The Cognitive Reflection Test: A Measure of Intuition/Reflection, Numeracy, and Insight
Problem Solving, and the Implications for Understanding Real-World Judgments and Beliefs

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Abstract

The Cognitive Reflection Test (CRT) has increasingly dominated theorizing about individual differences in intuitive/reflective thinking propensities, and it is associated with many real-world beliefs and judgments, such as religiosity, paranormal beliefs, and moral judgments. The CRT triggers common incorrect responses that come to mind easily, and it is assumed that recognizing this error is tantamount to solving the problems. As a result, incorrect answers on the CRT purportedly indicate an intuitive thought process, whereas correct answers purportedly indicate a reflective thought process. It has also been argued that the CRT problems are fundamentally different from insight problems because insight problems often cause people to sit lost in thought, unable to solve the problem until they correctly reframe it. The present research tested these assumptions and found that a substantial proportion of people have difficulty solving the problems even when the “intuitive” response is unavailable to them, the correct answer is among four multiple-choice options, and they take time to reflect. Associations between the CRT and beliefs (religiosity, paranormal beliefs, moral judgments, etc.) remained even under conditions in which CRT errors appeared to result from more reflective thought than correct responses. Furthermore, multi-dimensional item response theory models indicated that the CRT loaded onto numeracy and insight problem solving ability factors rather than its own unique factor. Additionally, regression analyses indicated that numeracy and insight may account for many associations between the CRT and real-world beliefs. Broader implications for dual-process theories of reasoning and judgment are discussed.

Keywords: Dual-Process, Cognitive Reflection, Intuition, Numeracy, Insight

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The distinction between thoughts that are fast, impulsive, and intuitive, versus those that are slow, analytical, and deliberative, has roots in ancient philosophy, and has greatly influenced modern psychology (Evans, 2008; Evans & Stanovich, 2013; Plato, 360 B.C./1949). The first type of thinking, commonly referred to as “Type 1” processing, is typically described as unconscious, automatic, low effort, rapid, default, and independent of working memory (Epstein, Pacini, Denes-Raj, & Heier, 1996; Evans, 2008; Evans & Stanovich, 2013; Gawronski, & Creighton, 2013; Kahneman, 2011; Stanovich & West, 2000). In contrast, “Type 2” processing is typically described as conscious, controlled, high effort, slow, and limited by working memory capacity (Epstein et al., 1996; Evans, 2008; Evans & Stanovich, 2013; Gawronski, & Creighton, 2013; Kahneman, 2011; Stanovich & West, 2000).

One longstanding point of interest in the dual-process literature is identifying individual differences in the propensity to use intuitive (Type 1) versus reflective/analytical (Type 2) processes (Epstein et al., 1996; Evans, 2008; Evans & Stanovich, 2013; Frederick, 2005; Kahneman & Frederick, 2005; Stanovich & West, 2000). Indeed, research has shown that individual differences in intuitive versus reflective thinking propensities potentially have real-world consequences. A recent review by Pennycook, Fugelsang, & Koehler (2015) found that people who tend to use more intuitive processes are more likely to hold paranormal and religious beliefs (Pennycook, Cheyne, Seli, Koehler, & Fugelsang, 2012; Shenhav, Rand, & Green, 2012), more likely to believe in conspiracy theories (Swami, Voracek, Stieger, Tran, & Furnham, 2014), more likely to make emotion-based moral judgments (Pennycook, Cheyne, Barr, Koehler, &

Fugelsang, 2014; Royzman, Landy, & Goodwin, 2014), and are less likely to believe in evolution (Gervais, 2015).

Individual differences in intuitive versus reflective thinking propensities are often assessed with self-report questionnaires, such as the Rational-Experiential Inventory (REI; Pacini & Epstein, 1999) and the Need for Cognition scale (NFC; Cacioppo & Petty, 1982). Although these measures are clearly useful in some respects, there is always some question about whether people are accurate in their self-assessments (Lucas & Baird, 2006; Nisbett & Wilson, 1977; Vazire & Carlson, 2010). More objective types of measures include judgment problems from the heuristics and biases literature, which are often designed such that the answers most commonly given answers are incorrect. Thus, obtaining the correct answer is assumed to require reflective, analytical thought (Frederick, 2005; Kahneman & Frederick, 2005; Stanovich, 1999).

One measure of this second type has become dominant in the literature: The Cognitive Reflection Test (CRT; Frederick, 2005). For example, the CRT was used as a measure of peoples' propensity to use intuitive versus reflective processing in 17 of the 25 studies reported in a recent review of the literature (Pennycook et al., 2015),¹ and has been cited extensively since its introduction (over 2,500 times on Google Scholar). Since the CRT is increasingly influential with regard to how we understand the consequences of individual differences in intuitive versus reflective thinking propensities, we focused on this measure in the present research.

The CRT consists of three questions:

1. A bat and a ball costs \$1.10 in total. The bat costs \$1.00 more than the ball. How much does the ball cost?

¹ Of the 17 studies: eight used the CRT alone to assess this individual difference, seven used the CRT in addition to base rate problems, one used the CRT in addition to base rate problems and a self-report questionnaire, and one used the CRT in addition to base rate problems, a heuristics and biases battery, and syllogistic reasoning problems.

2. If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets?

3. In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half the lake? (Frederick, 2005, p.27).

Perhaps the most important feature of these questions is that the majority of people consistently respond with specific incorrect answers (10 cents, 100, minutes, and 24 days, respectively), which come to mind seemingly without any effort (Frederick, 2005). People who ultimately respond correctly often produce these incorrect answers first (e.g. they cross out 10 cents, and write 5 cents), thus, it appears that mental effort is required to override that first incorrect response and arrive at the correct answers: 5 cents, 5 minutes, and 47 days (Frederick, 2005).

These observations have led to the following general understanding of the CRT:

The correct answer which requires only a little reasoning and no great arithmetical skill is 5 cents. Surprisingly, Ivy League university students give the wrong, intuitive answer more than 50% of the time. This must reflect lack of effort and motivation rather than cognitive ability. (Evans, 2011, p. 94)

However, from its inception, it was noted that the CRT shares variance with other cognitive abilities such as reading comprehension and numeracy (i.e., ease and skill with working with numbers) (Frederick, 2005). Hence, it is important to consider the possibility that performance on the CRT is determined by multiple underlying propensities, skills, and psychological processes rather than only representing individual differences in intuitive versus reflective thinking propensities. Indeed, Pennycook, Cheyne, Koehler, & Fugelsang (2016) suggested that incorrect responses on the CRT do not necessarily indicate a complete lack of

reflection, and that incorrect responses could result from analytic reasoning. More generally, responses on psychological tests usually are not process pure (Jacoby, 1991; Jacoby, Yonelinas & Jennings, 1997). Therefore, to the extent that the CRT assesses individual differences other than intuitive versus reflective thinking propensities, it would further be necessary to identify which one of these individual differences is responsible for the association between the CRT and real-world beliefs and judgments, such as beliefs in evolution (Gervais, 2015), paranormal beliefs (Pennycook et al., 2012), moral judgments (Royzman et al., 2014), and heuristics and biases (Toplak, West, & Stanovich, 2011).

In the present research, we considered the possibility that variance in CRT performance may in fact be attributable to at least three constructs: reflective thinking propensities, numeracy, and insight problem solving ability (i.e., the ability to reframe problems; cognitive restructuring). As described below, there is good reason to believe that CRT performance depends on both intuitive/reflective thinking propensities and numeracy. However, the prior literature has largely rejected the notion that the CRT assesses insight problem solving ability, asserting instead that the CRT problems are unique because an incorrect answer seems to come to mind quickly and effortlessly, and the correct answer is arrived at soon after the error is recognized (Toplak, et al., 2011; Toplak, West, & Stanovich, 2014; West, Meserve, & Stanovich, 2012). We propose that perhaps this conclusion was premature, and tested the possibility that the CRT problems are actually more similar to other types of insight problems than what has been commonly assumed. After reviewing evidence that CRT performance potentially reflects reflective thinking propensities, numeracy, and insight problem solving ability, we then provide three tests of the extent to which these factors are responsible for CRT performance and the associations between the CRT and real-world beliefs and judgments. Finally, we used multidimensional item response

theory (IRT) models to determine whether the CRT items measure a unique construct from both numeracy and insight problem solving ability.

The CRT as a Measure of Intuitive Versus Reflective Thinking Propensities

There is certainly evidence suggesting that the CRT assesses individual differences in propensity to use reflective versus intuitive thought processes. As discussed previously, the CRT problems seem to prompt specific incorrect answers that come to mind very quickly, suggesting that a fast, effortless, intuitive process produced them (Frederick, 2005). Furthermore, it is assumed that most people can easily solve the problems once they take a moment to reflect:

Anyone who reflects upon it [the bat and ball problem] for even a moment would recognize that the difference between \$1.00 and 10 cents is only 90 cents, not \$1.00 as the problem stipulates. In this case, catching that error is tantamount to solving the problem, since nearly everyone who does not respond “10 cents” does, in fact, give the correct response: “5 cents.” (Frederick, 2005, pp. 26-27).

Moreover, the CRT has also been shown to be moderately associated with NFC, e.g. r s between .22 and .28 (Frederick, 2005; Pennycook et al., 2016; Toplak et al., 2014). Since NFC is a self-report measure of preferences for greater or lesser amounts of thinking, this finding provides some evidence for convergent validity that the CRT measures intuitive versus reflective thinking propensities.

Additionally, Toplak et al. (2011) found that better CRT performance was associated with to providing fewer incorrect or heuristic responses on classic heuristics and biases problems (e.g. conjunction fallacy problem, gambler’s fallacy problems, syllogistic reasoning problems, etc.). The CRT remained significantly associated with these outcomes when measures of general intelligence, executive function, and self-reported thinking dispositions were included as control

variables, suggesting that the CRT assesses something beyond other measures of cognitive ability and self-reported thinking dispositions that is uniquely associated with susceptibility to heuristics and biases (Toplak et al., 2011). Altogether, these results suggest that the CRT assesses people's tendency to use intuitive versus reflective thought processes, and unlike other such measures (e.g., NFC) it has the advantage of not relying on individuals' subjective judgments about their thinking propensities or abilities.

The CRT as a Measure of Numeracy

The numerical nature of the CRT questions means that responses likely depend, at least in part, on individuals' numerical abilities. Numeracy is defined as the ability to use and comprehend numerical concepts, such as, calculating a 15% tip or converting a risk probability into a natural frequency (Peters et al., 2006; Peters, 2012). Indeed, research has found that the CRT and measures of objective numeracy are strongly correlated (r s between .40 and .56; Cokely, Galesic, Schulz, Ghazal, & Garcia-Retamero, 2012). Hence, one important question is whether the CRT is simply another test of numeracy or if it assesses other skills and propensities, such as intuitive/reflective thinking propensities, above and beyond numeracy.

Current research on this issue is mixed. On one hand, Liberali, Reyna, Furlan, Stein, & Pardo (2011) conducted a factor analysis including the CRT and several objective and subjective numeracy items. They concluded that the CRT is not simply another test of numerical ability because the CRT and the numeracy items did not all load onto a single factor (Liberali et al., 2011). On the other hand, Weller et al. (2013) included two of the CRT questions in an objective numeracy scale. Their justification came from a factor analysis that included several objective numeracy items and the CRT questions; they found that a one-factor solution of numeracy fit the

data about as well as a two-factor solution where the CRT questions were considered as a separate correlated factor from the numeracy items.

One reason that numeracy and the CRT may be related is because each shares variance with cognitive ability; numeracy and the Wonderlic IQ test have been correlated at $r = .41$ (Brooks & Pui, 2010), and the CRT and the Wonderlic IQ test have been correlated at $r = .43$ (Frederick, 2005). One point of resistance to the notion that the CRT is merely a measure of numeracy or general cognitive ability is that the CRT problems have an incorrect answer that comes to mind quickly for most people, and the process of overriding an initial wrong answer is outside the construct of numeracy (i.e., ability to use and comprehend numerical concepts; Peters, 2012). Furthermore, this override ability is not assumed to be exclusive to people of high cognitive ability (Toplak et al, 2011). Thus, proponents of the intuition/reflection view of the CRT have argued that although the CRT does in part assess numerical abilities, it primarily assesses individual differences in propensity to use intuition/reflection (Frederick, 2005; Toplak et al., 2011). Furthermore, proponents argue that the CRT problems require “no great arithmetical skill” (Evans, 2011, p. 94); that is, *if* people were to think about the CRT problems, then even people low in numeracy would answer the problems correctly (Frederick, 2005).

The CRT as a Measure of Insight Problem Solving Ability

Prior interpretations of the CRT have largely rejected the notion that the CRT could be a measure of insight problem solving ability (Toplak et al., 2011; Toplak et al., 2014; West et al., 2012). However, in the present research we revisited this assumption and put it to an empirical test. To explain the present impetus for testing this assumption, consider the following insight problem: “There is a container of Murples. The Murples double in number every day. The container will be full in 60 days. In how many days will it be half full?” (Gilhooly & Murphy,

2005, p. 285). This problem is from the insight literature and is (essentially) the same as the lily pad problem from the CRT. In a cluster analysis of insight problems and non-insight problems (e.g., Tower of Hanoi), the Murples problem clustered with other insight problems (Gilhooly & Murphy, 2005), suggesting that this problem—and, by extension, the lily pad problem—are measuring cognitive restructuring or insight.

Cognitive restructuring involves the ability to reinterpret a problem; that is, to see it differently from one's first interpretation (Gilhooly & Murphy, 2005; Fleck, 2008; Gilhooly & Fioratou, 2009). Restructuring can happen spontaneously (in which case it is referred to as "insight") or through explicit mental search process. Insight has been described as a process that "...involves suddenly seeing a problem in a new light, often without awareness of how that new light was switched on." (Jung-Beeman et al., 2004, p. 507). However, cognitive restructuring may also occur from a more stepwise, effortful reasoning process (i.e. Type 2 processing) such as when a person serially searches words or concepts in the problem to see where an interpretation can change, or when a person serially searches solutions to a problem until a correct solution is found (Kaplan & Simon, 1990; Fleck, 2008; Gilhooly, & Fioratou, 2009).

Insight and cognitive restructuring can be assessed with other problems such as, "A man in a small town married 20 different women of the same town. All are still living and he never divorced. Polygamy is unlawful but he has broken no law. How can this be?" (Gilhooly & Murphy, 2005, p. 280). Correctly answering this "marriage" problem requires that individuals reinterpret the common usage of the word "married". A major difference between the CRT and this type of insight problem is that these insight problems can feel like they have no solution; that is, there is no answer that quickly comes to mind, and instead these problems can feel impossible

to solve. This observation led West et al. (2012) to conclude that the CRT is fundamentally different from insight problems:

The three problems on the CRT (see Method section) seem at first glance to be similar to the well-known insight problems in the problem-solving literature, but they in fact display a critical difference. Classic insight problems (see Gilhooly & Fioratou, 2009; Gilhooly & Murphy, 2005) do not usually trigger an attractive alternative response. Instead the participant sits lost in thought trying to reframe the problem correctly, as in, for example, the classic nine dot problem. (p. 506)

However, other insight problems do trigger attractive incorrect solutions, much like the CRT. The Murples problem is one example; others include, “How much earth is there in a hole that is 3 ft by 3 ft by 3 ft?” (Gilhooly & Murphy, 2005, p. 286). Although the answer “27 cubic feet” requires a small amount of calculation and therefore does not necessarily instantly come to most people’s minds (i.e., is not likely to be a product of Type 1 processing), it is still a very common incorrect answer (and is incorrect because there is no dirt in a hole). Hence, just like the CRT problems, people make systematic errors (i.e., 27 cubic feet) on this type of insight problem. Furthermore, just like the CRT problems, *if* people were to think carefully about this type of insight problem, they would be more likely to get the answer correct, and the correct answer requires no great arithmetical skill. As a result of these considerations, it seems likely that the CRT has considerable overlap with the type of insight problem that strongly suggests incorrect answers, such as the Murples problem and the “earth in a hole” problem.

Furthermore, it is also possible that the CRT assesses psychological processes that are similar to those assessed by insight problems that *do not* strongly suggest incorrect answers, such as the “marriage problem” above. Although it is assumed that for the CRT catching the error “is

tantamount to solving the problem” (Frederick, 2005, p. 27), and therefore no one would sit “lost in thought” trying to solve the CRT problems (West et al., 2012, p. 506), no research to date has tested these assumptions. Therefore, it is possible that some people—or perhaps even many people—would indeed sit lost in thought, unable to solve the CRT problems, even after it becomes clear that their initial answer was wrong. For example, it could be the case that once people are told that the common incorrect answers (10 cents, etc.) are not correct, then they will think the situation is impossible, and experience great difficulty reframing the problem, much like the “marriage problem” from the insight literature. Hence, the present research tested the possibility that, like insight problems, a substantial proportion of errors on the CRT are the result of difficulty reframing the problem after it becomes clear that their initial answer is wrong.

The CRT and Real-World Beliefs

At this point we have reviewed evidence suggesting that differences in CRT performance are likely attributable to some combination of intuitive/reflective thinking propensities and numeracy. We also provided a rationale for testing the possibility that differences in CRT performance are additionally attributable to insight problem solving ability (i.e. cognitive restructuring). Although the extent to which the CRT assesses each of these skills is currently unclear, the CRT is clearly a useful predictor of many different judgments and beliefs. People who performed better on the CRT are less likely to believe in God (Shenhav et al., 2012), less likely to believe in the paranormal (Pennycook et al., 2012), more likely to believe in evolution (Gervais, 2015), less likely to judge counter-normative victimless behaviors (e.g. a brother and sister kissing each other passionately in private) as morally wrong (Pennycook, et al., 2014; Royzman et al., 2014), and less likely to believe fake news headlines (Pennycook & Rand, 2017). Better performance on the CRT has also been related to preferring larger delayed rewards

than smaller immediate rewards (Frederick, 2005), choosing gambles with better expected values (Frederick, 2005), preferring more explanatory detail (Fernbach, Sloman, Louis, & Shube, 2013), and performing better on heuristics and biases tasks (Toplak et al., 2011). Although some of these associations remain when statistically adjusting for cognitive ability (Pennycook et al., 2012; Pennycook et al., 2014; Shenhav et al., 2012; Toplak et al., 2011), few studies have adjusted for numeracy and no studies have adjusted for insight problem solving ability.

The extent to which the CRT overlaps with numeracy and insight has important implications for interpreting the relationship between the CRT and the aforementioned beliefs and judgments. For example, the association between the CRT and paranormal beliefs might indicate that one reason why people hold such beliefs is that they tend to insufficiently reflect on information, and are too quick to rely on their first intuitions (Pennycook et al., 2012). However, if CRT performance is multiply determined, then it stands to reason that associations with the CRT could potentially be due to any and/or all combinations of the individual differences that it assesses. For example, the association between the CRT and paranormal beliefs might be due to believers' insufficient reflection, insufficient numeracy (e.g., inability to understand the probability of rare and co-occurrences), and/or inability to reinterpret/restructure the information that one encounters (e.g., inability to think of non-paranormal explanations for observations).

The Present Research

The present research tested the possibility that incorrect responses on the CRT are produced in at least two different, theoretically relevant ways: (a) some people may fail to question their first response and therefore fail to engage in reflection, (b) some people may question their first response and engage in reflection, but fail to solve the problem. This latter

possibility for incorrect responding could be the result of low numerical skill and/or difficulty reframing the problem and identifying alternative solutions.

We first tested the possibility that the CRT problems might be similar to typical insight problems in that after people realize that their initial answer is wrong, many may become stuck, unsuccessfully attempting to solve the problems. That is, although there are clearly common answers that come quickly to mind for the CRT problems, many people might have difficulty solving the problems even when they are told that this first answer was wrong and they take time to reflect. If this were the case, it would potentially require a reinterpretation of the causes of incorrect responses on the CRT, and could help to bridge two literatures are currently treated as somewhat distinct (i.e. insight problem solving and dual-process theory).

To determine the extent of the similarity between the CRT and insight problems, the present research involved a correlational approach (i.e., correlated the CRT with classic insight problems as well as a numeracy scale; Studies 1 & 3), IRT modeling (Study 4), and an experimental approach (Studies 1-3). The experimental approach used the following rationale: If the CRT primarily measures individual differences in intuitive versus reflective thinking propensities, this implies that people should produce the correct answer easily once they recognize that they have made an error and they engage in “only a little reasoning” (Evans, 2011, p. 94). However, if a major cause of errors is an inability to reframe the problems, this predicts that many people will sit “lost in thought trying to reframe the problem correctly” (West et al., 2012, p. 506). Hence, we tested the possibility that some people might indeed become stuck in unsuccessful attempts at reframing the problems upon realizing that their first answer is wrong.

In Studies 1-3, we presented participants with the CRT questions in the typically administered open-ended response format, and compared performance in this condition to

performance in a condition in which the CRT was presented in a multiple-choice format in which the commonly produced incorrect (“intuitive”) answer was not an available option, and the correct answer was presented as one of four multiple-choice options. This multiple-choice format made it impossible to respond with the “intuitive” answer, and correct answers needed only to be identified out of four possible options. We strengthened this multiple-choice intervention by reassuring participants that the correct response was indeed among the four options (Study 2), and by instructing participants to reflect and not guess (Study 3).

In Studies 1-3, we also compared competing hypotheses with regard to CRT performance and response time. An intuition/reflection view of the CRT predicts that the multiple-choice version of the CRT will result in very few errors (e.g., 10% incorrect answers), and will decrease the amount of time taken to obtain the correct answer relative to the open-ended CRT response format (because the correct answer is displayed as one of four options). Furthermore, any errors that remained in this multiple-choice version were expected to be made very quickly because errors would only be made when participants refuse to give the problems any thought. Such results would confirm that these problems are trivially easy when the intuitive response is prevented, and that incorrect responses are largely due to a lack of reflection.

By contrast, an insight problem solving view of the CRT predicts that the multiple-choice version of the CRT will increase performance to a moderate extent but that there will still be a large proportion of errors (e.g., 25-50% incorrect responses on average). Moreover, an insight problem solving view predicts that the multiple-choice version of the CRT will *increase* the amount of time taken to respond *incorrectly* because when people recognize that their initial response is not one of the multiple-choice options (and therefore cannot be correct), it causes some people to experience the questions much like the “marriage” problem described earlier.

That is, it will not be clear to them what the correct answer could be, and they become stuck in unsuccessful attempts to reframe the problem. Thus, an insight problem view predicts that incorrect responders on the multiple-choice version of the CRT will engage in reflective thought but ultimately choose an incorrect answer, either because they give up or because they make an analytical error. Because the insight problem solving view suggests a smaller difference in performance between conditions, in each of Studies 1 – 3 we aimed to collect at least 176 participants per condition to provide 80% power to detect a small to medium sized difference (e.g., $d = 0.30$) in performance on the CRT between conditions.

A second purpose of the present research was to determine whether numeracy and/or insight problem solving ability are responsible for associations between the CRT and other individual differences. Reexamining the associations between the CRT and individual differences (e.g. NFC, religiosity, paranormal beliefs, performance on heuristics-and-biases tasks, etc.) while adjusting for numeracy and/or insight problem solving ability could change how these associations with the CRT are interpreted, having critical implications for how to interpret the existing literature. For example, previous research has suggested that individual differences in intuitive versus reflective thinking propensities have consequences for real-world beliefs, such as religiosity, paranormal beliefs, and moral judgments (Pennycook et al., 2015). Many of these studies used the CRT as a measure of intuitive versus reflective thinking propensities, but did not adjust for numeracy and/or insight problem solving. Indeed, numeracy or insight problem solving might better account for these associations. We used a measure of numeracy (Studies 1 and 3) and insight problem solving ability (Study 3) to determine whether adjusting for these measures would account for associations between the CRT and real-world beliefs and judgments.

Study 1

This study compared performance on the normal CRT to a condition in which participants responded to the CRT problems in the previously discussed multiple-choice format (four options that included the correct but not the “intuitive” response). The purpose of this manipulation was to test the aforementioned competing predictions borne out of the intuition/reflection view of the CRT versus the insight problem solving view. This study also examined associations between the CRT and other outcomes (e.g. religiosity, paranormal beliefs, moral judgments, etc.). We expected to replicate many of the previously observed associations between the CRT and these outcomes, and tested the possibility that these associations would be altered by the multiple-choice CRT format. For example, if the intuition/reflection predictions are borne out, then there would be little variability in performance on the CRT remaining in the multiple-choice versions of the problems, resulting in significantly weakened or null correlations in that condition. However, if the insight problem solving predictions are borne out then there will be considerable variability in performance remaining to correlate with other outcomes, but that variability could no longer be said to be due to intuitive/reflecting processing (because according to the insight view, both errors and correct responses would be produced after reflective processing). Therefore, if the insight view of the CRT is supported and the correlations are unchanged by the multiple-choice format, then it would be reasonable to conclude that associations between the CRT and these outcomes are not due to intuition/reflection, but instead might be due to deficits in other skills, such as numeracy and insight problem solving ability.

Method

Participants and Design. Five-hundred forty-seven participants from two introductory psychology courses (Introduction to Psychology $n = 329$, Introduction to Social Psychology $n = 218$) completed this study. All participants completed the study online. Participants were randomized to one of three different conditions pertaining to three different versions of the CRT described below.

Procedure. Participants first completed one of three versions of the CRT: (a) normal CRT with an open-ended response format, (b) multiple-choice CRT with four responses that included both the correct answer and the commonly produced incorrect (“intuitive”) answer, or (c) multiple-choice CRT with four responses that included the correct answer but *not* the “intuitive” answer. We will henceforth refer to these conditions as the *Normal*, *Multiple-Choice*, and *No Intuitive Response* conditions. The multiple-choice version that contained the “intuitive” response was included to ensure that changing the format of the CRT to multiple-choice did not substantially change performance on the CRT.

The participants that were recruited from the Social Psychology course had been previously exposed to the CRT questions in another study, but they had not been given feedback about their performance. These participants were presented with problems that were structurally the same as the original CRT but were reworded and with slightly different numbers (e.g., “a cheese and crackers snack costs \$2.20 in total. The cheese costs \$2.00 more than the crackers. How much do the crackers cost?”). Given the identical problem structure, we did not expect these reworded problems to be any more or less difficult than the original CRT problems. Moreover, prior exposure to the CRT has been found to have little influence on future CRT performance (Bialek & Pennycook, 2017). Details about the different versions of the CRT and the response options for the multiple-choice versions can be found in supplemental materials

(<https://osf.io/8srw4/>). After completing the CRT, participants completed a variety of outcome measures (in the order presented below) and then were debriefed.

Outcome Measures. Full text of survey protocol and data for Study 1 can be found at <https://osf.io/9yx73/>.

Number Correct and Confidence. Immediately after completing the CRT, participants stated how many of the CRT questions they thought they answered correctly (0-3) and how confident they were in their answers on a 1-7 Likert scale: from 1 (*Not at all confident*), to 7 (*Extremely confident*).

Prior Exposure. All participants indicated whether they had seen any of CRT questions before Yes/No/Not sure. “Yes” and “Not sure” responses were coded as (1), “No” responses were coded as (0). All Social Psychology participants who indicated in the demographics section that they participated in the other study were also coded as being previously exposed to the CRT (i.e. also received a code of 1).

Rational Experiential Inventory (REI). Participants completed the 40-item REI, which included the faith in intuition (FI) and need for cognition (NFC) subscales (Pacini & Epstein, 1999); 1-5 Likert scale, 1 (*Definitely not true of myself*), 5 (*Definitely true of myself*).

Actively Open-Minded Thinking (AOT). Participants completed the 7-item actively open-minded thinking scale (Haran, Ritov, & Mellers 2013); 1-7 Likert scale, 1 (*Completely Disagree*), 7 (*Completely Agree*), which assesses the extent to which people consider evidence before making decisions and are willing to change their beliefs.

Religiosity and Paranormal Beliefs. Participants completed the 25-item paranormal beliefs scale (Tobacyk & Milford, 1983), which includes items related to religiosity and various other paranormal beliefs such as psychic abilities, witchcraft, superstitions, spiritualism,

extraordinary life forms, and precognition; 1-5 Likert scale; 1 (*Strongly disagree*), 5 (*Strongly agree*).

Conspiracy Beliefs. Participants completed the 15-item generic conspiracist beliefs scale (Brotherton, French, & Pickering, 2013), which includes items related to government malfeasance, extraterrestrial cover-ups, malevolent global conspiracies, personal wellbeing/unknown testing, and control of information; 1-5 Likert scale, 1 (*Definitely not true*), 5 (*Definitely true*).

Belief in Evolution. Participants were asked to rate which statement is closer to their beliefs on a 9-point scale: 1 (*Humans and other living things have existed in their present form since the beginning of time*), and 9 (*Humans and other living things have evolved over time*) (Gervais, 2015).

Moral Judgments. Participants read ten vignettes that described different morally relevant scenarios. Eight scenarios involved behaviors that were victimless but involved behaviors that were weird, disgusting, and/or broke social norms (e.g. a woman throws her dead dog in the trash). These scenarios are designed to elicit feelings of moral wrongness despite being victimless behaviors. The remaining two scenarios were behaviors that had clear victims, such as selling counterfeit tickets. These scenarios had all been used in previous research (Haidt, Koller, & Dias, 1993; Helzer & Pizarro, 2011; Pennycook et al., 2014; Royzman, et al., 2014; Schnall, Haidt, Clore, & Jordan, 2008). Participants rated each of the scenarios on a 7-point scale: 1 (*Not morally wrong at all*), and 7 (*Extremely morally wrong*). See supplement (<https://osf.io/8srw4/>) for full text of all moral judgment scenarios.

Objective Numeracy. Participants responded to the Rasch Numeracy Scale (Weller et al., 2013). For the sake of this research the 2 CRT items that are normally part of the Rasch

Numeracy Scale were not included in the calculation of the numeracy score. To supplement the Rasch scale, participants additionally answered the four Berlin Numeracy Test questions (Cokely et al., 2012). Numeracy scores were computed as the total number of items correct out of all 10 questions.

Heuristics and Biases. Participants received 11 questions assessing seven concepts from the battery of heuristics-and-biases tasks from Toplak et al., 2011. The concepts included: (a) sample size sensitivity (2 questions), (b) gambler's fallacy (2 questions), (c) methodological reasoning, (d) denominator neglect, (e) probability matching, (f) sunk cost fallacy (2 questions), and (g) outcome bias (2 questions). Responses were coded as being either correct/non-heuristic/unbiased (1) or incorrect/heuristic/biased (0) for all questions except the sunk cost fallacy and outcome bias questions. For the sunk cost fallacy and the outcome bias, participants were asked two questions and participants were coded as unbiased (1) if they committed the fallacy/bias across the two questions, and (0) if they did not (see supplement). A total score of non-heuristic responding was created by summing the total number of non-heuristic responses of nine. See the supplement (<https://osf.io/8srw4/>) for the full text and scoring of all the heuristics and biases problems.

Insight Problems. As a result of an oversight in survey development, two insight problems were added after the first 124 participants had already completed the study. These were the "Dirt in a hole" (*How much dirt is there in a hole that is 3 ft. by 3 ft. by 3 ft.?*), and the "Ocean liner" (*At 12 noon a porthole in an ocean liner was 8 feet above the water line. The tide raises the water at a rate of 2 feet per hour. How long will it take the water to reach the porthole?*), both adapted from Gilhooly and Murphy (2005, p. 286). Each of these problems has a commonly stated incorrect response that nonetheless requires some calculation (e.g. $3 \times 3 \times 3$),

and cognitive restructuring (e.g., insight problem solving ability) is necessary to produce the correct response (there is no dirt in a hole). Since these problems were added midway through data collection, for Study 1 they were only used to determine whether the CRT was associated with these problems. Insight problems were not used as a control variable or predictor of outcomes in Study 1 (we used these problems as a predictor of outcomes in Study 3).

Demographics. Participants completed standard demographic questions (race, age, gender, education), and were debriefed afterwards.

Results

When visually inspecting the time taken to answer each of the CRT questions, there were clear outliers (e.g., greater than 13 hours to answer the lily pad problem). To reduce the effect of these outliers, particularly on response time analyses, participants were excluded from all analyses if they spent more than five minutes answering any of the individual CRT questions. This 5-minute criterion was used because there were a few outliers so influential that calculating an exclusion criteria based on three standard deviations above the mean response time would have retained less extreme responses that were still clearly outliers (e.g., 10 minutes to answer just the lily pad problem). The 5-minute criteria resulted in only eight exclusions: four participants from Normal condition, one participant from the Multiple-Choice condition, and three participants from the No Intuitive Response condition.

This left a final sample of 539 participants ($n = 325$ from Introduction to Psychology, $n = 214$ from Introduction to Social Psychology); Table 1 contains the demographic characteristics of the sample. Although CRT performance was positively skewed and appeared to violate ANOVA's assumption of normality, skew in all conditions ranged from 0.05 to 0.84 and kurtosis ranged from -1.24 to -0.59. ANOVA has been found to be robust to violations of normality of

skewness = 2 and kurtosis = 6 (Lix, Keselman, & Keselman, 1996). The homogeneity of variance assumption was not violated, with *SDs* on the CRT = 1.06 in all conditions.

Furthermore, previous research has treated the CRT as a continuous measure of intuitive versus reflective thinking propensities (Gervais, 2015; Royzman et al., 2014; Shenhav et al., 2011; Toplak et al., 2011; West et al., 2012). Therefore, CRT score was considered a continuous measure throughout. A factorial ANOVAs showed no interactions between course (Introduction to Psychology versus Introduction to Social Psychology) and condition (Normal, Multiple-Choice, and No Intuitive Response) on any of the outcome measures (all $F_s(2, 523) < 2.05$, $p_s > .131$, $\eta_p^2 < .01$), and so course type will not be discussed further.

There were 288 participants who had possibly had prior exposure to the CRT. A factorial ANOVA showed that prior exposure was associated with higher CRT performance ($F(1, 533) = 12.02$, $p = .001$, $\eta_p^2 = .02$, $M = 0.98$ versus $M = 1.30$), but this factor did not significantly interact with condition, $F(2, 533) = 0.72$, $p = .49$, $\eta_p^2 = .00$. Given that there was no interaction, we did not consider this variable further.

CRT Performance by Condition. A one-way between-subjects ANOVA was used to determine if participants in the No Intuitive Response condition performed better than those in the other conditions. It revealed significant differences among conditions on CRT performance, $F(2, 536) = 21.23$, $p < .001$, $\eta_p^2 = .07$. Tukey's HSD tests revealed that participants in the No Intuitive Response condition performed significantly better than participants in both the Normal condition ($M_{\text{diff}} = 0.63$, $p < .001$, $d = 0.59$) and the Multiple-Choice condition, ($M_{\text{diff}} = 0.64$, $p < .001$, $d = 0.60$); however, the average performance in the No Intuitive Response condition was only slightly above 50% correct responses (Table 2). Performance in the Normal condition did not differ from the Multiple-Choice CRT condition, $M_{\text{diff}} = 0.01$, $p = .97$, $d = 0.01$). Table 2

displays the mean CRT score in each condition as well as the means for participants' predicted score, confidence, and a measure of participants' calibration (predicted score minus actual score), separated by condition (we do not discuss the latter findings for the sake of brevity).

CRT Response Time by Condition. A one-way between-subjects ANOVA was used to determine whether participants in the No Intuitive Response condition spent more time responding to the all three CRT problems as compared to the other conditions. It revealed significant differences among conditions on total time spent answering all three CRT questions, $F(2, 536) = 22.16, p < .001, \eta_p^2 = .08$. Tukey's HSD tests revealed that participants in the No Intuitive Response condition spent more time responding to the CRT questions ($M = 2.21$ minutes total for all three questions, $SD = 1.47$) as compared to both the Normal condition ($M = 1.66$ minutes, $SD = 1.13, p < .001, d = 0.42$) and the Multiple-Choice condition, $M = 1.38$ minutes, $SD = 0.99, p < .001, d = 0.66$. Participants in the Normal condition did not differ in response time relative to participants in the Multiple-Choice condition, $M_{\text{diff}} = 0.28$ minutes (16.80 seconds), $p = .083, d = 0.26$.

There were significant positive correlations between CRT score and time to answer all three problems in both the Normal ($r = .18, p = .018$) and Multiple-Choice conditions ($r = .21, p = .004$), but no correlation between score and time in the No Intuitive Response condition ($r = .00, p = .996$). Although a regression analysis indicated that the correlations between CRT performance and response time were not different across conditions ($ps > .11$), Table 3 shows that the lack of correlation between response time and score in the No Intuitive Response condition was not due to high-performing participants taking *less* time, but instead was due to low performing participants taking *more* time. Among participants who answered all three problems incorrectly, an independent samples t-test showed that participants took longer to

respond in the No Intuitive Response condition ($M = 2.12$ minutes, $SD = 1.70$) than in the Normal condition ($M = 1.42$ minutes, $SD = 1.00$), $t(39) = 2.19$, $p = .034$, $d = 0.50$. By contrast, participants who got all 3 CRT questions correct took the same amount of time to identify the correct answers in the No Intuitive Response condition ($M = 2.18$, $SD = 1.27$) and the Normal conditions ($M = 2.07$, $SD = 0.94$), $t(68) = 0.32$, $p = .75$, $d = 0.09$. These results suggested that some participants made errors despite taking some additional time to think.

CRT Performance by Numeracy and Condition. One question is whether the effect of condition on CRT performance was moderated by numeracy. For example, perhaps participants who were unable to identify the correct response in the No Intuitive Response condition were individuals who were particularly low in numeracy, whereas only the more numerate individuals were helped by this altered CRT format. This type of result has been reported for conjunction fallacy problems (Scherer, Yates, Baker & Valentine, 2017). However, the present data indicated that the different CRT conditions had equivalent effects on CRT performance for individuals both low and high in numeracy. A regression using mean centered numeracy, dummy coded condition variables (with the Normal condition as the baseline group), as well as the Numeracy $\times$ Condition interaction terms to predict CRT performance revealed that participants higher in numeracy had better CRT performance than individuals lower in numeracy ($b = 0.24$, $SE = 0.03$, $t(533) = 8.15$, $p < .001$), but Condition did not moderate this association ($bs = 0.02$, $SEs = 0.04$, $ts(533) < 0.54$, $ps > .59$).

Individual Differences, Beliefs, and Judgments. Table 4 displays the means, standard deviations, Cronbach's alphas, and correlations among measures. Collapsing across conditions, the CRT was associated with all outcomes—in the direction consistent with previous research using the CRT—except for the moral judgments of behaviors with victims. In addition,

Numeracy was significantly related to all outcomes except for FI, Religiosity, and Moral Judgments of Victimless Behaviors. The associations between Numeracy and the outcomes were in the same direction as the associations between the CRT and the outcomes.

Before testing whether numeracy accounts for some of the associations between the CRT and these beliefs/judgments, it was important to determine whether the different CRT conditions altered the associations between the CRT and the outcomes. We conducted regressions using mean centered CRT score, dummy coded condition variables (with the Normal condition as the baseline group), as well as the CRT score $\times$ Condition interaction terms to predict these outcomes. Results of these regression analyses are shown in Table 5. Overall, the lack of CRT score $\times$ Condition interactions indicates that correlations between the CRT and other measures were generally not altered by changing the format of the CRT. However, the CRT score $\times$ Condition interaction term (No Intuitive Response versus Normal) was significant for two outcomes: paranormal beliefs ($b = -0.16$, $SE = 0.08$, $t(513) = -2.18$, $p = .030$), and general conspiracy beliefs, $b = -0.23$, $SE = 0.09$, $t(513) = -2.57$, $p = .010$. For paranormal beliefs, the strongest association with the CRT was in the No Intuitive Response condition ($r = -.42$, $n = 176$, $p < .001$), and the least strongest association was in the Normal condition, $r = -.20$, $n = 169$, $p = .011$. For general conspiracy beliefs, there was a significant negative association in the No Intuitive Response condition ($r = -.25$, $n = 176$, $p = .001$), but no association in the Normal condition, $r = .03$, $n = 169$, $p = .708$. Hence, if anything, the CRT was *more* predictive of these judgments in the No Intuitive Response condition than in the Normal condition.

These regression results suggested that the different CRT conditions did not affect most associations between the CRT and the outcomes. Next, to determine the extent to which numeracy and the CRT were each uniquely predictive of these outcomes, CRT performance and

Numeracy were used simultaneously in regressions predicting the outcome measures (Insight was considered an outcome and not a predictor for these analyses because there was no Insight data for many participants, and using these problems as a predictor would have reduced the sample by about one-fifth; we corrected this error and expanded the number and type of insight problems in Study 3). Table 6 shows that the regression model was significant for all outcomes except for Faith in Intuition (FI). The CRT was predictive of all outcomes except belief in evolution, conspiracy beliefs, and moral judgments with victims (the CRT was significantly predictive of FI even though the overall model was not significant). Numeracy was predictive of all outcomes except FI, religiosity, and moral judgments of victimless behaviors.

Discussion

Study 1 showed that preventing participants from responding with “intuitive” answers resulted in higher performance on the CRT, which seems to support the notion that the CRT measures intuitive versus reflective thinking propensities. However, there were still a considerable number of errors on the CRT in the No Intuitive Response condition (47.7% incorrect responses on average), indicating that it may have been difficult for many participants to identify the correct answer even when the intuitive response was not available and the correct answer was displayed as a multiple-choice option. According to an intuition/reflection view of the CRT, this multiple-choice format should have made the CRT problems trivially easy, but instead almost half of all responses were incorrect.

Moreover, when participants made errors in the No Intuitive Response condition, they did so after taking more time to respond than similar-performing participants in the Normal CRT condition, and after taking just as much time to respond as participants who responded to all three questions correctly. These results are consistent with an insight problem view of the CRT.

An insight problem solving view would suggest that informing people that the “intuitive” answer is incorrect may help some people reframe the problem correctly, but many people will still be stuck in their initial (incorrect) interpretation. Like the “marriage” problem, a person will be unable to identify the correct answer until they successfully reframe the problem, and this additional reframing process is not trivially easy for some people. This alternative interpretation of the CRT is important, because it suggests that incorrect answers may occur after several unsuccessful attempts at reframing (i.e. an effortful “Type 2” process). Furthermore, much of the variance in CRT score may be attributable to individual differences in reframing ability, rather than a reliance on intuitive versus reflective thought processes per se.

This study also replicated many of the associations between the CRT and outcomes, such as paranormal beliefs and moral judgments, but also showed that these associations were observed even when the CRT was altered such that the “intuitive” response was prevented. This indicates that associations between the CRT and these outcomes could possibly be attributed not to a tendency to be intuitive, but instead to poor ability to reframe one’s thinking (i.e. a lack of cognitive restructuring). Nonetheless, the CRT predicted many of these outcomes even when adjusting for numeracy, suggesting that numerical abilities alone cannot explain most of these associations. In Study 3, we will determine whether the CRT is predictive of these outcomes adjusting for both numeracy and a battery of insight problems.

Study 2

Study 2 was designed to address a potential limitation of the experimental manipulation used in Study 1. One possible explanation for the considerable number of errors made on the CRT in the No Intuitive Response condition is that participants did not believe that the correct answer was among the four multiple-choice options because their first answer (i.e. the “intuitive”

answer) was not present. To address this potential limitation, Study 2 included explicit instructions that confirmed that the “intuitive” answers were incorrect, and the correct answer was among the options given.

Method

Participants and Design. Participants ($N = 604$ completed this study) were recruited online from Amazon’s Mechanical Turk (Mturk) in exchange for a small amount of monetary compensation. Participants recruited from Mturk have often seen the CRT in other studies, so only participants who had completed 50 or fewer studies on Mturk were eligible to participate in this study (by contrast, many Mturk studies purposefully select “experienced” participants who have completed more than 100 studies). Participants were randomized to either the Normal CRT condition from Study 1, or the No Intuitive Response condition from Study 1, which also included some additional instructions (described below).

Procedure. Study 2 followed the same procedure and outcome measures as Study 1 with the following changes. All participants were given CRT problems with new wordings. As stated previously, participants recruited from Mturk have often seen the original versions of the CRT. As a result, they may have memorized the correct answers or they could quickly search for the correct answer online. Therefore, as in Study 1, novel alternative CRT problems were developed. These problems were uniquely designed for Study 2 using the same criteria from Study 1. For example, “a sandwich and chips snack costs \$5.80 in total. The sandwich costs \$5.00 more than the chips. How much do the chips cost?” replaced the bat and ball problem. Details about the different versions of the CRT can be found in the supplement (<https://osf.io/8srw4/>).

In this study, all participants were instructed to answer as many problems correctly as possible, to take as much time as they needed, and to try to answer the problems without

searching the internet. Otherwise, the Normal condition was the same as in Study 1. The No Intuitive Response condition was also the same as Study 1 (i.e. four multiple-choice answers that included the correct, but not the intuitive, response) but also included additional instructions that explicitly stated that the “intuitive” answers to the questions were incorrect and the correct answer was among the four multiple-choice options. For example, the text below the sandwich and chips problem read, “Many people think the correct answer to this question is \$0.80. However, this is **not** correct. The correct answer is one of the four options below. What is the correct answer?” After each CRT problem, all participants were asked to honestly report if they guessed on the problem (yes/no) and were informed that their answer would not affect their compensation.

After completing all the CRT problems, participants were asked whether they had previously seen problems similar to each of the reworded CRT problems (Have seen/Have **not** seen/Not sure). This was coded analogously to Study 1: Participants who reported “have seen” or “not sure” to at least one of the reworded CRT problems were coded as 1, and participants who reported “have not seen” for all problems were coded as 0. Participants were also asked whether they had found or received any help (either online or from another person) when solving the CRT problems.

After completing these questions about the CRT, participants responded to some of the same belief and judgment outcome measures from Study 1, but these measures will not be discussed here in the interest of brevity. The complete study data and list of outcome measures can be found at (<https://osf.io/bc3np/>). After completing these measures, participants completed demographic information and were debriefed.

Results

Fourteen participants (seven in the Normal condition and seven in the No Intuitive Response condition) were excluded from analyses because they admitted to receiving help on at least one of the CRT questions. As in Study 1 there were outliers in time spent to answer each of the CRT questions. To reduce the effect of these outliers on analyses we used the same exclusion criteria from Study 1: any participant that spent more than five minutes answering any of the individual CRT questions was removed from all analyses. This resulted in 48 exclusions, 20 from the Normal condition and 28 from the No Intuitive Response condition. This left a final sample of 542 respondents; Table 1 contains demographic characteristics of this sample.

There were 323 participants who reported having possible prior exposure to the CRT. A factorial ANOVA showed that prior exposure to the CRT questions was associated with higher CRT performance ($F(1, 534) = 63.85, p < .001, \eta_p^2 = .11, M = 1.07$ versus $M = 1.66$), but this factor did not significantly interact with condition, $F(1, 534) = 0.77, p = .38, \eta_p^2 = .00$. These results are consistent with results from Study 1, and we did not consider this variable further because there was no interaction with condition.

CRT Performance by Condition. An independent samples t-test was used to test differences between conditions on CRT performance. This analysis showed that participants in the No Intuitive Response condition performed much better compared to participants in the Normal condition ($M_{\text{diff}} = 0.93, t(540) = 10.26, p < .001, d = 0.88$); however, the average number of correct responses in the No Intuitive Response condition was still only slightly above 63% (Table 2). Table 2 also displays the means for participants' predicted score, confidence, and a measure of participants' calibration (predicted score minus actual score), separated by condition (we report the latter findings in Table 2 for interested readers, but do not discuss them for the sake of brevity).

CRT Response Time by Condition. An independent samples t-test was used to test differences between conditions on total time spent answering all three CRT questions. Participants in the No Intuitive Response condition spent more time responding to the CRT questions ($M = 3.29$ minutes total for all three questions, $SD = 1.76$) than participants in the Normal condition ($M = 2.20$ minutes, $SD = 1.45$), $t(515) = 7.83$, $p < .001$, $d = 0.67$. In addition, to determine whether the association between response time and performance on the CRT differed by condition, a regression was conducted using mean centered performance on the CRT, a dummy coded condition variable (with the Normal condition as the baseline group), and CRT score $\times$ Condition interaction term as predictors of response time on the CRT. The interaction term was significant, $b = -0.35$, $SE = 0.13$, $t(538) = -2.65$, $p = .008$. The nature of this interaction replicated the effects observed in Study 1: there was a significant positive correlation between CRT score and response time in the Normal condition ($r = .21$, $n = 275$, $p < .001$), but no correlation between score and response time in the No Intuitive Response condition, $r = -.03$, $n = 267$, $p = .576$.²

Table 3 shows mean response times for participants in each condition who received scores of 0, 1, 2, or 3 correct, and the correlation between score and response time. This table suggests that, like Study 1, the lack of an association between response time and CRT performance in the No Intuitive Response condition was due to lower performing participants taking more time and not due to highest performing participants taking less time. Specifically, a

² Because Study 2 had many more exclusions based on response time than Study 1, this regression analysis was also conducted without excluding participants based on response time. The interaction between condition and score predicting time to respond was still significant, $b = -0.96$, $SE = 0.28$, $t(586) = -3.44$, $p = .001$. The correlation between score and time in the Normal condition was positive and significant (but decreased in strength as compared to the reduced sample), $r = .13$, $n = 295$, $p = .021$. Furthermore, the correlation in the No Intuitive Response condition became significant and negative, i.e. longer time was associated with *worse* performance, $r = -.15$, $n = 295$, $p = .012$. This indicates that the exclusion criteria removed mostly participants in both conditions that were taking a large amount of time and ultimately answering incorrectly.

t-test showed that participants who answered all three questions incorrectly took significantly longer to respond in the No Intuitive Response condition ($M = 2.90$ minutes, $SD = 1.47$), as compared to participants in the Normal condition ($M = 1.81$ minutes, $SD = 1.21$), $t(159) = 4.28$, $p < .001$, $d = 0.80$. By contrast, participants who answered all three questions correctly did not differ between conditions in the time they took to respond, $t(86) = 1.43$, $p = .16$, $d = 0.26$.

Effect of Guessing. An independent samples t-test was used to test differences between conditions among the total number of times a participant reported guessing on CRT questions. On average participants reported guessing on more problems in the No Intuitive Response condition ($M = 1.05$ problems, $SD = 1.07$) than in the Normal condition ($M = 0.58$ problems, $SD = 0.76$), $t(519) = 5.67$, $p < .001$, $d = 0.49$. One important question is whether participants who performed poorly in the No Intuitive Response condition were simply guessing without taking time to reflect. If this were the case, then guesses would be associated with faster response times. A regression model using mean centered number of guesses on the CRT, dummy coded condition variable (with the Normal condition as the baseline group), and the interaction term as predictors of CRT response time showed that guesses were associated with taking *more* time to respond across both conditions ($b = 0.29$, $SE = 0.11$, $t(538) = 2.57$, $p = .010$), and the interaction was not significant, $b = -0.25$, $SE = 0.15$, $t(538) = -1.70$, $p = .089$. The direction of the effect of guessing suggests that participants who guessed were thinking about the problems and *then* guessing, rather than guessing thoughtlessly.

Discussion

In this study, half of participants were explicitly told that the “intuitive” answers were incorrect and that the correct answers were among the four multiple-choice options. Participants’ CRT performance improved with this intervention, which seems to support the notion that CRT

performance is determined, at least in part, by intuitive versus reflective thinking propensities. However, there was still a considerable number of errors (36.7% incorrect responses on average), suggesting that some individuals had difficulty identifying the correct answer even when they knew that it was among four presented options. CRT performance may have even been overestimated in the No Intuitive Response condition, because up to 25% of correct answers may have been obtained by chance.

Some participants reported guessing, which could indicate that they did not take time to reflect on the problem. However, guessing was associated with taking *more* time to respond, not less, relative to non-guesses. This result suggests that some participants spent some time—presumably thinking about the problem—before eventually guessing (either correctly or incorrectly). Moreover, this study replicated Study 1, showing that there was no correlation between response time and CRT performance in the No Intuitive Response condition, and that this was due to participants taking more time to produce incorrect responses (rather than taking less time to produce correct responses). Together, these results are inconsistent with an intuition/reflection view of the CRT, which would expect that the problems become “trivially easy” once one’s error is realized, and that any remaining errors would be committed by individuals who are not showing any evidence of effort. Instead, these results suggest that some people may experience the CRT problems very similarly to the way that they experience insight problems; that is, once they realize that their first answer is incorrect, they try to reframe the problem. Rather than finding the problems trivially easy, many people have difficulty reframing and after a period of unsuccessful reflection, they give up and guess.

Study 3

Study 3 was designed to address two as-yet unaddressed issues. One important limitation of Studies 1 and 2 was that participants who responded incorrectly on the CRT when there was no “intuitive” response may not have engaged in sufficient reflection. That is, these individuals might be *capable* of answering the questions correctly, but they were not willing to put forth the necessary effort, which would suggest that these individuals are more “intuitive” than participants who responded correctly. Although guessing was positively associated with time taken to respond to the CRT in Study 2 (which indicated thoughtful guessing, as opposed to thoughtless guessing), participants were not given strong instructions to engage in reflection and try to solve the problem *without* guessing. Thus, Study 3 addressed this limitation by including a more heavy-handed prompt to engage in reflection and not guess, in addition to presenting a multiple-choice answer format that did not include the intuitive response. The intuition/reflection view predicts that this intervention would eliminate the remaining proportion of incorrect responses.

Equally important, Study 3 included a broad battery of insight problems. Although Studies 1 and 2 suggested that the CRT is more similar to insight problems than what has been commonly assumed, the assessment of insight problem solving ability included only two problems in Study 1, and both of those problems were much like the CRT and of the type that suggests an initial incorrect response. It is still unclear whether the CRT is also associated with the type of insight problem that does *not* suggest an initial incorrect response (e.g., the marriage problem), which are presumed to be fundamentally different from the CRT. Moreover, insight problem solving ability could be responsible for some of the associations between the CRT and other outcomes (e.g. paranormal beliefs, heuristics and biases).

Thus, Study 3 included nine insight problems, five of which were of the type that suggest initial incorrect responses (e.g. the “dirt in a hole” problem), which were predicted to be moderately-to-strongly associated with the CRT, and four of which were of the type that do not suggest an initial incorrect response, which were predicted to be more weakly associated with the CRT. Our aim was to determine (a) whether one or both types of insight questions were associated with the CRT, and (b) whether insight problem solving performance accounts for some of the association between the CRT and the belief/judgment outcomes.

Method

Participants and Design. Six-hundred forty-three participants from two introductory psychology courses (Introduction to Psychology $n = 532$, Introduction to Social Psychology $n = 111$) at the University of Missouri completed the study. All Introduction to Psychology students completed the study on a computer in lab, while the Introduction to Social Psychology students completed the study online. Participants were randomized to one of three different conditions pertaining to three different versions of the CRT.

Procedure. Study 3 followed the same procedure and outcome measures as Study 1 with the following changes: All participants were given the CRT problems with their original wordings. The first two conditions were identical to Normal and No Intuitive Response conditions from Study 1, but the third condition used the No Intuitive Response multiple-choice format (i.e. 4 multiple-choice answers that included the correct, but not the intuitive, response) and added instructions to think carefully (henceforth simply the *Deliberation* condition). In this new Deliberation condition, participants were given instructions to think carefully and not guess on the problems:

You should take time to think carefully about each problem. We encourage you to use the scratch paper provided to help you solve the problems.³

Importantly, **do not guess**.

DO NOT MOVE ON TO THE NEXT QUESTION until you are CERTAIN that you have identified the correct answer.

AFTER 2 MINUTES HAVE PASSED, if you have tried your best to figure out the correct answer and you feel you are unable to solve it, you should click the button that says “I’m clicking this because I cannot figure out how to solve this question, and would like to move on to the next question.”

This button will become active after 2 minutes have passed and you should ONLY click this button if you have tried your best and still cannot solve the problem with confidence.

After participants read the instructions, they were presented with the CRT questions in a randomized order. Participants in the Normal and No Intuitive Response conditions simply responded to the questions. Participants in the Deliberation condition saw a header above each CRT question that read:

Remember: Take time to think carefully about the problem. We encourage you to use the scratch paper provided to help you solve the problems. **Do not guess**. **Do not move on to**

³ The participants who completed the study online had the wording changed slightly to reflect that they were not provided with scratch paper. In the Deliberation condition, the wording throughout all the instructions was: *We encourage you to get out scratch paper and use it to help you solve the problems.*

the next question until you are certain that you have identified the correct answer.

Below each question in the Deliberation condition were the words, “I’m clicking this because I cannot figure out how to solve this question, and would like to move on to the next question.”

Prior to two minutes this text was displayed but there was no checkbox; after two minutes the checkbox appeared to the left of the text, and the participant could click the checkbox.

After each CRT problem, all participants were asked to honestly report if they guessed on the problem (yes/no), which primarily served as a check for the deliberation manipulation. In addition, participants in the Deliberation condition who checked “*I cannot figure out how to solve this question*” were subsequently asked to provide a guess on the problem in order to obtain a response, as well as to make sure that if the instructions were too strong (i.e., participants thought they had identified the correct answer, but did not feel 100% certain), participants could still provide a response.

After completing the CRT, participants completed the same large list of outcome measures from Study 1, with the following additions.

Outcome Measures. Full text of survey protocol and data for Study 3 can be found at <https://osf.io/v32mc/>.

Cheating. Since some participants took the study online and could not be monitored, these participants were asked whether they looked up the answer to each of the CRT questions (Yes/No).

Heuristics and Biases. In addition to the seven concepts assessed in Study 1, we added problems assessing: (a) causal base rate reasoning, (b) regression to the mean, and (c) covariation detection. Responses were coded as being either correct/non-heuristic/unbiased (1) or incorrect/heuristic/biased (0) for all questions. A total score of non-heuristic responding was

created by summing the total number of non-heuristic responses given out of 12. See the supplement (<https://osf.io/8srw4/>) for the full text and scoring of all the heuristics and biases problems.

Insight Problems. All participants were asked nine insight problems. Participants were asked five insight problems similar to the “Dirt in the hole” problem described earlier, insofar as each question strongly suggests an initial incorrect answer. Four insight problems were similar to the “Marriage” problem described earlier, insofar as each question does not suggest any initial answer; therefore, these problems feel as if there is no possible answer. Many of these questions were adapted from Gilhooly and Murphy (2005). The total number of correct responses for each type were summed, resulting in two insight problem solving scores: one for questions similar to the CRT (i.e. that suggest an initial incorrect answer), and one for questions similar to the “Marriage” problem (see supplement for full list, <https://osf.io/8srw4/>).

Results

Three participants were excluded because they responded with the same number for all questions, including open-ended responses. Seven other participants were excluded from all analyses because they reported looking up the answer to at least one of the CRT questions (two participants from the Normal condition, two from the No Intuitive Response condition, and three from the Deliberation condition). For the sake of consistency with Studies 1 and 2, any participant that spent more than five minutes answering any of the individual CRT questions was removed from all analyses, resulting in only two exclusions, both from the Deliberation condition. These exclusions did not substantively change any of the results or conclusions described below. This left a final sample of 631 participants ($n = 531$ from Introduction to

Psychology, $n = 100$ from Introduction to Social Psychology), and Table 1 contains the demographic characteristics of the sample.

As in Study 1, factorial ANOVAs showed that there were no interactions between these two courses and condition on any of the outcome measures (all $F_s(2, 602) < 1.77$, $p_s > .16$, $\eta_p^2 < .02$), so course will not be discussed further. There were also 244 participants who had possibly had prior exposure to the CRT. A factorial ANOVA showed that prior exposure to the CRT was associated with higher CRT performance ($F(1, 625) = 15.22$, $p < .001$, $\eta_p^2 = .02$, $M = 1.28$ versus $M = 1.61$), but this factor did not significantly interact with condition, ($F(2, 625) = 1.21$, $p = .299$, $\eta_p^2 = .00$), which was consistent with results from Studies 1 and 2. Given that there was no interaction, we did not consider this variable further.

Deliberation Condition: CRT Performance by Compliance and Guessing. The data in the Deliberation condition were scrutinized to determine whether participants in that condition were compliant and followed instructions to think carefully about the problems and not guess. Due to a technical error, 22 of the 211 participants activated the “I cannot figure out this problem” button before 2-minutes had passed on one or more of the CRT questions. By clicking on or near the text, these participants had recorded a response to this question even though the checkbox was not visible to let them know that their response was recorded. Whether they were intentionally trying to activate the checkbox or whether it was activated accidentally was unclear, but activating the checkbox prevented these participants from answering the guessing question. Therefore, it was unknown if these participants were compliant (i.e. did not guess within the 2-minute timeframe) or if they had guessed. Thus, we analyzed these 22 participants separately.

For the remaining 189 participants in the Deliberation condition, participants were coded as compliant on a CRT problem (e.g., received a dummy code = 1) if they did not report

guessing or if they clicked the “I cannot figure out this problem” button after 2-minutes had passed. All participants who reported guessing were coded as 0. A compliance score was then calculated by summing the total number of problems on which a participant was compliant, resulting in a score that could range from 0 – 3.

Of these 189 participants in the Deliberation condition, 112 (59.3%) were compliant on all three CRT problems, with a mean CRT score = 2.13, $SD = 1.06$. A further 48 (25.4%) were compliant on two of the three problems, with a mean CRT score = 1.44, $SD = 0.80$. Twenty-four (12.7%) were compliant on only one of the three problems, (mean CRT score = 1.17, $SD = 0.96$), and 5 participants (2.6%) were completely non-compliant, with a mean CRT score = 0.60, $SD = 0.55$. The mean CRT score for the 22 participants with unknown compliance was 0.95, $SD = 0.84$. Completely compliant participants performed significantly better on the CRT than participants who were non-compliant on one or more questions ($M_{diff} = 0.83$, $t(181) = 5.90$, $p < .001$, $d = 0.86$). These data indicate that although not all participants completely followed instructions, a majority did. Of participants for whom compliance was calculated, 84.7% followed instructions on at least two of the three problems.

One theoretically relevant question is whether anyone answered incorrectly and claimed that they did not guess; such an outcome would further point to the difficulty of the problems as this would indicate that they had convinced themselves of an incorrect response. Indeed, results demonstrated that many participants responded incorrectly even when they claimed they did not guess. On the bat and ball problem, 122 participants reported that they answered the problem without guessing, but 21 (17.2%) of these responses were incorrect. On the lily pad problem, 161 participants reported that they answered the problem without guessing, but 65 (40.4%) were incorrect. On the widget problem, 162 participants reported that they answered the problem

without guessing, but 72 (44.4%) were incorrect. These data suggest that many participants convinced themselves that their incorrect answer was in fact correct, suggesting a procedural error or lack of ability. Finally, of the 93 participants who did not guess or give up on any question, the mean CRT score was $M = 2.19$ ($SD = 1.03$), or 73% correct responses. This suggests that in the Deliberation condition, participants who had answered the problems with certainty had convinced themselves of an incorrect response 27% of the time. At this point it is also worth reiterating that in the Deliberation condition the correct response (but *not* the intuitive response) was presented as one of four multiple-choice options; that is, participants were not forced to generate the correct answer themselves, but were merely asked to identify it. These results indicate that the CRT problems are not trivially easy for some participants.

CRT Performance by Condition. A one-way between-subjects ANOVA was used to test differences in CRT performance by condition. It revealed significant differences among conditions, $F(2, 628) = 32.51, p < .001, \eta_p^2 = .09$. A Tukey HSD test revealed that participants in the Deliberation condition performed significantly better than participants in the Normal condition ($M_{\text{diff}} = 0.77, p < .001, d = 0.73$), but did not perform better than participants in the No Intuitive Response condition ($M_{\text{diff}} = 0.11, p = .55, d = 0.10$). Average performance in the Deliberation condition was 56.7% correct responses, and average performance in the No Intuitive Response condition was 53% correct responses, (Table 2). Replicating Study 1, participants in the No Intuitive Response condition performed significantly better than participants in the Normal condition, $M_{\text{diff}} = 0.66, p < .001, d = 0.62$. When restricting the Deliberation condition to the 112 participants who were completely compliant, the omnibus ANOVA showed a somewhat larger effect of condition on CRT performance ($F(2, 529) = 49.91, p < .001, \eta_p^2 = .16$), and participants in the Deliberation condition performed significantly better

than participants in the No Intuitive Response condition ($M_{\text{diff}} = 0.54, p < .001, d = 0.50$). Thus, so long as participants were following instructions, they did perform better in the Deliberation condition than in the No Intuitive Response condition. Table 2 displays these means in addition to the means for participants' predicted score, confidence, and participants' calibration (predicted score minus actual score); we report the latter results for interested readers but do not discuss them for the sake of brevity.

CRT Response Time by Condition. A one-way between-subjects ANOVA tested differences among conditions on time taken to respond to all three CRT problems. It revealed that participants in the Deliberation condition spent more time responding to all three CRT questions ($M = 2.79$ minutes, $SD = 1.55$) as compared to both the Normal condition ($M = 1.73$ minutes, $SD = 1.15, p < .001, d = 0.78$) and the No Intuitive Response condition ($M = 2.04$ minutes, $SD = 1.06, p < .001, d = 0.56$), $F(2, 628) = 38.63, p < .001, \eta_p^2 = .11$. Participants in the No Intuitive Response condition also took more time answering all three CRT questions than participants in the Normal condition, $p = .032, d = 0.28$.

In addition, we examined the association between CRT performance and response time in each condition. There was no significant association between CRT score and response time in the Normal condition, although the trend was positive, similar to previous studies ($r = .11, n = 211, p = .105$). By contrast, there were significant *negative* correlations between CRT score and response time in both the No Intuitive Response ($r = -.22, n = 209, p = .002$) and the Deliberation conditions ($r = -.25, n = 211, p < .001$). There also was a negative association between CRT score and response time among the fully compliant participants in the Deliberation condition, $r = -.28, n = 112, p = .002$. A regression analysis confirmed that the slopes in the No Intuitive Response and Deliberation conditions were significantly different from the slope in the Control

condition, as denoted by two significant Condition $\times$ CRT score interactions (CRT score $\times$ dummy code for the No Intuitive Response versus the Normal condition $b = -0.34$, $SE = 0.12$, $t(625) = -2.92$, $p = .004$; CRT score dummy code for the Deliberation versus the Normal condition $b = -0.48$, $SE = 0.11$, $t(625) = -4.19$, $p < .001$). These results indicate that in the Deliberation and No Intuitive Response conditions, incorrect responses were associated with taking more time to respond, which is inconsistent with the notion that errors resulted from less reflection than correct responses.

Furthermore, Table 3 shows mean response times for participants in each condition who received scores of 0, 1, 2, or 3 correct. This table indicates that participants who answered all three problems incorrectly took longer to respond in the Deliberation condition than those participants in both the Normal ($M_{\text{diff}} = 1.78$ minutes (106.80 seconds), $p < .001$, $d = 1.47$) and the No Intuitive Response ($M_{\text{diff}} = 1.20$ minutes (72.00 seconds), $p < .001$, $d = 1.01$) conditions, $F(2, 167) = 38.70$, $p < .001$, $\eta_p^2 = .32$.

Individual Differences, Beliefs, and Judgments. Table 7 displays the means, standard deviations, Cronbach's alphas, and correlations among the outcome measures. This study replicated all significant associations from Study 1 with the CRT except for conspiracy beliefs. Critically, the CRT was significantly associated with the type of insight problems that prompted common incorrect responses ($r = .42$, $p < .001$), and was equally strongly associated with insight problems that did not suggest incorrect responses ($r = .42$, $p < .001$). The strength of this association did not differ by type of insight problem ($Z = 0.09$, $p = .93$).

Table 7 also shows that this study replicated all significant associations with Numeracy from Study 1, except for the association with Moral Judgments of Behaviors with Victims. Numeracy was additionally found to be negatively associated with Religiosity and Moral

Judgments of Victimless Behaviors. Performance on insight problems with “intuitive” solutions (which theoretically should be closely related to the CRT) was also significantly correlated with all outcomes except for FI, General Conspiracy Beliefs, Belief in Evolution, and Moral Judgments of Behaviors with Victims; performance on insight problems without “intuitive” solutions showed the same pattern of correlations except with regard to FI, where the correlation was significant. Hence, scores from all four measures—the CRT, numeracy, and both types of insight problems —were associated with many of the presently examined individual differences, beliefs, and judgments.

As in Study 1, one theoretically relevant consideration is whether the observed associations with the CRT changed in the different CRT conditions. To test this, regression analyses were conducted using mean centered CRT score, dummy coded condition variables (with the Normal condition as the baseline group), as well as the CRT score $\times$ Condition interaction terms as predictors of the outcome variables. Results of these regressions are shown in Table 8. This table shows that the associations between these outcomes and the CRT were generally not changed by the different CRT conditions, which is especially interesting for both sets of insight problems; that is, the CRT was not more strongly related to either type of insight problem in Normal condition as compared to the No Intuitive Response or Deliberation conditions. For insight problems that suggest an incorrect answer (e.g., the dirt in the hole problem), the correlations ranged from .40 to .48 across the three conditions, and for insight problems that do not suggest an incorrect answer (e.g., the marriage problem), the correlations ranged from .39 to .45 across the three conditions. This indicates that the CRT is consistently related to both types of insight problems, and that changing the format of the CRT does not make the problems become more or less similar to either type of insight problem.

The only case in which the CRT score $\times$ Condition interaction term (No Intuitive Response versus Normal) was significant was for the regression analysis predicting moral judgments of behaviors with victims, ($b = -0.21$, $SE = 0.09$, $t(604) = -2.27$, $p = .024$). There was not a significant association between CRT score and these moral judgments in the Normal condition ($r = .07$, $n = 201$, $p = .307$) or Deliberation condition ($r = -.06$, $n = 205$, $p = .435$), but there was a significant negative association in the No Intuitive Response condition ($r = -.16$, $n = 204$, $p = .022$). However, this interaction was not observed in Study 1, and the interactions that were observed in Study 1 were not replicated in this study. Thus, it is unclear whether any of these interaction effects reflect meaningful effects or Type I errors. For all other outcomes, the CRT was equally predictive across conditions.

Next, it was important to determine whether the insight problems were uniquely associated with the CRT after adjusting for Numeracy. Because the nine insight problems together were reliable ($\alpha = .79$) a sum insight score was calculated. A simultaneous regression was run using Numeracy and insight score to predict CRT performance. Both Numeracy ($b = 0.22$, $SE = .02$, $t(628) = 12.04$, $p < .001$) and Insight ($b = 0.15$, $SE = 0.02$, $t(628) = 9.61$, $p < .001$) accounted for a significant portion of variance in CRT performance, $F(2, 628) = 192.90$, $R^2 = .38$, $p < .001$.

Next, CRT Score, Numeracy, and Insight were used as simultaneous predictors in multiple regressions to predict the outcome measures. Table 9 shows that the regression model was significant for all outcomes except, FI, conspiracy beliefs, and moral judgments for behaviors with victims. Although the model was significant for Religiosity and Belief in Evolution, none of the predictors were uniquely associated with either outcome. Adjusting for Numeracy and Insight, higher CRT scores were associated with higher NFC, higher Heuristics-

and-Biases performance, and lower judgments of moral wrongness for victimless behaviors.

Adjusting for the CRT and Insight, higher Numeracy was associated with higher NFC, higher AOT, higher Heuristics-and-biases performance, lower Paranormal Beliefs, lower judgments of moral wrongness for victimless behaviors, and lower General Conspiracy Beliefs. Adjusting for the CRT and Numeracy, Insight was associated with higher NFC and higher AOT.

Discussion

Study 3 accomplished two goals. First, Study 3 examined CRT performance under heavy-handed instructions to engage in reflection and not guess, with the goal of identifying whether or not these problems are, in fact, trivially easy when an error has been detected and reflection has occurred. Second, Study 3 examined the extent to which numeracy and performance on insight problems may account for associations between the CRT and individual differences, beliefs, and judgments that are typically associated with the CRT.

With regard to the first goal, Study 3 showed that participants' CRT performance was considerably improved when (a) participants were prevented from responding with "intuitive" answers, (b) the correct response was presented as a multiple-choice option, and (c) participants followed instructions to think carefully and not guess. This appears to support the notion that the CRT measures intuitive versus reflective thinking propensities. However, that conclusion is qualified by the observation that many participants did not identify the correct answer, even when they reflected and the correct answer was displayed as a multiple-choice option. In the Deliberation condition, 27% of responses on average were incorrect even when participants claimed they did not guess, suggesting that they had wrongly convinced themselves that their incorrect answers were correct more than one-quarter of the time. For each individual CRT problem, 17.2% – 44.4% of non-guess responses were incorrect, and this was in a condition in

which the correct response, but not the “intuitive” response, was displayed as one of four multiple choice options. This is a very high rate of errors if these problems were, in fact, trivially easy.

Moreover, participants in the No Intuitive Response and the Deliberation conditions took more time on average to answer incorrectly than correctly. Thus, changing the CRT response format in this way revealed that CRT problems are much more similar to insight problems than what has been previously been assumed. That is, many people produced the “intuitive” response in the normal CRT condition (much like the “dirt in a hole” insight problem); however, when the “intuitive” response was not available, many participants appeared to sit stuck in thought (similar to the “marriage” insight problem), and ultimately failed to identify the correct solution.

Interestingly, it would have been reasonable to predict that the normal CRT would be more strongly associated with the type of insight problems that suggests an incorrect “intuitive” answer (e.g., the dirt in a hole problem), whereas the No Intuitive Response CRT would have been more strongly associated with insight problems that do not suggest an incorrect answer (e.g., the marriage problem). However, the CRT was equally correlated with both types of insight problems in all of the CRT conditions. These observations call into question the assumption that the CRT and insight problems suggesting “intuitive” responses share something in common that is distinct from insight problems that do not suggest an incorrect “intuitive” response.

With regard to our second goal, the associations between the CRT and other belief and judgment measures generally did not vary across the three CRT conditions. This indicates that the CRT performance is associated with these measures even when incorrect responses are produced with reflection, and in fact are associated with more reflection than correct responses.

This finding makes it difficult to conclude that the CRT's association with other measures is primarily due to individual differences in intuitive versus reflective thinking propensities. Instead, the CRT's association with these beliefs and judgments appears to be related to people's ability to solve these problems regardless of the amount of reflection.

The CRT was significantly associated with all but two of the individual differences, belief, and judgment measures; only moral judgments with victims and conspiracy beliefs were unrelated when examining the zero order correlations, replicating prior findings (Table 7). However, when adjusting for numeracy and insight problem performance the CRT was associated with only three outcomes: NFC, victimless moral judgments, and performance on heuristics-and-biases problems (Table 9). This further indicates that the CRT's association with some outcomes, (AOT, religiosity, beliefs in evolution, paranormal beliefs), should not necessarily be interpreted as indicating that these outcomes are related to individual differences in intuitive versus reflective thinking propensities. Numeracy, however, was a significant and unique predictor of six of the 10 outcomes (NFC, AOT, paranormal beliefs, general conspiracy beliefs, moral judgments of victimless behaviors, and heuristics-and-biases). This suggests that numeracy is likely important for understanding some of these individual differences.

Study 4

Data from Studies 1 – 3 have raised a number of issues that call into question the validity of the CRT as a measure of individual differences in intuitive versus reflective processing propensities. However, this prompts a further question: what *does* the CRT measure? Study 4 sought to address whether the CRT measures a separate construct (e.g., intuitive versus reflective thinking propensities) from both numeracy and insight problem solving. This question was answered by using multidimensional IRT models which allow for exploratory and confirmatory

factor analyses of binary response variables. If the CRT measures individual differences that are distinct from numeracy and insight problem solving, then a 3-factor model should fit the data best, with the CRT problems forming one factor, the insight problems forming another factor, and the numeracy problems forming the third factor. Although this 3-factor model factor is theoretically motivated and confirmatory models could be utilized, it may be the case that the data do not fit this model. Hence, alternative models were first explored to determine whether the data support a separate CRT factor.

Method

A total of 627 participants completed the CRT, numeracy, and insight measures during a mass survey, and the sample was randomly split into two halves. The exploratory models were run on the first half of the data, and the confirmatory models were run on the second half of the data. All responses to all questions were coded as incorrect (“0”) versus correct (“1”). The CRT problems were the reworded versions used in Study 1, the numeracy questions were the ones from Weller et al. (2013) scale that were not CRT problems, and the insight problems were taken from Study 3. Full text of survey protocol and data for Study 4 can be found at <https://osf.io/crjm3/>.

The following exploratory models were run on the first half of the data: 1-factor, 2-factor, 3-factor, 4-factor. All models were 2-parameter logistic (2-PL) models. After determining which of the exploratory models are viable (i.e., fits the data) and interpretable, the best three models were confirmed on the second half of the data, to compare which confirmatory model fit the data best. Thus, the best fitting model overall was whichever of the three best fitting exploratory models fits the data best following confirmatory analyses.

Results

The demographic characteristics of the sample can be found in Table 1. Neither half of the data differed by age ($t(614) = 0.95, p = .34$), gender ($\chi^2(1) = 0.14, p = .71$), or race, $\chi^2(1) = 2.08, p = .15$.

The standardized factor loadings for the oblimin rotated solution for the exploratory models can be found in Table 10. The 1-factor model did not have any loadings below 0.30, which seemed to indicate a general cognitive ability factor. The 2-factor model appeared most interpretable of the four models, showing numeracy questions forming one factor, the insight problems forming another factor, and CRT problems loading onto both of those factors. This model indicated that the CRT problems measured a combination of Numeracy and Insight Problem Solving Ability.

The 3-factor model appeared to break the insight problems into two separate factors, one for problems that suggest an incorrect “intuitive” response, and another for problems that do not suggest an incorrect “intuitive” response. However, the 3-factor model also contains many cross-loadings that complicated this interpretation. For example, some of the insight problems loaded onto what appeared to be a numeracy-related factor, and some of the numeracy problems loaded onto a factor that also loaded both CRT and (some) insight problems.

The 4-factor model showed numeracy problems loading onto two factors, with CRT problems and two insight problems loading onto one of these two factors. Furthermore, it appeared as though the insight problems formed two factors separate from these numeracy factors. These insight factors did appear to break the insight problems into problems that suggest an incorrect “intuitive” response and problems that do not. However, it was possible that this 4-

factor model had over fit the data. Notably, *none* of these models indicated a clear separate factor for the CRT problems.

Table 11 displays several model fit indices for each model. Based on the root mean square error of approximation (RMSEA), all models provided adequate fit (i.e., all RMSEA values are $< .070$). Despite all models providing adequate fit, the model fit indices did not converge on a single best fitting model: the Bayesian Information Criterion (BIC) indicated that the 2-factor model was the best fitting model, the M2 and corresponding p -value indicated that the 3-factor model was the best fitting model, and Akaike Information Criterion (AIC), the log likelihood, and RMSEA indicated the 4-factor model was the best fitting model.

Although the fit indices did not converge on a single best fitting model, this was not problematic because the top three models were to be confirmed. Thus, the second half of the data was used to confirm the 2-factor, 3-factor, and 4-factor models. All loadings above .30 were estimated, and all loadings below .30 were fixed to 0 in model estimation.

During confirmatory model estimation both the 3-factor and 4-factor models failed to converge when using the Expectation Maximization algorithm; however, to enable these models to be estimated the Metropolis-Hastings Robbins-Monro (MHRM) algorithm was used. Table 12 displays the standardized factor loadings for the confirmatory models using the MHRM algorithm for the 2-factor, 3-factor, and 4-factor models. Both the 3-factor and 4-factor models had at least one loading $< .30$. This indicated some misfit among the items in the confirmatory model. Furthermore, both of these models had factor correlations above .80, which would suggest that although the model fit separate factors because of model specification, these separate factors could possibly be condensed into fewer factors.

Table 13 displays model fit indices for the confirmatory models that could be estimated. Based on the RMSEA, both the 2 and 3-factor models showed good fit (i.e., RMSEAs $< .05$), but the 4-factor model had poor fit (i.e., RMSEA $> .10$). Although some of the model fit indices (AIC and Log-likelihood) suggested that the 4-factor model was the best fitting model, the 2-factor model was favored by the BIC and the RMSEA. Thus, the 2-factor model was considered the best fitting model because it was the most parsimonious of the confirmatory models, it did not contain any factor correlations above .80, it did not have any factor loadings below .30, and some of the model fit indices suggested it was the best fitting model.

Discussion

The results of this IRT analysis suggest that the CRT assesses a combination of insight problem solving ability and numeracy. Furthermore, these results suggest that the CRT problems do not measure a construct unique from numeracy and/or insight problem solving ability. The results of this research are consistent with previous findings that suggest that the CRT measures numeracy and something beyond numeracy (Liberali et al., 2012).

Moreover, this study suggests that the CRT is not only related to structurally similar insight problems (i.e., “dirt in a hole” problem), but also to problems that do not suggest a commonly given incorrect response (i.e., “marriage” problem). Thus, it seems a major component to solving all of these problems correctly (i.e., CRT and both types of insight problems) is the ability to restructure one’s initial interpretation of, or approach to, the problem. This restructuring may happen spontaneously and potentially without conscious effort (i.e., insight), or through explicit reasoning processes.

General Discussion

The CRT had been broadly influential in the dual-process literature, both as an

illustration of intuitive versus reflective processes, and as a measure of individual differences in intuitive versus reflective thinking propensities. The CRT purports to measure the tendency to question one's initial intuitions and engage in reflection, and it is assumed (given normal intelligence and basic math skills) anyone would be able to solve all the CRT problems with a little effort, provided that they recognize that their first response is incorrect. Yet, this assumption has rarely been tested, and is central to the notion that the CRT is a measure of intuitive versus reflective thinking propensities. The first purpose of this research was to test this assumption.

With regard to this purpose, the present findings suggested that the CRT is more difficult than what is currently assumed. A substantial proportion of errors on the CRT seem to result from difficulty reframing the problem after it becomes clear that their initial answer is wrong. Indeed, people often cannot identify the correct response out of four multiple-choice options, even when (a) the "intuitive" response is not included in those options (Studies 1-3) (b) the instructions clearly state that the "intuitive" answers are incorrect and that the correct answer is presented in the four response options (Study 2), and (c) participants are instructed to reflect and do not guess (Study 3). Two out of the three samples were college undergraduates, so these samples were at least average in intelligence (possibly higher as years of education and intelligence are positively correlated, Neisser et al, 1996), and have basic high school math skills. Hence, something more than error detection and a small amount of reflection is required to respond correctly to the CRT problems for some people. Results from this research, particularly Study 4, suggested that the additional needed skills are numeracy and insight problem solving ability, the latter of which is thought to involve the ability to reframe problems and think of

novel solutions (which might be arrived at through explicit search processes or as a sudden “aha!” moment).

The second purpose of this research was to determine whether numeracy and/or insight accounts for associations between CRT performance and other individual differences and beliefs (NFC, paranormal beliefs, moral judgments, etc.). Past research has largely concluded that intuitive versus reflective thinking propensities are responsible for the associations between the CRT and other outcomes, such as NFC (Frederick, 2005), AOT (Haran et al., 2013), religiosity (Shenhav et al., 2012), paranormal beliefs (Pennycook et al., 2012), belief in evolution (Gervais, 2015), moral judgments of victimless behaviors (Royzman et al., 2014), and performance on a heuristics-and-biases battery (Toplak, et al., 2011). One important observation from the present research was that the associations between the CRT and these individual differences and beliefs remained the same when the CRT was altered such that commonly given “intuitive” errors were not possible. Furthermore, non-intuitive errors were associated with as much or even *more* time spent on the problems as correct responses. These results indicate that the observed correlations between the CRT and real-world beliefs should be attributed to skills that allow a person to answer the CRT questions correctly *after* they have questioned their intuitions and reflected.

What Does the CRT Measure?

It might be argued that by changing the CRT problems to prevent “intuitive” responding, we fundamentally changed the nature of the CRT; that is, the original problems might primarily assess intuitive versus reflective thinking propensities, whereas the problems without the “intuitive” answers are more similar to insight or numeracy problems. However, both versions of the CRT were found to have the same correlation with insight problems, as well as with numeracy. Moreover, both versions of the CRT were equally correlated with insight problems,

and this included both insight problems with attractive incorrect answers, as well as insight problems that do not trigger an attractive, incorrect response. This pattern of results contrasts with the notion that there is something special about problems that produce commonly given “intuitive” incorrect answers versus insight problems that have no immediately plausible answers.

Furthermore, past research has shown that the CRT assesses numeracy and something else that is unique from numeracy (Liberali et al., 2012). Study 4 helped to clarify that finding using IRT models, which showed that the CRT problems loaded onto both numeracy and insight problem solving ability factors and did not load onto their own factor. Thus, these results suggest that the CRT problems are indeed unique, but not because they measure something unique apart from numeracy and insight, but rather because they assess both numeracy and insight simultaneously.

Implications for Dual-Process Theory

One major conclusion of the present research is that CRT errors can be the result of numerous distinct processes, including a failure to question one’s initial response and failure to engage in reflective thinking (both of which are the typical interpretation of CRT errors), in addition to failure to identify alternative solutions to the problem upon reflection, and low numerical skills. It may also be possible for people to arrive at the correct answer as their first response with very little effort, although the present research did not directly test this possibility (c.f. Bago & De Neys, 2017). Default interventionist dual-process models have proposed that on problems such as the CRT, as well as heuristics and biases tasks, there are multiple steps that must be accomplished in order to achieve the correct response, including (a) recognizing one’s error, (b) engaging in effortful thought, (c) having skills necessary to solve the problem, and (d)

successfully overriding one's first response (Evans & Stanovich, 2013; Stanovich & West, 2008). It would not be correct to conclude, on the basis of the present research, that these steps are irrelevant to the CRT, although it might be correct to conclude that skill (i.e., numeracy) and response override may be more important to CRT performance than what was previously believed.

With regard to response override, there is something of a debate in the literature with regard to whether errors on the CRT and other heuristics and biases tasks are determined primarily by lack of error detection and reflective thought (the typical interpretation), or if instead people are aware that their answer may be incorrect but fail to *override* their initial procedure and/or response (De Neys, Rossi & Houde, 2013; De Neys, Cromheeke & Osman, 2011; Scherer et al., 2017). Some studies have shown that people may have great difficulty overriding the first mental procedure that comes to mind, even when they are aware that this is the incorrect mental procedure. This suggests that conflict detection may occur but is insufficient for reducing incorrect responding (De Neys, 2012). For example, a person may select a mental procedure for how to respond (e.g. subtraction, $\$1.10 - \$1.00 = \$0.10$, or division, $48 \div 2 = 24$), but when they detect that this procedure is inadequate, they have difficulty identifying another mental procedure possibly because they have inhibited all other potential mental procedures. They know they are wrong, but they cannot identify alternative routes to a solution.

Similarly, insight problems require that an individual is able to produce novel solutions to problems, and not focus on a single unsuccessful solution. Yet, some of the insight literature does not typically interpret this process through a dual-process lens, because correct responses are thought to be produced either with an effortful serial search (i.e. a Type 2 process), or with sudden insight (i.e. an "ah ha!" moment, more similar to a Type 1 process), suggesting that even

correct answers that are produced after a long delay might not be strictly the product of effortful, conscious reasoning (Fleck, 2008; Gilhooly, & Fioratou, 2009). Hence, if one defines “intuition” as processes that occur quickly, effortlessly, and outside of awareness, and “reflection” as processes that occur slowly, effortfully and consciously, it appears that both CRT errors and correct responses (as well as insight problem errors and correct responses) could potentially be produced through both types of processes. Given the substantial overlap between the CRT and insight problems, it appears that a dual-process perspective that focuses on intuitive versus reflective processes is too simplistic a model to adequately explain responding on the CRT.

Indeed, dual-process theories may not encompass all the types of thinking processes that people use. Insight experiences have been suggested to not fit inside current dual-processing structures (e.g., Evans & Stanovich, 2013) because insight seems to operate unconsciously, but is also not necessarily rapid (Macchi & Bagassi, 2014). It is possible that insight solutions indicate a third type of processing that is both autonomous (i.e., acts independent of working memory and controlled processes) and does mental simulations (i.e., how is it possible that a man has married 20 women who are alive without breaking the law or getting divorced). This third type of process also seems to be implicated beyond solving insight problems such as overcoming tip-of-the-tongue phenomena (Brown, 1991), understanding jokes long after they have been told, and even prolonged thought experiences (Dijksterhuis, Strick, Bos, & Nordgren, 2014). Although an argument can be made that insight problem solving and these other phenomena result from the interaction of both Type 1 and Type 2 processing, default interventionist perspectives suggest a hierarchical structure to the processes such that Type 2 processing may or may not override Type 1 processing (Evans & Stanovich, 2013). Thus, a third type of process may be responsible for nonconscious mental simulations until solutions to problems are found, which would indicate

that the dual-processing theoretical framework may be too simplistic for all the types of thinking processes that people use (Dijksterhuis et al., 2014).

Limitations

One limitation of the present research is that even when participants were asked to engage in effortful deliberation, many still reported guessing despite explicit instructions not to guess. Nonetheless, we found that many participants who followed instructions (i.e. did not guess) still responded incorrectly. It is possible that some participants guessed and did not admit to doing so, but because there was no incentive to lie (e.g. payments for compliance), this seems unlikely. Although Study 3 contained participants who did not follow instructions, this did not undermine the conclusion that the CRT problems are much harder to solve than what is currently assumed.

Another limitation is that despite our efforts and extensive data collection, there are nonetheless ambiguities that remain. For example, even after adjusting for insight problem solving ability and numeracy, CRT scores were still related to NFC, moral judgments of victimless behaviors, and performance on heuristics-and-biases tasks. These significant associations suggest that the CRT is measuring something unique from numeracy and insight that is shared with these other measures, which could be another as-yet unmeasured construct, such as general intelligence. Nevertheless, these findings do not qualify our conclusion that there are considerable complexities to consider when using CRT correlations to draw conclusions about individual differences in intuitive/reflecting thinking propensities.

Future studies should include measures of numeracy, insight problems, and general intelligence to further parse apart the constructs assessed by the CRT. Studies could also administer the CRT in-person with explicit feedback about correctness until a person responds

correctly (although this approach has the potential to hinder CRT performance because of performance anxiety). This in-person approach was not used in the present studies because it would not necessarily distinguish between insight problems and the CRT. That is, it might be reasonable to expect that with enough time and/or pressure most people will eventually answer the CRT problems correctly, but this would also be expected of insight problems.

Conclusions

Thinking carefully and effortfully does not necessarily guarantee correct responding on the CRT, even when the “intuitive” response is not available and the correct answer is displayed as a multiple-choice option. These studies showed that the CRT and insight problems are more similar than what has previously been believed, and extended prior research examining the overlap between the CRT and measures of numeracy. It is necessary to consider both numeracy and insight problem solving ability when drawing conclusions about associations between the CRT and individual differences, judgment outcomes, and everyday beliefs. Thus, it is recommended that the CRT is not used as a straightforward measure of intuitive versus reflective thinking propensities.

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Tables

Table 1

Demographic characteristics of the samples.

Characteristic	Study 1	Study 2	Study 3	Study 4
<i>N</i>	539	542	631	627
Age range	18-24	18-71	18-53	18-38
Mean age (<i>SD</i>)	19.46 (1.19)	31.35 (9.89)	19.15 (2.15)	19.11 (1.56)
Gender				
Male	228	224	239	273
Female	304	312	389	346
Transgender/Other	0	1	2	1
Not reported	7	5	1	7
Race/Ethnicity				
Caucasian/White	458	475	529	533
Black/African American	54	37	67	56
Native American/Alaska Native	7	13	10	14
Asian/Asian American	28	29	43	35
Pacific Islander/Native Hawaiian	2	3	1	-
Other	9	9	11	21
Not reported	8	6	7	9
Education				
Some high school, but no diploma	1	5	2	-
High School	154	38	336	-
Trade School	1	10	0	-
Some college but no degree	345	170	268	-
Associate's degree	11	48	15	-
Bachelor's degree	20	181	8	-
Master's degree	0	71	0	-
Doctoral/Professional degree	1	41	0	-
Not reported	6	5	2	-

Note. In all studies, participants were allowed to select more than one race/ethnicity. Dashes indicate a question/category that was not asked of the participants.

Table 2

Means (SDs) of CRT score, mean time to answer all three CRT questions (in minutes), predicted number correct, confidence, and calibration by condition across Studies 1, 2, and 3.

Condition	<i>N</i>	Score	Time (minutes)	Predicted Score	Confidence	Calibration
Study 1						
Normal	174	0.94 _a (1.06)	1.66 _a (1.13)	2.41 _a (0.79)	5.09 _a (1.76)	1.47 _a (1.14)
Multiple-Choice	181	0.93 _a (1.06)	1.38 _a (0.99)	2.42 _a (0.76)	5.18 _a (1.69)	1.49 _a (1.18)
No-Intuitive Response	184	1.57 _b (1.06)	2.21 _b (1.47)	1.57 _b (1.06)	3.87 _b (2.07)	0.00 _b (0.85)
Study 2						
Normal	275	0.96 _a (1.08)	2.20 _a (1.45)	2.36 _a (0.76)	5.50 _a (1.52)	1.40 _a (1.19)
No Intuitive Response	267	1.90 _b (1.03)	3.29 _b (1.76)	2.06 _b (0.94)	4.94 _b (1.95)	0.16 _b (0.88)
Study 3						
Normal	211	0.93 _a (1.06)	1.73 _a (1.15)	2.29 _a (0.73)	5.34 _a (1.36)	1.36 _a (1.05)
No Intuitive Response	209 ^a	1.59 _b (1.07)	2.04 _b (1.06)	1.64 _b (0.97)	4.06 _b (2.00)	0.04 _b (0.82)
Deliberation	211 ^a	1.70 _b (1.07)	2.79 _c (1.55)	1.86 _c (0.96)	4.59 _c (1.93)	0.15 _b (0.82)
Deliberation: 100% compliant participants	112	2.13 _c (1.06)	2.62 _c (1.65)	2.39 _a (0.80)	5.58 _a (1.58)	0.27 _b (0.75)

Note. Calibration was calculated as participants predicted score minus their actual score. The different subscripts indicate significant differences ($p < .05$) among conditions within a Study.

^a One participant did not answer either the predicted score or confidence questions in each of these conditions; thus, the n for predicted score, confidence, and calibration is one less.

Table 3

Mean times in minutes (SD) to answer all three CRT questions separated by score and condition, and the correlation between CRT score and time across Studies 1, 2, and 3.

Condition	0 correct	1 correct	2 correct	3 correct	Correlation between score and time
Study 1 ($N = 539$)					
Normal	1.42 _a (1.00)	1.88 _{ab} (1.41)	1.64 _a (0.96)	2.07 _a (0.94)	.18 _a *
Multiple-Choice	1.15 _a (0.63)	1.43 _a (0.91)	2.03 _a (1.51)	1.51 _a (0.95)	.21 _a **
No Intuitive Response	2.12 _b (1.70)	2.28 _b (1.62)	2.21 _a (0.99)	2.18 _a (1.27)	.00 _a
Study 2 ($N = 542$)					
Normal	1.81 _a (1.21)	2.55 _a (1.75)	2.56 _a (1.51)	2.53 _a (1.32)	.21 _a ***
No Intuitive Response	2.90 _b (1.47)	3.42 _b (1.64)	3.78 _b (1.70)	2.96 _a (1.89)	-.03 _b
Study 3 ($N = 631$)					
Normal	1.57 _a (0.88)	1.84 _a (1.42)	2.02 _a (1.53)	1.77 _{ab} (0.85)	.11 _a
No Intuitive Response	2.15 _b (0.81)	2.26 _{ac} (1.22)	2.22 _{ac} (0.83)	1.55 _b (0.94)	-.22 _b **
Deliberation	3.35 _c (1.48)	3.02 _b (1.38)	2.83 _b (1.37)	2.26 _a (1.73)	-.25 _b ***
Deliberation: 100% compliant participants	3.75 _c (1.87)	2.70 _c (0.97)	2.93 _c (1.45)	2.19 _a (1.72)	-.28 _b **

Note. Time is in minutes. The different subscripts indicate significant differences ($p < .05$) among conditions within a Study.

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 4

Study 1 means, SDs, scale ranges, Cronbach's alphas and correlations among variables of interest.

Measure	Scale	<i>M</i> (<i>SD</i>)	1	2	3 ^a	4	5	6	7	8	9	10	11	12	13
1. CRT	0 – 3	1.15 (1.10)	(.62)												
2. Numeracy	0 – 10	4.80 (2.27)	.52***	(.74)											
3. Insight ^a	0 – 2	0.29 (0.57)	.35***	.34***	(.49)										
4. NFC	1 – 5	3.49 (0.55)	.23***	.30***	.17***	(.88)									
5. FI	1 – 5	3.39 (0.54)	-.10*	-.03	-.11*	.15**	(.89)								
6. AOT	1 – 7	4.89 (0.82)	.27***	.34***	.19***	.35***	-.03	(.68)							
7. Religiosity	1 – 5	3.72 (1.14)	-.15***	-.08	-.07	-.04	.18***	-.25***	(.90)						
8. BE	1 – 9	6.91 (2.69)	.14**	.18***	.12*	.20***	-.04	.30***	-.38***	-					
9. PB	1 – 5	2.19 (0.77)	-.28***	-.32***	-.12*	-.14**	.11*	-.30***	.21***	-.07	(.93)				
10. GCB	1 – 5	2.66 (0.86)	-.09*	-.15**	-.03	-.02	.09	-.03	.07	.07	.56***	(.94)			
11. Victimless Behaviors	1 – 7	5.38 (0.95)	-.13**	-.06	-.08	-.04	.13**	-.08	.35***	-.10*	-.02	-.04	(.72)		
12. Behaviors with Victims	1 – 7	5.98 (1.02)	.06	.14**	.06	.14**	.10*	.20***	.19***	-.03	-.21***	-.13**	.38***	(.54)	
13. HB	0 – 9	4.58 (1.53)	.34***	.39***	.24***	.25***	-.09*	.33***	-.12**	.15**	-.30***	-.20***	-.08	.08	(.25)

Note. Correlations $N = 519$. Cronbach's alphas are given along the diagonal in parenthesis. CRT=Cognitive Reflection Test. NFC = Need for Cognition. FI = Faith in Intuition. AOT = Actively Open-Minded Thinking. BE= Belief in Evolution. PB = Paranormal Beliefs. GCB = General Conspiracy Beliefs. HB = Heuristics-and-Biases.

^aCorrelations involving this variable are based on $N = 397$. * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 5

Study 1: Unstandardized regression coefficients (SEs) for regressions predicting each outcome variables with mean centered CRT score, dummy coded condition variables, and interaction terms.

Outcome Measure	Model Constant	CRT Score	Dummy Code 1: Multiple- Choice vs. Control	Dummy Code 2: No Intuitive Response vs. Control	CRT Score × Dummy Code 1	CRT Score × Dummy Code 2	Overall model <i>F</i> (5, 513)	<i>R</i> ²
Individual Differences								
Numeracy	5.30 (0.15)	1.17*** (0.14)	-0.25 (0.21)	-1.06*** [†] (0.21)	-0.08 (0.19)	0.07 (0.19)	44.87***	.30
Need for Cognition	3.55 (0.04)	0.14** (0.04)	-0.03 (0.06)	-0.13* [†] (0.06)	-0.02 (0.06)	0.00 (0.05)	6.81***	.06
Faith in Intuition	3.41 (0.04)	-0.07 (0.04)	0.01 (0.06)	-0.04 (0.06)	0.04 (0.06)	0.04 (0.06)	1.23	.01
Actively Open-Minded Thinking	4.97 (0.06)	0.14* (0.06)	-0.03 (0.09)	-0.21* [†] (0.09)	0.09 (0.08)	0.15 (0.08)	10.16***	.09
Beliefs								
Religiosity	3.89 (0.09)	-0.13 (0.08)	-0.19 (0.12)	-0.19 (0.13)	0.11 (0.11)	-0.14 (0.11)	4.49**	.04
Belief in Evolution	6.87 (0.21)	0.46* (0.20)	0.22 (0.30)	-0.24 (0.30)	-0.23 (0.28)	-0.03 (0.27)	2.64*	.03
Paranormal Beliefs	2.11 (0.06)	-0.14** (0.05)	0.07 (0.08)	0.23** [†] (0.08)	-0.06 (0.08)	-0.16* (0.08)	11.41***	.10
General Conspiracy Beliefs	2.58 (0.07)	0.03 (0.06)	0.11 (0.09)	0.19* [†] (0.10)	-0.09 (0.09)	-0.23* (0.09)	2.87*	.03
Moral Judgments								

Victimless Behaviors	5.42 (0.08)	-0.10 (0.07)	-0.07 (0.11)	-0.05 (0.11)	-0.01 (0.10)	-0.02 (0.10)	1.75	.02
Behaviors with Victims	6.10 (0.08)	0.14 (0.07)	-0.09 (0.11)	-0.23* [†] (0.11)	-0.12 (0.10)	-0.06 (0.10)	1.50	.01
Heuristics-and-Biases	4.62 (0.11)	0.45*** (0.11)	0.09 (0.16)	-0.24 (0.16)	0.05 (0.15)	0.12 (0.15)	14.25***	.12
Insight ^a	0.40 (0.05)	0.22*** (0.04)	-0.08 (0.07)	-0.23** [†] (0.07)	-0.02 (0.06)	-0.03 (0.06)	13.71***	.14

Note. Each row is a separate regression model. [†] The significant main effects of condition marked with this symbol are due to suppression: all these main effects that appear significant above were not significant in regressions including only the dummy coded condition variables as predictors, all $|ts|$ (516) < 1.61 , $ps > .10$, for the insight problems $-1.55 < |ts|$ (412) < 1.56 , $ps > .12$.

^a The *dfs* for the overall *F* for this measure are (5, 409). * $p < .05$; ** $p < .01$; *** $p < .001$.

Table 6

Study 1: Unstandardized regression coefficients (SEs) for regressions predicting each outcome variables with CRT score and Numeracy as predictors.

Outcome Measure	Model Constant	CRT Score	Numeracy	Overall model <i>F</i> (2, 516)	<i>R</i> ²
Individual Differences					
Need for Cognition	3.15 (0.06)	0.05* (0.03)	0.06*** (0.01)	27.83***	.10
Faith in Intuition	3.43 (0.06)	-0.06* (0.03)	0.01 (0.01)	2.81	.01
Actively Open-Minded Thinking	4.30 (0.08)	0.10** (0.04)	0.10*** (0.02)	38.92***	.13
Beliefs					
Religiosity	3.91 (0.12)	-0.16** (0.05)	0.00 (0.03)	6.15**	.02
Belief in Evolution	5.87 (0.28)	0.15 (0.12)	0.17** (0.06)	8.97***	.03
Paranormal Beliefs	2.70 (0.08)	-0.11** (0.03)	-0.08*** (0.02)	35.31***	.12
General Conspiracy Beliefs	2.93 (0.09)	-0.01 (0.04)	-0.05** (0.02)	6.05**	.02
Moral Judgments					
Victimless Behaviors	5.48 (0.10)	-0.12* (0.04)	0.01 (0.02)	4.14*	.02
Behaviors with Victims	5.69 (0.10)	-0.02 (0.05)	0.07** (0.02)	5.38**	.02
Heuristics-and-Biases	3.31 (0.15)	0.26*** (0.07)	0.20*** (0.03)	55.26***	.18
Insight ^a	-0.12 (0.06)	0.12*** (0.03)	0.06*** (0.01)	38.66***	.16

Note. Each row is a separate regression model. ^a The *dfs* for the overall *F* for this measure are (2, 412). * $p < .05$; ** $p < .01$; *** $p < .001$.

Table 7

Study 3 means, SDs, scale ranges, Cronbach's alphas, and correlations among variables of interest.

Measure	Scale	<i>M</i> (<i>SD</i>)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. CRT	0 – 3	1.41 (1.12)	(.62)													
2. Numeracy	0 – 10	4.98 (2.12)	.54***	(.68)												
3. Insight 1	0 – 5	1.47 (1.47)	.42***	.33***	(.71)											
4. Insight 2	0 – 4	1.51 (1.38)	.42***	.36***	.55***	(.68)										
5. NFC	1 – 5	3.58 (0.58)	.34***	.38***	.27***	.28***	(.88)									
6. FI	1 – 5	3.46 (0.56)	-.10*	-.07	-.07	-.08*	-.04	(.89)								
7. AOT	1 – 7	5.02 (0.81)	.23***	.31***	.21***	.23***	.25***	-.15***	(.62)							
8. Religiosity	1 – 5	3.80 (1.19)	-.12**	-.13**	-.09*	-.08*	-.02	.23***	-.35***	(.90)						
9. BE	1 – 9	7.21 (2.56)	.10*	.11**	.03	.05	.02	-.10*	.33***	-.42***	-					
10. PB	1 – 5	2.13 (0.70)	-.11**	-.15***	-.08*	-.08*	-.12**	.10*	-.20***	.25***	.03	(.91)				
11. GCB	1 – 5	2.63 (0.85)	-.04	-.10*	-.04	.02	-.07	.07	-.07	.08*	.04	.49***	(.93)			
12. Victimless Behaviors	1 – 7	5.51 (0.93)	-.25***	-.26***	-.16***	-.20***	-.12**	.17***	-.24***	.32***	-.20***	.07	.00	(.72)		
13. Behaviors with Victims	1 – 7	6.18 (0.97)	-.04	-.02	.01	-.06	.03	.09*	-.10*	.19***	-.18***	-.16***	-.20***	.37***	(.52)	
14. HB	0 – 12	5.58 (2.05)	.35***	.43***	.24***	.22***	.22***	-.10*	.30***	-.20***	.16***	-.17***	-.12**	-.32***	-.11**	(.45)

Note. Correlations $N = 610$. Cronbach's alphas are given along the diagonal in parenthesis. CRT=Cognitive Reflection Test. Insight 1 = Insight problems that suggest incorrect answers. Insight 2 = Insight problems that do not suggest incorrect answers. NFC = Need for Cognition. FI = Faith in Intuition. AOT = Actively Open-Minded Thinking. BE= Belief in Evolution. PB = Paranormal Beliefs. GCB = General Conspiracy Beliefs. HB = Heuristics-and-Biases. * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 8

Study 3: Unstandardized regression coefficients (SEs) for regressions predicting each outcome variables with mean centered CRT score, dummy coded condition variables, and interaction terms.

Outcome Measure	Model Constant	CRT Score	Dummy Code 1: No Intuitive Response vs. Control	Dummy Code 2: Deliberati on vs. Control	CRT Score × Dummy Code 1	CRT Score × Dummy Code 2 ^a	Overall model <i>F</i> (5, 604)	<i>R</i> ²
Individual Differences								
Numeracy	5.41 (0.14)	1.14*** (0.12)	-0.63** † (0.19)	-0.57** † (0.19)	-0.01 (0.17)	-0.09 (0.17)	52.82***	.30
Need for Cognition	3.61 (0.04)	0.19*** (0.04)	-0.01 (0.06)	-0.06 (0.06)	-0.01 (0.05)	-0.02 (0.05)	16.08***	.12
Faith in Intuition	3.39 (0.04)	-0.09* (0.04)	0.09 (0.06)	0.07 (0.06)	0.08 (0.05)	0.02 (0.05)	2.04	.02
Actively Open-Minded Thinking	5.13 (0.06)	0.15** (0.05)	-0.12 (0.08)	-0.22** † (0.08)	0.03 (0.07)	0.09 (0.07)	8.47***	.07
Beliefs								
Religiosity	3.79 (0.09)	-0.13 (0.08)	0.02 (0.13)	-0.07 (0.13)	0.03 (0.11)	0.00 (0.11)	1.98	.02
Belief in Evolution	7.29 (0.20)	0.11 (0.17)	0.16 (0.27)	-0.42 (0.27)	0.09 (0.24)	0.32 (0.24)	2.44*	.02
Paranormal Beliefs	2.18 (0.05)	-0.06 (0.05)	-0.07 (0.07)	-0.07 (0.07)	0.03 (0.07)	-0.03 (0.07)	1.93	.02
General Conspiracy Beliefs	2.58 (0.07)	-0.12 (0.06)	0.09 (0.09)	-0.01 (0.09)	0.12 (0.08)	0.12 (0.08)	1.10	.01
Moral Judgments								

Victimless Behaviors	5.40 (0.07)	-0.22*** (0.06)	0.19* [†] (0.10)	0.18 (0.10)	-0.06 (0.09)	0.01 (0.09)	9.63***	.07
Behaviors with Victims	6.16 (0.08)	0.07 (0.07)	0.08 (0.10)	0.02 (0.10)	-0.21* (0.09)	-0.12 (0.09)	1.48	.01
Heuristics-and-Biases	5.96 (0.15)	0.63*** (0.13)	-0.68** [†] (0.20)	-0.58** [†] (0.20)	0.18 (0.18)	0.12 (0.18)	20.58***	.15
Insight 1	1.80 (0.10)	0.60*** (0.09)	-0.45** [†] (0.14)	-0.55*** [†] (0.14)	-0.02 (0.13)	0.09 (0.13)	30.63***	.20
Insight 2	1.57 (0.10)	0.47*** (0.08)	0.09 (0.13)	-0.27* [†] (0.13)	0.11 (0.12)	0.10 (0.12)	28.13***	.19

Note. Each row is a separate regression model. The whole sample results are displayed above. Insight 1 = Insight problems that suggest incorrect answers. Insight 2 = Insight problems that do not suggest incorrect answers. ^a This interaction term was not significant ($|ts|$ (509) < 1.89, ps > .05) in any of the regressions where only the 100% compliant participants were used in the deliberation condition. [†] The significant main effects of condition marked with this symbol are due to suppression: all these main effects that appear significant above were not significant in regressions including only the dummy coded condition variables as predictors, all $|ts|$ (607) < 1.49, ps > .13. * p < .05; ** p < .01; *** p < .001.

Table 9

Study 3: Unstandardized regression coefficients (SEs) for regressions predicting each outcome variables with CRT score, Numeracy and Insight as predictors.

Outcome Measure	Model Constant	CRT Score	Numeracy	Total Insight Performance	Overall model $F(3, 606)$	R^2
Individual Differences						
Need for Cognition	3.05 (0.06)	0.07** (0.02)	0.07*** (0.01)	0.04*** (0.01)	45.84***	.19
Faith in Intuition	3.55 (0.06)	-0.03 (0.03)	-0.00 (0.01)	-0.01 (0.01)	2.46	.01
Actively Open-Minded Thinking	4.41 (0.08)	0.03 (0.04)	0.09*** (0.02)	0.05** (0.01)	26.31***	.12
Beliefs						
Religiosity	4.14 (0.12)	-0.07 (0.05)	-0.04 (0.03)	-0.02 (0.02)	4.38**	.02
Belief in Evolution	6.59 (0.26)	0.13 (0.12)	0.10 (0.06)	-0.02 (0.05)	2.94* ^a	.01
Paranormal Beliefs	2.37 (0.07)	-0.02 (0.03)	-0.04* ^a (0.02)	-0.01 (0.01)	4.87**	.02
General Conspiracy Beliefs	2.81 (0.09)	0.01 (0.04)	-0.04* (0.02)	0.01 (0.02)	2.07	.01
Moral Judgments						
Victimless Behaviors	6.10 (0.09)	-0.11** (0.04)	-0.07** (0.02)	-0.03 (0.02)	19.81***	.09
Behaviors with Victims	6.22 (0.10)	-0.03 (0.05)	0.00 (0.02)	-0.01 (0.02)	0.31	.00
Heuristics-and-Biases	3.46 (0.19)	0.27** (0.08)	0.32*** (0.04)	0.05 (0.03)	53.13***	.21

Note. Each row is a separate regression model. The results for the whole sample are displayed above. ^a These effects were not significant in regressions where the deliberation condition was restricted to just the 100% compliant participants (but all data from other conditions were used); all other effects remained significant or nonsignificant, * $p < .05$; ** $p < .01$; *** $p < .001$.

Table 10

Oblimin rotated standardized exploratory factor loadings, and the correlations among factors

	1-Factor	2-Factor		3-Factor			4-Factor			
Item	F1	F1	F2	F1	F2	F3	F1	F2	F3	F4
CRT 1	.66	-.57	-.33	-.30	-.65		-.53			
CRT 2	.82	-.46	-.55		-.88		-.97			
CRT 3	.83	-.42	-.59		-.86		-.72			
Insight 1	.72		-.77		-.55	-.30	-.37		-.30	-.34
Insight 2	.82		-.90	.33	-.71		-.51			-.31
Insight 3	.55		-.69	.36	-.48					-.56
Insight 4	.45		-.49		-.30					-.88
Insight 5	.67		-.85		-.36	-.51			-.40	-.55
Insight 6	.66		-.61			-.88			-.93	
Insight 7	.48		-.39			-.53			-.48	
Insight 8	.64		-.55			-.59			-.62	
Insight 9	.73		-.73			-.70			-.65	
Numeracy 1	.41	-.49			-.46		-.48			
Numeracy 2	.60	-.60		-.49	-.30		-.46	.45		
Numeracy 3	.43	-.44		-.43				.52		
Numeracy 4	.44	-.66		-.43	-.47		-.57			
Numeracy 5	.42	-.73		-.54	-.45		-.55	.46		
Numeracy 6	.32	-.77		-.86				1.00		
Factor Correlations	F1	F1	F2	F1	F2	F3	F1	F2	F3	F4
F1	1	1	.35	1	.15	.02	1	-.19	.43	.38
F2	-	.35	1	.15	1	.55	-.19	1	-.09	.06
F3	-	-	-	.02	.55	1	.43	-.09	1	.44
F4	-	-	-	-	-	-	.38	.06	.44	1

Note. Factor loadings $< |0.30|$ are not shown. All models were estimated using the Expectation-Maximization (EM) algorithm. Insight 1-5 are problems that suggest incorrect responses (e.g. dirt in a hole problem), and Insight 6-9 are problems that do not suggest an incorrect response (e.g. marriage problem).

Table 11

Exploratory Model fit indices

Model	BIC	AIC	Log Likelihood	RMSEA	M2 (df)	p-value
1-factor	5677.39	5542.41	-2735.21	0.067	325.47 (135)	<.001
2-factor	5667.60	5468.88	-2681.44	0.043	185.94 (118)	<.001
3-factor	5693.50	5434.79	-2648.40	0.010	105.33 (102)	0.39
4-factor	5734.90	5419.95	-2625.98	0.000	73.36 (87)	0.85

Note. Bolded values indicate the best fitting model. All models were estimated using the Expectation-Maximization (EM) algorithm.

Table 12

Standardized confirmatory factor loadings, and the correlations among factors.

Item	2-factor		3-factor			4-factor			
	F1	F2	F1	F2	F3	F1	F2	F3	F4
CRT 1	.54	.47	.39	.58		.79			
CRT 2	.67	.58		.90		.97			
CRT 3	.58	.35		.72		.77			
Insight 1		.84		.70	.29	.39		-.29	.74
Insight 2		.91	-.40	.90		.53			.65
Insight 3		.67	-.51	.78					.71
Insight 4		.73		.66					.78
Insight 5		.79		.52	.40			.04	.83
Insight 6		.73			.77			.78	
Insight 7		.60			.62			.61	
Insight 8		.64			.66			.67	
Insight 9		.82			.88			.88	
Numeracy 1	.56			.49		.51			
Numeracy 2	.73		.84	-.35		-.28	.84		
Numeracy 3	.69		.66				.69		
Numeracy 4	.51		.72	-.37		.46			
Numeracy 5	.70		.81	-.41		-.19	.77		
Numeracy 6	.55		.49				.51		
Factor Correlations	F1	F2	F1	F2	F3	F1	F2	F3	F4
F1	1	.59	1	.88	.69	1	.88	.78	.69
F2	.59	1	.88	1	.86	.88	1	.68	.51
F3	-	-	.69	.86	1	.77	.68	1	.89
F4	-	-	-	-	-	.69	.51	.89	1

Note. Factor loadings fixed to 0 are not shown. Factor loadings < |.30| are bolded to signify misfit in the factor structure. All models were estimated using the Metropolis-Hastings Robbins-Monro (MHRM) algorithm. Insight 1-5 are problems that suggest incorrect responses (e.g. dirt in a hole problem), and Insight 6-9 are problems that do not suggest an incorrect response (e.g. marriage problem).

Table 13

Confirmatory Model fit indices

Model	BIC	AIC	Log Likelihood	RMSEA	M2 (df)	p-value
2-factor	5532.08	5382.23	-2651.11	0.042	201.71 (131)	<.001
3-factor	5580.74	5404.67	-2655.33	0.046	205.08 (124)	<.001
4-factor	5555.89	5376.08	-2640.04	0.106	556.55 (123)	<.001

Note. Bolded values indicate the best fitting model. All models were estimated using the Metropolis-Hastings Robbins-Monro (MHRM) algorithm.