

Causation, magic and tense-modal interaction*

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In this talk we analyze the semantics of sentences such as (1).

- (1) Flicking the switch caused the light to turn on.

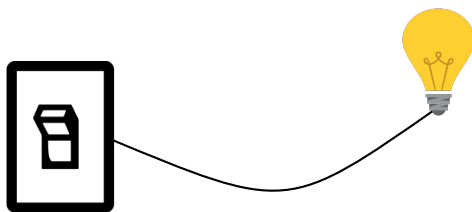


Figure 1: An everyday example of causality.

Research on the semantics of causal claims raises two questions:

- (2) **The modeling question:** What kind of information do we use when we judge that a causal relation holds?
- (3) **The meaning question:** Once we have a causal model, what is the semantics of causal claims, given in terms of that model?

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1 Causal models

1.1 Propositions

S	L	$S \leftrightarrow L$
0	0	1
0	1	0
1	0	0
1	1	1

Figure 2: Causality in terms of propositions

✓ Simple

- Only primitive needed is already in the semantics: propositions
- Only need truth conditions of S and L

✗ Symmetric

- Does not represent causal asymmetry
- $S \leftrightarrow L$ is equivalent to $L \leftrightarrow S$

1.2 Structural causal models

Applications in semantics: Pearl (2009, chapter 7), Schulz (2011), Briggs (2012), Ciardelli, Zhang, and Champollion (2018), Santorio (2019), Nadathur and Lauer (2020)

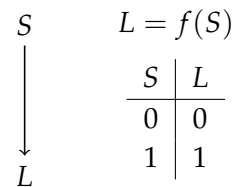


Figure 3: Structural causal model (Pearl 2009)

- $M = (V, E, F)$ where
 - V is a set of variables.

- $E \subseteq V \times V$ is an edge relation such that (V, E) is a directed acyclic graph.
- F is a set of functions of the form F_X , one for each variable $X \in V$, where the value of X is determined by the values of X 's parents in the graph.

✓ Asymmetric

- Capture causal asymmetry.
- $S \longrightarrow L$ is not equivalent to $L \longrightarrow S$.

✓ Computationally simple (Pearl 1988).

- Once variable set is chosen, causal inference is computationally tractable.

✗ Introduces new primitives into semantics.

- **Primitive 1.** Variable set V
 - Hand-picked by the modeler.
 - Worry that model's predictions vary with choice of V (see Halpern and Pearl 2005, Example 5.4).
- **Primitive 2.** Dependence relations (encoded in E and F)
 - Encode causal dependence directly.
 - Do not attempt to analyse causal dependence in terms of more familiar or independently motivated concepts.

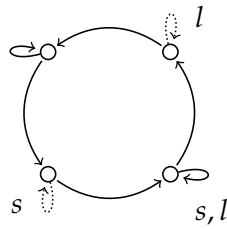
1.3 Possible sequences of states

(4) A *state* is a situation at a moment in time (i.e. a situation-time pair).

(5) **Proposed answer to the modeling question:**

A causal model determines what sequences of states are possible, and what sequences are impossible.

In this framework, the causal relationship between a light switch and a light is represented as a set of constraints on **what sequences of states are possible, and what sequences of states are impossible**. The constraints representing a light switch are summarized in Figure 4.



$s \wedge l$ immediately followed by $\neg s \wedge l$ is possible
 $s \wedge l$ immediately followed by $\neg s \wedge \neg l$ is impossible

Figure 4: Constraints on possible sequences of states for a light switch and a light (where dotted loops must be finite).

Constraints on possible sequence of states are already encoded in models of tense semantics (e.g. world-time pairs, situation-time pairs, the branching time model of Thomason and Gupta 1980).

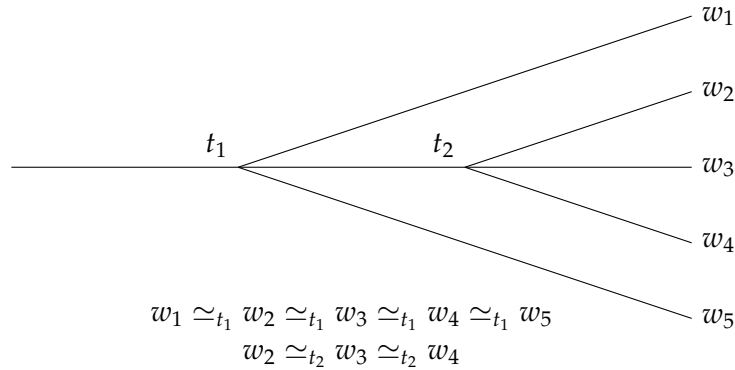


Figure 5: Branching time model from Condoravdi (2002, ex. 43)

✓ Simple

- Primitives (situations and time) are independently motivated.
 - **Situations.** Kratzer (1989), Arregui (2009) and others: Situations needed to calculate similarity order (used in counterfactuals, desire predicates Heim 1992).
 - **Time.** Ubiquitous in semantics (e.g. tense).
- Dependence relations.
 - Analyses causal dependence
 - Via what sequences of situations are possible.

✓ Asymmetric

- Captures asymmetry of causation
- Via asymmetry of the passage of time (cf. Figure 6).

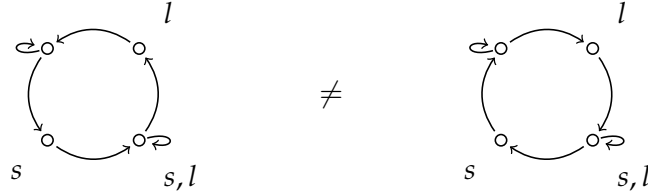


Figure 6: Capturing causal asymmetry via the asymmetry of the passage of time.

2 Counterfactual modality

- (6) a. A counterfactual is characterized by an empty modal base and a totally realistic ordering source (Kratzer 1981).
b. Modals have a temporal orientation and a temporal perspective (Condoravdi 2002).

The modal base changes with time (Condoravdi 2002, p. 80):

$$\begin{aligned}
 MB_t(w) &= \{w' \in W : w \simeq_t w'\} \\
 &= \{w' \in W : w' \text{ verifies exactly the same propositions as } w \text{ up to time } t\}
 \end{aligned}$$

I assume in addition that the ordering source changes with time (Fălăuș and Laca 2020):

- (7) a. From next Monday on, Mary will have to wear a uniform at school.
b. Until the beginning of the 90s, students could smoke in class.
(Fălăuș and Laca 2020, ex. 1)
- (8) a. He might have won the game. (Condoravdi 2002, ex. 6–7)
b. (i) He might have (already) won the game (# but he didn't).
[PRESSENT PERSPECTIVE, PAST ORIENTATION]
(ii) At that point he might (still) have won the game but he didn't in the end.
[PAST PERSPECTIVE, FUTURE ORIENTATION]

Putting Kratzer's and Condoravdi's insights together, counterfactual modals have:

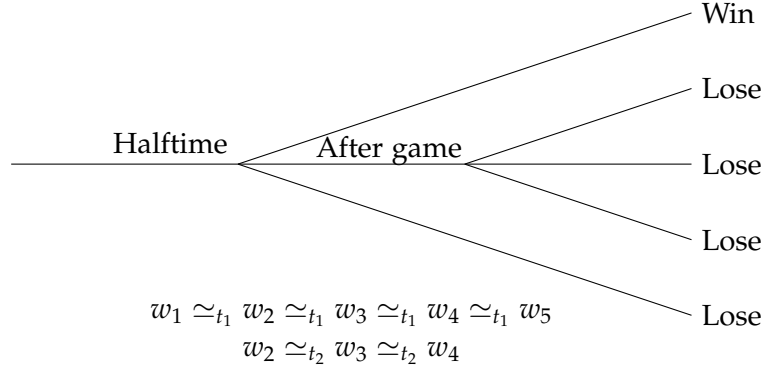


Figure 7: Applying Condoravdi's branching time model.

- an empty modal base,
- a totally realistic ordering source,
- past perspective, and
- future orientation.

3 Truth conditions for causal claims

The truth conditions of *cause* involve a conjunction of two conditions: *production* and *difference-making* (Beckers 2016).

- (9) **Claim.** the temporal perspective of the modal in *cause* is the time immediately before the cause's occurrence.
- (10) Condoravdi's *AT* operator (2002, ex. 19):

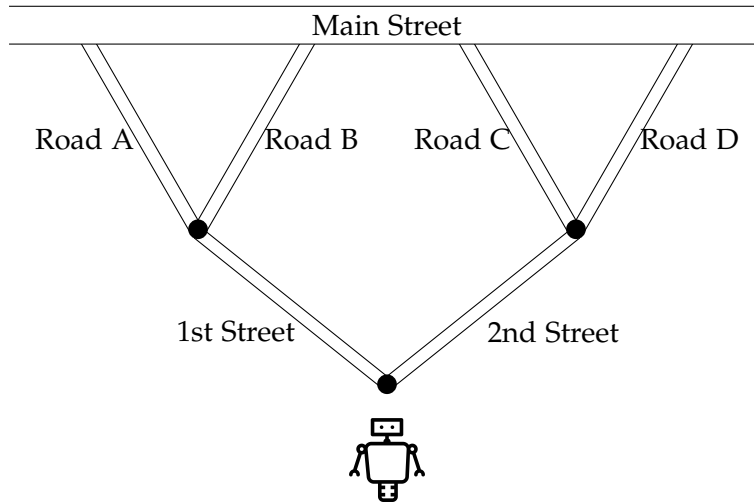
$$AT(t, w, p) = \begin{cases} \exists e[P(w)(e) \wedge \tau(e, w) \subseteq t] & \text{if } P \text{ is eventive} \\ \exists e[P(w)(e) \wedge \tau(e, w) \circ t] & \text{if } P \text{ is stative} \\ P(w)(t) & \text{if } P \text{ is temporal} \end{cases}$$

(11) **Semantics of *cause***

- a. Let $\Box_t$ be a counterfactual modal with temporal perspective t .
- b. Let $t(p)$ be the time immediately prior to p 's occurrence.
- c. $\llbracket \text{cause} \rrbracket(t)(w)(q)(p) = 1$ iff
 - (i) $AT(t, w, p) = 1$ and $AT(t, w, q) = 1$,
 - (ii) $\Box_{t(p)}(\text{if } p)(p \text{ produce } q)(t)(w)$, and
 - (iii) $\neg \Box_{t(p)}(\text{if } \neg p)(\neg p \text{ produce } q)(t)(w)$

Production
Difference-making

3.1 Production



- (12) The robot taking 1st street caused it to take Road B.

Predictions in the robot example:

- **Production.** (If the robot had taken 1st Street,) the robot taking 1st Street would have produced it to take Road B. ✗
- **Difference-making.** It is not the case that, if the robot had not taken 1st Street, the robot not taking 1st Street would have produced it to take Road B. ✓

The robot example shows why we need the modal base and ordering source to change with time, and the modal's temporal perspective to be before the cause's

occurrence:

- If the possibilities were evaluated after the Robot took Road B, the modal base would exclude the world where the robot took Road A instead.
- And the world where the robot takes Road A would not be among the most similar worlds to the actual world where the robot takes 1st Street.

This accounts for Nadathur and Lauer (2020)’s temporal location constraint:

(13) **Temporal location constraint.**

In the evaluation of a causative claim involving causing fact $C = 1$ and caused fact $E = 1$, the background situation can fix only those facts that are settled at the evaluation time of the causative claim. By default, the evaluation time is the time at which C is determined.

3.2 Difference-making

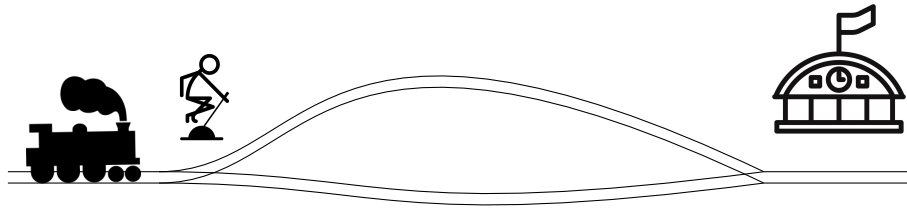


Figure 8: Switching scenario from Hall (2000, p. 205)

(14) Alice pulling the lever caused the train to reach the station.

Predictions in the train example:

- **Production.** (If the lever had been pulled,) pulling the lever would have produced the train to reach the station. ✓
- **Difference-making.** It is not the case that, if the lever had not been pulled, not pulling the lever would have produced the train to reach the station. ✗

4 Analogy with conditional perfection

(15a) “invites the inference” (Geis and Zwicky 1971) that (15b) is true.

- Where $p = \lambda w$. you mow the lawn in w , conditional perfection can be derived by exhaustification when $\neg p$ is an alternative to p (see e.g. Bassi and Bar-Lev 2018).¹

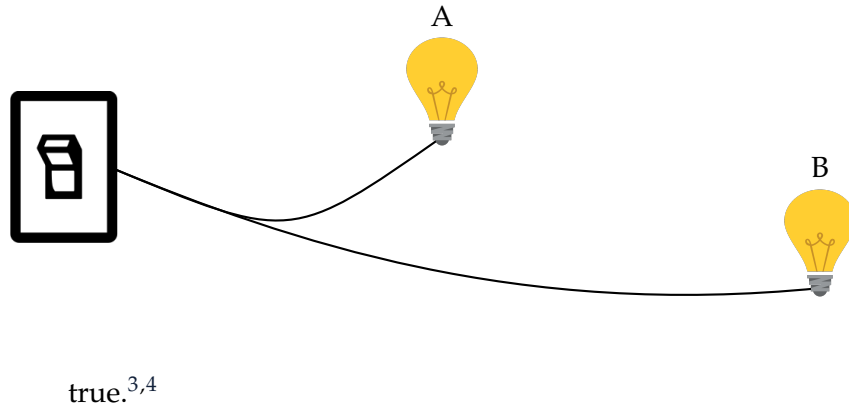
- In cases of conditional perfection, $\neg p$ is an optional alternative to p . But in *cause*, $\neg p$ is a lexically specified as an alternative; exhaustification is obligatory and part of the at-issue content.

- (18) *cause*(*p*, *q*)

- Cause* is not alone in adding an exclusive inference to its at-issue content:

- ¹EXH is defined as in Fox (2007):

- ²Since the production and difference-making conditions are logically independent.

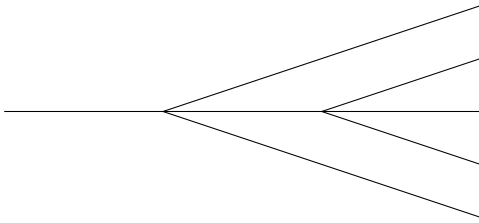


5 Magic

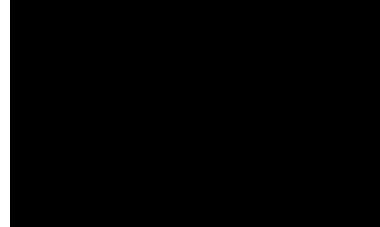
(21) I want to play the violin, but I don't want to learn it.

- (22) a. Flicking the switch caused light A to turn on
b. Light A turning on caused light B to turn on

- The use of a metaphysical modal base can force us to evaluate causal claims at very remote worlds (with respect to the ordering source).



(a) Condoravdi (2002)



(b) Everything is possible
(with a metaphysical modal base)!

Figure 9: There are more possibilities than Condoravdi (2002)'s diagram suggests

³where $O(p) = \lambda w[p(w) = 1 \wedge \forall q \in \text{Excl}(p)[q(w) = 0]]$ (Chierchia et al. 2012), and the set of p 's sub-alternatives is $\text{Sub}(p) = (\text{Alt}(p) - \text{IE}(p)) - \{p\}$.

⁴Thanks to Zhuoye Zhao (p.c.) for drawing my attention to Xiang (2016)'s work on *dou*.

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