CHAPTER 4

BIAS, CONFLICT, AND FAST LOGIC: TOWARDS A HYBRID DUAL PROCESS FUTURE?

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INTRODUCTION

Daily life experiences and scientific research on human thinking indicate that people's intuitions can often lead them astray. An intriguing illustration is the impact of "low fat" food labels. Somewhat ironically these labels can cause people to overeat and gain weight (Wansik & Chandon, 2006). Clearly, if you eat a low fat alternative instead of the original version of your, say, favorite potato chips, you will have consumed fewer calories (e.g., 60% of the regular x calories). However, the problem is that we seem to intuitively equate "low fat" with "healthy". Because people see no danger in eating healthy food, the simple intuitive association will make it more likely that they consume more of it – and finish a second bag of potato chips, for example.

What is striking is that one would expect that upon some minimal reflection and deliberation people would spot their error. Indeed, one doesn't need to be a rocket scientist to

De Neys, W. (2017). Bias, conflict, and fast logic : Towards a hybrid dual process future ?. In W. De Neys (Ed.), ***Dual Process Theory 2.0*** (pp. 47-65). Oxon, UK: Routledge.

realize that when doubling your intake, the low fat alternative becomes the least healthy option (e.g., 60% of regular x calories + 60% of regular x calories = 120% of regular x calories). Nevertheless, it seems hard for people to avoid this type of fallacious thinking.

Since the 1960s seminal work in the reasoning and decision-making field has shown how similar intuitive thinking can bias our inferences and make people violate the most basic logical and probabilistic rules. The dual process view of thinking was originally adopted to account for this bias phenomenon (Evans, 2016; Kahneman, 2011; Wason & Evans, 1975). At the heart of any dual process model lays the idea that human reasoning relies on two different types of systems or processes, which one can simply label System 1 and System 2 (Stanovich, 1999). System 1 (often also called the intuitive or heuristic system) is assumed to operate fast and effortless. It is this system that is supposed to mediate intuitive thinking and make us associate “low fat” with “healthy”, for example. System 2 (often also called the deliberate or analytic system) is assumed to be slower and more effortful in the sense that it burdens our limited executive cognitive resources. It is this second system that is supposed to mediate the type of deliberate thinking that is typically required for sound logical inferencing, for example[1].

Although different types of dual process models have been proposed through the years (Evans, 2008), the most influential one is the so-called serial or Default-Interventionist (DI) model that has been advocated and popularized through the groundbreaking work of prominent scholars such as Jonathan Evans (2006; Evans & Stanovich, 2013), Daniel Kahneman (2011), or Keith Stanovich (2010). At the core of this model lies a serial view on the interaction

[1] I use “logical” loosely in this chapter as a general header and handy shortcut to refer to reasoning in line with classic norms in standard logic, probability theory, or mathematics.

between System 1 and 2. The key idea is that when people are faced with a reasoning problem, they will typically rely on System 1 to generate an answer. This is the default system. If needed, people can activate System 2 in a later phase to intervene and correct System 1 output. But this System 2 engagement only occurs after System 1 has been engaged and it is also optional. That is, activation of System 2 is not guaranteed. More generally, in the serial DI model reasoners are conceived as cognitive misers who try to minimize cognitive effort (Kahneman, 2011). Since System 2 thinking is hard, people will tend to refrain from it and stick to the default System 1 response. Consequently, in cases in which System 1 cues a response that conflicts with more logical considerations – as in the typical classic reasoning task – most people will not detect this conflict. Hence, reasoners end up being biased because they simply don't notice that their intuitive response is unwarranted. And the few people who do notice it will need to correct the initially cued System 1 response after demanding System 2 intervention.

There is little doubt that the serial DI model offers an appealing explanation for the massive bias that has been observed in the reasoning and decisions-making literature. It is also clear that the model has been highly instrumental in organizing and generating new research questions. However, in recent years evidence is amassing that its underlying assumptions might be problematic. As I noted in the opening chapter, this was one of the reasons for putting this volume together. In the present chapter I will specifically focus on work from my own team that has led me to re-think the way we need to conceive of the interaction between the two systems. I have organized the chapter in four sections. I start with a short theoretical discussion of alternative dual process models. In the second and third section I give an overview of my empirical work. Finally, in the fourth section I discuss emerging themes, outstanding questions, and future directions.

THREE THEORETICAL MODELS: SERIAL, PARALLEL, AND HYBRID

Before digging into the empirical data I want to introduce two alternatives to the dominant serial DI model: The parallel and hybrid model. Figure 4.1 presents a schematic illustration. I will return to a more detailed discussion in the remainder of the chapter, but I believe that briefly sketching the basic model features might be helpful to position the empirical work.

It is important to bear in mind that although the serial DI dual process model has been highly influential there have always been rival models around. The most-well known traditional competitor is the parallel processing model such as it has been presented in the work of Sloman (1996) or Epstein (1994), for example. Whereas the serial DI model assumes that System 2 is activated after System 1, the parallel model assumes that both systems are activated simultaneously from the start of the reasoning process. The fact that System 2 is engaged does not imply that its operations will always be successfully completed but it at least suffices to detect possible conflict between the two systems. One implication is that, pace the serial model, the parallel model does not postulate that biased reasoners are blind to the logically questionable nature of their response.

The hybrid model is a more recent competitor to the serial (and parallel) model. It is this model that is in my opinion best supported by recent empirical data. Although the serial and parallel model make different assumptions about biased reasoners' conflict detection efficiency, they both assume that detection of the erroneous nature of a System 1 response results from System 2 activation (the difference is that the serial model postulates that this System 2 activation only occurs for correct responders). Here lies the key difference with the hybrid model. At the most general level, the hybrid model postulates that the response that is traditionally considered to be computed by System 2 can also be cued by System 1. Hence, System 1 is assumed to generate (at least) two different types of intuitive responses. One of these is the traditional "heuristic" intuitive response based on semantic and visuospatial associations that is also assumed to be cued intuitively by the serial and parallel model. The other one is what I refer to as a "logical" intuitive response based on elementary knowledge of basic logical and probabilistic principles. The underlying idea here is that even biased reasoners implicitly grasp elementary logical and probabilistic principles and activate this knowledge automatically when faced with a reasoning task. This intuitive logical knowledge allows one to detect that the heuristic intuition is questionable in case of conflict without a need to engage in demanding System 2 computations.

It should be clear that the hybrid model shares some key features with both the serial and parallel model (hence, its name). Just like the serial model it assumes that System 1 and System 2 are activated in a serial fashion. So just like the serial model it postulates that System 2 activation is optional and only occurs after initial System 1 activation. But just like the parallel model, the hybrid model also entails that there is parallel activation. However, the parallel activation concerns activation of different types of System 1 intuitions rather than parallel activation of System 1 and System 2.

Figure 4.1 about here

In the next section I will review the empirical findings that have led me to favor the hybrid model. But before doing so I want to clarify some common misconceptions that may confuse readers. First, in the dual process literature authors sometimes tend to equate System 2 processing and normative correctness. That is, the System 1 response is often referred to as the incorrect response, whereas the System 2 response is referred to as the correct response. This is a handy simplification because in most classic reasoning tasks that are studied in the field it is typically the case that the intuitively cued response is incorrect from a normative point of view (i.e., within traditional standard logic, probability theory, or mathematics), whereas arriving at the correct response is assumed to require the type of deliberative thinking that is typical of System 2. However, it should be clear that there is obviously nothing "magical" about System 2 computation that makes its output universally normatively correct. It is simply the case that the two features (i.e., whether a response has been generated by System 1 or 2 and whether it is normatively correct or not) are often correlated in the type of problems we typically study (Evans, 2012). Obviously, there are cases in which the System 1 response will be correct as well. For example, there is no doubt whatsoever that adults can give the correct answer to a problem such as "How much is 5 + 5?" intuitively without any deliberation. Likewise, there can be situations in which too much deliberation will lead you astray (e.g., Reyna, 2004). Hence, one needs to bear in mind that the normative correctness of a response is not a defining feature of System 1 and 2 processing. It's a convenient overgeneralization that facilitates writing.

Second, the labels "serial", "parallel", and "hybrid" are functional labels to describe the postulated processing architecture during the core reasoning process. Literally speaking, a response to a reasoning problem can never be purely intuitive. That is, before System 1 can cue an intuitive response one will need to read or listen to the problem premises, for example. It is well established that such reading and comprehension processes can require deliberation and draw on the very same executive resources that System 2 requires. Consequently, one can argue that every reasoning process starts with initial System 2 activation. Likewise, one might argue that every reasoning process also ends with System 2 activation. That is, once I have computed a response to a problem, I will need to verbalize, write-down, or type my answer. This answer production may also require System 2. In this sense, it can be said that even the serial DI model assumes that System 2 is always "on". But the idea here is that System 2 is in a "low-effort" mode in which it simply accepts the suggestions made by System 1 without checking them (Kahneman, 2011). Hence, it does not engage in any proper deliberation so its core function is not activated. In sum, it is useful to keep in mind that the debate between the different models concerns the processing during the actual "reasoning" stage and not the initial encoding of the preambles or the ultimate overt response production.

EMPIRICAL FINDINGS: CONFLICT BLIND SPOT?

The processing architecture that is put forward by the serial dual process model leads to at least two testable core predictions. First, biased responding in classic reasoning tasks results from a failure to activate System 2 and detect that an intuitively cued System 1 response conflicts with deliberate System 2 computations. Second, correct responding in these cases requires a correction of the intuitively cued System 1 response by System 2. Put differently, biased reasoners should not notice that they are biased and correct reasoners will correct their initial answer after deliberation. For convenience, I will refer to these core predictions as the “conflict blind spot” and “System 2 correction” assumption. Most of my work in the last ten years has focused on an empirical testing of these hypotheses. I review the work on the conflict-blind-spot in this section and move to the System-2-correction studies in the next one.

Evidence for successful conflict detection

The conflict-blind-spot entails that biased reasoners who violate elementary logical and probabilistic principles in classic reasoning and decision-making tasks will not detect that their intuitive answer conflicts with them. This is based on the assumption that taking these principles into account depends on System 2 processing and this optional System 2 processing is not engaged for biased reasoners who stick to the default System 1 response. In other words, biased reasoners will be blind to their bias and will not detect that their intuitively cued System 1 response is incorrect. One can see how this can easily lead to a somewhat grim characterization of the biased reasoner as a blind fool who errs without having any clue she’s doing so (De Neys, Rossi, & Houdé, 2013; Hoffrage & Marewski, 2015). In my work on conflict detection during thinking I have directly tested this assumption.

The methodological rationale is simple. Classic reasoning tasks that have been used to study intuitive bias in the field are typically constructed such that System 1 generates an appealing but incorrect intuitive response which conflicts with some normative logical, probabilistic, or mathematical principle. Take for example, the infamous bat-and-ball problem (Frederick, 2005):

"A bat and a ball together cost $1.10. The bat costs $1 more than the ball. How much does the ball cost?"

Intuitively, the answer "10 cents" immediately springs to mind because people naturally parse the $1.10 in $1 and 10 cents (Kahneman, 2011). However, although it is intuitively appealing the answer is obviously wrong. Clearly, if the ball costs 10 cents and the bat costs $1 more, then the bat would cost $1.10. In this case, the bat and ball together would cost $1.20 and not $1.10 as stated in the problem. After some reflection it is clear that the ball must cost 5 cents and the bat costs – at a dollar more - $1.05 which gives us a total of $1.10.

Now, in addition to the traditional "conflict" problems, participants in the conflict detection studies are also presented control "no-conflict" problems. By introducing small content transformations, the intuitively cued System 1 response is made coherent with the appropriate System 2 response in these versions. In other words, in the control problems the intuitively cued response is also correct. For example, a no-conflict control problem of the bat-and-ball problem might read:

"A bat and a ball together cost $1.10. The bat costs $1. How much does the ball cost?"

Obviously, in this control version the intuitive splitting of $1.10 and selection of the "10 cents" answer is also mathematically correct.

To test reasoners' conflict or bias detection sensitivity we can simply contrast their processing of the conflict and control versions. Basic studies on conflict or error monitoring in the cognitive control field (e.g., Botvinick, 2007) have long shown that error and conflict detection results, for example, in longer response latencies and decreased response confidence. The key difference between the conflict and control problems is the fact that the intuitively cued System 1 response happens to be incorrect in the conflict problem. If biased reasoners are sensitive to the erroneous nature of their answer, one can expect that this detection will affect their processing. And this is precisely what has been observed (e.g., De Neys & Glumicic, 2008; De Neys et al., 2013; De Neys, Cromheeke, & Osman, 2011). Biased reasoners who solve the conflict problems, typically need more time to solve them and are less confident about the correctness of their response compared to the control problem (on which their intuitively cued response is also correct). This directly implies that biased reasoners are not blind to the questionable nature of their biased response.

Critically, these findings have been validated with a range of methods and tasks. For example, gaze tracking and memory studies indicate that biased reasoners also fixate the logically crucial problem parts longer and show better recall of this information on the conflict problems (De Neys & Glumicic, 2008; Franssens & De Neys, 2009). Neuroimaging work further indicates that the Anterior Cingulate cortex – the brain region that is often assumed to mediate conflict and error detection, e.g., Botvinick, 2007), shows increased activation when biased reasoners solve conflict vs control problems (e.g., De Neys, Vartanian, & Goel, 2008; Simon, Lubin, Houdé, & De Neys, 2015). Hence, in line with the behavioral findings this suggests that even biased, incorrect responders to traditional (i.e., conflict) reasoning problems are detecting that the intuitively cued System 1 answer is questionable.

As I noted, in addition to multiple methods the conflict sensitivity effects have also been observed on a range of classic tasks (e.g., conjunction fallacy, bat-and-ball problem, ratio-bias, belief bias syllogisms, base-rate neglect problems, number conservation task, see De Neys, 2015). Clearly, any finding that is based on a single method or single problem is open to confounds (Aczel, Szollosi, & Bago, 2016; Mata, Schubert, & Ferreira, 2014; Pennycook, Fugelsang, & Koehler, 2012; Singmann, Klauer, & Kellen, 2014). Hence, the generalization across methods and tasks lends credence to the findings. In this sense it is also important to highlight that similar findings have been reported by different teams (e.g., Bonner & Newell, 2010; Gangemi, Bourgeois-Gironde, & Mancini, 2015; Morsanyi & Handley, 2012; Pennycook, Trippas, Handley, & Thompson, 2014; Thompson & Johnson, 2014; Villejoubert, 2009; Stupple, Ball, Evans, & Kamal-Smith, 2011). In sum, taken together, there seems to be reliable evidence against the conflict blind spot hypothesis (De Neys, 2014, 2015).

Evidence for intuitive conflict detection

The finding that biased reasoners show successful conflict detection is not predicted by the serial DI model. However, it fits with both the parallel and hybrid model. Indeed, proponents of the parallel model have long predicted that biased reasoners will show conflict sensitivity. The key difference with the hybrid model is that this conflict sensitivity is believed to result from effortful parallel System 2 engagement. The hybrid model entails that it results from automatically activated competing System 1 intuitions. Hence, after having established that there is evidence for biased reasoners' conflict sensitivity, the critical next step is to determine where this sensitivity is coming from: Is it driven by System 1 or System 2?

Addressing this issue is also relatively straightforward. The defining feature of System 2 processing is that it is slow and cognitive resource demanding. By depriving people of the time or resources to engage in System 2, we can experimentally "knock-out" System 2. For example, we can limit the time people get to give an answer (i.e., time pressure manipulation) or force them to allocate their cognitive resources to another task during reasoning (i.e., concurrent load manipulation). In my studies I often show people a complex spatial dot pattern (e.g., four dots placed in a 3x3 grid) before the reasoning task which they have to memorize during reasoning. Because this memorization task requires executive resources needed for System 2 deliberation, System 2 processing will be hampered. If the conflict sensitivity effects (e.g., longer decisions times and lower confidence on conflict vs control problems) result from System 2 processing, they should be attenuated under load or time pressure. Since System 1 operations do not require executive resources, they should by definition not be hampered by the executive load.

By now a range of studies have shown that conflict detection is typically preserved under load and time pressure (Bago & De Neys, 2017a; Franssens & De Neys, 2009; Johnson, Tubau, & De Neys, 2016; see also Pennycook et al., 2014, and Thompson & Johnson, 2014).

Hence, knocking out System 2 does not affect the efficiency of conflict detection, which suggests it is an intuitive System 1 process.

It is this evidence for the intuitive nature of successful conflict detection that has led me to propose a hybrid model and postulate that people have logical intuitions. If biased reasoners show sensitivity to violations of basic logico-mathematical principles in the absence of System 2 deliberation, we have to assume that they have some knowledge of these principles and activate these automatically when faced with the reasoning problem.

EMPIRICAL FINDINGS: CORRECTIVE NATURE OF SYSTEM 2?

After having initially focused on the "conflict blind spot" assumption, my more recent empirical work shifted to an empirical test of the alleged corrective nature of System 2 processing. Bluntly put, one might say that whereas the conflict detection work primarily focused on incorrect responders, the focus here lies specifically on those few participants who do respond correctly. To recap, the "corrective System 2" assumption entails that on classic reasoning tasks in which System 1 cues an incorrect heuristic response, correct responding requires System 2 operations to override the initially cued System 1 response. So the idea is that people who respond correctly in the end, initially also generate the incorrect "heuristic" System 1 response. In other words, in the time course of the reasoning process the correct response is always preceded by the incorrect response: Everyone is intuitively biased at first but System 2 helps some people to correct this initial incorrect answer. Note that this assumption is made by both the traditional serial DI and parallel model. Although the parallel model entails that both systems are activated simultaneously, the fact that System 1 is faster implies that its output will be available first and will need to be overridden by the slower System 2 to respond correctly in case of conflict.

In recent work with Bence Bago we have begun to test this corrective time-course assumption directly (Bago & De Neys, 2017a, 2017b). Initially we were somewhat surprised to see that – given how central the corrective assumption is for traditional dual process models – there is, in fact, little hard empirical evidence that supports it. I suspect that one reason is that the assumption seems so self-evident. Introspectively, it certainly feels that on traditional conflict tasks such as the bat-and-ball problem the intuitive response pops-up immediately ("it's 10 cents!") and we have to think harder to correct it. However, we know that introspective impressions can be misleading (e.g., Mega & Volz, 2014). One might also argue that latency studies have clearly established that correct responses take longer than biased responses (e.g., De Neys, 2006; Pennycook et al., 2015). Although this supports the dual process claim that System 1 is faster than System 2, it does not entail that people who gave the correct response, initially considered the incorrect heuristic response. They might have needed more time for System 2 calculations without ever having considered the System 1 response.

To obtain more direct evidence we adopted the two-response paradigm that has been introduced by Valerie Thompson and colleagues (e.g., Thompson, Prowse-Turner, & Pennycook, 2011). In the paradigm participants are asked to give a first, initial response as quickly as possible and subsequently they are given all the time they want to reflect on the problem and select a final response. This simple procedure allows us to examine the time-course of reasoners' (potential) answer change. The serial DI and parallel models predict two types of response patterns on traditional reasoning tasks: In line with classic findings in the literature most people should be biased, so both their initial and final response will be incorrect (we can label this a "00" pattern, i.e., two subsequent incorrect responses). In addition, some people will initially also generate the incorrect response but will correct this in the end after they had the time to engage in System 2 deliberation (we can label this a "01" pattern).

Obviously, it is important to make absolutely sure that participants respect the instructions and indeed respond with the first response that comes to mind. If participants were to "cheat" and actually reflect before entering their initial response, it would not be surprising that they might give the correct answer as their first response. Therefore, in our version of the two-response paradigm we experimentally "knock-out" System 2 by imposing both time pressure and a load task. Participants need to enter their initial response within a very strict deadline (e.g., 4 s for our studies with the bat-and-ball problem – the time needed in a pretest to simply read the problem). In addition, during the initial response phase they are also burdened with a load task (e.g., the dot memorization task I introduced above) to further minimize the possibility that they deliberate during the first response phase. With this procedure we can be maximally sure that the initial response is truly intuitive in nature (Bago & De Neys, 2017a).

In one published (Bago & De Neys, 2017a) and one ongoing study (Bago & De Neys, 2017b) we have run this paradigm with three different reasoning tasks (i.e., base-rate task, syllogisms, and the bat-and-ball problem) in a total of 12 experiments in which we tested about 1000 participants. Results are very consistent. Not surprisingly, the dominant response pattern (48% to 76% of trials) is the "00" case in which participants give the intuitively cued heuristic response both as their final and initial answer. Obviously, this is what all models would predict: in line with classic findings people are typically biased when solving these infamous reasoning problems. In line with serial DI (and parallel) predictions, we also find a small subset of “01” trials (7% to 10% of trials) on which participants initially give the incorrect heuristic response and correct this after deliberation in the second response stage. They key finding is that we also frequently observe a “11” pattern (15% to 42% of trials) in which the correct response is already given in the initial response stage. Overall, this “11” pattern is about two times more frequent than the “01” pattern. In other words, of those participants who manage to give the correct answer as their final response, the vast majority (+66%) already selects this response as their initial answer. This implies that the corrective pattern that is envisaged by the traditional serial and parallel dual process models is the exception rather than the rule. People who respond correctly after deliberation do not necessarily need to override their initial response; they already give this correct answer intuitively.

For completeness, note that it is not the case that correct intuitive responses simply result from random guessing. We always present multiple conflict (and no-conflict) items. Participants’ response pattern across items is almost perfectly stable. That is, if you give a correct intuitive response on one trial, you do so on all trials. If initial correct responses resulted from guessing, people should obviously show more variability in their responses. Likewise, we also control for problem familiarity (e.g., if participants have seen the problem before and know the solution, it would not be surprising that they do not need to deliberate about it).

As I noted, our empirical findings have been highly consistent across the different tasks and studies we have run. Moreover, independent work by Valerie Thompson and colleagues is pointing towards the same trends (Newman, Gibb, & Thompson, 2017). Hence, the empirical data seems to be robust. But how do we make theoretical sense of this? Clearly, the finding that correct deliberation is preceded by correct intuitive responding is hard to account for by the serial DI and parallel model. However, the logical intuition idea in the hybrid model suggests an explanation. A core feature of the model is that people have both a heuristic and logical intuition. However, this does not imply that both intuitions are necessarily equally strong. Indeed, for most people, the heuristic intuition will be stronger than the logical intuition (De Neys, 2012). This explains why heuristic responses still dominate and most people are biased on these tasks: Although the presence of a logical intuition allows them to detect the unwarranted nature of their heuristic response, it remains hard to override the dominant heuristic intuition. But in line with recent suggestions by Pennycook et al. (2015), it is reasonable to assume that there can be individual differences in the strength of both intuitions. That is, everyone has both intuitions but they vary in activation strength. For example, the dominant "00" case will be characterized by a very strong heuristic and weaker logical intuition. Intuitive correct "11" responders will show the opposite pattern with a very strong logical and weak heuristic intuition. For the "01" responders who correct their answer after deliberation, both intuitions would be more moderate and similar in strength.

Interestingly, conflict detection findings support the strength theorizing. In our two response experiments we always present participants with conflict and no-conflict control problems, as in the conflict detection studies discussed in the previous section. Although all reasoners show a conflict detection effect at the initial response stage (i.e., decreased response confidence for conflict vs no-conflict problems), this effect is much more pronounced for the

"01" responders whose intuitions are assumed to be most similar in strength (Bago & De Neys, 2017a). Hence, it is quite reasonable to conclude that the more similar the intuitions are, the more you are in doubt. This fits with a view in which our reasoning performance is determined by the absolute (which intuition dominates?) and relative (how big is the strength difference?) difference in the strength of the competing intuitions. Figure 4.2 presents an illustration of this idea.

Our work on the corrective System 2 assumption clearly indicates that people can answer some of the most infamous classic reasoning problems correctly without deliberation. This strengthens the case for the hybrid model's postulation of logical intuitions. Hence, in addition to logical responding on the basis of slow deliberate System 2 operations – as it is traditionally conceived – we also need to postulate a type of fast, intuitive logical responding on the basis of System 1 operations. However, it is important to stress that although these "fast" and "slow" logical operations might result in the same output, they are assumed to originate from two different types of processes (System 1 and System 2, respectively) and will have different characteristics. In our studies with the bat-and-ball problem we also tried to pinpoint these different characteristics experimentally (Bago & De Neys, 2017b). For example, we simply asked participants to explain and justify why their answer was correct - both after the initial and final response. We observed that at the final response stage the vast majority of reasoners who gave the correct response, managed to justify why their answer was correct (e.g., they typically referred to variants of the mathematical equation "[x + (x + 100) = 110] so [x = (110-100)/2]). However, these same participants did not manage to come up with such a justification after the initial response stage (i.e., they typically refer to an undefined "gut feeling" here). Hence, although they systematically gave the correct response based on mere intuitive processing, they could not explain why it was correct. It seems that deliberative System 2 thinking is indispensable in this respect (see further).

The point I want to clarify is that in talking about "fast" or "intuitive" logic I do not entail that people are going through the exact same complex calculations as they would during System 2 processing. Bago and De Neys (2017a) have tried to illustrate this by drawing an analogy with the recall and recognition distinction in memory research (e.g., Haist, Shimamura, & Squire, 1992). Imagine you are presented with a list of 10 names you need to memorize. Ten minutes later you might explicitly recall and jot down that "Tom", "Mary", "Chris", and "Peter" were on the list. But in addition your recognition memory might allow you to decide whether or not a certain item was on the list when it is presented to you (e.g., you might manage to say "yes" when asked whether "Tim" was among the presented names or not). Sometimes you might not be able to recall a name, but you could still recognize whether you saw it on the list or not. Recall and recognition can both allow us to retrieve a memory trace but they differ (among other things) in the processes involved in memory retrieval. This recall/recognition dichotomy is akin to what I am alluding to here. The idea is that the type of fast logical responding can be conceived as a more superficial, recognition memory-like process that activates a stored logical principle and allows us to recognize that a competing heuristic intuition is questionable, without us being able to explicitly label or justify the principle (Bago & De Neys, 2017a). Hence, the key point is that the logical intuition theorizing does not entail that fast, System 1 logical responses are similar – let alone superior – to System 2 logical responses.

Figure 4.2 about here

EMERGING THEMES, OUTSTANDING ISSUES, AND FUTURE DIRECTIONS

I hope to have illustrated in this chapter that there are good empirical reasons to revise key assumptions of the traditional dual process model and move to a hybrid view. However, it is also important to highlight that the development of this new hybrid model is a work in progress. I do not consider the theoretical model that I suggested as an endpoint. More work is needed to fine-tune the model, and this will lead to further revisions and developments. In this final section I will point to some key emerging issues that will require more attention in the coming years.

Individual differences

When I have argued that biased reasoners show conflict detection I am talking about the average or modal biased reasoner (De Neys & Bonnefon, 2013). That is, the empirical conflict detection studies are always run at the group level. The analyses focus on the group of biased reasoners as a whole and test whether this group shows a significant conflict detection effect. As I outlined, we typically observe that this is the case. This suggests that the "average" biased reasoner does not have a conflict or bias blind spot. However, this does not imply that every single individual in the group shows this effect. This point has been rightly stressed by a number of colleagues and commentators (Mata et al., 2014; Mata, Ferreira, Voss, & Kollei, 2017; Mevel et al., 2015; Pennycook et al., 2015; Stupple et al., 2011).

In ongoing work I am actively focusing on this issue in collaboration with Darren Frey. One methodological problem is that conflict detection measures (e.g., confidence ratings, response latencies, etc.) are quite noisy. One of the reasons why psychologists have generally preferred to run studies at the group level is that by averaging over a large number of participants we can reduce the intrinsic measurement noise. When we analyze the data of one single subject, the noise can easily lead to misclassifications. In our ongoing work we tackle this problem by co-registering different conflict detection measures. If an individual consistently shows detection effects across different measures (e.g., shows both more doubt *and* longer latencies on conflict problems) we are more certain that the effect does not result from chance or a measurement error. Our initial results show that the majority of biased reasoners indeed consistently show conflict detection effects across multiple measures (Frey, Johnson, & De Neys, 2017). However, we also find a smaller subgroup of reasoners (up to 15% of biased reasoners) who consistently fail to show any detection effects. Hence, there are definitely exceptions to the rule that biased reasoners show error or conflict sensitivity: Some individuals do show a conflict detection blind spot. One of our future goals is to characterize and predict who these non-detecting individuals are (e.g., in terms of cognitive capacity and/or personality traits). In the same vein, we would obviously also like to characterize and predict which reasoners will show a dominant logical intuition and manage to solve problems correctly without deliberation. I envisage that this individual differences work will become ever more important in coming years.

Nature of the logical intuition signal

In my opinion there are good empirical reasons for the postulation of logical intuitions. People show sensitivity to violations of logical principles and some reasoners even manage to give intuitive correct responses. However, more work is needed to pinpoint the exact nature of these logical intuitions. It is clear that one can conceive of logical intuitions at different levels of specificity (e.g., Travers, Rolison, & Feeney, 2016). If we take the bat-and-ball problem, for example, I believe we can distinguish at least 3 levels (e.g., high, moderate, or low specificity). A high level of specificity would imply that people intuitively figure out and know that the correct response is "5 cents". A moderate level of specificity might entail that people detect that the heuristic "10 cents" response is questionable because they realize it is too high. That is, people intuitively realize that "10 + (100 + 10) > 110", for example, but without actually knowing that the correct response is "5 cents". A low level of specificity might entail that people doubt the heuristic "10 cents" response that is cued by System 1 because they detect that they did not properly process the preambles. That is, people intuitively realize they neglected the "more than" statement, for example (e.g., people detect that "100 ≠ (100 + 10)"), but without knowing that the correct response is "5 cents" or even whether the "10 cents" are too high or too low.

At present the available data does not really allow us to clearly differentiate between these different levels. This is crucial since it is evident that the different specificity levels might be based on quite different underlying computations. Furthermore, there might also be individual differences here. Although all (or most) reasoners might have a logical intuition, these intuitions might differ in specificity for different individuals. For example, it might be that intuitive correct responders in our two response paradigm (e.g., the “11” group) have a highly specify intuition whereas incorrect responders (e.g., the “00” group) have only a low or moderately specific intuition. Obviously, such fine-grained characterization will be an important challenge for future work.

Nature of System 2: why do we need System 2?

In the traditional serial DI and parallel dual process model the role of System 2 is well-defined: It will help to correct the initial heuristic System 1 response. In the hybrid model such correction is not necessarily needed. But if we do not need System 2 deliberation to correct System 1, what do we need it for? Why do we need System 2, if we can generate the correct response intuitively?

I believe that the key role of System 2 lies in a justification and validation process. Although reasoners might have an intuitive hunch about the correct response, they do not seem to be able to explicitly justify it in the absence of deliberate thinking. Such justification or validation is important for at least two reasons. First, it can function as a safeguard. It allows you to reduce possible erroneous conclusions. People might not have correct intuitions about each and every problem they will be faced with in daily life. Hence, deliberatively double checking your intuitive hunches in those cases where you have the time to do so can help to minimize errors. Second, deliberation will allow you to come up with a valid justification. This allows you to produce a good explanation or argument for why your response is correct. Such arguments are critical for communicative purposes (e.g., Mercier & Sperber, 2011). Imagine that we’re having a discussion and I try to convince you that my answer to a problem is the correct one. If I just tell you that X is correct "because I felt it", I will not be very successful in convincing you. If I come up with a good explanation, however, you will be much more likely to change your mind (Trouche, Sander, & Mercier, 2014). Such argumentative persuasion has been argued to be the evolutionary driving force behind the development of the human capacity to reason (Mercier & Sperber, 2011). It is here, in the production of good, communicable arguments that I see a key role for System 2.

In a sense one could claim that in my work I have been arguing that we need to upgrade the role of System 1. Indeed, I strongly believe that System 1 is capable of more than we have traditionally assumed in the field. However, this should not be conceived as an argument against the role or importance of System 2. Upgrading the role of System 1 does not imply we have to downplay the role of System 2. Although we shouldn't underestimate the capacity of System 1, there are also things it cannot do and for which System 2 will be indispensable. The point here is not whether one system is "better" than the other. More generally, I believe that the reason the *two* systems evolved – and we still have them – is precisely because they are both valuable and needed.

Generalization

In the introduction I stated that it is hard to overestimate the impact of the serial DI dual process view. One illustration is that the ideas of prominent advocates such as Evans and Kahneman have inspired the construction of dual process models in other fields as well. Two examples are the dual process model of cooperation in economic interactions (Rand, Greene, & Nowak, 2012) and the dual process model of moral cognition (Greene, 2014). In a nutshell, the dual process model of human cooperation focuses on cases in which self-interest can conflict with group interest (e.g., get more money yourself or share more with others). The dual process model of moral cognition focuses on situations in which utilitarian and deontological considerations can lead to conflicting moral decisions (e.g., is it acceptable to torture a terrorist if it can save the lives of innocent civilians?). These models have been highly influential in their respective fields and generated an impressive amount of empirical work. Although I find these applications fascinating and I am impressed by the breadth of the studies, I also feel that the critical question about the precise interaction between the two postulated systems has been largely neglected. The research reviewed here indicates that there are good reasons to question core assumptions of the traditional (serial *and* parallel) dual process models during logical and probabilistic reasoning. I believe it is paramount to examine the implications of these findings for the applications of the dual process framework in other fields too (e.g., see Bialek & De Neys, 2016, 2017, and Gürçay & Baron, 2017, for some initial explorations in the moral cognition case). Is there better support for the serial (parallel) assumptions in the case of moral reasoning and cooperation decisions or should we favor a hybrid processing architecture in these cases too?

The general point I want to make is that I believe we need a much closer interaction between the type of "generic" dual process theorizing in the reasoning and decision-making field that is discussed in this chapter (and book) and applications of the dual process model in other fields. On one hand, other fields can use the alternative models (and methods) as a starting point. The exploration of the interaction issue does not need to start from scratch but can build on existing models and methodological paradigms. On the other hand, it allows "generic" dual process theorists to test the generality of their models. That is, the end goal of our research should not be to build a model of logical or probabilistic reasoning per se, but a model of human thinking in all its different facets. I realize this might be an (overly) ambitious or even naive goal but I nevertheless feel it is important to keep this general cross-field applicability of our models in mind. Here too I see an important challenge for future work.

CONCLUSION

In this chapter I have tried to review my empirical work and sketch the rationale behind the hybrid dual process model that I favor. Although the traditional dual process models have been instrumental for the field, I believe the emerging evidence is pointing to a clear need to revise core assumptions. For me personally, these revisions feel like a quite natural development and illustration of the way science proceeds. Just like dual process theorists have not been afraid to revise their initial theorizing in light of new evidence in the past (e.g., Evans, 2006), we're at the point where we need to reconsider the way we conceive of the interplay between System 1 and System 2. Obviously, not all scholars will agree with the specific model and ideas I proposed here, but I believe that we should at least acknowledge that it is time to move to a new conceptualization.

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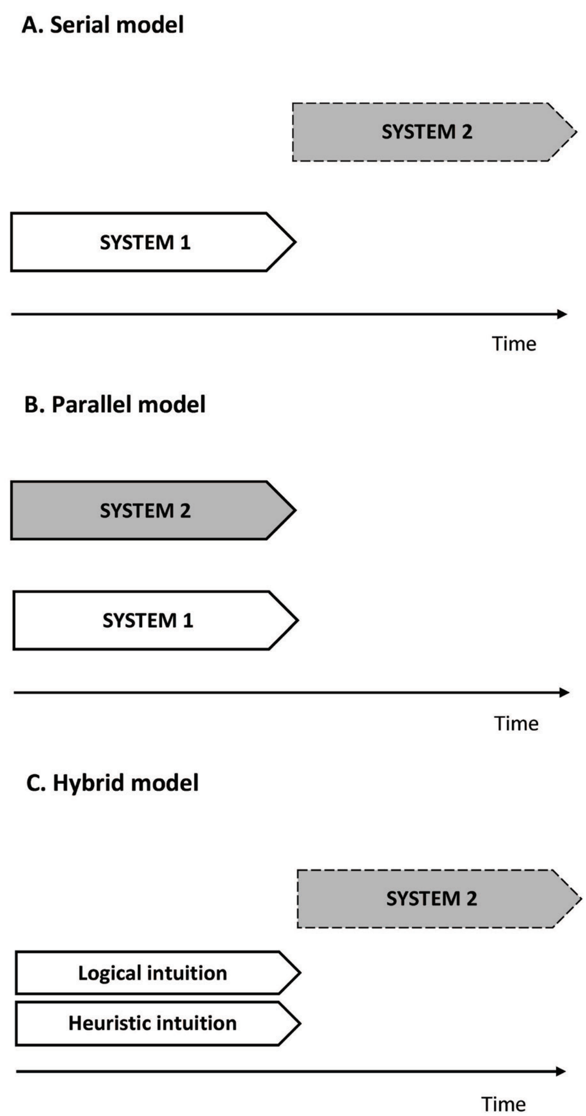
(Figure captions)

Figure 4.1. Illustration of the serial, parallel, and hybrid view on the relation between System 1 and System 2 processing. System 1 is represented by white bars and System 2 by grey bars. The horizontal axis represents the time flow. The dashed lines represent the optional nature of the System 2 engagement in the serial and hybrid model.

Figure 4.2. In the hybrid model different intuitions can differ in activation strength. The modal case (A) is the one in which the heuristic intuition will dominate. The more dominant the logical intuition becomes, the more likely that the reasoner will give an intuitive correct response (B). The smaller the relative strength difference between the competing intuitions, the more likely that deliberation will lead to correction (C)***.***



(Figure 4.1)

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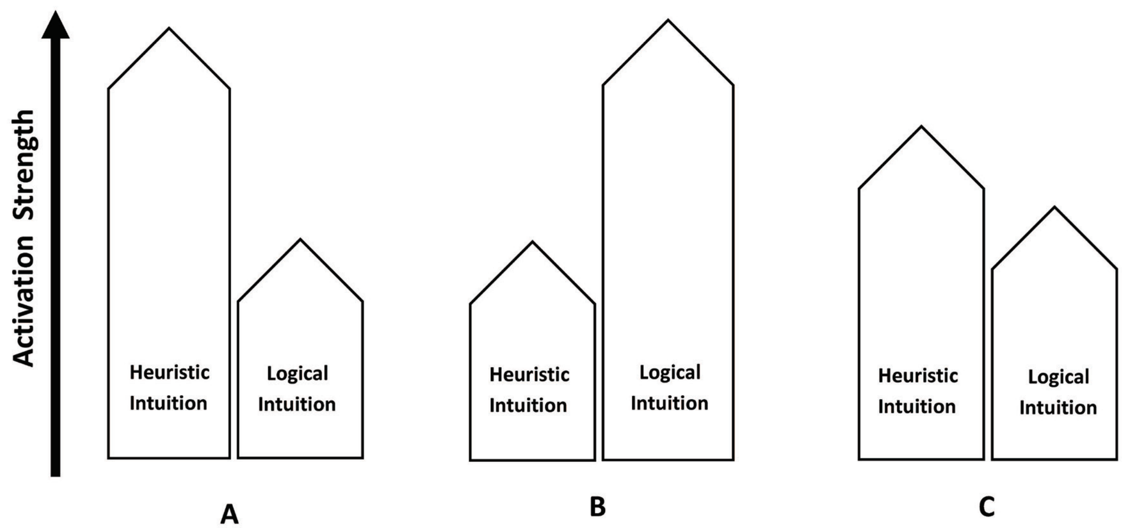

(Figure 4.2)

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