

# The Revision of Beliefs about Causes and Enabling Conditions

Caren A. Frosch (froschc@tcd.ie)

School of Psychology, University of Dublin, Trinity College.  
Dublin 2, Ireland

P. N. Johnson-Laird (phil@princeton.edu)

Department of Psychology Princeton University  
Princeton NJ 08540, USA

## 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 trials in which participants encountered information consistent with an earlier interpretation, most of them maintained their belief in a particular enabling condition whereas only half of the participants maintained their belief in a particular cause. On trials in which they encountered information inconsistent with an earlier interpretation, just over half of them 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.

**Keywords:** belief revision; causality; enabling conditions; mental representation; reasoning.

## 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. 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, but the effect cannot precede its cause or enabler.

Goldvarg and Johnson-Laird (2001) showed that participants do distinguish between causes and enabling conditions. For example, given the premises:

*Eating protein will cause her to gain weight.  
She will eat protein.*

the participants in an experiment tended to draw the conclusion: *She will gain weight*. But, as the theory predicts, they tended not to draw this conclusion from the premises:

*Eating protein will allow her to gain weight.  
She will eat protein.*

In contrast, given the premises:

*Eating protein will allow her to gain weight.  
She won't eat protein.*

the participants tended to draw the conclusion: *She won't gain weight*. But, they tended not to draw this conclusion from the premises:

*Eating protein will cause her to gain weight.  
She won't eat protein.*

Although the difference between causes and enabling conditions depends on the fully explicit possibilities compatible with assertions, individuals tend to consider one possibility at a time, and to represent it in a mental model, which do not make explicit what's false in a possibility (Goldvarg and Johnson-Laird, 2001, *pace* Kuhnmüch & Beller, 2005). One consequence is that individuals to focus on the possibility in which the cause (or enabler) and the effect both occur, and so they are not able to distinguish between causal and enabling claims – a phenomenon that explains the tendency for theorists to argue that they don't differ in meaning. Nevertheless, their difference in meaning shows up in the conclusions that the participants drew in the reasoning experiment.

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, Kuhnmüch 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 were causal vignettes derived from a study in Goldvarg and Johnson-Laird (2001). We divided these vignettes into two sentences: the first sentence was ambiguous, and the second sentence in principle 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. In line with Cheng and Novick (1991) and Goldvarg and Johnson-Laird (2001), we only gave minimal instruction about the difference between causes and enabling conditions. Accordingly, a cause was described as something that brings about the event and an enabling condition was described as something that makes the event possible. Participants made five 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. Kuhnmüch and Beller, 2005), and whether the cause or the enabler was in the first or second clause of the initial sentence (where its 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*)

Biological (*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 eight new participants. We realized that the instructions had not been clear enough in emphasizing that one event was the cause and one the enabling condition, we therefore 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 included in the analysis carried out a total of 90 trials. We excluded six of these trials from the analysis as participants had identified a combination of both events as the enabling condition. On an additional 39 trials, the participants identified the same event as both the cause and the enabler, that is they said sunshine was both the cause and the enabling condition. 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 (61% of all trials) identifications of enabler whereas the cue ‘if’ led to a mean of 1.8 (39%) 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 wholly ambiguous: 90% of participants chose the same pairing of cause and enabler for the psychological and mechanical materials after reading the first sentence.

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 3.4 (standard deviation, 1.1) trials fitted the prediction and a mean of 1.2 (standard deviation, 1.1) 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 interaction was reliable (Wilcoxon test,  $z = 2.1$ ,  $p < .05$ ). As the table shows, on consistent trials, only 12% switched the identity of the enabler to being the cause (88% maintained versus 12% switched, 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: Percentages of trials on which participants switched identification of enabler to the cause and switched identification of cause to the enabler, after disambiguating sentences that were consistent or inconsistent with initial identification.

	Switched belief in enabler to cause	Switched belief in cause to enabler
Consistent trial	12	42*
Inconsistent trial	57	18

\* The balance of the percentages in each row were the trials on which the participants maintained their beliefs.

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 1 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. On a mean of 1.9 trials (standard deviation, 1.3) participants maintained their belief in a particular cause on a consistent trial and switch their belief on an inconsistent trial. But, on a mean of 2.9 trials (standard deviation, 1.6) trials went against this pattern. The interaction was in the opposite direction to the interaction found for the enabling conditions (Wilcoxon test,  $z = 2.6$   $p < .01$ ). 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 (58% versus 42%, Wilcoxon test,  $z = .89$ , n.s.). On inconsistent trials, however, the majority of participants maintained their identification of the event as the cause even though it had been disambiguated as the enabling condition (82% versus 18%, Wilcoxon test,  $z = 3.11$ ,  $p < .002$ ).

We examined the five different contents for deviations from the pattern of responses found for the combined materials. Table 2 presents a breakdown for the different contents compared to the overall pattern. We carried Friedman non-parametric tests to check whether the contents led to different patterns of revision for causes and for enabling conditions. Neither test yielded reliable results: for enablers  $\chi^2_r = 3.1$ ,  $df = 4$ ,  $p = .5$ ; and for causes  $\chi^2_r = 3.8$ ,  $df = 4$ ,  $p = .4$ . We also examined whether there were any differences in the frequency with which participants followed the overall pattern of results. Again the two Friedman tests, failed to yield reliable results: for enablers  $\chi^2_r = 1.7$ ,  $df = 4$ ,  $p = .8$ ; and for causes  $\chi^2_r = 2.7$ ,  $df = 4$ ,  $p = .6$ .

Table 2: Comparison of the five different contents on rates (in percentages) of belief revision.

	Switched belief in enabler to cause	Switched belief in cause to enabler
<b>Consistent trial</b>		
Total	12	42
psychological	0	21
socio-economic	9	59
physiological	17	58
mechanical	20	35
physical	13	31
<b>Inconsistent trial</b>		
Total	57	18
psychological	45	32
socio-economic	57	29
physiological	71	0
mechanical	50	13
physical	67	11

## 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 results failed to corroborate this view. The tendency to use this cue occurs only because no semantic difference is available in the first sentence to guide judgment. The responses to the second, disambiguating, sentence also indicate that some participants had difficulty in distinguishing causes and enabling conditions as evidenced by some participants’ tendency to identify the same event as the cause and the enabling condition. Skeptics might argue that this difficulty demonstrates that causes and enabling conditions are *not* distinct. However, this claim is inconsistent with the results we found for enabling conditions and it is also inconsistent with comments made in “think aloud” protocols

(not reported here). We asked participants to think aloud during the last pair of trials. There is evidence in these protocols of their understanding of the distinction between the two even when their written responses are not always consistent with this understanding.

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. However, our content analysis shows that even for these materials, where participants had prior ideas about the cause and the enabler, the patterns of responses were not significantly different from those to the other materials.

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 that a distinction exists 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 do not know for certain why this difference occurred. One possibility is that enabling conditions are more mutable, because weak enablers are consistent with any contingency. Another possibility is that the second sentence highlights the dependence of the cause on the enabling condition. In other words, in the second sentence the cause can no longer be regarded as sufficient for bringing about the event. The second sentence makes the following model explicit:

cause      no enabler      no effect

It is also possible that some participants viewed the second sentence in isolation from the first sentence. This factor would explain why some participants chose the same event as the cause and as the enabling condition, neglecting the information given to them in the first sentence where both events were given causal roles. The experiment shows that

the distinction between causes and enabling conditions is worthy of further investigation.

### **Acknowledgments**

This research was funded by the Irish Research Council for the Humanities and Social Sciences major research grants. We thank Geoffrey Goodwin and four anonymous reviewers for comments on an earlier draft of this manuscript. We would also like to thank Clare Walsh for her comments on this research.

### **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.)