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CHAPTER 39

Intelligence and Rationality

Keith E. Stanovich, Richard F. West, and Maggie E. Toplak

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, narrowly defined by what intelligence tests measure, fails to encompass rational thinking. In this chapter we will (1) define the concept of rational thought; (2) show how its components could be measured; (3) show how its components are not assessed on traditional tests of intelligence; and (4) demonstrate why intelligence is a very imperfect correlate of rational thought.

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. In analyzing this phenomenon, we need first to ask ourselves whether this expression makes any sense. For example, Robert Sternberg once edited a book titled *Why Smart People Can Be So Stupid* (2002b), considered the logic of the title of his volume, and found it wanting! 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 much like being intelligent, according to the dictionary. Sternberg (2002a) points out that the same dictionaries 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 and, by the law of contradiction, someone cannot be intelligent and not intelligent, then the "smart people being stupid" phrase seems to make no sense.

But if we look at the secondary definitions of the term, we see what is motivating the phrase "smart but acting stupid." The second definition of the word stupid in Dictionary.com 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 intelligent, 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 similar to that of stupid: tending to make poor decisions. These phrases pick out a particular meaning of "stupid" or "dumb" – albeit not the primary one.

For this reason, Sternberg (2002a) suggested that a better phrasing for these examples is that they represent smart people acting foolishly. Perkins (1995, 2002) likewise prefers the term "folly" to characterize what is being described in these examples. A foolish person is a person "lacking good sense or judgment; showing a lack of sense; unwise; without judgment or discretion." This definition 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).

We are not at all concerned with arguing about the terminology here. However we phrase it – "smart but acting dumb," "smart but acting foolish," or whatever – it is only essential that the phrase pick out the phenomenon that we are discussing: intelligent people taking injudicious actions or holding unjustified beliefs. But there is one more problem here. Some conceptualizations of intelligence define it, at least in part, as the ability to adapt to one's environment by making judicious decisions (Neisser et al., 1996; Sternberg & Detterman, 1986). Thus, we are right back at the problem of contradiction again. If we are concerned with cases where intelligent people make foolish decisions (decisions that do not serve their goals), and intelligence is in part the tendency to make decisions that serve one's goals, then we have a contradiction – smart people can't *possibly* have the (general) tendency to act foolishly. We should stress here that we are speaking of a *systematic* pattern of irrational actions – not a single, isolated instance of irrational thought or action.

What is happening here is that we are bumping up against an old controversy in the study of cognitive ability – the distinction between broad and narrow theories of intelligence. Broad theories include aspects of functioning that are captured by the *vernacular* term intelligence (adaptation to the environment, showing wisdom and creativity, etc.) whether or not these aspects are actually measured by existing tests of intelligence. Narrow theories, in contrast, confine the concept of intelligence to the set of mental abilities actually tested on extant IQ tests. Narrow theories adopt the operationalization of the term that is used in psychometric studies of intelligence, neurophysiological studies using brain imaging, and studies of brain disorder. This definition involves a statistical abstraction from performance on established tests and cognitive ability indicators. It yields a scientific concept of general intelligence usually symbolized by *g* or, in cases where the fluid/crystallized theory is adopted, Gf and Gc. The latter theory is sometimes termed the Cattell/Horn/Carroll (CHC) theory of intelligence (Carroll, 1993; Cattell, 1963, 1998; Horn & Cattell, 1967). The theory posits that tests of mental ability tap a small number of broad factors, of which two are dominant. Fluid intelligence (Gf) reflects reasoning abilities operating across a variety of domains – including novel ones. It is measured by tests of abstract thinking such as figural analogies, Raven Matrices, and series completion. Crystallized intelligence (Gc) reflects declarative knowledge acquired from acculturated learning experiences. It is measured by vocabulary tasks, verbal comprehension, and general knowledge assessments. Ackerman (1996) discusses how the two dominant factors in the CHC theory reflect a long history of considering two aspects of intelligence: intelligence-as-process (Gf) and intelligence-as-knowledge (Gc).

The narrow view of intelligence then takes these operationally defined constructs – *g*, Gf, Gc – and validates them in studies of brain injury, educational attainment, cognitive neuroscience, developmental trends, and information processing. These constructs of the narrow theory are grounded in the types of mental abilities measured on traditional tests of intelligence. 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 unstated assumption that we wish to challenge. Instead, we wish to argue that intelligence tests are radically incomplete as measures of *cognitive* functioning – in addition to whatever they fail to assess in noncognitive domains.

When laypeople think of individual differences in reasoning they think of IQ tests. It is quite natural that this is their primary associate, because IQ tests are among the most publicized products of psychological research. This association is not entirely inaccurate either, because intelligence – as measured using IQ-like instruments – is correlated with performance on a host of reasoning tasks (Ackerman, Kyllonen, & Roberts, 1999; Carroll, 1993; Deary, 2000, 2001; Flynn, 2007; Lohman, 2000; Lubinski, 2004; Sternberg, 1977, 1985). Nonetheless, a major theme of this chapter will be that 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. Thus, in our cognitive framework, which employs the narrow view of intelligence, the notion of smart people acting stupidly becomes completely explicable.

In this chapter we will argue that intelligence-related individual differences in thinking are largely the result of differences at the algorithmic level of cognitive control. Intelligence tests thus largely fail to tap processes at the reflective level of cognitive control. Because understanding rational behavior necessitates understanding processes operating at both levels, an exclusive focus on intelligence-related individual differences will tend to obscure important differences in human thinking. We will begin by explicating the difference between the algorithmic and reflective level of processing as they are understood in contemporary dual-process theories of cognition.

Dual Process Models of Cognition

Evidence from cognitive neuroscience and cognitive psychology is converging on the conclusion that the functioning of the brain can be characterized by two different types of cognition having somewhat different functions and different strengths and weaknesses (Evans, 1984, 2006, 2008; Evans & Frankish, 2009; Kahneman & Frederick, 2002; Sloman, 1996, 2002; Stanovich, 2004, 2009). The wide variety of converging evidence for this conclusion is indicated by the fact that theorists in a diverse set of specialty areas (including cognitive psychology, social psychology, cognitive neuroscience, and decision theory) have proposed that there are both Type 1 and Type 2 processes in the brain (e.g., Brainerd & Reyna, 2001; Feldman Barrett, Tugade, & Engle, 2004; Frank, Cohen, & Sanfey, 2009; Haidt, 2001; McClure, Laibson, Loewenstein, & Cohen, 2004; Metcalfe & Mischel, 1999; Prado & Noveck, 2007; Smith & Decoster, 2000). Type 1 processing is fast and automatic heuristic processing. Type 2 is, slow, analytic, and computationally expensive.

There are many such theories (over 20 dual-process theories are presented in a table in Stanovich, 2004) and they have some subtle differences, but they are similar in that all distinguish autonomous from nonautonomous processing. The two types of processing were termed systems in earlier writings, but theorists have been moving toward more atheoretical characterizations, so we shall follow Evans (2009) in using the terms Type 1 and Type 2 processing.

The defining feature of Type 1 processing is its autonomy. Type 1 processes are termed autonomous because (1) their execution is rapid, (2) their execution is mandatory when the triggering stimuli are encountered, (3) they do not put a heavy load on central processing capacity (i.e., they do not require conscious attention), (4) they are not dependent on input from high-level control systems, and (5) they can operate in parallel without interfering with themselves or with Type 2 processing. Type 1 processing would include behavioral regulation by the emotions; 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 Evans, 2007, 2008; Stanovich, 2004, 2009). Type 1 processing, because of its computational ease, is a common processing default.

In contrast, Type 2 processing is relatively slow and computationally expensive – it is the focus of our awareness. And what we can attend to – be aware of – is limited. We call it "*paying* attention" for a reason: Attention is a limited resource and it has costs in terms of available computational power. Many Type 1 processes can operate at once in parallel, but only one (or a very few) Type 2 thoughts can be executed at once. Type 2 processing is thus serial processing, and it is what psychologists call controlled processing. It is the type of processing going on when we talk of things like "conscious problem solving."

Although either Type 1 or Type 2 processing can lead to rational behavior, most individual differences in rational thought result from variation in Type 2 processing. In fact, one of the most critical functions of Type 2 processing is to override Type 1 processing. Type 1 processing (processes of emotional regulation, Darwinian modules, associative and implicit learning processes) can be overgeneralized and produce responses that are irrational in a particular context if not overridden. In order to override Type 1 processing, Type 2 processing must display at least two (possibly related) capabilities. One is the capability of interrupting Type 1 processing and suppressing its response tendencies. Type 2 processing thus involves inhibitory mechanisms of the type that have been the focus of work on executive functioning (e.g., Hasher, Lustig, & Zacks, 2007; Kane & Engle, 2003; Miyake, Friedman, Emerson, & Witzki, 2000; Salthouse, Atkinson, & Berish, 2003; Zelazo, 2004).

However, the ability to suppress Type 1 processing gets the job only half done. Suppressing one 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, 2007; Evans & Over, 2004; Kahneman & Tversky, 1982; Nichols & Stich, 2003; Suddendorf & Corballis, 2007). 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 – the ability to distinguish our representations of the real world from representations of imaginary situations. For example, when considering an alternative goal state different from the one we currently have, we must be able to represent our current goal and the alternative goal and to keep straight which is which. Likewise, we need to be able to differentiate the representation of an action about to be taken from representations of potential *alternative* actions we are considering. The latter must not infect the former while the mental simulation is being carried out.

In a much-cited article, Leslie (1987) modeled pretense by positing a so-called secondary representation (see Perner, 1991) that was a copy of the primary representation but that was decoupled from the world so that it could be manipulated – that is, be a mechanism for simulation. 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. In fact, decoupling operations might well be a major contributor to a distinctive Type 2 property – its seriality.

Figure 39.1 represents a preliminary model of mind, based on what we have outlined thus far. We have said that by taking offline early representations triggered by

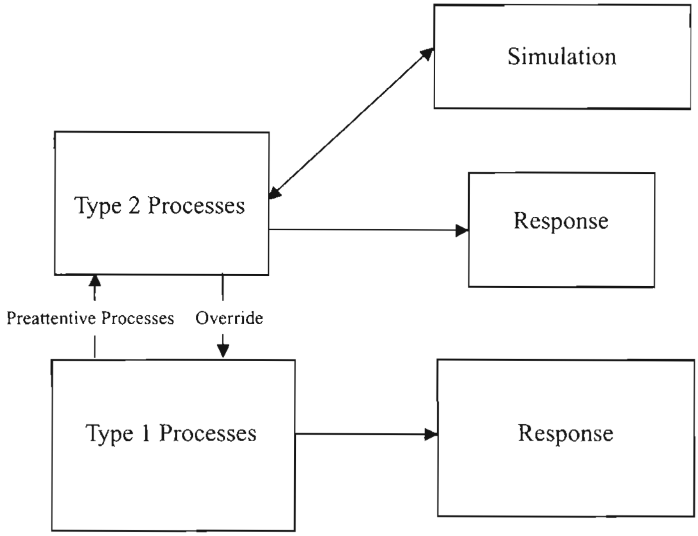

Figure 39.1. A preliminary dual-process model. Reprinted from *What Intelligence Tests Miss: The Psychology of Rational Thought* by Keith E. Stanovich, courtesy of Yale University Press.

Type 1 processing, we can often optimize our actions. Type 2 processing (slow, serial, computationally expensive) is needed to inhibit Type 1 processing and to sustain the cognitive decoupling needed to carry out processes of imagination whereby alternative responses are simulated in temporary models of the world. The figure shows the 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 fix the content of most Type 2 processing (see Evans, 2009).

Three Kinds of Minds and Two Kinds of Individual Differences

In 1996, philosopher Daniel Dennett wrote a book about how some aspects of the human mind were like the minds of other animals and how other aspects were not. He titled the book *Kinds of Minds* to suggest that within the brains of humans are control systems of very different types – different kinds of minds. In the spirit of Dennett, we will here make a "kinds of minds" distinction between aspects of Type 2 processing in terms of levels of control. The distinction is best understood by analogy to the different levels of explanation in 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 the 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 in operation in incident A (the gravitational laws that describe why the woman will be crushed upon impact) are also operative 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. Further, 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. Cognitive scientists refer to this level of analysis as the algorithmic level (Anderson, 1990; Marr, 1982; Stanovich, 1999). In the realm of machine intelligence, this would be the level of the instructions in the abstract computer language used to program the computer (BASIC, C, etc.). 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.). For example, a simple letter pronunciation task might entail encoding the letter, storing it in short-term memory, comparing it with information stored in long-term memory, if a match occurs making a response decision, and then executing a motor response. 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.

In the terms of Stanovich (2009), 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.[1] This terminology captures the fact that we turn to an analysis of goals, desires, and beliefs to understand a case such as B. The algorithmic level provides an incomplete explanation of behavior in cases like incident B because it provides an information-processing explanation of how the brain is carrying out a particular task (in this case, jumping off a cliff) but no explanation of *why* the brain is carrying out this particular task. We turn to the level of the reflective mind where we ask questions about the *goals* of the system's computations (*what* the system is attempting to compute and *why*). 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 (e.g., choice of action that is optimal given the system's goals and beliefs) implicate the reflective mind in many issues of rationality. Assessing the reflective mind means assessing rational thought and rational action. The algorithmic mind can be evaluated in terms of efficiency, but high computational efficiency in the algorithmic mind is not a sufficient condition for rationality.

This concern for the efficiency of information processing as opposed to its rationality is mirrored in the status of intelligence tests. They are measures of computational efficiency but not rationality – a point made clear by considering a distinction that is very old in the field of psychometrics. Psychometricians have long distinguished typical performance situations from optimal

1 This example also helps to contextualize our use of the term *reflective*. Obviously, given this example involving suicide, we do not wish to imply that goals associated with the reflective mind necessarily exemplify wisdom or prudence. In fact, as in this example, sometimes the reflective mind is not *well* reflective. Our use of the term refers only to the necessity of employing intentional-level goal states (and belief states) to describe behavior. Those goals and beliefs can lead to irrational as well as rational outcomes.

(sometimes termed maximal) performance situations (see Ackerman, 1994, 1996; Ackerman & Heggestad, 1997; Ackerman & Kanfer, 2004; Cronbach, 1949; Matthews, Zeidner, & Roberts, 2002; Sternberg, Grigorenko, & Zhang, 2008). Typical performance situations are unconstrained in that no overt instructions to maximize performance are given, and the task interpretation is determined to some extent by the participant. The goals to be pursued in the task are left somewhat open. The issue is what a person would typically do in such a situation, given few constraints. Typical performance measures are measures of the reflective mind – they assess in part goal prioritization and epistemic regulation. In contrast, optimal performance situations are those in which the task interpretation is determined externally.[2] The person performing the task is instructed to maximize performance. Thus, optimal performance measures examine questions of efficiency of goal pursuit – they capture the processing efficiency of the algorithmic mind. All conventional tests of 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 thinking dispositions that have been investigated by psychologists are actively open-minded thinking, need for cognition (the tendency to think a lot), consideration of future consequences, need for closure, superstitious thinking, and dogmatism (Cacioppo et al., 1996; Kruglanski & Webster, 1996; Norris & Ennis, 1989; Schommer-Aikins, 2004; Stanovich, 1999, 2009; Sternberg, 2003; Sternberg & Grigorenko, 1997; Strathman et al., 1994).

The literature on these types of thinking dispositions is vast and our purpose is not to review that literature here. It is only necessary to note that 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 short, individual differences in thinking dispositions are assessing variation in people's goal management, epistemic values, and epistemic self-regulation – differences in the operation of the reflective mind. They are all psychological characteristics of the reflective mind that underpin rational thought and action.

The cognitive abilities assessed on intelligence tests are not of this type. They are not about high-level personal goals and their regulation, or about the tendency to change beliefs in the face of contrary evidence, or about how knowledge acquisition is internally regulated when not externally directed. People have indeed come up with *definitions* of intelligence that encompass such things. Theorists often define intelligence in ways that encompass rational action and belief but, nevertheless, *the actual measures of intelligence in use assess only algorithmic-level cognitive capacity*. No current intelligence test that is even moderately

2 The exception of course is cross-cultural uses of intelligence tests, a situation that is beyond the scope of our argument. We restrict our discussion here to individual difference comparisons *within* a culture.

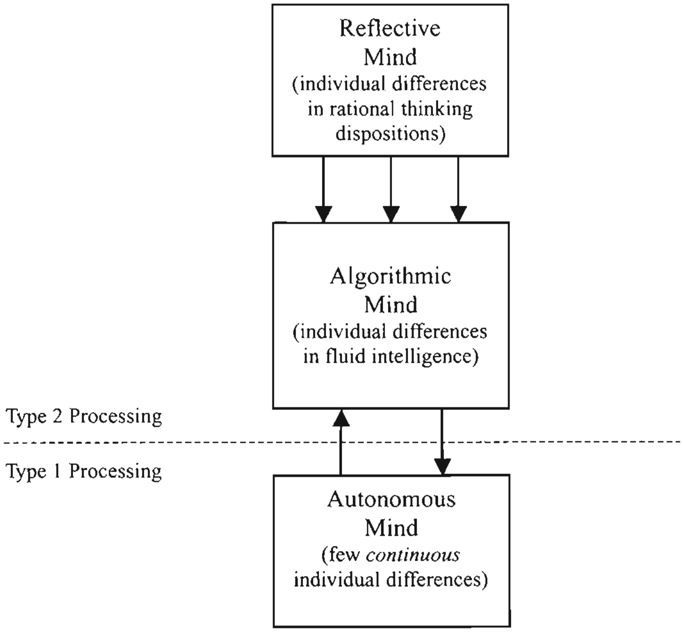

Figure 39.2. Individual differences in the tripartite structure. Reprinted from *What Intelligence Tests Miss: The Psychology of Rational Thought* by Keith E. Stanovich, courtesy of Yale University Press.

used in practice assesses rational thought or behavior.

We now have the distinctions needed to identify three kinds of minds. Figure 39.2 represents the classification of individual differences in the tripartite view presented in this chapter. The part of the mind that carries out Type 1 processing we will call the autonomous mind. 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 what we will call the algorithmic mind. In contrast, thinking dispositions index individual differences in what will be termed the reflective mind. In terms of individual differences, the reflective and algorithmic minds are characterized by continuous variation. Disruptions to the autonomous mind often reflect damage to cognitive modules that results in very discontinuous cognitive dysfunction such as autism or the agnosias and alexias (Anderson, 2005; Bermudez, 2001; Murphy & Stich, 2000).

Figure 39.2 highlights an important sense in which rationality is a more encompassing construct than intelligence. To be rational, a person must have well-calibrated beliefs and must act appropriately on those beliefs to achieve goals – both properties of the reflective mind. The person must, of course, have the algorithmic-level machinery that enables him or her 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 intelligence (the algorithmic mind) or because of individual differences in thinking dispositions (the reflective mind). To put it simply, the concept of rationality encompasses two things (thinking dispositions of the reflective mind and algorithmic-level efficiency) whereas the concept of intelligence – at least as it is commonly operationalized – is largely confined to algorithmic-level efficiency.

The conceptualization in Figure 39.2 has two great advantages. First, it conceptualizes intelligence in terms of what intelligence tests actually measure. That is, all current tests assess various aspects of algorithmic efficiency. But that is all that they assess. None attempt to measure directly an aspect of epistemic or instrumental rationality, nor do they examine any thinking dispositions that relate to rationality. To think rationally means adopting appropriate goals, taking the appropriate action given one's goals and beliefs, and holding beliefs that are commensurate with available evidence. Standard intelligence tests do not assess such functions (Perkins, 1995, 2002; Stanovich, 2002, 2009; Sternberg, 2003, 2006). For example, although intelligence tests do assess the ability to focus on an immediate goal in the face of distraction, they do not assess whether a person has the tendency to develop goals that are rational in the first place. Likewise, intelligence tests are good measures of how well a person can hold beliefs in short-term memory and manipulate those beliefs, but they do not assess whether a person has the tendency to *form* beliefs rationally when presented with evidence. Finally, intelligence tests are good measures of how efficiently a person processes information that has been provided, but they do not at all assess whether the person is a *critical assessor* of information as it is gathered in the natural environment.

It is clear from Figure 39.2 why rationality and intelligence can become dissociated. As long as variation in thinking dispositions is not perfectly correlated with fluid intelligence, there is the statistical possibility of dissociations between rationality and intelligence. Substantial empirical evidence indicates that individual differences in thinking dispositions and intelligence are far from perfectly correlated. Many different studies involving thousands of subjects (e.g., Ackerman & Heggestad, 1997; Austin & Deary, 2002; Baron, 1982; Bates & Shieles, 2003; Cacioppo et al., 1996; Eysenck, 1994; Goff & Ackerman, 1992; Kanazawa, 2004; Kokis et al., 2002; Zeidner & Matthews, 2000) have indicated that measures of intelligence display only moderate to weak correlations (usually less than .30) 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; Klaczynski, Gordon, & Fauth, 1997; Klaczynski & Lavallee, 2005; Klaczynski & Robinson, 2000; Kokis et al., 2002; Newstead, Handley, Harley, Wright, & Farrelly, 2004; Macpherson & Stanovich, 2007; Parker & Fischhoff, 2005; Sá & Stanovich, 2001; Stanovich & West, 1997, 1998a, 2000; Toplak, Liu, Macpherson, Toneatto, & Stanovich, 2007; Toplak & Stanovich, 2002). These empirical studies indicate that different types of cognitive predictors are tapping separable variance, and the reason that this is to be expected is because cognitive capacity measures such as intelligence and thinking dispositions map on to different levels in the tripartite model.

The functions of the different levels of control are illustrated more completely in Figure 39.3. 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 function 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 39.3, it is represented by arrow B which represents, in machine intelligence terms, the call to the algorithmic mind to override the Type 1 response by taking it offline. This is a different mental function from the override function itself (arrow A), and we have presented evidence indicating that the two functions are indexed by different types of individual differences – the ability to sustain the inhibition of the Type

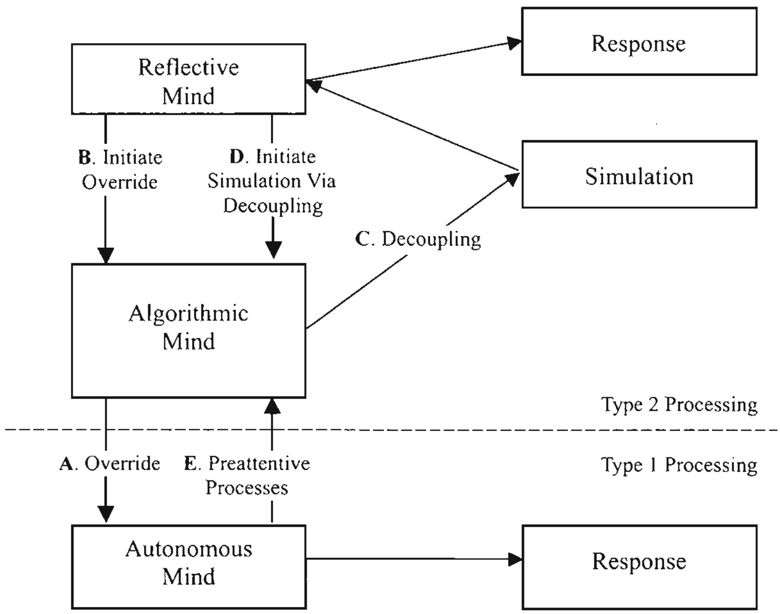

Figure 39.3. A more complete model of the tripartite framework. Reprinted from *What Intelligence Tests Miss: The Psychology of Rational Thought* by Keith E. Stanovich, courtesy of Yale University Press.

1 response is indexed by measures of fluid intelligence, and the tendency to initiate override operations is indexed by thinking dispositions such as reflectiveness and need for cognition.

Figure 39.3 represents another aspect of cognition somewhat neglected by previous dual-process theories. Specifically, the override function has loomed large in dual-process theory but less so the simulation process that computes the alternative response that makes the override worthwhile. Figure 39.3 explicitly represents the simulation function as well as the fact that the call to initiate simulation originates in the reflective mind. The decoupling operation (indicated by arrow C) itself is carried out by the algorithmic mind and the call to initiate simulation (indicated by arrow D) by the reflective mind. Again, two different types of individual differences are associated with the initiation call and the decoupling operator – specifically, rational thinking dispositions with the former and fluid intelligence with the latter. Finally, the algorithmic mind receives inputs from the computations of the autonomous mind (arrow E) via so-called preattentive processes (Evans, 2006, 2007, 2008, 2009).

Mindware in the Tripartite Model

Knowledge bases, both innate and derived from experience, also importantly bear on rationality. We have used the term mindware to refer to these knowledge bases. The term mindware was coined by Perkins (1995) to refer to the rules, knowledge, procedures, and strategies that a person can retrieve from memory to aid decision making and problem solving. Each of the levels in the tripartite model of mind has to access knowledge to carry out its operations, as illustrated in Figure 39.4. As the figure indicates, the reflective mind not only accesses general knowledge structures but, importantly, also accesses the person's opinions, beliefs, and reflectively acquired goal structure. The algorithmic mind accesses microstrategies for cognitive operations and production system rules for sequencing behaviors and thoughts. Finally, the autonomous mind accesses not only evolutionarily compiled encapsulated

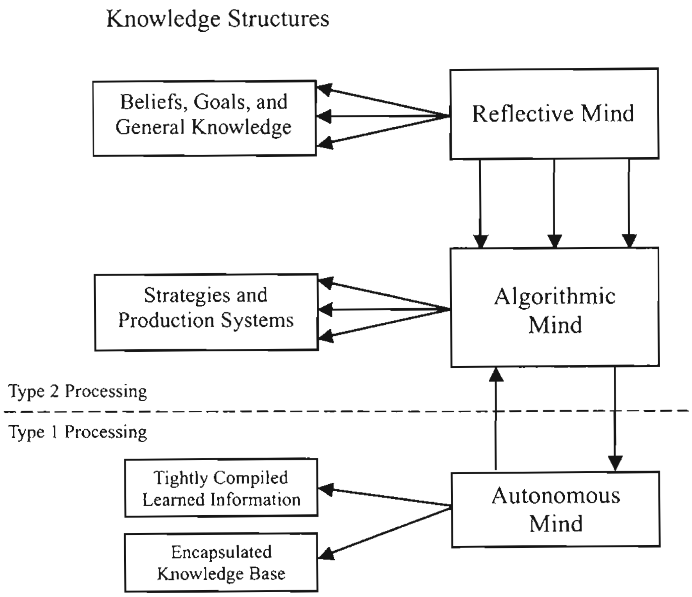

Figure 39.4. Knowledge structures in the tripartite framework.

knowledge bases, but also retrieves information that has become tightly compiled and available to the autonomous mind due to overlearning and practice.

It is important to note that what is displayed in Figure 39.4 is the knowledge bases that are *unique* to each mind. Algorithmic- and reflective-level processes also receive inputs from the computations of the autonomous mind (see arrow E in Figure 39.3). The mindware available for retrieval, particularly that available to the reflective mind, is in part the product of past learning experiences. The knowledge structures available for retrieval by the reflective mind represent Gc, crystallized intelligence. Recall that Gf, fluid intelligence (intelligence-as-process), is already represented in Figure 39.3. It is the general computational power of the algorithmic mind – importantly exemplified by the ability to sustain cognitive decoupling.

It is important to see how both of the major components of Gf/Gc theory 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 39.3) and to initiate simulation activities (arrow D in Figure 39.2) are both aspects of the reflective mind unassessed by intelligence tests, so the tests will miss these components of rationality.

The situation with respect to Gc is a little different. It is true that much of the mindware of rational thought would be classified as crystallized intelligence in the abstract. But is it the kind of crystallized knowledge that is specifically assessed on the tests? The answer is no. The mindware of rational thought is somewhat specialized mindware (it clusters in the domains of probabilistic reasoning, causal reasoning, and scientific reasoning; see Stanovich, 2009). In contrast, the crystallized knowledge assessed on IQ tests is deliberately designed to be nonspecialized. The designers of the tests, to make sure the sampling of Gc is fair and unbiased, explicitly attempt to *broadly* sample vocabulary, verbal comprehension domains, and general knowledge. The broad sampling ensures elimination of bias in the test, but it inevitably means that the specific knowledge bases critical to rationality will not be assessed. In short, Gc, as traditionally measured, does not assess individual differences in rationality, and Gf will do so only indirectly and to a mild extent.

Rational Thought and Its Operationalizations in Cognitive Science

To this point we have established that rationality is a more encompassing construct than intelligence, narrowly defined. We have seen conceptually the components of rationality that IQ tests miss. What if we were to attempt to assess the larger concept – rational thought? As psychologists, we would turn to how the concept of rationality has been operationalized within cognitive science. This avoids a number of pitfalls. First, dictionary definitions of rationality ("the state or quality of being in accord with reason") tend to be weak and not specific enough to be testable. Additionally, some theorists have wished to downplay the importance of rationality and have promulgated a caricature of rationality. Such caricatures are exemplified in discussions that seem to restrict its definition to the ability to do the syllogistic reasoning problems that are encountered in Philosophy 101. The meaning of rationality in modern cognitive science is, in contrast, much more robust and important.

Cognitive scientists recognize two types of rationality: instrumental and epistemic. In its simplest definition, *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. 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. The model of rational judgment used by decision scientists is one in which a person chooses options based on which option has the largest expected utility (see Baron, 2008; Dawes, 1998; Hastie & Dawes, 2001; Wu, Zhang, & Gonzalez, 2004).

The other aspect of rationality studied by cognitive scientists is termed *epistemic rationality*. This aspect of rationality concerns how well beliefs map onto the actual structure of the world. Epistemic rationality is sometimes called theoretical rationality or evidential rationality (see Audi, 1993, 2001; Foley, 1987; Harman, 1995; Manktelow, 2004; Over, 2004). Instrumental and epistemic rationality are related. In order to take actions that fulfill our goals, we need to base those actions on beliefs that are properly calibrated to the world.

Although many people feel (mistakenly or not) that they could do without the ability to solve textbook logic problems (which is why the caricatured view of rationality works to undercut its status), virtually no person wishes to eschew epistemic rationality and instrumental rationality, properly defined. Virtually all people want their beliefs to be in some correspondence with reality, and they also want to act to maximize the achievement of their goals. 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.

The literature of cognitive science contains many examples of advantages of epistemic rationality and the disadvantages of epistemic irrationality. People who lack epistemic rationality tend to get many surprises in life – they think they know things that they do not. They have poor knowledge calibration, to use the technical term. In a knowledge calibration paradigm, for example, they tend to say that they are 99% certain of things that they actually know with only 70% accuracy (Fischhoff, Slovic, & Lichtenstein, 1977). Likewise, research has demonstrated the many practical consequences of failing to follow the strictures of instrumental rationality. For example, in the domains of personal finance and investing it has been found that people who violate the principles of instrumentally rational thought suffer more financial misfortune and make less money from investments (Camerer, 2000; Fenton-O'Creevy, et al., 2003; Hilton, 2003).

One of the fundamental advances in the history of modern decision science was the demonstration that if people's preferences follow certain patterns (the so-called axioms of choice – things like transitivity and freedom from certain kinds of context effects) then they are behaving as if they are maximizing utility – they are acting to get what they most want (Edwards, 1954; Jeffrey, 1983; Luce & Raiffa, 1957; Savage, 1954; von Neumann & Morgenstern, 1944). This is what makes people's degrees of rationality measurable by the experimental methods of cognitive science. Although it is difficult to assess utility directly, it is much easier to assess whether one of the axioms of rational choice is being violated. This has been the logic of the seminal heuristics and biases research program inaugurated in the much-cited studies of Kahneman and Tversky (1972, 1973, 1979; Tversky & Kahneman, 1974, 1981, 1983, 1986).

Researchers in the heuristics and biases tradition have demonstrated, in a host of empirical studies, that people violate many of the strictures of rationality and that the magnitude of these violations can be measured experimentally. For example, people display confirmation bias, they test hypotheses inefficiently, they display preference inconsistencies, they do not properly calibrate degrees of belief, they overproject their own opinions onto others, they combine probabilities incoherently, and they allow prior knowledge to become implicated in deductive reasoning (for summaries of the large literature, see Baron, 2008; Evans, 1989, 2007; Gilovich, Griffin, & Kahneman, 2002; Kahneman & Tversky, 2000; Shafir & LeBoeuf, 2002; Stanovich, 1999, 2004, 2009). These are caused by many well-known cognitive biases: base-rate neglect, framing effects, representativeness biases, anchoring biases, availability bias, outcome bias, and vividness effects, to name just a few. Degrees of rationality can be assessed in terms of the number and severity of such cognitive biases that individuals display.[3] Failure to display a bias becomes a measure of rational thought.

The Requirements of Rational Thinking

Within the tripartite framework, rationality requires mental characteristics of three different types. First, algorithmic-level cognitive capacity (intelligence) is needed in order that override and simulation activities can be sustained. 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 (these might be termed the fluid aspects of rational thought). Finally, the mindware that allows the computation of rational responses needs to be available and accessible during simulation activities (this mindware might be described as the crystallized aspect of rational thought). Intelligence tests assess only the first of these three characteristics that determine rational thought and action. As measures of rational thinking, IQ tests are radically incomplete.

Problems in rational thinking arise when cognitive capacity is insufficient to sustain autonomous system override, when the necessity of override is not recognized, or when simulation processes do not have access to the mindware necessary

3 There of course has been considerable debate about the extent to which people display rational thinking errors both in the lab and in real life (Cohen, 1981; Gigerenzer, 1996, 2007; Kahneman & Tversky, 1996; Stanovich, 1999, 2004, 2009; Stein, 1996). Most (but perhaps not all) of these debates are orthogonal to the arguments made in this chapter because of our focus on individual differences. That is, virtually all commentators in these disputes acknowledge that there are substantial individual differences displayed on rational thinking tasks (see Stanovich, 1999; Stanovich & West, 2000).

for the synthesis of a better response. The source of these problems, and their relation to intelligence, helps to explain one data trend that has been uncovered – that some rational thinking problems show surprising degrees of dissociation from cognitive ability (Stanovich, 2009; Stanovich & West, 2007, 2008a, 2008b; West, Toplak, & Stanovich, 2008). Myside bias, for example, is virtually independent of intelligence (Macpherson & Stanovich, 2007; Sá, Kelley, Ho, & Stanovich, 2005; Stanovich & West, 2007, 2008a, 2008b; Toplak & Stanovich, 2003). For example, individuals with higher IQs in a university sample are no less likely to process information from an egocentric perspective than are individuals with relatively lower IQs.

Irrational behavior can occur because the right mindware (cognitive rules, strategies, knowledge, and belief systems) is not available to use in decision making. We would expect to see a correlation with intelligence here because mindware gaps most often arise because of lack of education or experience. Nevertheless, while it is true that more intelligent individuals learn more things than less intelligent individuals, much knowledge (and many thinking dispositions) relevant to rationality are picked up rather late in life. Explicit teaching of this mindware is not uniform in the school curriculum at any level. That such principles are taught very inconsistently means that some intelligent people may fail to learn these important aspects of critical thinking. In university samples, correlations with cognitive ability have been found to be roughly (in absolute magnitude) in the range of .20–.35 for probabilistic reasoning tasks and scientific reasoning tasks measuring a variety of rational principles (Bruine de Bruin, Parker, & Fischhoff, 2007; Kokis et al., 2002; Parker & Fischhoff, 2005; Sá, West, & Stanovich, 1999; Stanovich & West, 1997, 1998a, 1998b, 1999, 2000; Toplak & Stanovich, 2002). This is again a magnitude of correlation that allows for substantial discrepancies between intelligence and rationality. Intelligence is thus no inoculation against many of the sources of irrational thought. None of these sources of rational thought are directly assessed on intelligence tests, and the processes that *are* tapped by IQ tests are not highly overlapping with the processes and knowledge that explain variation in rational thinking ability.

In fact, there is enough important cognition missing from IQ tests in this domain that we can easily conceive of the need for a rational thinking test. Indeed, perhaps assessing rationality more explicitly is what is needed in order to both draw more attention toward rational thinking skills and to highlight the limitations of what intelligence tests assess. At present, of course, there is no IQ-type test for rationality – that is, a test that results in an RQ (rationality quotient). Of course, such instruments are not constructed on the back of an envelope – it would instead take an effort costing millions of dollars. Nevertheless, there is nothing *conceptually* or *theoretically* preventing us from developing such a test. We know the types of thinking processes that would be assessed on 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. In the next section we illustrate what the cognitive science of rationality suggests such a test would look like.

What Would Rationality Assessment Look Like?

A Framework for the Assessment of Rational Thinking

Rationality is a multifarious concept – not a single mental quality. Cognitive scientists have developed ways to test both epistemic rationality and instrumental rationality as they were defined earlier. For example, psychologists have studied aspects of epistemic rationality such as the ability to avoid the following: 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 toward self-serving personal judgments; the tendency to evaluate evidence with a myside bias; and the tendency to ignore the alternative hypothesis.

Additionally, psychologists have studied aspects of instrumental rationality such as the ability to avoid these biases: the tendency to show inconsistent preferences because of framing effects; the tendency to show a default bias; 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 overly affected by vivid stimuli; and the tendency for decisions to be affected by irrelevant context.

In terms of concepts discussed in the tripartite model presented in this chapter, Figure 39.5 shows what we propose as the conceptual structure of rational thought. The first partition in the figure indicates that rational thought can be partitioned into fluid and crystallized components by analogy to the Gf and Gc of the Cattell/Horn/Carroll fluid-crystallized theory of intelligence (Carroll, 1993; Cattell, 1963, 1998; Horn & Cattell, 1967). Fluid rationality encompasses the process part of rational thought – the thinking dispositions of the reflective mind that lead to rational thought and action. The top part of the figure illustrates that unlike the case of fluid intelligence, fluid rationality is likely to be multifarious – composed of a variety of cognitive styles and dispositions. Some of these styles and dispositions will be related (for instance, actively open-minded thinking and objective reasoning styles) but others probably not – research on the interrelationships among these thinking dispositions is in its infancy (Bruin de Bruine et al., 2007; Klaczynski, 2001; Parker & Fischhoff, 2005; Stanovich & West, 1998a; West et al., 2008). As a multifarious concept, fluid rationality cannot be assessed with a single type of item in the manner that the homogeneous Raven Progressive Matrices, for example, provides a measure of Gf.

Crystallized rationality is likewise multifarious. However, the bottom part of Figure 39.5 illustrates that the concept of crystallized rationality introduces another complication. Problems with rational thinking in the domain of mindware come in two types – mindware gaps and contaminated mindware (Stanovich, 2009). Mindware gaps occur because people lack declarative knowledge that can facilitate rational thought – they lack crystallized facilitators as indicated in Figure 39.5. A different type of mindware problem arises because not all mindware is helpful – either to attaining our goals (instrumental rationality) or to having accurate beliefs (epistemic rationality). In fact, some acquired mindware can be the direct cause of irrational actions that thwart our goals. This type of problem has been termed contaminated mindware (Stanovich, 2009; Stanovich, Toplak, & West, 2008). It occurs when a person has acquired one (or more) of the crystallized inhibitors listed in Figure 39.5.

Figure 39.5 presents components of rationality that are of all three types – components of fluid rationality as well as some of the most common crystallized facilitators and crystallized inhibitors. Figure 39.5 should not be mistaken for the kind of list of "good thinking styles" that appears in textbooks on critical thinking, however. In terms of providing a basis for a system of rational thinking assessment, it goes considerably beyond such lists in a number of ways. First, unlike the many committee-like attempts to develop feature-lists of critical thinking skills (e.g., Facione, 1990), our conceptual components are grounded in paradigms that have been extensively researched within the literature of cognitive science. This will be illustrated more concretely when we discuss Table 39.1. Second, many textbook attempts at lists of "good thinking styles" deal only with aspects of fluid rationality and give short shrift to the crystallized knowledge bases that are necessary supports for rational thought and action. In contrast, our framework for rationality assessment emphasizes that crystallized knowledge underlies much rational responding (crystallized facilitators) and that crystallized knowledge can also be the direct cause of irrational behavior (crystallized inhibitors).

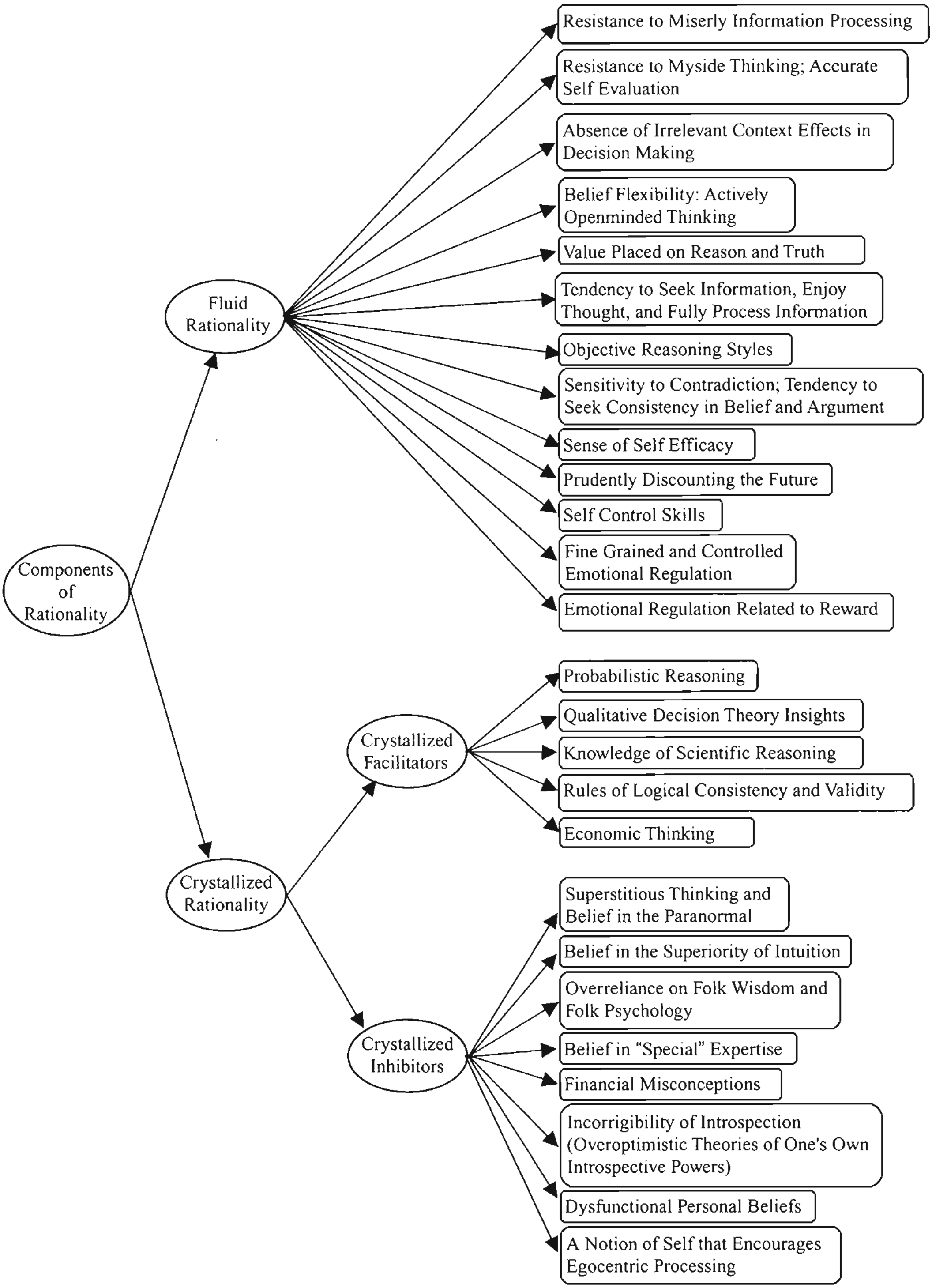

Figure 39.5. The conceptual structure of rational thought.

Table 39.1

Components of Rational Thought			
Fluid Rationality			
Major Dimensions	*Measurement Paradigms*	*Source for Paradigm*	*Example Item*
Resistance to Miserly Information Processing	Belief Bias Paradigms	Evans, Barston, & Pollard (1983) or Markovits & Nantel (1989)	Decide if the conclusion follows logically from the premises, assuming the premises are absolutely true: All flowers have petals; roses have petals; therefore, roses are flowers.
	Attribute Substitution (i.e., Vividness Substitution; Affect Substitution; Denominator Neglect)	Kahneman & Frederick (2002); Slovic et al. (2002); Denes-Raj & Epstein (1994)	Assume that you are presented with two trays of marbles that are spread in a single layer in each tray. You must draw out one marble (without peeking, of course) from either tray. If you draw a black marble you win $100. Consider a condition in which the small tray contains 1 black marble and 9 white marbles, and the large tray contains 8 black marbles and 92 white marbles. From which tray would you prefer to select a marble?
	Cognitive Reflection Test	Frederick (2005)	A bat and a ball cost $1.10 in total. The bat costs a dollar more than the ball. How much does the ball cost?
	Disjunctive Reasoning Tasks	Toplak & Stanovich (2002)	Jack is looking at Ann but Ann is looking at George. Jack is married but George is not. Is a married person looking at an unmarried person? A) Yes B) No C) Cannot be determined
	Accurate Perception of Risks and Benefits	Finucane, Alhakami, Slovic, & Johnson (2000)	Judgments of risks and benefits should be independent. For example, information about the benefits of nuclear energy should not reduce the risk estimate for this source of energy.
	Resistance to Baserate Neglect	Tversky & Kahneman (1982)	A cab was involved in a hit-and-run accident at night. Two cab companies, the Green and the Blue, operate in the city in which the accident occurred. You are given the following fact: 85% of the cabs in the city are Green and 15% are Blue. A witness reported that the cab in the accident was blue. The court tested the reliability of the witness under the same circumstances that existed on the night of the accident and concluded that the witness called about 80% of the Blue cabs blue, but called 20% of the Blue cabs green. The witness also called about 80% of the Green cabs green, but called 20% of the Green cabs blue. What is the probability (expressed as a percentage ranging from 0 to 100%) that the cab involved in the accident was Blue?

Components of Rational Thought			
		Fluid Rationality	
Major Dimensions	*Measurement Paradigms*	*Source for Paradigm*	*Example Item*
	Outcome Bias Paradigms; Status Quo Bias; Endowment Effects	Baron & Hershey (1988); Kahneman, Knetsch, & Thaler (1990, 1991)	A 55-year-old man had a heart condition. He had to stop working because of chest pain. He enjoyed his work and did not want to stop. His pain also interfered with other things, such as travel and recreation. A type of bypass operation would relieve his pain and increase his life expectancy by 5 [15] years. However, 8% [2%] of the people who have this operation die from the operation itself. His physician decided to go ahead with the operation. The operation succeeded [failed, and the man died]. Evaluate the physician's decision to go ahead with the operation.
	Hindsight Bias Paradigms	Fischhoff (1975) or Pohl (2004)	An immigrant arriving at Ellis Island in 1900 was most likely to be from (a) England or Ireland; (b) Scandinavia; (c) Latin America; *(d) Eastern Europe The correct answer to the item is indicated by an asterisk. Please indicate on the scale provided the probability that you would have answered this item correctly.
	Diagnostic Hypothesis Testing	Doherty et al. (1979) or Stanovich (2010a)	Four-card selection task: If there is a vowel on one side of the card, then there is an even number on the other. Your task is to decide which card or cards must be turned over to find out whether the rule is true or false.
	Accuracy of Affective Forecasting	Kermer, Driver-Linn, Wilson, & Gilbert (2006)	Part 1: How happy/sad do you think you will be if you win/lose this coin toss? Part 2: Now that you have won/lost the coin toss, how happy/sad are you right now?
Resistance to Myside Thinking; Accurate Self-Evaluation	Overconfidence Paradigms; Fairness Paradigms; Argument Evaluation Test	Fischhoff, Slovic, & Lichtenstein (1977); Messick & Sentis (1979); Stanovich & West (1997)	Select the correct answer: Absinthe is (a) a precious stone or (b) a liqueur. What is the probability that the alternative you selected is correct?
	Unbiased Processing of Evidence	Klaczynski (2000) or Taber & Lodge (2006)	In this part of the task, we will ask you to read a set of arguments on gun control and tell us how weak or strong you believe each argument is.

(*continued*)

Table 39.1 *(continued)*

Components of Rational Thought			
Fluid Rationality			
Major Dimensions	*Measurement Paradigms*	*Source for Paradigm*	*Example Item*
Absence of Irrelevant Context Effects in Decision Making	Framing Effects; Preference Reversals	Frisch (1993); Lichtenstein & Slovic (2006)	Decision 1. Imagine that the United States is preparing for the outbreak of a disease which is expected to kill 600 people. If Program A is adopted, 200 people will be saved. If Program B is adopted, there is a one-third probability that 600 people will be saved and a two-thirds probability that no people will be saved. Which of the two programs would you favor? Decision 2. Imagine that the United States is preparing for the outbreak of a disease which is expected to kill 600 people. If Program C is adopted, 400 people will die. If Program D is adopted, there is a one-third probability that nobody will die and a two-thirds probability that 600 people will die. Which of the two programs would you favor?
	Avoidance of Irrelevant Anchoring	Jacowitz & Kahneman (1995) or Epley & Gilovich (2004)	Is the length of the Mississippi River greater than 3,000 [less than 200] miles? What is the length of the Mississippi River?
Belief Flexibility: Actively Open-minded Thinking	Actively Open-minded Thinking Scale; Need for Closure; Dogmatism; Belief Identification; Epistemological Understanding	Stanovich & West (2008a); Kruglanski & Webster (1996); Christie (1991); Sá, West, & Stanovich (1999); Kuhn et al. (2000)	Agree or disagree: Changing your mind is a sign of weakness (reflected item)
Value Placed on Reason and Truth	The Master Rationality Motive Scale	Stanovich (2008)	Agree or disagree: I like to think that my actions are motivated by sound reasons.
Tendency to Seek Information, Enjoy Thought, and Fully Process Information	Measures of Need for Cognition and Typical Intellectual Engagement	Cacioppo et al. (1996); Goff & Ackerman (1992)	Agree or disagree: I like the responsibility of handling a situation that requires a lot of thinking.
	Disjunctive Reasoning Tasks	Toplak & Stanovich (2002)	There are 5 blocks in a stack pictured in the figure below. Block 1 is on the bottom and Block 5 is on the top. Block 4 (the second from the top) is green, and Block 2 (the second from the bottom) is not green. Is there a green block *directly* on top of a non-green block? (a) Yes (b) No (c) Cannot be determined

Components of Rational Thought			
		Fluid Rationality	
Major Dimensions	*Measurement Paradigms*	*Source for Paradigm*	*Example Item*
Objective Reasoning Styles	Separating Fact from Opinion and Theory from Evidence; Recognizing the Validity and Invalidity of Informal Arguments; Argument Evaluation Test	Kuhn (1991); Watson & Glaser (1980) or Ricco (2007); Stanovich & West (1997)	Dale states: Seat belts should always be worn to make traveling by car safer. A critic's counterargument is: There are times when your life may be saved by your being thrown free of a car during an accident (assume statement factually correct); Dale's rebuttal is: You are several times more likely to be killed if you are thrown from a car (assume statement factually correct). Indicate the strength of Dale's rebuttal to the critic's counterargument.
Sensitivity to Contradiction; Tendency to Seek Consistency in Belief and Argument	Informal Reasoning and Argument Evaluation Paradigms	Baron (1995) or Perkins (1985) or Toplak & Stanovich (2003) or Halpern (2008)	Subsequent to rating their level of agreement with positions expressed in a series of statements (e.g., The cost of gasoline should be doubled to discourage people from driving), participants were asked to write down arguments both for and against the position.
Sense of Self-Efficacy	Locus of Control Scales	Lefcourt (1991)	Agree or disagree: When bad things happen, they were just going to happen no matter what you did. (reflected)
Prudently Discounting the Future	Temporal Discounting of Reward	Kirby (2009); Shamosh et al. (2008)	Would you prefer $55 today, or $75 in 60 days?
Self-Control Skills	Delay of Gratification Paradigms; Time Preference; Future Orientation	Rodriguez, Mischel, & Shoda (1989); Steinberg et al. (2009); Strathman et al. (1994)	Which description best describes you: Some people would rather be happy today than take their chances on what might happen in the future, but other people will give up their happiness now so that they can get what they want in the future.
Fine-Grained and Controlled Emotional Regulation	Measures of Alexithymia	Bagby, Parker, & Taylor (1994)	Agree or disagree: I am often confused about what emotion I am feeling.
Emotional Regulation Related to Reward	Iowa Gambling Task	Bechara, Damasio, Damasio, & Anderson (1994)	Participants choose from four decks of cards, each of which is associated with a different potential payoff. They must learn to avoid decks that produce high immediate gains but larger future losses.

(continued)

Table 39.1 (*continued*)

Crystallized Rationality: Crystallized Facilitators			
Major Dimensions	*Measurement Paradigms*	*Source for Paradigm*	*Example Item*
Probabilistic Reasoning	Importance of Sample Size	Tversky & Kahneman (1974) or Griffin & Tversky (1992) or Fong et al. (1986)	A certain town is served by two hospitals. In the larger hospital about 45 babies are born each day, and in the smaller hospital about 15 babies are born each day. As you know, about 50% of all babies are boys. The exact percentage of baby boys, however, varies from day to day. Sometimes it may be higher than 50%, sometimes lower. For a period of one year, each hospital recorded the days on which more than 60% of the babies born were boys. Which hospital do you think recorded more such days? (a) The larger hospital will have more days with more than 60% boys (b) The smaller hospital will have more days with more than 60% boys (c) About the same for both hospitals
	Consistent Probability Judgments	Bruine de Bruin et al. (2007); Peters et al. (2006)	In each time frame, some item pairs present nested subset and superset events (e.g., dying in a terrorist attack is a subset of the superset dying from any cause). To be scored as correct, the probability of a subset event should not exceed that of its superset event.
	Resistance to Baserate Neglect	Sloman et al. (2003); Jepson et al. (1983)	Imagine that disease X occurs in one in every 1,000 people. A test has been developed to detect the disease. Every time the test is given to a person who has the disease, the test comes out positive. But sometimes the test also comes out positive when it is given to a person who is completely healthy. Specifically, 5% of all people who are perfectly healthy test positive for the disease. Imagine that we have given this test to a random sample of Americans. They were selected by a lottery. Those who conducted the lottery had no information about the health status of any of these people. What is the chance that a person found to have a positive result actually has the disease?

Crystallized Rationality: Crystallized Facilitators

Major Dimensions	*Measurement Paradigms*	*Source for Paradigm*	*Example Item*
	Resistance to Gambler's Fallacy	Ayton & Fischer (2004) or Burns & Corpus (2004) or Toplak et al., (2007)	When playing slot machines, people win something about 1 in every 10 times. Lori, however, has just won on her first three plays. What are her chances of winning the next time she plays?
	Use of Chance in Explanatory Frameworks; Understanding Random Processes	Fenton-O'Creevy et al. (2003); Towse & Neil (1998)	Simulate the random outcome of tossing a fair coin 150 times in succession.
	Understanding Regression Effects	Nisbett et al. (1983); Fong et al. (1986)	After the first two weeks of the major league baseball season, newspapers begin to print the top 10 batting averages. Typically, after two weeks, the leading batter often has an average of about .450. However, no batter in major league history has ever averaged .450 at the end of the season. Why do you think this is?
	Recognizing Biased and Unbiased Samples	Nisbett et al. (1983); Fong et al. (1986)	An economist was arguing in favor of a guaranteed minimum income for everyone. He cited a recent study of several hundred people in the United States with inherited wealth. Nearly 92% of those people, he said, worked at some job that provided earned income sufficient to provide at least a middle-class lifestyle. The study showed, he said, that contrary to popular opinion, people will work in preference to being idle. Thus a guaranteed income policy would result in little or no increase in the number of people unwilling to work. Comment on the economist's reasoning.
	Diagnostic Hypothesis Testing	Doherty & Mynatt (1990); Mynatt et al. (1993)	Imagine you are a doctor. A patient comes to you with a red rash on his fingers. What information would you want in order to diagnose whether the patient has the disease "Digirosa." Which of the following pieces of information are necessary to make the diagnosis? (a) percentage of people without Digirosa who have a red rash; (b) percentage of people with Digirosa; (c) percentage of people without Digirosa; (d) and percentage of people with Digirosa who have a red rash.
	Accurate Perception of Risks	Lichtenstein et al. (1978)	Consider all the people now living in the United States – children, adults, everyone. Which cause of death is more likely? (a) dying in a tornado; (b) dying of tuberculosis

(*continued*)

Table 39.1 (*continued*)

Crystallized Rationality: Crystallized Facilitators			
Major Dimensions	*Measurement Paradigms*	*Source for Paradigm*	*Example Item*
Qualitative Decision Theory Insights	Stable Preferences; Adherence to Basic Probability/Utility Trade-offs in SEU Theory; Preferences in Line with SEU Axioms	Moore (1999) or Lichtenstein & Slovic (1971, 1973); Frederick (2005) or Benjamin & Shapiro (2005); Birnbaum (1999)	Choose A or B: A. You get $0.40 for sure. B. If a die comes up 1, 2, or 3, you get $1.58. If a die comes up 4, 5, or 6, you get nothing.
Knowledge of Scientific Reasoning	Scientific Control Concepts; Causal Variable Isolation; Control Group Necessity; Understanding Placebo and Selection Effects	Greenhoot et al. (2004); Tschirgi (1980); Lehman et al. (1988); Lehman & Nisbett (1990)	The city of Middletown has had an unpopular police chief for the past 2 years. He is a political appointee who is a crony of the mayor and he had little previous experience in police administration when he was appointed. The mayor has recently defended the police chief in public, announcing that in the time since he took office, crime rates had decreased by 12%. What evidence would most refute the mayor's claim and instead show that the police chief may not be doing a good job?
	Avoidance of Confirmation Bias	Taber & Lodge (2006)	Search for pro or con information about a highly valenced issue (affirmative action, gun control, etc.)
	Diagnostic Covariation Judgment	Wasserman, Dörner, & Kao (1990)	Imagine that you are a research chemist for a pharmaceutical company. You want to assess how well a certain experimental drug works on psoriasis, a severe skin rash. In your experiment, you will give some rats the drug and others a placebo, which is known to have no effect on psoriasis. After the experiment, there will be four types of rats: Those who did not receive the drug and whose psoriasis did not improve . . . etc. Was the treatment effective?
	Covariation Detection Free of Belief Bias; Avoidance of Illusory Correlations	Stanovich & West (1998b); Fiedler (2004)	As the cell above except for an issue with valence and/or prior belief, such as: Do couples who live together before marriage have more successful marriages?

Crystallized Rationality: Crystallized Facilitators			
Major Dimensions	*Measurement Paradigms*	*Source for Paradigm*	*Example Item*
	Difference Between Correlation and Causation; Recognizing Spurious Correlation	Halpern (2008); Burns (1997)	A recent report in a magazine for parents and teachers showed that adolescents who smoke cigarettes also tend to get low grades in school. As the number of cigarettes smoked each day increased, grade-point averages decreased. One suggestion made in this report was that we could improve school achievement by preventing adolescents from smoking. Based on this information, would you support this idea as a way of improving the school achievement of adolescents who smoke?
	Understanding Falsifiability as a Context for Confirmation; Thinking of the Alternative Hypothesis	Oswald & Grosjean (2004) or Gale & Ball (2006) or Tweney et al. (1980)	I have made up a rule for the construction of sequences of numbers. For instance, the three numbers 2–4–6 satisfy this rule. To find out what the rule is, you may construct other sets of three numbers to test your assumption about what the rule is. I will give you feedback about whether your set satisfies my rule or not. If you are sure you have the solution, you may stop testing and tell me what you believe the rule to be. [the rule is "increasing numbers"]
	Differentiating Theory from Evidence	Kuhn (1991, 1992)	"How do you know that this is the cause?" "If you were trying to convince someone else that your view, [focal theory repeated here], is right, what evidence would you give to try to show this?"
	Appreciation of Converging Evidence	Stanovich (2010b)	The principle of converging evidence urges us to base conclusions on data that arise from a number of slightly different experimental sources.
	Appreciating the Limits of Personal Observation, Testimonials, and Single-Case Evidence	Jepson et al. (1983) and Halpern (2008)	The Caldwells looked in *Consumer Reports* and there they found that the consensus of the experts was that the Volvo was superior to the Saab. Mr. Caldwell called up friends. One Volvo owner hated his car. Which car do you think the Caldwells should buy?

(continued)

Table 39.1 (*continued*)

Crystallized Rationality: Crystallized Facilitators			
Major Dimensions	*Measurement Paradigms*	*Source for Paradigm*	*Example Item*
Rules of Logical Consistency and Validity	Logical Validity Judgment Tasks	Evans, Handley, Harper, & Johnson-Laird (1999)	For "All A are B" evaluate logically: 1. No A are B 2. Some A are B 3. Some A are not B 4. All B are A 5. No B are A 6. Some B are A 7. Some B are not A Answer: conclusions 2 and 6 are necessary; 4 and 7 are possible (but not necessary); and 1, 3, and 5 are impossible.
Economic Thinking	Cost/Benefit Reasoning; Limited Resource Reasoning	Larrick, et al. (1993) or NCEE (2005); Larrick, et al. (1990)	When a person rents an apartment, who benefits from the transaction?
	Recognizing Opportunity Costs	Larrick, et al. (1990); Thaler (1985, 1987)	What are the costs involved in attending university. List all of the costs you can.
	Avoiding Sunk Costs	Arkes & Blumer (1985)	You are staying in a hotel room on vacation. You paid $6.95 to see a movie on pay TV. After 5 minutes you are bored and the movie seems pretty bad. Would you continue to watch the movie or not?
	Understanding Externalities	Heath (2001)	A customer walks into a small convenience store and gives the store's owner $8 for a six-pack of beer. The owner of the store hands over the six-pack. After this transaction is complete, describe the gains and losses to everyone affected by this transaction.
	Awareness of the Logic of Exponential Growth and Compounding	Wagenaar & Sagaria (1975); Dorner (1996)	Pollution Index: 1970 – 3; 1971 – 7; 1972 – 20; 1973 – 55; 1974 – 148; 1975 – ?
	Understanding Commons Dilemmas, Zero-sum, and Nonzero-sum Games	Komorita & Parks (1994); Shafir & Tversky (1992)	Two players must choose to either cooperate or compete with the other player while being blind to the other's choice.

Crystallized Rationality: Crystallized Facilitators

Major Dimensions	*Measurement Paradigms*	*Source for Paradigm*	*Example Item*
	Recognizing Regression Effects that Encourage Buying High and Selling Low	Nisbett et al. (1983)	Harold, a boys' football coach, says the following of his experience: "Every year we add 10–20 younger boys to the team on the basis of their performance at the try-out practice. Usually the staff and I are extremely excited about two or three of these kids – but they usually turn out to be no better than the rest." Why do you suppose that the coach usually has to revise downward his opinion of players that he originally thought were brilliant?
	Appropriate Mental Accounting and Understanding of Fungibility	Thaler (1980, 1985, 1987)	Imagine that you go to purchase a calculator for $30. The salesperson informs you that the calculator you wish to buy is on sale for $20 at the other branch of the store which is 10 minutes away by car. Would you drive to the other store? Option A: Yes, Option B: No Imagine that you go to purchase a jacket for $250. The salesperson informs you that the jacket you wish to buy is on sale for $240 at the other branch of the store which is 10 minutes away by car. Would you drive to the other store? Option C: Yes, Option B: No

Crystallized Rationality: Crystallized Inhibitors

Superstitious Thinking and Belief in the Paranormal	Paranormal, Superstitious Thinking, and Luck scales; Illusion of Control	Stanovich (1989) or Tobacyk & Milford (1983); Fenton-O'Creevy et al. (2003) or Thompson (2004)	Agree or disagree: If you break a mirror, you will have bad luck.
Belief in the Superiority of Intuition	Faith in Intuition Scale	Epstein et al. (1996)	Agree or disagree: My initial impressions of people are almost always right.
Overreliance on Folk Wisdom and Folk Psychology	Bias Blind Spot Test	Pronin, Lin, & Ross (2002)	Psychologists have claimed that people show a "self-serving" tendency in that they take credit for success but deny responsibility for failure. Questions to participants: A. To what extent do you believe that *you* show this effect or tendency? B. To what extent do you believe the *average American* shows this effect or tendency?

(*continued*)

Table 39.1 (*continued*)

Crystallized Rationality: Crystallized Facilitators			
Major Dimensions	*Measurement Paradigms*	*Source for Paradigm*	*Example Item*
Belief in "Special" Expertise	High Value Placed on Nongrounded Knowledge Sources	Eckblad & Chapman (1983)	Agree or disagree: Horoscopes are right too often for it to be a coincidence.
Financial Misconceptions	Financial Literacy/Illiteracy Scales	Chen & Volpe (1998); Mandell (2009); NCEE (2005)	What is the best way to minimize the dollar amount in finance charges on a credit card?
Incorrigibility of Introspection (Overoptimistic Theories of One's Own Introspective Powers)	Accuracy of Affective Forecasting	Kermer, Driver-Linn, Wilson, & Gilbert (2006)	Part 1: How happy/sad do you think you will be if you win/lose this coin toss? Part 2: Now that you have won/lost the coin toss, how happy/sad are you right now?
	Bias Blind Spot Test	Pronin, Lin, & Ross (2002)	Psychologists have shown that people tend not to trust media sources that contradict their views. Questions to participants: A. To what extent do you believe that *you* show this effect or tendency? B. To what extent do you believe the *average American* shows this effect or tendency?
Dysfunctional Personal Beliefs	Measures of Irrational Personal Beliefs	Terjesen, Salhany, & Sciutto (2009) or Lindner et al. (1999)	Agree or disagree: If important people dislike me, it is because I am an unlikable, bad person
A Notion of Self that Encourages Egocentric Processing	Unbiased Processing of Evidence	Klaczynski & Gordon (1996)	Belief-consistent conclusions were drawn from those experiments which yielded results that cast participants' religions in a positive light. Belief-inconsistent conclusions were drawn from research that yielded results casting participants' religions in a negative light. Unbiasedness is defined as rating the quality of the experiment independent of its level of belief consistency.
	Self-Perception Biases and Unrealistic Optimism	Weinstein (1980)	Compared to other students – same sex as you – what do you think are the chances that the following events will happen to you: You will get a good job before graduation.

Even more important than these points, however, is that unlike many such lists of thinking skills in textbooks, the fluid characteristics and crystallized knowledge bases listed in Figure 39.5 are each grounded in a task or paradigm in the literature of cognitive science. That is, they are not just potentially measurable, but in fact have been operationalized and measured at least once in the scientific literature – and in many cases (e.g., context effects in decision making; tendency to enjoy thought; probabilistic reasoning) they have generated enormous empirical literatures.

Table 39.1 shows some of the paradigms that ground the component concepts and that could be used as the basis for constructing test items. There are many paradigms that have been used to measure the resistance to miserly information processing, the first major dimension of fluid rationality in Table 39.1. Many of these paradigms have been extensively investigated and have yielded tasks that could be used to devise assessment items. 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 many such items (Balcetis & Dunning, 2006; Dias, Roazzi, & Harris, 2005; Evans, Barston, & Pollard, 1983; Evans & Curtis-Holmes, 2005; Handley, Capon, Beveridge, Dennis, & Evans, 2004; Klaczynski & Lavallee, 2005; Klauer, Musch, & Naumer, 2000; Markovits & Nantel, 1989; Sá, West, & Stanovich, 1999).

Likewise, good decision making is in part defined by decisions that are not unduly affected by irrelevant context (the third major dimension of fluid rationality in Table 39.1). Two paradigms that assess the latter tendency have each generated enormous literatures. Resistance to framing has been measured with countless tasks (Epley, Mak, & Chen Idson, 2006; Friedrich, Lucas, & Hodell, 2005; Kahneman & Tversky, 1984, 2000; Levin et al., 2002; Maule & Villejoubert, 2007; Schneider, Burke, Solomonson, & Laurion, 2005; Tversky & Kahneman, 1981, 1986), as has the resistance to irrelevant anchoring in decisions (Brewer & Chapman, 2002; Epley & Gilovich, 2004, 2006; Jacowitz & Kahneman, 1995; LeBoeuf & Shafir, 2006; Mussweiler & Englich, 2005; Tversky & Kahneman, 1974).

As a final example of an area of rational thinking with a history dense with empirical research and with paradigms that could serve as assessment devices, consider the tendency to conform, qualitatively, to the insights of normative decision theory – the second major dimension of crystallized rationality facilitators in Table 39.1. Since the early 1950s (see Edwards, 1954), psychologists have studied the tendency to adhere to the axioms of expected utility theory with a variety of tasks and paradigms (Baron, 2008; Dawes, 1998; Kahneman & Tversky, 2000; Koehler & Harvey, 2004; Nickerson, 2004, 2008; Shafir & LeBoeuf, 2002; Tversky, 2003; Wu et al., 2004).

Not all of the concepts of rational thought listed in Table 39.1 have potential measurement paradigms with as much background research on them as those discussed here, but in fact *most* of them do. For the reader not as conversant with the literature of cognitive psychology as the last several paragraphs have presumed, we have listed in Table 39.1 a source for each of the potential measurement paradigms. That is, Table 39.1 points the reader to specific studies or review papers in the research literature that contain examples of tasks that could be adapted to serve as actual test items. In most cases, the citations in Table 39.1 will allow the reader to uncover an extensive literature on such tasks (as in the examples in the previous paragraphs). At a minimum, the citations provide clear guidance on how such task items might be developed.

The citations in Table 39.1 are to papers that will lead the reader to empirical studies containing measurement paradigms that would make a good source of assessment items. The citation is *not* intended as a reference to the classic introduction to the effect, or to the paper with priority of discovery, or to the most historic or most cited paper. This is because often the best source for test items is not the paper in which the effect/task was introduced. For example, for framing effects (the first measurement paradigm from the top under fluid rationality) we have listed Frisch (1993) as the pointer citation because it contains a large number of framing items (we could equally have cited Levin et al., 1998, 2002) rather than the classic Tversky and Kahneman (1981) paper where framing was introduced with the now-famous Asian Disease problem.

In the far right column of Table 39.1 is an example of an item type from each of the measurement paradigms. The reader is warned that because of the size of the table (i.e., number of different paradigms), many of these items have been truncated, abridged, or paraphrased so that they would fit into a reasonable space. They are not meant to be literal exemplars that could be immediately inserted into a test but are there merely to give the reader unfamiliar with the measurement paradigm a flavor of what is being measured. Items of that type are explicated in detail in the citations given.

Some measurement paradigms appear in Table 39.1 more than once. For example, diagnostic hypothesis testing appears as a measure of resistance to miserly processing and as a measure of probabilistic reasoning. Likewise, the accuracy of affective forecasting appears as a measure of resistance to miserly processing and as a measure of contaminated mindware (belief in absolutely accurate introspection). These measurement paradigms are complex in this manner simply because some tasks measure more than one rationality dimension.

Table 39.1 illustrates the basis for our statement that there is no *conceptual* barrier to creating a test of rational thinking. However, this does not mean that it would be *logistically* easy. Quite the contrary, we have stressed that both fluid and crystallized rationality are likely to be more multifarious than their analogous intelligence constructs. Likewise, we are not claiming that there exist comprehensive assessment devices for each of these components with adequate psychometric properties. However, in virtually every case, laboratory tasks that have appeared in the published literature give us, at a minimum, a hint at what comprehensive assessment of the particular component would look like. In fact, in some cases, there do exist fully developed measures with adequate psychometric properties (for example, measures of self efficacy, see Lefcourt, 1991).

Thus, Table 39.1 displays, in visual form, what we mean by claiming that the measurement of rational thought is conceptually possible with the use of currently available instruments. Nonetheless, the complexity of the table illustrates that measuring rational thought could be logistically daunting. For example, the factor structure of the table is still undetermined. We do not know the correlational relationships between the major dimensions or the measurement paradigms. This means that we do not know whether it might be possible to measure several features by measuring one with high multicollinearity.

Work on the structure of rational thought is nascent, but there are indications that there may be considerable separability in these components (Bruine de Bruin et al., 2007; Klaczynski, 2001; Parker & Fischhoff, 2005; Slugoski, Shields, & Dawson, 1993; Stanovich & West, 1998a, West et al., 2008). It may be that to get reasonable coverage of the domains listed in Table 39.1 each of the domains would have to be assessed separately. It might be that a comprehensive assessment of rational thought could not be accomplished in a single sitting. Although this represents a logistical problem, a diffuse factor structure does not negate the importance of assessing individual differences in rational thought. Rational thought does not require a *g* factor in order to justify its measurement. More important will be research linking these rational thinking tendencies to real-life decision making, and a reasonable amount of such research has already been conducted (Baron, Bazerman, & Shonk, 2006; Camerer, 2000; Fenton-O'Creevy, et al., 2003; Groopman, 2007; Hilton, 2003; Milkman, Rogers, & Bazerman, 2008; Thaler & Sunstein, 2008)

In short, the assessment of rational thought will be determined by the importance of the content domains listed in

Table 39.1 and by the fact that they fit within extant conceptual models of reasoning and judgment. Their importance, and hence the necessity for assessment, stands or falls on the conceptual model, not on any future psychometric finding. An oversimplified example will illustrate the point. Imagine that highway safety researchers found that braking skill was causally associated with lifetime automobile accident frequency, that knowledge of the road rules was causally associated with lifetime automobile accident frequency, that city driving skill was causally associated with lifetime automobile accident frequency, that cornering skill was causally associated with lifetime automobile accident frequency, that defensive driving was causally associated with lifetime automobile accident frequency, and a host of other relationships. In short, these skills, collectively, define a construct called "overall driver skill." Now we could in fact ask of these studies whether driving skill is a *g* factor or whether it is really 50 little separate skills. But the point is that the outcome of the investigation of the structure of individual differences in driving skill would have no effect on the conceptual definition of what driving skill is. It may have logistical implications for measurement, however. Skills that are highly correlated might not all have to be assessed to get a good individual difference metric. But if they were all causally related to accident frequency, they would remain part of the conceptual definition of overall driver skill.

It is likewise with rational thinking. There is independent evidence in the literature of cognitive science that the cognitive components in Table 39.1 form part of the conceptual definition of rational thought. 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. It would, however, have logistical implications by making the assessment of rational thought time-consuming and unwieldy. 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 research group has contributed to clarifying that structure. We have found that certain rational thinking tasks consistently correlate with each other even after cognitive ability has been partialed 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 partialed out (Stanovich & West, 1998a; West et al., 2008). Additionally, our group has consistently found rational tasks that are predicted by thinking dispositions after cognitive ability has been partialed – particularly tasks involving statistical reasoning and informal argumentation (Kokis et al., 2002; Stanovich & West, 1997, 1998a; West et al., 2008).

Our point here, though, is to emphasize that the importance of assessing rational thought is not contingent on any empirical outcome – and it especially is not contingent on any type of psychometric outcome. We want to spur efforts at assessing components of rational thought, and thus in this early stage of the endeavor we do not want the effort to be impeded by unthoughtful protests that it cannot be measured because its psychometric structure is uncertain. That structure will become clarified once our call for greater attention to the measurement of this domain is heeded. We do not fail to measure something because of lack of knowledge of the full structure of its domain. We would not fail to measure braking skill if we were ignorant of its relationship to cornering ability or knowledge of road rules.

If neither the fluid nor the crystallized components of rational thought cluster in the manner of a *g* factor (which we suspect), then rational thought will be a difficult concept to practically assess in its entirety. But again, we should not shirk from measuring something just because it is logistically difficult – particularly if the domain is important. Economists and public policy experts measured the size of their country's GDP in 1935 despite (by present standards) primitive statistical tools and data gathering technology. The myriad components of the GDP (wheat, corn, ingots produced, heavy machinery produced, clothing, financial services, etc.) were each an important component of GDP in and of themselves, and it was not an argument against measuring them that they were hard to measure, that there were myriad components, and that we did not know how all of the components hung together statistically. In 1935, economists measured what they could with the tools they had, and they simply hoped that better knowledge via better tools lay in the future. We are at a similar juncture in the measurement of the multifarious concept of rational thought.

The Rationality Concept Is Superordinate to Critical Thinking as Well as Intelligence

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. Like the study of wisdom (Sternberg, 2001, 2003; Sternberg & Jordan, 2005), the study of rational thinking is a normative/evaluative endeavor (Lee, 2008). 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 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 a normative model of what we mean by better thinking (Baron, 1993, 2008).

A somewhat analogous issue arises 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 to foster multiplist and evaluative thinking (Kuhn, 1993, 2001, 2005; Kuhn & Udell, 2007) rather than absolutist thinking? 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). We value certain thinking dispositions because we think that they will at least aid in bringing belief in line with the world and in achieving our goals. By a parallel argument, we could equally well claim that the superordinate goal is to educate for wisdom (Sternberg, 2001, 2002a, 2003).

We can see that it is rationality, and not critical thinking per se, that is the higher level goal by conducting some simple thought experiments or imaginative hypotheticals. For example, we could imagine a person with excellent epistemic rationality (his or her degree of confidence in propositions being well calibrated to the available evidence relevant to the proposition) and optimal practical rationality (the person optimally satisfies desires) who was *not* actively open-minded – that is, who was not a good critical thinker under standard assumptions. Of course, we would still want to mold such an individual's dispositions in the direction of open-mindedness for the sake of society as a whole. But the essential point for the present discussion is that, from a purely *individual* perspective, we would now be hard-pressed to find reasons for *wanting* to change such a person's thinking dispositions if – whatever they were – they had led to rational thought and action in the past.

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 – or as Sternberg (2001, 2005) argues, a wiser, less foolish person. 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, 2010; Reyna, 2004; Siegel, 1988, 1997). Grounding critical thinking within the concept of rationality in this manner has an advantage because the concept of rationality is deeply intertwined with the data and theory of modern cognitive science (see LeBoeuf & Shafir, 2005; Over, 2004; Samuels & Stich, 2004; Stanovich, 2004, 2009) in a way that the concept of critical thinking is not.

In short, our theoretical argument seeks to "tame" the concept of critical thinking by pointing out that it does not trump the concept of rationality. Likewise, we hope in this chapter to open up some space for rationality in the lexicon of the mental and, in doing so, tame the intelligence concept. Our goal is to prevent the intelligence concept from absorbing the concept of rationality – something that IQ tests do not measure. Restricting the term *intelligence* to what the tests actually measure has the advantage of getting usage in line with the real world of measurement and testing. 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.

The tripartite model of mind presented in this chapter explains why rationality is a more encompassing construct than intelligence. Rationality requires the proper functioning of both the reflective and the algorithmic mind. In contrast, intelligence tests index the computational power of the algorithmic mind. Likewise, the construct of critical thinking is subsumed under the construct of rationality. For example, the processes of critical thinking are often summarized as a set of thinking dispositions that must be developed or inhibited: need for cognition, actively open-minded thinking, belief identification, consideration of future consequences, reflectivity/impulsivity, rational/experiential orientation, need for closure, openness, conscientiousness, and so on. These thinking dispositions are the individual difference constructs that capture fluid rationality in the tripartite model (see Figure 39.5 and Table 39.1).

It is important to note that the thinking dispositions of the reflective mind are the psychological mechanisms that underlie rational thought. *Maximizing* these dispositions is *not* the criterion of rational thought itself. Rationality involves instead the maximization of goal achievement via judicious decision making and optimizing the fit of belief to evidence. The thinking dispositions of the reflective mind are a *means* to these ends. Certainly high levels of such commonly studied dispositions as reflectivity and belief flexibility are needed for rational thought and action. But high levels do not necessarily mean the maximal level. One does not maximize the reflectivity dimension, for example, because such a person might get lost in interminable pondering and never make a decision. Likewise, one does not maximize the thinking disposition of belief flexibility either, because such a person might end up with a pathologically unstable personality. Reflectivity and belief flexibility are "good" cognitive styles (in that most people are not high enough on these dimensions, so that more would be better), but they are not meant to be maximized.

In the context of this model (see Figures 39.3 and 39.4), rationality requires three things: the propensity to override suboptimal responses from the autonomous mind; the algorithmic capacity to inhibit the suboptimal response and to simulate an alternative; and finally the presence of the mindware that allows the computation of an alternative response. The propensity to override suboptimal responses from the autonomous mind – a property of the reflective mind – captures virtually all of the propensities of critical thinking that have been discussed in the traditional literature on that construct. The algorithmic capacity to inhibit the suboptimal response and to simulate an alternative is captured in standard tests of fluid intelligence such as the Raven Matrices.

We can further tame the intelligence concept in folk psychology by pointing out that there are legitimate scientific terms for the other valued parts of cognitive life and that some of these are measurable. This strategy uses to advantage a fact of life that many IQ-test critics have lamented – that intelligence tests are not going to change any time soon. The tests have the label "intelligence" and thus what they measure will always be dominant in the folk psychology of intelligence. We would argue that it is mistake to ignore this fact. The tests do not measure rationality, and thus the ability to think rationality will be a subordinate consideration in our schools, in our employment selection devices, and in our society as a whole as long as we conflate it with intelligence. We have tried to separate the two here by showing that they are conceptually different and by showing that rationality is in principle measurable in ways very much like intelligence is measured by IQ tests.

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