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THE DEVELOPMENT OF RATIONAL THOUGHT: A TAXONOMY OF HEURISTICS AND BIASES

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I. Introduction

The most well-known indicators of cognitive functioning, intelligence and cognitive ability tests, do not assess a critical aspect of thinking—the ability to think rationally. 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;

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Stanovich, 2002, 2008c; 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 at all 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 at all whether a person has the tendency to *form* beliefs rationally when presented with evidence. And again, similarly, 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.

Variation in intelligence has been one of the most studied topics in psychology for many decades (Deary, 2001; Geary, 2005; Lubinski, 2004), and the development of the cognitive abilities related to intelligence is likewise a central topic in developmental science (Anderson, 2005; Bjorklund, 2004; Kail, 2000). In contrast, variation in rational thought among adults has only recently been the focus of research (Bruine de Bruin, Parker, & Fischhoff, 2007; Stanovich & West, 1998b, 2000). Similarly, the empirical literature on the development of rational thinking is still relatively sparse (see Byrnes, 1998; Klaczynski, 2001a; Kokis *et al.*, 2002; Reyna, Lloyd, & Brainerd, 2003). In this chapter, we summarize some of the existing work on the development of rational thought and we attempt to provoke more such work by providing a framework for classifying rational thinking errors.

II. Experimentally Tractable Definitions of Rational Thought

Cognitive scientists recognize two types of rationality: instrumental and epistemic. The simplest definition of instrumental rationality is: Behaving in the world so that you get exactly what you most want, given the resources (physical and mental) available to you. 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 the option which has the largest expected utility (see 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. The aspect of beliefs that enter into instrumental calculations (i.e., tacit calculations) are the probabilities of states of affairs in the world.

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, test hypotheses inefficiently, display preference inconsistencies, do not properly calibrate degrees of belief, overproject their own opinions onto others, combine probabilities incoherently, and allow prior knowledge to become implicated in deductive reasoning (for summaries of the large literature, see Baron, 2000; Evans, 1989, 2007; Gilovich, Griffin, & Kahneman, 2002; Kahneman & Tversky, 2000; Shafir & LeBoeuf, 2002; Stanovich, 1999, 2004). These violations of rational strictures have spawned the biases that have been conjectured to explain the irrational thinking: 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. Failure to display a bias becomes a measure of rational thought.

The thinking errors and biases that have been demonstrated in the judgment and decision-making literature have proliferated to the extent that a taxonomy of these systematic error types is badly needed. We have developed a taxonomy for the adult literature (Stanovich, 2008a, 2008b; Toplak *et al.*, 2007), and in the remainder of this chapter will demonstrate its applicability to the sparse but growing literature on the development of rational thought. The taxonomy builds on the concepts of dual-process theories of cognition. Because such theories have been discussed previously in *Advances* (see Klaczynski, 2004), we shall provide only a brief introduction in Section III before moving on to introduce the taxonomy.

III. Dual-Process Models of Cognition

Virtually all attempts to classify heuristics and biases tasks end up utilizing a dual-process framework because most of the tasks in the heuristics and biases literature were deliberately designed to pit a heuristically triggered response against a normative response generated by the analytic system. As Kahneman (2000) notes, "Tversky and I always thought of the heuristics and biases approach as a two-process theory" (p. 682). Since Kahneman and Tversky launched the heuristics and biases approach in the 1970s, a wealth of evidence has accumulated in support of the dual-process approach. Evidence from cognitive neuroscience and cognitive psychology converges on the conclusion that mental functioning can be characterized by two different types of cognition having somewhat different functions and different strengths and weaknesses (Brainerd & Reyna, 2001; Evans, 2003, 2008a, 2008b; Evans & Over, 1996, 2004; Kahneman & Frederick, 2002, 2005; Metcalfe & Mischel, 1999; Sloman, 1996, 2002; Stanovich, 1999).

There are many such theories (over 20 dual-process theories are presented by 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 (2008b) 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 do not depend on input from high-level control systems, and (5) they can operate in parallel without interfering with each other 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, 2008a; Stanovich, 2004).

Type 2 processing contrasts with Type 1 processing on each of the critical properties that define the latter. Type 2 processing is relatively slow and computationally expensive—it is the focus of our awareness. Many Type 1 processes can operate at once in parallel, but only one (or a very few) Type 2 thoughts can be executing at once—Type 2 processing is thus serial processing. Type 2 processing is often language based.

One of the most critical functions of Type 2 processing is to override Type 1 processing. All of the different kinds of Type 1 processing (processes of emotional regulation, Darwinian modules, associative and implicit learning processes) can produce responses that are 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 recent work on executive functioning (Hasher, Lustig, & Zacks, 2007; Miyake *et al.*, 2000; Zelazo, 2004).

But 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; Kahneman & Tversky, 1982; Nichols & Stich, 2003). When we reason hypothetically, we create temporary models of the world and test out actions (or alternative causes) in that simulated world. 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. But the latter must not infect the former while the mental simulation is being carried out. Thus, 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 do any other Type 2 operation. In fact, decoupling operations might well be a major contributor to a distinctive Type 2 property—its seriality.

Cognitive decoupling must take place when an individual engages in a simulation of alternative worlds in order to solve a problem. Problem-solving tasks that necessitate fully disjunctive reasoning (see Johnson-Laird, 2006; Shafir, 1994) provide examples of the situations that require fully decoupled simulation. Fully disjunctive reasoning involves considering all possible states of the world when deciding among options or when choosing a problem solution in a reasoning task. Consider the following problem, taken from the work of Levesque (1986, 1989) and studied by our research group (see Toplak & Stanovich, 2002): Jack is looking at Anne but Anne 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

The vast majority of people answer (C) (cannot be determined) when in fact the correct answer to this problem is (A) (yes). To answer correctly, both possibilities for Anne's marital status (married and unmarried) must be considered to determine whether a conclusion can be drawn. If Anne is married, then the answer is "Yes" because she would be looking at George who is unmarried. If Anne is not married, then the answer is still "Yes" because Jack, who is married, would be looking at Anne. Considering all the possibilities (the fully disjunctive reasoning strategy) reveals that a married person is looking at an unmarried person whether Anne is married or not. The fact that the problem does not *reveal* whether Anne is married suggests to people that nothing can be determined. Many people make the easiest (incorrect) inference from the information given and do not proceed with the more difficult (but correct) inference that follows from fully disjunctive reasoning.

Not all Type 2 processing represents fully explicit cognitive simulation, however. Or, to put it another way: all hypothetical thinking involves Type 2 processing (Evans & Over, 2004), but not all Type 2 processing involves hypothetical thinking. What has been termed serial associative cognition (Stanovich, 2008a) represents this latter category. It can be understood by considering a discussion of the four-card selection task in a theoretical paper on dual-processes by Evans (2006) (see also Evans & Over, 2004). In Wason's (1966) four-card selection task the participant is told the following:

> Each of the boxes below represents a card lying on a table. Each one of the cards has a letter on one side and a number on the other side. Here is a rule: If a card has a vowel on its letter side, then it has an even number on its number side. As you can see, two of the cards are letter-side up, and two of the cards are number-side up. Your task is to decide which card or cards must be turned over in order to find out whether the rule is true or false. Indicate which cards must be turned over.

The participant chooses from four cards labeled K, A, 8, 5 (corresponding to not-P, P, Q, and not-Q). The correct answer is to pick the A and the 5 (P and not-Q), but the most common answer is to pick the A and 8 (P and Q)—the so-called matching response.

Evans (2006) points out that the previous emphasis on the matching bias evident in the task (Evans, 1972, 1998, 2002; Evans & Lynch, 1973) might have led some investigators to infer that the analytic system is not actively engaged in the task. In fact, matching bias might be viewed as just one of several such suggestions in the literature that much thinking during the task is Type 1 processing (see Hardman, 1998; Margolis, 1987; Stanovich & West, 1998a; Tweney & Yachanin, 1985). In contrast, however, Evans (2006) presents evidence indicating that Type 2 processing may be going on during the task—even on the part of the majority who do not give the normatively correct response but instead give the PQ response.

First, in discussing the card inspection paradigm (Evans, 1996) that he pioneered (see also Ball *et al.*, 2003; Lucas & Ball, 2005; Roberts & Newton, 2001), Evans (2006) notes that although participants look disproportionately at the cards they will choose (the finding leading to the inference that heuristic processes were determining the responses), the lengthy amount of time they spend on those cards suggests that analytic thought (Type 2 processing) is occurring (if only to generate justification for the heuristically triggered choices). Secondly, in verbal protocol studies, participants can justify their responses (indeed, can rationalize any set of responses they are told are correct; see Evans & Wason, 1976) with arguments that sometimes refer to the hidden side of cards chosen.

In fact, Type 2 processing is occurring in this task, but it is not full-blown cognitive simulation of alternative world models. It is thinking of a shallower type—serial associative cognition. Serial associative cognition is not rapid and parallel like Type 1 processes, but is nonetheless rather inflexibly locked into an associative mode that takes as its starting point a model of the world that is *given* to the subject. In the inspection paradigm, individuals are justifying heuristically chosen responses (P and Q for the standard form of the problem), and the heuristically chosen responses are driven by the model given to the participant by the rule.

Likewise, Evans and Over (2004) note that in the studies of verbal protocols, when participants made an incorrect choice, they referred to the hidden sides of the cards they are going to pick, but referred only to verification when they did so. Thus, the evidence suggests that people accept the rule as given, assume it is true, and simply describe how they would go about verifying it. The fact that they refer to hidden sides does not mean that they have constructed any alternative model of the situation beyond what was given to them by the experimenter and their own assumption that the rule is true. They then reason from this single focal model—systematically generating associations from this focal model but never constructing another model of the situation. This is why the central characteristic of serial associative cognition is that it displays a *focal bias*.

One way in which to contextualize the idea of focal bias is as the second stage in a framework for thinking about human information processing that dates to the mid-1970s—the idea of humans as cognitive misers (Dawes, 1976; Taylor, 1981; Tversky & Kahneman, 1974). There are in fact two aspects of cognitive miserliness. Dual-process theory has heretofore highlighted only Rule 1 of the cognitive miser: default to Type 1 processing whenever possible. But defaulting to Type 1 processing is not always possible—particularly in novel situations where there are no stimuli available to domain-specific evolutionary modules. Type 2 processing procedures will be necessary, but a cognitive miser default is operating even there. Rule 2 of the cognitive miser is that, when Type 1 processing will not yield a solution: default to serial associative cognition with a focal bias (*not* fully decoupled cognitive simulation).

The notion of a focal bias conjoins several closely related ideas in the literature—Evans, Over, and Handley's (2003) singularity principle, Johnson-Laird's (1999, 2005) principle of truth, focusing (Legrenzi, Girotto, & Johnson-Laird, 1993), the effect/effort issues discussed by Sperber, Cara, and Girotto (1995), and finally the focalism (Wilson *et al.*, 2000) and belief acceptance (Gilbert, 1991) issues that have been prominent in the social psychological literature. Our notion of focal bias conjoins many of these ideas under the overarching theme that they all have in common—that humans will find any way they can to ease the cognitive load and process less information. Focal bias combines all of these tendencies into the basic idea that the information processor is strongly disposed to deal only with the most easily constructed cognitive model.

So the focal model that will dominate processing—the only model that serial associative cognition deals with—is the most easily constructed model. The most easily constructed model: tends to represent only one state of affairs; it accepts what is directly presented and models what is presented as true; it ignores moderating factors—probably because taking account of those factors would necessitate modeling several alternative worlds and this is just what a focal processing allows us to avoid. And finally, given the voluminous literature in cognitive science on belief bias and the informal reasoning literature on myside bias, the easiest models to represent clearly appear to be those closest to what a person already believes and has modeled previously (e.g., Evans & Feeney, 2004; Stanovich & West, 2007).

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

IV. A Preliminary Taxonomy of Rational Thinking Errors

To this brief overview of the architectural assumptions of dual-process theory, we need to add one reminder before proceeding to outline our taxonomy. That reminder is about the importance of knowledge bases. An aspect of dual-process theory that has been relatively neglected is that the override process is not simply procedural but instead utilizes content—that is, it uses declarative knowledge and strategic rules (linguistically coded strategies) to transform a decoupled representation. In the previous dual-process literature, override has been treated as a somewhat disembodied process. The knowledge bases and strategies that are brought to bear on the secondary representations during the simulation process have been given little attention. Thus it is important to remember that Type 2 processes access not only knowledge structures but, importantly, accesses the person's opinions, beliefs, and reflectively acquired goal structure. Also accessed are micro-strategies for cognitive operations and production system rules for sequencing behaviors and thoughts. Likewise Type 1 processing implicates not only encapsulated knowledge bases from evolutionary adaptations, but also information that has become tightly compiled and available to the Type 1 processing of the autonomous mind due to overlearning and practice.

The rules, procedures, and strategies that can be retrieved and used to transform decoupled representations have been referred to as mindware (Perkins, 1995). If one is going to trump a Type 1 response with conflicting information or a learned rule, one must have previously learned the information or the rule. If, in fact, the relevant mindware is not available because it has not been learned, then the cause of the thinking error will be missing mindware rather than override failure. This distinction in fact represents the beginning of a taxonomy of the causes of cognitive failure related to rational behavior that we have used to organize the heuristics and biases literature (Stanovich, 2008a, 2008b), and to classify various practical problems of rational thinking—for example, to understand the thinking problems of pathological gamblers (Toplak *et al.*, 2007).

Figure 1 presents an initial attempt at a taxonomy of rational thinking problems. Presented at the top of Figure 1 are the two defaults of the cognitive miser listed in order of relative cognitive engagement. The characteristic presented first is defaulting to the response options primed by Type 1 processing. It represents the shallowest kind of processing because

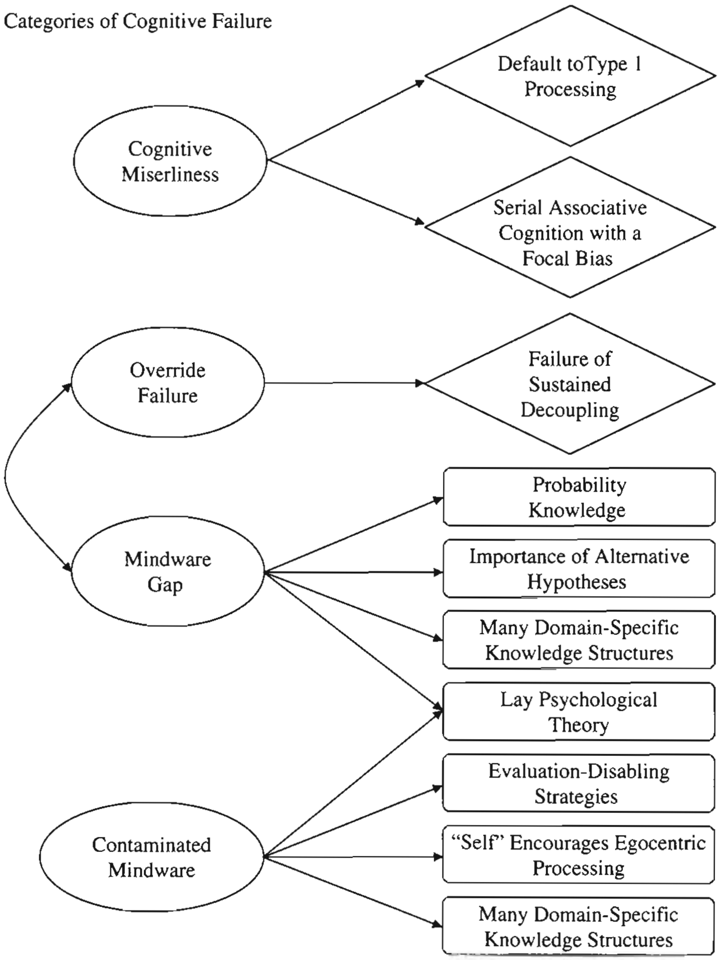

Fig. 1. A preliminary taxonomy of thinking errors.

no Type 2 processing is done at all. The second type of processing tendency of the cognitive miser is to engage in serial associative cognition with a focal bias. This characteristic represents a tendency to over-economize during Type 2 processing—specifically, to fail to engage in the full-blown simulation of alternative worlds or to engage in fully disjunctive reasoning.

The third category of rational thinking problems represented is that of override failure. Here, unlike in the first two cases, Type 2 cognitive decoupling is engaged. Inhibitory Type 2 processes try to take the Type 1 processing offline, but they fail. So in override failure, cognitive decoupling does take place, but it fails to suppress Type 1 processing.

Portrayed next in Figure 1 are categories of cognitive failure that are related to mindware problems. Mindware problems are divided into mindware gaps and contaminated mindware. When an override of Type 1 processing is necessary but the mindware necessary for a substitute response is not available, then we have a case of a mindware gap. Although mindware gaps may lead to sub-optimal reasoning, the next category in the taxonomy is designed to draw attention to the fact that not all mindware is helpful—either to goal attainment or to epistemic accuracy. In fact, some acquired mindware can be the direct cause of irrational actions that thwart our goals. Such effects thus define another category in the taxonomy of cognitive failures: contaminated mindware.

Turning first to the category of mindware gaps, the curved rectangles in the figure are meant to represent missing knowledge bases. We have not represented an exhaustive set of knowledge partitionings—to the contrary, we have represented a minimal sampling of a potentially large set of coherent knowledge bases in the domains of probabilistic reasoning, causal reasoning, logic, and scientific thinking, the absence of which could result in irrational thought or behavior. The two represented are mindware categories that have been implicated in research in the heuristics and biases tradition: missing knowledge about probability and probabilistic reasoning strategies; and ignoring alternative hypotheses when evaluating hypotheses. These are just a few of many mindware gaps that have been suggested in the literature on behavioral decision making. There are many others, and the box labeled "Many Domain-Specific Knowledge Structures" indicates this.

Finally, at the bottom of Figure 1 is the category of contaminated mindware. The curved rectangles represent problematic knowledge and strategies. They do not represent an exhaustive partitioning (the mindware-related categories are too diverse for that), but instead represent some of the mechanisms that have received some discussion in the literature. First is a subcategory of contaminated mindware that is much discussed in the literature—mindware that contains evaluation-disabling properties.

Some of the evaluation-disabling properties that help keep some mindware lodged in their hosts are: the promise of punishment if the mindware is questioned; the promise of rewards for unquestioning faith in the mindware; or the thwarting of evaluation attempts by rendering the mindware unfalsifiable (Dawkins, 1993; Dennett, 2006; Lynch, 1996; Stanovich, 2004).

The second subcategory of contaminated mindware that has been discussed by several theorists is a concept of "self" that serves to encourage egocentric thinking (Blackmore, 1999; Dennett, 1991, 1995). The self, according to these theorists, is a mechanism that fosters one characteristic of focal bias: that we tend to build models of the world from a single myside perspective. The egocentrism of the self was of course evolutionarily adaptive. Nonetheless, it is sometimes nonoptimal in a technological environment different from the environment of evolutionary adaptation. For example, myside processing makes difficult such modern demands as: unbiasedness; sanctioning of nepotism; and discouragement of familial, racial, and religious discrimination. Finally, the last subcategory of contaminated mindware pictured in Figure 1 is meant to represent what is actually a whole set of categories: mindware representing specific categories of information or maladaptive culturally conditioned beliefs. As with the mindware gap category, there may be a large number of misinformation-filled or contaminated mindware that would support irrational thought and behavior.

Lay psychological theory (or, folk theory) refers to the theories that people have about their own minds and is represented as both contaminated mindware and a mindware gap in Figure 1. Mindware gaps in this domain would be represented by the many things about our own minds that we do not know; for example, how quickly we will adapt to both fortunate and unfortunate events (Gilbert, 2006). Other things we think we know about our own minds are wrong. These misconceptions represent contaminated mindware. An example would be the folk belief that we accurately know our own minds. This contaminated mindware accounts for the incorrect belief that we always know the causes of our own actions (Nisbett & Wilson, 1977) and thinking that although others display myside and other thinking biases, we ourselves have special immunity from the very same biases (Ehrlinger, Gilovich, & Ross, 2005; Pronin, 2006).

Finally, note the curved, double-headed arrow in Figure 1 indicating an important relation between the override failure category and the mindware gap category. In case of override failure, an attempt must be made to trump a response primed by Type 1 processing with alternative information or a learned rule. For an error to be classified as an override failure, one must have previously learned the alternative information or an alternative rule different from the Type 1 response. If, in fact, the relevant mindware is not available because it has not been learned—or at least not learned to the requisite level to sustain override—then we have a case of a mindware gap rather than override failure.

Note one interesting implication of the relation between override failure and mindware gaps—the fewer gaps one has, the more likely that an error may be attributable to override failure. Errors made by someone with considerable mindware installed are more likely to be due to override failure than to mindware gaps. Of course, the two categories trade off in a continuous manner with a fuzzy boundary between them. A well-learned rule not appropriately applied is a case of override failure. As the rule is less and less well instantiated, at some point it is so poorly compiled that it is not a candidate to override the Type 1 response and thus the processing error becomes a mindware gap.

V. Classifying Heuristics and Biases

Table I classifies many of the thinking errors discussed in the heuristics and biases literature in terms of the taxonomy in Figure 1. For example, the three Xs in the first column signify three phenomena that represent defaulting to Type 1 processing: vividness effects, affect substitution, and impulsively associative thinking. Defaulting to the most vivid stimulus is a common way that the cognitive miser avoids Type 2 processing (Nisbett & Ross, 1980). Likewise defaulting to affective valence is often used in situations with emotional salience. And affect substitution is a specific form of a more generic trick of the cognitive miser, attribute substitution (Kahneman & Frederick, 2002)—substituting for a hard question an easier one that requires only Type 1 processing. Previously, we discussed a disjunctive reasoning problem from the work of Levesque (1986, 1989): "Jack is looking at Anne but Anne is looking at George." Failure on problems of this type is an example of the intellectual laziness termed impulsively associative thinking (Stanovich, 2008a, 2008b). Here, participants look for any simple association that will prevent them from having to engage in Type 2 thought (in this case associating Anne's unknown status with the response "cannot be determined").

The second category of thinking error presented in Table I is overreliance on serial associative cognition with a focal bias (the most easily constructed model). This error often occurs in novel situations where some Type 2 processing is necessary. Framing effects are the example here ("the basic principle of framing is the passive acceptance of the formulation given," p. 703, Kahneman, 2003). The frame presented to the subject is

Table I
A Basic Taxonomy of Thinking Errors

Tasks, effects, and processing styles	The cognitive miser		Override failure	Mindware gaps (MG)		MG and CM	Contaminated mindware (CM)	
	Default to Type 1 processing	Focal bias	Failure of sustained decoupling	Probability knowledge	Alternative thinking	Lay psychological theory	Evaluation disabling strategies	Self and egocentric processing
Vividness effects	X							
Attribute substitution	X							
Impulsively associative thinking	X							
Framing effects		X						
Denominator neglect			X					
Belief bias			X					
Self-control problems			X					
Conjunction errors				X				
Noncausal baserates				X				
Bias blind spot						X		
Four-card selection		X			X			
Myside processing		X						X
Affective forecasting errors		X				X		
Confirmation bias		X			X		X	

taken as focal, and all subsequent thought derives from it rather than from alternative framings because the latter would require more thought.

Pure override failure—the third category of thinking errors presented in Table I—is illustrated by three effects: belief bias effects (e.g., De Neys, 2006; Dias, Roazzi, & Harris, 2005; Evans, 2007; Evans, Barston, & Pollard, 1983; Evans & Curtis-Holmes, 2005; Evans & Feeney, 2004; Markovits & Nantel, 1989), denominator neglect (Denes-Raj & Epstein, 1994; Kirkpatrick & Epstein, 1992; Pacini & Epstein, 1999) and self-control problems such as the inability to delay gratification (Ainslie, 2001; Baumeister & Vohs, 2007; Loewenstein, Read, & Baumeister, 2003; Mischel, Shoda, & Rodriguez, 1989; Rachlin, 2000). (Belief bias and denominator neglect are discussed below).

Table I also portrays two examples of mindware gaps related to missing probability knowledge: noncausal base-rate usage and conjunction errors (Kahneman & Tversky, 1972, 1973; Tversky & Kahneman, 1983). Listed next is the bias blind spot—the fact that people view other people as more biased than themselves (Pronin, 2006). The bias blind spot is thought to arise because people have incorrect lay psychological theories. They think, incorrectly, that biased thinking on their part would be detectable by conscious introspection. In fact, most social and cognitive biases operate unconsciously.

Several of the remaining tasks illustrated in Table I represent irrational thought problems that are hybrids. That is, they are co-determined by several different cognitive difficulties. For example, we speculate that problems with the Wason four-card selection task (Evans, 2007; Wason, 1966, 1968) are multiply determined. People may have trouble with that task because they have not well instantiated the mindware of alternative thinking—the learned rule of the value in thinking of the false situation or thinking about a hypothesis other than the one you have. Alternatively, people might have trouble with the task because of a focal bias: they focus on the single model given in the rule (e.g., "a vowel must have even number on its other side") and do all of their reasoning from only this assumption without fleshing out other possibilities. Table I represents both of these possibilities.

Another thinking error with multiple determinants is myside processing (Baron, 1995; Klaczynski & Lavallee, 2005; Perkins, 1985, 1995; Stanovich & West, 2007). Excessive myside thinking is no doubt fostered by contaminated mindware—our notion of "self" makes us egocentrically think that the world revolves around ourselves. But a form of focal bias may be contributing to that error as well—the bias to base processing on the mental model that is the easiest to construct. What easier model is there to construct than a model based on our own previous beliefs and experiences? Such a focal bias is different from the egocentric mindware of the self. The focal bias is not egocentric in the motivational sense that we want to build our self esteem or sense of self worth. The focal bias is simply concerned with conserving computational capacity and it does so in most cases by encouraging reliance on a model from a myside perspective. Both motivationally driven "self" mindware and computationally driven focal biases might be contributing to myside processing, making it another multiply determined bias.

Errors in affective forecasting are likewise multiply determined (see Table I). Affective forecasting refers to our ability to predict what will make us happy in the future. People are surprisingly poor at affective forecasting (Gilbert, 2006; Hsee & Hastie, 2006; Kahneman, Diener, & Schwarz, 1999; Kahneman *et al.*, 2006). We often make choices that reduce our happiness because we find it hard to predict what will make us happy. For instance, people underestimate how quickly they will adapt to both fortunate and unfortunate events. One reason that people overestimate how unhappy they will be after a negative event is that they have something missing from their lay psychological theories—the personal theories they use to explain their own behavior. They fail to take into account the rationalization and emotion-dampening protective thought they will engage in after the negative event ("I really didn't want the job anyway," "colleagues told me he was biased against older employees"). People's lay theories of their own psychology do not give enough weight to these factors and thus they fail to predict how much their own psychological mechanisms will damp down any unhappiness about the negative event.

Another even more important source of affective forecasting errors is focal bias. Researchers in the affective forecasting literature have theorized specifically about focalism interfering with hedonic predictions ("predictors pay too much attention to the central event and overlook context events," p. 31, Hsee & Hastie, 2006). For example, a sports fan overestimates how happy the victory of the home team will make him two days after the event. When making the prediction, he fixates on the salient focal event—winning the game—simulates the emotion he will feel in response to the event, and projects that same emotion two days into the future. What does not enter into his model—because such models are not easy to construct in imagination (hence too effortful for the cognitive miser)—is the myriad of other events that will be happening two days after his game and that will then impinge on his happiness in various ways (most of these other events will not be as happiness-inducing as was winning the game).

Finally, Table I simply notes with one example that there may be even more complex effects in the heuristics and biases literature. The confusing concept of confirmation bias (Evans, 1989, 2007; Klayman & Ha, 1987; Nickerson, 1998) may be an example. Depending on how it is defined, it could result from focal bias or from a failure to have instantiated the thinking mindware that prompts a consideration of alternative hypotheses. In more motivationally based accounts however, confirmation bias might arise because of evaluation-disabling strategies embodied in contaminated mindware.

VI. Exemplar Developmental Studies in the Different Categories of the Taxonomy

Table I is not an exhaustive listing of heuristics and biases tasks, but it does give a flavor for how some much-cited effects and biases fit into the framework (for other attempts to classify rational thinking errors, see Arkes, 1991; Harvey, 2007; Larrick, 2004; McFadden, 1999; Reyna *et al.*, 2003; Stanovich, 2008b). However, the complexity of even this partial list will help to explain why we earlier characterized the literature on the developmental of rational thinking ability as sparse. Although there have been some initial developmental studies on most of the tasks in the heuristics and biases literature, none of the biases in the list has been the subject of intense investigation. In short, the literature is spread widely, but it is thin. In this section, we discuss exemplar developmental studies from several of the categories in the taxonomy.

A. DEFAULT TO TYPE 1 PROCESSING: VIVIDNESS EFFECTS

One of the most common Type 1 processing defaults of the cognitive miser is the tendency to default to vivid presentations of information and to avoid nonsalient numerical presentations of evidence. In the heuristics and biases literature, a typical problem would require the participant to make an inductive inference in a simulation of a real-life decision. The information relevant to the decision is conflicting and is of two different types. One type of evidence is statistical: either probabilistic or aggregate base-rate information that favors one of the bipolar decisions. The other evidence is a concrete case or vivid personal experience that points in the opposite direction. The classic Volvo versus Saab item (see p. 285 of Fong, Krantz, & Nisbett, 1986) provides an example. In this problem, a couple is deciding to buy one of two otherwise equal cars. Consumer surveys, statistics on repair records, and polls of experts favor the Volvo over the Saab. However, a friend reports experiencing a severe mechanical problem with the Volvo he owns. The participant is asked to provide advice to the couple. Preference for the Volvo indicates a tendency to rely on the large-sample information in spite of salient personal testimony. A preference for the Saab indicates reliance on the personal testimony over the opinion of experts and the large-sample information.

Kokis *et al.* (2002) adapted several problems such as this for children. For example, one problem went as follows:

> Erica wants to go to a baseball game to try to catch a fly ball. She calls the main office and learns that almost all fly balls have been caught in section 43. Just before she chooses her seat, she learns that her friend Jimmy caught 2 fly balls last week sitting in section 10. Which section is most likely to give Erica the best chance to catch a fly ball?
>
> (a) Definitely section 43
> (b) Probably section 43
> (c) Probably section 10
> (d) Definitely section 10

Selection of option (a) or (b) indicates the use of the aggregate base-rate information. Selection of options (c) or (d) indicates that the child is using the vivid information from a friend (that happens to be of lower diagnosticity). Kokis *et al.* (2002) found a significant developmental trend whereby 13–14-year-olds displayed significantly less reliance on the vivid personal information than did a group of 10–11-year-olds.

Jacobs and Potenza (1991) found an analogous significant developmental trend in the so-called object condition of their experiment where the problems were similar to those used by Kokis *et al.* (2002). However, in the so-called social condition of the Jacobs and Potenza study, the developmental trend was in the opposite direction—more reliance on the vivid information and less reliance on the more diagnostic statistical information by the *older* children. A consideration of the nature of the social problems reveals why this was the case. Here is an example of a social problem:

> In Juanita's class, 10 girls are trying out to be cheerleaders and 20 are trying out for the band. Juanita is very popular and very pretty. She is always telling jokes and loves to be around people. Do you think Juanita is trying out to be a cheerleader or for the band?

Here, the statistical information points in the direction of band but the personal information points in the direction of cheerleader. But to understand the diagnosticity of the indicant information in this problem one must have knowledge of a social stereotype (that popular girls are drawn more to cheerleading than to band). Knowledge of this stereotype might well increase with age and thus be less available to the younger children. In short, the indicant information is less available to the younger children in the social condition.

Thus, the performance in the Jacobs and Potenza (1991) study is less inconsistent with the findings of Kokis *et al.* (2002) than may be apparent on the surface. The same is true of the social problems in a study by Davidson (1995). Finally, the developmental trend in Kokis *et al.* and in the object condition of Jacobs and Potenza (1991) is consistent with studies of individual differences within an age group. Reliance on vivid individuating information is negatively correlated with cognitive ability (Kokis *et al.*, 2002; Stanovich & West, 1998b, 1998c).

B. FOCAL BIAS: FRAMING EFFECTS

The second default of the cognitive miser is to default to serial associative cognition with a focal bias. Framing effects represent the classic example of this default in the heuristics and biases literature. For example, in discussing the mechanisms causing framing effects, Kahneman has stated that "the basic principle of framing is the passive acceptance of the formulation given" (2003, p. 703). The frame presented to the subject is taken as focal, and all subsequent thought derives from it rather than from alternative framings because the latter would require more thought. One of the most compelling framing demonstrations is from the early work of Tversky and Kahneman (1981):

> **Decision 1.** Imagine that the U.S. is preparing for the outbreak of an unusual disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimates of the consequences of the programs are as follows: 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, Program A or Program B?

Most people when given this problem prefer Program A—the one that saves 200 lives for sure. There is nothing wrong with this choice taken alone. However, inconsistent responses to another problem define a framing effect:

> **Decision 2.** Imagine that the U.S. is preparing for the outbreak of an unusual disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimates of the consequences of the programs are as follows: 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, Program C or Program D?

Most people when presented with Decision 2 prefer Program D. Thus, across the two problems, the most popular choices are Program A and

Program D. The problem here is that Decision 1 and Decision 2 are really the same decision—they are merely redescriptions of the same situation. Program A and C are the same. That 400 will die in Program C implies that 200 will be saved—precisely the same number saved (200) in Program A. Likewise, the two-thirds chance that 600 will die in Program D is the same two-thirds chance that 600 will die ("no people will be saved") in Program B. Many people show inconsistent preferences—their choice switches depending on the phrasing of the question. This is an example of a problem with very transparent equivalence. When presented with both versions of the problem together, most people agree that the problems are identical and that the alternative phrasing should not have made a difference.

Such a lack of so-called descriptive invariance is a very fundamental violation of some of the simplest strictures of rational thought (see Tversky & Kahneman, 1981, 1986). A theory of why these framing effects occur was presented in the prospect theory of Kahneman and Tversky (1979) which contains the key assumption that the utility function is steeper (in the negative direction) for losses than for gains. This explains why people tend to be more risk averse for gains than for losses.

The literature on framing effects in adults is vast (see Kahneman & Tversky, 1984, 2000; Kuhberger, 1998; Levin *et al.*, 2002; Maule & Villejoubert, 2007). However, the developmental literature is quite small. Obviously, the complexity of the problems has to be vastly reduced and made appropriate for children. Outcomes in developmental studies become small prizes that the children receive instead of the imaginary deaths or real money that is used in adult studies. Several investigators have creatively adapted framing paradigms for children, but the results of these experiments have not converged. Levin and colleagues (Levin & Hart, 2003; Levin *et al.*, 2007) found no developmental trend for framing effects. Children (6–8-year-olds) were more risk averse for gains than for losses in the manner that prospect theory predicts, but the magnitude of the framing effects that they displayed was the same as that found for adults.

The results of Levin and colleagues were not completely convergent with those in a study by Reyna and Ellis (1994). The data patterns in the latter study were complex, however, and highly variable over the ages studied. Framing interacted with level of risk and magnitude of reward at certain ages. Briefly though, preschoolers' responses were consistent across frames—they displayed no framing effect. Second graders displayed a small reverse framing effect—they were more risk averse for losses. Fifth-graders displayed a small reverse framing effect at the highest reward magnitude and the standard framing effect (more risk seeking for losses) only for lowest reward magnitude.

The results of Levin and colleagues and those of Reyna and Ellis (1994) are consistent in one important respect however—neither study found a monotonically decreasing framing effect with age. This lack of developmental trend converges with studies of individual differences within an age group. Framing effects show very small (sometimes zero) correlations with cognitive ability (Bruine de Bruin *et al.*, 2007; Parker & Fischhoff, 2005; Stanovich & West, 1999, 2008b; Toplak & Stanovich, 2002).

C. OVERRIDE FAILURE: DENOMINATOR NEGLECT

One of several phenomena in the heuristics and biases literature that illustrates the failure of sustained decoupling (see Table I) is the phenomenon of denominator neglect. Epstein and colleagues (Denes-Raj & Epstein, 1994; Kirkpatrick & Epstein, 1992; Pacini & Epstein, 1999) demonstrated that it can result in a startling failure of rational judgment. Adults in several of his experiments were presented with two bowls of jelly beans. In the first were nine white jelly beans and one red jelly bean. In the second were 92 white jelly beans and 8 red jelly beans. A random draw was to be made from one of the two bowls and if the red jelly bean was picked, the participant would receive a dollar. The participant could choose which bowl to draw from. Although the two bowls clearly represent a 10% and an 8% chance of winning a dollar, a number of subjects chose the 100 bean bowl, thus reducing their chance of winning. The majority did pick the 10% bowl, but a healthy minority (from 30 to 40% of the participants) picked the 8% bowl. Although most of these participants in the minority were aware that the large bowl was statistically a worse bet, that bowl also contained more enticing winning beans—the 8 red ones. In short, the tendency to respond to the absolute number of winners, for these participants, trumped the formal rule (pick the one with the best percentage of reds) that they knew was the better choice.

Kokis *et al.* (2002) found no significant trend for denominator neglect to decrease across their two age groups of 10–11-year-olds and 13–14-year-olds. However, Kokis *et al.* (2002) did find that cognitive ability was negatively correlated with denominator neglect to a significant degree. Kokis *et al.* used a paradigm very similar to that of Epstein and colleagues, but Klaczynski (2001b) altered the paradigm in an interesting way, by presenting options with equal probabilities and a response option that reflected the equivalent status of the two options. He had participants select from three alternatives: (a) a jar with 1 winning ticket out of 10; (b) a jar with 10 winning tickets out of 100; and (c) that it would not matter which jar was picked. Picking alternative (b) would indicate denominator neglect. Alternative (c) is the normatively correct response. Only a minority of participants chose the normatively correct response, but the normatively correct response did increase across three groups: early adolescents, middle adolescents, and young adults. In contrast, the majority response—denominator neglect—did not show a developmental trend.

D. OVERRIDE FAILURE: BELIEF BIAS

Clearer results have been obtained with another phenomenon caused by the failure of sustained decoupling—belief bias (see Table I). Consider the following syllogism:

> **Premise 1**. All living things need water
>
> **Premise 2**. Roses need water
>
> Therefore, Roses are living things
>
> Judge the conclusion as either logically valid or invalid.

Premise 1 says that all living things need water, not that all things that need water are living things. So, just because roses need water, it does not follow from Premise 1 that they are living things. However, consider the following syllogism with exactly the same structure:

> **Premise 1**. All insects need oxygen
>
> **Premise 2**. Mice need oxygen
>
> Therefore, Mice are insects

In both problems, prior knowledge about the nature of the world (that roses are living things and that mice are not insects) is becoming implicated in a type of judgment that is supposed to be independent of content: judgments of logical validity. In the rose problem, prior knowledge was interfering, and in the mice problem prior knowledge was facilitative.

Belief bias occurs when judgments of the believability of the conclusion interfere with judgments of logical validity. Using syllogistic reasoning problems suitably modified for children, Kokis *et al.* (2002) found a significant developmental trend whereby 13–14-year-olds displayed significantly less belief bias than did a group of 10–11-year-olds. The developmental trend in Kokis *et al.* is consistent with studies of individual differences within an age group, in which belief bias is negatively correlated with cognitive ability (De Neys, 2006; Handley *et al.*, 2004; Sá, West, & Stanovich, 1999; Stanovich & West, 1998b).

E. MINDWARE GAPS

Mindware gaps are common in the domain of probability knowledge and judgment. Many notable heuristics and biases cluster in that domain (see the classic studies by Kahneman & Tversky, 1972, 1973). Conjunction effects represent rational thinking errors that arise because of mindware gaps in the domain of probability. Consider another problem that is famous in the literature of cognitive psychology, the so-called Linda problem (Tversky & Kahneman, 1983).

> Linda is 31-years-old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations. Please rank the following statements by their probability, using 1 for the most probable and 8 for the least probable.
>
> a. Linda is a teacher in an elementary school ___
> b. Linda works in a bookstore and takes Yoga classes ___
> c. Linda is active in the feminist movement ___
> d. Linda is a psychiatric social worker ___
> e. Linda is a member of the League of Women Voters ___
> f. Linda is a bank teller ___
> g. Linda is an insurance salesperson ___
> h. Linda is a bank teller and is active in the feminist movement ___

Most people make what is called a "conjunction error" on this problem. Because alternative h (Linda is a bank teller and is active in the feminist movement) is the conjunction of alternatives c and f, the probability of h cannot be higher than that of either c (Linda is active in the feminist movement) or f (Linda is a bank teller). All feminist bank tellers are also bank tellers, so h cannot be more probable than f—yet often over 80% of the adults in studies rate alternative h as more probable than f, thus displaying a conjunction error.

Davidson (1995) reported the counterintuitive finding of a developmental trend of increasing conjunction errors with age. However, the stimuli in this study had the same problem as those in the social condition of the Jacobs and Potenza (1991) study discussed above—they depended on the knowledge of a stereotype that might increase with age. For example, one item went as follows:

> Mrs. Hill is not in the best health and she has to wear glasses to see. Her hair is gray and she has wrinkles. She walks kind of hunched over. Do you think that Mrs. Hill is: a waitress in a local restaurant; an old person who has grandchildren and a waitress at a local restaurant; etc.

Knowledge of the stereotype might lead children to make a conjunction error, but the knowledge of the stereotype is undoubtedly more extensive among sixth graders (Davidson's oldest group) than among second graders (Davidson's youngest group).

Another way to state the problem with the Davidson (1995) stimuli is to say that the potential of the stimuli to trigger a representativeness judgment is confounded with age. Such stimuli are fine for certain questions but they are not appropriate stimuli to use when addressing the generic question of whether the propensity to commit a conjunction error with age increases or decreases. Klaczynski (2001a) used stimuli that were less confounded in this manner and found no developmental trend in the number of conjunction errors from early adolescence (mean age 12.4 years) to middle adolescence (16.3 years).

A developmental trend in favor of more optimal reasoning by older than younger adolescents has been found in other domains of probabilistic reasoning, including the gambler's fallacy and the law of large numbers (Klaczynski, 2000, 2001a, 2001b; Klaczynski & Narasimham, 1998).

F. HYBRID REASONING PROBLEMS

As Table I illustrates, several thinking errors in the heuristics and biases literature are multiply determined. In Wason's four-card selection task, at the very least incorrect responses are due to focal bias and to the failure to understand the importance of thinking about alternative hypotheses. There may be even more sources of error on this problem (Evans, 2007; Klauer, Stahl, & Erdfelder, 2007; Osman & Laming, 2001). Developmental and individual differences studies of the task are consistent, however. Superior performance on the task is associated with development (Klaczynski, 2001a; Overton, Byrnes, & O'Brien, 1985) and with cognitive ability (DeShon *et al.*, 1998; Stanovich & West, 1998a; Toplak & Stanovich, 2002; Valentine, 1975).

As a final example of a multiply determined cognitive bias, consider myside bias: People evaluate evidence, generate evidence, and test hypotheses in a manner biased toward their own opinions (Baron, 1991, 1995; Kuhn, 1991; Perkins, 1985; Perkins, Farady, & Bushey, 1991; Stanovich & West, 2007; Toplak & Stanovich, 2003). Myside bias derives from focal bias but also from mindware that structures our knowledge of the world from an egocentric perspective.

Developmental trends in myside processing have been studied by Klaczynski and colleagues (1997; Klaczynski & Gordon, 1996; Klaczynski, Gordon, & Fauth, 1997; Klaczynski & Lavallee, 2005; Klaczynski & Narasimham, 1998). They presented participants with flawed hypothetical experiments that led to either opinion-consistent or opinion-inconsistent conclusions and evaluated the quality of the reasoning used when the participants critiqued the flaws in the experiments. In these experiments, myside bias effects were also evident—participants found more flaws when the experiment's conclusions were inconsistent than when they were consistent with their opinions and beliefs. However, there was no developmental trend for myside bias to increase or decrease—at least for the early, middle, and late adolescent groups that were the focus of most of the Klaczynski lab's research.

The lack of a developmental trend in myside bias in the Klaczynski group's studies is consistent with studies of individual differences within an age group. Across a variety of myside paradigms, there has been little evidence that myside bias is associated with cognitive ability (Klaczynski & Lavallee, 2005; Klaczynski & Robinson, 2000; Macpherson & Stanovich, 2007; Sá *et al.*, 2005; Stanovich & West, 2007, 2008a; Toplak & Stanovich, 2003).

VII. Conclusion: Specificity and Generality in the Development of Rational Thought

The overall conclusion we derive from our survey of results from our own laboratory and others is that the development of rational thought has been inadequately specified. Collectively, these biases (and many others in the heuristics and biases literature not covered here) define departures from rationality and hence indirectly index rationality itself. The minimal conclusion to be drawn from the body of developmental work taken as a whole is that children unequivocally do show every one of the biases that have been displayed in the adult literature: vividness effects, framing effects, denominator neglect, belief bias, conjunction errors, myside bias, etc.

Beyond this minimal conclusion, however, few conclusions about development appear to generalize across the various domains and biases. First, none of the areas covered in this review have been the subject of enough research with convergent outcomes to establish developmental trends with confidence. This caveat aside, the suggestive trends that are in the literature vary considerably across the various cognitive biases. Across the age ranges studied, there appear to be developmental increases in the avoidance of belief bias, analytic responding in the selection task, and reliance on statistical information in the face of conflicting personal testimonials. All of these trends are in the direction of increasingly rational thought, at least according to accepted normative standards.

These findings contrast, however, with the trends apparent in developmental studies of myside bias and framing effects. Neither of these biases was attenuated by development. The lack of developmental decreases in these two biases is interestingly convergent with findings that neither bias displays much of a correlation with intelligence (Stanovich & West, 2007, 2008b). These aspects of rational thought are thus quite independent of cognitive ability, reinforcing the fundamental point with which we started this chapter: measures of cognitive ability, as traditionally defined, fail to assess degrees of rationality.

In the case of denominator neglect and conjunction errors, the literature on developmental trends is simply too inconsistent and sparse to warrant any conclusions at this point. These two effects highlight how thin the literature is on children's rational thought. One cannot amalgamate all of the studies reviewed here (as well as others not reviewed) as evidence on a single issue—this would misleadingly suggest that the literature is more extensive than it is. Rational thought spans many domains—it encompasses many different thinking dispositions and knowledge domains, each of which has been investigated separately in the adult literature. For example, there is an enormous literature on conjunction effects (Fisk, 2004), on framing (Kahneman & Tversky, 2000), on base-rate usage (Koehler, 1996), and on every one of the myriad effects in the heuristics and biases literature. A parallel effort in each of these domains will be necessary in order to fully understand the development of rational thought.

Understanding the development of rationality will clearly be a tall order. It will be worth the effort, however, not just for scientific reasons. Assumptions about the nature and development of rationality are implicated in judgments of legal responsibility. Reyna and Farley (2006) have recently emphasized how background assumptions about adolescent rationality frame efforts to change adolescent risk behavior. For example, theories that stress adolescent feelings of invulnerability serve to avoid the attribution of irrationality to adolescents who engage in high-risk behavior. If these adolescents have strong feelings of invulnerability, or if they drastically underestimate the probabilities of negative outcomes, then a consequentialist calculation might well make engaging in high-risk behaviors rational for them.

An alternative approach, one supported by the research in the heuristics and biases tradition, would relax the rationality assumption, and conclude instead that some of these adolescent behaviors violate standard rational strictures (Stanovich, 2004, 2008c). Such a stance finds additional motivation from an observation that Reyna and Farley (2006) discuss: many adolescents making poor choices are alienated from the choices they make. As Reyna and Farley put it "people who take unhealthy risks often agree that their behavior is irrational, on sober reflection, but they gave in to temptation or were not thinking at the time of the decision, and are worse off for having done so" (p. 35). Instead of the economics-like assumption of adolescents as coherent rational actors, dual-process theories of the type we have discussed highlight the image of a decision maker in conflict. This comports well with the fact that many adolescents with behavior problems will indeed verbally reject their own behavior. Such a philosophical reorientation could, as Reyna and Farley (2006) demonstrate, have profound implications for how we interpret many findings in the area of adolescent decision making.

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