

HEURISTICS, DUAL-PROCESS THEORIES, LOGIC, AND MENTAL MODELS

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Abstract: *Dual-process theories differentiate two components in the human mind. Intuition is the main ability in one of them: System 1. The essential ability of the other one, System 2, is deliberation. Heuristics have been linked to System 1, to System 2, and to both of them. The latter alternative is adopted by Nadurak. This paper follows that alternative too. It takes an example Nadurak gives and, based on it, shows that deliberation is indeed necessary to modify heuristics. The paper shows this from two perspectives: from an approach considering the human mind to be led by standard logic, and from a framework rejecting that very idea: the theory of mental models.*

Keywords: *classical logic; dual-process theories; logic; mental models; possibility.*

Introduction

Heuristics have been related to intuition (e.g., Bruers, 2013). They have also been linked to deliberation (e.g., Liao, 2016). There is one more possibility: they correspond to both of them, that is, to intuition and deliberation. The latter is, for example, Nadurak's (2022) position. Nadurak (2022) bases this idea on the framework provided by dual process theories (e.g., Stanovich, 2012). These theories understand that intuition and deliberation are two manners of processing or systems (see also, e.g., Evans, 2008). The systems are sometimes named 'Type 1', which is the manner or system corresponding to intuition, and 'Type 2', which is the manner or system referring to deliberation (e.g., Evans & Stanovich, 2013). Another usual denomination is

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that of 'System 1', for intuitive processes, and 'System 2', for deliberative processes (e.g., Khemlani, Byrne, & Johnson-Laird, 2018). Conventionally, this paper will follow the System 1 and System 2 terminology.

The aim here is to show that, both if the idea that the human mind is led by standard logic is adopted and if the theory of mental models (which denies any relations between the human mind and that logic) is assumed, it is possible to argue that heuristics can be linked to deliberative processes, that is, System 2. Thus, the present paper will try to give further support to Madurak's (2022) thesis that System 2 can also have an influence on heuristics.

It will do that by means of three sections. The first section will explain what heuristics are and the general lines of dual-process theories. Likewise, it will describe an example given by Nadurak (2022) in order to show that heuristics (or, at least, their updating or modification) can be results of System 2. The second one will argue that, from a framework mainly based on standard logic, it is also possible to conclude that Nadurak's (2022) example reveals the need for deliberation and System 2. Finally, some relevant theses of the theory of mental models will be indicated. This theory proposes a mental dual-process too, and rejects that human reasoning follows classical logic. It will be claimed that, if the theory of mental models is accepted, Nadurak's (2022) example also leads to the idea that System 2 can be involved in the development of heuristics.

Heuristics and dual-process theories

As Nadurak (2022) indicates, there are several definitions of heuristics. The one Nadurak's paper assumes is that of Shah & Oppenheimer (2008, p. 207): "...methods that use principles of effort-reduction and simplification. By definition, heuristics must allow decision-makers to process information in a less effortful manner than one would expect from an optimal decision rule" (see also Nadurak, 2022, p. 49). This will be the definition taken here.

From the point of view of dual-process theories, to link heuristics to intuitions, deliberations, or both intuitions and deliberations is to link heuristics to System 1, System 2, or both System 1 and System 2. Nadurak paraphrases the definition of the two systems Kahneman and Frederick (2002) give. Thus, Nadurak says that, following Kahneman and Frederick (2002), "the processes of System 1 (intuitive) are automatic, effortless, associative, rapid, parallel, opaque, and result in skilled action. The processes of System 2 (deliberative) are effortful, deductive, slow, serial, self-aware, and rule-

based” (Nadurak, 2022, p. 50). The present paper assumes this definition with an important exception. System 1 sometimes leads to generalizations, prejudices, and stereotypes. It is hard to accept that a generalization, prejudice, or stereotype is a skilled action.

As said, Nadurak (2022) thinks that heuristics are related to both System 1 and System 2. Nadurak’s thesis is that what characterizes System 2 is a ‘continuum’ between its different levels, and that it is possible to speak about a ‘spiral model’ in which the two systems interact with heuristics. As shown in most of the works in the literature (e.g., Kahneman & Frederick, 2005), the relations between the two systems are in the core of dual-process theories. This can be seen even with physical skills. A simple case can be that of some activities that are learned via System 2. After a number of repetitions, because of System 1, the actions corresponding to those activities become quick and unconscious. An example can be that of people learning to drive. When people are learning to drive a car, at first, they should resort to System 2 to make the right movements with their hands and feet in order to control the components of the car. With practice, the movements are progressively transformed into automatic and unconscious. The result is that, lastly, System 1 leads and the movements are rapid (examples such as this can be considered from works such as that of Kahneman, 2011). But one of the examples of heuristics offered by Nadurak in this way is as follows:

A rule in System 1 can be (1).

- (1) “Help if you are asked for help” (Nadurak, 2022, p. 57).

The people with this rule in their System 1 can remind that an individual asking them for help hurt them a lot. This memory causes System 2 to act. This modifies (1) into (2). One might think that, over time, (2) becomes the new rule in System 1.

- (2) “Help only those who have not done you much harm” (Nadurak, 2022, p. 57).

Nadurak’s (2022) arguments are clear. However, the present paper will try to present further support in this way. Both if it is assumed that reasoning is consistent with classical logic and if it is thought that is not the case, Nadurak’s arguments seem to hold. The next section will address the alterna-

tive that reasoning is coherent with standard logic. The third section will deal with the opposite idea.

Modification of heuristics and standard logic

There are different theories claiming that human reasoning is logical (see, e.g., Braine & O'Brien, 1998; Henlé, 1962; Rips, 1994). Many times, those theories point out that the mental logic should be different from classical logic in some senses (see also, e.g., O'Brien, 2014). Nevertheless, the explanation below is so general that, perhaps without much theoretical effort, can be admitted for all the theories stating the existence of a mental logic in human beings.

A sentence such as (1) can be presented in standard propositional logic as (3).

$$(3) P \rightarrow Q$$

In (3), 'P' represents the fact that people ask for help, 'Q' stands for the fact that you help the people asking for help, and ' \rightarrow ' symbolizes logical implication.

Likewise, a well-formed formula in that very logic to capture (2) can be (4).

$$(4) (P \wedge R) \rightarrow Q$$

In (4), 'R' means the fact that the people asking for help have not hurt you and ' \wedge ' is the symbol for conjunction.

Therefore, to support Nadurak's (2022) thesis, it is necessary to argue that the step from (3) to (4) cannot be taken without using System 2. System 2 is needed if cognitive effort is required. So, what should be shown is that the step from (3) to (4) requires a great deal of deliberation, analysis, and mental effort.

Lukowski (2013) explains some circumstances in which formulae such as (3) can be converted into formulae such as (4). They are cases of apparent non-monotonicity. As Lukowski (2013) reminds, in propositional calculus, if (3) is true, (4) has to be true as well. This is because, in that calculus, if (3) is correct, (5) is correct too.

$$(5) P \therefore Q$$

In (5), '∴' indicates logical derivation.

And (4) is correct if (6) is correct too.

(6) $\{P, R\} \therefore Q$

So, if it is possible to derive proposition Q from proposition P, it should also be possible to derive proposition Q from propositions P and R. However, in daily life, it is easy to find cases in which this does not apparently hold. For example, one might think that (3), and hence (5), are true with these equivalences.

$P =_{df}$ they go to the movie theater

$Q =_{df}$ they watch a film

But if it is assumed that

$R =_{df}$ the tickets are sold out

While (3) and (5) can be accepted, (4) and (6) can be rejected.

One might consider this to be an instance of non-monotonicity. It can be thought even that this challenges the ability of logic to address everyday situations. Nevertheless, Lukowski's (2013) explanation is that this apparent non-monotonicity is not real. The antecedent of the conditional in (3) is not expressed in its entirety (accordingly, all the premises in (5) are not expressed either). In general, a conditional such as (3) has in its antecedent implicit conjuncts that are not explicitly mentioned. Those conjuncts refer to facts having to happen in order that the consequent has to be the case. The real structure of a formula such as (3) is often (7).

(7) $(P \wedge F_1 \wedge \dots \wedge F_n) \rightarrow Q$

In (7), 'F₁, ..., F_n' are implicit facts needing to occur in order that Q has to hold.

If it is supposed that

$F_i =_{df} \neg R$

Where, $i > 1 < n$ and '¬' represents negation.

It is possible to come to (8) from (7)

$$(8) (P \wedge F_1 \wedge \dots \wedge F_i \wedge \dots \wedge F_n) \rightarrow Q$$

And to (9) from (5).

$$(9) \{P, F_1, \dots, F_i, \dots, F_n\} \therefore Q$$

From Lukowski's (2013) point of view, formula (4) and deduction (6) do not offer examples of non-monotonicity with regard to (3) and (5), or, if preferred, (7) -or (8)- and (9). (4) only shows that the antecedent of (3) is not true. (6) only reveals that not all the premises necessary to derive Q are true (works such as that of Stenning and van Lambalgen, 2005, are also interesting with respect to this argumentation).

The point is that, if $F_1, \dots, F_i, \dots, F_n$ are implicit content, they cannot be considered without cognitive effort, that is, System 2. If all of this is applied to Nadurak's (2022) example, it can be said that the equivalences for P and Q (i.e., respectively, 'people ask for help' and 'you help the people asking for help') are correct. Nonetheless, that of R is not. A suitable equivalence for R can be:

$R =_{df}$ the people asking for help have hurt you

Thereby, to come from (1) to (2), previously implies a process akin to that to come from (3) to (7) -or (8)- and from (5) to (9). Only in this way it is possible to realize that a fact that should happen in order that Q has to happen (i.e., you help the people asking for help) is F_i , that is, $\neg R$ (i.e., the people asking for help have not hurt you). If R is the case, Q does not have to be the case. As argued, System 2 is necessary to notice this.

Modification of heuristics and the theory of mental models

If it is thought that cognition has nothing to do with classical logic, it is also possible to argue that the step from (1) to (2) needs deliberation. If the thesis that the human mind follows a logic is rejected, an alternative is the the-

ory of mental models (e.g., Johnson-Laird & Ragni, 2019). The theory of mental models considers the human mind not to work based on formulae or rules such as those in propositional calculus (see also, e.g., Quelhas, Rasga, & Johnson-Laird, 2017). People only deal with iconic possibilities corresponding to sentences (see also, e.g., Byrne & Johnson-Laird, 2020). But the theory of mental models is a dual-process theory. This means that the iconic possibilities people recover depend on the system, System 1 or System 2, which is working (see also, e.g., Johnson-Laird, Quelhas, & Rasga, 2021). This is clear in the case of the conditional (see also, e.g., López-Astorga, Ragni, & Johnson-Laird, 2022). Given a conditional such as (10),

- (10) If they go to the movie theater, then they will watch a film

System 1 only gives one possibility to it:

- (11) Possible (they go to the movie theater & they watch a film)

Reflection and effort, and, accordingly, System 2, can lead to note two more possibilities, that is, to (12).

- (12) Possible (they go to the movie theater & they watch a film)
& Possible (they do not go to the movie theater & they watch a film)
& Possible (they do not go to the movie theater & they do not watch a film)

The theory deems sets of possibilities such as (12) as ‘conjunctions of possibilities’ (see also, e.g., Khemlani, Hinterecker, & Johnson-Laird, 2017). The two new possibilities added are presuppositions: they can hold whether or not (10) is true (see also, e.g., Goodwin & Johnson-Laird, 2018).

However, the important point here is that the information that the tickets are sold out does not lead to formulae such as (4). So, it does not cause monotonicity problems. That information implies to add one more possibility to (12): the possibility in which they go to the movie theater and they do not watch a film. That possibility is the last one in (13).

- (13) Possible (they go to the movie theater & they watch a film)
& Possible (they do not go to the movie theater & they watch a film)
& Possible (they do not go to the movie theater & they do not watch a film)
& Possible (they go to the movie theater & the tickets are sold out & they do not watch a film)

If to get (12) already requires effort, to get (13) needs even more effort. An objection could be that the possibility corresponding to ‘they go to the movie theater & the tickets are sold out & they do not watch a film’, that is, the fourth possibility in (13), could be directly added to (11), without the need to first consider (12). In this way, it would be possible to come to (14) from (11) more quickly.

- (14) Possible (they go to the movie theater & they watch a film)
& Possible (they go to the movie theater & the tickets are sold out & they do not watch a film)

The literature seems to suggest that, following the theory of mental models, the process is from (11) to (12), and from (12) to (13). But even if it is assumed that the process is from (11) to (14), the action of System 2 is also necessary, since System 1 only leads to the possibility in (11).

If Nadurak’s (2022) example is taken into account, (1) only needs System 1, which reveals (15).

- (15) Possible (people ask for help & you help those people)

In the same way as (11) only includes what is mentioned in (10), just what is pointed out in (1) is in (15). So, System 2 is not necessary. Nevertheless, if it is required to consider the cases in which the people asking for help have hurt you a lot, a higher level of reflection is necessary. This allows thinking about more possible scenarios, in particular, a scenario in which the people asking for help have done a lot of harm to you, and hence you do not help them. That scenario sums one more possibility to (15):

- (16) Possible (people ask for help & you help those people)

& Possible (people ask for help & those people hurt you & you do not help those people)

Conjunction of possibilities (16) requires System 2, as it implies to address an additional scenario. Nonetheless, the required effort can be even higher. Intermediate steps can be needed. For example, individuals can note that, apart from the possibility in (15), there are other possibilities. One of those possibilities can be that you help the people without their request, or that neither they ask for help nor you help them. This would lead from (15) to (17).

- (17) Possible (people ask for help & you help those people)
& Possible (people do not ask for help & you help those people)
& Possible (people do not ask for help & you do not help those people)

After detecting all the possibilities in (17), the case in which the people that hurt you ask for help and you do not help them would be added. The result would be conjunction of possibilities (18).

- (18) Possible (people ask for help & you help those people)
& Possible (people do not ask for help & you help those people)
& Possible (people do not ask for help & you do not help those people)
& Possible (people ask for help & those people hurt you & you do not help those people)

The processes from (15) to (17) and from (17) to (18) require more effort than the process from (15) to (16). However, as in the previous case, the process from (15) to (16) already needs effort, and, therefore, System 2. This allows stating that, from a perspective rejecting classical logic, it is also possible to support the idea that heuristics are not only related to System 1.

Conclusions

As Nadurak indicates, from dual-process theories, there are three options with regard to heuristics: they are linked to System 1, they are linked to

System 2, and they are linked to both System 1 and System 2. Nadurak's theoretical position is the third one.

This paper has tried to present further support to Nadurak's thesis from an example (coming from Nadurak, 2022). It has been intended to show that the example reveals that, even adopting opposite cognitive alternatives, System 2 can be necessary in the processes for reviewing heuristics.

Two perspectives have been considered. The first one is that there is a relation between the human mind and a logic akin to standard logic. The second one is that of the theory of mental models, and, accordingly, it proposes that the mental processes are different from the logical processes. From the first perspective, the example leads to consider hidden contents. Those hidden contents can be understood as implicit conjuncts in the antecedents of conditionals, or as implicit premises in deductions. In any of those cases, the hidden content causes System 2 to act.

From the second approach, that is, the framework of the theory of mental models, the mind works addressing iconic possibilities. Here, what the example reveals is that it is necessary to think about at least an additional possibility. But an additional possibility means additional effort, and, again, System 2.

One might think that the action of System 2 in cases such as that analyzed in the present paper is limited. It only operates when certain circumstances lead to review heuristics. Once the revisions are over, heuristics are linked back to System 1. Even if this is correct, it is already important. Beyond the fact that System 2 can also review rules such as (2) and show that there are occasions in which you should help people asking for help that hurt you (e.g., when those people hurt you with no intention), System 2 can correct heuristics that are actually generalizations, prejudices, or stereotypes. So, the study in this direction is relevant. In any case, it is necessary to remind that Nadurak's idea is not that simple. Nadurak proposes a continuum within System 2 and a model that is spiral-shaped.

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