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The Cognitive Reflection Test is robust to multiple exposures

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The Cognitive Reflection Test (CRT) is a widely used measure of the propensity to engage in analytic or deliberative reasoning in lieu of gut feelings or intuitions. CRT problems are unique because they reliably cue intuitive but incorrect responses and, therefore, appear simple among those who do poorly. By virtue of being comprised of so-called “trick-problems” that, in theory, could be discovered as such, it is commonly held that the predictive validity of the CRT is undermined by prior experience with the task. Indeed, recent studies show that people who have previous experience with the CRT score higher on the test. Naturally, however, it is not obvious that this actually undermines the predictive validity of the test. Across six studies with ~2500 participants and seventeen variables of interest (e.g., religious belief, bullshit receptivity, smartphone usage, susceptibility to heuristics and biases, numeracy), we did not find a single case where the predictive power of the CRT was significantly undermined by repeated exposure. This was despite the fact that we replicated the previously reported increase in accuracy among individuals who report previous experience with the CRT. We speculate that the CRT remains robust after multiple exposures because less reflective (more intuitive) individuals fail to realize that being presented with apparently easy problems more than once confers information about the tasks’ actual difficulty.

Experience increases our wisdom but doesn't reduce our follies.

Josh Billings

People often rely on their intuitions and gut feelings, for better or for worse (Gigerenzer, 2007; Kahneman, 2011). Moreover, when people *do* engage in extending thinking about a topic, they often spend their time finding ways to convince themselves that they were correct all along (Kahan, 2013; Kunda, 1990; Mercier & Sperber, 2011). Nonetheless, some people are, in fact, more analytic by disposition and are willing to genuinely reflect on problems they face rather than merely justify their gut feelings – a disposition that has consequences for a wide range of psychological factors (Pennycook, Fugelsang, & Koehler, 2015; Noori, 2017), such as religious and paranormal belief (Pennycook, Cheyne, Seli, Koehler, & Fugelsang, 2012), moral judgments and values (Pennycook, Cheyne, Barr, Koehler, & Fugelsang, 2014), technology use (Barr, Pennycook, Stolz, & Fugelsang, 2015), overconfidence (Bialek & Domurat, 2017), impulsivity (Toplak, West & Stanovich, 2011) and the detection of bullshit (Pennycook, Cheyne, Barr, Koehler, & Fugelsang, 2015).

The Cognitive Reflection Test (CRT, Frederick, 2005) has emerged as the most widely used measure of the willingness to think analytically (i.e., analytic cognitive style). The following is a particularly well known item from the task:

*If a baseball and a bat cost \$1.10 together, and the bat costs \$1.00 more than the ball,
how much does the ball cost?*

The intuitive response is 10 cents. Yet, it's incorrect: If the ball costs 10 cents, the bat would have to cost \$1.10 and in total they would cost \$1.20. The correct response is 5 cents, an answer that is reached by only roughly 30% of university undergraduates, depending on the university (De Neys, Rossi, & Houdé, 2013; Frederick, 2005; Pennycook, Cheyne, Koehler, & Fugelsang, 2016). However, errors are also not random: Almost all who get CRT questions wrong give the

intuitive response (Campitelli & Gerrans, 2014; Frederick, 2005; Pennycook, Cheyne, Koehler, & Fugelsang, 2015). Moreover, the majority of participants who answer correctly are aware of the incorrect intuitive answer, while those who got it wrong naturally failed to consider the correct answer (Mata, Ferreira, & Sherman, 2013; Pennycook, Ross, Koehler, & Fugelsang, 2017). Although the CRT obviously requires some degree of numeracy, it is thought to also capture the propensity to think analytically (Pennycook & Ross, 2016; Toplak, West, & Stanovich, 2011). That is, those who do well on the CRT are also less prone to rely on heuristics and biases even after measures of cognitive ability have been taken into account (Toplak, West, & Stanovich, 2014; Toplak et al., 2011). Moreover, the CRT predicts a wide range of variables after controlling for numeracy (Pennycook et al., 2015; Pennycook & Ross, 2016).

Perhaps because it is short and strongly predictive of a variety of outcome variables, the CRT has become a nearly ubiquitous psychological test. It is widely held that so-called “trick problems” like the above bat-and-ball problem will not be robust to multiple testing because participants will realize that the problems only *seem* easy at first blush (Haigh, 2016; Stieger & Reips, 2016). Indeed, prior experience with the CRT is associated with higher scores (Haigh, 2016; Stieger & Reips, 2016). This casts doubts about whether the test can continue to be used as a valid tool for assessing analytic cognitive style. As a consequence, much effort has been put into finding newer versions of the CRT (Primi, Morsanyi, Chiesi, Donati, & Hamilton, 2015; Thomson & Oppenheimer, 2016; Toplak et al., 2014).

Although there is a strong agreement that multiple exposures to the CRT invalidates it as a test, there have remarkably been no empirical tests of this claim (that we are aware of). Does the CRT continue to predict important psychological factors even among people who have been given the test before? There is good reason to believe that it should: Namely, if people who do poorly on the CRT are genuinely intuitive (i.e., they are not willing to think analytically), the

most intuitive among them will either not realize that they are seeing a repeated problem or, if they realize this, they will not consider that the (apparently simple) problem is being repeated *for a reason*. Put differently, repeated exposure can be thought of as an additional sort of CRT test. Researchers can be confident that those who continue giving intuitive responses after being presented with the problem more than once are strongly intuitive. Moreover, those who do relatively well on the CRT originally do not gain much from repeated exposure. The effect of repeated exposure, then, may only cause researchers to mislabel a genuinely intuitive person as reflective (based on accuracy) in a relatively small proportion of cases.

To investigate this issue, we used previously collected datasets to test how prior exposure to the CRT affects the strength of the reported correlations with different behavioural and cognitive factors of theoretical interest.

Empirical tests

A set of 6 experiments with almost 2,500 participants was used to test the effect of previous exposure on the CRT. In the reported re-analyses, we compare participants who declared (when asked directly) that they have seen at least one CRT item before (“experienced”) with participants who had no recollection of prior exposure (“unexperienced”). Prior experience was probed using the following question: “Have you seen any of the last 3 word problems before?”. Participants who indicated ‘yes’ were considered experienced and those who selected ‘maybe’ or ‘no’ were considered unexperienced. The results include data from every published or submitted manuscript (where the present authors’ were the lead author) that asked about prior experience with the CRT. This was the only inclusion criteria. Data for all studies is available on the Open Science Framework: <https://osf.io/kawv8/>.

CRT scores are affected by prior experience.

Table 1 presents average accuracy for the 3-item CRT for individuals with and without prior experience. Mean accuracy on the CRT is followed by direct t -test, estimation of the effect size, and a Bayesian test which weights the evidence for the CRT score in the unexperienced group being lower than in the group of individuals with experience. Bayes factor (BF) is interpreted in a continuous manner as a strength of evidence supporting one model against the other, but $BF > 3$ is often interpreted as a lowest acceptable evidence to support a particular hypothesis (Dienes, 2014; Masson, 2011). As is evident from Table 1, individuals who had prior exposure to the CRT (about a third of our tested sample) scored higher ($d = .57$). This is consistent with previously reported findings of Haigh (2016) and Stieger and Reips (2016), although their effect sizes were slightly smaller ($d = 0.48$ and $d = 0.41$ respectively).

Table 1. Mean accuracy (standard deviation) for the Cognitive Reflection Test (CRT) in unexperienced and experienced groups.

Study	Sample	Sample size	G1: CRT unexperienced	G2: CRT experienced	<i>t</i> -tests	Cohen's <i>d</i>	BF ₁₀ (G1 < G2)
1. Pennycook et al. (2014, TAR)	Mechanical Turk	504	.40 (0.37) <i>N</i> = 203	.58 (0.39) <i>N</i> = 301	$t(502) = 5.06, p < .001$	0.46	19,441
2. Pennycook et al. (2015, JDM)*	Undergraduates	279	.32 (0.35) <i>N</i> = 114	.39 (0.38) <i>N</i> = 165	$t(277) = 1.60, p = .110$	0.02	0.85
3. Barr et al. (2015, CiHB)**	Undergraduates	262	.32 (0.35) <i>N</i> = 205	.54 (0.35) <i>N</i> = 57	$t(260) = 4.38, p < .001$	0.66	1,006
4. Pennycook et al. (2016, BRM)	Undergraduates	497	.34 (0.34) <i>N</i> = 373	.54 (0.38) <i>N</i> = 124	$t(495) = 5.53, p < .001$	0.56	405,894
5. Pennycook et al. (2016, PLoS ONE)***	Undergraduates	786	.34 (0.36) <i>N</i> = 611	.64 (0.36) <i>N</i> = 175	$t(784) = 9.83, p < .001$	0.83	5.23×10^{22}
6. Bialek & Sawicki (2017)	Mechanical Turk	166	.39 (0.36) <i>N</i> = 67	.52 (0.40) <i>N</i> = 99	$t(164) = 1.90, p = .060$	0.30	1.72
Pooled		2494	.34 (0.36) <i>N</i> = 1573	.55 (0.39) <i>N</i> = 921	$t(2492) = 13.49, p < .001$	0.57	8.19×10^{36}

*Data are from Study 1

**Data are from Study 2

***Data are from Studies 1, 2, & 4.

Prior experience does not affect CRTs predictive validity

We compared the magnitude of the CRTs correlation with a variety of outcome variables using Fishers z -test (Table 2). A significant result on the z -test indicates that the relationship between the CRT and other variable was different in the unexperienced and experienced groups. Finally, we present a suggested method for future testing – partial correlations, in which correlations between CRT and dependent variables are controlled by the CRT-exposure score. If prior exposure undermines the predictive validity of the CRT, it should not be predictive for the experienced group (or, at least, should be less predictive than for the unexperienced group).

Table 2. Correlations between the CRT and various outcome variables for those with or without prior experience.

Correlate	Full sample	CRT unexperienced	CRT experienced	<i>Fisher's z</i>	Partial correlation
1. Pennycook et al. (2014, TAR)	<i>N</i> = 505	<i>N</i> = 203	<i>N</i> = 301		
Base-rate neglect (accuracy)	.213	.175	.235	-0.69, <i>p</i> = .247	.214
Verbal intelligence	.338	.323	.319	0.05, <i>p</i> = .481	.314
Numeracy	.340	.337	.342	-0.06, <i>p</i> = .475	.346
Religious belief	-.226	-.226	-.222	-0.05, <i>p</i> = .480	-.222
Social conservatism	-.092	-.069, <i>p</i> = .328	-.105, <i>p</i> = .07	0.4, <i>p</i> = .345	-.094
Binding (traditional) moral values	-.220	-.178	-.237	0.68, <i>p</i> = .251	-.216
Moral judgment Zoophilia	-.306	-.269	-.312	0.51, <i>p</i> = .305	-.297
Incest	-.230	-.292	-.192	-1.16, <i>p</i> = .123	-.231
2. Pennycook et al. (2015, JDM)	<i>N</i> = 279	<i>N</i> = 165	<i>N</i> = 114		
CRT (alternative version)*	.565	.530	.612	-0.99, <i>p</i> = .161	.566
Heuristics/biases (accuracy)	.488	.385	.614	-2.51, <i>p</i> = .006	.489
Verbal intelligence	.396	.409	.391	0.174, <i>p</i> = .431	.401
Numeracy	.348	.299	.428	-1.21, <i>p</i> = .113	.350
Bullshit receptivity	-.335	-.319	-.361	0.39, <i>p</i> = .350	-.335
Ontological confusion	-.313	-.276	-.375	0.9, <i>p</i> = .184	-.316
Religious belief	-.213	-.253	-.142, <i>p</i> = .131	-0.94, <i>p</i> = .174	-.208
3. Barr et al. (2015, CiHB)	<i>N</i> = 262	<i>N</i> = 205	<i>N</i> = 57		

Heuristics/biases (accuracy)	.544	.460	.650	-1.81, $p = .035$	.506
Verbal intelligence	.336	.271	.385	-0.84, $p = .201$	.298
Numeracy	.421	.418	.443	-0.02, $p = .421$	.403
Smartphone internet use	-.239 _(N = 227)	-.182 _(N = 179)	-.474 _(N = 48)	1.98, $p = .024$	-.159
Search engine use	-.194 _(N = 227)	-.187 _(N = 179)	-.265 _(N = 48)	0.49, $p = .312$	-.168
4. Pennycook et al. (2016, BRM)	$N = 497$	$N = 372$	$N = 124$		
Faith in Intuition	-.176	-.205	-.087, $p = .334$	-1.15, $p = .125$	-.173
Need For Cognition	.343	.289	.402	-1.23, $p = .110$	.321
5. Pennycook et al. (2016, PLoS)	$N = 787$	$N = 611$	$N = 175$		
CRT (alternative version)*	.589 _(N = 639)	.559 _(N = 494)	.580 _(N = 144)	-0.33, $p = .372$	.564
Base rate neglect (accuracy)	.257 _(N = 520)	.182 _(N = 411)	.235 _(N = 108)	-0.56, $p = .306$	.194
Heuristics/biases (accuracy)	.478 _(N = 267)	.446 _(N = 200)	.482 _(N = 67)	-0.32, $p = .375$	.455
Verbal Intelligence	.379	.345	.371	-0.35, $p = .365$	.350
Numeracy	.410	.404	.382	0.30, $p = .382$	.399
Religious belief	-.241	-.211	-.197	-0.17, $p = .433$	-.208
6. Białek & Sawicki (2017)	$N = 166$	$N = 67$	$N = 99$		
Discount rates accelerating	.279	.271	.279	-0.05, $p = .479$	.276
Discount rates delaying	.253	.257	.261	-0.03, $p = .489$	.259

All $p < .05$ unless otherwise indicated. Full sample is a sum of all participants regardless whether they declared their experience with CRT or not, but particular subsamples does not include the individuals who failed to declare their previous experience with the CRT.

* via Toplak, West, & Stanovich (2014)

** The N's were variable for Pennycook et al. (2016, PLoS ONE) because the data set was actually the combination of four separate studies that used different combinations of variables (but always the original CRT, verbal intelligence scale, numeracy scale, and religious belief scale). The reported correlations are from 3 of the 4 studies in Pennycook et al. (2016, PLoS ONE) because one of the studies (Study 3) included data from Barr et al. (2015, CiHB).

As is evident from Table 2, the Fisher z -test comparing correlations between experienced and unexperienced participants was only significant in 3 out of 23 cases. However, in all three cases, the CRT was *more* predictive among participants who reported having previous experience. Among these exceptions were two cases where the CRT became more strongly predictive of performance on the heuristics and biases battery (via, Toplak et al., 2011) – a set of tasks that include problems taken from Kahneman and Tversky’s heuristics and biases program of research (Kahneman, Slovic, & Tversky, 1982). The battery includes problems relating to the conjunction fallacy, base-rate neglect, the gamblers fallacy, and so on. Perhaps the most straightforward explanation for the increase in the strength of the correlation between the CRT and heuristics and biases battery is that the two tests are often used in conjunction with each other (prior exposure to the heuristics and biases battery was not assessed).

For the other cases – smartphone internet use – it is unclear why the CRT correlation was *stronger* among experienced participants. One possibility is that the CRT is more reliable among the experienced participants. However, we tested for changes in the reliability (Cronbach’s alpha) of the CRT for experienced relative to unexperienced groups and found no consistent differences (reliability was larger for the experienced group in three studies, but was smaller in two others, and in one case the two groups were equal): Study 1, $\alpha_{\text{unexperienced}} = .65$, $\alpha_{\text{experienced}} = .72$; Study 2, $\alpha_{\text{unexperienced}} = .64$, $\alpha_{\text{experienced}} = .60$; Study 3, $\alpha_{\text{unexperienced}} = .61$, $\alpha_{\text{experienced}} = .53$; Study 4, $\alpha_{\text{unexperienced}} = .57$, $\alpha_{\text{experienced}} = .65$; Study 5, $\alpha_{\text{unexperienced}} = .63$, $\alpha_{\text{experienced}} = .63$; Study 6, $\alpha_{\text{unexperienced}} = .62$, $\alpha_{\text{experienced}} = .76$. In fact, reliability was lower in the experienced group in the study that included the smartphone internet use question (Study 3).

It should be noted that non-significant differences between reported correlations cannot be used as positive evidence against group differences (Dienes, 2014). For example, one reason for a non-significant Fisher’s z -test result would be having too little power to detect small differences

between the groups. In our case, however, we are concerned with the practical issue of the CRTs predictive validity and therefore small significant differences are not our primary concern.

Nonetheless, the reported correlations are fairly consistent across the experienced and naive groups, and our least powered comparison (Study 6) was sensitive enough to detect differences in correlations of $r = .161$. Such differences are small enough to justify our claim that any smaller differences having little practical importance (Ellis & Steyn, 2003; Taylor, 1990).

There were two cases where an originally significant correlation was not significant among individuals who had prior experience with the CRT. In one case, the correlation between CRT performance and religious belief was not significant among experienced participants (Study 2), $r(114) = -.14, p = .131$. Nonetheless, this is well within the range of previous studies on the topic (see Pennycook, Ross, Koehler, & Fugelsang, 2016 for a meta-analysis). Moreover, CRT negatively predicted religious belief among experienced participants in two larger studies (Study 1 and Study 5, see Table 2). In the other case, the CRT did not predict Faith in Intuition among those with experience on the CRT. Nonetheless, the correlation with Faith in Intuition among the unexperienced was small in the first place, $r(372) = -.205$. Moreover, to reiterate, the difference between the correlation coefficients for experienced and unexperienced participants was not significant.

Discussion

Across six data sets with close to 2,500 participants and seventeen variables of theoretical interest, we did not find a single case where prior exposure on the CRT had a significant negative impact on its predictive validity. Indeed, the correlation coefficients stayed fairly consistent regardless of prior exposure, with 3 exceptions where the correlations became stronger with additional exposure to the CRT. We therefore conclude that exposure does not adversely affect the correlation of the CRT with other variables.

We replicated the finding that CRT accuracy increases with experience (Haigh, 2016, Stieger & Reips, 2016). Hence, there is a chance that, when doing an experiment that compares accuracy across two groups (rather than using the CRT as an individual difference measure, as done here), one group will have artificially higher scores because it contains more experienced participants than the other. To avoid this problem, researchers could ask participants if they have prior experience with the CRT and set an analysis plan where they use CRT experience as a covariate (and thus controlling for experience level differences between conditions).

The present results indicate that the CRT remains strongly predictive of a variety of outcome variables given prior experience. However, the results offer no clues as to *why* this is the case. We see two non-mutually exclusive explanations. The first hypotheses relates to the possibility that those who do poorly on the CRT have a metacognitive disadvantage (Mata et al., 2013; Pennycook et al., 2017). Namely, only relatively analytic individuals increase their performance on the CRT with repeated testing; whereas relatively less analytic and more intuitive individuals continue to do poorly on the test. This may occur because relatively intuitive individuals fail to realize that being presented with apparently easy problems more than once confers information about the tasks' apparent difficulty. This coincides with research showing that participants who do well on the CRT massively overestimate their performance (that is, they do not realize that they are doing poorly; Pennycook, Ross, Koehler, & Fugelsang, 2017), which indicates that intuitive individuals may have a metacognitive disadvantage (see also: Mata, Ferreira, & Sherman, 2013). Other research indicates that more reflective individuals are also better able to detect conflict during reasoning (Pennycook, Cheyne, Barr, Koehler, & Fugelsang, 2014; Pennycook, Fugelsang, & Koehler, 2015), which may, in turn, explain their metacognitive advantage.

It is also possible that the increase in accuracy on the CRT upon repeated exposure is actually the result of a self-selection effect – that is, smarter individuals are more likely to complete more studies. Hence, their CRT score is higher not because multiple exposures allows helps them to solve the problems, but because this subgroup of participants is simply more reflective than the rest of population (i.e., a selection instead of a treatment effect). This would increase overall accuracy on the CRT but would not affect how it correlates with various outcome variables. Further research is required to delineate between these accounts (and, of course, additional accounts are possible). An experiment aimed directly at the effects of retesting could isolate which people show improved performance over time and whether predictive validity changes over time.

The current data also do not allow us to claim that *many* repeated exposures do not eventually undermine the CRT's predictive validity. In Studies 2-5, participants were asked how many times they have seen the CRT and the majority (~85%) declared they only saw the CRT one to three times. However, focusing on the study that had the most participants who reported seeing the CRT more than 3 times (Study 5), the correlation between CRT and religious belief (for example) was very similar among highly experienced participants, $r(37) = -.20$, as among those with no prior CRT experience, $r(828) = -.18$ (this pattern emerged for all other variables of interest as well). Nonetheless, this sample is not sufficient to definitively test whether the predictive validity of the CRT will eventually break down after repeated exposure. Naturally, this is less of a pragmatic concern for researchers who are interested in using the CRT since, in most cases, a large number of repeated exposures is less common than a small number.

Another limitation of the current analysis is that none of the participants were asked *where* they previously encountered the CRT. Haigh (2016) found that, among those who reported prior exposure to the CRT, 30.6% were exposed via popular media and 22.2% were exposed via a

course in school or university. In such contexts, it is likely that the CRT was not simply presented, but *explained*. It is quite possible that this type of exposure has relevance for whether the CRT remains a potent predictor.¹ We suggest that future CRT studies ask “have you seen the last 3 word problems before” (response options: ‘yes’, ‘maybe’, ‘no’) *and* give participants an opportunity to indicate the context that this occurred (response options, selecting all that apply: ‘previous research studies’, ‘in popular media, such as books, websites, and social media’, ‘school or university’, and ‘not sure’). Exclusions based on these questions should be preregistered or, at least, fully reported along with alternative analyses to demonstrate that the presented results do not rely on a particular *post hoc* exclusion criteria.

The CRT is far from a perfect measure. Apart from issues that may emerge from familiarity with the task (however overblown), the CRT consists of only three items, is not particularly reliable, and suffers from range restriction issues (across the 1624 naive participants in our sample, 42.2% got none of the questions correct and 12.9% got all of the questions correct). Thus, despite the current results, the continued development and testing of expanded versions of the CRT remains imperative (see Primi, Morsanyi, Chiesi, Donati, & Hamilton, 2015; Thomson & Oppenheimer, 2016; Toplak et al., 2014). Indeed, Stanovich and colleagues have developed a more comprehensive measure of rational thinking (the “Rationality Quotient”; Stanovich, 2016; Stanovich, West, & Toplak, 2016) that will be an important tool for future work in psychology and education.

Our analysis provides a clear answer to the potential problem of prior exposure on the CRT: The CRT is robust to multiple testing and there is no need to abandon it as an individual difference measure. Although some people may benefit from experience with the task, these

¹ We thank Matthew Haigh for this suggestion.

individuals are evidently among the more analytic in the sample and therefore do not impact the overall predictive validity of the CRT.

Author Note

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References

- Barr, N., Pennycook, G., Stolz, J. A., & Fugelsang, J. A. (2015). The brain in your pocket: Evidence that Smartphones are used to supplant thinking. *Computers in Human Behavior*, 48. <https://doi.org/10.1016/j.chb.2015.02.029>
- Białek, M., & Domurat, A. (2017) Cognitive abilities, analytic cognitive style and overconfidence: a commentary on Duttte (2016). *Buletin of Economic Research*. *in press*. <https://doi.org/10.1111/boer.12117>
- Białek, M., & Sawicki, P. (2017). Cognitive reflection effects on time discounting. *submitted*.
- Campitelli, G., & Gerrans, P. (2014). Does the cognitive reflection test measure cognitive reflection? A mathematical modeling approach. *Memory & Cognition*, 42(3), 434–47. <https://doi.org/10.3758/s13421-013-0367-9>
- De Neys, W., Rossi, S., & Houdé, O. (2013). Bats, balls, and substitution sensitivity: cognitive misers are no happy fools. *Psychonomic Bulletin & Review*, 20(2), 269–73. <https://doi.org/10.3758/s13423-013-0384-5>
- Dienes, Z. (2014). Using Bayes to get the most out of non-significant results. *Frontiers in psychology*, 5, 781. <https://doi.org/10.3389/fpsyg.2014.00781>
- Ellis, S., & Steyn, H. (2003). Practical significance (effect sizes) versus or in combination with statistical significance (p-values): Research note. *Management Dynamics*, 12(4), 51-53.
- Frederick, S. (2005). Cognitive Reflection and Decision Making. *Journal of Economic Perspectives*, 19(4), 25–42. <https://doi.org/10.1257/089533005775196732>
- Gigerenzer, G. (2007). *Gut feelings: The intelligence of the unconscious*. Viking, New York.
- Haigh, M. (2016). Has the standard cognitive reflection test become a victim of its own success? *Advances in Cognitive Psychology*, 12(3), 145-149.
- Kahan, D. M. (2013). Ideology, motivated reasoning, and cognitive reflection. *Judgment and Decision Making*, 8(4), 407–424.
- Kahneman, D. (2011). *Thinking, fast and slow*. New York, NY: Farrar, Straus and Giroux.
- Kahneman, D., Slovic, P., & Tversky, A. (1982). Judgments under uncertainty. *Heuristics and Biases*, Cambridge.
- Kunda, Z. (1990). The case for motivated reasoning. *Psychological Bulletin*, 108(3), 480–498. <https://doi.org/10.1037/0033-2909.108.3.480>
- Mata, A., Ferreira, M. B., & Sherman, S. J. (2013). The metacognitive advantage of deliberative thinkers: A dual-process perspective on overconfidence. *Journal of Personality and Social Psychology*, 105(3), 353–373. <https://doi.org/10.1037/a0033640>
- Mercier, H., & Sperber, D. (2011). Why do humans reason? Arguments for an argumentative theory. *The Behavioral and Brain Sciences*, 34(2), 57-74-111. <https://doi.org/10.1017/S0140525X10000968>
- Noori, M. (2016). Cognitive reflection as a predictor of susceptibility to behavioral anomalies. *Judgment and Decision Making*, 11(1), 114-120.
- Pennycook, G., & Ross, R. M. (2016). Commentary: Cognitive reflection vs. calculation in decision making. *Frontiers in Psychology*, 7. <https://doi.org/10.3389/fpsyg.2016.00009>
- Pennycook, G., Cheyne, J. A., Barr, N., Koehler, D. J., & Fugelsang, J. A. (2014). Cognitive style and religiosity: The role of conflict detection. *Memory and Cognition*, 42(1). <https://doi.org/10.3758/s13421-013-0340-7>
- Pennycook, G., Cheyne, J. A., Barr, N., Koehler, D. J., & Fugelsang, J. A. (2014). The role of analytic thinking in moral judgements and values. *Thinking & Reasoning*, 20(2), 188–

214. <https://doi.org/10.1080/13546783.2013.865000>
- Pennycook, G., Cheyne, J. A., Barr, N., Koehler, D. J., & Fugelsang, J. A. (2015). On the reception and detection of pseudo-profound bullshit. *Judgment and Decision Making*, 10(6), 549–563. <https://doi.org/10.3389/fpsyg.2013.00279>
- Pennycook, G., Cheyne, J. A., Koehler, D. J., & Fugelsang, J. a. (2015). Is the cognitive reflection test a measure of both reflection and intuition? *Behavior Research Methods*,. <https://doi.org/10.3758/s13428-015-0576-1>
- Pennycook, G., Cheyne, J. A., Seli, P., Koehler, D. J., & Fugelsang, J. A. (2012). Analytic cognitive style predicts religious and paranormal belief. *Cognition*, 123(3), 335–346. <https://doi.org/10.1016/j.cognition.2012.03.003>
- Pennycook, G., Fugelsang, J. A., & Koehler, D. J. (2015). Everyday Consequences of Analytic Thinking. *Current Directions in Psychological Science*, 24(6). <https://doi.org/10.1177/0963721415604610>
- Pennycook, G., Fugelsang, J. A., & Koehler, D. J. (2015). What makes us think? A three-stage dual-process model of analytic engagement. *Cognitive Psychology*, 80, 34–72. <https://doi.org/10.1016/j.cogpsych.2015.05.001>
- Pennycook, G., Ross, R. M., Koehler, D. J., & Fugelsang, J. A. (2016). Atheists and Agnostics Are More Reflective than Religious Believers: Four Empirical Studies and a Meta-Analysis. *Plos One*, 11(4), e0153039. <https://doi.org/10.1371/journal.pone.0153039>
- Pennycook, G., Ross, R. M., Koehler, D. J., & Fugelsang, J. A. (2017). Dunning–Kruger effects in reasoning: Theoretical implications of the failure to recognize incompetence. *Psychonomic Bulletin & Review*, (Type 1). <https://doi.org/10.3758/s13423-017-1242-7>
- Primi, C., Morsanyi, K., Chiesi, F., Donati, M. A., & Hamilton, J. (2015). The Development and Testing of a New Version of the Cognitive Reflection Test Applying Item Response Theory (IRT). *Journal of Behavioral Decision Making*. <https://doi.org/10.1002/bdm.1883>
- Stanovich, K. (2016). The comprehensive assessment of pational thinking. *Educational Psychology*, 51(1), 23–34. <https://doi.org/10.1080/00461520.2015.1125787>
- Stanovich, K., West, R., & Toplak, M. (2016). *The rationality quotient: toward a test of rational thinking*. Cambridge, MA: MIT Press.
- Stieger, S., & Reips, U.-D. (2016). A limitation of the Cognitive Reflection Test: familiarity. *PeerJ*, 4, e2395.
- Taylor, R. (1990). Interpretation of the correlation coefficient: a basic review. *Journal of Diagnostic Medical Sonography*, 6(1), 35–39.
- Thomson, K. S., & Oppenheimer, D. M. (2016). Investigating an alternate form of the cognitive reflection test. *Judgment and Decision Making*, 11(1), 99–113.
- Toplak, M., West, R. F., & Stanovich, K. (2011). The Cognitive Reflection Test as a predictor of performance on heuristics-and-biases tasks. *Memory & Cognition*, 39(7), 1275–1289. <https://doi.org/10.3758/s13421-011-0104-1>
- Toplak, M. E., West, R. F., & Stanovich, K. E. (2014). Assessing miserly information processing: An expansion of the Cognitive Reflection Test. *Thinking & Reasoning*, 20(2), 147–168. <https://doi.org/10.1080/13546783.2013.844729>