A brief intro to forces/From force dynamics to causal models

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Announcements

- The scheduled January date conflicts with Agency and Intention in Language 2 (call for papers: https://ail-workshop.github.io/AIL2-Workshop/call.html) so it is moved to January 26th, same time
- OASIS website delays; interim website at bcopley.com/cocoa
- Wonder room

1 Starting point

(1) Davidson 1967
  a. John buttered the toast with a knife, in the kitchen, at midnight.
  b. with-a-knife(e), in-the-kitchen(e), at-midnight(e)

What's the matter with event arguments?

Korzybski 1933: "A map is not the territory it represents"

Copley & Harley 2015, 2020 ms.: Davidsonian event arguments are not the best "map" for the "territory", not because they're arguments but because they're *atomic*, and because they're *events*. (What's the commonsense notion of an event? Maybe "change"; see Lombard 1979.)

- Hard to represent **interaction** between events
- Hard to represent **(a)telicity**
- Both of these ⇒ **overly complex mapping** to morphosyntax

2 About forces

Copley, Bridget. 2018. In Robert Truswell (ed.): *Oxford Handbook of Event Structure*: 103—149. http://bcopley.com/wp-content/uploads/18Copleyforcedynamics.pdf

2.1 What is a force?

- Intuitively, a force is an input of energy
- It has an origin, a direction, and magnitude ⇒ vector representation
- It has a *ceteris paribus* condition for its result (≈ normality/stereotypicality/closed-world/efficacy)
- We can define abstract forces based on concrete forces

Things the concept of force easily captures:

- Interaction or lack thereof (*ceteris paribus*/defeasibility/normality/stereotypicality/closed world/efficacy)
- Entrained (cotemporal) results

In thinking of forces, we need to distinguish change and energy. Change is not energy (see Croft 2012, 2015), but change and energy are closely related (Bohnemeyer & Swift 2006); change cannot happen without energy. But look at how the word "dynamic" is used...

(2) *dynamic* as 'characterized by change':
   a. Bohnemeyer & Swift 2006: "we propose the basic meaning of dynamicity is change"
   b. Beavers 2008: dynamic predicates are those that "involve some "change" or potential change in one participant"
   c. Fábregas & Marín 2014: "dynamicity" refers to "(abstract) movement in some quality space"
   d. Maienborn 2007: definition of "dynamic predicates" excludes predicates such *sleep* and *stay*

(3) *dynamic* as 'characterized by energy':
   a. Comrie 1976: "With a dynamic situation, ... the situation will only continue if it is continually subject to a new input of energy"
   b. Smith 1991: "The bounded nature of events can be derived by their dynamicity. Events require a constant input of energy."
   c. Bach 1986: 'dynamic' predicates are *sit*, *lie*, etc.
   d. Beavers 2011: "I assume that change can only be encoded in dynamic predicates. But which dynamic predicates involve changes ...?"

2.2 Forces are needed

(4) Talmy (1972, ..., 2000)

a. The ball was rolling along the green.

b. The ball kept rolling along the green.

(5) Copley & Harley 2015: *keep* + SC hard to do with event arguments

a. Mary kept her door open.

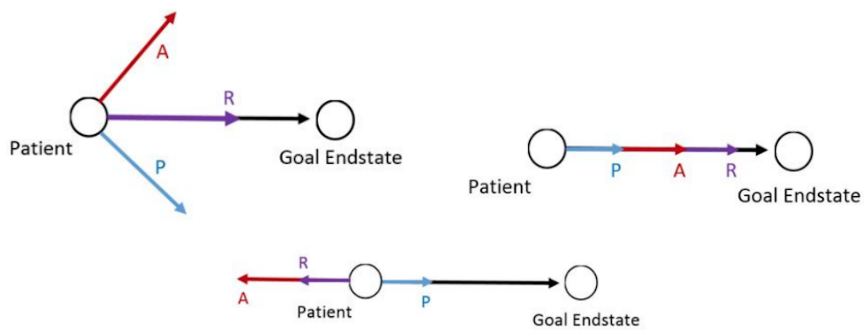
b. *keep open* = cause to stay open

c. *stay open* ≠ *be open* (complexity, difference in Aktionsart)

d. *stay open* ≠ *cause to be open*

e. Solution: *stay open*: there is a force whose entrained (cotemporal) result is the door being open

(6) CAUSE, ENABLE, PREVENT (Wolff & Song 2003, Wolff 2007)



2.3 Forces come for free

- Hume: Causally-derived regularities can be perceived but causal relations themselves cannot be, they come from the mind
- Wolff & Shepard (2013): Temporal gaps, direction influence causal impression ⇒ representation of causation must include time and direction ⇒ must not be mere regularities
- Robles-De-La-Torre & Hayward (2001): force perception competes favorably with other kinds of perception
- Runeson & Frykholm 1981, 1983: Force-dynamic information can be recovered from information about kinematics alone, difficult to ignore or obscure

	data	force arguments	event arguments	categories
Zwarts 2010, Goldschmidt & Zwarts 2016	force verbs and prepositions	are vectors (Zwarts & Winter 2000)	are associated with paths along which forces are exerted in time	syntax-semantics interface, vector-oriented
Pross & Rossdeutscher 2015	conative alternation, other force verbs and prepositions	are atomic, introduced by force head within PP	are atomic, introduced by v head, interpreted as exertions of forces	syntax-semantics interface, vector-oriented
van Lambalgen & Hamm 2005	event structure, viewpoint aspect	are functions from times to truth values ("fluents"), but the *Trajectory* predicate is closer to a force vector	are atomic; eventualities are ordered quadruples that include events and fluents	calculus that derives only and all the occurring events given starting conditions, *ceteris paribus*-oriented
Copley & Harley 2015, 2018	event structure, viewpoint aspect	are functions from situations to situations	are replaced by force or situation arguments	syntax-semantics interface, *ceteris paribus*-oriented

2.4 Copley & Harley 2015

- Basic idea: Dynamic verbs convey that the application of a force results (either by launching or entrainment) in a (perhaps zero) change provided that nothing intervenes
- Reify energy as force functions
- "Flavors" of v (following Folli & Harley 2008)

- Dual ontology: grammatical/linguistic/language map vs. conceptual/cognitive territory
- This is familiar: it's $[\![\ ]\!]$. (Not familiar: using $[\![\ ]\!]$ on variables)
- Forces (inputs of energy) arise in an initial situation
- Forces (inputs of energy) are represented by functions from situations to situations

(7) $\langle [\![\ \ ]\!], U_\sigma, U_\varphi, U_s, U_f, net, init, fin\rangle$ is a causal structure iff:
- a. $[\![\ ]\!]$ is an evaluation function
- b. U_σ is a non-empty set of conceptual situations
- c. U_φ is a (possibly empty) set of conceptual forces (representing inputs of energy).
- d. U_s is a non-empty set of linguistic situations such that $\forall s \in U_s, \exists\sigma : s = \sigma$
- e. U_f is a (possibly empty) set of functions from U_s to U_s.
- f. net is a partial function from U_s to U_f such that $\forall s \in U_s, \forall f \in U_f : net(s) := f$ iff f is the net force of s.
- g. $init(f) :=$ the inverse function of net (i.e., $net(init(f)) = f$)

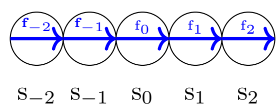
h. $fin(f) := f(init(f)$

(8)

language	**language-cognition interface**	**cognition**
f	— related by evaluation function to —	φ
		| is the net force of (arises from all the individuals and property attributions in) |
s	— related by evaluation function to —	σ

We define two linked sequences, one of situations and one of force functions:

(9) $\ldots, \mathrm{s}_{-2}, \mathrm{s}_{-1}, \mathrm{s}_0, \mathrm{s}_1, \mathrm{s}_2, \ldots$
$\ldots, \mathrm{f}_{-2}, \mathrm{f}_{-1}, \mathrm{f}_0, \mathrm{f}_1, \mathrm{f}_2, \ldots$



(10) a. Let $f = net(s)$ iff f is the net force of s
b. $f_n = net(s_n)$
c. $s_{n+1} = f(s_n)$

(11) a. $init(f_n) = s_n$
b. $fin(f_n) = s_{n+1}$

Causal sequence, not temporal sequence. Causally-mediated temporal relation: effects do not begin before their causes.

- Stative predicates such as *be in the room, know French* are treated as predicates of situations, type st.
- Dynamic predicates such as *eat* and *stay* are predicates of forces, type ft, aka ss,t.
- Active Voice, when present, introduces the Agent/Causer as the (main) SOURCE of the energy constituting the force.

(12) be -ing = $\lambda p_{fd} \lambda s p(net(s))$

(13) a. v_{become} : $\lambda p \lambda f p(init(f)) p(fin(f))$
(cf Dowty's (1979) BECOME: $\neg$p(t_1) & p(t_2))
b. $v_{occur} = \lambda \pi \lambda f.[\exists f' < fin(f) : \pi(f')]$
c. v_{appear} : $\lambda x \lambda f.x$ is part of $fin(f)$ (presupposed: x is not part of $init(f)$
d. v_{stay} : $\lambda p \lambda f.p(fin(f))$ (presupposed: $p(init(f))$)

(14) a. heat the soup (a little/to boiling).
b. λfsoup hot($init(f)$)soup hot($fin(f)$)

(15) a. dance
b. $\lambda f.[\exists f' < fin(f) : \text{dance}(f')]$

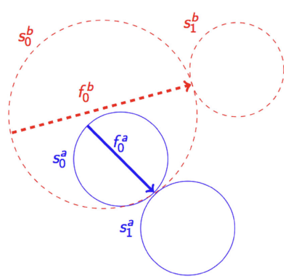
(16) a. write a poem
b. $\lambda f.[\exists x : x$ is part of fin(f): a poem(x)] (presupposed: x is not part of $init(f)$)

(17) a. stay there
b. $\lambda p \lambda f$.there($fin(f)$) (presupposed: there($init(f)$))

- Both telic and atelic predicates specify a result situation as well as a causing situation.
- The result situation need not be a state, though it can be.
- In the world, there can be an entrained and a launched result, though our description usually picks one of these.
- Given a causing and a result situation, world/lexical knowledge tells us whether the result situation referred to in the description begins as the causing situation ends (launching), or begins as the causing situation begins, as a "cotemporal result" (entrainment).

3 Benefits to having forces in the grammatical ontology

- Force **interaction** is easy to represent using a part structure for situations



- Entrainment is easy to represent (= **atelicity**), bringing activities into alignment with causal treatments of accomplishments
- We can represent goal-directed action: the actor has an intention/goal in s, and from s arises the actor's action to bring about a situation of which the goal holds
- The Davidsonian argument is retained (though it is no longer a commonsense event)
- There is a natural distinction between events and states (namely, energy) that accounts for verbs of maintaining
- *Ceteris paribus*/closed-world condition: The existence of a causal relation doesn't entail the occurrence of the result, and no need to rule out irrelevant possibilities (partitions)
- We get the benefits of explicitly talking about causal relations, e.g. for direct/indirect distinction

Quantification over primitive possible worlds IS TO explicit causal relations

AS

Optimality Theory IS TO transformational phonology

******Olga's talk*********

4 Why would we not want to use forces?

4.1 Dynamic verbs don't always describe an input of energy

(18) a. The ball rolled down the hill.
b. The soup cooled.
c. John let the children eat.
d. Bill killed my plants by not remembering to water them.

But causal models allow us to represent relations between any two sets of values, so e.g. *whether Bill remembered to water my plants* can influence *whether my plants are alive* and then we can say that the latter has the value 0.

cool and *roll down*: something causes a decrease in temperature; something causes a rolling change in height

stay actually uses a stimulatory function!

4.2 Causal statives

(19) a. That wall supports the ceiling.
b. That wall must support the ceiling.
c. In case you want to know, that wall supports the ceiling.

(20) a. That curtain lets the light through.
b. That curtain must let the light through.
c. In case you want to know, that curtain lets the light through.

(21) a. The flowers decorate the room beautifully.
b. The flowers must decorate the room beautifully.
c. In case you want to know, the flowers decorate the room beautifully.

(22) a. #John decorates the room beautifully.
b. John must decorate the room beautifully.
c. In case you want to know, John decorates the room beautifully.

Causal statives can represent merely a caused difference; no energy!

5 Causal models get us nearly all of the benefits of forces

5.1 Force interactions

Force interactions are easy to represent as colliders. Two ways to figure out the value of a node that has incoming arrows:

- Value of a node is determined from the values of all its influences (standard causal model)
- Each arrow represents a function and incoming arrows "compete" to determine the value of the node (more like force dynamics)

5.2 Launching/entrainment

The variables can be relativized to times (Halpern & Pearl 2005: 18): $X_{i_1}, X_{i_2}, X_{i_3}$ ...

(23) a. Launching (for telicity): time of evaluation of influencing node $<$ time of evaluation of affected node
b. Entrainment (for atelicity): time of evaluation of influencing node $=$ time of evaluation of affected node

Another possibility: Variables have values, and these values are relativized to times. The valuation function (call it $\mathcal{R}$) could be redefined to take a time argument in addition to the variable argument. So, $\mathcal{R}(X)(i) = x$, or in a more semantics-friendly notation,
$\mathcal{R}(X) = \lambda i.\ [\![\text{p}]\!](i)$.

5.3 Intentions

If one is doing an action intentionally, the value of the result listens to the value of the intention. So the causing node could be an intention.

5.4 Davidsonian arguments

Statisticians who use causal models talk about $X = x$ as an "event". So a node can be whether a Davidsonian event occurs.

(24) a. John was buttering the toast in the kitchen.
b. John was slowly buttering the toast.

(25) a. *In the hall, John was buttering the toast in the kitchen.
b. *Quickly, John was slowly buttering the toast.

But we have some nice flexibility as to what the nodes are, as in this possible analysis for nominalizations (Data from Sichel 2010, Alexiadou et al 2013)

(26) a. The scientists justified the evacuation.
$\textcircled{P} \to \textcircled{E}$
$\textcircled{P}$ = whether $\exists p : p(\mathit{scientists})(i)$
$\textcircled{E}$ = whether $\mathit{occur}(e_{justification-of-evacuation})(i')$
b. The hurricane justified the evacuation.
$\textcircled{P} \to \textcircled{J}$
$\textcircled{P}$ = whether $\exists p : p(\mathit{hurricane})(i)$
$\textcircled{J}$ = whether $\mathit{justified}_{adj}(x_{evacuation})(i')$
c. The hurricane destroyed the marina.
$\textcircled{P} \to \textcircled{E}$
$\textcircled{P}$ = whether $\exists p : p(\mathit{hurricane})(i)$
$\textcircled{\textit{E}}$ = whether $\mathit{occur}(e_{destruction-of-the-marina})(i')$

(27) a. The scientists' justification of the evacuation
$\iota e \ldots$
b. *The hurricane's justification of the evacuation
No event argument to bind!

c. The hurricane's destruction of the marina
$\iota e \ldots$

5.5 To sum up...

- We get the benefits of explicitly talking about causal relations, even when there are multiple influences and/or effects
- *Ceteris paribus*/closed-world condition: The existence of a causal relation doesn't entail the occurrence of the result, and no need to rule out irrelevant possibilities
- Interaction is easy to represent
- Entrainment is easy to represent, bringing activities into alignment with causal treatments of accomplishments
- Better than mere dependency (e.g. Lewis 1973) in accounting for direct/indirect distinctions
- We can represent goal-directed action (intention node)
- The Davidsonian argument ~~is~~ can be retained ~~(though it is no longer a commonsense event)~~
- ~~There is a natural distinction between events and states (namely, energy)~~

Some more vague but still useful reasons to take up causal models:

- More clarity around what the arrows are: they represent dependencies between values that are marked as being causal in nature
- Influences are much easier to individuate
- More freedom with functions/relations to represent e.g. inhibitions