walking without it (*nobody will disagree that educated adults can intuitively solve a problem such as "Is 9 more than 1?"*), but he thinks that dual-process theories are not responsible for explaining this fact (*as any scientific theory, dual-process models make their assertions within a specific application context. For the dual-process model of logical reasoning, the application context concerns situations in which an intuitively cued problem solution conflicts with a logico-mathematical norm*). As a description of dual-process theories, this may be true. Still, it's fair to ask whether it should be.

Whether conflict paradigms are informative depends on what dual-process theories are meant to be theories of. If they aim to explain interference itself – how and under what circumstances it appears, disappears, hinders, or helps – then conflict paradigms are an excellent tool for eliciting the explanandum. But if dual-process theories are theories of reasoning, then studying interference can tell us roughly as much about reasoning as shackling strongmen on a gym track can tell us about walking. If, as is typically the case, the interference is designed to impede reasoning, then conflict paradigms will create a performance limitation that necessarily underestimates reasoning competence. Nevertheless, despite their limited "application context," dual-process theories make many claims about reasoning, tout court. For instance, De Neys describes how reasoning develops: *The working model postulates that intuitive responses primarily emerge through an automatization or learning process*. But his working model is based on evidence from different flavors of conflict and no-conflict paradigms, so the developmental claim is a non-sequitur. Evidence about how some other process does or does not interfere with reasoning cannot warrant any conclusion about how the interfered-with reasoning develops.

This is, in fact, a hard-won lesson from the history of developmental psychology. Jean Piaget (1950) famously studied children's ability to reason about number, volume, and other abstract concepts, and he frequently used conflict paradigms. For example, to investigate how children thought about number, Piaget showed them two identical rows of coins across from each other. When he asked children if the rows had the same number, they correctly said "yes." But Piaget worried that children were relying on a proxy to number, the equal lengths of the rows. To test this, he created a conflicting cue. He spread one row out so it looked longer and asked the same question again. Children as old as 6 years of age consistently switched to saying "no," the rows did not have the same number. Piaget concluded that 6-year-olds could not reason about number per se without conflating it with other properties, like length or area. Just like later dual-process theorists, Piaget presented his participants with a conflicting cue designed to tempt the wrong answer, showed that participants fell for it, and concluded that there was something wrong with their reasoning ability generally.

In the seven decades since, a vast body of work has shown that much younger children know much more about number than Piaget believed (see Carey, 2009; Carey & Barner, 2019). Summarizing this literature would take a book, but for present purposes it holds two critical lessons for dual-process theories. First, evidence that younger children have rich numerical understanding did not come from more or better variants of conflict paradigms. It came from new tasks that were designed to eliminate both the confounds that Piaget worried about and the conflicting cues he added, to make reasoning as easy as possible given the requisite competence. Second, this new understanding emerged without anyone figuring out exactly why children fail on Piaget's conflict paradigm. It turns out there are many different ways to make that task easier (e.g., McGarrigle & Donaldson, 1974; Mehler & Bever, 1967; Rose & Blank, 1974; Samuel & Bryant, 1984), but still no comprehensive theory of exactly what makes it hard. Understanding the interference proved unnecessary for understanding the interfered-with competence.

The science of children's thinking progressed not by drilling down on conflict paradigms, but by leaving them behind. It is well past time to let the science of adults' thinking do the same. The deep, difficult question about reasoning is, and has always been, the one De Neys and other dual-process theorists locate outside of the theory's scope. Discussing the conjunction fallacy, Kahneman (2011) notes in passing that it doesn't always arise. Everyone agrees that "Jane is a teacher" is more likely than "Jane is a teacher and walks to work." Kahneman even explains why: *In the absence of a competing intuition, logic prevails*. Right! Now, how does *that* work?

Acknowledgments. The author is grateful to David Barner, Gabor Brody, Rhea Feiman, and Tyler Knowlton for helpful discussion.

Financial support. This work was supported in part by a Research Fellowship from the Jacobs Foundation, and by NSF DRL Grant no. 2000661.

Competing interest. None.

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Fast and slow language processing: A window into dual-process models of cognition

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doi:10.1017/S0140525X22003041, e121

Abstract

Our understanding of dual-process models of cognition may benefit from a consideration of language processing, as language comprehension involves fast and slow processes analogous to those used for reasoning. More specifically, De Neys's criticisms of the exclusivity assumption and the fast-to-slow switch mechanism are consistent with findings from the literature on the construction and revision of linguistic interpretations.

Sometimes language processing can be hard. Just as many problems are easy to solve, many sentences are easy to interpret – for example, *the cat chased the dog*. Alternatively, just as some problems leave us stumped, some sentences defy our comprehension mechanisms – for example, the infamous *the horse raced past the barn fell*. For decades, psycholinguists have attempted to explain what makes sentences difficult to understand, with some models pointing to the costs of integrating information over long distances (Gibson, 1998), others focusing on the effects of the unexpectedness of each word as it is encountered (so-called surprisal-based models; Hale, 2016), and others emphasizing the consequences of ambiguity (Ferreira & Henderson, 1991). Here we concentrate on syntactic ambiguity because it highlights many of the issues associated with fast and slow processing. Specifically, in his target article, De Neys challenges researchers in decision making to reevaluate the exclusivity assumption and to specify how the switch mechanism that triggers the switch from fast to slow reasoning works. We believe consideration of these issues from the perspective of language processing could prove useful, as they have been at the center of theoretical debates in psycholinguistics.

During comprehension, the system that assigns syntactic structure, the parser, will often encounter a sequence that can be assigned more than one grammatical analysis. In those cases, given a range of linguistic biases, the parser may select an analysis that will require revision. Take the sequence *Mary believes Tom*. On the parser's first encounter with the postverbal noun phrase *Tom*, it will likely analyze the phrase as a direct object. But if the sentence continues with a verb such as *lied*, the parser has a problem: *lied* must be syntactically integrated but there is no grammatical place for it in the structure. The only solution is for the initial analysis to be revised so that *Tom* is not a direct object but rather the subject of a complement clause. Moreover, not only does the structure require revision, but also the meaning must be recomputed as well, because Mary does not in fact believe Tom. These processes can be viewed within the dual-processing framework De Neys discusses, with the initial analysis being the output of system 1 and the revised interpretation the output of system 2. The first response is fast and automatic, and the second requires a slower, more deliberate mode of processing in which the structure and the interpretation are systematically undone and rebuilt.

Much debate has centered around the question of what determines the initial analysis. For the purposes of this commentary, we set that question aside to focus on the two issues De Neys considers in the target article: the exclusivity assumption and the switch mechanism. Taking exclusivity first, psycholinguists know that often an initial, intuitive analysis will align with what a more deliberate process would deliver. Sentences sometimes resolve themselves in a way that is consistent with initial syntactic expectations (e.g., *Mary believes Tom implicitly*), and with knowledge and experience, many experienced language users will succeed in obtaining the correct interpretation of even the more challenging sentences right from the start, with no need for revision. In other cases, the initial system will deliver multiple interpretations of an ambiguous sequence, which means revision may involve a simple shift from one analysis to another. Findings from language comprehension, then, make clear that system 1 can deliver a correct analysis.

Turning now to the switch mechanism, much is known in psycholinguistics about what triggers the switch to a more deliberate, system 2 processing mode. One critical factor is a breakdown in coherence. In the case of so-called garden-path sentences such as *Mary believes Tom lied*, the trigger is syntactic collapse: The tree formed for the first three words cannot accommodate the verb *lied*. This breakdown in syntactic coherence shifts the parser into a repair mode in which it revisits its previous syntactic decisions, attempts new solutions, and tries to create a revised, integrated structure. In other cases, the trigger is a breakdown in semantic coherence. For example, given *Mary believes the rain…* (as in *Mary believes the rain will stop soon*), an initial analysis on which *the rain* is analyzed as a direct object can be revised when the more deliberative system detects the semantic anomaly of believing rain. This semantic incoherence will cause the parser to review its past syntactic decisions and attempt new choices that lead to a better semantic outcome. In reasoning, a switch from fast to slow processing may similarly be triggered by a breakdown in coherence, albeit at a conceptual rather than a linguistic level of representation.

Recent work on the influence of literacy can also be interpreted according to this dual-processing framework and is particularly relevant for thinking about exclusivity and the switch from system 1 to 2 modes that De Neys discusses. Literacy, for instance, uniquely predicts participants' ability to correctly accept and reject spoken sentences according to the prescriptive grammatical norms of their language (Favier & Huettig, 2021). In linguistics, such judgments are known to involve both systems 1 and 2 processes. Literacy also makes comprehension of challenging linguistic forms more automatic (as evidenced by enhanced prediction abilities; Favier, Meyer, & Huettig, 2021), providing one potential mechanism for how system 2 can, over time, turn into system 1 processing. A dual-systems approach to language processing thus has the potential to provide new mechanistic answers about the automatization of system 2 responses as well as the interplay between fast and slow systems.

In summary, our view is that a domain in which the exclusivity assumption and the switch mechanism highlighted by De Neys can be profitably scrutinized is language processing, a cognitive system that has not often been invoked in discussions of systems 1 and 2 processing and the coordination of their outputs. We believe that considering language processing through the lens of this dual-processing framework will help to illuminate the issues related to thinking that De Neys discusses in the target article.

Financial support. Preparation of this work was supported by the National Institutes of Health/NICHD under grant number 1R01HD100516 awarded to Fernanda Ferreira.

Competing interest. None.

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https://doi.org/10.1017/S0140525X2200142X Published online by Cambridge University Press