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Distinguishing Between Causes and Enabling Conditions—Through Mental Models or Linguistic Cues?

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Abstract

The mental model theory of naive causal understanding and reasoning (Goldvarg & Johnson-Laird, 2001, *Cognitive Science, 25,* 565–610) claims that people distinguish between causes and enabling conditions on the basis of sets of models that represent possible causal situations. In the tasks used to test this hypothesis, however, the proposed set of models was confounded with linguistic cues that frame which event to assume as given (the enabling condition) and which to consider as responsible for the effect under this assumption (the cause). By disentangling these two factors, we were able to show that when identifying causes and enabling conditions in these tasks, people rely strongly on the linguistic cues but not on the proposed set of models and that this set of models does not even reflect people's typical interpretation of the tasks. We propose an alternative explanation that integrates syntactic and causal considerations.

Keywords: Causal reasoning, Causal roles, Enabling conditions, Mental models, Linguistic cues, Dual-source approach

1. Introduction

In everyday life, people often distinguish between causes and enabling conditions. Suppose a gardener is experimenting with various cultivation conditions for a particular kind of poor, but decorative, flowers. The following statements summarize the gardener's observations:

1. Given that poor flowers get enough sunlight: If a particular new fertilizer is added to the ground, then poor flowers grow well. However, if poor flowers do not get enough sunlight, then they do not grow well, even if the new fertilizer is added to the ground.

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The gardener mentions two precursors to the growth of the poor flowers: enough sunlight and a new fertilizer. Which factor is—according to the statements of the gardener—an *enabling condition* that makes good growth possible, and which is the *cause* that brings this effect about?

Goldvarg and Johnson-Laird (2001) conducted an experiment in which they scrutinized this distinction of causal roles (Experiment 2). Their tasks included a scenario similar to the one previously mentioned and seven further scenarios of different content but with descriptions syntactically analogous to (1). In the poor flowers example (1), people typically identified "enough sunlight" as an enabling condition and "new fertilizer" as the cause. The answers obtained depended neither on which factor was mentioned first (e.g., sunlight) nor on specific causal knowledge that might establish a general preference for assigning a certain causal role to one of the factors (e.g., sunlight being preferred as an enabling condition). When the causal factors were interchanged in the descriptions, participants' answers also became inverted. Across all eight tasks, 85% of Goldvarg and Johnson-Laird's participants ($N = 20$; 160 tasks) gave the corresponding answers. Thus people clearly identified causes and enabling conditions.

How are these roles distinguished? Goldvarg and Johnson-Laird (2001) proposed that people interpret the previously mentioned description as three conditionals, "*If* sunlight then *if* fertilizer then growth; and *if* not sunlight then not growth" (p. 588), which yield the following five fully explicit models of possible situations:

(m1)	sunlight	fertilizer	growth
(m2)	sunlight	¬fertilizer	growth
(m3)	sunlight	¬fertilizer	¬growth
(m4)	¬sunlight	fertilizer	¬growth
(m5)	¬sunlight	¬fertilizer	¬growth

These models correspond with the correct propositional logical interpretation of the three conditionals (a truth-functional derivation is available online from Annex A at http://www.cognitivesciencesociety.org/supplements/). According to the definitions that Goldvarg and Johnson-Laird (2001) gave their participants, an enabling condition makes an event possible, implying that—all other circumstances being equal—the event cannot occur without this condition. In the context of the task outlined previously, an enabling condition is thus a *necessary* causal factor. This applies for just one factor: without sunlight, the poor flowers will not grow well (cf. Models m4 and m5). The other factor cannot play the role of an enabling condition, as good growth is still possible without the new fertilizer (cf. Model m2). The new fertilizer, however, is a cause that is *sufficient* to bring about the effect of good growth given the presence of sunlight (cf. Model m1).

A clear experimental result and a seemingly plausible explanation—so why is it not convincing? Three aspects are particularly surprising: First, according to Goldvarg and Johnson-Laird's (2001) account, people do not seem to apply a causal interpretation to the given description—it is simply understood as a sequence of conditionals from which the five models follow according to propositional logic (a similar objection was raised by Sloman & Lagnado, 2005, in the context of other causal tasks). The second point is associated with this: It is claimed that people—without any difficulty—flesh out and handle five alternative models at the same time. This is astonishing because the reasoning literature shows that people often do not even construct the three models possible from a single conditional (Evans, Newstead, & Byrne, 1993; Johnson-Laird & Byrne, 1991, 2002; Over, 2004). Why should they be able to surpass this in these tasks? Finally, not even the results of Goldvarg and Johnson-Laird's first experiment on the meaning of causal assertions in terms of possible situations do convincingly support the claim of a logical difference of causal roles: In each of the two relevant cases (i.e., the assertions "cause" and "allow"[1]) 10 out of 19 answers reported by Goldvarg and Johnson-Laird (p. 587) corresponded with one and the same interpretation that differs from the definition of causal roles in the role assignment tasks (Goldvarg & Johnson-Laird, Experiment 2).

We argue that people do not solve the role assignment tasks on the basis of the models assumed by Goldvarg and Johnson-Laird (2001), but rather on the basis of the following two considerations, which can be illustrated by the introductory example: (i) The clause "Given that poor flowers get enough sunlight" describes an assumption under which the effect of the new fertilizer is to be interpreted. The assumption linguistically marks a necessary factor, that is, an enabling condition. (ii) The second clause "If a particular new fertilizer is added to the ground, then poor flowers grow well" introduces the new fertilizer as sufficient for the effect; hence it is a cause that brings about the effect under the assumption mentioned before. Consequently, the linguistic framing of the causal connection makes it quite easy to assign the causal roles—without any need to derive models. Because in Goldvarg and Johnson-Laird's tasks the two factors are muddled, it cannot be decided which explanation is correct.

Where is the causality in people's reasoning about such descriptions? We assume that two causal questions guide people's interpretation: (iii) The first question is: Which factors are causally relevant? People consider the two factors "sunlight" and "new fertilizer" to be the only relevant factors as no others are mentioned in the task. (iv) The second question refers to the relation between the factors: Are they to be integrated conjunctively or disjunctively? In the latter case, "fertilizer" alone would be sufficient for the effect, and "sunlight" would thus not be necessary. This contradicts consideration (i) as well as the last statement given by the gardener in description (1), which both focus on the necessity of "sunlight." The two factors must therefore be related conjunctively: "enough sunlight" and "fertilizer" are *respectively necessary* for poor flowers to grow well, and as they bring about the effect in combination, they are *jointly sufficient*.

The five models proposed by Goldvarg and Johnson-Laird (2001) contradict the assumption of two necessary causal factors. Consider the models (m2) and (m3):

(m2)	sunlight	¬fertilizer	growth
(m3)	sunlight	¬fertilizer	¬growth

The two possibilities are identical with regard to the causal factors—sunlight is present and fertilizer is absent—but they differ in terms of the effect. One explanation for this ambiguity may be a probabilistic causal connection. This interpretation, however, is not consistent with Goldvarg and Johnson-Laird's (2001) own perspective. They claim (p. 574) that the typical human notion of causality is *not* probabilistic, yet acknowledging that people sometimes induce causal relations from probabilistic data.[2] This leaves us with one last plausible explanation: The causal connection described by their models includes a latent causal factor that allows good growth even in the absence of the fertilizer. Some of the plants, for instance, may grow well in symbiosis with a particular kind of fungus, even without fertilizer. However, according to our analysis, there is no reason to assume such a latent factor in this task.

Two predictions follow from our analysis: The first concerns the causal roles of the two precursors. We argued previously that in Goldvarg and Johnson-Laird's (2001) original tasks, the assumed set of five explicit models is confounded with linguistic cues, as both point toward the same solution. To demonstrate that people base their solution on the cues, but not on the models, we need a task that disentangles the two factors. Consider the following description:

1s. Given that a particular new fertilizer is added to the ground: If poor flowers get enough sunlight then poor flowers grow well. If poor flowers grow well then they have got enough sunlight.

If we apply Goldvarg and Johnson-Laird's (2001) interpretation schema to this *switched* version, we can paraphrase it as "*If* fertilizer then *if* sunlight then growth; and *if* growth then sunlight." If people are really able to derive the fully explicit five models from the original description as assumed by Goldvarg and Johnson-Laird, they will also be able to do so for the switched version. The models deducible by propositional logic are identical to those derived by Goldvarg and Johnson-Laird from description (1), except for the order of models and causal factors (a formal proof is available online from Annex A at http://www.cognitivesciencesociety.org/supplements/):

(m1)	fertilizer	sunlight	growth
(m4)	fertilizer	¬sunlight	¬growth
(m2)	¬fertilizer	sunlight	growth
(m3)	¬fertilizer	sunlight	¬growth
(m5)	¬fertilizer	¬sunlight	¬growth

If people base their answer on these models, the categorization of causal roles should remain the same: Enough *sunlight* enables the new fertilizer to cause the good growth. If people follow the linguistic cues instead, then the causal roles should switch because the framing assumption now points toward the *fertilizer* as an enabling condition, whereas the causal effect of sunlight is subordinated to this assumption. With such switched tasks, we are therefore able to disentangle the competing explanations.

Note that the last conditional in description (1s) is not prognostic but diagnostic. It mentions cause and effect in reversed order: the effect in the antecedent clause and the causal factor in the consequent clause. Do we thus have to fear that people get confused about the direction of causality? Such a confusion is not likely as temporal markers were used to indicate the temporal priority of the cause. Another objection might be that this reversal affects the order in which the effect "growth" enters into the mental models. But, if the three factors are integrated in the order of mention in the first part of each description, both causal factors—fertilizer and sunlight—enter into the model construction *before* the effect (as this is the case in the original tasks). The diagnostic conditional only constrains the number of possible models because it implies that good growth is not possible without enough sunlight. Finally, both prognostic and diagnostic inferences can be deduced equally well from a representation of causally possible situations (see Beller & Spada, 1998, for a set of corresponding inference rules). For these reasons, we assume that the switched problems are solved in the same way as the original ones.

The second prediction concerns the possible situations that are consistent with description (1) and (1s). If our causal argumentation (cf. principles iii and iv) is correct, then people should not follow the conditional interpretation of the descriptions and indicate the corresponding five situations, but should instead indicate only *four* situations as being consistent with both the original description (1) and the switched description (1s):

(m1)	sunlight	fertilizer	growth
(m3)	sunlight	¬fertilizer	¬growth
(m4)	¬sunlight	fertilizer	¬growth
(m5)	¬sunlight	¬fertilizer	¬growth

These four situations correspond with two respectively necessary and jointly sufficient causes. Due to the elimination of Model m2, the necessity and sufficiency status of the two causal factors is now identical. Consequently, the four situations alone cannot explain how people differentiate between causal roles. If people do indicate these four causal possibilities as consistent with the descriptions, then their distinction of causal roles will not be a logical one.

We tested our predictions concerning both the linguistic cuing effect and the model generation in an experiment with two scenarios. The first was the poor flowers scenario described previously, which was adapted from Goldvarg and Johnson-Laird's (2001) original study. With this scenario, we wanted to replicate the finding that people's answers do not depend on specific causal knowledge and to demonstrate that people rely on the linguistic cues rather than on the models assumed by Goldvarg and Johnson-Laird. As this is a quite *familiar* scenario, it might activate biological knowledge relevant to the necessity and sufficiency status of the two causal factors and could therefore be susceptible to content effects. For this reason, we also constructed a second scenario that does not activate additional knowledge about the status of the causal factors. The aim of this was to demonstrate the cuing effect with *unfamiliar* tasks and to show that this effect does not depend on the order of mention of the causal factors, as has been shown for the poor flowers scenario by Goldvarg and Johnson-Laird.

2. Experiment

2.1. Method

2.1.1. Participants

A total of 128 students from the University of Freiburg volunteered to participate in the experiment. The students were from various disciplines, excluding psychology, mathematics, and philosophy. Sixty-two were men and 66 women, and the mean age was 22.7 years (*SD* = 3.7; 18–45 years). Participants were untrained in logic and received 5 Euros for participating.

2.1.2. Materials

In addition to the poor flowers scenario (adapted from Goldvarg and Johnson-Laird, 2001), we used the unfamiliar scenario "light box." In this scenario, terrestrial researchers examine the function of an artifact (the light box) found on an alien planet. Like the poor flowers scenario, the light box scenario also mentioned two precursors (pressing a yellow vs. a blue button) to an effect (the flashing of a lamp on top of the light box).

Two pairs of descriptions were prepared for each scenario. In the poor flowers scenario, the first pair follows the *original* formulations with complementary causal roles as given in the article of Goldvarg and Johnson-Laird (2001, pp. 588–589; italics added here for presentation purposes only):

1. Given that poor flowers get *enough sunlight*: If a particular new fertilizer is added to the ground then poor flowers grow well. However, if poor flowers do not get enough sunlight then they do not grow well even if the new fertilizer is added to the ground.

2. Given that a particular *new fertilizer* is added to the ground: If poor flowers get enough sunlight then poor flowers grow well. However, if the new fertilizer is not added to the ground then poor flowers do not grow well even if they get enough sunlight.

The introduction of the framing assumption, as well as the models assumed by Goldvarg and Johnson-Laird (2001), focuses on the sunlight as the enabling condition in the first description, but on the new fertilizer in the second. The corresponding descriptions of the second pair *switch* the factor that is focused on by the framing assumption, whereas the corresponding models remain the same as in the original formulations:

1s. Given that a particular *new fertilizer* is added to the ground: If poor flowers get enough sunlight then poor flowers grow well. If poor flowers grow well then they have got enough sunlight.

2s. Given that poor flowers get *enough sunlight*: If a particular new fertilizer is added to the ground then poor flowers grow well. If poor flowers grow well then the new fertilizer has been added to the ground.

In the light box scenario, the first pair of descriptions also follows the *original* formulation schemas used by Goldvarg and Johnson-Laird (2001), with the second description (3′) reversing the order of mentioning the framing assumption (i.e., the second causal factor) to control for order effects (italics added):

3. Given that the *yellow button* is pressed: If the blue button is pressed then the lamp flashes. However, if the yellow button is not pressed then the lamp does not flash even if the blue button is pressed.

3′. If the blue button is pressed—given that the *yellow button* is pressed—then the lamp flashes. However, if the yellow button is not pressed then the lamp does not flash even if the blue button is pressed.

Again, the corresponding descriptions of the second pair *switch* the factor that is focused on by the framing assumption from the yellow to the blue button, whereas the corresponding models remain the same:

3s. Given that the *blue button* is pressed: If the yellow button is pressed then the lamp flashes. If the lamp flashes then the yellow button has been pressed.

3′s. If the yellow button is pressed—given that the *blue button* is pressed—then the lamp flashes. If the lamp flashes then the yellow button has been pressed.

Note that although both scenarios are equally concrete, they differ with respect to *familiarity.* We assume that people are quite familiar with the content of the poor flowers scenario—plants and their growing—if not with the biological details, then at least with some basic principles. These could include presumptions about the causal relation between sunlight, fertilizer, and good growth, or presumptions about other factors that produce or prevent good growth. It is well known from other reasoning tasks that such content-specific knowledge often affects the interpretation of the material (e.g., Beller & Spada, 2003; Evans et al., 1993). The light box scenario is less susceptible to such content effects, because people are not familiar with this alien artifact: They do not have specific knowledge about the relation between the pressing of the buttons and the flashing of the lamp, and thus have to concentrate solely on the given descriptions of the causal relation.

We constructed two types of tasks from the descriptions. (1) In the *categorization task,* the descriptions were preceded by a short introduction. In the poor flowers scenario, for example, this introduction read as follows: "A gardener is cultivating decorative flowers. While doing so, he discovers that there is a particular type of poor flowers that are not growing well. To find out the reason for this, the gardener lays out a separate field on which he cultivates only this type of poor flowers. In this field, he experiments with various cultivation conditions and observes the poor flowers over a protracted period of time. The gardener summarizes his observations with the following two statements:" Subsequent to the description of the observations (e.g., 1), participants received the same definitions of causal roles as in Goldvarg and Johnson-Laird's (2001) experiment (translated into German): "An *enabling condition* makes an event possible" and "A *cause* brings about an event." We used the terms *Grundbedingung* (enabling condition) and *ursächliche Bedingung* (cause) to refer to the causal roles. These terms correspond quite well with their English equivalents, and the given definitions compensated for possible nuances in meaning. Finally, participants were required to decide whether "*enough sunlight* is an enabling condition and *new fertilizer* is a cause" or vice versa.

(2) The *model evaluation task* required participants to decide which situations are possible and which are not according to the given description. Varying the presence or absence of the two causal factors and of the effect results in eight possible situations, each of which was printed on a separate line. In the poor flowers scenario, for example, two such situations read: "Enough sunlight, *no* new fertilizer, and good growth" and "Enough sunlight, *no* new fertilizer, and *no* good growth." The light box tasks were constructed analogously.

2.1.3. Design and procedure

A between-group design was used. Participants were randomly assigned to one of eight experimental conditions (n = 16) corresponding to the eight descriptions. Each participant received a booklet with general instructions and one description and was required first to solve the categorization task and then the model evaluation task for this description. The order of the response alternatives was balanced. A further scenario that participants were required to work on is analyzed elsewhere (Beller & Kuhnmünch, 2005). This additional scenario and the corresponding tasks were clearly distinct from the materials described previously, and the order of both scenarios was balanced in each experimental group to control for potential order effects.

2.2. Results

First, we analyzed how the participants assigned the two causal roles in the categorization tasks. In a preparatory step, we wanted to exclude that there was a general preference for assigning a particular causal role to one of the factors in the familiar tasks (poor flowers), and that the position of the framing assumption had an effect on the unfamiliar tasks (light box). We therefore compared the frequency of the Goldvarg and Johnson-Laird (2001) solution to the frequency of the complementary solution in both pairs of original tasks and both pairs of switched tasks by means of 2 × 2 contingency tables.

The original descriptions (1) and (2) of the poor flowers scenario should both support the Goldvarg and Johnson-Laird (2001) solution equally well despite mentioning different factors in the framing assumption. A significant difference in the frequency of the Goldvarg and Johnson-Laird solution would indicate a content effect, that is, a general preference across both descriptions for either the sun or the new fertilizer as "the cause." We found no such difference; $\chi^2(1, 32) = .139$, $p = .71$. Analogously, there was no indication for a general preference for either causal factor in the switched descriptions (1s) and (2s); $\chi^2(1, 32) = 2.133$, $p = .144$. The two original descriptions (3) and (3′) of the light box scenario should also support the Goldvarg and Johnson-Laird solution despite different orders of mention of the framing assumption. This time, a significant difference in the frequency of the Goldvarg and Johnson-Laird solution would indicate an order effect. As expected, the order of mention of the framing assumption did not affect people's role assignment in the original tasks, $\chi^2(1, 32) = 0$; $p = 1$; and it did not do so in the switched tasks (3s) or in the 3′s tasks either; $\chi^2(1, 32) = 0$, $p = 1$, in both cases. This means that there was no systematic preference for one of the factors in the familiar tasks and no position effect in the unfamiliar tasks so that we were able to aggregate the results over these conditions. The aggregated answers are reported in Table 1.

In the next step, we checked the data for the predicted cuing effect. If people determine causes and enabling conditions on the basis of Goldvarg and Johnson-Laird 's (2001) models, they should prefer the Goldvarg and Johnson-Laird solution equally in the original and the

Table 1
Frequency (%) of categorizing cause and enabling condition according to Goldvarg and Johnson-Laird aggregated over the two original and the two switched versions, respectively ($n = 32$ in each group)

	Scenario			
	Poor Flowers (Familiar)		Light Box (Unfamiliar)	
Categorization	Original (1 and 2)	Switched (1s and 2s)	Original (3 and 3′)	Switched (3s and 3′s)
Goldvarg and Johnson-Laird solution	65.6[a]	15.6	93.8[a]	12.5
Complementary solution	34.4	84.4[a]	6.2	87.5[a]

[a]Solution predicted by the linguistic cues.

switched tasks. If, instead, they solve the tasks on the basis of the linguistically marked framing assumption, the answers of the switched tasks should be complementary to the ones of the original tasks. The results clearly follow this second pattern (cf. Table 1): By swapping the causal factor of the framing assumption, the causal roles also switched. This effect appeared in the familiar poor flowers scenario, $\chi^2(1, 64) = 16.58$, $p < .001$, and was even more marked in the unfamiliar light box scenario, $\chi^2(1, 64) = 42.41$, $p < .001$.

Finally, we analyzed the model evaluation tasks that required participants to decide which situations are compatible with the descriptions given in the tasks. According to our prediction, participants should select—in the original as well as in the switched tasks—the four situations that describe the precursors as two respectively necessary and jointly sufficient factors, but not the five situations consistent with Goldvarg and Johnson-Laird 's (2001) models. As predicted, the majority of participants preferred the combination of four situations over that of five situations equally in all tasks (cf. Table 2).

A log-linear analysis (Kennedy, 1992) revealed no effect of the independent variables "scenario" (poor flowers vs. light box) and "description" (original vs. switched) on the dependent variable "selected situations" (with three categories: the five situations assumed by Goldvarg & Johnson-Laird, 2001, the four situations according to our prediction, and all other combinations). The simplest log-linear model with an adequate fit was the one without interaction or main effects of the independent variables (goodness of fit: $G^2 = 10.98$; $df = 6$, $p = .089$). Aggregated over all tasks, the predicted combination of four situations was chosen by 59.5% of the participants. The second most frequent combination was that consistent with Goldvarg and Johnson-Laird's five models (9.5%), but the predicted combination of four situations clearly dominated: $\chi^2(1, 87) = 45.6$, $p < .001$. All other solutions (31.0%) were distributed over 14 different combinations in the poor flowers scenario (one missing answer) and over 10 different combinations in the light box scenario (one missing answer).

If we compare how often each of the eight situations was chosen across all 126 answers, we get a similar picture: Each of the predicted four situations was chosen by nearly all participants (94.8% on average), whereas each of the other situations was chosen by less than a quarter of participants (the fifth situation, according to Goldvarg and Johnson-Laird (2001), by 24.6% and the remaining three situations by 6.1%, on average).

Table 2
Frequency (%) of selecting Goldvarg and Johnson-Laird's five situations versus our four situations as consistent with the causal descriptions aggregated over the two original and the two switched versions, respectively

	Scenario				
	Poor Flowers (Familiar)		Light Box (Unfamiliar)		
Combination	Original (1 and 2)	Switched (1s and 2s)	Original (3 and 3′)	Switched (3s and 3′s)	*M*
Five situations	15.6	6.5	16.1	0.0	9.5
Four situations	59.4	54.8	61.3	62.5	59.5
Others	25.0	38.7	22.6	37.5	31.0
n	32	31[a]	31[a]	32	

[a]One missing answer.

3. Discussion

The results strongly corroborate our two hypotheses. They demonstrate that the distinction of causal roles is not based on the set of models assumed by Goldvarg and Johnson-Laird (2001) and that this set of models does not even reflect people's typical interpretation of the tasks. Instead, most people interpret the two factors as logically equivalent: They are respectively necessary and jointly sufficient for the effect. As people nevertheless differentiated causes and enabling conditions in a systematic way, the causal roles must have been distinguished on the basis of principles other than logical ones.

We proposed two syntactical principles (cf. i, ii) and two causal principles (cf. iii, iv) that explain precisely the assignment of causal roles *and* the situations participants had typically chosen in all tasks of our experiment. Are there alternative explanations for our findings? For our main result—the distinction of causal roles—two accounts are conceivable: a temporal and a covariational one.

People might have interpreted the causal factor linguistically marked as "given" not only as a superordinate framing assumption under which the second factor is evaluated, but also as temporarily prior to the other factor. In addition, the definitions of causal roles make clear that a "cause brings about an event," and therefore participants might have concluded that causes must occur *after* enabling conditions (an argument that applies to our task as well as to Goldvarg & Johnson-Laird's, 2001, task). We cannot exclude that such a temporal interpretation influenced our participants' answers, thereby strengthening the cuing effect. However, this does not weaken our objection to the logical difference between causal roles claimed by Goldvarg and Johnson-Laird, as the temporal criterion is an extralogical factor, too. Temporal priority alone, however, is not sufficiently general to cover the distinction of causal roles. Suppose, for example, that the autopilots of an airplane are not functioning correctly. The defect might remain without any consequences until the airplane reaches a field of strong turbulences. Although being temporally prior to the turbulences, the malfunction of the autopilots would presumably be classified as the cause (rather than as the enabling condition) of a near-crash.

Cheng and Novick (1991) proposed another criterion for the distinction of causal roles. They classify, on the basis of their probabilistic contrast model, causal factors that covary with the effect as causes, and causally relevant factors that do not covary with the effect as enabling conditions. Covariation is computed over a focal set of events (implied by the context) in terms of differences in the probabilities of the effect conditional on the presence versus absence of potential causal factors, with necessity and sufficiency as extreme cases. To apply this approach to our tasks, we need to clarify which sets of events form the basis for computing contrasts. Are these the four situations that the majority of our participants classified as being consistent with the description? In this case, the causal roles could not be differentiated because both causal factors covary with the effect within this set of events in exactly the same way. On the other hand, if we try to derive the contrasts directly from the descriptions, it is not in all cases obvious which causal factor covaries with the effect and which does not. Take, for instance, Goldvarg and Johnson-Laird's (2001) original description (1): "Given that poor flowers get enough sunlight: If a particular new fertilizer is added to the ground, then poor flowers grow well. However, if poor flowers do not get enough sunlight, then they do not grow well even if the new fertilizer is added to the ground." Does this description highlight "sunlight" as covarying with the effect? Good growth is possible given enough sunlight, and impossible without it. In this case, "sunlight" should be interpreted as the cause. Or does the description highlight the "new fertilizer" as covarying with good growth? Accordingly, this factor should be classified as the cause, as has been done by Goldvarg and Johnson-Laird 's and our participants. It is thus not obvious how to apply focal sets to this example. We acknowledge, however, that covariational information could be a valid criterion for distinguishing causal roles in other contexts (cf. the boiling example that follows), and we also agree with Cheng and Novick (1991, p. 83) that this distinction cannot be explained purely in terms of necessity and sufficiency.

In the categorization tasks, participants were explicitly asked to distinguish causal roles. Yet even in everyday situations, this distinction takes place for logically indistinguishable factors. Take, for instance, the causal connection of heat, atmospheric pressure, and the boiling of pure water at 100 °C: The heat and a pressure of one bar are respectively necessary and jointly sufficient for the effect (boiling at 100 °C). Although many people know from their physics lessons that adequate pressure is as necessary for the effect as the heat, the latter is more likely to be classified as the cause and pressure as an enabling condition. The four possible situations consistent with this causal connection are analogous to the ones we had predicted in the poor flowers scenario and light box scenario. As the necessity and sufficiency status of both factors is identical, a logical difference cannot account for the distinction of causal roles either. This example clarifies that even if people had been able to derive the five situations predicted by Goldvarg and Johnson-Laird (2001) in the experimental scenarios, Goldvarg and Johnson-Laird's explanation, building as it does on a logical difference, is too specific to be the basis of a general account for the distinction of causal roles.

The assignment of roles in the boiling example can be explained by extralogical factors, for instance, by the pattern of data resulting from everyday experience: Typically, the atmospheric pressure is quite *constant,* whereas the heat is a factor that *covaries* with the boiling of water. If we interpret this pattern of data in terms of focal sets, the pressure—given knowledge about its causal relevance—should be classified as an enabling condition and the heat as the cause. Another extralogical criterion for the distinction of causal roles in this example could be the generative potential of heat: It provides the necessary energy for the boiling, whereas the pressure can both facilitate and suppress the boiling. Temporal criteria, covariational information, and prior beliefs about the generative potential of causes are just a few examples of extralogical factors, which play a crucial role in most psychological and philosophical theories about causal roles (e.g., Cheng & Novick, 1991; Einhorn & Hogart, 1978; Hart & Honoré, 1985; Hilton & Erb, 1996; Mackie, 1980; Mill, 1874; White, 1995). Goldvarg and Johnson-Laird (2001) concluded from their experiments that such extralogical factors do not lie at the heart of the distinction of causal roles, but this conclusion cannot stand up to our results. We do not want to rule out the possibility that in some cases logical differences of causal factors might be a valid criterion, but a general account of the distinction of causal roles certainly must not ignore extralogical factors.

We agree with Goldvarg and Johnson-Laird (2001) that people, when interpreting a causal task, build an integrated mental representation of the causal situation that enables them to draw causal inferences flexibly and quite accurately, as could be shown, for instance, with causal selection tasks (e.g., Beller & Spada, 2003) or with causal inference tasks (e.g., Beller &

Kuhnmünch, 2005; Goldvarg and Johnson-Laird, 2001; Experiment 3). The proposed syntactical and causal principles do not contradict the mental models approach as such, but they do suggest a different model construction process that integrates the cuing effect as an extralogical factor. Consider the poor flowers scenario (1) once again:

The introduction of the framing assumption, "Given that poor flowers get enough sunlight: … " in the first statement establishes a model that includes sunlight as a necessary factor (marked as assumption "A") under which subsequent information is subordinated (principle i):

(m1)	[A: *sunlight*	…	]

The conditional, "If a particular new fertilizer is added to the ground, then poor flowers grow well," which is nested under the assumption, introduces the fertilizer as a sufficient factor (principle ii):

(m1)	[A: *sunlight*	fertilizer	growth
		…	]

As sunlight has been introduced as a necessary factor, the two factors cannot be integrated disjunctively (principle iv). The fertilizer is thus a necessary factor as well: Without fertilizer the poor flowers do not grow well (Model m3):

(m1)	[A: *sunlight*	fertilizer	growth
(m3)		¬fertilizer	¬growth]

Finally, because sunlight and fertilizer are the only causal factors mentioned in this task, people assume that there are no other relevant factors that could produce the effect of good growth. Because both are necessary factors, poor flowers will not grow if one of them is absent (principle iii). The set of models can thus be completed as follows (Models m4 and m5):

(m1)	[A: *sunlight*	fertilizer	growth
(m3)		¬fertilizer	¬growth]
(m4)	[¬sunlight	fertilizer	¬growth
(m5)		¬fertilizer	¬growth]

The second statement of description (1) "However, if poor flowers do not get enough sunlight, then they do not grow well even if the new fertilizer is added to the ground" emphasizes once more the necessity of sunlight (cf. Models m4 and m5).

In the switched version (1s), the fertilizer is introduced as an assumption, whereas sunlight is the subordinated factor. Therefore, the causal roles are switched. Note that the second statement of description (1s), "If poor flowers grow well, then they have got enough sunlight," makes clear that there are no cases of good growth without enough sunlight. Here, too, sunlight is a necessary causal factor. The fact that our participants still chose fertilizer as an enabling condition is another argument for the relevance of the linguistic cuing in the first statement. This explanation also fits the unfamiliar light box scenario, including the descriptions 3′ and 3′s: The order of mention of the assumption is irrelevant, as it always points toward the same causal factor.

According to this model construction process, the distinction between causes and enabling conditions does not result from the set of possible situations—in which both causal factors have the same logical status—but rather from the way in which both factors are integrated, namely, as a superordinate or a subordinate causal factor. Other extralogical factors relevant for the distinction of causal roles could be integrated in the mental model theory in a similar way. Because both domain-independent (syntactic) information and domain-specific (causal) information are necessary for an adequate interpretation of the results, our study is a further example of the *dual-source approach* (Beller & Spada, 2003), which considers both sources of information as essential for an adequate understanding of reasoning processes. Neglecting their interplay can yield inadequate interpretations of empirical data and prevent the construction of informative experiments about human reasoning.

Notes

1. In this experiment, Goldvarg and Johnson-Laird (2001) used the assertion "allow" instead of "enable" to avoid undesired connotations (cf. p. 571).
2. Note that although people are able to induce causality from probabilistic data, this is not necessarily the kind of data they prefer (cf. Ahn, Kalish, Medin, & Gelman, 1995).

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