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Title
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Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 20(0)

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Publication Date
1998

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Conditional Reasoning With a Point of View: The Logic of Perspective Change

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Abstract

Is human domain specific reasoning illogical? The effect of perspective change on reasoning about social contracts is one of the puzzling phenomena known from research on Wason's selection task that seems to corroborate an affirmative answer to this question. Therefore, some authors postulated non-logical cognitive processes specialized for reasoning about social contracts. In contrast to this view, we argue that such effects reflect the influence of domain specific knowledge on logical reasoning. This knowledge must not be ignored when checking the deductive validity of subjects' inferences. Taking it into account sheds a new light on individuals' deductive competence. Further, it becomes possible to predict such effects not only for the domain of social contracts. We present a model of causal reasoning that allows us to derive new effects of perspective change. We argue that these effects do not show that people make illogical inferences but, on the contrary, that subjects validly reason deductively from their causal knowledge. Finally, we present empirical results that strongly support our arguments.

Introduction

It is one of the theoretically most puzzling findings of recent research on human deduction that logically valid inferences can not only be facilitated by using thematic instead of abstract reasoning tasks, but they can also be "suppressed" A recent example builds on research on Wason's famous selection task (Wason, 1966), namely, the effect of perspective change on conditional reasoning (Gigerenzer & Hug, 1992). Reasoning about the violation of social contracts expressed as conditionals was said not to be based on logical considerations but on pragmatic ones that depend on the adopted perspective, e.g., which of the parties engaged in a social contract is possibly cheating (Gigerenzer & Hug, 1992) or violating its duties (Holyoak & Cheng, 1995; Politzer & Nguyen-Xuan, 1992). This view was tested by comparing two thematic versions of the selection task: *standard* vs. *reversed*.

An example of a task in *standard version* goes as follows (adapted from Gigerenzer & Hug, 1992): A rule created by a local authority says

> 'If a home owner gets a subsidy from his local authority, then that person has installed a modern heating system.'

There is an officer of the local authority who has heard rumors about home owners having violated the rule. He has to check information about four home owners represented on cards. On one side of each card there is information about whether the home owner installed a modern heating system, on the other side whether that person got a subsidy but only one side of each card is visible. The four cards read: 'got a subsidy', 'did not get a subsidy', 'installed a modern heating system', and 'did not install a modern heating system'. Which card or cards does the officer definitely need to turn over to determine whether the rule has in fact been violated?

In the *reversed version*, subjects were cued into the opposite perspective, namely, that home owners who are willing to install a modern heating system have heard rumors that the local authority has violated the rule.

What are the solutions to these tasks? Abbreviating 'A home owner gets a subsidy' as 'P' and 'A home owner installs a modern heating system' as 'Q' we can represent the rule as the conditional $P \rightarrow Q$ and the four cards as P, $\neg P$, Q, and $\neg Q$ respectively[1]. It was argued that from a logical point of view a conditional is violated only if the antecedent (P) is true and the consequent (Q) false; in all other cases it is true. Since the rule is the same in both versions of the task one should choose *the same* pattern of cards ($P/\neg Q$): the P-card to check whether Q is true, and the $\neg Q$-card to check whether P is false. By contrast, adopting the different point of view of each version should result in *opposite* selection patterns: From the perspective of the local authority, a home owner has cheated when he got a subsidy (P) but did not install a modern heating system ($\neg Q$). This can be checked for by turning over the cards $P/\neg Q$. From the perspective of a home owner, the local authority has cheated, when a home owner did install a modern heating system (Q) but did not get a subsidy ($\neg P$), which can be checked for by turning over the cards $\neg P/Q$.

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[1] The logical operators used and their approximate linguistic form:

$\neg P$	'not P'	(negation)
$P \wedge Q$	'P and Q'	(conjunction)
$P \vee Q$	'P or Q'	(disjunction)
$P \rightarrow Q$	'If P then Q'	(conditional)
$P \leftrightarrow Q$	'If and only if P then Q'	(biconditional)
$\forall X$	'For all X'	(universal quantifier)
$P \Rightarrow Q$	indicates a deductive derivation	

Table 1: Frequencies of the two critical selection patterns P/¬Q and ¬P/Q from 6 studies (see text)

	Standard (N = 412)		Reversed (N = 380)	
P/¬Q	48,4 %	(199,5)	4,1 %	(15,5)
¬P/Q	2,8 %	(11,5)	45,4 %	(172,5)

The empirical results are clear: Reversing the perspective changes the predominant P/¬Q response into a ¬P/Q response. Table 1 summarizes the data from six studies (Gigerenzer & Hug, 1992; Holyoak & Cheng, 1995; Liberman & Klar, 1996; Manktelow & Over, 1991; Nagy, 1994; Politzer & Nguyen-Xuan, 1992; for details see Beller, 1997). The results of Cosmides (1989) were similar: She reversed the conditional rule leaving perspective constant and observed the same changes in ¬P/Q response patterns.

Two implications of these results were discussed in the debate on content effects. First, the observation of "illogical" ¬P/Q responses would rule out the interpretation that thematic content facilitates logical reasoning compared to content-free reasoning (Cosmides, 1989; Gigerenzer & Hug, 1992). Second, Cosmides (1989) argued that social contracts were a special content domain because "... no thematic rule that is not a social contract ... has ever produced a content effect that is both robust and replicable ..." (p. 200). And indeed nearly all content effects in Wason's selection task were found for social rules.

In the following we analyze both arguments: Is Cosmides right in claiming that 'no content effects in selection tasks without social rules'? Do effects of perspective change really contradict logical reasoning? We argue that content effects in general reflect the influence of domain specific knowledge on logical reasoning. This knowledge must not be ignored when checking the deductive validity of subjects' inferences. Taking it into account sheds a new light on individuals' deductive competence with interesting implications for the psychology of deduction and the philosophical debate on rationality. Further, our position implies that it should be possible to predict such effects from *any* kind of knowledge.

In the following, we first sketch out our general idea using an example of a simple conditional inference of another domain. Then we present a model of causal reasoning that allows us to derive new effects of perspective change. We show that the seemingly illogical answers are properly valid inferences from the causal knowledge. Finally, we present experimental results that strongly support our arguments.

Explaining Content Effects: The General Idea

Suppose two persons, Peter and Lisa, are talking to each other. Peter says: "If Tom is in Paris, then Tom is in the Louvre". Lisa knows "Tom is not in Paris" and Peter concludes "Then Tom is not in the Louvre". What about Peter's conclusion? Is it deductively valid? When you first look at it from the point of view of formal logic you would say 'no': The corresponding inference pattern

(1) in(Tom, Paris) → in(Tom, Louvre)
(2) ¬in(Tom, Paris)

(1 & 2 ⇒ 3) ¬in(Tom, Louvre)

is a prominent logical fallacy widely known as *denial of the antecedent*. The logically correct answer would have been that nothing follows from 1 & 2. But Peter's "illogical" conclusion can be explained if we assume that he uses *content specific knowledge* that the museum called 'Louvre' exists only in Paris, therefore being not in Paris implies being not in the Louvre:

(4) ∀ X: ¬in(X, Paris) → ¬in(X, Louvre)

Adding this premise to Peter's argument makes his conclusion perfectly valid.

What can we learn about content effects from this simple example? First, we have to distinguish between the "superficial logical form" of an inference task and additional premises that people associate with the content the task refers to. Content effects of the suppressive but also of the facilitative type can be attributed to the influence of such additional premises, and it is these premises that back up the deductive validity of the inferences in question. Second, this principle itself is not content specific. It can be applied to explain the influence of spatial knowledge as in the example above, as well as to predict effects of, e.g., causal knowledge on the solution of selection tasks. Crucial for this prediction is a detailed specification of the assumed causal knowledge.

Modeling Causal Perspective Change

The Representation of Causal Knowledge

Causal knowledge deals with *dependencies between events*, more precisely how effects depend on causal conditions. This knowledge can be used in *reasoning* to predict events or to diagnose causes.

The representation of causal dependencies: We understand a cause as an event that changes the outcome of later events (a position going back to the Scottish philosopher David Hume, 1711-1776; see Lewis, 1973). A cause sufficiently determines the occurrence of an effect. Had it been absent, then — all other conditions equal — the effect would have been absent as well. At least one cause is necessary to elicit an effect. *Each effect has its causes, and without causes there is no effect*, therefore, we represent the dependency between an effect (E) and its causes (Cs) as an equivalence relation: causation(Cs ↔ E). Each single effect E is represented separately together with *all causes* known to elicit E. *Causes may be complex* which means that several causal factors together are necessary to elicit the effect. We represent complex causes as a conjunction of single causal factors. In addition complex causes may contain *inhibitory factors* which are modeled by negation (they have to be *absent* so that the effect can occur). *Alternative (complex) causes* for one and the same effect are represented as disjunctive factors. Thus, we represent the different (complex) causes for one effect as a disjunction of conjunctions of single causal factors (see Graßhoff & May, 1995).

A simple example: A person may have the following idea of how the airbag of a car correctly works: It is inflated only if the car has an accident:

(5) $\forall$ car: accident(car) $\leftrightarrow$ inflated(airbag(car))

But the airbag may also react erroneously. There are two possibilities: One observes a cause but no effect or an effect without a known cause. A fault of the first type may be put down to an *inhibitory causal factor* not yet considered, e.g., an insensitive airbag sensor that would prevent the airbag from being inflated when the car has an accident. The corresponding causal knowledge would be:

(6) $\forall$ car: accident(car) $\wedge$ $\neg$insensitive(sensor(car))
$\leftrightarrow$ inflated(airbag(car))

A fault of the second type may be explained by an *alternative cause*, e.g., an oversensitive airbag sensor that inflates the airbag without the car having an accident:

(7) $\forall$ car: accident(car) $\vee$ oversensitive(sensor(car))
$\leftrightarrow$ inflated(airbag(car))

Deduction rules for causal reasoning (Table 2): The knowledge about causal dependencies can be used both to *predict* the occurrence of effects from the observation of causal factors and to explain observed effects by *diagnosing* possible causes. If we represent causal dependencies as described above, four inference rules are sufficient: We can predict an effect E, if at least one of the complex causes Cs occurred (rule `r1`). If none of the causes Cs did occur we predict that there is no effect E (rule `r2`). Diagnosing causes is more complex. We diagnose a single causal factor C of a complex cause, if the associated effect E occurred and all alternative causes A can be ruled out (rule `r3`). If all additional necessary factors N of a single causal factor C occurred but the effect E did not, then we diagnose this factor C as absent (rule `r4`).

Table 2: Inference rules for predicting and diagnosing events

Predicting an effect E:

r1 causation(Cs $\leftrightarrow$ E) $\wedge$ Cs
$\Rightarrow$ E

Predicting the absence of an effect E:

r2 causation(Cs $\leftrightarrow$ E) $\wedge$ $\neg$Cs
$\Rightarrow$ $\neg$E

Diagnosing a causal factor C:

r3 causation(((C $\wedge$ N) $\vee$ A) $\leftrightarrow$ E) $\wedge$ E $\wedge$ $\neg$A
$\Rightarrow$ C

Diagnosing the absence of a causal factor C:

r4 causation(((C $\wedge$ N) $\vee$ A) $\leftrightarrow$ E) $\wedge$ $\neg$E $\wedge$ N
$\Rightarrow$ $\neg$C

Note. Cs = causes, E = effect, C = a single causal factor, N = additional necessary factors, A = alternative causes.

Suppose a person wants to diagnose a faulty airbag sensor. She knows that the airbag of a car has been inflated:

(8) inflated(airbag(car_1))

If the person believes

(6) $\forall$ car: accident(car) $\wedge$ $\neg$insensitive(sensor(car))
$\leftrightarrow$ inflated(airbag(car))

then she will infer with rule `r3` that the airbag sensor behaved correctly and was not insensitive:

(6 & 8 $\Rightarrow_{r3}$ 9) $\neg$insensitive(sensor(car_1))

However a person who believes

(7) $\forall$ car: accident(car) $\vee$ oversensitive(sensor(car))
$\leftrightarrow$ inflated(airbag(car))

cannot say anything about the airbag sensor: It could have been oversensitive or not.

The Prediction of New Empirical Phenomena

Having specified the assumed content specific (causal) knowledge we are now able to predict new effects of perspective change.

Perspective change in selection tasks: The original effect was demonstrated by comparing two versions of selection tasks that were said to have the *same logical form* (namely a conditional rule P $\rightarrow$ Q), and the *same instruction*, to diagnose cases of rule violation (P $\wedge$ $\neg$Q). But the two versions were designed in such a way that subjects understood the instruction *differently* with reference to the adopted perspective on the content domain, e.g., cheating of the one party corresponded to P $\wedge$ $\neg$Q, cheating of the other party to $\neg$P $\wedge$ Q. Most subjects ignored the conditional and followed the perspective. On the basis of our model of causal reasoning, we are able to predict analogous effects.

Consider two task versions with the same conditional rule

C1 'If a car has an accident (P),
then the airbag of the car is inflated (Q)'

but with different perspectives: A *standard version* suggesting that the airbag sensor may possibly not react because of an insensitive sensor:

(6) $\forall$ car: accident(car) $\wedge$ $\neg$insensitive(sensor(car))
$\leftrightarrow$ inflated(airbag(car))

and a *reversed version* suggesting that the airbag sensor may erroneously react because of an oversensitive sensor:

(7) $\forall$ car: accident(car) $\vee$ oversensitive(sensor(car))
$\leftrightarrow$ inflated(airbag(car))

In both versions the task is to detect cases of rule violation. It can be interpreted causally as to detect the respective fault. On the basis of (6) an insensitive sensor can be detected if *a car has an accident* but *the airbag is not inflated* (classified with reference to C1 as P $\wedge$ $\neg$Q). In contrast, on the basis of (7) an oversensitive sensor can be detected if *a car has no accident* but *the airbag is inflated* ($\neg$P $\wedge$ Q with reference to C1). Thus, changing the point of view, that is to say changing the relevant causal background knowledge, results in differ-

Table 3: The prediction of causal perspective change: Changing the point of view (P1 vs. P2) results in different violation checking behavior. Classified with reference to the conditional statements C1 'If a car has an accident (P), then the airbag of the car is inflated (Q)' vs. C2 'If a car has no accident (P), then the airbag of the car is not inflated (Q)' we expect the typical effect of perspective change ($P \wedge \neg Q$ vs. $\neg P \wedge Q$).

Point of view		Violation = fault diagnosis	Classified with reference to C1 as	Classified with reference to C2 as
P1: Additional inhibitory causal factor (6)				
∀ car:	accident(car) ∧ ¬insensitive(sensor(car)) ↔ inflated(airbag(car))	accident(car) ∧ ¬inflated(airbag(car)) $\Rightarrow_{r4}$ insensitive(sensor(car))	$P \wedge \neg Q$ standard	$\neg P \wedge Q$ reversed
P2: Additional alternative causal factor (7)				
∀ car:	accident(car) ∨ oversensitive(sensor(car)) ↔ inflated(airbag(car))	¬accident(car) ∧ inflated(airbag(car)) $\Rightarrow_{r3}$ oversensitive(sensor(car))	$\neg P \wedge Q$ reversed	$P \wedge \neg Q$ standard

Note. The conditional C1 can be violated only given perspective P1, the conditional C2 only given perspective P2.

ent violation checking behavior regardless of the conditional rule. We therefore expect in causal selection tasks the typical answer patterns: P/¬Q in the standard version and ¬P/Q in the reversed version (see Table 3). Note that with respect to the conditional C1 diagnosing an oversensitive sensor in the reversed version seems deductively not valid, but with respect to the causal knowledge (7) it is.

Perspective change in a rule evaluation task: In explaining the effect of perspective change in the selection task we assume that most subjects ignore the conditional rule because the instruction enables them to do so. But if we ask for an evaluation of the rule itself we should expect a logically correct handling.

Suppose a person believes

(6) ∀ car: accident(car) ∧ ¬insensitive(sensor(car)) ↔ inflated(airbag(car)).

Asked which of the two conditionals could be violated

C1 'If a car has an accident, then the airbag of the car is inflated' or

C2 'If a car has no accident, then the airbag of the car is not inflated'

the person should answer 'only C1'. If she assumes that a car really has an accident (P), then it is not sure on the basis of (6) that the airbag is really inflated. It depends on the sensor. If it is insensitive, then the airbag is not inflated (¬Q), and the conditional C1 is violated[2]. However a person who believes

(7) ∀ car: accident(car) ∨ oversensitive(sensor(car)) ↔ inflated(airbag(car))

should give the opposite answer. Now only the conditional C2 can be violated, if the car really has no accident (P) but the airbag is inflated (¬Q) because the sensor is oversensitive.

[2] Proof schema: $P \wedge (\neg Q) \Rightarrow \neg(P \rightarrow Q)$.

Causal Reasoning With a Point of View

On the basis of our considerations on causal reasoning we predict two different phenomena. First, changing the point of view in causal selection tasks should change the predominant selection pattern in the same way as in selection tasks with social rules. Second, if we ask subjects explicitly to evaluate conditional statements using their causal knowledge they should handle them formally correct. In the following we present an experiment designed to test both predictions.

Materials

We used two scenarios, *airbag* and *fire extinguisher*. Both have an identical structure, therefore the materials are described only for the first one. For each scenario we developed two different types of tasks: selection tasks and rule evaluation tasks. All tasks were presented in German.

Selection tasks: Each task consisted of a conditional rule, a context story, and an instruction. We used two conditional rules (C1/C2) both in cause-effect order. C1 was formulated affirmatively, C2 was negated:

C1 'If a car has an accident, then the airbag of the car is inflated' and

C2 'If a car has no accident, then the airbag of the car is not inflated'

Two context stories were used (P1/P2). Both instructed the subjects to take the role of a mechanic who has to diagnose a faulty airbag. Version P1 cued the subjects to believe the fault (an insensitive sensor) to be an *inhibitory causal factor*. In version P2 the fault (an oversensitive sensor) could be interpreted as an *alternative cause*. The subjects' task was to check information about four cars (written on cards) to find out whether the rule has been violated. On one side of each card there was information about whether the car had an accident, on the other side whether the airbag of the car was inflated. The four cards read 'had an accident', 'had no accident', 'the airbag was inflated', and 'the airbag was not inflated'. Combining the two conditionals (C1/C2) with the two context stories (P1/P2) we got four task versions: two standard versions and two reversed versions (see Table 3 for the concrete predictions).

Rule evaluation tasks: The same two context stories as in the selection tasks were used. This time the subjects' task was to decide on the basis of the causal knowledge triggered by the context story (P1/P2) which of the two conditionals in question (the affirmative C1 or the negated C2) can be violated (none, one of them, or both). Taking into account the causal knowledge only one of the two conditionals can be violated in each of the task versions (see Table 3 for the concrete prediction).

Subjects

168 students from the University of Freiburg participated in the experiment. Students were paid volunteers from all disciplines (excluding psychology, mathematics, and philosophy). They were untrained in logics, and none of them had any prior experience with the selection task. Subjects were investigated in small groups.

Design

We used a mixed design: The two causal scenarios (*airbag* and *fire extinguisher*) were given within subjects, and the different task versions per scenario (*selection tasks* and *rule evaluation tasks*) varied between subjects (21 subjects per task version). Each subject received one task of each causal scenario in a booklet together with others tasks not analyzed here. One of the tasks triggered an additional inhibitory causal factor the other an additional alternative causal factor. The two tasks were balanced with respect to type (*standard* vs. *reversed* selection task, and *rule evaluation* task). They were presented in random order to each subject. In addition, the order of the four cards in each selection task was also randomly.

Results

The results of the selection tasks are presented in Table 4 for both scenarios (*airbag* and *fire extinguisher*) separately. As predicted, changing the point of view from standard to reversed changes the predominant selection pattern from

Table 4: Frequencies of the two critical selection patterns P/¬Q and ¬P/Q in the selection tasks depending on task version (*standard* vs. *reversed*) and scenario (*airbag* vs. *fire extinguisher*)

	Standard (n each 42)		Reversed (n each 42)	
		Airbag		
P/¬Q	81,0 %	(34)	9,5 %	(4)
¬P/Q	2,4 %	(1)	69,1 %	(29)
		Fire extinguisher		
P/¬Q	69,1 %	(29)	2,4 %	(1)
¬P/Q	7,1 %	(3)	66,7 %	(28)

P/¬Q to ¬P/Q. In each of the four task versions of both scenarios twelve or more of 21 subjects selected the predicted card pattern. The exact random probability p that one observes a frequency x of five or more predicted answers is already $p < 0.01$ ($p(x \geq 5; 21; r = 1/16)$, computed on the basis of the binomial distribution with r being the probability to produce the right answer by guessing). So each single result is highly significant. In addition, we computed ϕ-correlation coefficients between the task version (*standard* vs. *reversed*) and the frequencies of the critical selection patterns (P/¬Q vs. ¬P/Q) for each scenario separately. Correlation coefficients of $\phi = -0{,}86$ ($\chi^2 = 49.80$, $df = 1$, $p < 0.01$) for the airbag scenario, and $\phi = -0{,}87$ ($\chi^2 = 46.26$, $df = 1$, $p < 0.01$) for the fire extinguisher scenario respectively, indicate large effects.

Table 5: Frequencies of the four possible answer patterns in the rule evaluation tasks of both scenarios (*airbag* and *fire extinguisher*)

	Airbag (n = 42)		Fire extinguisher (n = 42)	
Correct	69,1 %	(29)	69,1 %	(29)
Opposite	14,3 %	(6)	11,9 %	(5)
Both	7,1 %	(3)	9,5 %	(4)
None	9,5 %	(4)	9,5 %	(4)

Table 5 gives the results of the rule evaluation tasks aggregated over the two task versions for each scenario (*airbag* and *fire extinguisher*) separately. In each of the four single task versions twelve or more subjects chose the correct conditional rule as being logically violated given the respective perspective (exact probability $p(x \geq 11; 21; r = 1/4) < 0.01$). Again each single result is highly significant.

Conclusions

The empirical results and the theoretical analysis strongly back up our position. First, we were able to predict and to empirically demonstrate effects of perspective change in causal selection tasks and thereby disprove Cosmides' (1989) claim that there are no content effects in selection tasks without social rules. Second, we argued that in the causal selection tasks with reversed perspective an inconsistency exists between the conditional rule and both the context story and the background knowledge of the subjects. In these tasks checking whether the conditional rule is violated does not mean the same as diagnosing the technical fault as suggested by the perspective. Most subjects decided to follow the perspective, thereby solving the tasks "illogically" with respect to the conditional rule. With reference to the causal knowledge the subjects' answers are perfectly valid. Finally, the rule evaluation tasks show that people do really handle thematic conditionals logically correctly if we explicitly ask them to do so. Thus, in our opinion the effect of causal perspective change does not contradict logical reasoning. A comparable fine grained analysis of the original effect with social rules yields the same result (Beller, 1997). The subjects' reasoning is logically in line with the knowledge given by the perspective which in the reversed version is inconsistent with the conditional rule. But, who is to blame, the experimenter developing such inconsistent tasks or the subjects who have to solve them?

What implications for the theoretical debate on human deductive reasoning can be drawn from these results? The significance of these effects is that they make us aware of the importance of the interpretive process (Fillenbaum, 1993). We have to think carefully about how subjects interpret our reasoning tasks on the basis of their background knowledge. Further, we have to consider such knowledge in our general theories of deductive reasoning (e.g., Johnson-Laird, 1983, Rips, 1994) otherwise we cannot explain the difference between reasoning with abstract materials and reasoning with thematic materials. Again Wason's selection task gives an impressive example for such a difference: the classical abstract version (in contrast to thematic versions) is normally solved correctly by less than 10 % of the subjects (Wason & Johnson-Laird, 1972). Understanding these differences means that we have to take the notion of "content" seriously. In line with other authors (e.g. Cheng & Holyoak, 1985; Gigerenzer, 1995) we see the need for integrating "content" in our theories of deductive reasoning, but we think that one cannot play "content" off against "logic".

Acknowledgments

This research was supported by a grant from the German Science Foundation (DFG) to the first author within the graduate program "Intelligence in Humans and Machines" at the University of Freiburg. We thank Josef Nerb, Hansjörg Neth, Klaus Opwis, and Rolf Plötzner for helpful comments on earlier versions of this paper.

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