Commentary on De Neys (in press): Reframing Single- and Dual-Process Theories as Cognitive Models[1]

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De Neys (in press) argues that the debate between single- and dual-process theorists of thought has become both empirically intractable and scientifically inconsequential. I argue that this is true only under the traditional framing of the debate—when single- and dual-process theories are understood as claims about whether thought processes share the same defining properties (e.g. making mathematical judgments) or have two different defining properties (e.g. making mathematical judgments autonomously vs. via access to a central working memory capacity), respectively. But if single- and dual-process theories are understood in cognitive modelling terms as claims about whether thought processes function to implement one or two broad types of algorithms, respectively, then the debate becomes scientifically consequential and, presumably, empirically tractable. So, I argue, the correct response to the current state of the debate is not to abandon it, *contra* De Neys (in press), but to reframe it as a debate about cognitive models.

Keywords: dual-process theory; analytic engagement; algorithm; cognitive model

De Neys (in press) argues that the debate between single- and dual-process theorists of thought has become both empirically intractable and scientifically inconsequential: there is neither the evidence nor the need to determine whether intuition (generally known as Type-1 processing) and deliberation (generally known as Type-2 processing) are *qualitatively* or only *quantitatively* different.

From a theoretical perspective, though, this debate *must* matter, because psychology is a science and positing types (of psychological processes) is indispensable to scientifically generalizing over observations (of behaviour). So, whether intuition and deliberation belong to the same or different types is no less relevant to psychology than whether, e.g., dorsal- and ventral-stream visual processing belong to the same or different types.

In this commentary, I argue that De Neys (in press) draws this conclusion because the debate is traditionally framed as whether Type-1 and Type-2 processing have *sufficiently* different properties to count as qualitatively different. But this debate is better framed in terms of cognitive models—as whether thought processes function to implement one or two types of algorithms. And this framing makes the debate theoretically interesting and, hence, scientifically consequential.

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§1. Differences in Dual Properties

Dual-process theories typically distinguish between the dual properties of Type-1 and Type-2 processing: e.g. being automatic vs. effortful (Kahneman, 2011), autonomous vs. attentionally controlled (Evans & Stanovich, 2013), and intuitive vs. deliberative (De Neys, in press). But dual properties lie on opposite ends of continuums: e.g. being autonomous vs. attentionally controlled lie on opposite ends of the continuum of attentional control (Keren & Schul, 2009; Kruglanski & Gigerenzer, 2011; De Neys, in press).

If Type-1 and Type-2 processing are defined by being autonomous vs. attentionally controlled, respectively, then they also lie on opposite ends of a continuum. There is a sense in which this is already enough to conclude that there is no *qualitative* distinction between Type-1 and Type-2 processing (Keren, 2013; Kruglanski, 2013; Osman, 2013). But dual-process theorists suggest that there is another sense in which *qualitative* differences are just *sufficiently-large quantitative* differences (Samuels, 2009; Evans & Stanovich, 2013).

De Neys (in press) is right to argue that this suggestion is irrelevant to psychology. For one, no amount of data can tell us whether the differences between, e.g., intuition and deliberation are *sufficiently* small to count as quantitatively different or *sufficiently* large to count as qualitatively different. For another, this semantic/metaphysical debate is inconsequential: knowing whether the differences between intuition were sufficiently small or large wouldn't allow us to make "a single prediction… about how intuition and deliberation work and how they interact" (De Neys, in press).

§2. Differences in Functional Algorithms

However, there are better ways to distinguish between two types of cognitive processes than by distinguishing between their dual properties. For example, in the cognitive modelling literature, types of cognitive processes are distinguished in virtue of the different types of discrete information-processing tasks (i.e. *algorithms*) that the cognitive processes function to implement (e.g. Marr, 1982; Pylyshyn, 1984; Anderson, 1990; Griffiths et al., 2015).

I recommend that dual-process theorists take the cognitive modelling approach and argue that there are two interestingly-distinctive types of algorithms that are functionally implemented by thought processes. Then the thought processes that function to implement Type-1 and Type-2 algorithms are Type-1 and Type-2 processes, respectively. Likewise, I recommend that single-process theorists should deny this: they should argue that there's no interesting way to partition the algorithms that are functionally implemented by thought processes into two types.

§3. Analytic Engagement

Let's make my proposal a bit more concrete by considering one theoretical approach for resolving this debate. One of the primary themes of modern dual-process theories, which De Neys (2017) has classified as "Dual-Process Theory 2.0", is *analytic engagement*: the process of engaging additional computational resources when conflict is detected in processing (e.g. Thompson et al., 2011, 2013; Pennycook et al., 2015; De Neys & Pennycook, 2019). One

consequence of analytic engagement is that it distinguishes processes that *precede* it from processes that *follow* it.

I propose that dual-process theorists should argue that (initial) analytic engagement is an all-or-nothing process that makes a discrete (initial) amount of computational resources available for generating and selecting responses.[2] Then analytic engagement would be a discrete event that *qualitatively* distinguishes processes that precede it from those that follow it. This would be the *defining* qualitative distinction, then: Type-1 processes are the type of processes that function to implement their algorithms *before* analytic engagement and Type-2 processes are the type of processes that function to implement their algorithms *after* analytic engagement.

§4. Typological Constraints

But we already know that qualitative distinctions are cheap: we could just as easily define Type-1 processes as those that involve less than X amount of control and Type-2 processes as those that involve more than X amount of control. But we obviously *shouldn't* draw that distinction because it's arbitrary and uninteresting. The lesson is that distinctions belong in our typology only if they are non-arbitrary and interesting. But this raises an important question: the qualitative distinction between processes that precede vs. follow analytic engagement wouldn't be arbitrary, but would it be *sufficiently* interesting to deserve inclusion into our typology?

The cognitive modelling perspective suggests that this defining distinction only matters if it creates interesting differences in the distinguished sets of algorithms.[3] For example, analytic engagement might create interesting differences in cost.[4] Preceding processes might implement *discretely-less*-expensive algorithms—from suboptimal rules like the substitution heuristic on the bat-and-ball task (Kahneman & Frederick, 2005) to optimal rules like the take-the-best heuristic on decision tasks (Gigerenzer & Goldstein, 1996). By comparison, following processes might implement *discretely-more*-expensive algorithms—from optimal rules like the algebraic solution to the bat-and-ball task (Kahneman & Frederick, 2005) to suboptimal rules like multiple regressions on decision tasks (Gigerenzer & Goldstein, 1996).

This difference in the cost of algorithms that precede and follow analytic engagement would be interesting, but it probably wouldn't be sufficient to individuate the set of substitution heuristics, take-the-best heuristics, etc. as Type-1 algorithms and the set of algebraic solutions, multiple regressions, etc. as Type-2 algorithms. Dual-process theorists would still need to look for other interesting differences between these two sets of algorithms. So, it's an open and empirical

[2] Such a proposal is neuroscientifically plausible: *initial* analytic engagement could just be the initial recruitment of a threshold-gated control network and any *subsequent* analytic engagement could just be the continuous modulation of the network by signals that cross the threshold gate. After all, thresholds are ubiquitous in neural systems.

[3] These are known in philosophy as "homeostatic property clusters" (Boyd, 1991): e.g. an underlying mechanism distinguishes two clusters of correlated properties, such that the defining distinction is the different relations of the two clusters to the underlying mechanism but the correlated distinctions are what determine whether the defining distinction is sufficiently interesting to be included in a scientific typology. See Samuels (2009) for a full, related discussion of homeostatic property clusters in dual-process theories.

[4] These correlated differences in the cost of algorithms are *quantitative*, but that doesn't undermine dual-process theory because these differences only serve to make the *defining qualitative* distinction (i.e. between processes that precede and follow analytic engagement) sufficiently interesting to include in our typology.

question whether there are *enough* interesting differences to justify individuating these two sets as Type-1 and Type-2 algorithms. But my proposal is just that this is the empirical commitment that dual-process theories should make: the processes that precede and follow the discrete event of analytic engagement implement two interesting types of algorithms and so deserve to be distinguished as Type-1 and Type-2 processes, respectively.

§5. Typological Onus

Critics have two ways to refute this formulation of dual-process theory. First, they may argue that (initial) analytic engagement is an ongoing process that continuously modulates the amount of computational resources that is available for generating and selecting responses. Then analytic engagement would be a *continuous* process, which can't distinguish between processes that "precede" and "follow" it. Second, they may argue that even if analytic engagement is a discrete, all-or-nothing event, the differences in the algorithms that are functionally implemented before and after analytic engagement aren't sufficiently interesting to classify them as Type-1 and Type-2 algorithms. Then there wouldn't be reason to individuate the processes that precede and follow analytic engagement as Type-1 and Type-2 processing, respectively.

Notice how the debate becomes much easier for single-process theorists than for dual-process theorists: the former only need to falsify two bold predictions whereas the latter need to confirm them. But dual-process theorists can't complain that the debate is rigged. After all, both single-process and dual-process theorists agree that there is one type of processing: e.g. thought processes that function to implement algorithms that solve judgment-making tasks. But dual-process theorists add that this single type of processing is sub-divided into two further types: i.e. two types of thought processes that function to implement two types of algorithms that solve the same judgment-making tasks. This isn't a cheap claim: we don't get to add types to our typology for free. So, the onus is on dual-process theorists, but we should never have expected otherwise.

§6. Conclusion

The debate between single- and dual-process theories is best understood in cognitive modelling terms as a typological disagreement about whether thought processes implement only one type of algorithm or three types of algorithms (the single type and the two subdividing types). After all, this framing allow dual-process theorists to genuinely *qualitatively* distinguish between the theoretical definitions of Type-1 and Type-2 processing: the former are processes that function to precede analytic engagement and implement Type-1 algorithms and the latter are processes that function to follow analytic engagement and implement Type-2 algorithms. Moreover, the disagreement between single- and dual-process theorists about whether this qualitative distinction belongs in our typology is scientifically consequential: it answers questions about how we should scientifically generalize over behavioural observations.

However, it remains to be shown how to empirically resolve this theoretically important debate. Experimental work requires operational definitions, but the definitions that I've defended are theoretical—not operational. And it's reasonable to expect that the issues that De Neys (in press)

raises for theoretical definitions will recur for operational definitions.[5] This might make it difficult or impossible to qualitatively distinguish the operational definitions of Type-1 and Type-2 processing. Still, I'm optimistic: if there is an interesting difference in the algorithms that are functionally implemented by the processes that precede and follow analytic engagement, the history of scientific success predicts that there will be empirical consequences and that we will eventually find them. That said, there is no guarantee that these empirical consequences will be accessible via behavioural methods, which have been the *modus operandi* for psychologists in this debate (with a few exceptions: e.g. De Neys et al., 2008). I suspect that neuroscientific methods may be necessary to get further inside the black box of cognition and adjudicate whether analytic engagement is a discrete event (perhaps, implemented by a threshold-gated network) or a continuous process (perhaps, implemented by ungated networks).

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[5] Still, I do believe that some progress has been made. Dual-process theorists have struggled to draw genuinely qualitative distinctions in both theoretical definitions and operational definitions. What I've offered is a strategy for them to draw qualitative distinctions in their theoretical definitions. That doesn't solve the full problem of verifying dual-process theories, but it's a step in that direction. I thank Wim De Neys for raising this problem under review.

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