CARNAP VERSUS POPPER: WHAT SCIENTISTS ACTUALLY DO

Miguel López ASTORGA

ABSTRACT: Carnap and Popper proposed ways scientists have to work. According to Carnap, they should look for confirmations for hypotheses. In Popper's view, what is important is to try to falsify hypotheses. Cognitive science seems to prove that, in real scientific research, both activities play a role. First, people attempt to confirm hypotheses. Second, they seek examples refuting those hypotheses. This paper is intended to show that the theory of mental models can describe the mental processes involved in both tasks: confirmation and falsification. It addresses the mental possibilities individuals consider in both cases. In addition, the paper reveals that, in accordance with both Carnap's framework and Popper's approach, both mental activities are related to conditional reasoning.

KEYWORDS: conditional reasoning, confirmation, falsifiability, mental models, possibilities

Introduction

In 1968, it was noted that, given a rule or hypothesis, people tend to confirm it (Wason 1968). Later, it was found that confirmation is only the activity people do at first. After it, individuals look for counterexamples, that is, they try to refute the rule or hypothesis (e.g., Tweney 1989; see also, e.g., Dunbar and Klahr 2012).

This discussion is important in epistemology and science. In philosophy of science there are different theoretical positions. Some of them claim that scientists need to confirm hypotheses (e.g., Carnap 1936, 1937). Other approaches ask for falsifying them (Popper 2002). Thus, what philosophy of science has proposed is what scientists must do. The relevance of works such as those in cognitive science (e.g., Dunbar and Klahr 2012; Tweney 1989; Wason 1968) is that they do not speak about what scientists should do, but about what they actually do.

The present paper will address the two tasks, confirmation and falsification, from the theory of mental models (e.g., Johnson-Laird 2023). Taking the models involved in each of these two activities, the paper will make two points. First, it will argue that the theory of mental models can describe the mental processes linked to confirmation and refutation. Second, it will also reveal that, if that description based on the theory of mental models holds, as proposed from different approaches in philosophy of science (e.g., Carnap 1936, 1937; Popper 2002), scientific knowledge is related to conditional inferences.

The first section will be devoted to the findings about these issues in cognitive science. The next section will show how the theory of mental models can understand the confirmation process. It will propose that, within the theory, that process is a conditional reasoning process. The last section will do the same addressing the falsification process. It will present the way the theory of mental models can explain falsification. Then, it will indicate the reasons why, from the theory, that process is a conditional reasoning process too.

Hypotheses, Confirmation, and Refutation

Peter Wason (1968) was who noted that people tend to confirm hypotheses. Wason (1968) noted this fact by means of a reasoning task. The task presented a sequence with three numbers, for example, 2/4/6. Participants had to indicate more sequences. After that, they would get information on their sequences. In particular, they could know whether their sequences were coherent or incoherent with the rule the initial sequence followed. Almost all of participants thought that the rule provided that the second number in the sequence was the first number plus 2, and that the third number was the second number plus 2, the three numbers being even. The interesting finding was that participants gave examples of sequences confirming that hypothetical rule. That was not a good strategy, since the right rule was different: the next number in the sequence is higher than the previous one (see also, e.g., Dunbar and Klahr 2012).

The wrong rule participants supposed can be expressed as (1).

(1) $N_i/N_j/N_k$, where N_i, N_j, and N_k are even numbers, $N_j = N_i + 2$, and $N_k = N_j + 2 = N_i + 4$

So, what participants did is to offer sequences confirming (1) such as 6/8/10 or 26/28/30.

However, as said, the true rule was simpler. It was (2).

(2) $N_i/N_j/N_k$, where N_i, N_j, N_k are numbers, and $N_k > N_j > N_i$

Works such as that of Tweney (1989) changed this idea, or rather complemented it. Those works revealed that confirmation is just the first phase in the mental process by means of which people review hypotheses. When individuals consider confirmation to be enough, they start to think about cases refuting the hypothesis (see also, e.g., Dunbar and Klahr 2012).

If the example of Wason's (1968) task is taken into account, the discovery of the second phase would imply to propose sequences such as 2/4/5 or 2/4/7 in that new phase. These sequences would violate (1), but they would be consistent with, for instance, (2).

From the point of view of philosophy of science, it can be said that individuals first act as philosophers such as Carnap (1936, 1937) point out. After that, they do what Popper (2002) claims. As mentioned, what is important about this is that both Carnap (1936, 1937) and Popper (2002) only refer to what scientists should do, not to what they really do. What scientists actually do can be discovered from works such as those analyzed in this section.

The next section is devoted to the first phase in the review of hypotheses, that is, to confirmation. It is dealt with from the theory of mental models. Inter alia, it is shown that, from this theory, confirmation processes imply conditional reasoning.

Confirmation and the Theory of Mental Models

If it is assumed that $s_1, s_2, \ldots, s_n$ are sequences with numbers, and that

$Px =_{df}$ x has three numbers

Then,

$Ps_1 =_{df} s_1$ has three numbers
$Ps_2 =_{df} s_2$ has three numbers
.
.
.
$Ps_n =_{df} s_n$ has three numbers

If it is added that

$Qx =_{df}$ x is consistent with (1)

It can be derived that

$Qs_1 =_{df} s_1$ is consistent with (1)
$Qs_2 =_{df} s_2$ is consistent with (1)
.
.
.
$Qs_n =_{df} s_n$ is consistent with (1)

In this way, when individuals search for confirmations for (1), what they do is to search for cases such as those expressed in (3).

(3) $(Ps_1 \& Qs_1) \& (Ps_2 \& Qs_2) \& \ldots \& (Ps_n \& Qs_n)$

Conjunction (3) indicates that sequences with three numbers coherent with (1) are possible. (3) gives n examples. Accordingly, (3) allows assuming (4).

(4) PS (Px & Qx)

Where 'PS' means that what follows between brackets is possible, in the sense 'possible' has in natural language (not in the sense it has in modal logic).

Although (3) offers n examples, just one would suffice to affirm (4). But what is most important is that, contrary to what modal logic requires, people often think that, if something is possible, its denial is also possible (e.g., Espino, Byrne, and Johnson-Laird 2020). Hence, if (4) is a possibility, (5) is a possibility as well.

(5) PS [Not-(Px & Qx)]

If (5) is a possibility, then (6), (7), and (8) are possibilities too.

(6) PS (Px & Not-Qx)

(7) PS (Not-Px & Qx)

(8) PS (Not-Px & Not-Qx)

Possibilities (7) and (8) are not problematic. In them, x does not have three numbers. They refer to cases in which x does not fulfill the first condition (i.e., P). That means that x does not match the structure of the sequences in Wason's (1968) task. For that reason, (7) and (8) cannot falsify (1). The only possibility that would refute (1) would be (6). The latter possibility would indicate that x has three numbers and, nevertheless, it is inconsistent with (1). Thereby, it can be said that there is a 'conjunction of possibilities' (which is the expression used in the theory of mental models; e.g., Khemlani, Hinterecker, and Johnson-Laird 2017) representing the kinds of scenarios in which (1) can be the case. That is conjunction of possibilities (9).

(9) PS (Px & Qx) & PS (Not-Px & Qx) & PS (Not-Px & Not-Qx)

This conjunction of possibilities is the conjunction that, following the theory of mental models, corresponds to the conditional (e.g., Quelhas, Rasga, and Johnson-Laird 2017). According to the theory of mental models, sentences are related to the models in which they are true. A possibility expresses a model of that type (see also, e.g., Johnson-Laird and Ragni 2019). A conjunction of possibilities such as (9) corresponds to a sentence such as (10) (see also, e.g., Goodwin and Johnson-Laird 2018).

(10) If Px then Qx

Several points are interesting about this. The theory of mental models is a psychological theory, no a logical one. P and Q do not have the properties predicates have in calculi such as first-order predicate calculus. (10) is not a well-formed formula in that calculus. The theory of mental models only tries to account for what people do in daily life. But in daily life, individuals do not always deduce that the possibilities that can be linked to a sentence such as (10) with thematic content are those in (9) (see also, e.g., Byrne and Johnson-Laird 2020). For example, (7) and (8) are often ignored (see also, e.g., Byrne and Johnson-Laird 2009). In this way, it is important that the theory deems (7) and (8) as presuppositions. This is because, as shown below, they are valid possibilities both if (10) is true and if (10) is false (see also, e.g., López-Astorga, Ragni, and Johnson-Laird 2022). So, to look for cases of (4) is, from this point of view, to look for cases that actually confirm a conditional such as (10).

Therefore, the theory of mental models can describe the confirmation mental processes. It can be thought that those processes happen in the first phase when a scientific hypothesis is addressed. The next section tries to argue the same with regard to the falsification mental processes, that is, the processes occurring in the second phase of analysis of scientific hypotheses.

Refutation and the Theory of Mental Models

In a similar way as in the previous mental process, when people try to falsify, they search for cases such as those in (11).

(11) $(P_{s1}$ & Not-$Q_{s1})$ & $(P_{s2}$ & Not-$Q_{s2})$ &…& $(P_{sn}$ & Not-$Q_{sn})$

If the cases included in (11) were found, that would show that there are sequences with three numbers violating (1), and that hence the latter rule is false. For the example considered in this paper, that is, that of Wason's (1968) task, the cases in (11) could be, for instance, cases inconsistent with (1) but compatible with (2). (11) would inform n cases revealing that (1) does not hold. Thereby, (12) could be concluded from (11).

(12) PS (Px & Not-Qx)

As mentioned above for confirmation, although (11) gives n examples, one example would be enough to assume (12). As also said, the theory of mental models supposes the idea that if something is possible, its opposite is possible too. This idea can also be applied to (12). So, possibility (12) implies possibility (13).

(13) PS [Not-(Px & Not-Qx)]

Possibility (13) leads to possibilities (4), (7), and (8). This is because (4), (7), and (8) are the possibilities that, in principle, appear to make (12) false. Nonetheless, as in the case of (4) and (5), there are two possibilities that are not a problem for (12). Again, they are those in which the first condition is not fulfilled, that is, those including Not-P, that is, (7) and (8). For the same reasons as in confirmation (7) and (8) cannot falsify (1), they cannot falsify (12) either. The only controversial possibility confirming (1) is (4) now. As mentioned, (4) expresses that x has three numbers and is consistent with (1). The conjunction of possibilities for falsification is (14).

(14) PS (Px & Not-Qx) & PS (Not-Px & Not-Qx) & PS (Not-Px & Qx)

Conjunction of possibilities (14) is the conjunction the theory of mental models assigns to the negation of the conditional. This is one more difference between the theory of mental models and standard logics. Standard logics tend to understand the conditional as Philo of Megara did (e.g., Bocheński 1963; O'Toole & Jennings 2004). As it is well known, from Philo's view, the negation of a conditional such as (10) leads to a conjunction such as (15).

(15) Px & Not-Qx

Nevertheless, the theory of mental models interprets the conditional based on what empirical experiments reveal. According to the theory, there are experiments (e.g., those in Khemlani, Orenes, and Johnson-Laird 2014) showing the way people actually deny conditionals. Thus, following the results of those experiments, the theory of mental models considers (16) to be the negation of (10) (see also, e.g., López-Astorga et al. 2022).

(16) If Px then Not-Qx

Hence, from what was said about the conditional within the theory of mental models in the previous section, it can be stated that the theory provides that the negation of a conditional corresponds to a conjunction of possibilities such as (14). In (14), the second and third possibilities, that is, respectively, (8) and (7), keep being presuppositions. They can be accepted whether the conditional is true or false. So, they can be accepted both for (10) and for (16).

All of this means that to look for cases of (12) is to look for cases confirming (16) and, therefore, refuting (10). Presuppositions are valid whether or not the conditional holds. Accordingly, they are not the key here.

In summary, the theory of mental models can also describe the mental processes that happen in the second phase when analyzing a hypothesis. This is because the theory can describe the refutation mental processes. In these processes, reasoning is related to the conditional too. This is not a problem. It is rather a strength of the theory of mental models. The reasons for that are two. On the one hand, in the reduction sentences Carnap (1936, 1937) proposes, that is, in the sentences that, following Carnap (1936, 1937), should be used in confirmation, the conditional structure is essential. On the other hand, Popper (2002) understands the falsification processes as the application of Modus Tollendo Tollens. One of the premises in the latter rule is a conditional.

Conclusions

Philosophers of science such as Carnap and Popper tried to show the manner scientists should work to accept or reject hypotheses. The former is a representative of a school of thought claiming confirmation as the basic task. On the contrary, Popper argued that the scientific task needs to be based on refutation.

Proposals such as these are presented as what scientists must do. But cognitive science has revealed how people actually act when they try hypotheses. From works such as those of Tweney or Wason, one might infer that there are two phases of analysis. First, individuals attempt to confirm hypotheses. Then they search for refutations of those very hypotheses (see also, e.g., Dunbar and Klahr 2012).

What the present paper shows is that the theory of mental models can explain how both of those processes happen in the human mind. Confirmation is understood as the quest for possible cases in which both the antecedent and the consequent of a conditional hold. The other possibilities in which that conditional can be the case are not addressed because they are presuppositions. They refer to scenarios that are also possible if the conditional is false. As far as falsification is concerned, the theory interprets it as the process seeking possible circumstances in which the antecedent of a conditional is true and the consequent of that very conditional is false. Again, the other possible situations in which the conditional can be false are not dealt with. They are presuppositions as well. In fact, they are the same presuppositions as those corresponding to the conditional when it is true.

On the one hand, these results are not far from logical and philosophical conceptions such as those of Carnap or Popper. Both of them deemed the processes of analysis of scientific hypotheses as processes in which the conditional is involved. The structure of Carnap's reduction sentences is conditional. In Popper's view, refutation reproduces the application of a logical rule containing a conditional: Modus Tollendo Tollens. On the other hand, these results can also be understood as evidence in favor of the theory of mental models. The latter theory is not intended to account for what the human mind should do, but what it actually does. The present paper has tried to argue that the theory of mental models is able to describe what scientists actually do.[1]

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[1] **Acknowledgments:** PIA Ciencias Cognitivas, Centro de Investigación en Ciencias Cognitivas, Instituto de Estudios Humanísticos, Universidad de Talca; Fondo Fondecyt de Continuidad para Investigadores Senior, código FCSEN2102, Universidad de Talca; Fondequip (Programa de Equipamiento Científico y Tecnológico) 2019, código EQM190153.

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