Deliberative control is more than just reactive: Insights from sequential sampling models

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TITLE: Deliberative control is more than just reactive: Insights from sequential sampling models

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ABSTRACT

Activating relevant responses is a key function of automatic processes in De Neys' model; however, what determines the order or magnitude of such activation is ambiguous. Focusing on recently-developed sequential sampling models of choice, we argue that proactive control shapes response generation but does not cleanly fit into De Neys' automatic-deliberative distinction, highlighting the need for further model development.

MAIN TEXT

We applaud De Neys' work to define a set of domain-agnostic organizing principles that better clarify discussion on dual process theories. This reformulation makes a welcome contribution to the field by proposing that (1) fast and intuitive response generation can activate multiple competing responses, leading to choice uncertainty, and (2) that this uncertainty drives subsequent activation of control-related deliberation. However, critical properties of these processes remain ambiguous in the current framework. Specifically, given the central role of fast and intuitive response generation processes, it is imperative to better specify how response options are generated, what determines their relative strength and time-course, and how these intuitions are compared to select a response. In this commentary, we draw on insights from the sequential sampling modeling literature to argue that even initial response generation and evaluation may not be exclusively driven by fast, automatic, and intuitive associative recall, but also

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modulated by controlled processes that operate rapidly from prior knowledge. In particular, we argue that deliberative control is deployed to prioritize information sampling and attribute evaluation, and thus response generation. We discuss how these forms of proactive control, in contrast to reactive control, pose a challenge to De Neys' current framework.

In De Neys' formulation, intuitive *responses* are the computational units that drive decisions. But these responses are themselves driven by the consideration of different cues or samples of information. Thus, the intuition generation process seems conceptually related to, if not synonymous with, the activation of relevant choice attributes in sequential sampling models. In these models, samples are drawn from noisy distributions of attribute values and accumulated as evidence for response options until the evidence passes a threshold for choice (Ratcliff & McKoon, 2008; Shadlen & Shohamy, 2016). The order in which attributes are considered can strongly influence decisions (Sullivan et al., 2015; Sullivan & Huettel, 2021). The present dual process framework appears to utilize a similar probabilistic sampling process, suggesting that insights from the growing literature on sequential sampling models could prove informative.

Recent work on sequential sampling models demonstrates that people strategically prioritize gathering more valuable information, which can change both the temporal dynamics and strength of response generation. For example, in altruistic choice under time pressure, selfish people prioritize gathering information about their own, rather than others', outcomes (Teoh et al., 2020). This systematically biases visual attention within the first few hundred milliseconds of choice presentation. In De Neys' terms, strategic allocation of attention changes the order of intuitive responses. Furthermore, this rapid reprioritization is context-sensitive: changing the incentives of a social interaction (e.g. dictator vs ultimatum game; Teoh & Hutcherson, 2022) or the framing of a risky gamble (e.g. gain vs loss frame; Roberts et al., 2022) change which information is processed first, in a goal consistent manner. Thus, prior information shapes information search patterns *prior* to information sampling and response generation, appearing to operate *independently* of the uncertainty-triggered control in De Neys' model.

Similarly, evidence suggests that prestimulus control-related signals can also change the order or strength of information recall, proactively shaping the response generation process. For example, time-varying sequential sampling models of food choice demonstrate that instructions to focus on health-related goals-- a presumably deliberative process-- results in faster activation of health-related information (Maier et al., 2020). In addition to changing the temporal dynamics of information retrieval, holding health-related goals increases how much weight people place on health relative to taste in their food choices (Hare et al., 2011; Tusche et al., 2018). This suggests that retrieving and generating response options is not solely automatic. Instead, effortfully-maintained goals can determine which information is most relevant, and can change the order in which response-relevant attributes are considered.

These results from both attention and memory sampling highlight an important distinction between *reactive control*, which are triggered by an event and strongly resembles the uncertainty-triggered deliberation of De Neys' model, and *proactive control*, which refers to regulatory processes that occur

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before encountering a stimulus (Braver et al., 2007; Braver, 2012). Importantly, as we have suggested above, our own and others' work suggests that this form of control can modulate when and what intuitions are activated even in the absence of conflict, and can alter the strength or order of information processing *before* rather than *after* intuitions are retrieved.

Better specifying how prestimulus control influences response generation may not only better link the current model to the self-regulation literature, but extend it to more general models of information processing. The Iterative Reprocessing framework (Cunningham et al., 2007) is one such model which allows both stimulus-driven, bottom-up processes to inform goal-based, top-down processes, and vice versa. This echoes findings in attention (Corbetta & Shulman, 2002; Asplund et al., 2010) and memory (Ciaramelli et al., 2008; Burianová et al., 2012) which propose that there are distinct but related top-down and bottom-up processes which mutually inform each other. Under this framework, organizational, top-down processes are *always* informing what is considered most relevant by stimulus-driven processes. This top-down influence could become more effortful or directed with reflective control (Cunningham & Zelazo, 2007), but pre-existing knowledge plays an important causal role in determining the relevance of automatically retrieved information.

As uncertainty-triggered deliberative processes remain to be fully specified in De Neys' model, it is unclear whether proactive control processes should be considered a separate process, or whether it might utilize the same architecture. Either way, considering when and how proactive deliberative processes are activated represents a fruitful area of inquiry. For example, dieters are often highly motivated to engage in healthy eating, yet may fail to spontaneously engage in proactive control (Cosme et al., 2020). While learning can automatize these priorities, as De Neys discusses, the effortful engagement of proactive control is not well incorporated into the current automatic-deliberative division. This case study thus highlights the need for a better articulation of how *both* intuitive and deliberative processes shape the initial response generation process, and points to the benefits of marrying dual process models with the richness of recent computational models of information sampling and choice.

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COMPETING INTEREST STATEMENT

The authors declare no competing interests.

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