1. Causal statements about singular events (as described by inflected predicates) rely on causal models for their truth conditions

2. Eventuality predicates correspond to **event types**, which are collections of interrelated conditions **(situation)** that constitute (complex) eventualities of the right type
   Eventuality predicates are about causal models

   a. *Consequently:* the relata of causal models are 'conditions' (properties, state transitions)*, no 1-1 correspondence with singular linguistic events

* They may be underspecified (e.g., with respect to individual participants)

Singular events and causal models

Claim 1: Causal statements about singular events get their truth conditions from causal models

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A causal view of singular events goes back to Davidson (1967, 1969):

- the set of semantic objects includes events (as a type of entity)
- events let us capture entailment relationships between certain kinds of descriptions

(1) a. Brutus stabbed Caesar (with a knife) (in the forum).
    b. B stabbed C & **it** was with a knife & **it** was in the forum
    c. $\exists e[\texttt{stabbing}(e) \,\&\, \texttt{AG}(e, \texttt{B}) \,\&\, \texttt{PAT}(e, \texttt{C}) \,\&\, \texttt{INS}(e, k) \,\&\, \texttt{LOC}(e, f)]$

- **implicit:** distinct descriptions can apply to the same event

Quine: "no entity without identity"

What are the identity conditions for (singular) events?

Singular events and causal models

Claim 1: Causal statements about singular events get their truth conditions from causal models

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What are the identity conditions for singular events? (Davidson 1969)

1. $e_1 = e_2$ if e_1, e_2 have the same location *insufficient*
2. …and occupy the same time *insufficient*
3. …and involve the same participants *insufficient*

(2) Brutus stabs Caesar at 10pm, resulting in Caesar's death at 11:15.

Brutus stabbed Caesar $\not\equiv$ Brutus killed Caesar

4. …and involve "identical changes to identical substances"

"Events are identical iff they have exactly the same causes and effects"

$$(e_1 \equiv e_2) \text{ iff } \forall e_3(e_3 \text{ caused } e_1 \leftrightarrow e_3 \text{ caused } e_2) \;\&\; \forall e_3(e_1 \text{ caused } e_3 \leftrightarrow e_2 \text{ caused } e_3)$$

The inner lives of events

Claim 1: Causal statements about singular events get their truth conditions from causal models

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Singlar events can be simple (up to a certain level of granularity):

(3) a. Brutus stabbed Caesar — $\texttt{stabbing}(e_1, \texttt{B}, \texttt{C})$

b. Caesar died — $\texttt{dying}(e_2, \texttt{C})$

. . . but they can also subsume other (singular) events

(4) Brutus killed Caesar — $\texttt{killing}(e_3, \texttt{B}, \texttt{C})$

$$e_1 \not\equiv e_2,$$

$$e_1, e_2 \sqsubset e_3$$

Causative descriptions (e.g.; *killing, breaking*) pick out complex events:

- event structure, subevent relations rely on Davidsonian identity conditions

*See also Croft (1991): event descriptions $\sim$ descriptions of **causal chains**

Truth conditions for singular events (Claim 1)

Causative claims express singular instances of causation:

(5) Brutus opened the door (e_3)
e_3 subsumes: *B did something (e_1) & the door opened (e_2) & e_1 conforms to standard means of realizing e_2 & $e_2 \not\prec e_1$*

Following Nadathur & Lauer (2020), Baglini & Bar-Asher Siegal (2021) and taking a Davidsonian perspective on the internal structure of complex events), **(5) does not constitute a causal model, but relies on the existence of relevant model** (M_{door}):

- causation between e_1, e_2 is **not directly observable**
- M_{door} provides information about which observables ($e_1, e_2, e_1 \prec e_2$) can justify a claim of singular causation
- **token-model** correspondence *licenses* the causal claim: (5) holds *in virtue* of causal relations between conditions (properties, state transitions; Clm 2a) in the type-level model M_{door}
- conversely, (5)'s truth indicates (speaker belief in) applicability of M_{door} in the ref. context

Truth conditions for singular events

Claim 1: Causal statements about singular events get their truth conditions from causal models

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Singular descriptions require certain sets of conditions (*situations*) to hold at certain times/places, **causation holds in virtue of model properties:**

- linguistic choices signal what sort of model is relevant:

(6) a. Brutus opened the door *Normal*

b. Brutus got/caused/forced the door the open *Abnormal*

- distinct causation 'types' captured as differential model structure (Nadathur & Lauer 2020, a.o.)
- model structure + θ-assignments determines verifying observations
- truth conditions can be expressed set-theoretically (e.g., 'direct' causes complete a sufficient set of conditions for effect) (Baglini & Bar-Asher Siegal 2021)
- no 1-1 relationship between (syntactically-available) subevents, model nodes

Causal models as event types

Claim 2: eventuality predicates correspond to causal models

What is the linguistic status of a causal model?

eventuality predicate $\leftrightarrow$ event type $\leftrightarrow$ causal model

Precedent for this claim:

- Dowty's (1979) aspect calculus:
  "The idea is that the different aspectual properties of the various kinds of verbs can be explained by postulating a single homogeneous class of predicates—stative predicates—plus three or four sentential operators and connectives."

  (4) Brutus killed Caesar
  := [[B does something] CAUSE [BECOME [NOT [ALIVE (C)]]]]

- Dowty's CAUSE is restricted to a binary relation between events; network-based causal models allow for richer representation

Accomplishment predicates as causal models

Claim 2: eventuality predicates correspond to causal models

Case study: accomplishment predicates

- causative for Dowty (+ CAUSE), but accomplishments are not coextensive with lexical causatives (Levin 2000, a.o.)
- **event types** for accomplishment predicates involve complex interrelationships between process (steps) and culmination: **the event type necessarily contains causal information** (Nadathur & Bar-Asher Siegal 2022)

An **accomplishment event type** for predicate P is a causal model M_P:

- culmination condition C_P occurs as a dependent variable
- M_P links properties, conditions/steps to C_P (and to one another)
- M_P specifies **processes** (causal pathways S) for C_P as sets of jointly sufficient conditions for realizing C_P $\texttt{SUFF}_{M_P}(S, C_P)$
- as well as sufficient sets S' for **non-culmination** $\texttt{SUFF}_{M_P}(S', \neg C_P)$

An application: the imperfective paradox (Claim 2)

Progressives of accomplishments do not entail culmination:

- ‘traditional’ approaches:
  - $[\![P]\!]$ picks out exclusively culminated eventualities
  - `PROG` is treated as intensional
- roughly, claiming that accomplishment progressives are true just in case reference time facts predict culmination

Difficult to reconcile with progressives’ acceptability where culmination is not expected/outright precluded:

(7)
a. Mahler was writing his tenth symphony when he died (from a long-established, developing disease).
b. Benny joined an endurance race with insufficient training. He was running a marathon when he collapsed (at mile 10).

Representing event types in terms of causal models gives us a framework to link reference-time facts to culmination conditions without predicting local culmination.

An application: the imperfective paradox (Claim 2)

Assuming **event types** $\sim$ **causal models** (p.10), we can:

- express intuitive truth conditions for progressives set-theoretically
- capture the relevance of world knowledge for progressive judgements

Informally:
Given model M_P for predicate P with culmination condition C_P, the **progressive** is true at time t iff the situation s at t is a **possible cross-section of a non-culminated P-eventuality:**

(a) s realizes some part (condition Q) of a causal pathway for C_P
(b) s does not realize a complete pathway for C_P
(c) s does not realize a sufficient set for non-culmination ($\neg C_P$)

Formally:

(8) $\textsc{prog}(P, t) = 1$ iff

$$\exists s[\tau(s) \circ t \wedge [\exists Q \exists S : Q \in S \wedge \textsc{suff}^{M_P}(S, C_P) \wedge Q(s)] \quad \text{(a)}$$

$$\wedge [(\forall S' : \textsc{suff}^{M_P}(S', C_P)[\exists Q' \in S' : Q'(s) \rightarrow \exists Q'' \in S' : \neg Q''(s)]] \quad \text{(b)}$$

$$\wedge [\forall \Omega : \textsc{suff}^{M_P}(\Omega, \neg C_P)[\exists \omega \in \Omega : \neg \omega(s)]]] \quad \text{(c)}$$

Event types and causal models

Claim 2: eventuality predicates correspond to causal models

In the accomplishment case:

- accomplishment predicates aren't (binary) **causatives**, but they are **causal**: culminations are understood as (canonically) caused
- defining $[\![P]\!]$ in terms of model structure gives us a body of causal information for truth-value judgements (eg. progressives)
- `PROG`'s compatibility with accomplishments follows from aspects of an appropriate model (durativity, telicity)

The approach leads to **Claim 2a:** **where a causal model corresponds to an event type, its relata are 'conditions'**

- these include stative properties (intention, speed, stamina, θ-roles)
- punctual state transitions (culminations, discrete process steps)
- and possibility homogeneous/iterative processes (akin to statives; cf. Dowty 1979)

Causal models are (not) about events

Summary: linguistic events have a close relationship with causal models

1. Causal statements about singular events (as described by inflected predicates) rely on causal models for their truth conditions

   Example: Lexical (& periphrastic) causative claims

2. Eventuality predicates correspond to **event types**, which are collections of interrelated conditions that constitute (complex) eventualities of the right type

   Example: Accomplishment predicates as models for (caused) culminations, imperfective paradox effects

   a. *Consequently:* the relata of causal models are 'conditions' (properties, state transitions)*, no 1-1 correspondence with singular linguistic events

      Follows from the types of conditions relevant for (2)

Looking ahead

Bigger goal: a new 'aspect calculus' in terms of causal models

- Dowty's goal is to derive aspectual class distinctions, properties, compositional behaviour from their decompositional analysis
- Causal models are the right tool: they capture complex world knowledge about interrelationships between properties and events & allow us to formulate set-theoretic truth conditions
- Promising early results for non-culmination phenomena ... which we hope to extend to other aspectual operations (e.g. coercion)

(Some of the) open puzzles:

- $[\![P]\!]$ is traditionally a set of eventualities: need to reconcile with a (mereological) event structure that gives us access to relevant model properties (e.g., sufficient sets)
- Aspectual composition: what's the formal relationship between (e.g.) *run* and *run a mile*?
- In type-level models, semantic roles can be represented as properties: how does the assignment of individuals to roles occur?