A perspective on the theoretical foundation of dual-process models

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Educating the mind without educating the heart is no education at all. – Aristotle (384 – 322 BCE)

Where the senses fail us, reason must step in. – Galileo Galilei (1564 – 1642 ACE)

The heart has its reasons of which reason knows nothing. – Blaise Pascal (1623 – 1662 ACE)

Faith consists in believing when it is beyond the power of reason to believe. – Voltaire (1694 – 1778 ACE)

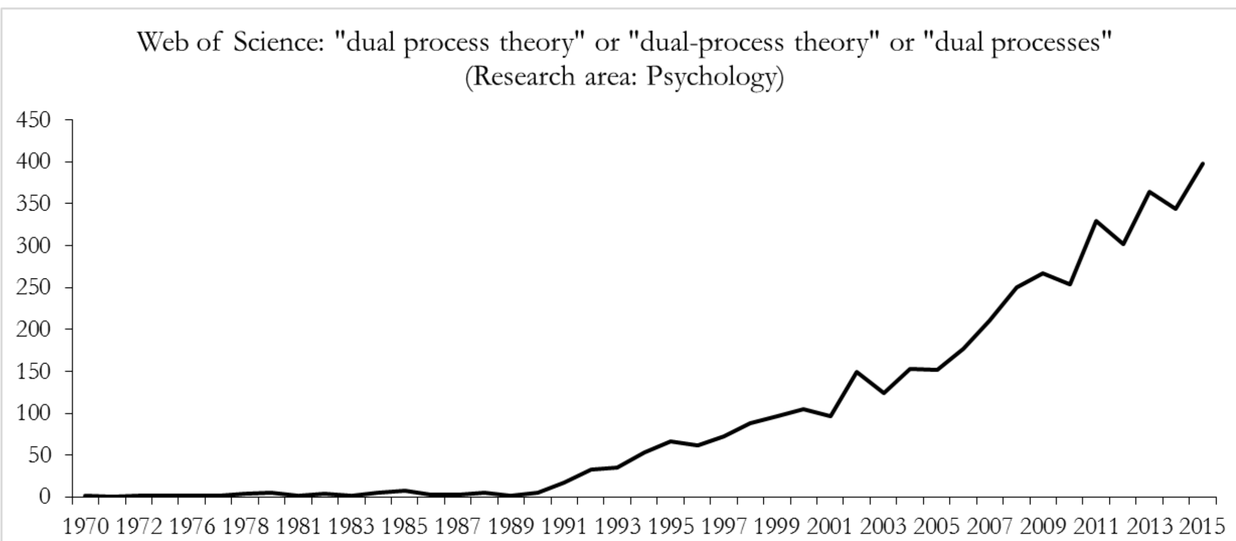
Reason is, and ought only to be the slave of the passions, and can never pretend to any other office than to serve and obey them. – David Hume (1711 – 1776 ACE)

Dual-process theories formalize a salient feature of human cognition: We have the capacity to rapidly formulate answers to questions, but we sometimes engage in deliberate reasoning processes before responding. It does not require deliberative thought to respond to the question "what is your name". It did, however, require some thinking to write this paragraph (perhaps not enough). We have, in other words, two minds that might influence what we decide to do (Evans, 2003; Evans & Frankish, 2009). Although this distinction is acceptable (and, as I'll argue, essentially irrefutable), it poses serious challenges for our understanding of cognitive architecture. In this chapter, I will outline what I view to be important theoretical groundwork for future dual-process models. I will start with two core premises that I take to be foundational: 1) dual-process theory is irrefutable, but falsifiable, and 2) analytic thought has to be triggered by something. I will then use these premises to outline my perspective on what I consider the most substantial challenge for dual-process theorists: We don't (yet) know what makes us think.

Introduction

The distinction between intuition (heart, senses, passion, faith) and reflection (mind, reason, analytic thinking) dates, at least, to antiquity and has been the object of philosophical musing for centuries (as evidenced by the opening quotations). It is perhaps unsurprising, then, that dual-process theories are popular in many domains of psychology (see Evans, 2008 for a review), such as reasoning (Evans, 1989; Sloman, 1996; Stanovich & West, 2000), decision making (Barbey & Sloman, 2007; Kahneman, 2011; Kahneman & Frederick, 2005), social cognition (Chaiken & Trope, 1999; Epstein, Pacini, Denes-Raj, & Heier, 1996), cognitive development (Barrouillet, 2011; Brainerd & Reyna, 2001; Klaczynski, 2001), clinical psychology (Beevers, 2005; Pyszczynski, Greenberg, & Solomon, 1999), and cognitive neuroscience (Goel, 2007; Greene, Sommerville, Nystrom, Darley, & Cohen, 2001; Lieberman, 2007). Indeed, as evidenced by Figure 1, dual-process theories in psychology have proliferated (see Frankish & Evans, 2009 for an historical overview).

Figure 1. Number of journal articles using the terms “dual process theory”, “dual-process theory”, or “dual processes” in the field of psychology since 1970. Search completed on November 25th, 2016.



Naturally, contemporary dual-process theories go well beyond the musings of philosophers like Aristotle and Voltaire (see De Neys, this volume). The proliferation of dual-process theories evidenced in Figure 1 corresponds with a proliferation of characteristics that have been used to distinguish the two types of processes. Intuitive (or ‘Type 1’, or ‘System 1’) processes have been considered autonomous, fast, domain specific, evolutionarily old, unconscious, high capacity, and associative (among others), whereas analytic (or ‘Type 2’ or

'System 2') processing has been considered deliberative, slow, domain general, evolutionarily young, conscious, capacity limited, and rule-based (among others). Recently, Evans and Stanovich (2013) noted that most of these are merely *correlated* features of intuition and reflection, and that a few characteristics can be isolated as *defining* features of Type 1 and 2 processes. Specifically, they argued that Type 1 processes operate autonomously and do not require working memory whereas Type 2 processes require working memory and allow for cognitive decoupling and mental simulation.

Evans and Stanovich's (2013) new synthesis represents a crucial step forward for dual-process theories insofar as they have provided a framework that can be used to organize and guide future theorization. This work corresponds with previous attempts to delineate and eliminate common fallacies in dual-process theorizing (Evans, 2012), such as the claim that intuition always leads to errors whereas reflection always produces normatively correct responses. Nonetheless, there is still much work to be done (hence the necessity of this volume). The goal of this chapter is to discuss what I think is the most crucial problem facing dual-process theories: We have a good sense of what intuitive and analytic processes *are*, but we do not have a good sense of how they *operate*. That is, dual-process theories have not sufficiently modelled analytic engagement.

My goal with this chapter is to lay out what I take to be the core theoretical foundations that should guide the pursuit of a better understanding of analytic engagement. I will then use these foundations to briefly outline an updated dual-process theory – the three-stage dual-process model (Pennycook, Fugelsang, & Koehler, 2015) – as a way to formalize and (begin to) address the crucial question: "What makes us think?" (i.e., What triggers Type 2 processing?).

Prior to outlining the three-stage dual-process model, which I view as largely a synthesis of previous models (with a few added components), I will explicate the two key premises that form the motivation for the model and by which the model is built. The premises are as follows:

Premise 1: Dual-process theory is irrefutable, but falsifiable.

Premise 2: Analytic thought has to be triggered by something.

These premises will provide the organization for the first half of this chapter.

Premise 1: Dual-process theory is irrefutable, but falsifiable

Evans and Stanovich (2013) isolated both autonomy and working memory as defining features of dual-process theories. However, it is only necessary for a single dimension to distinguish intuitive and reflective processes for the theory to be based on an acceptable proposition. Indeed, Thompson (2013) has argued that autonomy is the only feature needed to distinguish the two types of processes – an argument that I agree with. Thus, to understand why dual-process theory, at its most basic level, is irrefutable[1], the concept of autonomy needs to be explained.

Plainly, some cognitive outputs are engendered directly as a result of stimulus-response pairings. One cannot help but think of their name when asked "what is your name". Autonomous processes initiate and complete outside of deliberate control and there is little doubt that this is something that actually occurs in the mind (Stanovich, 2009).[2] However, there is also little doubt that humans are capable of reasoning in the absence of an immediate autonomous response. Consider the following arithmetic problems (c/o Thompson, 2013): [2 x 0 = ?] and [2217 x 72 =

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[1] A more accurate but clunky way to phrase this is: "the central claim on which dual-process theories rest is essentially irrefutable".

[2] This is a simplification as it is possible that autonomy occurs on a continuum. Regardless, just because autonomous thing differ on a continuum does not mean that some things are not best considered not autonomous. The reading of that sentence, for example.

?]. The former cues an autonomous response (assuming a basic level of mathematics education) whereas a response to the latter can only be generated with some effort. This highlights an important aspect of analytic processing: The reasoner can decide whether to carry-out (or continue carrying-out) a mental operation. That is, humans are able to decide about deciding. Crucially, this can occur even in cases where an intuitive response is evident. Imagine, for example, if you were told to perform addition when the symbol for multiplication was present. The problem [2 x 0 = ?] would still engender the initial response ('0'), but (under normal conditions) you would be able to stop yourself from answering '0' in lieu of the alternative analytic response ('2'). Naturally, one could also choose to not bother with the addition operation. Note in this case, the actual operation of adding 2 and 0 does not require analytic thought. Rather, replacing multiplication with addition is what requires analytic thought.

It is important to note that this is a falsifiable claim. It needn't be the case that people are capable of autonomous processing – 2 x 0 does not have to automatically equal 0[3]. Similarly, it needn't be the case that people must be able to purposefully deliberate. Bechara, Damasio, Damasio, and Anderson (1994) famously observed that patients with damage to the ventromedial prefrontal cortex are insensitive to the future consequences of decisions. Moreover, analytic thinking increases during adolescent development (Kokis, Macpherson, Toplak, West, & Stanovich, 2002). That most adult humans are capable of generating both intuitive and reflective answers to questions is merely an empirical observation. Dual-process theory – or, at least, the basic claim that individual dual-process theories all assume – is irrefutable. The very act of

[3] Even more complicated multiplication problems can be automatic and working memory independent (Ashcraft, Donley, Halas, & Vakali, 1992; Tronsky, 2005).

arguing against this proposition would require deliberative processes (following, perhaps, an autonomous visceral reaction to the polemical use of the term ‘irrefutable’).

The observation that the distinction between intuition and reflection is irrefutable is foundational because it means that dual-process models should not be concerned with justifying this claim. That is, dual-process models must take this distinction as a given and build from there. If we know with a reasonable degree of certainty that the mind has this capacity for two different types of processes (autonomous and non-autonomous), where do we go from there?

Premise 2: Analytic thought has to be triggered by something

The irrefutability of dual-process theory does not bear on its usefulness. Indeed, the true test of a good theory is whether it can be applied successfully to problems and generate hypotheses (see Evans & Stanovich, 2013 for a discussion of this issue in the context of DPT). Thus, the mere distinction between intuition and reflection based on autonomy is sufficient for the claim that dual-process theory is irrefutable, but not sufficient for the claim that the theory is worth anyone’s time. What is needed, then, is a discussion of the ways that the distinction bears on further cognitive processing. This can then be used to generate further hypotheses.

Focusing on autonomy as the defining feature that distinguishes intuitive and analytic processing is beneficial for more reasons than that it offers an irrefutable foundation for the theory. Namely, the concept of autonomy naturally leads to questions about the potential *source* of the cognitive output. For an autonomous intuitive response, the answer to the question is straightforward: The (proximal[4]) source of the response is the stimulus-response pairing(s). There is a direct and uninterrupted mapping between the stimulus and the intuitive output. This may be either external, such as when someone asks your name, or internal, such as through

[4] Delineating the ultimate source requires evolutionary theorizing, which is a separate topic.

associative processes (e.g., thinking about one's name could automatically prime aspects of self-concept).

But what is the source of an analytic response? Put differently, when analytic processing is used to engage in some way with representation content (e.g., via hypothetical thought; Evans, 2007), what causes the process to initiate? While there may be many answers to this question, it is important to note that some are more central to our understanding of cognitive architecture. For example, one way to force participants to initiate analytic thought is to simply instruct them to do so (Evans, Handley, Neilens, Bacon, & Over, 2010). There are also situations in which individuals should intuitively recognize when analytic thought is necessary. When an individual is handed an entrance exam, it is no mystery why they spent a lot of time pondering the questions contained therein. Regardless, even within these contexts there may be things that trigger increased analytic processing – such as a particularly difficult problem on an intelligence test. Moreover, there are many situations in which there is little obvious incentive to spend time thinking analytically, but at least some people nonetheless think analytically (at least some of the time). Thus, the task is to determine what causes individuals to engage analytic processing in the absence of some obvious situational or instructional cue (Gordon Pennycook et al., 2015).

To illustrate the phenomena of interest, consider the following problem (Frederick, 2005):

> A bat and ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost?

This problem, now famous, is one of three from the original Cognitive Reflection Test (CRT). The majority of participants answer $0.10 to this problem (e.g., 64.9% among Canadian undergraduate students; Pennycook, Cheyne, Koehler, & Fugelsang, 2016) although a cursory double-check shows that the ball cannot cost $0.10 as it would mean the bat would have to cost

$1.10 (totalling $1.20). Performance is surprisingly poor on the bat-and-ball problem because 10 cents comes to mind quickly and fluently – it is an autonomous intuitive response.

Still, some people do successfully solve the bat-and-ball problem (e.g., 30.3% in Pennycook, Cheyne, et al., 2016; very few give an answer other than $0.10 or $0.05). Moreover, accuracy on the CRT has been shown to correlate with a wide range of measures of psychological interest (see Pennycook, Fugelsang, & Koehler, 2015 for a review). Indeed, one only needs the single bat-and-ball problem to predict an impressive range of beliefs and behaviours. To demonstrate, I re-analyzed the studies that my research group published in the period between 2012 and 2016 (the duration of my Ph.D.) with the goal of demonstrating the predictive power of the single bat-and-ball problem. For simplicity, I did not include redundant measures (i.e., religious belief was included in various studies, but only the largest and most recent sample is shown in Table 1). Those who give the correct answer to the bat-and-ball problem differ on a wide range of measures, ranging from religious belief to morality to creativity to technology use to distress following sleep paralysis episodes. There is very strong evidence that the CRT (and the bat-and-ball problem) measures something that is of some importance for human psychology. It should also be noted that cognitive ability or intelligence rarely explain these correlations (see Pennycook, Fugelsang, et al., 2015). A wide range of other potential third-variables have been explored in some cases as well (most substantively in the case of religious belief, see Pennycook, 2014).

Table 1. Various correlates of the bat-and-ball problem. Participants were put into one of three groups based their answer. Means are of DVs converted to z-scores. See sources for more information on DVs. *** $p < .001$, ** $p < .01$, * $p < .05$. N's listed in subscript.

Source	Dependent Variable	Intuitive ($0.10)	Other (e.g., $1.05)	Correct ($0.05)	ANOVA
Pennycook, Ross, Koehler, & Fugelsang (2016) – Studies 1-4	Religious Belief	0.13 $_{(629)}$	0.10 $_{(40)}$	-0.21 $_{(394)}$	$F(2, 1060) = 14.97^{***}$
Barr, Pennycook, Stolz, & Fugelsang (2015) – Study 3	Online Smartphone Use	0.15 $_{(144)}$	0.20 $_{(10)}$	-0.32 $_{(73)}$	$F(2, 224) = 5.77^{**}$
Pennycook, Cheyne, Barr, Koehler, & Fugelsang (2015) – Study 1	Bullshit Receptivity	0.18 $_{(170)}$	0.14 $_{(16)}$	-0.36 $_{(93)}$	$F(2, 276) = 9.33^{***}$
	Ontological Confusions	0.20 $_{(170)}$	-0.08 $_{(16)}$	-0.35 $_{(93)}$	$F(2, 276) = 9.67^{***}$
Pennycook, Cheyne, Barr, Koehler, & Fugelsang (2014)	Moral Judgment (Disgust-based dilemmas)	0.24 $_{(280)}$	-0.54 $_{(16)}$	-0.29 $_{(204)}$	$F(2, 497) = 21.03^{***}$
	Traditional Moral Values	0.20 $_{(282)}$	-0.07 $_{(16)}$	-0.27 $_{(207)}$	$F(2, 502) = 13.58^{***}$
	Social Conservatism	0.14 $_{(281)}$	-0.37 $_{(16)}$	-0.17 $_{(207)}$	$F(2, 501) = 7.14^{**}$
	Fiscal Conservatism	0.10 $_{(281)}$	-0.37 $_{(16)}$	-0.11 $_{(207)}$	$F(2, 501) = 3.88^{*}$
Barr, Pennycook, Stolz, & Fugelsang (2015)	Cross Domain Analogy (Accuracy)	-0.22 $_{(60)}$	-- (3)	0.37 $_{(38)}$	$F(1, 96) = 8.82^{**}$
	Remote Associates Test (Accuracy)	-0.15 $_{(60)}$	-- (3)	0.27 $_{(38)}$	$F(1, 96) = 4.17^{*}$
Cheyne & Pennycook (2013)	Sleep Paralysis Post-Episode Distress	0.09 $_{(210)}$	-0.10 $_{(12)}$	-0.24 $_{(76)}$	$F(2, 295) = 3.09^{*}$
Pennycook, Cheyne, Seli, Koehler, & Fugelsang (2012) – Study 2	Paranormal Belief	0.11 $_{(196)}$	-0.11 $_{(11)}$	-0.27 $_{(76)}$	$F(2, 280) = 4.10^{*}$

The question, then, is what does the bat-and-ball question measure? Perhaps the most common argument is that the presence of the intuitive response means that one must be willing to think analytically to solve the problem (e.g., Pennycook & Ross, 2016). That is, the CRT is thought to measure one's propensity to engage in deliberative processing and override the incorrect intuitive response (Campitelli & Gerrans, 2014; Toplak, West, & Stanovich, 2014; Toplak, West, & Stanovich, 2011). This stance follows directly from Stanovich's (Stanovich, 1999, 2005; Stanovich & West, 2000; Stanovich & West, 1998; Stanovich, 2012) influential work distinguishing analytic thinking disposition from standard intelligence or cognitive ability. The argument, in short, is that both the *willingness* and *ability* to engage analytic reasoning are important components of human rationality.

This is a largely acceptable account of CRT performance, but a significant question remains: How does the analytic person know to engage analytic processing? Perhaps the answer is simply that analytic individuals are cautious when given reasoning problems. This may be an acceptable account when it comes to the bat-and-ball problem, but what of the wide variety of things with which the bat-and-ball problem correlate (Table 1)? The presumption here is that the bat-and-ball problem is predictive because the propensity to think analytically is applied not only to reasoning problems in psychology studies, but also in people's everyday lives (Pennycook, Fugelsang, et al., 2015). The idea that analytic people are simply cautious when given reasoning problems in the lab cannot explain why these people are also, evidently, more likely to think analytically about religious and paranormal claims, or how they use technology, or their sleep paralysis experiences, etc. There has to be something that spontaneously *triggers* analytic thought and the cues that cause people to think analytically in all of these cases surely differ. What this means is that dual-process theories require a mechanism to explain how the mind detects when analytic processing is necessary. Unfortunately, this problem has not received the attention that it deserves by dual-process theorists. Fortunately, there are some clues from related literatures.

Understanding what makes us think: Parallels between dual-processing and executive functioning

There is a very clear parallel between the foregoing and a diverse range of theorizing in the executive functioning literature. Indeed, the concepts used to explain dual-processes in reasoning are very similar to those used to explain cognitive control. The primary difference has to do with scope: Dual-process theorists are concerned with high-level reasoning tasks (often with response times of 15-30 seconds) whereas the cognitive control literature grapples with relatively low-level tasks (e.g., the Stroop task) with millisecond response times (RTs). Moreover, the cognitive control literature is characterized by a stronger focus on neuroscientific (Mars, Sallet, Rushworth, & Yeung, 2011) and computational (Botvinick & Cohen, 2014) models. Nonetheless, a key question for cognitive control has to do with determining what causes our cognitive system to engage controlled processing (Botvinick, Cohen, & Carter, 2004; Carter et al., 1998; Shenhav, Botvinick, & Cohen, 2013). Parsimony suggests that the low-level mechanism that triggers controlled processing also triggers analytic processing. Moreover, the difference between ‘controlled’ and ‘analytic’ processing may merely be one of scope[5].

According to Botvinick and Braver (2015) cognitive control refers to “that set of superordinate functions that encode and maintain a representation of the current task—i.e., contextually relevant stimulus-response associations, action-outcome contingencies, and target

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[5] Although I think that theorists who are interested in executive functioning would benefit from a greater understanding of phenomena in the reasoning literature, delineating how this might be achieved is beyond the scope of this chapter.

states or goals—marshaling to that task subordinate functions including working, semantic, and episodic memory; perceptual attention; and action selection and inhibition" (p. 85). The Stroop task, where conflict between colour words and colour names causes increased in RT, is a classic example of cognitive control task (MacLeod, 1991).

In parallel with the bat-and-ball example, part of the reason why people engage cognitive control on Stroop-like tasks is obvious: They were given a task to do and are simply completing it. Nonetheless, the reason why the Stroop task is interesting is because there are trials in which participants engage in more controlled processing (as indexed by increased RT). People spend more time when the colour word and name conflict than when they correspond. Moreover, incentives enhance cognitive control (as indexed by RTs on the Stroop task; Padmala & Pessoa, 2010). Thus, as with the explanation of the bat-and-ball problem, some aspect of cognitive control is discretionary. The question, then, is how does the cognitive system know when further processing is necessary?

Consider the comparison offered in Table 2. Verily, the Stroop task does not appear at all similar to the reasoning task (in this case, a base-rate neglect problem; De Neys & Glumicic, 2008). Nonetheless, in both cases there is a strong prepotent response. It has long been noted in the Stroop literature that reading the colour word ('BLUE') interferes with naming the word colour (red) (MacLeod, 1991). The cognitive control literature has therefore focused largely on response conflict as an initiator of controlled processing (see Botvinick & Cohen, 2014 for a historical overview). According to Botvinick and Cohen (2014), for example, "circumstances that demand control are typically characterized by the presence of processing conflict" (see also Berlyne, 1957) and "conflict is quantified as the coactivation of competing representations" (p. 1257). The monitoring of conflict is thought to occur in the anterior cingulate cortex, which then leads to controlled processing in the dorsolateral prefrontal cortex (e.g., Botvinick et al., 2004; Carter & van Veen, 2007; Shenhav et al., 2013).

Table 2. Comparison of a classic cognitive control task (Stroop, 1935) with a classic reasoning and decision making task (Kahneman & Tversky, 1973).

<table>
<tr><th colspan="2">A trial from the Stroop task</th><th colspan="2">A trial from a base-rate neglect task</th></tr>
<tr><td colspan="2">What colour is the word?

BLUE</td><td colspan="2">In a study 1000 people were tested. Among the participants there were 995 nurses and 5 doctors. Paul is a randomly chosen participant of this study.

Paul is 34 years old. He lives in a beautiful home in a posh suburb. He is well spoken and very interested in politics. He invests a lot of time in his career.

What is most likely?
(a) Paul is a nurse.
(b) Paul is a doctor.</td></tr>
<tr><td>Prepotent response:
Blue</td><td>Correct answer:
Red</td><td>Prepotent response:
Doctor</td><td>“Correct” answer:
Nurse</td></tr>
</table>

In parallel with the cognitive control literature, conflict has also been an important component of dual-process theorizing (Evans, 2007; Sloman, 1996). In fact, there are fMRI studies that report patterns of activation in the prefrontal cortex that correspond nicely to that reported in the cognitive control literature (e.g., Goel, Buchel, Frith, & Dolan, 2000; Goel & Dolan, 2004; Stollstorff, Vartanian, & Goel, 2012). Moreover, the congruence-sequence effect (Egner, 2007) – a crucial finding in the cognitive control literature wherein the effect of conflict on Stroop-like tasks is smaller after incongruent (conflict) relative to congruent (non-conflict trials) – has recently been reported in the context of a decision-making paradigm (Aczel & Palfi, 2017). This indicates parallel modulation of control following conflict processing in quite different paradigms.

In the case of the base-rate task, there is a strong tendency for people to respond according to the intuitive stereotypical information presented in the personality description despite the presence of objective and contradictory base-rate information about the sample (this is the “representativeness heuristic”; (Kahneman & Tversky, 1973; see Pennycook & Thompson, 2016 for a review). A core finding is that people tend to take longer and are less confident when given “conflict” versions of this task (as seen in Table 2) relative to “non-conflict” versions (e.g., if the base-rates were reversed in the Table 2 example), even in cases when the stereotypical response is given (De Neys, Cromheeke, & Osman, 2011; De Neys & Glumicic, 2008). This indicates that the conflict between base-rate and stereotype has an effect on later reasoning.

Notably, De Neys, Vartanian, and Goel (2008) found increased activation in the anterior cingulate cortex when participants gave stereotypical responses to incongruent (conflict) versions of base-rate problems relative to congruent (non-conflict) baseline. De Neys et al. also reported increased activation in the right lateral prefrontal cortex when participants override the intuitive stereotypical response in lieu of the alternative base-rate response. This directly parallels neuroimaging experiments in the cognitive control literature – a remarkable convergence given the difference between the tasks (as illustrated in Table 2; see also Simon, Lubin, Houdé, & De Neys, 2015).

The foregoing indicates a strong convergence between two very different literatures. There is, however, one key difference in terms of theorizing: Cognitive control theorists have grappled with “disarming the homunculus” (Botvinick & Cohen, 2014) – that is, a source of intelligence used to fill theoretical gaps – more seriously and substantially than have dual-process theorists. The conflict monitoring hypothesis (e.g., Botvinick et al., 2004) requires only the coactivation of competing responses to explain what initiates control. Modeling work illustrates how cognitive control can be adjusted based on "local computations" (basically, comparisons of coactivated response outputs; see Botvinick & Cohen, 2014).

As has been argued elsewhere (Pennycook, Fugelsang, et al., 2015), the most common assumption among dual-process theorists is that Type 2/System 2 (analytic) processing is responsible for monitoring the output of Type 1/System 1 (intuitive) processes (Evans, 2006; Kahneman & Frederick, 2005; Stanovich, 1999). When considered in light of the question "what makes us think" and alongside research on cognitive control, it is clear that this assumption is untenable. Type 2 processing cannot be responsible for monitoring Type 1 processing because Type 2 processing would therefore have to be responsible for its own initiation. Type 2 processing would have to cause itself. This indicates that a third process is necessary to explain how Type 1 and Type 2 processes interact (Thompson et al., 2013; Thompson, Prowse Turner, & Pennycook, 2011; Thompson, 2009; Thompson & Morsanyi, 2012).

An important downstream consequence of the foregoing assumption is that conflict in reasoning tasks has most commonly been considered a conflict *between* Type 1 and Type 2 processes (De Neys & Glumicic, 2008; Evans, 2007; Sloman, 1996). This is also an untenable position: If it's the conflict between Type 1 and Type 2 responses that initiates Type 2 processing, how was the initial Type 2 response generated? The only possible answer that I can see is that the Type 2 response was generated as a direct result of the stimulus, which then presumes that it was generated autonomously. This violates the key component of the first premise (that Type 1 and 2 processes are distinguished by autonomy) and would therefore mean that dual-process theory is not only refutable, but easily so.

Two conclusions emerge from this line of reasoning: 1) In keeping with the cognitive control literature, conflict during reasoning should be considered a result of the coactivation of competing *Type 1* responses, and 2) Considering the reasoning process in stages may help delineate what is causing what. I will conclude by discussing these in the context of two recent dual-process models.

The logical intuition model

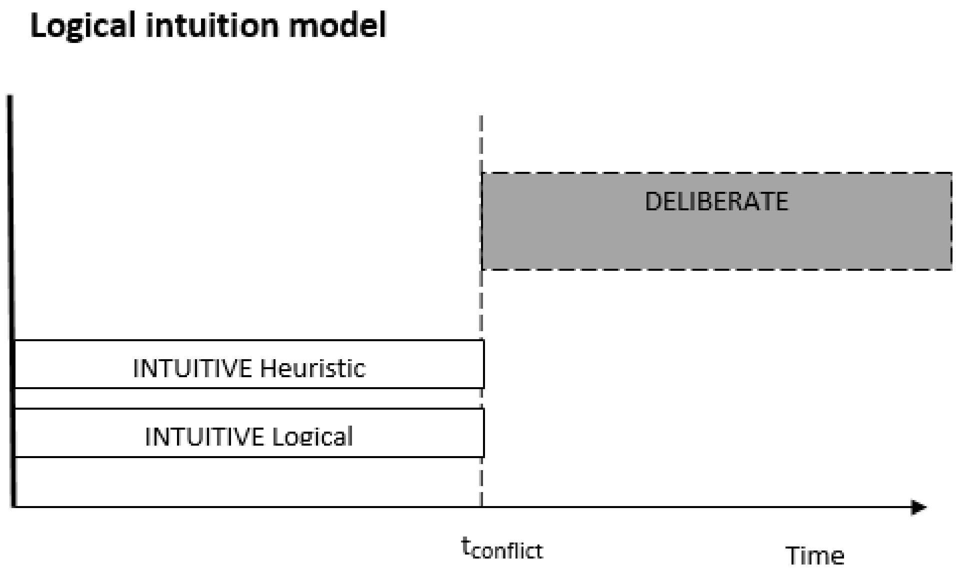
As outlined elsewhere in this volume (De Neys, others?), evidence that people are capable of detecting conflicts between reasoning outputs has been mounting (De Neys, 2012; De Neys, 2014). Evidence from RT, confidence, and neuroimaging experiments in the context of base-rate neglect has already been discussed. However, there is also good evidence for successful detection of conflict between logic and belief in the context of syllogistic reasoning (De Neys & Franssens, 2009; Handley, Newstead, & Trippas, 2011; Handley & Trippas, 2015; Trippas, Handley, Verde, & Morsanyi, 2016). There is even evidence for conflict detection (via confidence measures) in the context of the bat and ball problem that was introduced earlier in this chapter (De Neys, Rossi, & Houdé, 2013; Johnson, Tubau, & De Neys, 2016; but see Travers, Rolison, & Feeney, 2016)[6]. A wide range of additional dependent variables has been employed, including memory recall (De Neys & Franssens, 2009; De Neys & Glumicic, 2008), skin conductance response (De Neys, Moyens, & Vansteenwegen, 2010), liking ratings (Morsanyi & Handley, 2012; Trippas, Handley, et al., 2016), eye tracking (Ball, Phillips, Wade, & Quayle, 2006), and ERP (Banks & Hope, 2014; De Neys, Novitskiy, Ramautar, & Wagemans, 2010).

[6] Although I must admit that it is unclear to me what is conflicting with what in this problem. It is clear that the correct answer is not being computed intuitively otherwise accuracy would be much higher. Speculatively, it may be that participants pick up on the mismatch between the (apparent) easiness of the problem and the fact that a psychologist deemed it necessary to administer the problem.

The tension that these results revealed for dual-process models was evident from the outset. If there are two types of processes that are capable of producing different answers, what process determines if those answers correspond? De Neys and Glumicic (2008) used "shallow analytic monitoring" (SHAM) to explain how a type of Type 2 processing could accomplish this. However, the SHAM was clearly patchwork – it was thought to "always accompany" heuristic (intuitive) processing but also is not "full-fledged" analytic thinking (p. 1278). It is not clear what makes this monitoring process "analytic", apart from the fact that it held the function that was typically attributed to analytic processing (an untenable attribution, as I have outlined above). From what I can tell, SHAM was only referred to directly in one subsequent publication (Pennycook & Thompson, 2012), although it was discussed indirectly by Bonner and Newell (2010).

The core theoretical insight that emerged from this line of work was that conflict detection effects can be parsimoniously explained by appealing to a conflict between intuitions (De Neys, 2012; Pennycook & Thompson, 2012). De Neys' logical intuition model formalized this argument (De Neys, 2012; De Neys, 2014; De Neys & Bonnefon, 2013, see Figure 2). The term "logical intuition" refers to the observation that, in the context of the reasoning paradigms that have been employed, conflict detection relies upon the presence of some sort of intuition that emerges from more logical considerations or principles.

Figure 2. Updated logical intuition model (De Neys, personal communication). Analytic (deliberate, Type 2) processing is represented by the gray bar and intuitive (Type 1) processing by the white bars. The horizontal axis represents time. Deliberate processing is triggered by conflict ($t_{conflict}$) between intuitive 'heuristic' and intuitive 'logical' processing. The dashed lines represent the "optional nature of the triggered deliberate processing" (De Neys, personal communication).



The logical intuition model (Figure 2) was, in my view, an important step forward for the dual-process literature (for another important perspective, see Handley & Trippas, 2015, Trippas, this volume). Nonetheless, there are elements that I disagree with. First, and most pedantically, I view the term "logical intuition" to be unnecessarily specific. It is perfectly possible (and perhaps more common) for *illogical* intuitions to conflict and lead to analytic processing. That intuitions have the appearance of logicality in some situations does not mean that this is necessary for Type 1-Type 1 conflict to initiate Type 2 processing. Indeed, one of the things that I think will be important for future theorizing is a broader view of intuitions.

Second, and more substantively, the logical intuition model assumes perfectly efficient (De Neys, 2012) – or, at least, highly efficient (De Neys, 2014, Figure 2) – conflict detection. One of the key arguments is that even particularly biased individuals detect conflicts (De Neys & Bonnefon, 2013). This is a crucial issue because it tells us about the source of bias. Namely, if biased individuals successfully detect conflicts, bias cannot be the result of lax conflict monitoring and must therefore be the result of faulty Type 2 processing (e.g., through inhibition failures). This has been the context that the logical intuition model has been largely framed.

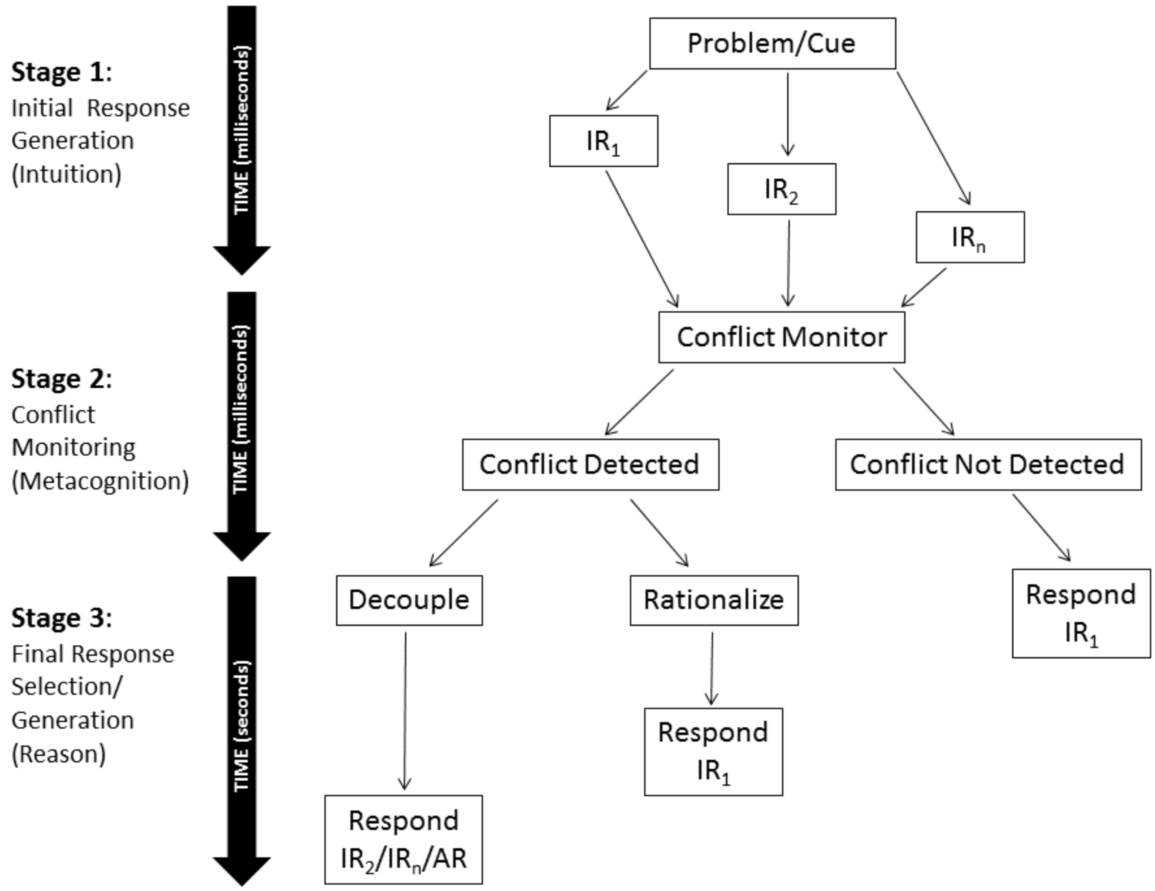
There are, however, reasons to believe that conflict detection is not highly efficient in terms of initiating analytic thinking. Pennycook, Fugelsang, and Koehler (2012) found that subtle manipulations to prior probabilities in base-rate neglect problems was sufficient to abolish the increase in RT for stereotypical response. Specifically, there was consistent evidence for conflict detection when base-rates are extreme (e.g., 995 lawyers, 5 engineers), but no evidence when base-rates were implicit (e.g., by using natural base-rates, such as between the low number of statistics majors and high number of psychology majors at the University of Waterloo) or moderate (e.g., 70 lawyers, 30 engineers). Later work with a larger set of base-rate problems that produce shorter and more reliable RTs (i.e., a more sensitive measure) successfully found a conflict detection effect using moderate base-rates (Pennycook, Fugelsang, & Koehler, 2015b). However, this effect was driven primarily by a small number of individuals who were particularly *un*biased (that is, they did not fall prey to the stereotypes as consistently as most). In other words, conflict detection was evident among those who demonstrated a propensity to override the intuitive stereotypes – presumably because conflict detection leads to analytic thinking, which increases the likelihood of analytic override of stereotypical responses. There was little-to-no evidence of conflict detection among those who primarily gave stereotypical responses (the particularly 'biased' individuals). This negative correspondence between bias and conflict detection has been reported elsewhere as well (Mevel et al., 2015). This indicates that conflict detection errors do occur and are an important component of biased responding.

One possibility, discussed by Pennycook, Fugelsang, et al. (2015b), is that conflict *detection* is efficient in the sense that the signal in the anterior cingulate cortex is usually present, but that some people are not *responsive* to conflict. Indeed, there is evidence that people with an intuitive thinking disposition have smaller conflict detection effects (RT differences for base-rate problems; Pennycook, Cheyne, Barr, Koehler, & Fugelsang, 2014; Pennycook, Fugelsang, et al., 2015b). Regardless, in the context of the dual-process models, conflict detection that does not cue a meaningful (detectable) increase in analytic processing should not, in my opinion, be considered "efficient". That is to say, it is important to include this aspect of conflict detection in our dual-process models. This leads me to the three-stage model.

The three-stage model

The evidence for conflict detection inefficiency complicates the picture offered by the fairly straightforward logical intuition model. Most directly, if conflicts are sometimes not detected, what determines the likelihood of conflict detection? Given that, in accordance with the cognitive control literature (as discussed above), conflict detection can be viewed as a key determinant of analytic thinking, the underlying processes that influence conflict detection can be considered a window into the key question of 'what makes us think'. This is the context within which the three-stage model (Figure 3) was developed. I will focus on the components of the three-stage model that bear on the current issue ('what makes us think') for present purposes. For further discussion of the third stage of the model and, in particular, the distinction between rationalization and decoupling, see the full explication of the model in Pennycook, Fugelsang, et al. (2015b).

Figure 3. Three-stage dual-process model of analytic engagement (Pennycook, Fugelsang, et al., 2015b). IR = initial response. IR's are numbered to reflect alternative speeds of generation – it is the difference between generation speeds (answer fluency) that determines the likelihood of conflict detection. IR1 is the most salient and fluent possible response. IRn refers to the possibility of multiple, potentially competing, initial responses. AR = alternative response. IRn refers to the possibility of an alternative response that is grounded in an initial response.



Given the foundational claim that intuitive processing is autonomous (as argued above), it must also therefore be the case that more than one intuition (IR) can come to mind in parallel. That is, autonomous processes are the result of activated stimulus-response pairings and more than one stimulus-response pairing is always possible (if not probable). Moreover, as discussed above, evidence for parallel processing has been mounting (Bago & Neys, 2017; Handley et al., 2011; Newman, Gibb, & Thompson, 2017; Pennycook, Trippas, Handley, & Thompson, 2014; Trippas, Handley, et al., 2016; Trippas, Thompson, & Handley, 2016). Thus, in the first stage of the model, problems/cues/stimuli may automatically lead to the generation of more than one initial response (IR). These are intuitive or heuristics responses, although the labels are generic as the model need not apply only to the sorts of responses typical associated with “intuition”.

That is, the first initial response (IR_1) could very well refer to the output of the colour reading process in the Stroop task (and, likewise, IR_2 would refer to the output of the colour naming process).

As argued by Thompson, Ackerman, et al. (2013) (see also, Pennycook, Trippas, Handley, & Thompson, 2014; Thompson & Johnson, 2014), some intuitive responses should reasonably be expected to come to mind faster than others – a concept referred to as answer fluency. This aspect of autonomous output generation is not a component of the logical intuition model (Figure 2, but see De Neys, 2014). However, in the three-stage model, answer fluency is displayed as the length of arrow between the problem and the IR (short arrows indicate a very fast and fluent answer). Crucially, it is the association between the answer fluencies of the initial responses that determines the likelihood of successful conflict detection. That is, two IRs that come to mind in close succession (both could be fast and fluent or relatively slow and disfluent) are likely to be recognized as conflicting (it should be noted that IRs may actually coincide, in which case conflict would not be detected). This admittedly abstract discussion of conflict monitoring accords with neurocomputational models of cognitive control which, as quoted above, quantify “conflict” as the “coactivation of competing representations” (Botvinick & Cohen, 2014).

The question, then, is what evidence is there that the difference in processing fluencies of initial responses determines the likelihood of conflict detection. The answer is, unfortunately, very little. It is possible that moderate (as opposed to extreme) base-rates lead to less fluent (or less consistently fluent) intuitive responses, thereby explaining why moderate base-rates apparently decrease the likelihood of conflict detection (Pennycook, Fugelsang, et al., 2015b).

However, this is more of an explanation of a known effect using the three-stage framework than evidence for the framework itself.

Limitations and future directions

As is often the case, the *explanans* gained from conflict detection experiments has created a new *explanandum*. If conflict detection causes analytic thinking, what determines the success of conflict detection? Here I've furthered the proposal (from Pennycook, Fugelsang, et al., 2015b) that the difference in processing fluencies of initial (intuitive) responses determines the likelihood of successful conflict detection. I believe that this is a solid proposal because if follows from the following premises:

1) More than one autonomous response is always possible.

2) It is unlikely that autonomous responses are equally fluent. That is, stimulus-response pairings are sometimes strong and sometimes weak. Moreover, some responses (such as stereotypical responses) are strongly favored over others (such as base-rate responses).

3) Conflict monitoring relies on the coactivation of competing responses.

If these premises are sound, as I believe them to be, it follows that fluency differences should result in differential coactivation and, in turn, differential likelihood of conflict detection. Nonetheless, future research is required to test this idea directly.

Another issue for the three-stage model is that it is vague in terms of metacognitive processes. Consider, for example, recent findings from experiments using the 2-response paradigm (Thompson et al., 2011). In these studies (see Thompson, this volume), participants are asked to a) quickly give the first response that comes to mind, b) indicate how "right" that response "feels", and c) give a second response (a "final answer") over free time. A crucial finding from this paradigm is that less fluent initial responses (i.e., slower IRs) are positively associated with lower feelings of rightness, which is positively associated with time spent giving the final answer (Bago & De Neys, 2017; Thompson & Johnson, 2014; Thompson, Ackerman, et al., 2013; Thompson, Evans, & Campbell, 2013; Thompson et al., 2011). Importantly, the presence of conflict decreases feelings of rightness in these experiments as well. Bago and De Neys (2017) recently found that confidence was lower for the initial response (implying a higher degree of experienced conflict) when participants ultimately changed their answer relative to when the first and final answer stayed the same (see also Thompson & Johnson, 2014). This pattern of results indicates subtle (and early) changes in confidence levels as a function of conflict. Thus, in keeping with the three-stage model, Bago and De Neys argued that this pattern of results could be explained by activation differences between alternative intuitive (logical and heuristic) responses. Again, however, these results do not offer direct evidence that differential response fluencies determine the likelihood of conflict detection. This is an important area for future research.

Conclusion

The capacity to reason is arguably the feature that most saliently sets humans apart from other animals (Stanovich, 2005). The dual-process framework is a solid theoretical[7] approach to understanding human reasoning and decision making. Indeed, as I've argued, the foundation of dual-process theory – that is, the assumption of autonomous processing – is essentially irrefutable (but falsifiable). However, as evidenced by this volume, there are notable gaps in the dual-process theory literature. One of the most important gaps is the lack of solid explanation of how analytic thinking is actually triggered. I have reviewed the background of this problem and offered my own perspective. Specifically, there is now considerable evidence that conflict

[7] Or, perhaps, metatheoretical (Evans & Stanovich, 2013).

monitoring is a key determinant of analytic thinking. This parsimoniously accords with evidence and theorizing from the parallel cognitive control literature. Nonetheless, this has merely pushed the explanation of what causes us to think back a level. There is still much work to be done and my goal for the present chapter was to facilitate this progress. My stance is that the three-stage model is certainly incorrect, but it may be correct enough to be useful. This is also my stance on the current chapter.

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