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.

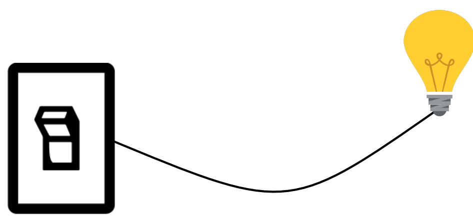

Figure 1: An everyday example of causality.

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

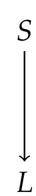
- Only primitive needed is already in the semantics: propositions
- Only need truth conditions of S and L

✗ Symmetric

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

1.2 Structural causal models

Applications in semantics: Pearl (2000, chapter 7), Schulz (2011), Briggs (2012), Ciardelli, Zhang, and Champollion (2018), Santorio (2019), Nadathur and Lauer (2020)



$L = f(S)$

S	L
0	0
1	1

Figure 3: Structural causal model (Pearl 2000)

- $M = (V, E, F)$ 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.

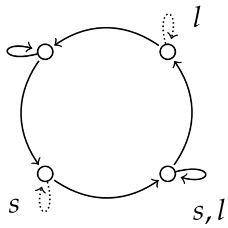
- **Primitive 1.** Variable set V
  - Hand-picked by the modeler.
  - Worry that model's predictions vary with choice of V
    (see Halpern and Pearl 2005, Example 5.4).
- **Primitive 2.** Dependence relations (encoded in E and F)
  - Encode causal dependence directly.
  - Do not attempt to analyse causal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

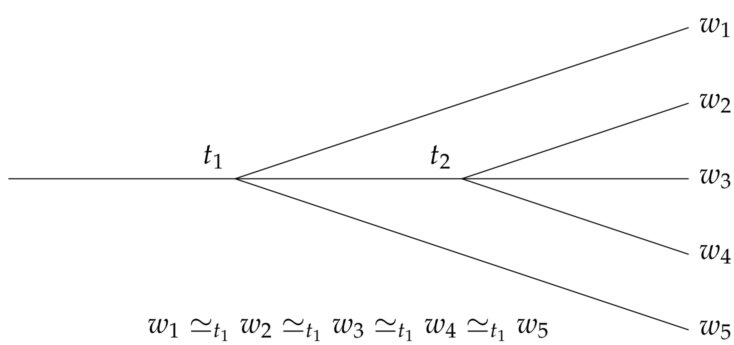
In this framework, the causal relationship between a light switch and a light is represented as a set of constraints on **what sequences of states are possible, and what sequences of states are impossible**. The constraints representing a light switch are summarized in Figure 4.



$s \wedge l$ 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).



$$w_1 \simeq_{t_1} w_2 \simeq_{t_1} w_3 \simeq_{t_1} w_4 \simeq_{t_1} w_5$$
$$w_2 \simeq_{t_2} w_3 \simeq_{t_2} w_4$$

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

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✓ 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).

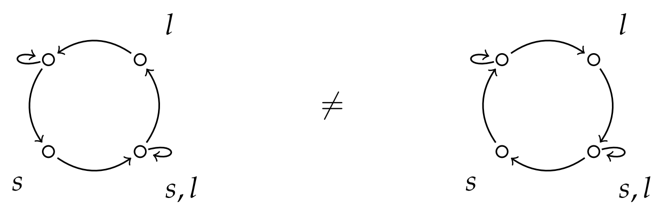


Figure 6: Capturing causal asymmetry via the asymmetry of the passage of time.

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 (Fălăuş 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.
(Fălăuş 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).
[PRESENT 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:

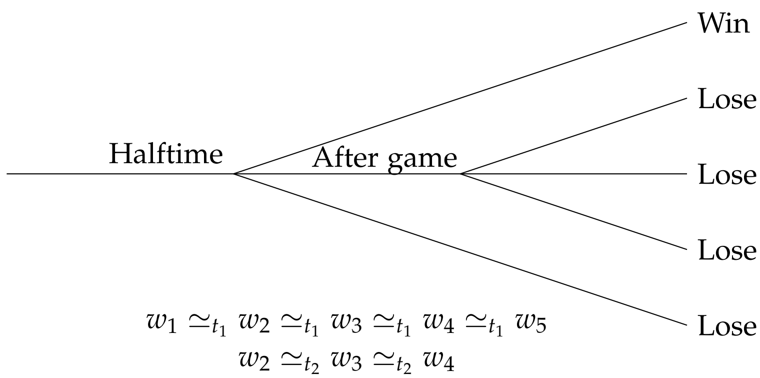


Figure 7: Applying Condoravdi's branching time model.

- 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.

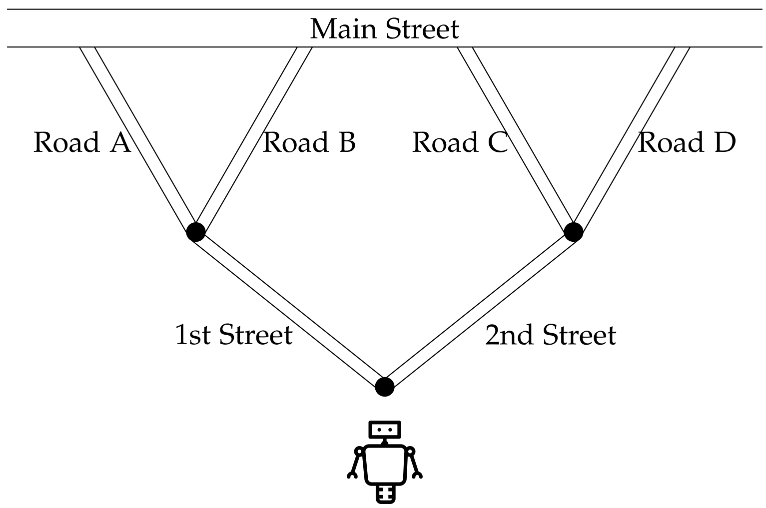
c. $[\![cause]\!](t)(w)(q)(p) = 1$ iff

(i) $AT(t, w, p) = 1$ and $AT(t, w, q) = 1$,

(ii) $\Box_{t(p)}(\mathit{if}\ p)(p\ \mathit{produce}\ q)(t)(w)$, and *Production*

(iii) $\neg\Box_{t(p)}(\mathit{if}\ \neg p)(\neg p\ \mathit{produce}\ q)(t)(w)$ *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

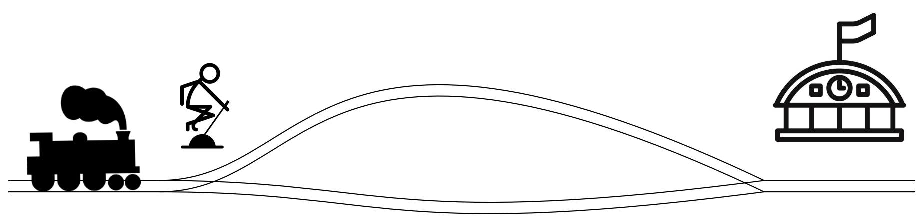


Figure 8: Switching scenario from Hall (2000, p. 205)

(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.

(15) a. If you mow the lawn I'll give you ten dollars
b. ¬(If you don't mow the lawn I'll give you ten dollars)

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]

(16) If $\neg p \in \text{Alt}((15a))$, then $\textsc{exh}_{\text{Alt}(p)}[\![(15a)]\!]$ entails $[\![(15b)]\!]$.

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.

(17) a. $\textsc{exh}(\Box(\textit{if } p)(\textit{produce}(p,q)))$
(i) **Asserts truth of prejacent:** $\Box(\textit{if } p)(\textit{produce}(p,q))$
(ii) **Implicates:** $\neg\Box(\textit{if } \neg p)(\textit{produce}(\neg p,q))$
b. $\textsc{exh}(\neg\Box(\textit{if } p)(\textit{produce}(p,q)))$
(i) **Asserts truth of prejacent:** $\neg\Box(\textit{if } p)(\textit{produce}(p,q))$
(ii) **Implicates:** $\Box(\textit{if } \neg p)(\textit{produce}(\neg p,q))$[2]

(18) $\textit{cause}(p,q)$
a. **Asserts:** $\Box(\textit{if } p)(\textit{produce}(p,q))$
b. **<u>Asserts</u> exclusive inference:** $\neg\Box(\textit{if } \neg p)(\textit{produce}(\neg p,q))$

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

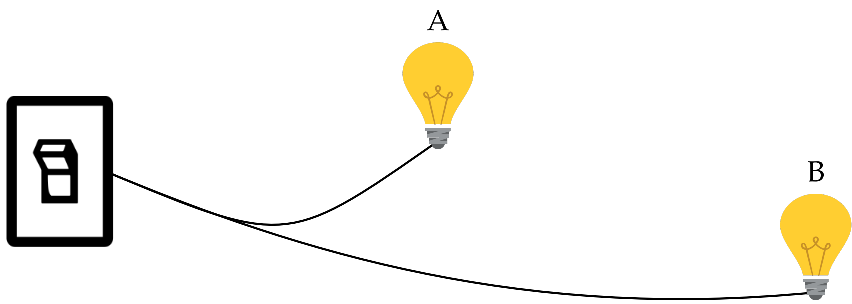
(19) Thomas and Deo (2020) on English *just*: $\textit{just}(p)$
a. **Asserts truth of prejacent:** p is true at the finest level of granularity available in the context, and
b. **<u>Asserts</u> exclusive inference:** p is not true at any coarser level of granularity that would make a stronger claim.

(20) Xiang (2016) on Mandarin *dou*: $\textit{dou}(p)$
a. **Asserts truth of prejacent:** p is true
b. **<u>Asserts</u> exclusive inference:** for no sub-alternative q of p is $O(q)$

[1] $\textsc{exh}$ is defined as in Fox (2007):

(i) a. $[\![\textsc{exh}]\!](Alt(p))(p)(w) \Leftrightarrow p(w) \wedge \forall q \in \textsc{ie}(p, Alt(p))[q(w)]$
where $Alt(p)$ is the set of alternatives of the prejacent p.
b. $\textsc{ie}(p, Alt(p)) = \bigcap\{Alt(p)' \subseteq Alt(p) : Alt(p)'$ is a maximal set in $Alt(p)$ such that $\{\neg q : q \in Alt(p)'\} \cup \{p\}$ is consistent$\}$.

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



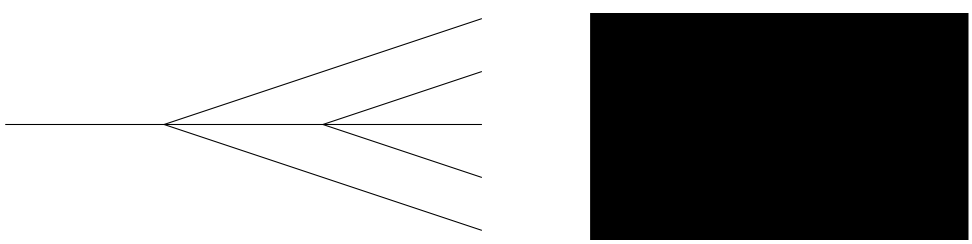
true.[3,4]

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

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

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

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