REDUCTION, INTUITION, AND COGNITIVE EFFORT IN SCIENTIFIC LANGUAGE

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ABSTRACT: In his search for a better scientific language, Carnap offered a number of definitions, ideas, and arguments. This paper is devoted to one of his definitions in this regard. In particular, it addresses a definition providing rules to add new properties to the descriptions of objects or beings by taking into account other properties of those very objects or beings that are already known. The main point that this paper tries to make is that, if a current cognitive theory such as the theory of mental models is assumed, it can be said that those rules are easy to use by scientists and philosophers of science. This is because, following the essential theses of this last theory, the rules do not demand excessive cognitive effort to be applied. On the contrary, they are simple rules that make researchers' work harder in no way.

KEYWORDS: Rudolf Carnap, dual-process theory, predicates, scientific language, theory of mental models

Introduction

It is well known that Rudolf Carnap tried to build a language for science.[1] Thus, he gave different definitions and proposals. This paper will be focused on one of such definitions.[2] That definition includes four formulae and three rules to link new predicates to elements from other relations between predicates already provided. Thereby, the idea is to express, by means of logical formulae, new relations between predicates in order to make it explicit that, if an object or being has one predicate, that object or being must also have another one. In this way, the rules allow introducing gradually new properties from just a few primitive properties in the language. The formulae are the following:

(1) IF Q_1 THEN (IF Q_2 THEN Q_3)

[1] E.g., Rudolf Carnap, "Testability and meaning," *Philosophy of Science* 3, 4 (1936): 419-471.
[2] Carnap, "Testability and meaning," 442-443; Definition 10.

With other symbols, (1) is (R) in Carnap's account.[3] 'IF…THEN…' stands for logical conditional relation, and, as (R) in Carnap's account,[4] (1) is universally quantified and the universal quantifier is omitted only for shorten. Accordingly, what (1) means is that, for every object or being, if that object or being has property Q_1, then if that object or being also has property Q_2, that object or being has property Q_3 too.

(2) IF Q_1 THEN (IF Q_2 THEN Q_3)

(3) IF Q_4 THEN (IF Q_5 THEN not-Q_3)

There is no doubt that (2) is identical to (1). However, Carnap presents (2) and (3) as a pair separated from (1). That is because, as shown below, in his framework, (1) is used to give a rule by itself, and (2) and (3) are taken together to offer another different rule. Thereby, with other symbols, (2) and (3) are (R_1) and (R_2) in Carnap's account,[5] and they are, as (1), universally quantified sentences.

(4) IF Q_1 THEN (Q_3 IFF Q_2)

Clearly, '…IFF…' is an abbreviation for '…IF AND ONLY IF…', it represents logical biconditional relation, and (4), which is (R_b) in Carnap's account,[6] is a universally quantified sentence as well.

These formulae are interesting because Carnap[7] indicates limitations for them, and those limitations can reveal several points. For example, an analysis of them can show that (1), (2), (3), and (4) may not be so demanding for scientists or philosophers of science. At least, if a theory such as the theory of mental models[8] is assumed as the approach that describes the actual manner human beings think, reason, and make inferences.

This is what will be shown then. First, what the three rules and four formulae are and what their restrictions are will be explained in more detail. Second, relevant aspects of the theory of mental models for the analysis of (1), (2), (3), and (4) will be commented on. Lastly, the reasons why, under the theory of mental models, it can be thought that, if (1), (2), (3), and (4) were taken as elements to the construction of scientific language, that would not require additional greater intellectual effort from

[3] Carnap, "Testability and meaning," 442.
[4] Carnap, "Testability and meaning," 442.
[5] Carnap, "Testability and meaning," 442.
[6] Carnap, "Testability and meaning," 442.
[7] Carnap, "Testability and meaning," 442-443.
[8] E.g., Ruth M. J. Byrne and Philip N. Johnson-Laird, "*If* and *or*: Real and counterfactual possibilities in their truth and probability," *Journal of Experimental Psychology: Learning, Memory, and Cognition* 46, 4 (2020): 760-780.

researchers will be pointed out. Thus, it will also be argued that, beyond Carnap's initial intentions, on the contrary, the limitations of those formulae would lead to simplify their cognitive activity.

Four Formulae and Three Rules for the Building of Scientific Language

Carnap's proposal[9] is much more comprehensive and is not limited to the four formulae above. In fact, (1), (2), (3), and (4) are examined by Carnap with much more attention than the way they will be dealt with here. Nevertheless, that is not a problem because the aim of this paper is simple. It is just to show that the formulae and their restrictions, at a minimum, it their initial presentation, do not add further requirements to researchers' activity. In fact, they can even make that very activity easier.

Focusing on the formulae, if the following equivalences are assumed, it is not difficult to get an example for (1) with thematic content.

Q_1: To be an animal.

Q_2: To be rational.

Q_3: To be a human being.

Thus, the example would be:

(5) For every x, IF x is an animal THEN (IF x is rational THEN x is a human being)

Nonetheless, according to Carnap,[10] (1) should be a 'reduction sentence' regarding its last consequent, that is, Q_3 (or 'to be a human being'). This means that (1) should be a sentence related to the degree in which a predicate such as Q_3 can be confirmed.

At this point, perhaps it is important to remind that, although that is sometimes forgotten, Carnap's view in this connection is not very different from the one of Popper.[11] This is explicitly mentioned by Carnap.[12] In this sense, it seems that Carnap's idea of reduction does not necessarily refer to definitive confirmation. In a similar manner as for Popper, it can be related to just levels of confirmation.

But, this said, the most relevant point here is that, for Carnap,[13] (1) can be a reduction sentence for the consequent of the conditional between its brackets if and only if a condition is fulfilled:

[9] Carnap, "Testability and meaning," 419-471.
[10] Carnap, "Testability and meaning," 442.
[11] Karl Popper, *The Logic of Scientific Discovery* (New York: Routledge Classics, 2002).
[12] Carnap, "Testability and meaning," 426.
[13] Carnap, "Testability and meaning," 442.

(6) Not-(Q_1 & Q_2) cannot be a valid formula.

Undoubtedly, '&' in (6) indicates logical conjunction, and, because (1) is universally quantified, the meaning of (6) is obvious. (1) can be admitted if and only if both Q_1 and Q_2 can be true, the cases in which one of those predicates is false having to be ignored.

This is not a difficulty for example (5) at all. (5) can be a reduction sentence for the predicate 'to be a human being' (Q_3) because there are animals (Q_1) and there are rational beings (Q_2). The point of (6) for the goals of this paper will be made below.

As far as (2) and (3) are concerned, the previous definitions of Q_1, Q_2, and Q_3 can be kept to offer examples with thematic content. It would only be necessary to add these new equivalences:

Q_4: To be a mammal.

Q_5: To have fins.

Thereby, the example for (2) would be the same as the one for (1), that is, (5). The example for (3) would be as follows:

(7) For every x, IF x is a mammal THEN (IF x has fins THEN x is not a human being)

However, there is a condition given by Carnap[14] here too. (2) and (3) can be a 'reduction pair' for the last predicate in (2), or the predicate negated in (3), that is, again, Q_3, if and only if:

(8) Not-[(Q_1 & Q_2) OR (Q_4 & Q_5)] cannot be valid.

'OR' denotes in (8) logical inclusive disjunction. Therefore, what (8) implies is, in a similar way as in the previous case, that (2) and (3) can be assumed if and only if Q_1, Q_2, Q_3, and Q_4 can be all true. The situations in which that does not happen are irrelevant and should not be considered. Nevertheless, examples (5) and (7) continue not to be a problem. As said, there are animals and rational beings, but there are both mammals (Q_4) and animals having fins (Q_5) too. The importance of (8) will be made explicit below as well.

Finally, with regard to (4), Carnap[15] says that it is a special case in which these equivalences occur:

$Q_4 = Q_1$

$Q_5 = \text{not-}Q_2$

[14] Carnap, "Testability and meaning," 442.

[15] Carnap, "Testability and meaning," 441-442.

Given these last equivalences, following Carnap,[16] it can be stated that (3) could be transformed into:

(9) IF Q_1 THEN (IF not-Q_2 THEN not-Q_3)

As Carnap[17] reminds, (9) is equivalent to:

(10) IF Q_1 THEN (IF Q_3 THEN Q_2)

And, as he also points out,[18] from (1) and (10), it is possible to derive (4).

It is easy to give an example with thematic content for (4) from the previous equivalences too:

(11) For every x, IF x is an animal THEN (x is a human being IFF x is rational)

Nonetheless, (4) has, following Carnap,[19] its restriction as well. (4) is a 'bilateral reduction sentence' for the left predicate of the biconditional in its brackets, that is, again, for Q_3, if and only if this is correct:

(12) For every x, not-Q_1 cannot be valid.

Because of the previous definition of Q_1, that is, 'to be an animal,' (12) is not a difficulty for (11) either. What (12) provides is the need for Q_1 to be possible, since it leads not to take into account the cases in which Q_1 does not happen. Nevertheless, none of this has an influence on (11), since, as said, there are animals.

A theory such as the theory of mental models can show the interest that restrictions such as (6), (8), and (12) can have, irrespective of Carnap's real perspective, from the cognitive point of view. Those restrictions can in turn cause (1), (2), (3), and (4) to be very relevant elements in the process of construction of scientific language. But to show why all of this is the case, it is necessary to explain some theses of the theory of mental models before.

The Conjunction of Possibilities of the Conditional

For the theory of mental models, the conditional is a 'sentential connective.'[20] Of course, the conditional is not the only sentential connective the theory of mental

[16] Carnap, "Testability and meaning," 442.
[17] Carnap, "Testability and meaning," 442.
[18] Carnap, "Testability and meaning," 442.
[19] Carnap, "Testability and meaning," 443.
[20] E.g., Philip N. Johnson-Laird and Marco Ragni, "Possibilities as the foundation of reasoning," *Cognition* 193 (2019). DOI: 10.1016/j.cognition.2019.04.019.

models addresses.[21] However, for the aims of the present paper, the conditional is the most important connective to deal with.

Sentential connectives, including the conditional, link sentences to 'conjunctions of possibilities.'[22] Thus, in the case of a conditional such as:

(13) IF Q_2 THEN Q_3

Following the usual way to express conjunctions of possibilities in the latest papers supporting the theory,[23] its conjunction of possibilities would be akin to this one:

(14) Possible (Q_2 & Q_3) & Possible (not-Q_2 & Q_3) & Possible (not-Q_2 & not-Q_3)

Nevertheless, another important aspect of the theory of mental models is that its proponents often deem it as a 'dual-process' theory.[24] As it is well known, dual-process theories[25] distinguish between two systems. Those systems are usually named 'System 1' and 'System 2.' Generally, System 1 allows inferring quick conclusions because it does not carry out deductive processes. Basically, it is the system responsible for the activities related to intuition. However, System 2 works in a slow way. This is because it leads deductive processes. Accordingly, it can be said that its mental processes are more rigorous.

Under this framework, the theory of mental models also claims that individuals might use only one of those two systems. This, in the case of the conditional, means that, when the system working is System 1, only the first conjunct in a conjunction of possibilities such as (14) is detected. The other two

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[21] E.g., Philip N. Johnson-Laird, "Inference with mental models," in *The Oxford Handbook of Thinking and Reasoning*, eds. Keith J. Holyoak and Robert G. Morrison (New York: Oxford University Press, 2012), 134-145.

[22] See also, e.g., Sangeet Khemlani, Thomas Hinterecker, and Philip N. Johnson-Laird, "The provenance of modal inference," in *Computational Foundations of Cognition*, eds. Glenn Gunzelmann, Andrew Howes, Thora Tenbrink, and Eddy J. Davelaar (Austin: Cognitive Science Society, 2017), 663-668.

[23] E.g., Johnson-Laird and Ragni, "Possibilities as the foundation of reasoning"; Khemlani et al., "The provenance of modal inference," 663-668.

[24] E.g., Philip N. Johnson-Laird, Sangeet Khemlani, and Geoffrey P. Goodwin, "Logic, probability, and human reasoning," *Trends in Cognitive Sciences* 19, 4 (2015): 201-214.

[25] E.g., Jonathan St. B. T. Evans, "How many dual-process theories do we need? One, two or many?" in *In Two Minds: Dual Processes and Beyond*, eds. Jonathan St. B. T. Evans and Keith Frankish (Oxford: Oxford University Press, 2009), 33-54; Keith Stanovich, "On the distinction between rationality and intelligence: Implications for understanding individual differences in reasoning," in *The Oxford Handbook of Thinking and Reasoning*, eds. Keith J. Holyoak and Robert G. Morrison (New York: Oxford University Press, 2012), 343-365.

conjuncts are harder to identify and require the action of System 2.[26] In fact, the theory of mental models deems the second and third conjuncts as presuppositions people make when they manage to note that those conjuncts are possibilities for a conditional.[27]

From this point of view, it can be thought that any activity demanding only to identify the first conjunct and hence to use System 1 must be a not challenging activity. This is what occurs with Carnap's rules and it is shown in the next section.

Reduction and System 1

Indeed, if the theory of mental models is right, it seems that what is proposed by Carnap[28] is not really a great requirement for scientists or philosophers of science. In this way, there are many reasons why the theory should be accepted. Its predictions have been confirmed many times.[29] Besides, its proponents have developed even a software (mReasoner) which, following strictly the main principles of the theory, tries to imitate human reasoning.[30] However, beyond that discussion, what will be argued below, as said, is just that, if the theory of mental models is correct, the mental activity demanded by Carnap[31] to build scientific language is very simple and basic, since it only needs to use System 1.

Starting by (1), it can be claimed that, if only System 1 were utilized, its only possibility would be:

(15) Possible [Q_1 & (IF Q_2 THEN Q_3)]

Nevertheless, if people resorted to System 2 instead, two more conjuncts should be added:

(16) Possible [Q_1 & (IF Q_2 THEN Q_3)] & Possible [not-Q_1 & (IF Q_2 THEN Q_3)] &

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[26] See also, e.g., Johnson-Laird, "Inference with mental models," 134-145.

[27] E.g., Johnson-Laird and Ragni, "Possibilities as the foundation of reasoning."

[28] Carnap, "Testability and meaning," 419-471.

[29] See, in addition to the works supporting the theory of mental models cited along the present paper, e.g., Monica Bucciarelli and Philip N. Johnson-Laird, "Deontics: Meaning, reasoning, and emotion," *Materiali per una Storia della Cultura Guiridica* XLIX, 1 (2019): 89-112; Sangeet Khemlani and Philip N. Johnson-Laird, "Why machines don't (yet) reason like people," *Künstliche Intelligenz* 33 (2019): 219-228; Ana Cristina Quelhas, Célia Rasga, and Philip N. Johnson-Laird, "The analytic truth and falsity of disjunctions," *Cognitive Science* 43, 9 (2019). DOI: https://doi.org/10.1111/cogs.12739.

[30] See, e.g., Khemlani et al., "The provenance of modal inference," 663-668; Johnson-Laird et al., "Logic, probability, and human reasoning," 201-214; for download: https://www.modeltheory.org/models/mreasoner/

[31] Carnap, "Testability and meaning," 419-471.

Possible [not-Q_1 & not-(IF Q_2 THEN Q_3)]

But the second conjunct in all of the possibilities both in (15) and (16) is also a conditional (IF Q_2 THEN Q_3). So, that conjunct would be linked to possibilities too, and (15) and (16) would not be the final conjunctions of possibilities. In the case of (15), that is, of the situation in which only System 1 is used, the second conjunct of the possibility has to be transformed in this way:

(17) Possible [Q_1 & Possible (Q_2 & Q_3)]

Certainly, the conditional (IF Q_2 THEN Q_3) is again transformed into just a possibility [Possible (Q_2 & Q_3)], since, as indicated, when the system that is taken into account is System 1, only the first conjunct in a conjunction of possibilities such as (14) is considered. However, if so, (17) is describing only a possible scenario, which can be better expressed as follows:

(18) Possible (Q_1 & Q_2 & Q_3)

Undoubtedly, the situation is much more complex when the system is System 2. In that circumstance, the conditional (IF Q_2 THEN Q_3) has to be deployed in three possibilities in the cases of the two first conjuncts in (16). That is not necessary for the last conjunct, as it is negated. Nonetheless, that negation implies an additional difficulty too. It requires to understand that the negation of a conditional refers to the affirmation of its antecedent and the negation of its consequent. Thus, the conjunction of possibilities in the case of System 2 would be:

(19) Possible [Q_1 & Possible (Q_2 & Q_3)] & Possible [Q_1 & Possible (not-Q_2 & Q_3)] & Possible [Q_1 & Possible (not-Q_2 & not-Q_3)] & Possible [not-Q_1 & Possible (Q_2 & Q_3)] & Possible [not-Q_1 & Possible (not-Q_2 & Q_3)] & Possible [not-Q_1 & Possible (not-Q_2 & not-Q_3)] & Possible [not-Q_1 & Possible (Q_2 & not-Q_3)]

Of course, (19) can be simplified if its possibilities are manipulated in a way similar to the one used to transform (17) into (18). Thereby, the result would be:

(20) Possible (Q_1 & Q_2 & Q_3) & Possible (Q_1 & not-Q_2 & Q_3) & Possible (Q_1 & not-Q_2 & not-Q_3) & Possible (not-Q_1 & Q_2 & Q_3) & Possible (not-Q_1 & not-Q_2 & Q_3) & Possible (not-Q_1 & not-Q_2 & not-Q_3) & Possible (not-Q_1 & Q_2 & not-Q_3)

Still, (20) keeps being a very complex conjunction of possibilities. And it could be even harder to manage. The theory of mental models also raises the fact that people can tend to negate a conditional in a manner different from that suitable in classical logic. They can interpret that the negation of a sentence such as (13) is equivalent to that very sentence with its consequent negated,[32] that is, to:

[32] See, e.g., Sangeet Khemlani, Isabel Orenes, and Philip N. Johnson-Laird, "The negation of

(21) IF Q_2 THEN not-Q_3

And System (2) would lead to these possibilities for (21):

(22) Possible (Q_2 & not-Q_3) & Possible (not-Q_2 & not-Q_3) & Possible (not-Q_2 & Q_3)

Which in turn would increase the number of conjuncts in (20). It would be necessary to consider nine possibilities, as shown in (23).

(23) Possible (Q_1 & Q_2 & Q_3) & Possible (Q_1 & not-Q_2 & Q_3) & Possible (Q_1 & not-Q_2 & not-Q_3) & Possible (not-Q_1 & Q_2 & Q_3) & Possible (not-Q_1 & not-Q_2 & Q_3) & Possible (not-Q_1 & not-Q_2 & not-Q_3) & Possible [not-Q_1 & Possible (Q_2 & not-Q_3)] & Possible [not-Q_1 & Possible (not-Q_2 & not-Q_3)] & Possible [not-Q_1 & Possible (not-Q_2 & Q_3)]

Or, if preferred, by simplifying the three last conjuncts in (23) as done in (18) from (17) and in (20) from (19):

(24) Possible (Q_1 & Q_2 & Q_3) & Possible (Q_1 & not-Q_2 & Q_3) & Possible (Q_1 & not-Q_2 & not-Q_3) & Possible (not-Q_1 & Q_2 & Q_3) & Possible (not-Q_1 & not-Q_2 & Q_3) & Possible (not-Q_1 & not-Q_2 & not-Q_3) & Possible (not-Q_1 & Q_2 & not-Q_3) & Possible (not-Q_1 & not-Q_2 & not-Q_3) & Possible (not-Q_1 & not-Q_2 & Q_3)

However, at this point, what is important is that the rule had a limitation: (6). If (6) were followed, all of the possibilities in (24) including not-Q_1 or not-Q_2 would have to be removed. But, if that were done, the result would be (18), and only System 1 is needed to come to (18). Accordingly, Carnap's[33] proposal regarding (1) does not imply a greater mental effort. Under the theses of the theory of mental models, the cognitive effort to work with (1) would be minimal, since eight of the nine possibilities could be ignored. Furthermore, for the theory, the eight possibilities that would not be necessary to take into account are the possibilities related to higher levels of cognitive difficulty.

Something similar can be argued with regard to (2) and (3). Because it is identical to (1), the case of (2) can be considered already explained. As far as (3) is concerned, its account would be easy to present too.

Based upon the previous explanation, if only System 1 were used, (3) would have just a possibility:

(25) Possible (Q_4 & Q_5 & not-Q_3)

Nevertheless, paying attention to System 2, six more possibilities would have to be added:

conjunctions, conditionals, and disjunctions," *Acta Psychologica* 151 (2014): 1-7.

33 Carnap, "Testability and meaning."

(26) Possible (Q_4 & Q_5 & not-Q_3) & Possible (Q_4 & not-Q_5 & not-Q_3) & Possible (Q_4 & not-Q_5 & Q_3) & Possible (not-Q_4 & Q_5 & not-Q_3) & Possible (not-Q_4 & not-Q_5 & not-Q_3) & Possible (not-Q_4 & not-Q_5 & Q_3) & Possible (not-Q_4 & Q_5 & Q_3)

As in the previous case, the number of possibilities can be even greater. If the trend to understand negated conditionals to be conditionals in which just its consequent is negated is assumed here as well, the real conjunction of possibilities may not be (26), but (27).

(27) Possible (Q_4 & Q_5 & not-Q_3) & Possible (Q_4 & not-Q_5 & not-Q_3) & Possible (Q_4 & not-Q_5 & Q_3) & Possible (not-Q_4 & Q_5 & not-Q_3) & Possible (not-Q_4 & not-Q_5 & not-Q_3) & Possible (not-Q_4 & not-Q_5 & Q_3) & Possible (not-Q_4 & Q_5 & Q_3) & Possible (not-Q_4 & not-Q_5 & Q_3) & Possible (not-Q_4 & not-Q_5 & not-Q_3)

Nonetheless, in any case, the restriction (8) also simplifies the number of conjunctions here. (8) includes a negated disjunction, and the first disjunct of that disjunction (Q_1 & Q_2) can play exactly the same role as (6) for (24) in the case of (2). As pointed out, (2) is identical to (1), and, therefore, the explanation for (1) also holds for (2). So, as (1), (2) would only admit (18) and, as also indicated, (18) can be detected resorting only to System 1. On the other hand, the second disjunct (Q_4 & Q_5) of that very disjunction in (8) prevents from considering possibilities with not-Q_4 or not-Q_5, which leads to (25). But, as accounted for too, (25) is the possibility that could be derived from (3) by means of just System 1. Again, this demonstrates that no special mental effort is required for this rule either.

Hence, only the case of (4) remains to explain. It is true that the theory of mental models also offers an account of the biconditional that is not exactly identical to the one it gives for the conditional.[34] Nevertheless, given that the expression 'if and only if' is not very usual in natural language, that, in many cases, biconditionals are really expressed with the form of conditional sentences, that is, using the words 'if' and 'then,'[35] and that people generally come to biconditional interpretations from conditional sentences by considering the second possibility in conjunctions such as (14) to be unacceptable,[36] perhaps it is better that the explanation of (4) is not based on that account. It can be easier just to focus on the fact that, according to Carnap,[37] as indicated, (4) is actually the result of combining (1) and (10).

Thereby, to analyze (4) it can be enough to review, separately, (1) and (10) in order to check if System 2 is necessary in their cases. (1) has already been dealt with.

[34] E.g., Johnson-Laird, "Inference with mental models," 134-145.

[35] E.g., Philip N. Johnson-Laird and Ruth M. J. Byrne, "Conditionals: A theory of meaning, pragmatics, and inference," *Psychological Review* 109, 4 (2002): 646-678.

[36] See also, e.g., Johnson-Laird and Byrne, "Conditionals," 646-678.

[37] Carnap, "Testability and meaning," 442.

As seen, given restriction (6), only (18) needs to be addressed in its particular case. But, as argued, System 1 suffices to come to (18).

As far as (10) is concerned, it is evident that its explanation should not be very different from that of (1). If only System 1 works, only this possibility can be assigned to (10):

(28) Possible (Q_1 & Q_3 & Q_2)

As it can be noted, (28) is identical to (18). Just the order of the conjuncts into the possibility is different between them.

On the other hand, when (10) is processed by System 2, the conjunction of possibilities is this one:

(29) Possible (Q_1 & Q_3 & Q_2) & Possible (Q_1 & not-Q_3 & Q_2) & Possible (Q_1 & not-Q_3 & not-Q_2) & Possible (not-Q_1 & Q_3 & Q_2) & Possible (not-Q_1 & not-Q_3 & Q_2) & Possible (not-Q_1 & not-Q_3 & not-Q_2) & Possible (not-Q_1 & Q_3 & not-Q_2)

Of course, here it can also be interpreted that conditionals are negated by simply negating their consequents. That would allow transforming (29) into (30).

(30) Possible (Q_1 & Q_3 & Q_2) & Possible (Q_1 & not-Q_3 & Q_2) & Possible (Q_1 & not-Q_3 & not-Q_2) & Possible (not-Q_1 & Q_3 & Q_2) & Possible (not-Q_1 & not-Q_3 & Q_2) & Possible (not-Q_1 & not-Q_3 & not-Q_2) & Possible (not-Q_1 & Q_3 & not-Q_2) & Possible (not-Q_1 & not-Q_3 & not-Q_2) & Possible (not-Q_1 & not-Q_3 & Q_2)

But, once again, what is important is the restriction. Because, as argued by Carnap,[38] (4) comes from a special case of (3) in which $Q_4 = Q_1$ and $Q_5 =$ not-Q_2, one might think that, beyond (12), the restriction for (3), that is, (8) applies to (10) too. This is even less difficult to accept if it is noted that (8) is stronger than (12). Thus, the first disjunct in the disjunction in (8) allows eliminating the cases of not-Q_1 and not-Q_2 in both (29) and (30), which leads to (31).

(31) Possible (Q_1 & Q_3 & Q_2) & Possible (Q_1 & not-Q_3 & Q_2)

So, the problem would be only the second possibility in (31). It is a possibility for (10) that requires System 2 to be detected and, therefore, seems to undermine the thesis of the present paper. Nevertheless, this is not necessarily that way. Even if System 2 were used, the second conjunct in (31) would be never considered. If an individual resorts to System 2, this last system can note that, for a sentence such as (13), the only forbidden possibility is that missing in (14), that is, that in which Q_2 happens and Q_3 does not occur. A situation such as this one is exactly what is described in the second possibility of (31). In this manner, because (4) is built by

[38] Carnap, "Testability and meaning," 441-442.

means of (1) and (10), and (13) is included in (1), the second conjunct in (31) could be attributed to (4) in no way, whether or not System 2 is used.

That means that only the first possibility in (31) is relevant for (4), and, as indicated, that is the possibility corresponding to (10) if only System 1 is taken into account - it is equivalent to (28). Accordingly, it can be said that the possibilities that could be detected for (4) by resorting to System (2) would not be suitable for it either.

Therefore, none of the rules addressed in this paper would require the effort related to System 2. In all the cases, because of restrictions, it would be enough to use System 1.

Conclusions

This reveals that, as said, the particular instructions given by Carnap[39] to build scientific language dealt with here do not necessarily make scientific or philosophical work harder (regardless of Carnap's real intentions with those instructions). This is true, at least, from the framework of the theory of mental models.

It is not the first time the theory of mental models is linked to Carnap's approach. The literature shows several examples. However, most of the links are provided to his semantic method of extension and intension.[40] So, such links can appear to be obvious, as an essential element of that method is a set of 'state-descriptions' or 'possible worlds.'[41]

But, beyond those facts, perhaps it is important to highlight that several points remain to be explored. The paper by Carnap[42] not only analyzes formulae (1), (2), (3), and (4). It also reviews much more different aspects related to language, science, testability, and confirmation. The paper has even a second part that keeps moving forward from his ideas.[43] Accordingly, maybe it would be relevant to continue to study the greatest possible number of theses of Carnap's general work in order to check whether or not their trend is not to imply additional effort to scientific tasks and activities regarding the development and application of knowledge.

On the other hand, Carnap's theoretical framework should be somehow reviewed by means of its implementation in practice as well. Thus, it would be

[39] Carnap, "Testability and meaning," 419-471.

[40] Rudolf Carnap, *Meaning and Necessity: A Study in Semantics and Modal Logic* (Chicago: The University of Chicago Press, 1947).

[41] For some relations between these two frameworks, see, e.g., Miguel López-Astorga, "Apparent L-falsity and actual logical structures," *Problemos* 97 (2020): 114-122.

[42] Carnap, "Testability and meaning," 419-471.

[43] Rudolf Carnap, "Testability and meaning – Continued," *Philosophy of Science* 4, 1 (1937): 1-40.

opportune to confirm that formulae such as (1), (2), (3), and (4), and restrictions such as (6), (8), and (12) can be used in very different scientific fields and capture their concepts and theses. It is evident that this would be a gradual work of confirmations that, probably, it would never finish. However, it would not be actually very far from Carnap's approach. As mentioned, in this particular aspect, his view is not very different from Popperian philosophy. For that, it would be coherent with his ideas to keep researching in this direction.

In any case, what can be stated for sure currently is that, if the theory of mental models can be accepted, particular proposals by Carnap such as those analyzed above can continue to be interesting. As also stated, there are reasons for assuming the theory of mental models and, under its approach, the rules reviewed can be advisable. In addition to give clarity to the daily work carried out by scientists, and offer relevant inputs for the debate about the characteristics that scientific language should have, they do not lead to higher levels of effort from the cognitive point of view. All of this, of course, beyond Carnap's actual goals.[44]

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