46 Intelligence and Rationality

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Intelligence tests are often treated as if they encompassed all cognitive abilities. Our goal in this chapter is to challenge this assumption by showing that an important class of cognitive skills is missing from commonly used intelligence tests. We accomplish this by showing that intelligence, operationally defined by what current intelligence tests measure, fails to encompass rational thinking.

One way of understanding the difference between rationality and intelligence is to do a little analysis of a phenomenon we have all observed: smart people acting stupidly. We get surprised when someone whom we consider to be smart acts foolishly. But why should we be so surprised? It seems that smart people do foolish things all the time. Wasn't the financial crisis of 2008 just littered with smart people doing dumb things – from the buyers and sellers of the toxic mortgage securities to the homebuyers who seemed to think their house price would double every three years?

So, if it is not rare for smart people to act foolishly, then why the surprise? In fact, the confusion here derives from being caught up in the inconsistencies and incoherence of folk language. The folk terms being used in this discussion are in dire need of some unpacking. Consider the title of an edited book to which we contributed a chapter: *Why Smart People Can Be So Stupid* (Sternberg, 2002). A typical dictionary definition of the adjectival form of the word "smart" is "characterized by sharp quick thought; bright" or "having or showing quick intelligence or ready mental capacity." Thus, being smart seems a lot like being intelligent, according to the dictionary. Dictionaries also tell us that a stupid person is "slow to learn or understand; lacking or marked by lack of intelligence." Thus, if a smart person is intelligent and stupid means a lack of intelligence, then the "smart person being stupid" phrase seems to make no sense.

However, a secondary definition of the word stupid is "tending to make poor decisions or careless mistakes" – a phrase that attenuates the sense of contradiction. A similar thing happens if we analyze the word "dumb" to see if the phrase "smart but acting dumb" makes sense. The primary definition describes "dumb" as the antonym of intelligence, again leading to a contradiction. But, in phrases referring to decisions or actions such as "what a dumb thing to do!," we see a secondary definition like that of stupid: tending to make poor decisions or careless mistakes. These phrases pick out a particular meaning of "stupid" or "dumb" – albeit not the primary one.

It is likewise with the word foolish. A foolish person is a person "lacking good sense or judgment; showing a lack of sense; unwise; without judgment or discretion." This picks out the aspect of "stupid" and "dumb" that we wish to focus on here – the aspect that refers not to intelligence (general mental "brightness") but instead to the tendency to make judicious decisions (or, rather, injudicious ones).

However we phrase it – "smart but acting dumb," "smart but acting foolish," or whatever – we have finally specified the phenomenon: intelligent people taking injudicious actions or holding unjustified beliefs. Folk psychology is picking out two different traits: mental "brightness" (intelligence) and making judicious decisions (*rational* thinking). If we were clear about the fact that the two traits were different, the sense of paradox or surprise at the "smart but acting foolish" phenomenon would vanish. What perpetuates the surprise is that we tend to think of the two traits as one, or at least that they should be strongly associated. The confusion is fostered because psychology has a measurement device (the intelligence test) for the first but not, until recently (see Stanovich, West, & Stanovich, 2016), the second. Psychology has a long and storied history (more than a hundred years old) of measuring the intelligence trait. Although, there has been psychological work on rational thinking, this research started much later (Tversky & Kahneman, 1974) and it was not focused on individual differences.

The 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. Such a student would be right. Many *theoretical* definitions of intelligence incorporate the rationality concept by alluding to judgment and decision-making in the definition. 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 – are assessed on *actual tests* of intelligence.

In short, many treatments of the intelligence concept could be characterized as *permissive* conceptualizations rather than *grounded* conceptualizations. Permissive theories include in their definitions of intelligence aspects of functioning that are captured by the vernacular term "intelligence" (adaptation to the environment, showing wisdom, creativity, etc.) *whether or not* these aspects are actually measured by existing tests of intelligence. Grounded theories, in contrast, confine the concept of intelligence to the set of mental abilities actually tested on IQ tests. Adopting permissive definitions of the concept of intelligence serves to obscure what is absent from extant IQ tests. Instead, in order to highlight the *missing* elements in IQ tests, we adopt a thoroughly grounded notion of the intelligence concept in this chapter – one that anchors the concept in what actual IQ tests measure. Likewise, we ground the concept of rationality in operationalizations from current cognitive science.

A Grounded Theory of Intelligence

The closest thing to a consensus, grounded theory of intelligence in psychology is the Cattell-Horn-Carroll (CHC) theory of intelligence (Carroll, 1993; Cattell, 1963, 1998; Horn & Cattell, 1967). It yields a scientific concept of general intelligence, usually symbolized by *g*, and a small number of broad factors, of which two are dominant. Fluid intelligence (G*f*) reflects reasoning abilities operating across of variety of domains – including novel ones. It is measured by tests of abstract thinking such as figural analogies, Raven's Matrices, and series completion (e.g., what is the next number in the series 1, 4, 5, 8, 9, 12, __). Crystallized intelligence (G*c*) reflects declarative knowledge acquired from acculturated learning experiences. It is measured by vocabulary tasks, verbal comprehension, and general knowledge measures. Although substantially correlated, Gf and Gc reflect a long history of considering two aspects of intelligence: intelligence-as -process and intelligence-as-knowledge (Ackerman, 1996, 2014; Duncan, 2010; Hunt, 2011; Nisbett et al., 2012). In addition to G*f* and G*c*, other broad factors represent things like memory and learning, auditory perception, and processing speed (for a full account, see Carroll, 1993).

There is a large literature on the CHC theory and on the processing correlates of Gf and Gc (see Duncan, 2010; Duncan et al., 2008; Engle, 2018; Geary, 2005; Gignac, 2005; Hunt, 2011; Mackintosh & Bennett, 2003; McGrew, 2009; Nisbett et al., 2012). The constructs in the theory have been validated in studies of brain injury, educational attainment, cognitive neuroscience, developmental trends, and information processing. There are, of course, alternative models to the CHC conception (Deary, 2013; Hunt, 2011). For example, Hunt (2011) discusses Johnson and Bouchard's (2005) g-VPR model as an alternative model that is empirically differentiable from the CHC theory. However, for the purposes of the theoretical contrast with rationality, it makes no difference which of the currently viable grounded theories of intelligence we choose. All of them ignore a critical level of cognitive analysis that is important for rationality.

Rationality in Cognitive Science

Rationality is a torturous and tortured term in intellectual discourse. It is contentious and has a multitude of definitions. The term is claimed by many disciplines and parsed slightly differently by each discipline. Philosophy, economics, decision theory, psychology – all claim the term and have their own definitions. For example, animal behaviorists claim to measure degrees of rationality in animals (Kacelnik, 2006); yet, by some of the definitions used in other disciplines, animals couldn't have rationality at all!

Many philosophical notions of rationality are crafted so as to equate all humans – thus, by fiat, defining away the very individual differences that a psychologist wishes to study. For example, some definitions of rationality derive from a categorical notion of rationality tracing to Aristotle that posits humans as the only animals who base actions on reason. As de Sousa (2007) has pointed out, such a notion of rationality as "based on reason" has as its opposite not irrationality but *arationality.* Aristotle's characterization is categorical – the behavior of entities is either based on thought or not rational. In this conception, humans are rational; other animals are not. There is no room for individual differences in rational thinking *among* humans in this view.

In contrast, rationality – in the sense employed in cognitive science and in this chapter – is a normative notion. Normative models of optimal judgment and decision-making define rationality in the noncategorical manner employed in cognitive science. Rationality thus comes in degrees defined by the distance of the thought or behavior from the optimum defined by a normative model (Etzioni, 2014). Thus, when cognitive scientists term a behavior less than rational, they mean that the behavior departs from the optimum prescribed by a particular normative model. The scientist is not implying that no thought or reasoning was behind the behavior, as in the categorical sense.

One reason why psychologists do not adopt categorical definitions of rationality is that, under such definitions, there is no motivation for cognitive reform or cognitive change. Continuous definitions of rationality motivate cognitive reform, because most people are less than optimally rational, and thus most people can improve their rational thinking tendencies.

Rationality: Instrumental and Epistemic

We follow many cognitive science theorists in recognizing two types of rationality, instrumental and epistemic (Manktelow, 2004; Over, 2004) – roughly mapping into the terms practical and theoretical that philosophers prefer. The simplest definition of instrumental rationality is: behaving in the world so that you get exactly what you most want, given the resources (physical and mental) available to you. Epistemic rationality concerns how well beliefs map onto the actual structure of 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. For our beliefs to be rational they must correspond to the way the world is – they must be true (epistemic rationality). For our actions to be rational, they must be the best means toward our goals – they must be the best things to do (instrumental rationality).

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; and (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 occurring and then summing those products over all of the possible outcomes.

In practice, assessing rationality in this computational 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), then the people are behaving as if they are maximizing utility (Dawes, 1998; Edwards, 1954; Jeffrey, 1983; Luce & Raiffa, 1957; Savage, 1954; von Neumann & Morgenstern, 1944). These analyses have led to what has been termed the 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.

The axiomatic approach to choice defines instrumental rationality as adherence to certain types of consistency and coherence relationships. For example, one such axiom is that of *transitivity*: If you prefer A to B and B to C, then you should prefer A to C. All of the axioms of choice (independence of irrelevant alternatives, transitivity, independence, and reduction of compound lotteries, etc.), in one way or another, ensure that decisions are not influenced by irrelevant context (Stanovich, 2013). There is considerable empirical evidence in cognitive science indicating that people sometimes violate the axioms of utility theory (Kahneman & Tversky, 2000; Thaler, 2015). It is also known that there is considerable variability in the tendency to adhere to the basic axioms of choice that define instrumental 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. 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. That is, their estimates must follow the so-called probability calculus.

A substantial research literature – one comprising literally hundreds of empirical studies conducted over several decades – has firmly established that people's responses sometimes deviate from the performance considered normative on many reasoning tasks. For example, people assess probabilities incorrectly, they test hypotheses inefficiently, they violate the axioms of utility theory, they do not properly calibrate degrees of belief, their choices are affected by irrelevant context, they ignore the alternative hypothesis when evaluating data, and they display numerous other information-processing biases (Baron, 2008, 2014; Evans, 2014; Kahneman, 2011; Koehler & Harvey, 2004; Stanovich, 1999, 2011; Stanovich, West, & Toplak, 2016; Thaler, 2015). Much of the operationalization of rational thinking in cognitive science comes from the heuristics and biases tradition where these thinking errors were first discovered in the 1970s (Kahneman & Tversky, 1972, 1973; Tversky & Kahneman, 1974). The term biases refers to the systematic errors that people make in choosing actions and in estimating probabilities and the term heuristic refers to *why* people often make these errors – because they use mental shortcuts (heuristics) to solve many problems.

To this point, using grounded theories of intelligence and rationality, we have established that there are individual differences in performance in both of these domains. In the next sections, we will outline the functional cognitive theory that will situate both concepts. Even more specifically, we will show that rationality is actually a more encompassing mental construct than is intelligence. Thus, as measures of rationality, the tasks in the heuristics and biases literature, while tapping intelligence in part, actually encompass more cognitive processes and knowledge than are assessed by IQ tests.

A Dual-Process Cognitive Architecture

There is a wide variety of evidence that has converged on the conclusion that some type of dual-process model of the mind is needed in a diverse set of specialty areas not limited to cognitive psychology, economics, social psychology, naturalistic philosophy, and decision theory (Alós-Ferrer & Strack, 2014; Chein & Schneider, 2012; De Neys, 2018; Evans, 2008, 2010, 2014; Evans & Frankish, 2009; Evans & Stanovich, 2013; Lieberman, 2009; McLaren et al., 2014; Sherman, Gawronski, & Trope, 2014; Stanovich, 1999, 2004). Evolutionary theorizing and neurophysiological work also have supported a dual-process conception (Corser & Jasper, 2014; Frank, Cohen, & Sanfey, 2009; Lieberman, 2009; McClure & Bickel, 2014; McClure et al., 2004; Prado & Noveck, 2007; Rand et al., 2017; Toates, 2005, 2006).

Because there is now a plethora of dual-process theories (for a list of the numerous versions of such theories, see Stanovich, 2011, 2012), there is currently much variation in the terms for the two processes. For the purposes of this chapter, we will most often adopt the Type 1/Type 2 terminology discussed by Evans and Stanovich (2013) and occasionally use the similar System 1/System 2 terminology of Stanovich (1999) and Kahneman (2011). 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 seventy-seven 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 have been posited by evolutionary psychologists; processes of implicit learning; and the automatic firing of overlearned associations (see Barrett & Kurzban, 2006; Carruthers, 2006; Evans, 2008, 2009; Moors & De Houwer, 2006; Samuels, 2005, 2009; Shiffrin & Schneider, 1977).

Type 1 processing encompasses many rules, stimulus discriminations, and decision-making principles that have been practiced to automaticity (e.g., Kahneman & Klein, 2009; Shiffrin & Schneider, 1977). These processes can lead to correct or incorrect responding on rational thinking tasks (Evans & Stanovich, 2013). Some participants provide correct immediate responses with high confidence (Bago & De Neys, 2017), which is not surprising if these participants have practiced and consolidated skills in this particular domain. Alternatively, this learned information can sometimes be just as much a threat to rational behavior as are evolutionary modules that fire inappropriately in a modern environment. Rules learned to automaticity can be overgeneralized – they can autonomously trigger behavior when the situation is an exception to the class of events they are meant to cover (Arkes & Ayton, 1999; Hsee & Hastie, 2006).

In contrast with Type 1 processing, Type 2 processing is nonautonomous. It is relatively slow and computationally expensive. Many Type 1 processes can operate at once 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 because Type 1 processing heuristics depend on benign environments providing obvious cues that elicit adaptive behaviors. In hostile environments, reliance on heuristics can be costly (see Hilton, 2003; Over, 2000; Stanovich, 2004). A benign environment means one that contains useful (that is, diagnostic) cues that can be exploited by various heuristics (for example, affect-triggering cues, vivid and salient stimulus components, convenient and accurate anchors). Additionally, for an environment to be classified as benign, it must also contain no other individuals who will adjust their behavior to exploit those relying only on Type 1 processing. In contrast, a hostile environment for heuristics is one in which there are few cues that are usable by autonomous processes or there are misleading cues (Kahneman & Klein, 2009). Another way that an environment can turn hostile for a user of Type 1 processing occurs when other agents discern the simple cues that are being used and arrange them for their own advantage (for example, advertisements, or the strategic design of supermarket floor space in order to maximize revenue).

All of the different kinds of Type 1 processing (processes of emotional regulation, Darwinian modules, associative and implicit learning processes) can produce responses that are suboptimal in a particular context if not overridden. For example, humans often act as cognitive misers by engaging in attribute substitution (Kahneman & Frederick, 2002) – the substitution of an easy-to-evaluate characteristic in place of a harder one, even if the easier one is less accurate. For example, the cognitive miser will substitute the less effortful attributes of vividness or affect as a replacement for the more effortful retrieval of relevant facts (Slovic & Peters, 2006; Slovic & Slovic, 2015). But, when we are evaluating important risks – such as the risk of certain activities and environments – we do not want to substitute vividness for careful thought about the situation. In such situations, we want to employ Type 2 override processing to block the attribute substitution of the cognitive miser.

Once detection of the conflict between the normative response and the response triggered by System 1 has taken place (on detection, see Bago & De Neys, 2017; Pennycook et al., 2015; Stanovich, 2018; Stanovich et al., 2016; Thompson et al., 2011), Type 2 processing must display at least two related capabilities in order to override Type 1 processing. One is the capability of interrupting Type 1 processing. Type 2 processing thus involves inhibitory mechanisms of the type that have been the focus of work on executive functioning (Kovacs & Conway, 2016; Miyake & Friedman, 2012; Nigg, 2017). But the ability to suppress Type 1 processing gets the job only half done. Suppressing one response is not helpful unless there is a better response available to substitute for it. Where do these better responses come from? One answer is that they can come from processes of hypothetical reasoning and cognitive simulation that are a unique aspect of Type 2 processing (Evans, 2007, 2010; Evans & Stanovich, 2013).

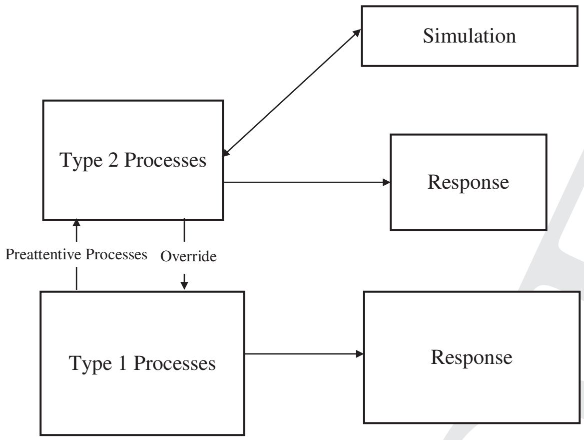

Figure 46.1 *A preliminary dual-process model.*
Reprinted from *What Intelligence Tests Miss: The Psychology of Rational Thought* by Keith E. Stanovich, courtesy of Yale University Press.

When we reason hypothetically, we create temporary models of the world and test out actions (or alternative causes) in that simulated world. In order to reason hypothetically we must, however, have one critical cognitive capability – we must be able to prevent our representations of the real world from becoming confused with representations of imaginary situations. The so-called cognitive decoupling operations (Stanovich, 2011; Stanovich & Toplak, 2012) are the central feature of Type 2 processing that make this possible and they have implications for how we conceptualize both intelligence and rationality, as we shall see. The important issue for our purposes is that decoupling secondary representations from the world and then maintaining the decoupling while simulation is carried out is a Type 2 processing operation. It is computationally taxing and greatly restricts the ability to conduct any other Type 2 operation simultaneously.

A preliminary dual-process model of mind, based on what we have outlined thus far, is presented in Figure 46.1. The figure shows the Type 2 override function we have been discussing, as well as the Type 2 process of simulation. Also rendered in the figure is an arrow indicating that Type 2 processes receive inputs from Type 1 computations. These so-called preattentive processes (Evans, 2008) establish the content of most Type 2 processing.

Three Kinds of Minds and Two Kinds of Individual Differences

In this section, we will explain why rational thinking stresses a level in the hierarchical control system of the brain that is only partly tapped by IQ tests. This is because the override mechanism depicted in Figure 46.1 needs to be conceptualized in terms of two levels of processing. To understand the two levels in a vernacular way, consider two imaginary stories.

Both stories involve a lady walking on a cliff. The stories are both sad – the lady dies in each. The purpose of this exercise is to get us to think about how we explain the death in each story. In incident A, a woman is walking on a cliffside by the ocean and goes to step on a large rock but what appears to be a rock is not a rock at all. Instead, it is actually the side of a crevice and she falls down the crevice and dies. In incident B, a woman attempts suicide by jumping off an ocean cliff and dies when she is crushed on the rocks below.

In both cases, at the most basic level, when we ask ourselves for an explanation of why the woman died, we might say that the answer is the same. The same laws of physics operating in incident A (the gravitational laws that describe why the woman will be crushed on impact) are also operating in incident B. However, we feel that the laws of gravity and force somehow do not provide a complete explanation of what has happened in either incident. When we attempt a more fine-grained explanation, incidents A and B seem to call for a different level of explanation if we wish to zero in on the *essential* cause of death.

In analyzing incident A, a psychologist would be prone to say that when processing a stimulus (the crevice that looked somewhat like a rock), the woman's information-processing system malfunctioned – sending the wrong information to response decision mechanisms, which then resulted in a disastrous motor response. We will refer to this level of analysis as the algorithmic level (on terminology, see Stanovich, 1999). The cognitive psychologist works largely at this level by showing that human performance can be explained by positing certain information-processing mechanisms in the brain (input coding mechanisms, perceptual registration mechanisms, short- and long-term memory storage systems, etc.). In the case of the woman in incident A, the algorithmic level is the right level to explain her unfortunate demise. Her perceptual registration and classification mechanisms malfunctioned by providing incorrect information to response decision mechanisms, causing her to step into the crevice.

Incident B, on the other hand, does not involve such an algorithmic-level information-processing error. The woman's perceptual apparatus accurately recognized the edge of the cliff and her motor command centers quite accurately programmed her body to jump off the cliff. The computational processes posited at the algorithmic level of analysis executed quite perfectly. No error at this level of analysis explains why the woman is dead in incident B. Instead, this woman died because of her overall goals and how these goals interacted with her beliefs about the world in which she lived.

We will present our model of cognitive architecture (building on Stanovich, 2011) in the spirit of Dan Dennett's (1996) book *Kinds of Minds*, where he used that title to suggest that within the brain of humans are control systems of very different types – different kinds of minds. In our terms, the woman in incident A had a problem with the algorithmic mind and the woman in incident B had a problem with the reflective mind. In short, the reflective mind is concerned with the goals of the system, beliefs relevant to those goals, and the choice of action that is optimal given the system's goals and beliefs. All of these characteristics implicate the reflective mind in many issues of rationality. High computational efficiency in the algorithmic mind is not a sufficient condition for rationality.

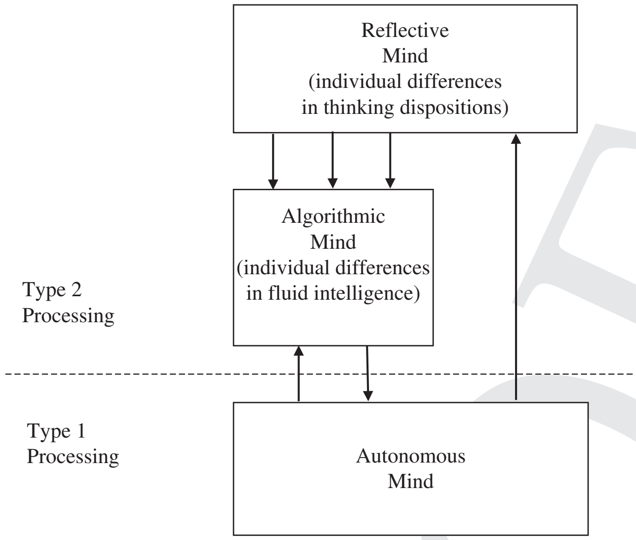

Figure 46.2 *The tripartite structure and the locus of individual differences.* Reprinted from *What Intelligence Tests Miss: The Psychology of Rational Thought* by Keith E. Stanovich, courtesy of Yale University Press.

Our attempt to differentiate the two levels of control involved in Type 2 processing is displayed in Figure 46.2. The psychological literature provides much converging evidence and theory to support such a structure. First, psychometricians have long distinguished typical performance situations from optimal (sometimes termed maximal) performance situations (Ackerman & Kanfer, 2004; Cronbach, 1949; Sternberg, Grigorenko, & Zhang, 2008). Typical performance measures implicate, at least in part, the reflective mind – they assess goal prioritization and epistemic regulation. In contrast, optimal performance situations are those where the task interpretation is determined externally. The person performing the task is told the rules that maximize performance. Thus, optimal performance tasks assess questions of the *efficiency* of goal pursuit – they capture the processing efficiency of the algorithmic mind. All tests of intelligence or cognitive aptitude are optimal performance assessments, whereas measures of critical or rational thinking are often assessed under typical performance conditions.

The difference between the algorithmic mind and the reflective mind is captured in another well-established distinction in the measurement of individual differences – the distinction between cognitive ability and thinking dispositions. The former are, as just mentioned, measures of the efficiency of the algorithmic mind. The latter travel under a variety of names in psychology – thinking dispositions or cognitive styles being the two most popular. Many thinking dispositions concern beliefs, belief structure, and, importantly, attitudes toward forming and changing beliefs. Other thinking dispositions that have been identified concern a person's goals and goal hierarchy. Examples of some thinking dispositions that have been investigated by psychologists are actively open-minded thinking, need for cognition, consideration of future consequences, reflection/intuition, and dogmatism (Baron et al., 2015; Cacioppo et al., 1996; Phillips et al., 2016; Stanovich, 1999, 2011; Sternberg, 2003; Strathman et al., 1994).

In short, measures of individual differences in thinking dispositions are assessing variation in people's goal management, epistemic values, and epistemic self-regulation – differences in the operation of reflective mind. People have indeed come up with *definitions* of intelligence that encompass the reflective level of processing but, nevertheless, *the actual measures of intelligence in use assess only algorithmic-level cognitive capacity.*

Figure 46.2 represents the classification of individual differences in the tripartite view. The broken horizontal line represents the location of the key distinction in older, dual-process views. The figure identifies variation in fluid intelligence (Gf) with individual differences in the efficiency of processing of the algorithmic mind. To a substantial extent Gf measures the ability to cognitively decouple – to suppress Type 1 activity and to enable hypothetical thinking. The raw ability to sustain such simulations while keeping the relevant representations decoupled is one key aspect of the brain's computational power that is being assessed by measures of fluid intelligence. This is becoming clear from converging work on executive function and working memory, which both display correlations with fluid intelligence that are quite high (Chuderski, 2015; Duncan, et al., 2008; Hicks, Harrison, & Engle, 2015; Jastrzębskia, et al., 2018; Kane, Hambrick, & Conway, 2005). This is because most measures of executive function, such as working memory, are direct or indirect indicators of a person's ability to sustain decoupling operations (Feldman Barrett, Tugade, & Engle, 2004). Thus, Type 2 processes are strongly associated with Gf (Burgess et al., 2011; Chuderski, 2014; Engel de Abreu, Conway, & Gathercole, 2010; Kovacs & Conway, 2016; McVay & Kane, 2012; Mrazek et al., 2012; Salthouse et al., 2003). Finally, the reflective mind is identified with individual differences in thinking dispositions related to beliefs and goals.

Why Rationality Is a More Encompassing Construct Than Intelligence

Figure 46.2 highlights an important sense in which rationality is a more encompassing construct than intelligence. As previously discussed, to be rational, a person must have well-calibrated beliefs and must act appropriately on those beliefs to achieve goals – both of these depend on the thinking dispositions of the reflective mind. The types of cognitive propensities that these thinking disposition measures reflect are the tendency to collect information before making up one's mind, the tendency to seek various points of view before coming to a conclusion, the disposition to think extensively about a problem before responding, the tendency to calibrate the degree of strength of one's opinion to the degree of evidence available, the tendency to think about future consequences before taking action, the tendency to explicitly weigh pluses and minuses of situations before making a decision, and the tendency to seek nuance and avoid absolutism.

In order to achieve both epistemic and instrumental rationality, individuals must also, of course, have the algorithmic-level machinery that enables them to carry out the actions and to process the environment in a way that enables the correct beliefs to be fixed and the correct actions to be taken. Thus, individual differences in rational thought and action can arise because of individual differences in fluid intelligence (the algorithmic mind) or because of individual differences in thinking dispositions (the reflective mind) or from a combination of both.

To put it simply, the concept of rationality encompasses thinking dispositions and algorithmic-level capacity, whereas the concept of intelligence (at least as it is commonly operationalized) is largely confined to algorithmic-level capacity. Intelligence tests do not attempt to measure aspects of epistemic or instrumental rationality, nor do they examine any thinking dispositions that relate to rationality. It is clear from Figure 46.2 why rationality and intelligence are separable. Rational thinking depends on thinking dispositions as well as algorithmic efficiency. Thus, as long as variation in thinking dispositions is not perfectly correlated with fluid intelligence, there is the statistical possibility of rationality and intelligence explaining at least partially separable variance.

In fact, substantial empirical evidence indicates that individual differences in thinking dispositions and intelligence are far from perfectly correlated. Studies (e.g., Ackerman & Heggestad, 1997; Cacioppo et al., 1996; Kanazawa, 2004; Zeidner & Matthews, 2000) have indicated that measures of intelligence display only moderate to weak correlations with some thinking dispositions (e.g., actively open-minded thinking, need for cognition) and near zero correlations with others (e.g., conscientiousness, curiosity, diligence). Other important evidence supports the conceptual distinction made here between algorithmic cognitive capacity and thinking dispositions. For example, across a variety of tasks from the heuristics and biases literature, it has consistently been found that rational thinking dispositions will predict variance after the effects of general intelligence have been controlled (Bruine de Bruin, Parker, & Fischhoff, 2007; Finucane & Gullion, 2010; Klaczynski & Lavallee, 2005; Kokis et al., 2002; Macpherson & Stanovich, 2007; Parker & Fischhoff, 2005; Stanovich & West, 1997, 1998; Toplak et al., 2007; Toplak & Stanovich, 2002; Toplak, West, & Stanovich, 2011, 2014a, 2014b).

Rationality and Intelligence in a Fleshed-Out Tripartite Cognitive Architecture

The functions of the different levels of control are illustrated more completely in Figure 46.3. There, it is clear that the override capacity itself is a property of the algorithmic mind and it is indicated by the arrow labeled A. However, previous dual-process theories have tended to ignore the higher-level cognitive operation that initiates the override function in the first place. This is a dispositional property of the reflective mind that is related to rationality. In the model in Figure 46.3, it corresponds to arrow B, which represents the instruction to the algorithmic mind to override the Type 1 response by taking it offline. This is a different mental function

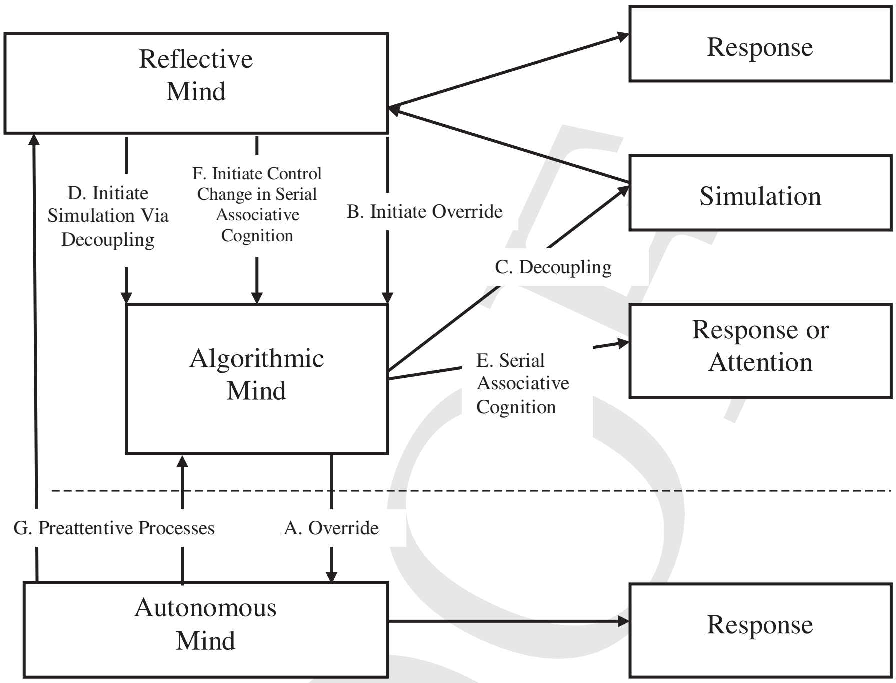

Figure 46.3 *A more complete model of the tripartite structure.* Reprinted from *What Intelligence Tests Miss: The Psychology of Rational Thought* by Keith E. Stanovich, courtesy of Yale University Press.

than the override function itself (arrow A) and the evidence cited above indicates that the two functions are indexed by different types of individual differences.

The override function has loomed so large in dual-process theory that it has somewhat overshadowed the simulation process that computes the alternative response that makes the override worthwhile. Thus, Figure 46.3 explicitly represents the simulation function as well as the fact that the instruction to initiate simulation originates in the reflective mind. The decoupling operation (indicated by arrow C) itself is carried out by the algorithmic mind. The instruction to initiate simulation (indicated by arrow D) is carried out by the reflective mind. Again, two different types of individual differences are associated with the initiation call and the decoupling operator – specifically, thinking dispositions with the former and fluid intelligence with the latter. Also represented is the fact that the higher levels of control receive inputs from the autonomous mind (arrow G) via so-called preattentive processes (Evans, 2006, 2009).

The arrows labeled E and F reflect the decoupling and higher-level control of a kind of Type 2 processing (serial associative cognition) that does not involve fully explicit cognitive simulation (see Stanovich, 2011). There are types of slow, serial cognition that do not involve simulating alternative worlds and exploring them exhaustively. Their existence points to an important fact: All hypothetical thinking involves Type 2 processing (Evans & Over, 2004) but not all Type 2 processing involves hypothetical thinking. Serial associative cognition represents this latter category. This kind of Type 2 processing is not a full-blown cognitive simulation of alternative world models. It is thinking of a shallower type – cognition that is inflexibly locked into an associative mode that takes as its starting point a model of the world that is given to the subject.

Thus, serial associative cognition is defined by its reliance on a single focal model that triggers all subsequent thought. Framing effects, for instance, are clear examples of serial associative cognition with a focal bias. As Kahneman (2003) notes, "the basic principle of framing is the passive acceptance of the formulation given" (p. 703). The frame presented to the subject is taken as focal and all subsequent thought derives from it rather than from alternative framings because the latter would necessitate more computationally expensive simulation operations. In short, serial associative cognition is sequential and analytic (as opposed to holistic) in style but it relies on a single focal model that triggers all subsequent thought.

Returning to Figure 46.3, we can now identify a third function of the reflective mind – initiating an interrupt of serial associative cognition (arrow F). This interrupt signal alters the next step in a serial associative sequence that would otherwise direct thought. This interrupt signal might stop serial associative cognition altogether in order to initiate a comprehensive simulation (arrow C). Alternatively, it might start a new serial associative chain (arrow E) from a different starting point by altering the temporary focal model that is the source of a current associative chain.

Although taking the Type 1 response priming offline might itself be procedural, the process of synthesizing an alternative response often utilizes stored knowledge of various types. During the simulation process, declarative knowledge and strategic rules (linguistically-coded strategies) are used to transform a decoupled representation. The knowledge, rules, procedures, and strategies that can be retrieved and used to transform decoupled representations have been referred to as mindware, a term coined by Perkins (1995; 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 there will be individual differences in the ability to simulate better alternatives to a Type 1 response based on variation in the mindware available (Frey, Johnson, & De Neys, 2018; Stanovich, 2018).

Because the CHC theory of intelligence is one of the most comprehensively validated theories of intelligence available, it is important to see how two of its major components miss critical aspects of rational thought. Fluid intelligence will, of course, have some relation to rationality because it indexes the computational power of the algorithmic mind to sustain decoupling. Because override and simulation are important operations for rational thought, Gf will definitely facilitate rational action in some situations. Nevertheless, the tendency to initiate override (arrow B in Figure 46.3) and to initiate simulation activities (arrow D in Figure 46.3) are both aspects of the reflective mind not assessed by intelligence tests, so the tests will miss these components of rationality. Such propensities are instead indexed by measures of typical performance (cognitive styles and thinking dispositions) as opposed to measures of maximal performance such as IQ tests. Measures of wisdom likewise try to tap typical performance (Grossmann, 2017; Sternberg, 2003).

The situation with respect to crystallized intelligence is a little different. Rational thought depends critically on the acquisition of certain types of knowledge (Stanovich, 2018). That knowledge would, in the abstract, be classified as crystallized intelligence. But is it the kind of crystallized knowledge that is assessed on actual tests of intelligence? The answer is "no." The knowledge structures that support rational thought are specialized. They cluster in the domains of probabilistic reasoning, causal reasoning, and scientific reasoning (Stanovich et al., 2016). In contrast, the crystallized knowledge assessed on IQ tests is deliberately designed to be nonspecialized. The designers of the tests, in order to make sure the sampling of vocabulary and knowledge is fair and unbiased, explicitly attempt to *broadly* sample vocabulary, verbal comprehension domains, and general knowledge. In short, crystallized intelligence, as traditionally measured, does not assess individual differences in rationality.

Finally, it may have seemed from our discussion so far that only the algorithmic and reflective minds are implicated in rational thought. Such an interpretation would represent a mistaken implication. In fact, the autonomous mind, as well as the algorithmic and reflective minds, often operates to support rational thought. There is one particular way that the autonomous mind supports rationality that we would like to emphasize. It is the point mentioned previously, that the autonomous mind contains rational rules and normative strategies that have been tightly compiled and that are automatically activated due to overlearning and practice. This means that, for some people, in some instances, the normative response emanates directly from the autonomous mind rather than from the more costly Type 2 process of simulation (see Bago & De Neys, 2017).

Figure 46.4 illustrates more clearly the point we wish to make here. This figure has been simplified by the removal of all the arrow labels and the removal of the boxes representing serial associative cognition, as well as the response boxes. In the upper right is represented the accessing of mindware that is most discussed in the literature. In the case represented there, a nonnormative response from the autonomous mind has been interrupted and the computationally taxing process of simulating an alternative response is underway. That simulation involves the computationally expensive process of accessing mindware for the simulation.

In contrast to this type of normative mindware access, indicated in the lower left of the figure is a qualitatively different way that mindware can determine the normative response. The figure indicates the point we have stressed earlier, that within the autonomous mind can reside normative rules and rational strategies that have been practiced to automaticity and that can *automatically* compete with (and often immediately defeat) any alternative nonnormative response that is also stored in the autonomous mind (Bago & De Neys, 2017; Pennycook et al., 2015).

So it should be clear from Figure 46.4, that it does not follow from the output of a normative response that System 2 was necessarily the genesis of the rational responding. Neither does it necessarily follow (as has been wrongly inferred in some recent research on dual-process theory) that a rapid response should necessarily

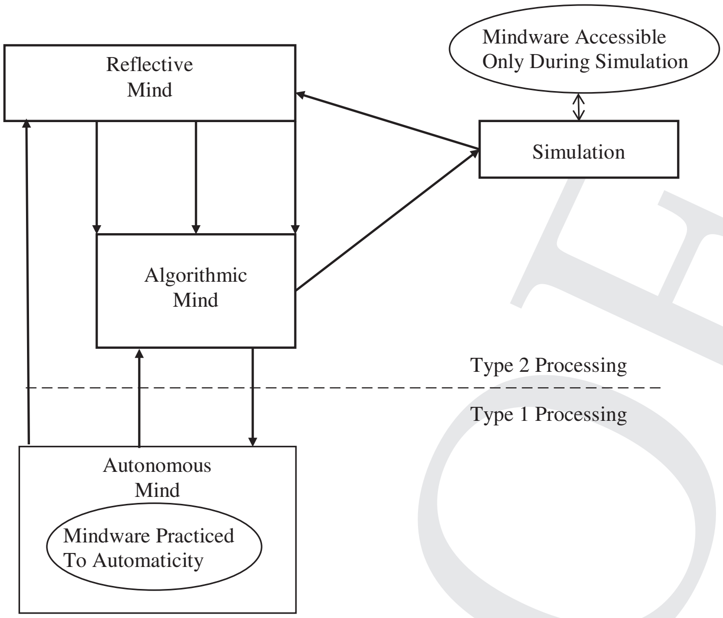

Figure 46.4 *A simplified model showing both automatized mindware and mindware accessible during simulation.*

be an incorrect one (Stanovich, 2018). The main purpose of Figure 46.4 is to concretize the idea that the normative mindware of rational responding is not exclusively retrieved during simulation activities, but can become implicated in performance directly and automatically from the autonomous mind if it has been practiced enough.

According to the model just presented, rationality requires three different classes of mental characteristics. First, algorithmic-level cognitive capacity (Gf) is needed for override and sustained simulation activities. Second, the reflective mind must be characterized by the tendency to initiate the override of suboptimal responses generated by the autonomous mind and to initiate simulation activities that will result in a better response. Finally, the mindware that allows the computation of rational responses needs to be available and accessible during simulation activities or be accessible from the autonomous mind (see Figure 46.4) because it has been highly practiced. Intelligence tests primarily assess only the first of these three characteristics that determine rational thought and action. This is why rationality requires more than just intelligence.

Rationality and the Heuristics and Biases Literature

There exists a nascent literature on the assessment of rational thinking (Bruine de Bruin et al., 2007; Halpern, 2008, 2010; Stanovich, 2009, 2011, 2016; Stanovich & West, 1998, 2008; Stanovich et al., 2016). All of these efforts have drawn on the vast literature in cognitive psychology that has demonstrated violations of the normative models of instrumental and epistemic rationality, especially the heuristics and biases literature (Baron, 2008, 2014; Kahneman, 2011; Kahneman & Tversky, 2000). This is certainly true of our own rational thinking assessment instrument, the Comprehensive Assessment of Rational Thinking (CART; Stanovich et al., 2016).

As measures of rationality, the tasks in the heuristics and biases literature, while tapping intelligence in part, actually encompass more cognitive processes and knowledge than are assessed by IQ tests. Heuristics and biases tasks are often conceptualized within dual-process architectures 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; Kelman, 2011). These tasks, interpreted within a dual-process framework, end up being diagnostic of the dominance of Type 1 versus Type 2 processing in determining the final response. As mentioned previously, for a person who defaults often to Type 1 processing, environments can be either benign or hostile. We have argued (Stanovich, 2004; Stanovich & West, 2000) that the modern world is becoming increasingly hostile to responses derived from Type 1 processing, 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. 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.

Most of the tasks in the heuristics and biases literature have both processing and knowledge requirements. From a processing standpoint, the necessity of overriding Type 1 processing must be detected (unless the relevant normative response is highly automated). 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 mindware discussed previously. The mindware available for use during cognitive simulation is in part the product of past learning experiences. This means that there will be individual differences in the ability to simulate better alternatives to a Type 1 response based on variation in the mindware available.

The fact that many items on the CART tap process as well as knowledge is specifically intended (as it was in the original heuristics and biases literature) and is not a flaw. It is a designed feature, not a drawback. In the domain of rational thinking, we are interested in individual differences in the *sensitivity* to probabilistic reasoning principles, for example. People can have knowledge of these principles without the propensity to use them. They can have the knowledge but not the propensity to see situations in terms of probabilities. A typical item on the CART will pit a statistical way of viewing a problem against a nonstatistical way of viewing a problem in order to see which kind of thinking dominates in the situation. So, for example, we would not design an item where the subject chooses between a nine out of ten chance of winning versus a three out of ten chance of winning, with no other context provided. Instead, on most of the Probabilistic Reasoning subtest items on the CART, statistical information is presented but also a *nonstatistical* way of thinking about the problem. People who may get the pure mathematics of statistical reasoning correct might well not see certain problems themselves as probabilistic. Rational thinking assessment taps variance in sensitivity to *seeing* a problem as probabilistic.

The CART Tasks and Framework

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 knowledge and process both quite strongly.

Table 46.1 presents the overall framework for the CART, as well as some indication of the tasks used for assessment. The left column of Table 46.1 serves to represent tasks saturated with processing requirements. The second column from the left represents tasks that are 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 46.1 to emphasize this point.

Working down the left column, Table 46.1 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 forty years of research in psychology and cognitive science (see Dawes, 1976; Kahneman, 2011; Simon, 1955, 1956; Taylor, 1981; Tversky & Kahneman, 1974; for the evolutionary reasons why, 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 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 (Type 2 processing) take up a great deal of attention, tend to be slow, tend to interfere with other thoughts and actions we are carrying out, and they require great concentration that is often experienced as aversive. Humans are cognitive

Table 46.1 *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		Superstitious Thinking Subtest	Actively Open-Minded Thinking Scale
Scientific Reasoning Subtest		Anti-Science Attitudes Subtest	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			

misers because their basic tendency is to default to other less-accurate processing mechanisms of low computational expense (the Type 1 processes).

The CART contains several subtests that assess a person's ability to avoid miserly information processing. One, the Reflection Versus Intuition subtest, was inspired by a famous problem introduced into the literature by Kahneman and Frederick (2002): A bat and a ball cost \$1.10 in total. The bat costs \$1 more than the ball. How much does the ball cost?

When they answer this problem, many people give the first response that comes to mind – 10 cents – without thinking further and realizing that this cannot be correct. The bat would then have to cost \$1.10 and the total cost would be \$1.20 rather than the required $1.10. People often do not think deeply enough to realize their error and cognitive ability is no guarantee against making the error. Frederick (2005) found that large numbers of highly select university students at MIT, Princeton, and Harvard were cognitive misers – they responded that the cost was 10 cents rather than the correct answer: 5 cents. The other direct measures of miserly processing are overcoming belief bias in a syllogistic reasoning task, the ability to overcome ratio bias, and the ability to engage in fully disjunctive reasoning.

Continuing down the left column of Table 46.1 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. In any case, they are all are important measures of rational thinking in their own right whether or not they are due to miserly information processing. The left-hand column of Table 46.1 shows several of these important 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 46.1 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 46.1 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, not all mindware is helpful or useful in fostering rationality (Stanovich, 2004, 2009, 2011). Indeed, the presence of certain kinds of mindware is often precisely the problem. We use the category label *contaminated mindware* for the presence of declarative knowledge bases that foster irrational rather than rational thinking.

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 46.1 lists the four categories of contaminated mindware that are assessed on the CART: superstitious thinking; anti-scientific attitudes; conspiracy beliefs; and dysfunctional personal beliefs.

Superstitious thinking is measured with twelve items such as "a person's thoughts can influence the movement of a physical object" and "astrology can be useful in making personality judgments". Anti-scientific attitudes are measured with thirteen items such as "I don't place great value on scientific facts, because scientific facts can be used to prove almost anything". Dysfunctional personal beliefs are measured with nine items such as "I worry a lot that I am unlikable". Finally, there are twenty-four items on the Conspiracy Beliefs subtest of the CART. We drew on a large number of conspiracies that have been studied in the literature and added a few new ones of our own. Our subtest covered a wide range of conspiratorial beliefs. Most importantly, it contained conspiracies of both the political left and the political right. Unlike some previous measures, it was not just a proxy for political attitudes. Some of the commonly studied conspiracies that we assessed were the assassination of President John F. Kennedy, the 9/11 attacks, fluoridation, the moon landing, pharmaceutical industry plots, the spread of AIDS, oil industry plots, and Federal Reserve conspiracies.

Finally, the far right column of Table 46.1 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. There are many different thinking dispositions studied in psychology. However, we have chosen those specifically relevant to rational thinking. 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 is not to be equated with the 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, thinking dispositions subscales are segregated in the CART and not treated as direct measures of rational thinking themselves.

The Unique Features of Rationality Assessment:CART Subtests ≠ IQ Test Components

With the construction of the CART, we now have an instrument designed to assess the types of cognitive skills that have been studied for forty years in the heuristics and biases literature. It is amazing that until now we have not had a battery that comprehensively assesses these cognitive skills, given their epic influence on cognitive science. The 1974 *Science* paper by Tversky and Kahneman had, by the year 2018, received more than 46,000 citations according to Google Scholar. Kahneman's recent (2011) book had received more than 18,000 citations by the same time. These numbers, along with the 2002 Nobel Prize to Kahneman, represent an unprecedented scientific influence. Yet, until the CART and the work that preceded it (Bruine de Bruin et al., 2007; Stanovich & West, 1998), psychologists had completely neglected to develop assessment devices for these unique cognitive skills.

Of course, small sets of heuristics and biases tasks have been examined together before (Cokely & Kelley, 2009; Liberali et al., 2012; Stanovich & West, 1998). Nevertheless, our collection is unique in its comprehensiveness. However, it is important to stress that the issue of measuring rationality goes far beyond the comprehensiveness of the heuristics and biases battery that is involved. Instrumental and epistemic rationality, as defined in this chapter, both implicate important knowledge bases when their definitions are operationalized. The CART is unique in this particular respect, that is, in explicitly encompassing important declarative knowledge bases in its assessment model. Beyond the measurement of the important probabilistic reasoning tendencies and reflective reasoning tendencies that are well captured by the heuristics and biases tasks, the CART taps knowledge bases that importantly facilitate rational thought and behavior as well as knowledge bases that importantly impede normative responding.

The emphasis on heuristics and biases tasks (e.g., Probabilistic and Statistical Reasoning subtest) and subtests composed more purely of knowledge assessment (e.g., Financial Literacy subtest) in the CART highlights the two most important ways in which the CART is different from IQ tests. Regarding knowledge, the important point to note is that the knowledge bases assessed on the CART are domain-specific (financial literacy; avoidance of conspiracy beliefs) and not like the broad-based vocabulary assessments of IQ tests.

Regarding the parts of the CART that are composed of heuristics and biases tasks, the logic of these tasks makes it possible for the CART to measure the *propensity* to use a cognitive skill in a way that IQ tests do not. In the domain of rational thinking, we are interested in individual differences in the *sensitivity* to probabilistic reasoning principles and in the *tendency* to apply scientific principles when seeking causal explanations. People who can answer an explicit probability question on a test, or who can accurately define "control-group" when asked, may not show the sensitivity to invoke these principles when their relevance to a problem is partially disguised. In contrast, the cognitive skills assessed by IQ tests are explicit ones. The respondent does not have to recognize their applicability – and does not have to overcome an intuitive response that the problem deliberately activates. On IQ tests, people are not tempted to engage in miserly processing due to the presence of an intuitively compelling alternative.

The results that we have obtained with our Actively Open-Minded Thinking (AOT) thinking disposition scale are consistent with these differences between the CART and IQ tests. Although the AOT scale is correlated with both, it correlated significantly more strongly with CART performance than with cognitive ability (Stanovich et al., 2016). The AOT also remains a significant predictor of most of the subtests after cognitive ability has been partialled out. Our AOT results indicate a startlingly tight linkage between a particular thinking disposition and rational thinking. A generic style of thought – one characterized by the cultivation of reflectiveness rather than impulsivity, the seeking and processing of information that disconfirms one's beliefs (as opposed to confirmation bias in evidence seeking), and the willingness to change one's beliefs in the face of contradictory evidence – has been linked in our data to a very comprehensive measure of rational thought. The results from the AOT show that there is a global mental attitude that pervades these tasks. It is certainly not a specific cognitive skill but instead is best characterized as a generic mental attitude toward cognitive tasks – one of openness, full engagement, mental caution, exhaustiveness of thought, humility, and willingness to encompass new evidence. Rationality is multifarious, involving knowledge and process in complex and changing proportions across tasks and situations. Nevertheless, despite the multifariousness of the rationality construct itself, a global thinking style – actively open-minded thinking – does permeate almost all of the subtests of the CART.

Rational Thinking Subsumes Critical Thinking

We saw in a previous discussion that the concept of rationality – in encompassing both the reflective mind and the algorithmic mind – can be said to be a superordinate construct to intelligence. The study of rational thinking is a normative/evaluative endeavor (Lee, 2006). Specifically, if one's goal is to *aid* people in their thinking, then it is essential that one have some way of *evaluating* thinking. The admonition to educators to "teach critical thinking skills" contains implicit evaluative assumptions. The students *already* think. Educators are charged with getting them to think *better* (Adams, 1993; Baron, 1993). This of course implies normative models of what we mean by better thinking (Baron, 1993, 2008). The assessment of rational thinking explicitly uses those normative models.

Normative issues arise when thinking dispositions are discussed in the educational literature of critical thinking. Why do we want people to think in an actively open-minded fashion? Why do we want people to be reflective? It can be argued that the superordinate goal we are actually trying to foster is that of rationality (Stanovich, 2004, 2009). That is, much of what educators are ultimately concerned about is rational thought in both the epistemic sense and the instrumental sense. We value certain thinking dispositions because we think that they will at least aid in bringing belief in line with the world (epistemic rationality) and in achieving our goals (instrumental rationality).

In short, a large part of the rationale for educational interventions to change thinking dispositions derives from a tacit assumption that actively open-minded critical-thinking dispositions make the individual a more rational person. Thus, the normative justification for fostering critical thought is that it is the foundation of rational thought. Our view is consistent with that of many other theorists who have moved toward conceptualizing critical thinking as a subspecies of rational thinking, or at least as closely related to rational thinking (Kuhn, 2005; Moshman, 2004; Siegel, 1997). Additionally, theory in cognitive science differentiates rationality from intelligence and explains why rationality and intelligence sometimes dissociate. This finding confirms a long-standing belief in education that intelligence does not guarantee critical thinking.

The Context of Rational Thinking Assessment

For many years, we have argued 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 (Stanovich, 1993, 2009; Stanovich, Toplak, & West, 2008). With the development of the CART, our research group has turned this prediction into reality (Stanovich et al., 2016). 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 would be assessed by such an instrument 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. The existence of the CART demonstrates that there is no practical limitation to constructing a rational thinking test.

The current version of the CART, which has twenty subtests and four supplementary thinking dispositions scales, takes less than three hours to complete. The total CART score has a reliability of 0.86 but the reliability of the individual subtests varies widely. Nevertheless, most of the subtests are themselves reliable enough for research purposes. In a study of the full CART employing more than 700 subjects (discussed in Stanovich, West, & Stanovich, 2016), we found that the amalgamated total score on the CART displayed substantial correlations, in the range of 0.50–0.70, with various measures of cognitive ability. Importantly, though, the subcomponents of the CART display quite variable correlations with cognitive ability. Components such as scientific reasoning and reflective thinking display moderate correlations with cognitive ability (0.51 and 0.54), whereas other components show much lower associations with cognitive ability – for example, avoiding overconfidence (0.38), optimal temporal discounting (0.06), and argument evaluation (0.37). Importantly, the cognitive disposition of actively open-minded reasoning predicts performance on virtually all of the CART subtests after cognitive ability has been partialled out. This is true of the total CART score as well. Finally, a very short form of the CART consisting of just two of the subtests – scientific reasoning and probabilistic reasoning – can be used in many situations.

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., probabilistic reasoning) have generated enormous empirical literatures. For example, there are many paradigms that have been used to measure the avoidance of miserly information processing (left column of Table 46.1, third row). 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 46.1, fourth row). All three paradigms that assess the latter tendency have each generated enormous literatures. Resistance to framing has been measured with countless tasks (e.g., Levin et al., 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., 2016) of the twenty years of work on individual differences in rational thinking that went into the development of our prototype. Rationality is a multifarious concept and reporting outcomes across all of its components (see Table 46.1) is complex. Nevertheless, a reasonable amount of research has already been conducted linking rational thinking tendencies to real-life decision-making (Baron, Bazerman, & Shonk, 2006; Bruine de Bruin et al., 2007; Camerer, 2000; Fenton-O'Creevy, et al., 2003; Hilton, 2003; Milkman, Rogers, & Bazerman, 2008; Parker et al., 2015; Thaler, 2015; Thaler & Sunstein, 2008). In our book (Stanovich et al., 2016), we include a table indicating how each of the thinking skills assessed on the CART have been linked to real-life outcomes in the work of other investigators. Performance on several CART subtests has been shown to be related to several real-world behaviors, including secure computing and making prudent financial choices (Toplak, West, & Stanovich, 2017).

Implications of Rational Thinking Assessment

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 and real-life outcomes (Carroll, 1993; Deary, 2000; Hunt, 2011; Schmidt & Hunter, 2004). 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 that are missing from IQ tests because, as we noted at the beginning of this chapter, many theorists have adopted permissive conceptualizations of what intelligence is rather than a grounded conceptualization. In contrast, in this chapter, we have stressed that 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.

Now that we have the CART, we could, in *theory*, begin to assess rationality as systematically as we do IQ. We could choose tomorrow to more formally assess rational thinking skills, focus more on teaching them, and redesign our environment so that irrational thinking is not so costly. Whereas just thirty years ago we knew vastly more about intelligence than we knew about rational thinking, this imbalance has been redressed in the last few decades because cognitive scientists have developed laboratory tasks and real-life performance indicators to measure rational thinking.

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