Modeling progress:
Causal models, event types, and the imperfective paradox

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Telicity and culmination

Durative telic predicates (accomplishments) are associated with:

- **culmination (conditions):** object creation/destruction (*bake/eat a cookie*), terminus (*run a marathon*), state transition (*open a door*)
- **culmination assumption**: telic *P*s *only denote culminated events*

Observation: we can refer to **non-culminated stages** of telic events

(1) Henny wrote a symphony. → *He completed it.*

a. Henny began to write a symphony (but gave up right away).

b. Henny stopped writing a symphony (and never began again).

Two questions:

1. **Analytical:** what governs truth, felicity of non/culminated uses?
2. What (**conceptually, lexically, semantically**) links relevant processes and culmination conditions?

Telicity and the imperfective paradox

The puzzle of telic predicates is linked to the **imperfective paradox**:
(Dowty 1979)

- telic **progressives** are acceptable where culmination is precluded, clashing with the **culmination assumption**

(2) Henny was writing a symphony when she died. PAST+PROG
↛ *The symphony was eventually completed.*

Roadmap:

1. The imperfective paradox
2. Expectation and culmination
3. Proposal: causal models for telic predicates
4. Summary and questions

The imperfective (progressive) paradox

Telic **perfectives** often have **culmination entailments**:

(3) Maya wrote a book. → *A complete book came into being.*

Prevalent explanation:

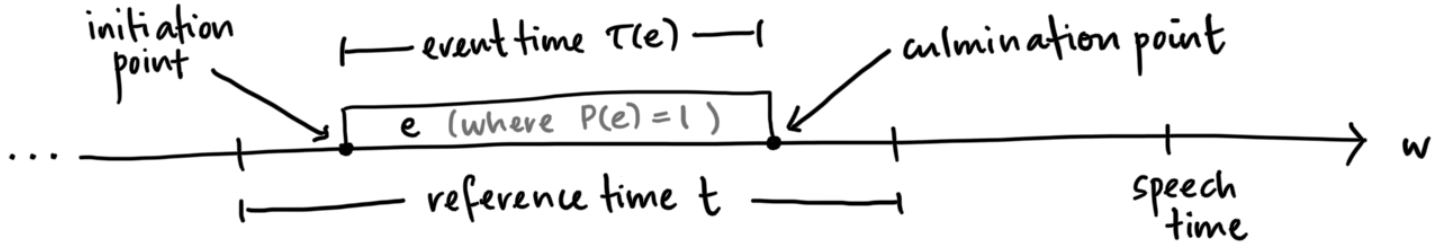
(i) **Culmination assumption:** $e \in [\![P_{\text{tel}}]\!]$ contains process + culmination

(ii) **Aspects instantiate P-eventualities** relative to reference time t

(4) $[\![\text{PFV}]\!] := \lambda w \lambda t \lambda P\,.\,\exists e[\tau(e) \subseteq t \wedge P(e)(w)]$

(cf. Klein 1994, Kratzer 1998, Bhatt & Pancheva 2005, a.o.)

Result: $e \in [\![P]\!]$ culminates, so t includes **culmination** . . .



. . . leading to **culmination entailment**

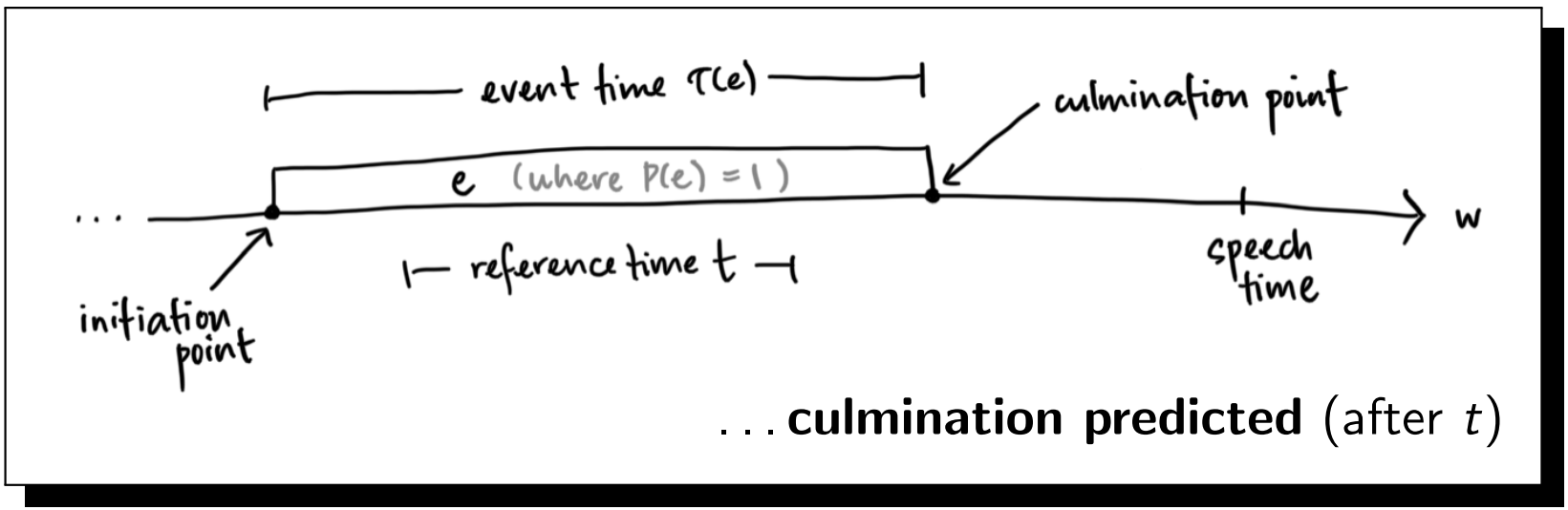
The imperfective (progressive) paradox

Wrong predictions for telic **progressives**:

If PROG instantiates $e \in [\![P]\!]$ as **ongoing** at t . . .

$$[\![\text{PROG}]\!] := \lambda w \lambda t \lambda P\,.\,\exists e[\tau(e) \supseteq t \wedge P(e)(w)]$$

. . . **culmination assumption** requires culmination in w^*



Contradicts empirical data, leading to 'paradox':

(5) Henrietta was crossing the street (when she was hit by a truck).
no entailment: $\not\rightarrow$ *Henrietta reached the opposite side.*

Two assumptions, two approaches

Puzzle: why/when does PROG(P) apply to **partial P-eventualities**?

(A) **Intensional** PROG: **culmination** takes place in alternative worlds
(Dowty 1979, Landman 1992, Asher 1992, Bonomi 1997, a.o.)

- maintain **culmination assumption**, but allow PROG to **introduce modal alternatives**
- **analytical challenge:**
  constrain the modal relationship so that some **P-eventuality 'begins' in** w^*

Two assumptions, two approaches

Puzzle: why/when does PROG(P) apply to **partial P-eventualities**?

(A) **Intensional** PROG: **culmination** takes place in alternative worlds
(Dowty 1979, Landman 1992, Asher 1992, Bonomi 1997, a.o.)

(B) **Extensional** PROG: instantiate **non-culminated** P-eventualities
(e.g., Bach's 1986 'partitive puzzle', Parsons 1990, Szabó 2008)

- maintain **extensional** PROG, but **revise the culmination assumption**
- **analytical challenge:**
  what properties **qualify a partial ('process') eventuality as making progress** towards culmination

Two assumptions, two approaches

Puzzle: why/when does PROG(P) apply to **partial P-eventualities**?

(A) **Intensional** PROG: **culmination** takes place in alternative worlds
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(B) **Extensional** PROG: instantiate **non-culminated** P-eventualities
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Our approach: ultimately, we need both perspectives

Culmination, expectation on the intensional view

Intensional PROG: (Dowty 1979, Asher 1992, a.o.)
A P-eventuality is ongoing if reference time facts predict culmination

- $\text{PROG}(P) = 1$ iff events at t develop to culmination in **all normal/ inertial alternatives** to w^*

  Inertial alternatives $\sim$ ongoing processes continue uninterrupted

- alternatives are projected from circumscribed **perspectives** (Asher)

  (5) Henrietta was crossing the street (when the truck hit her).

  A set of facts including Henrietta, the truck, & their physical properties predicts collision as 'inertial' outcome

Upshot: telic PROG's truth is tied to likelihood, expectation of culmination in relevant alternatives

Culmination, expectation on the intensional view

Intensional PROG:
$\text{PROG}(P) = 1$ iff ref time events develop into culminated P-eventualities in **all normal alternatives**

Impossible event (IE) progressives are out:

(6) **Context.** Meena's 5 year old daughter Maya wrongly believes that the earth is made entirely of sand and soil. She is digging a hole (with the intention of tunnelling all the way through).

Meena: **?/✗** Maya is digging a hole to China.

- **false**: no (objective) perspective has normal culmination alternatives

Culmination and expectation on the intensional view

Local culmination accessibility is a problem for **unlikely events (UEs):**

(7) Henrietta was crossing a minefield

(8) **The sailing competition** (Bonomi 1997)
An international association organizes a sailing competition to circumnavigate the globe. 100 boats take part, and they all set sail from the same point. A few days later, a spokesman says:

✓ 100 boats are circumnavigating the globe. Most will fail.

- **intensional** PROG requires all normal continuations to culminate
- **so:** (7)-(8) are predicted to be **false**
- **because:** 'typical' attempts will not end successfully (failure is normal)

Empirically: (7)-(8) are both acceptable and **true**

Culmination, expectation on the intensional view

Solution? Capture **IE/UE contrast** by weakening intensional PROG to an existential*

Still too strong for **out of reach (OOR)** contexts:

(9) **The un(der)trained runner** (cf. Szabó 2008, Varasdi 2014)
Benny began an ultramarathon for which he (knowingly) undertrained; it was certain before the start that he lacked the stamina to complete the run, but he meant go as far as he could.

a. *Friend/observer:* ✓Benny was running an ultramarathon (when he collapsed from exhaustion).
b. *Benny:* ✓I was running an ultramarathon (when I collapsed).

- predicted **false:** no situation containing Benny (+ relevant properties) is expected to continue to culmination

Empirically: (9)a-b are both acceptable and **true** in context

Beyond culmination and expectation

Acceptable **UE, OOR** cases show that telic PROGs don't need locally-accessible culmination alternatives, instead:

- what matters for (9) is whether Benny is doing what he *would need to be doing* to complete an ultramarathon
- **descriptively:** (9)a-b are **true** because Benny is pursuing a **plausible culmination procedure** at t
- **UE, OOR** PROGs are distinguished from **IE** PROGs by (world-historical) existence of a **culmination procedure**

Two requirements for telic PROGs:

1. the existence of a realistic strategy/process for realizing culmination (per speaker's epistemic state)
2. actual events match the culmination strategy: ref-time events must *make progress towards culmination*

Modeling progress: preview

Goal: combine intensionality, partitivity in the mereological structure of telic predicates

- process-culmination relationship is **modal** in nature
  process leads to culmination in some *normative* sense
- actual events constitute **part of a P-eventuality**
  (but without local culmination expectation)

Idea: telic Ps invoke knowledge about necessary, sufficient conditions for initiating, developing, completing culmination processes

- a **type-level causal model** for culmination condition C_P provides 'recipe(s)' for realizing C_P
  + relevant preconditions (properties, facts, events) and relationships
- model induces a **(causal) mereological structure,** mediated through the relationship between process and C_P
- actual eventualities *partially realize* P if they conform to a causal pathway ($\sim$ normative/teleologically-optimal process) for C_P

Overview: structural equation models (Pearl 2000)

Causal information is represented by a **directed acyclic graph** D:

- **nodes** (finite set Σ): salient prop. variables (can be valued $u, 0, 1$)
- **edges:** atomic relations of **causal relevance** ($P \xrightarrow{\text{c-influences}} Q$)
- **structural equations:** specify how nodes' values are determined from their ancestors'

  Function Θ_D assigns to each $X \in \Sigma$ a pair $\langle Z_X, \theta_X \rangle$ where Z_X is the set X's immediate ancestors, $\theta_X : \{0,1\}^{|Z_X|} \to \{0,1\}$
- **causal consequences:** of a *situation* s (3-way valuation of Σ) are calculated using D and Θ_D

In lexical semantics:

Causal language refers to (predicates, presupposes) particular structural configurations as different causal dependency types

(cf. Nadathur & Lauer 2020, Baglini & Bar-Asher Siegal 2021)

Causal relationships in a model

Model structure allows us to define different causal relations:

(Nadathur & Lauer 2020, Baglini & Bar-Asher Siegal 2021)

- **background:** causation is a property of sets; effects are realized as the result of collections of conditions acting together
- causative predicates pick out causes with particular (binary) relationships to an effect *within a set of causes acting together*

Relations of interest (informally):

- **Causal necessity:**
  Within a situation s with both C and E, fact C is causally necessary for fact E iff changing C changes E
- **Causal sufficiency (of sets):**
  A set s is sufficient for E iff E is true in s and s otherwise comprises necessary causes for E

Causal necessity and causal sufficiency, formally

Let $M = \langle D, \Theta_D \rangle$ be a causal model over set Σ, s a situation (set of pairs $\langle A, a \rangle$ with $A \in \Sigma$, $a \in \{0, 1\}$).

(10) a. **Causal ancestors:** For $X \in \Sigma$, the set A_X of **causal ancestors** of X is given by $A_X = \{Y \in \Sigma | R^T_{\Theta_D}(X, Y)\}$ (where $R^T_{\Theta_D}$ is the transitive closure of immediate ancestry)

b. **Domain of a situation:** For s a situation, let $\text{DOM}(s) = \{X \in \Sigma | \langle X, 1 \rangle \in s \vee \langle X, 0 \rangle \in s\}$

(11) **Causal necessity.**
A fact $\langle X, x \rangle \in s$ is **causally necessary** for fact $\langle Y, y \rangle \in s$ iff:

a. $X \in A_Y$

b. for any situation s' such that $\text{DOM}(s) = \text{DOM}(s'), s(X) \neq s'(X) \rightarrow s - s' = \{\langle X, x' \rangle, \langle Y, y' \rangle\}$, where $x \neq x', y \neq y'$

(12) **Causal sufficiency (of sets).**
A situation s is a **sufficient set** for a fact $\langle Y, y \rangle \in s$ iff:
$\forall X \in \{Z | Z \in A_Y \wedge Z \in \text{DOM}(s))\}, \langle X, s(X) \rangle$ is causally necessary for $\langle Y, y \rangle$

(11)-(12) adapted from Baglini & Bar-Asher Siegal

Causal models: from the specific to the general

Past work: (Bar-Asher Siegal & Boneh 2020, Nadathur & Lauer 2020, a.o.)

- **statements of singular causation** (causative claims): about **token instances** of causation (actual relations between specific events)
- licensed by models of local relationships; truth depends on variables taking values at specific places/times

(Hausman 1998, 2005; Woodward 2003)

Today: language also draws on **type-level causal models**

- models are built from experience, capture idealized representations of world knowledge: *how things work* and/or *how to do things*
- generalized representations of events capture causal regularity, correspond to claims about typical relationships between properties
- type models support specific (token) expectations, but need not be falsified by singular failures

> **Claim:** type-level models underlie lexicalization, use of complex eventuality predicates

Imperfective paradox: the view from causal models

Causal models: a framework for modeling progress that combines intensional, partitive perspectives on paradox effects

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

- culmination condition C_P occurs in M_P as a dependent variable
- M_P links certain conditions/steps to one another and to C_P
- a **process** for P (a **causal pathway** S for C_P) is a set of jointly sufficient conditions for C_P $(\text{SUFF}^{M_P}(S, C_P))$
- the model also specifies sufficient sets for **non-culmination** $(\neg C_P)$

M_P induces a **mereological structure** where $[\![P]\!]$ contains (non-)culminated eventualities; e_1, e_2 are comparable as subsets if they belong to the same causal pathway for C_P

Imperfective paradox: truth conditions for $\textsc{prog}(P)$

Informally:
Given model M_P for telic 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:
For telic predicate P with culmination condition C_P:

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

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

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

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

Culmination puzzles from a causal perspective

Intensional PROG accounts cannot differentiate between **IE, UE**, and **OOR** PROGs, but the causal approach does:

1. **IE** PROGs are **infelicitous** (not false): event model does not exist
   - e.g., no set of conditions sufficient for digging a hole to China
2. **UEs, OORs** have models: truth thus depends on actual events
   - to complete an ultramarathon, one must show up at the start, take steps along the path, . . .
   - even though Benny's properties ensure eventual failure, PROG holds because his actions up to collapse match a culmination pathway
   - **upshot:** it's predictable that his endurance will fail, but Benny's actions until then can *make progress towards culmination*

Globally necessary conditions

Globally necessary conditions have a special status in the model: they must be sustained throughout the development of a P-eventuality

Q is a **GNC** iff $\textsc{suff}^{M_P}(\{\neg Q\}, \neg C_P)$

Example: Intentions are GNCs for agentive accomplishments

(14) **Context.** Benny began running in a marathon at 9am. He sat down exhausted at 11:35, intending to end his run. But since he felt better after a short rest and refreshment, he decided to continue; he started running again at 11:50am.

Target: Benny was running a marathon

- **true** at 11:30, 11:55, **false** at 11:40 (additional judgements needed)

Captured by condition (c) for telic progressives:

(c) s does not realize a sufficient set for non-culmination

See also Varasdi (2014) on sustaining vs. indicative conditions for telic Ps

Globally necessary conditions: a refinement

Q is a **GNC** iff $\textsc{suff}^{M_P}(\{\neg Q\}, \neg C_P)$

GNCs are minimal conditions for P-eventualities to be in progress:

(cf. Bonomi 1997)

- no truth judgements where GNCs are underdetermined

(15) **Context.** Benny began running in a marathon (42K). Knowing he had undertrained, he intended to stop early. He planned to decide at 15K whether to stop there or continue to 21K. He collapsed at 10K, before making a decision. Later, he says:

Benny: **?** I was running a 15K/half marathon.

Presupposition: $\forall Q : \textsc{suff}^{M_P}(\{\neg Q\}, \neg C_P), Q(s) \neq u$

Non-agentive GNCs: momentum, velocity (conserved quantities) for inanimate objects; see Bonomi (1997) for relevant examples

Summary and outlook

Imperfective paradox needs a combined intensional, mereological view:

- (locally-assessed) **culmination potential** cannot be the whole story
- the model provides a structure against which to measure the conditions under which a **token qualifies as partial realization (of type-defined whole)**

Progressives of accomplishments require causal knowledge but are **not themselves causal statements**:

- we need a (plausible) causal model to license $\textsc{prog}(P)$
- use of $\textsc{prog}(P)$ indirectly (via presupposition) conveys a speaker's belief in a causal model for P's culmination (a belief that there is a way to do P)
- **but:** asserted content only reports a match between actual events and the structure of the type-level model

Outlook, questions

Debate has centered on **whether (uninflected) telic predicates or** PROGs are responsible for paradox effects: (Zucchi 1999, a.o.)

- **Event type models** are naturally tied to a predicate's meaning/representation (see also Nadathur & Filip 2021)
- How can non-telic (and punctual) predicates be linked to event-type causal models?
- What precisely is contributed by PROG, and what needs to be different for other cases of non-culmination (non-culminating perfectives, aspectual verbs)? (e.g., Martin 2020)
- Can the special status of **GNCs/sustaining conditions** be used to explain links between agentivity and (non-)culmination? (e.g., Martin & Schäfer 2012's *defeasible causatives*)

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