Neither the time nor the place: Omissive causes yield temporal inferences

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Abstract. Is it reasonable for humans to draw temporal conclusions from omissive causal assertions? For example, if you learn that not charging your phone caused it to die, is it sensible to infer that your failure to charge your phone occurred *before* it died? The conclusion seems intuitive, but no theory of causal reasoning explains how people make the inference other than a recent proposal by Khemlani and colleagues [2018a]. Other theories either treat omissions as non-events, i.e., they have no location in space or time; or they account for omissions as entities that have no explicit temporal component. Theories of omissions as non-events predict that people might refrain from drawing conclusions when asked whether an omissive cause precedes its effect; theories without any temporal component make no prediction. We thus present Khemlani and colleagues' [2018a] theory and describe two experiments that tested its predictions. The results of the experiments speak in favor of a view that omissive causation imposes temporal constraints on events and their effects; these findings speak against predictions of the non-event view. We conclude by considering whether drawing a temporal conclusion from an omissive cause constitutes a reasoning error and discuss implications for AI systems designed to compute causal inferences.

Keywords: omissive causation, mental models, reasoning, temporal inference

1 Introduction

Omissions are events that do not occur – for instance, a typically chipper coworker might fail to greet you in the morning. People often reason about omissions as they can be diagnostic: the lack of a greeting can indicate stress. And omissions can participate in causal relations, too: the absence of a particular action can cause some state of affairs to come about, such as when a taxpayer's failure to file her taxes leads to fines. As the example suggests, omissive causes are ubiquitous, and they can impact an individuals' health, welfare, and finances [Ferrara, 2013], where the costs of a failure to act have grave personal and legal consequences.

It may be compelling to think of omissions in omissive causes as nothing whatsoever. The idea is a prominent view among many philosophers [Hommen, 2014]. For instance, Moore [2009] argues that that when people assert omissive causal statements akin to *A not happening caused B*,

> "[they] are … saying that there was no instance of some type of action *A* at [time point] *t* when there is an omission to *A* at *t*"
>
> [Moore, 2009, p. 444]

Likewise, Sartorio [2009] argues that:

> "it's hard to count omissions as [causal] actions, for omissions don't appear to have specific spatiotemporal locations, intrinsic properties, etc."
>
> [Sartorio, 2009, p. 513]

Other theorists likewise defend the idea that omissions are non-entities: they have no metaphysical substance. They do not convey facts, truths, or presuppositions; they are not states of affairs or possibilities; they're not un-instantiated actions; and they're not features of space-time regions. They're just nothing [see Clarke, 2014, p. 38 et seq.; cf. Nelkin & Rickless, 2015].

For some philosophers, the metaphysics of omissions is so problematic that they deny that omissive causation is a meaningful concept [e.g., Beebee, 2004; Dowe, 2001; Hall, 2004; see Pundik, 2007, for a review]. Beebee [2004] explains that

> "The reason I deny that there's any such thing as causation by absence is that I want to uphold the view that causation is a relation between events."
>
> [Beebee, 2004, p. 291]

Cognitive scientists, in contrast, have moved in the opposite direction. Since people have little difficulty systematically interpreting omissive causal relations, omissions must be mentally represented in one way or another. Recent theoretical proposals concern the psychology, not the metaphysics, of omissive causations. Theorists disagree on whether humans mentally represent omissive causation as arrangements of forces [Wolff, Barbey, & Hausknecht, 2010], as counterfactual contrasts [Stephan, Willemsen, & Gerstenberg, 2017], or as sets of possibilities [Khemlani, Wasylyshyn, Briggs, & Bello, 2018]. But they concur that omissions are *something*, not nothing.

One way in which omissions have psychological import is that they yield systematic patterns of inference. Many researchers have observed that people draw counterfactual inferences from causal assertions. For instance, suppose a teacher says the following to the parent of a wayward student:

1. Not doing her homework caused her grade to fall.

The parent is justified in making the following counterfactual inference: if she had done her homework, her grades wouldn't have suffered.

Do reasoners draw other types of inferences from omissive causal assertions? In particular, do they make temporal inferences from omissions? People can certainly draw temporal conclusions from more orthodox causal assertions. For instance, if the parent was told:

2. Cheating on her test caused her grade to fall.

then the parent can sensibly interpret the temporal order of events: her child cheated *first*, and her grade fell *afterwards* (or perhaps simultaneously). Indeed, such an inference strikes us as trivial. But drawing temporal conclusions from omissive causes such as (1) can seem puzzling, particularly given the aforementioned philosophical concerns over omissions. If omissions are *nothing*, then they have no place in space and time. And so perhaps it doesn't make sense to infer any temporal relation between the events in (1), i.e., it doesn't make sense to infer that the student didn't do her homework *before* her grade fell, because her lack of doing homework isn't fixed to any spatiotemporal frame. It simply didn't occur. Hence, if people treat omissions as nothing whatsoever, there is no reason to infer temporal relations from omissive causes.

Psychological accounts of omissive causation likewise have difficulty explaining how temporal relations can be inferred from causal relations. Of the three psychological treatments of omissive causation, only one readily predicts that people should infer a temporal relation from (1) above: Khemlani et al. [2018] posit that reasoners mentally simulate omissive causes by constructing *temporally ordered* sets of possibilities. Because those possibilities reflect a temporal order, reasoners should have no difficulty drawing temporal conclusions from omissive causes. Stephan et al.'s [2017] account treats omissive causes as counterfactual simulations in a physics engine, and physics engines contain a veridical internal clock, so they can explicitly represent points in time. Hence, temporal order could be computed from its operations. But it's difficult to ascertain how those operations map onto psychological constructs, since humans don't possess a veridical clock. And Wolff et al. [2010] treat omissions as force vectors, which explicitly do not represent temporal order. Force vectors can represent only direction and magnitude – they cannot represent time, and computational implementations of the theory do not yield representations of temporal order.

In what follows, we briefly outline Khemlani et al.'s [2018] model-based theory of omissive causation. We describe two experiments that test the theory's prediction that reasoners should make temporal inferences from omissive causal assertions. We consider whether reasoners are justified in making temporal inferences or whether doing so constitutes an egregious error. We conclude by discussing directions for how the results can be applied to the construction of AI systems that compute causality.

2 Mental models and omissive causation

The mental model theory – the "model theory" for short – posits that people draw conclusions by building and scanning *mental models*, i.e., discrete representations of possibilities [Johnson-Laird, 2006; Johnson-Laird & Byrne, 1991; Goldvarg & Johnson-Laird, 2001; Goodwin & Johnson-Laird 2005]. The model theory makes a central primary representational assumption: models are iconic, i.e., they are isomorphic to the structure of what they represent [Peirce, 1931-1958, Vol. 4]. Hence, a mental model of a spatial relation such as *A is to the left of B* is a representation in which a token that represents *A* is located to the left of a token that represents *B*, as in this diagram:

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A      B
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Inferences emerge from iconic representations [Goodwin & Johnson-Laird, 2005]. For instance, reasoners can infer that *B is to the right of A* from the diagram above. Some concepts cannot be represented in an iconic way, and so the model theory allows that certain sorts of symbols can be integrated into models, such as a symbol denoting negation [Khemlani, Orenes, & Johnson-Laird, 2012].

The model theory proposes that people interpret omissive causes by building sets of possibilities in which omissive causes are represented as negated states of affairs [Khemlani et al., 2018a]. For instance, the statement, *not doing her homework caused a lower grade*, refers to three separate possibilities that can be depicted in the following diagram:

```
¬ homework    grade-fell
  homework  ¬ grade-fell
  homework    grade-fell
```

Each row of the diagram represents a different temporally ordered possibility that could render the statement true, and '¬' denotes the symbol for negation. Hence, the first row depicts the possibility in which the student didn't do her homework and her grade fell; the second row depicts the possibility in which she did her homework and her grade didn't fall (a counterfactual possibility; see Khemlani, Byrne, & Johnson-Laird, 2018); and the third row depicts the possibility in which she did her homework but her grade fell for some other reason (an alternative counterfactual). The causal relation in (1) is inconsistent with only one possibility, i.e., the situation in which she didn't do her homework and her grade didn't fall. The model above does not directly represent that possibility, since it represents only those possibilities that are consistent with the omissive causal relation.

Because maintaining three separate possibilities can be difficult for many reasoners, the theory posits that people tend to construct and reason with only one possibility at a time – the bolded possibility above, known as the mental model:

```
¬ homework    grade-fell
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The mental model can be scanned and combined with models of additional premises to make rapid inferences, but reasoners who construct mental models and not the full set of possibilities are prone to systematic mistakes [see Khemlani & Johnson-Laird, 2017, for a review]. And those reasoners who do construct the full set of models tend to tax their working memory resources, and so they should be relatively slower to respond than when they rely on mental models alone.

The model theory accounts for both orthodox causation, i.e. causation that involves events that do occur [Goldvarg & Johnson-Laird, 2001; Johnson-Laird & Khemlani, 2017; Khemlani, Barbey, & Johnson-Laird, 2014], and omissive causation. The main difference between the two treatments is that orthodox causation implies that causes are affirmative states of affairs, whereas omissive causation implies that causes are negative states of affairs [Khemlani et al., 2018a] and negations can increase difficulty in reasoning and interpretation [Khemlani et al., 2012]. Otherwise, the theory posits that people should yield similar patterns for reasoning about orthodox and omissive causes.

Because a mental model of a causal relation concerns a temporally ordered possibility, the theory predicts that people should draw temporal inferences from both orthodox and omissive causal relations (prediction 1). They should do so systematically, not haphazardly, i.e., they should infer that the student didn't do her homework *before* her grade was lowered, but they shouldn't infer that she didn't do her homework *after* her grade was lowered, because the causal relation is incompatible with that possibility (prediction 2). Two experiments tested these predictions.

3 Experiments

3.1 Experiment 1

Experiment 1 tested the model theory's prediction that people should draw temporal inferences from omissive and orthodox causal assertions. Participants were given a statement of the following schematic structure:

> [Doing / not doing] A caused B.

Their task was to respond to a question of the following format:

> Did [A / not A] occur before B? [cause-before-effect]

Half the problems asked participants to evaluate temporal relations in which the causal event, i.e., event A (or not A) occurred before event B, and the other half of the problems presented participants with the events reversed:

> Did B occur before [A / not A]? [cause-after-effect]

The model theory predicts that reasoners should respond "yes" to the first question, regardless of whether the events concerned an orthodox or an omissive cause (prediction 1). And it likewise predicts that they should reject the second question.

Method. *Participants.* 50 participants (mean age = 37.6 years; 31 males and 19 females) volunteered through the Amazon Mechanical Turk online platform [see Paolacci, Chandler, & Ipeirotis, 2010, for a review]. 17 participants reported some formal logic or advanced mathematical training and the remaining reported no training. All participants were native English speakers.

Design, procedure, and materials. Participants carried out the experiment on a computer screen. The study was designed in psiTurk [Gureckis et al., 2015]. After reading instructions, participants carried out a practice problem and then completed 12 experimental problems. Problems consisted of a causal premise and a question concerning a temporal relation. The events in the causal premise concerned magical spells (causes) and their fictitious effects. Half the problems concerned omissive causation by describing what occurred when a particular spell wasn't cast (e.g., "Not casting allimon..."); and the other half concerned orthodox causation by describing spells that were cast (e.g., "Casting allimon…"). The effects of the spells concerned fictitious diseases that afflicted a particular individual (e.g., "…caused Peter to have kandersa disease."). After reading the causal premise, participants were asked a question about a temporal relation. The format of the question depended on whether the causal premise described omissive or orthodox causation. For instance, if the premise described orthodox causation, the temporal relation concerned a cause and its effect, e.g.,

> Did casting allimon occur before Peter's kandersa disease occurred?

And if the premise described omissive causation, the temporal relation described a non-event and its effect:

> Did not casting allimon occur before Peter's kandersa disease occurred?

On half of the problems, the question described a relation in which the cause occurred before the effect, and on the other half the order was reversed. Participants responded by choosing one of three different options: "Yes", "No", and "Don't know for sure". The information for each problem was presented simultaneously, and participants could not continue without selecting one of the three options. The presentation order of the problems and the materials were randomized, as was the order of the three response options on the screen.

Results and discussion. Figure 1 shows participants' proportions of "yes" responses as a function of whether the inference concerned omissive or orthodox causation and as a function of whether participants evaluated the temporal order in which the causal event occurred before the effect or after it. Participants' percentages of "yes" responses did not differ as a function or whether the inference described an omissive or an orthodox causal relation (35% vs. 37%; Wilcoxon test, $z = .22$, $p = .83$, Cliff's $\delta = .01$). They responded "yes" more often to temporal relations when those relations described a cause that occurred before an effect rather than after (64% vs. 8%; Wilcoxon test, $z = 6.0$, $p < .0001$, Cliff's $\delta = .82$). Planned comparisons revealed that participants' selections of "yes" responses to cause-before-effect relations occurred reliably higher than chance, both for orthodox causes (Wilcoxon test, $z = 5.67$, $p < .0001$, Cliff's $\delta = .68$) and for omissive causes (Wilcoxon test, $z = 4.30$, $p < .0001$, Cliff's $\delta = .52$). Participants' tendency to accept temporal relations interacted as a function of the type of causation (orthodox vs. omissive) and the temporal order

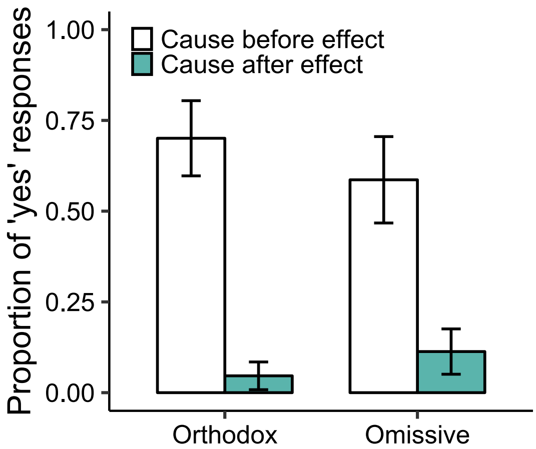

Fig. 1. Proportions of "yes" responses in Experiment 1 as a function of whether the causal relation concerned an orthodox or an omissive cause and as a function of whether the temporal relation evaluated described a cause that occurred before or after the effect. The balance of responses in the study were either "No" or "Don't know for sure."

(Wilcoxon test, z = 2.43; p = .02; Cliff's δ = .21): they were less likely to accept cause-before-effect temporal relations for omissive rather than orthodox causes, and they were more likely to accept cause-after-effect temporal relations for omissive rather than orthodox causes (see Figure 1). The interaction was not predicted, however, and it was not robust (B = 2.17, p = .22) in a follow-up generalized logistical mixed-model (GLMM) regression analysis that utilized the maximal random-effects structure for the data [following Barr et al., 2013].

Participants in Experiment 1 validated both of the model theory's central predictions. Reasoners inferred temporal relations from causal statements for both orthodox and omissive causes (prediction 1). And they inferred only those temporal relations that matched the temporal order predicted by the use of mental models (prediction 2). The absence of a reliable difference between orthodox and omissive causation lends further credence to the notion that the mental processes concerning omissive causes are similar to those concerning orthodox causes.

Experiment 1 was limited in that the task was evaluative, and so on each problem, participants were asked to infer a single temporal relation, namely *before*, which may have prevented them from considering alternative temporal relations. For example, participants often responded "Yes" to the following question about omissions:

Did not casting allimon occur before Peter's kandersa disease occurred?

Their affirmation might allow that the omissive cause ("not casting allimon") also occurred *after* Peter's kandersa disease occurred, but the evaluative nature of the task prohibited any such analysis. Another limitation of the task is that participants may have misconstrued it as asking about possibility, not necessity, and so perhaps they affirmed the temporal relation because they considered it a viable possibility. Experiment 2 ruled out these concerns.

3.2 Experiment 2

Experiment 2 was similar in design and execution to Experiment 1: problems comprised an (omissive or orthodox) causal assertion paired with an assertion that described a potential temporal relation between events. However, the second assertion given to participants was incomplete, and their task was to fill in the blank. Half the problems took on the following general structure:

> Suppose the following statement is true:
> [Doing / not doing] A caused B.
> Given the above statement, complete the following sentence:
> [A / not A] occurred ________ B occurred.

and the other half of the problems reversed the order of the events:

> B occurred ________ [A / not A] occurred.

Participants' task was to choose among three different options to fill in the blank: "after", "before", and "and also". The last option permitted participants to be agnostic about when events or non-events occurred in relation to other events, and so participants could select them as most appropriate for omissive causal relations. The model theory predicts, instead, that reasoners should select "before" or "after" depending on the order of events in the incomplete sentence.

Method. *Participants.* 50 participants volunteered through the Amazon Mechanical Turk online platform (mean age = 39.8 years; 28 males and 22 females). 30 participants reported no formal logic or advanced mathematical training and the remaining reported introductory to advanced training in logic. All were native English speakers.

Design, procedure, and materials. Participants completed 1 practice problem and 12 experimental problems, and they acted as their own controls. Each problem consisted of a causal assertion and presented participants with an incomplete sentence. The experiment manipulated whether the first event concerned orthodox or omissive causation. It also manipulated the order of the events in the incomplete sentence: half the problems described the cause, a blank relation, and the effect, and the other half of the problems described the effect, a blank relation, and the cause. The problems used the same materials as in Experiment 1, and so an example [omissive causal] problem is as follows:

> Suppose the following statement is true:
> Not casting allimon caused Peter to have kandersa disease.
> Given the above statement, complete the following sentence:
> Peter's kandersa disease occurred ________ not casting allimon occurred.

Three separate response options ("before", "after", and "and also") were presented as a dropdown menu to complete blank in the incomplete sentence. Participants were prevented from moving on to the next problem until they selected one of the three options. The presentation order of the problems was randomized, the contents of the problems were randomized, and the order in which the three response options appeared in the dropdown menu was randomized.

Results and discussion. An initial analysis examined participants' tendency to select "after" or "before" as a function of the type of cause in the causal assertion. No reliable differences occurred in their tendency to select "before" as a function of whether the causal assertion in the problem concerned an omissive or an orthodox cause (43% vs. 47%; Wilcoxon test, $z = 1.65$, $p = .09$, Cliff's $\delta = .11$) and likewise for their tendency to select "after" (43% vs. 48%; Wilcoxon test, $z = 1.09$, $p = .28$, Cliff's $\delta = .10$). Follow-up GLMM analyses that utilized maximal random-effects structures likewise revealed no reliable difference between the tendency to select "before" ($B = .84$, $p = .31$) or "after" ($B = -2.81$, $p = .15$) as a function of whether the causal relation was orthodox or omissive. The result corroborates the model theory's first prediction. In what follows, we pooled the data for orthodox and omissive causes except for one post-hoc planned comparison.

Figure 2 shows participants' tendency to select "before", "after", or "and also" responses as a function of the temporal order of the terms in the incomplete statement. Participants selected "before" more often when the cause occurred before the effect than vice versa (78% vs. 12%; Wilcoxon test, $z = 6.16$, $p < .0001$, Cliff's $\delta = .94$), and they selected "after" more often when the effect occurred before the cause than vice versa (79% vs. 12%; Wilcoxon test, $z = 6.06$, $p < .0001$, Cliff's $\delta = .95$). Selec-

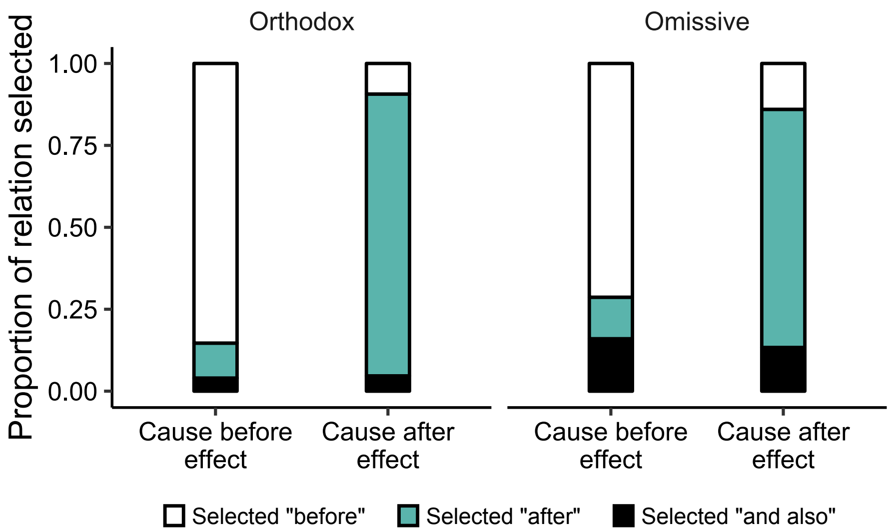

Fig. 2. Proportions of participants' selections of the three different types of relations in Experiment 2 as a function of whether the incomplete assertion described a cause that occurred before or after the effect, for both orthodox and omissive causation.

tions of “and also” responses did not differ as a function of the temporal order of events in the incomplete sentence (10% vs. 9%; Wilcoxon test, z = 1.15, p = .25, Cliff’s δ = .09).

A post-hoc planned comparison revealed that participants selected “and also” responses marginally more often for omissive causes than orthodox causes (14% vs. 4%; Wilcoxon test, z = 1.83, p = .07, Cliff’s δ = .16). Despite the lack of reliability, the difference might suggest that people do, on occasion, interpret omissive causes as nonevents that have no spatiotemporal frame. But, the vast majority of participants’ responses suggest otherwise: people interpreted both omissive and orthodox causal relations to yield distinct temporal inferences.

We conclude by considering whether participants’ responses in Experiments 1 and 2 constitute sensible inferences or striking reasoning errors and discuss implications for computational models designed to mimic human causal reasoning.

4 General discussion

In two experiments, participants accepted temporal conclusions from causal assertions, even for causal assertions that described omissive causes. The experiments validate a prediction of the model theory of causal reasoning [Goldvarg & Johnson-Laird, 2001; Johnson-Laird & Khemlani, 2017; Khemlani et al., 2014, 2018a]: reasoners should construct sets of temporally ordered possibilities when they interpret causal assertions. The temporal ordering makes it trivial for reasoners to draw temporal conclusions, but if the inferences are easy and obvious, as they appear to be for many reasoners, then other psychological accounts should readily explain how people make them. Yet no other account of causal reasoning has explained how people can draw temporal inferences from causal assertions [cf. Stephan et al., 2017; Wolff et al., 2010].

We continue by entertaining the possibility that participants’ responses reflect an egregious reasoning error. Consider statement (1) in the introduction concerning a student’s failure to do her homework:

1. Not doing her homework caused her grade to fall.

Prominent philosophers argue that omissions are non-events that don’t occur in space or time [Clarke, 2014, p. 38 et seq.]. If they’re right, then people are mistaken whenever they construe non-events as occurring in any location or point in time, or even a relative place or timepoint. There may be some credence to their view; after all, the following question seems bizarre:

3. Q: **Where* did she not do her homework?

As we’ve shown in our study, however, this question, and its answer, seem sensible:

4. Q: *When* did she not do her homework?
   A: She didn’t do her homework before her grade fell.

How can (4) make sense when (3) doesn't? Two explanations seem viable: either non-events don't occur in space or time, in which case reasoners err whenever they draw temporal inferences from causal assertions; or else non-events can occur in a temporal context without occurring in spatial context. And certain sorts of omissive events may promote temporal inferences more than others. Future research should adjudicate the two proposals.

Regardless of which proposal turns out to be right, the experiments we report demonstrate that people assign omissive causes temporal locations. AI systems need to do the same. AI systems enriched with the ability to reason causally may be able to infer causal relations in complex datasets, provide rich explanations of those relations, and serve as trustworthy interlocutors; and so it may be surprising that so few AI systems demonstrate adequate human-level causal reasoning [Gil & Selman, 2019]. One reason for the dearth of such systems is that humans reason in a manner elusive to formal frameworks of computational logic: they reason based on possibilities instead of truth-values or probabilities [Khemlani & Johnson-Laird, 2019]. Hence, human intuition serves as the best existing benchmark for testing systems that implement human-level causal thinking. Without yielding the "obvious" inferences that humans make on a routine basis, such as the inferences explored above, AI systems have no hope of simulating more complex causal reasoning behavior.

The present research responds to this need by presenting work on human reasoning about typical causation and omissive causation, because omissive causation challenges existing computational frameworks and philosophical treatments alike. Omissive causation requires a human to represent situations that do not exist in the world – there is no event onto which the representation of the omissive event can be mapped. Since humans assign omissive events temporality, cf. [2], then at minimum, any AI system must do the same and represent an omissive cause as an entity that can be temporally marked.

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