How we Revise our Beliefs about Causes and Enabling Conditions

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Abstract

We argue that propositions about causes differ in meaning from those about enabling conditions: with a cause the effect is necessary, whereas with an enabler it is possible. But, the salient mental model is the same for both. We report an experiment that tested this difference in a study of belief revision. The results showed that causes and enabling conditions are revised differently. On consistent trials, most participants maintained their belief in a particular enabling condition whereas only half of the participants maintained their belief in a particular cause. On inconsistent trials, just over half of the participants switched their belief in a particular enabling condition whereas the majority of participants maintained their belief in a particular cause. We discuss the results with reference to theories of causality.

Introduction

A cause brings about an effect whereas an enabling condition makes the effect possible, but it is not always easy to distinguish the two. For example, when individuals are told that low unemployment and low interest rates lead to a flourishing economy, they may not agree on which of these two events is the cause and which is the enabling condition. They may say they are joint causes. Following Mill (1874), many psychologists have argued that no difference in meaning exists between causes and enablers, and they have distinguished between them in other ways. They argue, for example, that the cause is an unusual state and the enabler is the usual state, the cause is inconstant whereas the enabling state is constant (Cheng and Novick, 1991), or the cause violates a norm whereas the enabling condition does not (Einhorn and Hogarth, 1986). According to another school of thought, the cause is the factor that is conversationally relevant in explanations. Hence, Hilton and Erb (1996) argue for a two stage process: "explanations are first cognitively generated by building mental models of the causal structure of events, from which particular factors are identified in conversationally given explanations" (p. 275). Speakers therefore mention causes rather than enabling conditions (Hilton, 1990; see Goldvarg and Johnson-Laird, 2001, for a review of theories).

An alternative view is that causes and enabling conditions do differ in meaning and, as a consequence, in their logical implications (Johnson-Laird, 1999; Goldvarg and Johnson-Laird, 2001). According to this theory, the claim that an event will *cause* an effect is compatible with three temporally-constrained possibilities:

cause effect

no cause effect

no cause no effect

Given the cause, the effect is therefore necessary, and in cases of strong causation, the cause is the only way to bring about the effect (the second possibility above cannot occur). In contrast, an enabling condition makes possible the effect:

enabler effect

enabler no effect

no enabler no effect

A weak sort of enabler allows all four possible contingencies, i.e., the assertion is a tautology. But, the stronger sense compatible with the three possibilities above is more informative. In short, with a cause the effect is necessary; with an enabler it is possible.

Goldvarg and Johnson-Laird (2001) showed that participants could distinguish between causes and enabling conditions in scenarios of this sort in which neither the cause nor the enabling condition is constant (pace Cheng and Novick, 1991):

> Given that there is good sunlight, if a certain new fertilizer is used on poor flowers, then they grow remarkably well. However, if there is not good sunlight, poor flowers do not grow well even if the fertilizer is used on them.

The complete set of possibilities consistent with the scenario is as follows:

sunlight fertilizer growth

sunlight no fertilizer growth

sunlight no fertilizer no growth

no sunlight fertilizer no growth

no sunlight no fertilizer no growth

In general, however, individuals construct one model at a time, and then tend to use mental models, which do not represent what's false in a possibility, rather than models of the complete possibilities above (Johnson-Laird & Byrne, 1991). One consequence is that those individuals who focus on the first model won't be able to distinguish between

causes and enabling effects – a phenomenon that explains the tendency for theorists to argue that they don't differ in meaning. Nevertheless, the participants in the experiment correctly identified the cause (e.g., the fertilizer in the example above) and the enabler (the sunlight) on 85% of the trials.

Our aim in the present study was to make a further test of the model theory of causes and enablers in the context of a study of belief revision. We made three main predictions.

First, participants should have some difficulty in distinguishing between causes and enabling conditions, especially if they are given an incomplete scenario that is ambiguous, e.g.:

Given that the sun shines, if a new fertilizer is used then the plants grow.

This assertion is compatible with all possibilities except one. It rules out as impossible the case in which the sun shines and the fertilizer is used, but the plants don't grow. Hence, the assertion treats the conjunction of sunshine and fertilizer as a jointly the cause and enabler of growth. Without one of them, the plants may, or may not, grow. In this case, individuals have no semantic basis to identify one event as the cause and another event as the effect.

Second, if participants have relevant general knowledge about the two antecedent events, then they should use it to try to identify cause and enabler. For example, they may suppose that fertilizers are in general more likely to be the cause of growth than sunlight. Similarly, Kuhnmünch and Beller (2005) have argued that the phrase "given that", though it is equivalent in meaning to "if", somehow signals an enabling condition.

Third, a subsequent disambiguating sentence, such as:

If the sun does not shine then whether or not the fertilizer is used the plants do not grow

should affect the participants' identification of cause and enabler. The two assertions together make clear that the sun shine is the enabling condition and the fertilizer is the cause. The disambiguation occurs in both the mental models and the fully explicit models of the two assertions. Hence, those individuals who made this initial interpretation should maintain it, and even be strengthened in their belief. But, those who made a different initial interpretation should no longer be so confident in their belief, and they may even switch their identifications of the two events. Given the different sets of possibilities compatible with causes as opposed to enablers, the disambiguating sentence may have different effects on their revisions. We carried out an experiment to test these predictions.

The Experiment

Materials and design

The materials derived from Goldvarg and Johnson-Laird's experiment mentioned in the introduction, because it had shown that participants could reliably identify enablers and causes from these descriptions. We broke up their vignettes into two sentences: the first sentence was ambiguous, and the second sentence resolved the ambiguity. The participants identified the cause and the enabler in the first sentence, by answering the question, e.g.:

What causes the plants to grow (i.e. brings about the event)?

They rated their confidence on a scale of 1-7. They then answered the question, e.g.:

What allows the plants to grow (i.e. makes the event possible)?

They again rated their confidence on a scale of 1-7. They then read the second sentence, and again identified the cause and the enabler and rated their confidence in their judgments. They made five such pairs of judgments with different contents, which were presented to each participant in a different random order. The materials also counterbalanced whether the cause or the enabler was introduced using the word "given" or "if" (cf. Kuhnmünch and Beller, 2005), and whether the cause or the enabler was in the first or second clause of the initial sentence (where its unequivocal identification depended on the second sentence). We counterbalanced the order of the two questions about cause and enabler for both sentences. And we counterbalanced which of the two events was identified as the enabler in the second sentence. There were accordingly eight versions of the first sentence and its questions, and four versions of the second sentence.

The contents of the materials concerned five different domains: psychological (given a person is sensitive if they are insulted then they get angry), socio-economic (given that there is low unemployment, if the banks lower the interest rates then the economy will flourish), physiological (given that a person exercises, if they follow this diet then they will lose weight), mechanical (given that there is a bullet in the chamber, if the trigger is pulled then the gun fires) and physical (given that there is fertilizer, if the sun shines then the plants grow). The different contents were assigned to the forms of item in a different random way for each participant.

Procedure

Participants were tested individually. Eight of the first 20 participants failed to distinguish between causes and enabling conditions in more than half of the first sentences, and instead identified both events as joint enabling conditions. Although we had predicted this difficulty, it made redundant the test of belief revision, and so we replaced these participants with a further eight and added the following sentence to the instructions: *Please note that an event is either the cause or else it allows the outcome to happen.* There was no time limit and completion of the task took about 15 minutes.

Participants

We tested eight Princeton undergraduates and 12 Trinity College undergraduates, and we replaced 8 of the latter with new participants from the same population (see the procedure). They took part for course credit. However, we excluded two of these eight because they also failed to distinguish between causes and enabling conditions on more than half the trials. The results are accordingly based on 18

participants (seven men and eleven women, ranging in age from 17 to 30 years).

Results

The 18 participants provided 90 trials for analysis. We excluded six of these trials from the analysis as participants had also identified both events as the enabling condition. On an additional 39 trials, the participants identified the same event as both the cause and the enabler. We therefore analyzed the responses for causes and enabling conditions separately, as if they were not interrelated.

The linguistic cue 'given' in the first sentence led to a mean of 2.8 identifications of enabler whereas the cue 'if' led to a mean of 1.8 identifications of enabler, but the difference was not reliable (Wilcoxon test, $z = 1.42$, $p > .1$; pace Kuhnmünch & Beller, 2005). The different contents, however, were not always ambiguous, and 90% of participants chose the same pairing of cause and enabler for the psychological and mechanical materials.

For the enablers, a trial was consistent if the event a participant judged to be the enabler after the first sentence was disambiguated as the enabler in the second sentence; otherwise, the trial was inconsistent. Although we could not determine in advance the distribution of the two sorts of trial, of the 84 trials in the analysis, 42 were consistent and 42 were inconsistent.

The overall prediction was that for consistent trials participants should maintain their judgment, but for inconsistent trials participants would change their judgment. A mean of 3.3 trials fitted the prediction and a mean of 1.4 trials went against it (the means do not sum to 5 because not all the participants provided relevant data on every trial). Table 1 shows that on consistent trials participants tended to identify the same event as the enabling condition after the second sentence, whereas they tended to switch identifications on inconsistent trials. This predicted interaction was reliable (Wilcoxon test, $z = 2.1$, $p<.05$,). As the table shows, on consistent trials, 88% maintained the identity of the enabler whereas only 12% switched it to being the cause (Wilcoxon test, $z = 3.43$, $p<.001$). The difference was not reliable for the inconsistent trials (43% versus 57%, Wilcoxon test, $z = .74$, n.s.). For the participants who maintained their belief 22% reduced their confidence in their belief and 17% increased their confidence in their belief, Wilcoxon test, $z = 0.45$, n.s..

Table 1: The percentages of trials on which the participants maintained their identification of an event as the *enabler,* or else switched its identification to the *cause*, after disambiguating sentences that were consistent or inconsistent with this identification.

	Maintained event as enabler	Switched event to cause
Consistent trial	88	12
Inconsistent trial	43	57

For the causes identified in the first sentence, a trial was consistent if it was the cause in the disambiguating sentence, otherwise the trial was inconsistent. Table 2 shows that on consistent trials participants tended to show a slight bias to identify the same event as the cause after the second sentence, but, strikingly, on inconsistent trials they showed an even greater tendency to maintain their identification (Wilcoxon test, $z = 2.4$ $p<.05$) Designed comparisons showed that on consistent trials, no reliable difference occurred between trials on which the participants maintained their belief in the cause or switched their identification of it to the enabler (57% versus 43%, Wilcoxon test, $z = .81$, n.s.). On inconsistent trials, however, the majority of participants maintained their identification of the event as the cause (80% versus 20%, Wilcoxon test, $z = 2.88$, $p<.005$).

Table 2: The percentages of trials on which the participants maintained their identification of an event as the *cause,* or else switched its identification to the *enabler*, after disambiguating sentences that were consistent or inconsistent with this identification.

	Maintained event as cause	Switched event to enabler
Consistent trial	57	43
Inconsistent trial	80	20

Discussion

The model theory of causes and enabling conditions was corroborated by the experiment in three main ways. First, the mental models of the two sorts of relation make salient the same possibility, and so it should not be easy to distinguish between them. When individuals are forced to make a decision, they are therefore likely to use any cue that they can. Some participants were unable to identify a cause and an enabler in the initial ambiguous sentence; others had a tendency to treat "given" as a cue to the enabler. Kuhnmünch and Beller (2005) argued that this cue is the only one that matters. But, our other results refute this view. The tendency to use this cue occurs only because no semantic difference is available in the first sentence to guide judgment.

Second, if relevant general knowledge was available, then it too exerted an effect in the identification of cause and effect in the first sentences. Thus, our participants knew that in the case of the psychological contents: given a person is sensitive if they are insulted then they get angry, sensitivity is an enabling condition, not a cause. Likewise, in the case of the mechanical contents: given that there is a bullet in the chamber, if the trigger is pulled then the gun fires, they knew that a bullet in the chamber is an enabling condition for the gun to fire, not its cause.

Third, according to the theory, the second sentence identifies the cause and the enabling condition in an unambiguous way. It therefore follows that if this

identification is consistent with a participant's previous judgment, the participant should maintain their judgment. But, otherwise they should tend to switch their judgments. The experiment corroborated this prediction for the enablers, but not for the causes. This difference bears out the distinction between them, but it raises a puzzle that we can illustrate with an example. Consider this sequence of sentences:

Given that the sun shines, if a new fertilizer is used then the plants grow.

If the sun does not shine then whether or not the fertilizer is used the plants do not grow.

Those participants who identified the fertilizer as the enabler in the first sentence, tended to switch its role to the cause condition when they encountered the second sentence. But, those participants who identified the sunshine as the cause in the first sentence did not switch their identification when they encountered the second sentence. We are uncertain about why this difference occurred. One possibility is that enabling conditions are more mutable, because weak enablers are consistent with any contingency. The question calls for further investigation.

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References

Cheng, P. W., & Novick, L. R. (1991). Causes versus enabling conditions. *Cognition*, 40, 83-120.

Einhorn, H.J., and Hogarth, R.M. (1986) Judging probable cause. *Psychological Bulletin*, 99, 3-19.

Goldvarg, E., & Johnson-Laird, P. N. (2001). Naïve causality: a mental model theory of causal meaning and reasoning. *Cognitive Science*, 25, 565-610.

Hilton, D. J. (1990). Conversational processes and causal explanation. *Psychological Bulletin, 107*(1), 65-81.

Hilton, D. J., & Erb, H. (1996). Mental Models and Causal Explanation: Judgments of Probable Cause and Explanatory Relevance. *Thinking and Reasoning*, 2(4), 273-308.

Johnson-Laird, P.N. (1999) Causation, mental models, and the law. *Brooklyn Law Review*, 65, 67-103.

Johnson-Laird, P. N., & Byrne, R. M. J. (1991). *Deduction*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Kuhnmünch, G., & Beller, S. (2005). Distinguishing Between Causes and Enabling Conditions-Through Mental Models or Linguistic Cues? *Cognitive Science, 29*, 1077-1090.

Mill, J.S. (1874) *A System of Logic, Ratiocinative and Inductive*. Eighth Edition. New York: Harper. (First edition published 1843.)