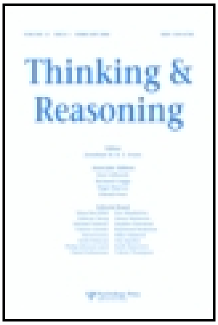

Thinking & Reasoning
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/ptar20

Conflict detection, dual processes, and logical intuitions: Some clarifications

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Published online: 03 Dec 2013.

Thinking & Reasoning, 2013
http://dx.doi.org/10.1080/13546783.2013.854725

Routledge
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Conflict detection, dual processes, and logical intuitions: Some clarifications

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Recent studies on conflict detection during thinking suggest that reasoners are sensitive to possible conflict between their heuristic judgement and elementary logical or probabilistic principles. I have argued that this conflict sensitivity calls for the postulation of logical intuitions and has implications for the way we conceive the interaction between System-1 and System-2 in dual process theories. In this paper I clarify potential misconceptions about this work, discuss the link with other approaches, and sketch directions for further research.

Keywords: Reasoning; Dual processes; Conflict detection.

When I started learning about biases in human thinking as an undergrad, I typically failed to solve the famous demonstration problems about feminist bank tellers, introvert engineers, and walking whales that I encountered in my textbooks. Just like the vast majority of educated participants who have been presented these tasks over the last decades, I typically tended to give the intuitively cued heuristic response and ended up being biased. However, although I did not manage to give the correct response,[1] I also found the

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I would like to thank Valerie Thompson, Jonathan Evans, and two anonymous reviewers for their comments on an earlier draft of this manuscript. In addition, presentation of the arguments here has benefited from discussions with Jean-François Bonnefon, Linden Ball, Magda Osman, Henrik Singmann, and my colleagues at the LaPsyDE in Paris. Preparation of the manuscript was supported by a grant from the Agence National de la Recherche [grant number ANR-12-JSH2-0007-01].

[1] For clarity, the reader should note that I am using the label "correct" or "logical" response as a shortcut to refer to "the response that has traditionally been considered as correct or normative according to standard logic or probability theory". The appropriateness of these traditional norms has sometimes been questioned (e.g., see Stanovich & West, 2000, or Evans & Over, 1996, for a review). Under this interpretation, the heuristic response should not be labelled as "incorrect" or "biased". For the sake of simplicity I stick to the traditional labelling. In the same vein, I use the term "logical" as a general header to refer both to standard logic and probability theory.

problems to be tricky and felt that something wasn't quite right with my answer. Over the last five years or so I have been running a set of studies that focused on this feeling. I have reviewed these so-called *conflict detection* studies and discussed their theoretical implications in a number of recent papers (e.g., De Neys, 2012; De Neys & Bonnefon, 2013). In this special issue paper I would like to clarify some potential misconceptions about this work, discuss the link with other approaches, and sketch directions for further research. For completeness, I will start with a very brief overview of the basic rationale and findings.

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The conflict detection studies have focused on people's processing of the famous demonstration problems that have been studied for decades in the reasoning and decision-making field (e.g., base-rate neglect tasks, ratio-bias tasks, conjunction fallacy, belief bias syllogisms, etc.). Giving the correct response in these tasks requires only the application of some very basic logical or probabilistic principles. However, the problems are constructed such that they intuitively cue a tempting heuristic response that conflicts with these principles. Consider, for example, the following adaptation of the classic base-rate neglect problem (Kahneman & Tversky, 1973):

> A psychologist wrote thumbnail descriptions of a sample of 1000 participants consisting of 5 women and 995 men. The description below was drawn randomly from the 1000 available descriptions.
>
> Sam is a 25 years old writer who lives in Toronto. Sam likes to shop and spends a lot of money on clothes.
>
> What is most likely?
>
> a. Sam is a woman.
>
> b. Sam is a man.

Intuitively many people will be tempted to conclude that Sam is a woman based on stereotypical beliefs cued by the description. However, given that there are far more males than females in the sample (i.e., 995 out of 1000) the base-rates favour the conclusion that a randomly drawn individual will most likely be a man. In other words, taking the base-rates into account should push the scale to the "man" side. Unfortunately, educated reasoners are typically tricked by their heuristic intuitions and fail to solve these types of problems correctly (e.g., De Neys & Glumicic, 2008).

The basic question that the detection studies have been trying to answer is whether people are sensitive to the intrinsic conflict between the cued heuristic response and the basic logical or probabilistic principles that are evoked in these problems, regardless of the response they eventually produce. Bluntly put, the studies try to establish whether biased reasoners at least notice that their heuristic response is questionable. Therefore the studies typically contrast people's processing of the traditional problem versions with newly constructed control versions. In the control or no-conflict versions the conflict is removed and the cued heuristic response is consistent with the response cued by consideration of the logico-probabilistic principles. For example, a no-conflict control version of the above base-rate problem would simply switch the base-rates around (i.e., the problem would state that there are 995 women and 5 men in the sample). Hence both heuristic considerations based on the description and logical ratio considerations cue the exact same response (see Appendix for illustrations of conflict and no-conflict versions of other classic tasks that have been used in the conflict detection studies).

In a nutshell, the conflict detection studies have introduced a range of processing measures to examine whether people process the conflict and no-conflict versions differently. The basic rationale for this design is that if people do not know the relevant logical principles, or if they are not used for monitoring conflicts, the two versions of the problem should be isomorphic and processed in the same manner.

Results of the studies typically suggest that reasoners (biased and unbiased alike) are sensitive to conflict. For example, it has been shown that even for biased reasoners, solving conflict problems as compared to their control versions resulted in increased response times (Bonner & Newell, 2010; De Neys & Glumicic, 2008; Stupple & Ball, 2008; Villejoubert, 2009; but see also Pennycook, Fugelsang, & Koehler, 2012), increased autonomic activation (De Neys, Moyens, & Vansteenwegen, 2010), increased activation of brain regions supposed to be mediating conflict detection (De Neys, Vartanian, & Goel, 2008), increased inspection of logically critical problem parts (Ball, Philips, Wade, & Qualyle, 2006; De Neys & Glumicic, 2008; Morsanyi & Handley, 2012a), and a decreased accessibility of semantic knowledge related to the intuitive heuristic response (De Neys & Franssens, 2009). In addition, biased reasoners also show a decreased response confidence after solving the classic conflict version of a problem (De Neys, Cromheeke, & Osman, 2011; De Neys & Feremans, 2013; De Neys, Rossi, & Houdé, 2013). All these results suggest that biased reasoners detect conflict just as unbiased reasoners do, and sense that their heuristic response is questionable. The fact that even biased reasoners show these conflict-related processing effects has been taken as evidence that bias does not result from a failure to detect conflict per se (Bonner & Newell, 2010; De Neys, 2012; De Neys & Glumicic, 2008; Morsanyi & Handley, 2012b; Villejoubert, 2009).

CLARIFICATIONS

Are the findings reliable?

I believe that one strong point of the conflict detection studies is that the findings have been validated using a range of different methods and problems. To recap, on the method side, evidence for successful detection has been reported using response times measures (Bonner & Newell, 2010; De Neys & Glumicic, 2008; Stupple & Ball, 2008; Villejoubert, 2009), eye tracking and gaze tracking (Ball et al., 2006; De Neys & Glumicic, 2008; Morsanyi & Handley, 2012a), memory probing (De Neys & Franssens, 2009; De Neys & Glumicic, 2008; Franssens & De Neys, 2009), confidence measures (De Neys & Feremans, 2013; De Neys et al., 2011, 2013), skin conductance responses (De Neys et al., 2010), EEG (De Neys, Novitskiy, Ramautar, & Wagemans, 2010), and fMRI (De Neys et al., 2008). On the problem side, findings have been validated with base-rate neglect problems (e.g., De Neys & Feremans, 2013; De Neys & Glumicic, 2008; De Neys et al., 2008; Morsanyi & Handley, 2012a), conjunction fallacy problems (De Neys et al., 2011; Villejoubert, 2009), ratio-bias problems (Bonner & Newell, 2010), belief bias syllogisms (De Neys & Franssens, 2009; De Neys et al., 2010), and the bat-and-ball problem (De Neys et al., 2013; Rossi, Cassotti, Agogué, & De Neys, 2013). In my own research I have explicitly been looking for such converging evidence to make sure that the findings were not driven by one or the other specific measurement or task confound. For completeness, I should also stress that my direct colleagues and I are not the only ones who have been demonstrating people's conflict sensitivity. Related findings have been reported by independent researchers across the world (e.g., Bonner & Newell 2010; Morsanyi & Handley, 2012a, 2012b; Stupple & Ball, 2008; Villejoubert, 2009). In sum, I believe that this generalisation across tasks, methods, and labs lends credence to the findings and underscores their reliability.

Problems with base-rate neglect problems?

A number of recent papers have questioned whether conflict detection findings might be driven by specific tasks features of the base-rate neglect problem version that I have used in my studies (e.g., Pennycook et al., 2012; see also discussion section of Klauer & Singmann, 2012). I address these comments here but first explain the rationale behind the selection of the task version that my colleagues and I adopted.

Why adaptations? In the first conflict detection studies that I ran (De Neys & Glumicic, 2008; De Neys et al., 2008) I decided to focus on Kahneman and Tversky's base-rate neglect or "lawyer-engineer" problem. Given the popularity of the problem it seemed like a good starting point. However, in the planning stages of the fMRI study that I had in mind, it became clear that to minimise potential complications we would need to make some adaptations to the classic task. Note that in the original lawyer-engineer task participants were asked to make an open-ended probability estimate and were given a 70/30 base-rate ratio. For a number of somewhat trivial reasons (e.g., the availability of an appropriate response box in the scanner) we decided we needed to opt for a binary response option. In and by itself this should not be a problem. However, it might become a problem when combined with the 70/30 base-rate ratio. The "correct" interpretation or norm of the base-rate problem has long been debated (e.g., Gigerenzer, Hell, & Blank, 1988). For example, from a Bayesian perspective one needs to combine the information contained in the base-rates (e.g., P[woman]) and description (i.e., P[description/woman]) to compute the probability that the person described in the description is a member of the specified group (i.e., P[woman/description]). The information value of the description can be quantified in pilot testing where participants are presented with the description in isolation (without the base-rate information) and are asked to rate how likely it is that it describes a member of each of the two groups that are specified (e.g., males or females). Overall, the typical values for the selected descriptions in our study where .80 and .30 for the most and least likely group, respectively. Now, when these values are entered in Bayes' theorem one can see that with the original 70/30 ratio, for example, the probability that the Sam character in the introductory example is a woman would be .53.[2] Hence, with a binary format, both someone who totally disregards the base-rates and a reasoner who correctly applies Bayes' theorem would pick the response that is cued by the description (i.e., it is most likely that Sam is woman, P[man/description] = .47). This potential problem is sidestepped when the base-rates are made more extreme.[3] For example, with the 995/5 base-rate value that we decided to opt for in our studies, Bayes' theorem stipulates that the probability that the Sam character in the example is a woman is less than .02. This guarantees that even a very approximate

[2] P[woman/description] = P[description/woman] * P[woman]/ (P[description/woman] * P [woman] + P[description/man] * P[man]).

[3] Clearly this only holds when the descriptions themselves are not too extreme. For example, if the description were to state that "the person gave birth to two children" even very extreme base-rates of males vs females in the sample would not warrant answering that Sam is a man. Obviously care was taken to avoid such extreme descriptions. The overall .80 and .30 description ratings of the selected descriptions guarantee that this condition was met (De Neys & Franssens, 2009; Franssens & De Neys, 2009).

Bayesian reasoner would need to pick the response cued by the base-rates (and answer “man” in the example).

Problems with extreme base-rates? Our initial findings indicated that our problem adaptations did not boost participants’ reasoning performance. As in the classic study of Kahneman and Tversky (1973), only a small minority managed to give the correct response on conflict problems. Furthermore, thinking-aloud protocols also showed that, although we used extreme base rates, participants did not explicitly mention that they were using these (De Neys & Glumicic, 2008). Furthermore, when we used less-extreme base-rates in subsequent studies (e.g., 95/5, see De Neys & Franssens, 2009; or 9/1, see De Neys & Feremans, 2013), we still observed successful conflict detection.

This convinced me personally that the problem adaptations, and specifically the extreme base-rates, were not affecting the detection findings. However, recent empirical data suggest I might have been wrong in this respect (Pennycook et al., 2012). In their study Pennycook et al. correctly note that even a 95/5 (or 9/1) ratio is more extreme than the original 70/30 ratio. In an extensive set of experiments Pennycook et al. replicated De Neys and Glumicic’s (2008) latency findings when using the 995/5 base-rate ratio: Even biased reasoners showed longer latencies for conflict vs no-conflict problems. However, when tested with the classic 70/30 base-rate and identical descriptions, the effect was no longer significant. Hence this indicates that conflict detection, as indexed by latencies, is more pronounced when more extreme base-rates are being used. Pennycook et al. suggested that the more extreme-base rates help to focus attention on the base-rate information and thereby facilitate conflict detection.

There are two points that I would like to make with respect to these findings. First, the general idea that task characteristics and contextual cues can serve as an attentional marker that might help conflict monitoring is making good sense, of course (e.g., Kahneman, 2011; Kahneman & Frederick, 2005). Such facilitatory effects have been demonstrated in elementary cognitive control studies (e.g., Botvinick, Cohen, & Carter, 2004). Note that my colleagues and I have also shown how conceptually related cueing (e.g., apparent stimuli movement in number conservation tasks, see De Neys, Lubin, & Houdé, 2013; or repeated testing, see De Neys et al., 2011, Experiment 3) can help to boost conflict detection in younger age groups with more limited detection skills. Second, although I still believe that the base-rate problem is a great tutoring tool, with hindsight the Pennycook et al. findings also suggest that it might not have been the best choice to start studying conflict detection questions (see Bonner & Newell, 2010, for a related claim; see also Bourgeois-Gironde & Vanderhenst, 2009). Indeed, I believe it is quite pointless to get stuck in a discussion about what the “correct” or “appropriate” base-rates or format should be in this specific task. In my view it is more fruitful to move to different tasks and test whether the basic findings hold across the board. The key point that I want to stress is that such generalisation has been presented. To be clear, although the initial conflict detection studies focused on base-rate problems, later work validated the initial findings with a range of problems and methods (including the ratio-bias problem and bat-and-ball problem advocated by Bonner & Newell and Bourgeois-Gironde & Vanderhenst; see above). Obviously it is always possible that one or the other specific task or method feature is driving the effects in each specific task. My point is simply that convergent evidence with different task and methods renders this possibility unlikely. Therefore I believe that the currently available data present quite convincing evidence for the claim that people are in general sensitive to the conflict between cued heuristics and basic logical principles during reasoning. In my view these data need to be taken into account and explained by any decent contemporary reasoning or decision-making framework.

Logical intuitions, feelings of rightness, Type 3, and dual processes

In my own attempts at making theoretical sense of the findings I have argued that the successful nature of conflict detection calls for the postulation of *logical intuitions* (De Neys, 2012). In a nutshell, the idea is that to detect conflict between intuitively cued heuristic intuitions and logical principles, the logical principles need to be activated at some level. The logical intuition suggestion boils down to the claim that this knowledge is implicit in nature and is activated automatically when people are faced with a reasoning task. In other words I suggest that, in addition to the well-established heuristic response, the classic reasoning tasks also automatically evoke an intuitive logical response. Whenever these responses conflict, arousal will be created. People will notice this arousal, and this will result in a questioning of the heuristic response. However, people will typically not manage to label this experience explicitly. That is, people will be aware that there is something fishy about their heuristic response, but they will not be able to put their finger on it and explain why their response is questionable (hence the idea of conflict detection as a "gut feeling"; see De Neys et al., 2010). Nevertheless, the logical intuition suffices to signal that the heuristic response is questionable (see De Neys, 2012, for a detailed account and empirical support).

I have argued that the logical intuition proposal has implications for dual process theories because it sketches a potential mechanism that allows us to decide whether it is needed to engage in deliberate System-2 thinking. This System-1/System-2 "switch" issue has puzzled dual process theorists for a long time (e.g., Evans, 2007). Bluntly put, the problem is that any realistic dual process model needs a way to detect whether System-2 thinking is required without having to engage in System-2 thinking (e.g., Evans, 2009;

Thompson & Morsanyi, 2012; Thompson, Turner, & Pennycook, 2011). The cueing of an intuitive logical response can help to solve this conceptual puzzle. If the intuitive System-1 cues both a logical and heuristic response, potential conflict can be detected without prior engagement of System-2. Hence the idea is that (rather than parallel activation of the two systems, e.g., Epstein, 1994; Sloman, 1996) there would be parallel activation of two different types of intuitive System-1 responses: A heuristic intuitive response based on mere semantic and stereotypical associations, and a logical intuitive response based on the activation of traditional logical and probabilistic principles. If the two intuitive responses are consistent, people will select the cued response, and the reasoning process ends without further deliberate System-2 reflection. Any conflict between the two responses would signal the need to engage System-2. Clearly the fact that deliberate operations are called upon does not imply that they will be successfully recruited or completed. However, it does present a clear switch rule to determine whether System-2 thinking is required.

I would like to stress explicitly here that my switch-mechanism proposal shares important conceptual ground with a number of recent proposals in the literature. The common ground boils down to the idea that the System-1/System-2 switch mechanism is an intuitive, automatic process that is effortless and does not require executive resource demanding System-2 thinking. This idea is indeed gaining ground in the field (e.g., Alter, Oppenheimer, Epley, & Eyre, 2007; Oppenheimer, 2008; Thompson, 2009; Thompson & Morsanyi, 2012; Thompson et al., 2011; Topolinski, 2011). For example, Thompson and colleagues (e.g., Thompson, 2009; Thompson & Morsanyi, 2012) have recently suggested that the switch decision might be affective in nature (but see also Alter, Oppenheimer, & Epley, 2013). Thompson and colleagues linked this affective switching idea to the metacognitive memory literature (e.g., Koriat, 1993) and labelled it the "feeling of rightness" or FOR. Their basic suggestion is that our intuitive System-1 judgements are always accompanied by an affective FOR response. The affective FOR response is assumed to arise from the fluency with which the initial answer is produced, such that fluently produced answers give rise to a strong FOR. Dysfluent processing, on the other hand, will result in negative affect and will lower the FOR.[4] A low FOR will signal the need to recruit System-2 thinking.

Evans (2009) has also stressed that the decision to engage System-2 cannot itself be based on System-2 thinking. Evans has therefore suggested that

[4] As a side-note I would like to highlight that Thompson and Morsanyi (2012) also mention that conflict between competing task cues might be one of the factors that will give rise to dysfluent processing and a low FOR. I believe this is an interesting idea that might allow us to integrate the conflict detection/logical intuition work and the FOR framework.

the switch decision would be mediated by what he refers to as a Type-3 (or System-3) operation. The key point is that this Type-3 monitoring process is also conceived to be automatic, unconscious, and independent from the executive resource-demanding processing that is typical for System-2 thinking.

Note that the switch mechanism suggested by the logical intuition framework (and the conflict detection findings) has two key components: conflict detection (or the switch decision) is typically (a) effortless and (b) successful. I tried to clarify in the above paragraph that there is indeed growing support for part (a) of the idea in the dual process community. However, I believe that the second point sets the different proposals apart. Indeed, a key finding in the conflict detection studies (and one of the reasons to posit logical *intuitions*) is precisely that even biased reasoner show the conflict signals. Moreover, the conflict signal, as measured for example by electrodermal recordings (e.g., De Neys et al., 2010), does not seem to be larger for unbiased reasoners than biased reasoners. Hence it does not seem to be the case that unbiased reasoners are necessarily better at conflict detection or more sensitive to conflict than unbiased reasoners. This suggest that the problem with judgement bias in general is not that people fail to detect the need to recruit System-2 thinking, but rather that this System-2 thinking is subsequently not successfully completed. In my view this is where my work differs with Thompson's and Evans' suggestions. In these frameworks a "switch" detection failure (i.e., a high FOR on conflict problems for biased reasoners or an unsuccessful Type-3 process) seems to play a more prominent role as cause of bias. For example, Thompson et al. (2011) and Thompson (2009) write:

> These data provide an explanation for the ubiquity of so-called reasoning biases (and the confidence with which they are held). Specifically, many of the classic reasoning problems prompt a response from automatic processes, such as linguistic comprehension, stereotyping, belief-evaluation, and imagery Kahneman, 2003; Stanovich, 2004). The ease with which these responses come to mind may create a sense of rightness that prevents subsequent analysis (Simmons & Nelson, 2006; Thompson, 2009). That is, these processes may create an experience of fluency that is strong and that results in a high FOR, which, in turn, signals that further analysis is not required. (Thompson et al, 2011,p. 135)

> Although studied extensively in other domains, the role of metacognitive processes in reasoning have been relatively neglected. However, it is almost certain that they play the same kind of role as they do in other judgments; namely, to provide a means to assess the output of one's cognitive processes and determine whether further action should be taken. Under this view, the explanation for the compellingness of many cognitive illusions is that the heuristic response is generated with a strong intuition that the answer is correct. It is this intuition, or Feeling of Rightness (FOR), that is the reasoner's cue to look no further afield for the answer. (Thompson, 2009, p. 175)

In other words, in general, one might suggest that the overall success rate of the conflict detection component in reasoning and decision making tasks is considered to be lower in Evans' and Thompson's work than in the logical intuition framework.[5]

To avoid confusion I should stress that my arguments here obviously focus on the conflict detection process. This does not imply that conflict detection is the only basis of FOR in Thompson's framework (e.g., see Thompson et al., 2013). In addition, I do not claim that Thompson or Evans would argue that conflict detection is necessarily unsuccessful for biased reasoners or that conflict detection failures are the sole cause of thinking bias. I believe that everyone in the field agrees that bias can have multiple causes and that the precise nature of bias will be contingent on task, context, person, or developmental factors (e.g., De Neys & Bonnefon, 2013; Reyna & Brainerd, 2011; Stanovich & West, 2008). For example, Thompson's experimental work (e.g., Thompson et al., 2011) shows that after giving a first initial response, biased reasoners may spend additional time rethinking their answer. Although they did not change their final answer, the additional processing time can be taken as an index of System-2 engagement. This illustrates that Thompson's work does not equate bias and a System-2 engagement failure. Clearly my arguments here concern what we consider to be the modal or typical reason for a biased response. My point is simply that, in this respect, detection failures are less prominent according to me than according to Thompson or Evans.

Finally, I readily acknowledge that the ultimate nature of the System-2 completion failure in the logical intuition framework is still open to different interpretations and remains to be clarified (e.g., De Neys & Bonnefon, 2013; De Neys & Franssens, 2009). This will need to be addressed in future studies. However, the framework (i.e., the empirical conflict detection data) does suggest that we can question the idea that the common failure to recruit System-2 thinking needs to be typically attributed to a mere failure to detect the need for such more reflective and demanding thinking.

Other (dual process) issues

In this section I would like to address a number of further issues that frequently come up in discussions with colleagues.

[5] I do realise that it is always hard to translate predictions across different frameworks. The way I see it, the critical question is whether the FOR/Type3 signal for conflict vs no-conflict problem is different for biased and unbiased reasoners or not. My point is that if the FOR/Type3 response reflects the same signal that is picked up in the conflict detection studies, even biased reasoners should show a lower FOR on the conflict problems.

Why are we still biased if we have the right (logical) intuitions? Some scholars wonder how it is possible that, if our System-1 is already cueing the correct response, reasoners nevertheless end up being biased: Why would people give a heuristic response if they detect that it is questionable? Here it is important to stress that conflict detection is a necessary condition for sound reasoning but not a sufficient one. Just as knowing that smoking is bad for you does not suffice to quit smoking, so successful conflict detection will not protect you against bias in and by itself. Clearly, after successful conflict detection, the conflict will still need to be resolved, for example by overriding the salient and tempting heuristic intuition. I have argued that the conflict detection findings indicate that the modal nature of heuristic bias can be attributed to a failure during this inhibition stage (De Neys & Bonnefon, 2013). In dual process terms I believe that it is at this point that proper, deliberate System-2 thinking is required. However, as I stressed in the previous paragraph, the precise nature of this inhibition failure (or System-2 completion failure) remains to be clarified. As De Neys and Bonnefon (2013) stipulated, one potential reason for the failure might be that biased reasoners lack the motivational and/or cognitive resources to complete the demanding inhibition process. Another possibility is that an intuitive heuristic response is only overridden when the conflict detection is followed by deliberate System-2 thinking and proper validation and justification of the initial logical intuition (e.g., by working memory demanding hypothetical thinking, e.g., Evans & Stanovich, 2013). Hence here System-2 would be specifically needed to "double-check" or validate the logical intuition. In sum, the demanding nature of what I refer to as the inhibition stage might not lie in the deactivation of the heuristic intuition per se, but rather in the fact that such deactivation will not be undertaken without production of an explicitly verified "logical" response. It is clear that the empirical conflict detection findings do not address this issue. Hence the conflict detection findings do not tell us why people are biased. The point is that they allow us to eliminate a prominent role for one potential candidate: detection failures.

A related question is why, if we really have both a logical and heuristic intuition, it is the heuristic intuition that typically wins in case of conflict. Why is it that without further System-2 involvement we typically give the heuristic answer and not the intuitive logical one? As I tried to clarify earlier (De Neys, 2012), it is important to stress that positing that people have both a heuristic and logical intuition does not entail that both intuitions have the exact same status or strength. I find it quite plausible that the heuristic intuition might be more strongly activated, salient, or appealing than the logical intuition (e.g., see also Pennycook & Thompson, 2012; Pennycook, Trippas, Handley, & Thompson, in press). I claim that conflict between the heuristic and logical intuition will make people question their heuristic intuition. However, this does not imply that people consider the logical response to be fully warranted. In absolute terms the intuitive heuristic response might still be stronger than the logical intuition. All that is needed is that conflict lowers the default activation or confidence level of the heuristic response. The point is that such an activation or confidence drop can serve as a signal to recruit System-2.

Do you favour a parallel, default-interventionist, or some hybrid dual process model? I believe that the conflict detection findings and Logical Intuition suggestion call for a hybrid view in which there is parallel activation of two different types of System-1 processes and an optional stage of System-2 processing (see De Neys, 2012, Figure 1, p. 34). To recap, my claim is that, rather than parallel activation of two systems, there would be parallel activation of two different types of intuitive System-1 processes: an intuitive heuristic process based on mere semantic and stereotypical associations, and what I refer to as an intuitive logical process based on the activation of traditional logical and probabilistic principles. Hence it is the "internal" System-1 conflict that triggers System-2.

I agree with proponents of the default-interventionist view (e.g., Evans & Stanovich, 2013; Kahneman, 2011; Thompson, 2009) that it makes no sense to postulate that people simultaneously engage both full-blown System-2 and System-1 processing from the start. However, to put it in default-interventionist terms, my point is that part of our default processing is the activation of stored knowledge about class inclusion, proportionality, simple logical rules, etc. It is the automatic activation of this implicit knowledge that I refer to as "Logical Intuitions". To be clear, once the default System-1 activation includes these logical intuitions, my view fits with the default-interventionist characterisation.

Are people consciously aware of the conflict? I avoid making strict claims about awareness and consciousness because they are such ill-defined, multilayered, complex concepts that seem bound to be misinterpreted. I try to stay close to the empirical data and opt for neutral terms (e.g., "detection" or "sensitivity").[6] What the data show us is that, on one hand, biased reasoners question their heuristic answer in case of conflict, as expressed in lowered confidence ratings for example (e.g., De Neys et al., 2011, 2013). However, on the other hand, thinking-aloud protocols and retrospective response justifications indicate that biased reasoners do not explicitly refer to conflict with logical principles or manage to justify why they are biased (e.g., De Neys & Glumicic, 2008; Evans & Over, 1996). That is why I conceive conflict detection as a gut feeling (De Neys et al., 2010; Franssens &

[6] In my experience it is hard to find labels that please everyone in this respect. Opinions on how "neutral" these labels are seem to differ widely.

De Neys, 2009): People know that their answer is not fully warranted but they do not know why. As I clarified, I argue that conflict between a logical and heuristic intuition creates arousal. To be clear, within the above boundaries, I would say that people experience this arousal consciously. Hence, in that sense one can claim that people are consciously aware that there is conflict. However, the point is that reasoners do not have conscious access to the nature or source of this conflict. That is, at the detection stage, people do not explicitly conceptualise it as a conflict between a heuristic response and a logical principle. I believe that this will require a proper justification and validation of the initial logical intuition. As I argued before, I believe that such validation is not possible without System-2 thinking and I agree with most theorists that biased reasoners fail to complete this stage.[7]

Boundary conditions

It is important to keep some critical boundary conditions and qualifications in mind when evaluating my claims with respect to the successful (or "flawless", e.g., Franssens & De Neys, 2009) nature of conflict monitoring and the logical intuitions proposal. I discuss these below and point out how these suggest new directions for further research:

Do we always detect conflict? Task difficulty. My claims apply specifically to the classic reasoning and decision-making tasks that have been the basis for most of the theorising in the reasoning and decision-making field (e.g., base-rate neglect task, conjunction fallacy, ratio-bias, bat-and-ball problem, belief-bias syllogisms, etc.). To be clear, I do not argue that people have logical intuitions about each and every problem that they need to solve in life. One of the main reasons for postulating that people intuitively consider the logical and probabilistic principles that are evoked in the classic problems is precisely the fact that these principles are so elementary and typically acquired quite early in life (see De Neys, 2012, for illustrations). In this respect the proposal should be distinguished from popular science claims that tend to celebrate the "unlimited power" of unconscious thinking (e.g., Dijksterhuis, 2007; Gladwell, 2005), for example. To be clear again, I would explicitly predict that more difficult tasks that require more complex logical or probabilistic computations will not give rise to conflict detection. A key condition for logical intuitions to arise is that the principles in question are automatically activated. Except for some highly trained expert

[7] As a side-note, an interesting observation in this respect is that in the thinking-aloud studies of De Neys and Glumicic (2008) with base-rate problems, the few people who explicitly referred to the base-rates when solving conflict problems were those reasoners who also gave the correct response.

logicians, the average reasoner is so infrequently exposed to complex logical arguments that I find it highly unlikely that these principles will have been automatised. Obviously, establishing which tasks and difficulty levels give rise to logical intuitions is an empirical question. While I suspect that the necessary conditions are met for most classic reasoning and decision-making tasks, I believe that precisely specifying and delineating these boundary conditions will be a key area for future research. For example, an interesting research strategy would be to measure conflict detection efficiency as a function of problem difficulty (e.g., one vs multiple model belief bias syllogisms).[8] My prediction here would be that conflict detection will become less likely for the more difficult task versions.

Note that it is also possible to sketch a priori criteria that might help us to determine whether a certain task will give rise to a logical intuition or not. One of the arguments that De Neys (2012) used to validate the logical intuition proposal was that adults typically show good performance when tested with so-called abstract versions of the classic conflict problems (e.g., Kahneman & Tversky, 1973). These abstract versions do not cue an intuitive heuristic response. For example, an abstract problem version of the introductory base-rate problem might not present a description, and simply ask whether it is most likely to draw a female or a male from a sample with 995 women and 5 males. The good performance with abstract versions established that reasoners are indeed familiar with the basic logico-mathematical principles that are evoked in the classics tasks. Hence one a priori condition to determine whether a new task will give rise to a logical intuition is that adults should show good performance with abstract versions. On top of that, an additional requirement for logical intuitions to arise is that the principles will be activated automatically. Given that this automatisation will require some repeated exposure and practice, one can also predict that the good performance with abstract versions will be observed at fairly early stages of our development.

Does everyone detect? University students. Another qualification that one needs to bear in mind is that the conflict detection studies have been typically run with *university* students. Of course, even the most biased university students with the lowest cognitive capacity scores are still pretty gifted and well educated when contrasted with the population at large. Currently we do not know whether the conflict results generalise to less-gifted and/or less-educated samples in the population (or uneducated samples in rural

[8] Note that my own studies with belief bias syllogisms (e.g., De Neys & Franssens, 2009; De Neys et al., 2010) adopted the problems that were extensively studied in Stanovich and West's research (e.g., 2000, 2008; see Appendix for an example). These are quite basic conditional syllogisms that require knowledge of the Modus Ponens and Affirmation of the Consequent rule.

societies, for example). Because the logical principles we are looking at are so basic, I am quite confident that even very basic formal education and cognitive skills should suffice for the intuitions to arise. However, this is ultimately an empirical question and remains to be tested.

Does everyone detect? Adults. My claims typically entail the performance of young *adult* participants. Clearly the fact that adults seem to have little difficulty detecting conflict does not imply that detection failures cannot play a more crucial role earlier on in our reasoning development. In fact, this hypothesis receives some support from basic neurological studies that suggest that the anterior cingulate cortex, the critical brain structure that is supposed to be mediating elementary conflict monitoring, is quite slow to mature and would only reach full functionality throughout adolescence (e.g., Davies, Segalowitz, & Gavin, 2004; Fitzgerald et al., 2010; Santesso & Segalowitz, 2008). Together with a number of colleagues I recently started to explore and test this developmental conflict detection hypothesis (e.g., De Neys & Feremans, 2013; De Neys et al., 2011; Rossi et al., 2013; Steegen & De Neys, 2012). The initial findings indeed suggest that conflict detection increases throughout adolescence (see De Neys, in press, for a review). In my view a further exploration of the developmental modulation of the conflict detection efficiency (and specifically its neurological basis) is also a prime area for further research.

Does everyone detect? Group vs individual level analysis. It is important to emphasise that, even in the studies with educated adults, work on conflict detection has focused on the *modal* or *average* biased reasoner. That is, as is often the case in reasoning and decision making research, the analyses are run at the group level and contrast the average performance of groups of biased and unbiased reasoners. By and large, these analyses allow us to draw conclusions about the typical nature of a biased response, as given by the majority of biased reasoners. The important theoretical implication from this work is that heuristic bias does not *typically* result from a conflict detection failure. However, even when the group analyses focus on the average performance of the most extremely biased reasoners (e.g., De Neys & Franssens, 2009; De Neys & Glumicic, 2008) this does not entail that there cannot be some individuals in the group who are biased for different reasons (De Neys & Bonnefon, 2013; Stanovich & West, 2008). It will be interesting to directly look for and characterise such individuals. Therefore future conflict detection studies will need to move from a group-level (biased vs unbiased response) to an individual-level analysis. Although this poses some practical challenges (e.g., need to test large samples, sensitivity of the detection measure, etc.), it will clearly present a valuable extension of the existing work.

CONCLUSION

To wrap up, I hope that this paper has clarified that the empirical work on conflict detection is fairly reliable, has interesting theoretical dual process implications, and leads to new predictions that can be tested in future studies. However, I also fully acknowledge that the conflict detection studies and the emerging theoretical ideas about logical intuitions are still quite "young". Obviously, further testing and fine tuning will be required in the coming years. Nevertheless, although the work might not yet have reached the status of a fully matured framework, I believe it has important implications for the thinking and reasoning community and should be given serious consideration in our theory development.

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APPENDIX

Examples of conflict (left) and no-conflict (right) versions of classic tasks that have been used in conflict detection studies

Conjunction fallacy task:

Conflict version:

Bill is 34. He is intelligent, punctual but unimaginative and somewhat lifeless. In school, he was strong in mathematics but weak in social studies and humanities.

Which one of the following statements is most likely?

1. Bill plays in a rock band for a hobby
2. Bill is an accountant and plays in a rock band for a hobby

No-conflict version:

Bill is 34. He is intelligent, punctual but unimaginative and somewhat lifeless. In school, he was strong in mathematics but weak in social studies and humanities.

Which one of the following statements is most likely?

1. Bill is an accountant
2. Bill is an accountant and plays in a rock band for a hobby

Base-rate neglect task:

Conflict version:

A psychologist wrote thumbnail descriptions of a sample of 1000 participants consisting of 995 females and 5 males. The description below was chosen at random from the 1000 available descriptions.

Jo is 23 years old and is finishing a degree in engineering. On Friday nights, Jo likes to go out cruising with friends while listening to loud music and drinking beer.

Which one of the following two statements is most likely?

1. Jo is a woman
2. Jo is a man

No-conflict version:

A psychologist wrote thumbnail descriptions of a sample of 1000 participants consisting of 995 males and 5 females. The description below was chosen at random from the 1000 available descriptions.

Jo is 23 years old and is finishing a degree in engineering. On Friday nights, Jo likes to go out cruising with friends while listening to loud music and drinking beer.

Which one of the following two statements is most likely?

1. Jo is a woman
2. Jo is a man

Ratio bias task:

Conflict version:

You are faced with two trays each filled with white and red jelly beans. You can draw one jelly bean without looking from one of the trays. Tray A contains a total of 10 jelly beans of which 2 are red. Tray B contains a total of 100 jelly beans of which 19 are red.

From which tray should you draw to maximise your chance of drawing a red jelly bean?

1. Tray A
2. Tray B

No-conflict version:

You are faced with two trays each filled with white and red jelly beans. You can draw one jelly bean without looking from one of the trays. Tray A contains a total of 10 jelly beans of which 2 are red. Tray B contains a total of 100 jelly beans of which 21 are red.

From which tray should you draw to maximise your chance of drawing a red jelly bean?

1. Tray A
2. Tray B

Syllogistic reasoning task:

Conflict version:

Premises: All flowers need water

Roses need water

Conclusion: Roses are flowers

1. The conclusions follows logically
2. The conclusion does not follow logically

No-conflict version:

Premises: All flowers need water

Roses are flowers

Conclusion: Roses need water

1. The conclusions follows logically
2. The conclusion does not follow logically

Bat-and-ball problem:

Conflict version:

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

No-conflict version:

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