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# Fast and slow thinking: Electrophysiological evidence for early conflict sensitivity

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ABSTRACT

Popular dual process models have characterized reasoning as an interplay between fast, intuitive (System 1) and slow, deliberate (System 2) processes, but the precise nature of the interaction between the two systems is much debated. Here we relied on the temporal resolution of electroencephalogram (EEG) recordings to decide between different models. We adopted base-rate problems in which an intuitively cued stereotypical response was either congruent or incongruent with the correct response that was cued by the base-rates. Results showed that solving problems in which the base-rates and stereotypical description cued conflicting responses resulted in an increased centro-parietal N2 and frontal P3. This early conflict sensitivity suggests that the critical base-rates can be processed fast without slow and deliberate System 2 reflection. Findings validate prior EEG work and support recent hybrid dual process models in which the fast System 1 is processing both heuristic belief-based responses (e.g., stereotypes) and elementary logico-mathematical principles (e.g., base-rates).

## 1. Introduction

For centuries, human thinking has been conceived as an interplay between more intuitive and deliberate processes. In the last decades dual process models that are inspired by this classic dichotomy have moved to the center stage in the cognitive and economic sciences (Evans and Stanovich, 2013; Greene, 2013; Kahneman, 2011; Rand, et al., 2012). At the heart of these dual process models lays the idea that human reasoning relies on two different types of thinking - often referred to as System 1 and System 2 processing (Stanovich, 1999). System 1 is assumed to operate quickly and effortlessly whereas System 2 is assumed to be slower and more effortful. It is System 1 (often also called the intuitive or heuristic system) that is supposed to mediate intuitive thinking whereas System 2 (often also called the deliberate or analytic system) is supposed to mediate more deliberate thinking.

Despite the popularity of dual process models, the approach is also criticized (e.g., De Neys and Glumicic, 2008; Gigerenzer and Regier, 1996; Keren and Schul, 2009; Osman, 2013). One key concern is that the framework lacks a precise processing specification of the two systems. A critical issue is the fact that the nature of the interaction between the two systems is not clear. Traditionally there has been some debate between proponents of a serial and parallel view. The parallel view entails that both systems are always activated simultaneously from the start of the reasoning process (Epstein, 1994; Sloman, 1996). The serial model entails that people initially only activate System 1 and optional System 2 activation occurs later in the reasoning process (Evans and Stanovich, 2013; Kahneman, 2011). More recently, so-called hybrid models have been put forward (e.g., Bago and De Neys, 2017; Banks, 2017; De Neys, 2012; Handley and Trippas, 2015; Pennycook et al., 2015; Thompson and Newman, 2017; Trippas and Handley, 2017a). Simply put, these hybrid models posit that the response that is traditionally expected to be calculated by System 2 can also be cued by System 1. System 1 would generate different types of intuitions such that possible conflict between them can be detected early in the reasoning process without slow System 2 computations.

To illustrate these different views, consider the following reasoning problem: You are told that there is a sample of 995 females and 5 males. Next, you're told that one person ("Person X") got drawn randomly

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from the sample and you're informed that we know that this person X is a surgeon. You are then asked whether it is more likely that Person X is male or female. This example is based on Tversky and Kahneman's (1974) famous base-rate neglect problems. Intuitively, many people will tend to say that Person X is a male based on stored stereotypical associations cued by the descriptive information ("Surgeons are male"). In case your only piece of information would be the job description of the person that might be a fair guess. In general, there are more male than female surgeons. However, there are also female surgeons and in the problem premises you were explicitly told that there were far more females than males in the sample where Person X was drawn from. If you take this extreme base-rate information into account this should push the scale to the "female" side. However, decades of studies have shown that people often fail to respect elementary logical considerations such as the base-rate principle and give the intuitive or so-called "heuristic" response that is cued by their stereotypical prior beliefs (e.g., Kahneman, 2011).

Traditional serial and parallel dual process models have typically assumed that taking logico-mathematical principles into account and giving the response favored by the base-rates, for example, requires System 2 deliberation. The key idea is that because System 2 operations are demanding and slow, most people will not wait for the slow process to complete or will simply refrain from engaging in it altogether. Consequently, they end up being biased and give the heuristic System 1 response. The hybrid model entails that people can also process the logical response intuitively. Hence, System 1 will cue at least two intuitive responses: a "heuristic" response based-on stereotypical associations and a "logical" intuitive response based on automatically activated elementary knowledge of logico-mathematical principles. Both the hybrid and traditional models can explain that the heuristic response will typically dominate: the traditional models because the logical response will not (yet) be computed at the time of decision; the hybrid model because the heuristic response can have a higher activation level (Bago and De Neys, 2017; Pennycook et al., 2015). However, the key difference is that the intuitive processing of logical features in the hybrid model implies that it allows reasoners to detect instantly that there are conflicting responses at play early on in the reasoning process without any engagement of the slow System 2.

Recent behavioral studies that aimed to test these different models have provided some initial support for the hybrid view (e.g., Franssens and De Neys, 2009; Johnson et al., 2016; Nakamura and Kawaguchi, 2016; Pennycook et al., 2014b; Thompson and Johnson, 2014; Trippas et al., 2016; Trippas et al., 2017b). For example, conflict detection studies have contrasted how people process classic reasoning problems in which an intuitively cued heuristic response conflicts with elementary logical considerations (i.e., conflict problems) and control no-conflict problems. In the control versions small content transformations guarantee that the intuitively cued heuristic response is also logically correct. For example, one can easily create a no-conflict control version of the introductory base-rate problem by switching the base-rates around (e.g., you are told that person X is a surgeon but is drawn from a sample with 995 males and 5 females). In this case both base-rate considerations and stereotypical associations triggered by the job description cue the exact same response.

Results show that people are sensitive to the presence of conflict as evidenced by increased response times (e.g., De Neys and Glumicic, 2008), decreased confidence (e.g., De Neys et al., 2011), or activation of brain regions that have long been known to mediate conflict detection (e.g., Anterior Cingulate Cortex, e.g., De Neys et al., 2008; Simon et al., 2015; Vartanian et al., 2018). Critically, these effects are observed even when people are put under time-pressure or cognitive load so that possible System 2 processing is experimentally minimized (e.g., Bago and De Neys, 2017; Franssens and De Neys, 2009; Howarth et al., 2016; Johnson et al., 2016; Newman et al., 2017; Pennycook et al., 2015; Thompson and Johnson, 2014). In sum, these conflict sensitivity findings suggest that base-rates and other logico-mathematical aspects of the reasoning problem are processed even when System 2 processing is minimized. This conclusion has been validated with a range of behavioral paradigms (e.g., Handley and Trippas, 2015; Trippas et al., 2016; Trippas et al., 2017b; but see also Mata et al., 2017; Pennycook et al., 2012; Travers et al., 2016).

However, all these behavioral studies face an intrinsic limitation: by definition, they are all response dependent. For example, confidence measures are typically collected post response. Likewise, response time measurements require overt response generation. Consequently, even when applying time pressure manipulations or minimal "rapid-response" task versions designed to allow for fast response generation (e.g., Pennycook et al., 2014a), it still takes at the very least a second or more before an overt response has been selected in a reasoning task. However, if the fast System 1 is indeed processing base-rate and other logical task features intuitively, it should be possible to find signs of early conflict sensitivity much earlier in the reasoning process, *before* the actual response has been given.

Banks and Hope (2014) were the first to realize the potential of electroencephalogram (EEG) recordings and their unique temporal resolution in this respect. Banks and Hope presented participants with syllogisms in which the logical validity of the conclusions could conflict with a heuristic response cued by the believability of the conclusion. For example, an illustration of a conflict problem would be a valid syllogism with an unbelievable conclusion (e.g., "All mammals can walk. Whales are mammals. Therefore, whales can walk."). An illustration of a no-conflict problem would be a valid syllogism with a believable conclusion (e.g., "All flowers need light. Roses are flowers. Therefore, roses need light"). By time-locking an event-related potentials (ERPs) analysis to the presentation of the last word of the conclusion (i.e., the exact point at which belief-logic conflict could occur), Banks and Hope could test whether early electrophysiological activation differed as a function of the conflict status of the problem. Such early conflict sensitivity would be expected if fast System 1 operations process the logical status of the problem. If slow System 2 processing is required, then detection of logic/belief conflict should occur much later in the reasoning process.

Results pointed to very early conflict sensitivity after a mere 200 ms were elapsed: In contrast with no-conflict problems, the conflict trials gave rise to a reduced N2 and enhanced P3 component. The N2 and P3 are well-known negative and positive deflections that occur between 200 and 350 ms and 300–500 ms after the event, respectively, and have been associated with information monitoring, control, and updating processes (e.g., Borst et al., 2013; Folstein and Van Petten, 2008; Polich, 2007; Ullsperger et al., 2014; Yeung and Summerfield, 2012).

Banks and Hope (2014) early conflict sensitivity findings indicate that logical reasoning—a process that is traditionally believed to require slow System 2 computations—can be literally accomplished in a split second. This fits with the hybrid dual process model's postulation of intuitive logical processing (Banks, 2017). However, to draw strong theoretical conclusions it is important to establish whether the results are robust. To avoid confusion, Banks and Hope (2014) were obviously not the first to study reasoning processes with EEG per se (e.g., Bonnefond et al., 2014; Bonnefond and Van der Henst, 2009, 2013; Luo et al., 2008, 2013; Luo et al., 2011; Malaia et al., 2015). However, the problem is that these prior studies were not specifically designed to test between different dual process models. For example, many studies used a design that was time-locked to the response generation (e.g., Luo et al., 2013) or initial presentation of the problem premises (e.g., Luo et al., 2011, 2008). This complicates testing for early conflict sensitivity (i.e., participants are still reading the premises or already responded). In addition, many studies did not manipulate belief-logic conflict experimentally (e.g., Bonnefond et al., 2014; Bonnefond and Van der Henst, 2009, 2013; Malaia et al., 2015).

In sum, to draw clear conclusions it is important to test the generalizability and robustness of the initial Banks and Hope (2014) findings. The present paper addresses this issue. We focused on the popular