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# The time course of conflict on the Cognitive Reflection Test

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ABSTRACT

Reasoning that is deliberative and reflective often requires the inhibition of intuitive responses. The Cognitive Reflection Test (CRT) is designed to assess people's ability to suppress incorrect heuristic responses in favour of deliberation. Correct responding on the CRT predicts performance on a range of tasks in which intuitive processes lead to incorrect responses, suggesting indirectly that CRT performance is related to cognitive control. Yet little is known about the cognitive processes underlying performance on the CRT. In the current research, we employed a novel mouse tracking methodology to capture the time-course of reasoning on the CRT. Analysis of mouse cursor trajectories revealed that participants were initially drawn towards the incorrect (i.e., intuitive) option even when the correct (deliberative) option was ultimately chosen. Conversely, participants were not attracted to the correct option when they ultimately chose the incorrect intuitive one. We conclude that intuitive processes are activated automatically on the CRT and must be inhibited in order to respond correctly. When participants responded intuitively, there was no evidence that deliberative reasoning had become engaged.



## 1. Introduction

The Cognitive Reflection Test (CRT; Frederick, 2005) is a brief test designed to measure individuals' ability to inhibit intuitive responses in favour of reflective and deliberative reasoning. In the bat-and-ball problem, one of the best-known CRT items, participants are asked:

*"A bat and a ball together cost £1.10.*
*A bat costs £1 more than a ball.*
*How much does a ball cost?"*

The appealing but incorrect response, to say "10p", is believed to be generated effortlessly and automatically by intuitive processes. Arriving at the correct response of "5p" may require that this intuitive response is inhibited in favour of the result of sustained, effortful deliberation.

The CRT has become a popular measure of individual differences, for example it has been cited 11 times in Cognition since 2012, including 6 experiments using the test. Higher CRT scores predict better performance on various cognitive tasks, including reduced framing effects, less discounting of delayed rewards (Cokely & Kelley, 2009; Frederick, 2005) and probability matching (Koehler & James, 2010), resistance to the illusion of explanatory depth (Fernbach, Rogers, Fox, & Sloman, 2013) and conjunction fallacies (Oechssler, Roider, & Schmitz, 2009), greater metacognitive awareness (Mata, Fiedler, Ferreira, & Almeida, 2013) and less endorsement of supernatural belief (Pennycook, Cheyne, Seli, Koehler, & Fugelsang, 2012; Shenhav, Rand, & Greene, 2012), as well as performance on various tasks that pit normative responding against intuition (Toplak, West, & Stanovich, 2011). Scores on the CRT correlate with measures of IQ and personality characteristics, and usually predict performance on other tasks even when these are controlled for (Toplak et al., 2011).

The CRT is viewed by some as a prototypical application of dual process theories of cognition (Kahneman & Frederick, 2005; Toplak et al., 2011). Dual process theories (Evans, 2008; Evans & Stanovich, 2013; Kahneman, 2011; Sherman, Gawronski, & Trope, 2014) broadly distinguish Type 1 processes that quickly and effortlessly generate intuitive responses, and Type 2 processes that are under deliberative control and are demanding on working memory resources. Consistent with this, a number of studies (Böckenholt, 2012; Campitelli & Gerrans, 2014; Campitelli & Labollita, 2010) have shown that performance on the CRT is predicted by a combination of dispositional factors, inhibitory control, and numerical ability.

Dual process theories differ in their account of CRT performance. Intuition is the default mode of processing in default-interventionist models (Evans, 2006; Kahneman & Frederick, 2005), which hold that Type 2 processes must be engaged for reflective and deliberative processing to inhibit and

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override intuitive responses. Failure to engage Type 2 processes has been linked to individual differences in personality and intelligence (Stanovich & West, 2008) and task characteristics (Rolison, Evans, Walsh, & Dennis, 2011). When Type 2 processes are engaged, they may nevertheless fail to adequately replace an intuitive response (Stanovich & West, 2008). Failure to engage Type 2 processes has been proposed to explain incorrect heuristic responses on the CRT. Default-interventionist models make an important prediction about cognitive conflict during reasoning on the CRT. When a heuristic response is given, deliberative Type 2 processing likely has failed to become properly engaged. However, when the correct response is given, the incorrect, Type 1, heuristic response must have been inhibited by Type 2 processing.

In contrast to default-interventionist accounts, parallel-competitive dual process theories (Sloman, 1996, 2014) hold that both Type 1 and Type 2 processes are activated simultaneously, and that they compete for control of behaviour. In common with default-interventionist models, these accounts predict that Type 1 intuitive responses must be inhibited in order to reason correctly. Uniquely though, parallel models would also predict Type 2 processes should attempt to signal the correct response, even when failing to overrule the output of Type 1 processes.

More recently, De Neys (2012, 2014) has proposed an intuitive logic model. This modifies the traditional default-interventionist model to account for many findings which indicate that when participants provide biased, heuristic responses, they are often implicitly aware of some conflict between their responses and the normative standard. According to this model, Type 1 processes are sensitive to normative principles, such as logical principles in syllogistic reasoning tasks, or mathematical rules on the bat-and-ball problem. As a result, they implicitly signal a conflict when the incorrect heuristic response is given. However, because the heuristic response is usually prepotent, participants often fail to inhibit it, even when they do detect that it conflicts with normative principles. It is unclear at present, however, how this conflict is actually detected. One possibility is that Type 1 processes simultaneously produce both heuristic and correct responses, and it is the conflict between these two partially active responses which is detected directly. Alternatively, the process may be more subtle, with Type 1 processes not generating a fully-formed correct response, but rather detecting, through some other means, that the heuristic response is questionable. Clearly, these two possibilities make different predictions about conflict between competing response options. In the former case, the intuitive logic model would, like a parallel-competitive account, predict that because both responses are partially cued, participants should be drawn towards giving the correct response during reasoning, even when they ultimately give the heuristic one. In the latter case, if Type 1 processes can signal conflict without actually generating the correct response, participants may experience conflict and uncertainty, but not be actually drawn towards the correct response when giving the heuristic one.

Evidence of the implicit conflict detection predicted by the intuitive logic model comes from a range of experimental paradigms (see De Neys, 2012, for a review). Typically, these studies compare conflict problems, in which the intuitive, heuristic response is incorrect, to no-conflict versions, where both heuristics and normative principles cue the same response. Type 1 processes cue both the heuristic response on conflict problems and the correct response on no-conflict problems. If participants detect the conflict between normative principles and their heuristic responses, they should show greater evidence of conflict on these problems, compared to the no-conflict problems. Such conflict has been measured using confidence ratings (De Neys, Cromheeke, & Osman, 2011), response times (De Neys & Glumicic, 2008), neuroimaging (De Neys, Vartanian, & Goel, 2008), and galvanic skin response (De Neys, Moyens, & Vansteenwegen, 2010), among other measures.

Two studies have directly tested the intuitive logic model when applied to the CRT. De Neys, Rossi, and Houdé (2013) showed that heuristic responses on conflict problems were given with less confidence than correct responses on no-conflict problems. Gangemi, Bourgeois-Gironde, and Mancini (2015) report similar effects, asking participants to fill out a brief questionnaire measuring their "feeling of error" after answering either the original bat-and-ball problem or a no-conflict control version, both when participants were asked to generate their responses, and when asked to choose between the heuristic and correct responses. These findings all suggest that participants are to some extent aware of the inadequacy of their heuristic responses.

One difficulty in interpreting the above findings is differentiating between *conflict* and *uncertainty*. Conflict requires that participants are drawn towards two responses at the same time — the correct one, and the heuristic one. Uncertainty, on the other hand, does not require that participants are drawn to the correct response when they select the heuristic one, merely that they experience some sense of unease, indecision, or lack of confidence while doing so. It is difficult to say, without additional evidence, whether conflict, or uncertainty, underlie the results of earlier studies of intuitive logic on the CRT.

In this study, we introduce a novel methodology which addresses this issue, and reveals the time-course of cognitive processing during reasoning on the CRT. Participants completed a computer-based multiple-choice version of the CRT while their mouse cursor movements were recorded. Mouse tracking has been used in other areas of psychology to reveal the time course of decisions on the basis of participants' mouse cursor trajectories over a short period of time (Freeman, Dale, & Farmer, 2011; Spivey, Grosjean, & Knoblich, 2005). We employ it here to capture the cognitive processing underlying CRT performance over a longer timescale. If a classic default-interventionist account explains performance on the CRT, participants should exhibit an initial attraction to an incorrect heuristic option when a correct deliberative option is chosen, but not vice versa, when the heuristic option is chosen. If instead a parallel-competitive model explains performance on the task, then participants should also show attraction to the correct option when the intuitive option is chosen. The predictions of the intuitive logic model depend on the nature of the conflict detection process. If participants detect conflict because both responses are simultaneously generated by Type 1 processes, then the intuitive logic model, like the parallel-competitive model, would predict conflict in both directions. Alternatively, if the conflict detection process is more subtle, relying on a feeling of uncertainty, then like the classic default-interventionist account it might predict that participants should be drawn to the heuristic option when selecting the correct one, but not the other way around.

## 2. Method

### 2.1. Participants

One hundred and thirty-one students at Queen's University Belfast participated in exchange for course credit.

### 2.2. Materials

Eight problems were adapted from Primi, Morsanyi, Donati, Chiesi, and Hamilton's (2015) extended version of the CRT. Each of these problems was modified to create a set of eight corresponding no-conflict problems, in which the intuitively appealing responses were also the correct ones (see the Appendix A). Participants were