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TOWARD A RATIONALITY QUOTIENT (RQ)

The Comprehensive Assessment of Rational Thinking (CART)

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Because we have been admirers of Ken Manktelow's work for some time, we are especially glad to participate in this volume honoring his work. In fact, Ken was one of the first to personally welcome us to the field of reasoning. This happened relatively recently because, although we are from Ken's cohort, our reasoning work did not begin until after we had made contributions to an entirely different research area. Although Richard and Keith had been admirers of the heuristics and biases tradition from its inception in the early 1970s, their first research contributions were in the psychology of reading, and this occupied them for 15 years (see Stanovich, 2000; Stanovich, Cunningham, & West, 1998). By the 1990s though, we had decided to make a contribution to the literature on thinking and reasoning that we had admired so much for so long.

Our earliest work garnered a very generous invitation from Jonathan Evans to address the Fourth International Thinking Conference in Durham in the summer of 2000. We say generous because we had just begun to contribute to the literature when we received the invitation. In terms of major publications, we had published our 1998 *Journal of Experimental Psychology: General* multiple experiment piece and we had summarized similar work in the book *Who Is Rational? Individual Differences in Reasoning* that had just come out (our *Behavioral and Brain Sciences* piece did not come out until 2001, even though it had a publication date of 2000). In short, we had only begun publishing in the field, and most of the main speakers at the conference had spent decades studying areas, tasks, and paradigms that we had only recently mastered.

As a result, we were excited about the conference but also relatively nervous when we arrived in Durham. We were meeting all the people who had studied in depth all of the tasks that we had put together in our individual differences studies. As Keith said to the Durham audience, our studies of individual differences were structured so that we had to look at associations and relationships across a wide variety of tasks. That put us in danger of being a kind of "Jack of all trades but master of none". We dreaded being grilled on a particular task by its inventor, when it was in fact just 1 of 20 or so that we had studied, and we of course were not experts on all of them. Well, we should not have worried. The attendees at that conference were quite gracious and fair. But most of all we remember running into Ken Manktelow early in the conference. Of course we knew not only of all his previous work, but we had been immensely influenced by his book *Reasoning and Thinking* that had just come out in 1999. Both Richard and Keith ended up teaching out of that book, but at the time we used it as a tremendous resource to get ourselves up to speed on the field. It is easy to imagine our relief when one of the first things Ken said to us was that *Who Is Rational?* had come out too late for him to comment on it in *Reasoning and Thinking*, as he would have done. We could not have been more reassured at the time, given that Ken's work on the selection task, deontic reasoning, causal reasoning, conditional reasoning, utility issues and reasoning tasks, and the distinction between epistemic and instrumental rationality had become essential tools in our research program. Thank you, Ken.

In the present chapter, we intend to give a sketch of where we have taken our work on individual differences in rational thought since that Durham conference. Our early empirical work on individual differences in rational thought (Stanovich & West, 1997, 1998c, 1999) was first cashed out in terms of theoretical insights concerning dual process theory and evolutionary psychology that were relevant to the Great Rational Debate in cognitive science (Stanovich, 1999, 2004; Stanovich & West, 2000). The next phase of our empirical work (see Stanovich & West, 2008b) led to the book *What Intelligence Tests Miss* (Stanovich, 2009). From that book, it was clear that the next logical step was following through on our claim that there was nothing preventing the construction of a rational thinking test. We outlined an early version of our framework for assessing rational thinking, along with suggested tasks, in Stanovich (2011, Chapter 10) and in Stanovich, West, and Toplak (2011). Building on this work, we have recently completed the construction of the first comprehensive assessment of rational thinking. We will describe the background of this effort in this chapter.

Conceptual background of the CART

Psychology has a long and storied history (more than 100 years old) of measuring the intelligence trait. Although, there has been psychological work on rational thinking, this research started much later and it was not focused on individual differences. Our research group has conducted one of the longest extant investigations of individual differences in rational thinking processes. We are near to completing (Stanovich, West, & Toplak, in press) our work on the first prototype of a comprehensive test of rational thought (the Comprehensive Assessment of Rational Thinking, CART), and we will describe the background of our test and the nature of our progress in this chapter.

A novice psychology student might be a bit confused at this point – thinking that somewhere along the line they have heard definitions of intelligence that included rationality. Many people – students and nonstudents alike – think that intelligence means acting rationally, more or less. Indeed, it is true that even in academic discourse many theoretical definitions of intelligence incorporate rationality by alluding to judgment and decision making in the definition (see Stanovich, 2009, for a fuller discussion). Other definitions emphasize behavioral adaptiveness and thus also fold rationality into intelligence. The problem here is that *none* of these components of rationality – adaptive responding, good judgment, and decision-making – is assessed on *actual tests* of intelligence.

Publishers of IQ tests and their proponents have encouraged the view that you get everything you need in cognitive assessment from such tests. But in fact, by giving an intelligence test, one does not automatically get a measure of rational thinking. To get the latter, we need to actually construct a test of rational thinking. That is why we embarked upon creating the CART. Our premise was that because we now have conceptually grounded theories of rationality and because we have a prodigious number of tasks that measure the components of rationality (Baron, 2008; Evans, 1989, 2014; Kahneman, 2011; Stanovich, 1999, 2011), it is now possible to see what would happen if we began from the ground up to construct a rationality test around that concept only.

Synthesizing theoretical work and empirical research that began more than two decades ago (Stanovich, 1993; Stanovich & West, 1997, 1998c), we now have a prototype of such a test (Stanovich et al., in press). We have proceeded with our eyes on the empirical literature on the nature of human judgment and decision making (Kahneman, 2011; Manktelow, 2012) and theoretical discussions of rationality in cognitive science (Evans, 2014; Stanovich, 2011, 2012). For years, we have been examining how one would go about constructing the best rational thinking test if the focus was solely on that construct (as opposed to viewing its study as somehow ancillary to investigations of intelligence). Finally, there is one further historical/contextual feature of the CART that deserves to be noted.

In 2002, cognitive scientist Daniel Kahneman won the Nobel Prize in Economics for work done with his longtime collaborator Amos Tversky (who died in 1996). The press release for the award from the Royal Swedish Academy of Sciences drew attention to the roots of the award-winning work in "the analysis of human judgment and decision-making by cognitive psychologists". Kahneman was cited for discovering "how human judgment may take heuristic shortcuts that systematically depart from basic principles of probability".

In short, Kahneman and Tversky's work was about how humans make choices and assess probabilities, and they uncovered very basic errors that are typical in decision making. Their work includes some of the most influential and highly cited studies in all of psychology, and it deserved to be honoured with the Nobel Prize. One reason this work was so influential was that it addressed deep issues concerning human rationality. Being rational means acting to achieve one's own life goals using the best means possible. To violate the thinking rules Kahneman and Tversky examined thus has the practical consequence that we are less satisfied with our lives than we might be.

Our research group has found systematic differences among individuals in the tendency to make errors of judgment and decision making (Stanovich & West, 1998c, 1999, 2000, 2008b; Toplak, West, & Stanovich, 2011, 2014a). The fact that there are systematic individual differences in the judgment and decision-making situations Kahneman and Tversky studied means that there are variations in important attributes of human cognition related to rationality – how efficient we are in achieving our goals. It is a curious fact that none of these critical attributes of human thinking is assessed on IQ tests (or their proxies such as the SAT test). This fact is curious for two related reasons. First, most laypeople are prone to think that IQ tests are tests of, to put it colloquially, good thinking. Scientists and laypeople alike would tend to agree that "good thinking" encompasses good judgment and decision making – the type of thinking that helps us achieve our goals. In fact, the type of "good thinking" that Kahneman and Tversky studied was deemed so important that research on it was awarded the Nobel Prize. Yet assessments of such good thinking are nowhere to be found on IQ tests. It is perhaps the most profound historical irony of the behavioral sciences that the Nobel Prize was awarded for studies of cognitive characteristics that are entirely missing from the most well-known mental assessment device in psychology – the intelligence test.

Critics of intelligence tests are eager to point out that the tests ignore important parts of mental life – many largely noncognitive domains such as socioemotional abilities, empathy, and interpersonal skills, for example. However, a tacit assumption in such critiques is that although intelligence tests miss certain key noncognitive areas, they do encompass most of what is important in the cognitive domain. It is just this assumption that we wish to challenge with the construction of the CART. Our test will operationalize an important cognitive domain not assessed by intelligence tests: the skills of judgment and decision making that are the foundation of rational thought and action.

Rationality in cognitive science

We follow many cognitive science theorists in recognizing two types of rationality: instrumental and epistemic (Manktelow, 2004; Over, 2004). The simplest definition of instrumental rationality, the one that emphasizes most that it is grounded in the practical world, is: Behaving in the world so that you get exactly what you most want, given the resources (physical and mental) available to you. Somewhat more technically, we could characterize instrumental rationality as the optimization of the individual's goal fulfillment. Economists and cognitive scientists have refined the notion of optimization of goal fulfillment into the technical notion of expected utility. Epistemic rationality concerns how well beliefs map onto the actual structure of the world. The two types of rationality are related. In order to take actions that fulfill our goals, we need to base those actions on beliefs that are properly matched to the world.

Manktelow (2004) has emphasized the practicality of both types of rationality by noting that they concern two critical things: what is true and what to do. Epistemic rationality is about what is true and instrumental rationality is about what to do. For our beliefs to be rational they must correspond to the way the world is – they must be true. For our actions to be rational, they must be the best means toward our goals – they must be the best things to do. Nothing could be more practical or useful for a person's life than the thinking processes that help them find out what is true and what is best to do.

More formally, economists and cognitive scientists define instrumental rationality as the maximization of expected utility. To be instrumentally rational, a person must choose among options based on which option has the largest expected utility. Decision situations can be broken down into three components: 1) possible actions; 2) possible states of the world; 3) evaluations of the consequences of possible actions in each possible state of the world. Expected utility is calculated by taking the utility of each outcome and multiplying it by the probability of that outcome and then summing those products over all of the possible outcomes.

In practice, assessing rationality in this manner can be difficult because eliciting personal probabilities can be tricky. Also, getting measurements of the utilities of various consequences can be experimentally difficult. Fortunately, there is another useful way to measure the rationality of decisions and deviations from rationality. It has been proven through several formal analyses that if people's preferences follow certain consistent patterns (the so-called axioms of choice: independence of irrelevant alternatives, transitivity, independence, and reduction of compound lotteries, etc.), then they are behaving as if they are maximizing utility (Dawes, 1998; Edwards, 1954; Jeffrey, 1983; Luce & Raiffa, 1957; Savage, 1954; von Neumann & Morgenstern, 1944). This is the so-called axiomatic approach to whether people are maximizing utility. It is what makes people's degrees of rationality more easily measurable by the experimental methods of cognitive science. The deviation from the optimal choice pattern according to the axioms is an (inverse) measure of the degree of rationality.

An axiomatic approach can be applied to assessing epistemic rationality as well. Recall that the expected utility of an action involves multiplying the probability of an outcome by its utility (and summing across possible outcomes). Thus, determining the best action involves estimating the probabilities of various outcomes. These probabilities are not conscious calculations of course – they are one's confidence estimates about states of the world. They are one's beliefs and the confidence that one has in them. If our probabilistic judgments about the states of the world are wrong, decision making will not maximize one's utility – our actions will not result in our getting what we most want. Thus, instrumental and epistemic rationality become intertwined. If we are to determine what to do, we need to make sure that our actions are based on what is true. It is in this sense that rationality of belief – epistemic rationality – is one of the foundations for rationality of action.

Rationality of belief is assessed by looking at a variety of probabilistic reasoning skills, evidence evaluation skills, and hypothesis testing skills. In order for a person to be epistemically rational, their probability estimates must follow the rules of objective probabilities – their estimates must follow the so-called probability calculus.

Mathematically, probability values follow certain rules. These rules form one of the most important normative models for subjective probability estimates.

The heuristics and biases literature

In the construction of our rational thinking assessment instrument, we have drawn on the vast literature that has demonstrated that people sometimes violate the normative rules of instrumental and epistemic rationality (Baron, 2008, 2014; Evans, 2014; Kahneman, 2011; Kahneman & Tversky, 2000; Koehler & Harvey, 2004; Manktelow, 2012). We have drawn heavily on this research, especially that of the so-called heuristics and biases tradition Kahneman and Tversky inaugurated in the early 1970s (Kahneman & Tversky, 1972, 1973; Tversky & Kahneman, 1974). The term *biases* refers to the systematic errors people make in choosing actions and in estimating probabilities, and the term *heuristics* refers to *why* people often make these errors – because they use mental shortcuts (heuristics) to solve many problems. Table 16.1 lists some of the tasks, effects, and biases from this literature that we have studied in our lab and from which we selected in order to construct the CART. Because much of the operationalization of our framework of rational thinking comes from the heuristics and biases tradition, it is important to explicate the logic of such tasks.

TABLE 16.1 Heuristics, biases, and effects studied in the Stanovich/West/Toplak lab

Tasks, effects, and biases	*Individual differences citation from the work of our lab*
Baserate neglect	Kokis, Macpherson, Toplak, West, & Stanovich, 2002; Stanovich & West, 1998c, 1998d, 1999, 2008b; West, Toplak, Stanovich, 2008
Conjunction fallacy	Stanovich & West, 1998b, Toplak et al., 2011; West et al., 2008
Framing effects	Stanovich & West, 1998b, 1999, 2008b; Toplak et al., 2014a, Toplak, West, Stanovich, 2014b
Anchoring effect	Stanovich & West, 2008b
Sample size awareness	Toplak et al., 2011; West et al., 2008
Regression to the mean	Toplak, Liu, Macpherson, Toneatto, & Stanovich, 2007; Toplak et al., 2011; West et al., 2008
Control group reasoning	Stanovich & West, 1998c; Toplak et al., 2011; West et al., 2008
Disjunctive reasoning	Toplak & Stanovich, 2002; West et al., 2008
Temporal discounting	Toplak et al., 2014a
Gambler's fallacy	Toplak et al., 2007; Toplak et al., 2011; West et al., 2008
Probability matching	Stanovich & West, 2008b; Toplak et al., 2007; Toplak et al., 2011; West & Stanovich, 2003
Overconfidence effect	Stanovich & West, 1998c
Outcome bias	Stanovich & West, 1998c, 2008b; Toplak et al., 2007; Toplak et al., 2011
Ratio bias	Kokis et al., 2002; Stanovich & West, 2008b; Toplak et al., 2014a, 2014b; West et al., 2008

(*Continued*)

TABLE 16.1 (Continued)

Tasks, effects, and biases	*Individual differences citation from the work of our lab*
Four-card selection task	Stanovich & West, 1998a, 2008b; Toplak & Stanovich, 2002; Toplak et al., 2014a; West et al., 2008
Ignoring P(D/~H)	Stanovich & West, 1998d, 1999; West et al., 2008
Sunk cost effect	Stanovich & West, 2008b; Toplak et al., 2011
Risk/benefit confounding	Stanovich & West, 2008b
Covariation detection	Stanovich & West, 1998c, 1998d; Sá, West, & Stanovich, 1999; Toplak et al., 2011; West et al., 2008
Belief bias in syllogistic reasoning	Macpherson & Stanovich, 2007; Stanovich & West, 1998c, 2008b; Toplak et al., 2014a, 2014b
Omission bias	Stanovich & West, 2008b
Informal argument evaluation	Stanovich & West, 1997, 2008b; Sá et al., 1999
Unconfounded hypothesis testing	Stanovich & West, 1998c; Toplak et al., 2011
Myside bias	Sá, Kelley, Ho, & Stanovich, 2005; Stanovich & West, 2007, 2008a, 2008b; Toplak & Stanovich, 2003; Toplak et al., 2014a, 2014b
Expected value maximization	Stanovich, Grunewald, & West, 2003; Toplak et al., 2007
Bias blind spot	West, Meserve, & Stanovich, 2012; Toplak et al., 2014a
Newcomb's problem	Stanovich & West, 1999; Toplak & Stanovich, 2002
Prisoner's dilemma	Stanovich & West, 1999; Toplak & Stanovich, 2002
Hindsight bias	Stanovich & West, 1998c
One-Side bias	Stanovich & West, 2008a
Certainty effect	Stanovich & West, 2008b
Willingness to pay/willingness to accept	Stanovich & West, 2008b
Evaluability: less is more effect	Stanovich & West, 2008b
Proportion dominance effect	Stanovich & West, 2008b

Heuristics and biases tasks were designed for human brains, not animal brains. What I mean by this is that heuristics and biases tasks were designed for brains that could at least *potentially* experience mental conflict. This is why Kahneman (2000) stressed that "Tversky and I always thought of the heuristics and biases approach as a two-process theory" (p. 682). All multiple-process models of mind, including the currently popular dual process theories (Evans & Stanovich, 2013), capture a phenomenal aspect of human decision making that is of profound importance – that humans often feel alienated from their choices. We display what both folk psychology and philosophers term *weakness of will*. For example, we continue to smoke when we know that it is a harmful habit; or we order a sweet after a large meal, merely an hour after pledging to ourselves that we would not. However, we display alienation from our responses even in situations that do not involve weakness of will.

Discussion of heuristics and biases tasks often leads to a conceptualization within a dual-process framework, because most of the tasks in the heuristics and biases literature were deliberately designed to pit an automatically triggered response against a normative response generated by more controlled types of processing (Kahneman, 2011). Since Kahneman and Tversky launched the heuristics and biases approach in the 1970s, a wealth of evidence has accumulated in support of the dual-process framework (Evans & Stanovich, 2013). In many such theories, the defining feature of Type 1 processing is its autonomy – the execution of Type 1 processes is mandatory when their triggering stimuli are encountered, and they are not dependent on input from high-level control systems. Autonomous processes have other correlated features – their execution tends to be rapid, they do not put a heavy load on central processing capacity, they tend to be associative – but these other correlated features are not defining (Stanovich & Toplak, 2012). The category of autonomous processes would include: processes of emotional regulation; the encapsulated modules for solving specific adaptive problems that evolutionary psychologists have posited; processes of implicit learning; and the automatic firing of overlearned associations.

In contrast with Type 1 processing, Type 2 processing is nonautonomous. It is relatively slow and computationally expensive. Many Type 1 processes can operate in parallel, but Type 2 processing is largely serial. One of the most critical functions of Type 2 processing is to override Type 1 processing. This is sometimes necessary because autonomous processing has heuristic qualities. It is designed to get the response into the right ballpark when solving a problem or making a decision, but it is not designed for the type of fine-grained analysis called for in situations of unusual importance (financial decisions, fairness judgments, employment decisions, legal judgments, etc.). Type 1 processing heuristics depend on benign environments. In hostile environments, they can be costly (see Hilton, 2003; Over, 2000; Stanovich, 2004).

In order to override Type 1 processing, Type 2 processing must display at least two related capabilities. One is the capability of interrupting Type 1 processing and suppressing its response tendencies. But suppressing the Type 1 response is not helpful unless a better response is available to substitute for it. Where do these better responses come from? One answer is that they come from processes of hypothetical reasoning and cognitive simulation that are a unique aspect of Type 2 processing (Evans, 2010; Evans & Stanovich, 2013; Stanovich, 2004, 2011). Humans alone appear to be able to represent a model of an idealized (i.e., hypothesized) response, while still maintaining a first-order model of current response tendencies.

When we said that heuristics and biases tasks were designed for human brains, not animal brains, we did not mean to say that rationality cannot be assessed in nonhuman animals. To the contrary, the axiomatic approach to rationality assessment mentioned previously allows the rationality of nonhuman animals to be assessed as well as that of humans, because it defines instrumental rationality as adherence to certain types of consistency and coherence relationships (see Kacelnik, 2006; Luce & Raiffa, 1957; Savage, 1954). In fact, many animals appear to have a reasonable degree of instrumental rationality (Hurley & Nudds, 2006). The adaptively shaped behavior of nonhuman animals can, in theory, deviate from the axioms of rational choice because it is possible for the optimization of fitness at the genetic level to dissociate from optimization at the level of the organism (Stanovich, 2004).

So although the assessment of nonhuman rationality and irrationality is possible, the really interesting issues of rationality arise when we have an organism with the possibility of different types of processing (Type 1 and Type 2) priming different responses. In such a situation (the situation that spawns dual-process conceptualizations), assessing which of the minds wins out becomes of immense interest (and diagnostic of degrees of rationality). It is just this situation that heuristics and biases tasks put under the microscope. These tasks, interpreted within a dual-process framework (Kahneman, 2011), end up being diagnostic of the dominance of Type 1 versus Type 2 processing in determining the final response.

For a person who defaults often to Type 1 processing, environments can be either benign or hostile. A benign environment is an environment that contains useful cues that, via practice or evolutionary history, have been well represented in Type 1 subsystems. Additionally, for an environment to be classified as benign, it must not contain other individuals who will adjust their behavior to exploit those relying only on Type 1 processing. We would argue (Stanovich, 2004; Stanovich & West, 2000) that the modern world is somewhat hostile to Type 1 processing in critical ways, thus making it important to assess rational thinking tendencies via the logic of heuristics and biases tasks.

It is appropriate here to emphasize another way in which intelligence tests fail to tap important aspects of rational thinking. The novice reader might have thought at this point that it seems that intelligence tests clearly measure Type 2 reasoning – that is, conscious, serial simulation of imaginary worlds in order to solve problems. This is all true, but there is a critical difference. Intelligence tests contain salient warnings that Type 2 reasoning is necessary. It is clear to someone taking an intelligence test that fast, automatic, intuitive processing will not lead to superior performance. Most tests of rational thinking do not strongly cue the subject in this manner. Instead, many heuristics and biases tasks suggest a compelling intuitive response that happens to be wrong.

In heuristics and biases tasks, unlike the case for intelligence tests, the subject must detect the inadequacy of the Type 1 response and then must use Type 2 processing to both suppress the Type 1 response and to simulate a better alternative. To illustrate this difference, we might imagine asking a subject if larger or smaller sample sizes were better, as we might in a university statistics course. This would be a much easier question than a traditional heuristics and biases item, because no issue of recognition is involved – the respondent would not have to detect the *relevance* of sample size. He/she would be *focused* on its relevance by being asked directly about it. This of course makes for a much easier problem. As statistics instructors ourselves, we have commonly seen that a student may answer a direct question about sample size correctly in a multiple choice format, but then when given something like Kahneman and Tversky's hospital problem, does not perceive the relevance of sample size and answers incorrectly.

In short, most of the tasks in the heuristics and biases literature were deliberately designed to pit an intuitive but incorrect response against a normative response. This means that such tasks have both processing and knowledge requirements. From a processing standpoint, the necessity of overriding Type 1 processing must be detected. Then, the intuitive response primed by Type 1 processing must be inhibited and the normative response must be retrieved or synthesized and then substituted by Type 2 processing.

In addition to these processing requirements, successful performance on heuristics and biases tasks requires the presence of several important knowledge bases. The knowledge, rules, and strategies that can be retrieved and used to replace a Type 1 intuitive response have been referred to as *mindware* (see Stanovich et al., 2011), a term David Perkins coined in a 1995 book (Clark, 2001, uses the term in a slightly different way from Perkins' original coinage). The mindware available for use during cognitive simulation is in part the product of past learning experiences. This means that individual differences will appear in the ability to simulate better alternatives to a Type 1 response based on variation available in the mindware. The mindware that allows the computation of more rational responses needs to be available and accessible during simulation activities.

The framework and composition of the CART

It is important to stress that knowledge and process are intertwined in most heuristics and biases tasks, but that it is not the case that the dependence on knowledge and the dependence on process are the same for each and every task. Some heuristics and biases tasks are more process dependent than knowledge dependent. Others are more knowledge dependent than process dependent. Still others seem to stress both knowledge and process quite strongly.

Table 16.2 presents the overall framework for the CART, as well as some indication of the tasks used for assessment and the assessment domains. The left column of Table 16.2 serves to represent tasks saturated with processing requirements. The second column from the left represents tasks relatively saturated with knowledge from specific rational thinking domains. The first two domains of rational thinking represented in the upper left – probabilistic and statistical reasoning and scientific reasoning – have process and knowledge so intertwined that they span both columns in Table 16.2 to emphasize this point.

Working down the left column, Table 16.2 next identifies some tasks that have heavy processing requirements. The first set of tasks are indicators of the tendency to avoid miserly information processing. That humans are cognitive misers has been a major theme throughout the past 40 years of research in psychology and cognitive science (see Dawes, 1976; Evans, 1984, 1989; Kahneman, 2011; Simon, 1955, 1956; Tversky & Kahneman, 1974; for the evolutionary reasons, see Stanovich, 2004, 2009). When approaching any problem, our brains have available various computational mechanisms for dealing with the situation. These mechanisms embody a tradeoff, however. The tradeoff is between power and expense. Some mechanisms

TABLE 16.2 Framework for classifying the types of rational thinking tasks and subtests on the CART

Tasks saturated with processing requirements (detection, sustained override, hypothetical thinking)	*Rational thinking tasks saturated with knowledge*	*Avoidance of contaminated mindware*	*Thinking dispositions that foster thorough and prudent thought, unbiased thought, and knowledge acquisition*
Probabilistic and Statistical Reasoning Subtest Scientific Reasoning Subtest		Superstitious Thinking Subtest Anti-Science Attitudes Subtest	Actively Openminded Thinking Scale Deliberative Thinking Scale
Avoidance of Miserly Information Processing Subtests: - Reflection versus Intuition - Belief Bias Syllogisms - Ratio Bias - Disjunctive Reasoning	Probabilistic Numeracy Subtest	Conspiracy Beliefs Subtest	Future Orientation Scale
Absence of Irrelevant Context Effects in Decision Making Subtests: - Framing - Anchoring - Preference Anomalies	Financial Literacy and Economic Knowledge Subtest	Dysfunctional Personal Beliefs Subtest	Differentiation of Emotions Scale
Avoidance of Myside Bias: - Argument Evaluation Subtest	Sensitivity to Expected Value Subtest		
Avoiding Overconfidence: - Knowledge Calibration Subtest	Risk Knowledge Subtest		
Rational Temporal Discounting Subtest			

have great computational power – they can solve a large number of novel problems with great accuracy. However, this power comes with a cost. These mechanisms take up a great deal of attention, tend to be slow, tend to interfere with other thoughts and actions we are carrying out, and require great concentration that is often experienced as aversive (the Type 2 processing discussed earlier in this chapter). Humans are cognitive misers because their basic tendency is to default to other less-accurate processing mechanisms of low computational expense (the Type 1 processing discussed earlier in this chapter). The CART contains several subtests that assess a person's ability to avoid miserly information processing.

Continuing down the left column of Table 16.2 are some other tasks that are best viewed as indirect measures of the avoidance of miserly processing. All are heavy in their processing requirements. All of these tasks and their associated effects, although involving miserly processing, are still quite complex tasks. More than miserly processing is going on when someone answers suboptimally in all of them. Our only theoretical claim is quite minimal – it is only that, whatever else is responsible for task performance, they are all likely to have miserly processing somewhat involved. In any case, they are all important measures of rational thinking in their own right, whether or not they are due to miserly information processing. Our focus with the CART is not on resolving the theoretical disputes surrounding every one of these effects. For example, the measurement of overconfidence would be part of our rational thinking assessment battery regardless of what the explanation for the effect turns out to be. With that caveat in mind, the left-hand column of Table 16.2 shows several other important additional categories of our assessment battery: the absence of irrelevant context effects in decision making; the avoidance of myside bias; the avoidance of overconfidence in knowledge calibration; and rational temporal discounting of future rewards.

In the second column from the left in Table 16.2 are four components of the CART that represent components that are particularly heavily dependent on knowledge bases. This is not to say that these components are completely independent of the degree of miserly processing, just that variation on them is considerably less dependent on processing considerations and much more dependent on the presence of certain specific types of declarative knowledge than other tasks. These subtests of the CART tap the following: probabilistic numeracy; financial literacy and economic knowledge; sensitivity to expected value; and risk knowledge.

The third column in Table 16.2 reflects the fact that irrational thinking is potentially caused by two different types of mindware problems. Missing mindware, or mindware gaps, reflect the most common type – where a person does not have access to adequately compiled declarative knowledge from which to synthesize a normative response to use in the override of Type 1 processing. However, Stanovich (2004, 2009, 2011) has discussed how not all mindware is helpful or useful in fostering rationality. Indeed, the presence of certain kinds of mindware is often precisely the problem. We coined the category label *contaminated mindware* for the presence of declarative knowledge bases that foster irrational rather than rational thinking, which is represented in the third column of this table.

There are probably dozens of different kinds of contaminated mindware if one looks very specifically at narrow domains of knowledge. It would obviously be impossible for a test of rational thinking to encompass all of these. Instead, we have focused on just a few of the broader categories of contaminated mindware that might have more general implications and might have some domain generality in their effects. Of course, rational thinking as indicated by CART performance is defined as the *avoidance* or *rejection* of these domains of contaminated mindware. The third column from the left in Table 16.2 lists the four categories of contaminated mindware that the CART assesses: the rejection of superstitious thinking; the rejection of anti-scientific attitudes; the rejection of conspiracy beliefs; and the avoidance of dysfunctional personal beliefs.

Finally, the far right column of Table 16.2 shows a set of supplementary measures that are included in the CART, but are not part of the overall rational thinking score on the test itself. Column four lists some thinking dispositions that we measure by self-report questionnaires. Psychology studies many different thinking dispositions. However, we have chosen those specifically relevant to rational thinking. For example, we have focused on thinking dispositions that foster prudent thought, and those that foster unbiased thought and unbiased knowledge acquisition. The four thinking dispositions that we assess are: actively open-minded thinking; deliberative thinking; future orientation; and the differentiation of emotions. These self-report measures are different from the other performance measures on the CART, which is why they are not part of the overall score on the test, but instead provide supplementary information. They are not part of the total score on the test because, among other things, the maximum score on a thinking disposition measure should not be equated with maximal rationality. Optimal functioning on these measures is traced instead by an inverted U-shaped function. Maximizing these dispositions is not the criterion of rational thought itself. Thinking dispositions such as these are a means to rationality, not ends in themselves. For this reason, the thinking dispositions subscales are segregated in the CART and not treated as direct measures of rational thinking themselves.

Overall, the CART assesses both epistemic rationality and instrumental rationality. Aspects of epistemic rationality that are assessed on our instrument include: the tendency to show incoherent probability assessments; the tendency toward overconfidence in knowledge judgments; the tendency to ignore base rates; the tendency not to seek to falsify hypotheses; the tendency to try to explain chance events; the tendency to evaluate evidence with a myside bias; and the tendency to ignore the alternative hypothesis.

Additionally, the CART assesses aspects of instrumental rationality and irrationality, such as: the ability to display disjunctive reasoning in decision making; the tendency to show inconsistent preferences because of framing effects; the tendency to substitute affect for difficult evaluations; the tendency to over-weight short-term rewards at the expense of long-term well-being; the tendency to have choices affected by vivid stimuli; and the tendency for decisions to be affected by irrelevant context.

Complications and context of rational thinking assessment

For many years, we have argued (see Stanovich, 2009) that professional inertia and psychologists' investment in IQ testing have prevented us from realizing that our science had developed enough to allow us to develop a parallel RQ test. With the development of the CART, my research group has turned this prediction into reality. Although our initial effort should be viewed more as a prototype, it accomplishes the task of showing that there is nothing conceptually or theoretically preventing us from developing such a test. We know the types of thinking processes that such an instrument would assess, and we have in hand prototypes of the kinds of tasks that would be used in the domains of both instrumental rationality and epistemic rationality – both of which are represented on the CART.

Unlike many such lists of thinking skills in textbooks, the conceptual components of the CART are each grounded in a task or paradigm in the literature of cognitive science. In fact, many (e.g., context effects in decision making; probabilistic reasoning) have generated enormous empirical literatures. For example, many paradigms have been used to measure the avoidance of miserly information processing (left column of Table 16.2, third row). The study of belief bias – that people have difficulty processing data pointing toward conclusions that conflict with what they think they know about the world – has yielded several such paradigms (e.g., Evans, Barston, & Pollard, 1983; Evans & Curtis-Holmes, 2005; Markovits & Nantel, 1989).

Another part of the CART that is richly populated by work in cognitive science is a set of tasks that collectively define the mental tendency to not be affected by irrelevant context in decision making (left column of Table 16.2, fourth row). All three paradigms that assess the latter tendency have generated enormous literatures. Resistance to framing has been measured with countless tasks (e.g., Levin, Gaeth, Schreiber, & Lauriola, 2002; Maule & Villejoubert, 2007), as has the resistance to irrelevant anchoring in decisions (e.g., Epley & Gilovich, 2004, 2006; Jacowitz & Kahneman, 1995). Lichtenstein and Slovic (2006) summarized several decades worth of work on preference anomalies that followed their seminal research in the 1970s (Lichtenstein & Slovic, 1971, 1973).

The existence of the CART is our attempt to follow through on a claim made years ago (Stanovich, 2009) – that there is no *conceptual* barrier to creating a prototype of a test of rational thinking. This does not of course mean that there is not substantial work to be done in turning the prototype into an easily usable test. We have given a book-length treatment (Stanovich et al., in press) of the 20 years of work on individual differences in rational thinking that went into the development of our prototype.

We are exploring the full psychometric structure of our instrument in the ongoing study. Regarding the psychometrics of our instrument, many pairs of relationships have been explored already (see Stanovich et al., in press), but the full structure remains to be investigated. It is important, though, to understand what various psychometric structures would – and most important – would not tell us. For example, if several components or measurement paradigms turn out to be highly correlated, that will make assessment more efficient and logistically easier, but it will not enhance or diminish the status of these components as aspects of rational thought. Conversely, finding that many of the components or measurement paradigms are separable in individual difference analyses in no way detracts from the importance of any component. In short, the point is that psychometric findings do not trump what cognitive scientists have found are the conceptually essential features of rational thought and action.

All of this is not to deny that it would obviously be useful to really know the structure of rational thinking skills from a psychometric point of view. Our past research has contributed substantially to clarifying that structure. We have found that certain rational thinking tasks consistently correlate with each other even after cognitive ability has been partialled out. For example, we have found that the ability to avoid belief bias in syllogistic reasoning is related to the ability to reason statistically in the face of conflicting case evidence – and that this relationship is maintained after intelligence is partialled out (Stanovich & West, 1998c; West et al., 2008). Additionally, our group has consistently found rational thinking tasks that are predicted by thinking dispositions after cognitive ability has been partialled – particularly tasks involving statistical reasoning and informal argumentation (Kokis et al., 2002; Stanovich & West, 1997, 1998c; Toplak et al., 2011, 2014a; West et al., 2008).

Rationality is a multifarious concept. It is unlikely to yield as substantial a g-factor as is the case with intelligence (Deary, 2013; Hunt, 2011). Thus, assessment might be logistically difficult and reporting outcomes from a rational thinking test might be complex. However, we should not shirk from measuring something just because it is logistically difficult – particularly if the domain is important.

Integrating rational thinking assessment into psychological science

When a layperson thinks of individual differences in reasoning, they think of IQ tests. It is quite natural that this is their primary association, because IQ tests are among the most publicized products of psychological research. This association is not entirely inaccurate either, because intelligence is correlated with performance on a host of reasoning tasks (Carroll, 1993; Deary, 2000; Hunt, 2011). Nonetheless, certain very important classes of individual differences in thinking are ignored if only intelligence-related variance is the primary focus. A number of these ignored classes of individual differences are those relating to rational thought.

We tend not to notice the mental processes missing from IQ tests because many theorists have adopted a *permissive* conceptualization of what intelligence is rather than a grounded conceptualization. Permissive theories include aspects of functioning that are captured by the *vernacular* term *intelligence* (adaptation to the environment, showing wisdom, creativity, etc.) whether or not existing tests of intelligence actually measure these aspects. *Grounded* theories, in contrast, confine the concept of intelligence to the set of mental abilities actually tested on extant IQ tests. Adopting permissive definitions of the concept of intelligence serves to obscure what is missing from extant IQ tests. Instead, in order to highlight the missing elements in IQ tests, my research group has adopted a more scientifically justified (see Stanovich, 2009) grounded notion of the intelligence concept.

Grounded theories adopt the operationalization of the term that is used in both psychometric studies of intelligence and neurophysiological studies. This definition involves a statistical abstraction from performance on established tests and cognitive ability indicators. The grounded view of intelligence then takes the operationally defined construct and validates it in studies of educational attainment, cognitive neuroscience, developmental trends, and information processing.

The operationalization of rationality is different from that of intelligence and thus, as every introductory psychology student is taught, the concepts must be treated as different. Our comprehensive test of rational thinking will go a long way toward grounding the rationality concept – a concept that captures aspects of thought that have heretofore gone unmeasured in assessment devices.

In summary, we have coherent and well-operationalized concepts of rational action and belief formation. We have a coherent and well-operationalized concept of intelligence. No scientific purpose is served by fusing these concepts, because they are very different. To the contrary, scientific progress is made by differentiating concepts. We have a century-long history of measuring the intelligence concept. It is high time we put equal energy, as a discipline, into the measurement of a mental quality that is just as important – rationality.

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