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You know my methods, Watson.

—Sherlock Holmes
(Doyle, 1893/2000, p. 163)

One way we identify developmental changes in cognition is that we see progress to higher levels of rationality. But do formal operations, rooted in a formal logic, encompass all of advanced rationality?

Rationality, in its oldest, broadest, and deepest sense, is a matter of having good reasons for one’s beliefs and actions (Audi, 1997, 1998, 2001; Keefer, 1996; Moshman, 1990b, 1994; Nozick, 1993; Rescher, 1988; Searle, 2001; Sen, 2002; Siegel, 1988, 1997; Stanovich, 2008). Formal logic provides very good reasons for inferring particular conclusions from particular premises and is thus an important aspect of rationality. But we can be rational in interpreting complex evidence that does not logically require one particular conclusion or in choosing among alternatives in cases where none of the potential choices can be logically eliminated. Even in the absence of formal proof, we often have good enough reason to choose one belief or course of action over another. There is much more to rationality than formal logic (Bickhard & Campbell, 1996; Blasi & Hoeffel, 1974; Evans, 2002; King & Kitchener, 1994; Koslowski, 1996; Searle, 2001).

The Ubiquity of Inference

Cognition is inferential: It always goes beyond the data. We assimilate reality to active structures of knowledge and inference and
adolescent rationality and development

accommodate those structures to the realities assimilated. This is how we know; we have no direct access to reality itself. However true to reality it may be, our factual knowledge is in part a function of our cognitive structures. Understanding, in turn, is more than recording facts. Even perception is now understood to go far beyond the data of our senses. And however real our memories seem, remembering is now recognized as an active reconstruction of the past. The language of assimilation and accommodation is Piagetian, but this conception of inference beyond the data as intrinsic to cognition has been widely accepted by cognitive and developmental psychologists since the 1970s.

Young children, it should be added, don’t just go beyond the data. They make analogical, probabilistic, and deductive inferences. Their ability to act in accord with rules of inference would be impressive even if their rules were incorrect, but in fact preschool children routinely make logical and other normatively defensible inferences (Braine & O’Brien, 1998; Chen, Sanchez, & Campbell, 1997; Scholnick & Wing, 1995; Singer-Freeman, 2005; Singer-Freeman & Bauer, 2008). There is a rationality, it appears, intrinsic to our inferential systems.

Inferential systems can make inferences that are in accord with logical and other norms without being aware of their own rationality. But we can become aware of our rationality and advance it. The development of rationality is in large part a process of becoming aware of our inferences, evaluating them, and gaining control over them. Total awareness and control, however, not only is unachievable but would surely be maladaptive. Given the information processing limitations of the human mind, automatic inferences permit efficient functioning in complex environments (Moors & De Houwer, 2006). The development of thinking and reasoning, to which we now turn, supplements automatic systems of inference but does not replace them. Automatic inference remains, throughout life, a ubiquitous aspect of cognitive functioning.

Thinking as Purposeful Inference

Thinking may be defined as the deliberate application and coordination of one’s inferences to serve one’s purposes (Moshman, 1995a). There are multiple types of thinking serving multiple purposes. Research on the development of thinking (Kuhn, 2009)
has concerned itself with the development of **problem solving** (DeLoache, Miller, & Pierroutsakos, 1998), **decision making** (Baron & Brown, 1991; Byrnes, 1998, 2005; Galotti, 2002; Jacobs & Klaczynski, 2005; Klaczynski, Byrnes, & Jacobs, 2001; Umeh, 2009), **judgment** (Jacobs & Klaczynski, 2005; Kahneman, 2003; Millstein & Halpern-Felsher, 2002), and **planning** (Galotti, 2005; Scholnick & Friedman, 1993).

Decision making has been an area of particular concern with regard to adolescents, in part because of its perceived link to risky behavior (Beyth-Marom, Austin, Fischhoff, Palmgren, & Jacobs-Quadrel, 1993; Michels, Kropp, Eyre, & Halpern-Felsher, 2005; Reyna, Adam, Poirier, LeCroy, & Brainerd, 2005; Reyna & Farley, 2006; Van Leijenhorst & Crone, 2010; see Chapter 16). Taking risks is not in itself irrational, however. Systematic evaluations of adolescent decision making with respect to the elaboration of options, consideration of pros and cons, and reasonable weighing of multiple dimensions show that adolescents at their best are capable of a level of deliberate decision making rarely seen in children (Moshman, 1993; Weithorn & Campbell, 1982). Of course adolescents fall far short of standards of perfect rationality, but so do adults, whose decision making does not differ notably from that of adolescents (Beyth-Marom et al., 1993). In a commentary on a set of chapters concerning decisions in context, Cynthia Berg (2005) noted that although adolescents fall short of perfect decision making, an emphasis on their shortcomings is highly misleading:

As I read the chapters on adolescent decision making, I wondered how different adolescent decision making really is from adult decision making. Could not the same characterizations of adolescents (i.e., thoughtful and impulsive, deliberative and impetuous) characterize adults’ decisions regarding whether to engage in potentially risky behaviors (e.g., investing in a volatile stock market, having an affair that may cause the dissolution of one’s marriage, trying diet supplements to lose weight)? Both adolescent and adult decision making can be characterized by competence and incompetence, rationality and irrationality, depending on the specific domain of decision making and the activation of one’s emotional, cognitive, and motivational systems. (p. 246)

Research on problem solving, judgment, and planning generates results generally consistent with what is seen in the decision-making literature. Rather than examine each of these, let me
suggest four generalizations about the nature and development of thinking.

First, good thinking is not just the application of logic, though it does include good judgments about when and how logic is relevant. In daily life we routinely face problems for which there is no single logically correct solution and decisions that cannot be made by logically eliminating all but one of a set of options. Logic may play a role in making defensible judgments and formulating coherent plans, but there is rarely a uniquely correct judgment or plan mandated by formal rules. Thinking is not just a matter of logic.

In fact, thinking is very much a part of daily life, highly intertwined with emotions and social relations and highly influenced by task demands, environments, and cultural contexts. This is the second generalization. All people everywhere plan, judge, face problems, and make decisions, but how they go about these activities is highly variable.

Third, adolescents and adults often show forms or levels of thinking rarely seen in children. Even if formal operations is just one piece of advanced rationality, it allows adolescents and adults to generate and consider hypothetical possibilities in a systematic fashion that enables advanced forms of problem solving, decision making, judgment, and planning.

Finally, postchildhood developmental changes in thinking are not tied to age and do not culminate in a state of maturity. Although it seems likely that many individuals show progress beyond childhood in the quality of their problem solving, decision making, judgment, and planning (Cauffman & Woolard, 2005; Steinberg & Scott, 2003), the deployment and progress of thinking in adolescence and beyond is highly variable, depending on specific interests, activities, and circumstances (Fischer, Stein, & Heikkinen, 2009). No theorist or researcher has ever identified a form or level of thinking routine among adults that is rarely seen in adolescents. Adolescent thinking often develops but not through a fixed sequence and not toward a universal state of maturity.

Reasoning as Self-Constrained Thinking

Reasoning may be defined as epistemologically self-constrained thinking (Moshman, 1995a)—that is, thinking aimed at reaching
justifiable conclusions. To reason is to think in such a way as to constrain your inferential processes on the basis of logical and other norms. The prototypical case of reasoning is **logical reasoning**, in which the norms are most clear and their justifiability is least in doubt. As we will see, **scientific reasoning** and **argumentation** are also epistemologically self-constrained, but their rationality is not simply a matter of following logical rules.

## Logical Reasoning

Logical reasoning is reasoning in accord with logical norms. The prototypical case of logical reasoning is **deductive reasoning**, in which the norms consist of strict rules of deduction that respect the constraints of **logical necessity**. This includes **conditional reasoning**, which involves premises of the form *If p then q* that link an **antecedent** (*p*) to a **consequent** (*q*) in a conditional relation (*If … then*).

The study of conditional reasoning has been a mainstay of cognitive and developmental psychology since the 1960s. The most basic conditional inference is **modus ponens**, which takes the form *If p then q; p; therefore, q* (major premise, minor premise, and conclusion, respectively). Another valid conditional inference is **modus tollens**, which takes the form *If p then q; not-q; therefore, not-p*. There are also two standard fallacies of conditional reasoning. **Denial of the antecedent** (DA) takes the form *If p then q; not-p; therefore, not-q* (the minor premise denies the antecedent of the major premise). **Affirmation of the consequent** (AC) takes the form *If p then q; q; therefore, p* (the minor premise affirms the consequent of the major premise). Both are fallacies because the conclusion does not necessarily follow from the premises.

Henry Markovits, Paul Klaczynski, and others have investigated conditional reasoning developmentally (Daniel & Klaczynski, 2006; De Neys & Everaerts, 2008; Klaczynski, Schuneman, & Daniel, 2004; Markovits, 2006; Markovits & Barrouillet, 2002). One major focus has been the influence of content. Consider, for example, the premises “If zig then zark. Zark.” It seems natural to conclude “zig,” thus succumbing to the AC fallacy. Suppose instead you face the premises “If I exercise then I lose weight. I lost weight.” The conclusion “I exercised” again seems natural, but you may immediately remember that diet is an alternative basis for weight loss, so the weight loss
cannot be attributed conclusively to exercise. Thus, having meaningful content that enables you to recall an alternative antecedent dissuades you from this unjustified conclusion. In other cases, however, meaningful content may interfere with good reasoning by distracting you from the underlying logic of an argument. If you disagree with a potential conclusion, and especially if you deem it highly objectionable, you may be less likely to see that it follows necessarily from premises you have accepted (see Chapter 13). Thus conditional reasoning is not always easier with meaningful content; rather it involves a complex interplay of content knowledge and formal logic.

Consider now a child given the premises “If zig then zark. Zig.” Even a very young child is likely to conclude “zark.” Does this modus ponens inference show conditional reasoning? It certainly is a proper conditional inference and a good reminder that we should not dismiss young children as illogical. But before we call this reasoning, we should note that the same child will also make the erroneous AC inference noted above. Automatically concluding zig from zark and vice versa is sometimes a proper inference and sometimes not, but it is not epistemologically self-constrained and thus does not constitute reasoning. You and I also make erroneous inferences, but upon reflection we understand in the abstract why arguments of the AC form are invalid.

Preschool children often make proper logical inferences, and adults often make fallacious ones. Nonetheless, adolescents and adults at their best can recognize that an inference is fallacious, whereas children, regardless of whether their inferences are justified, have limited ability to reflect on inference and justification (see the research on formal operations in Chapter 1). The developmental transition from childhood to adolescence is a matter not of learning correct inferences but of attaining greater awareness, understanding, and control of one’s inferences (a matter of metalogical understanding; see Chapter 3).

Research on other forms of deductive reasoning is generally consistent with research on conditional reasoning (Ricco, 2010). Adolescents and adults show metalogical competencies not seen in children, but no one of any age relies on logic alone. Paul Klaczynski, Eric Amsel, and others (Amsel et al., 2008; Evans, 2002, 2007; Kahneman, 2003; Klaczynski, 2000, 2001, 2004, 2005, 2009; Stanovich, 1999; Stanovich & West, 2000) have shown that logical
reasoning coexists with a variety of nonlogical inferences, as suggested by dual processing theories (discussed below).

**Scientific Reasoning**

The developmental study of scientific reasoning is rooted in Inhelder and Piaget's (1958) research and theory on formal operational reasoning (Chapter 1) but has evolved far beyond its roots in formal logic. Thus the study of scientific reasoning provides a good example of the role and limits of logic in advanced reasoning.

Suppose I believe children understand short sentences better than long sentences. I test my hypothesis by comparing a group of 10-year-old girls reading short sentences in a quiet room to a group of 8-year-old boys reading long sentences in a noisy room. I report that, as predicted, the short sentences are better understood. You would likely respond, politely I hope, that my research is flawed and fails to support my hypothesis.

What precisely is the problem? My evidence is indeed consistent with the hypothesis that short sentences are understood better. The problem is that the design of my research does not rule out a variety of alternative explanations for my results. Perhaps the two groups differ because 10-year-olds, in general, comprehend more than 8-year-olds. Perhaps they differ because girls, in general, are better readers than boys. Perhaps they differ because children, in general, learn more in quiet settings. Logically, the research is inconclusive because, without additional information, I have no way of knowing whether it is age, gender, setting, sentence length, or some combination of these that accounts for the difference between the two groups.

What should I have done to provide a genuine test of my hypothesis? I should have compared groups that were identical to each other with regard to age and gender and made sure that the reading took place in identical conditions. This insight is not based on substantive knowledge about the psychological processes involved in reading or on particular beliefs about age or gender differences or effects of setting. At issue is a purely formal insight about the logic of hypothesis testing: To determine the effect of a variable, one must manipulate that variable while holding all other variables constant.

In the classic presentation of the theory of formal operations, Inhelder and Piaget (1958) argued that the ability to isolate
variables to determine their effects is an important aspect of formal operational logic and showed that this ability develops in early adolescence. Extensive research by Deanna Kuhn, Eric Amsel, Leona Schauble, and their associates provides a detailed picture of how children, adolescents, adults, and scientists coordinate theories and evidence (Amsel & Brock, 1996; Amsel, Goodman, Savoie, & Clark, 1996; Kuhn, 1989; Kuhn, Amsel, & O’Loughlin, 1988; Kuhn, Garcia-Mila, Zohar, & Andersen, 1995; Schauble, 1996). Consistent with other research on formal operational reasoning (Chapter 1), the results show some progress in at least some adolescents in understanding the logic of hypothesis testing, but appropriate isolation of variables and logically defensible inferences from data remain far from consistent even among adults.

Without denying the importance of isolating some variables in some circumstances, a variety of theorists have proposed that conformity to logically derived formal rules of scientific methodology is not sufficient for scientific reasoning (Kuhn, Iordanou, Pease, & Wirkala, 2008; Zimmerman, 2000). Not only must researchers avoid confounding potentially relevant variables, but they must select variables and interpret results on the basis of a domain-specific theoretical understanding of the phenomena under investigation. This typically requires judgments that are rational in the sense that good reasons can be provided but that are not mandated by formal logical or methodological rules. In the words of Leona Schauble (1996),

Rationality entails more than mere logical validity. To decide which of several potential causes are plausible, people bring to bear both specific knowledge about the target domain and general knowledge based on experience about the mechanisms that usually link causes with effects. … The goal of scientific reasoning is not primarily the formulation of inductive generalizations, but rather the construction of explanatory models. … Explanatory models, in turn, are constrained in that their hypothesized causal mechanisms must be consistent with and sufficient to account for the known data. Thus prior knowledge guides observations, as surely as new observations lead to changes in knowledge. (p. 103)

Barbara Koslowski (1996) conducted an extensive program of research on adolescent scientific reasoning and, on the basis of her
results and related considerations from the philosophy of science, reached a similar conclusion:

I have argued that neither covariation alone nor theory alone constitute algorithms that guarantee the right answer in scientific reasoning. Theory and data are both crucial, and theory and data are interdependent. Sound scientific reasoning involves bootstrapping: considerations of theory or mechanism constrain data, and data in turn constrain, refine, and elaborate theory. (p. 86)

Scientific reasoning, then, is something richer and more complex than a logic of scientific inference, but it is nonetheless rational. In addition to the logic of hypothesis testing, there is, at least potentially, a rationality rooted in the domain-specific theories that guide the process of theorizing, promoting justifiable choices about what variables to investigate, what constitutes relevant evidence, what hypotheses to pursue, and so forth (see also Koslowski, Marasia, Chelenza, & Dublin, 2008).

Even young children, however, have and test domain-specific theories (Karmiloff-Smith, 1992; Kuhn, 2000; Wellman & Gelman, 1998). This has led many theorists to see children as fundamentally like scientists: Both children and scientists, they suggest, engage in the same sort of rational processes, differing mostly in that scientists have more experience and expertise. This conception of the child as scientist fits with Piaget’s constructivist image of the child but underplays the sort of domain-general reasoning competencies associated with his stage of formal operations.

In a major critique of the child-as-scientist metaphor, Deanna Kuhn (1989) acknowledged that children, like scientists, have rich structures of domain-specific conceptual knowledge and continually test and refine this knowledge. But children, in contrast to scientists, fail to understand the distinction between theory and evidence and thus are unable to coordinate these in a conscious and deliberate manner:

In scientific exploration activities, lack of differentiation and coordination of theory and evidence is likely to lead to uncontrolled domination of one over the other. Exploration may be so theory-bound that the subject has difficulty “seeing” the evidence, or so data-bound that the subject is confined to local interpretation of isolated results, without benefit of a theoretical representation that would allow the subject to make sense of the data. (Kuhn, 1989, p. 687)
Progress in scientific reasoning consists of progress in thinking about theories, rather than merely with them, and thinking about evidence, rather than merely being influenced by it. This development is thus metacognitive, as well as strategic. From a very early age, children modify their primitive theories in the face of evidence, but only through the development that has been the topic of this article does one attain control over the interaction of theory and evidence in one’s own thinking. It is a development that occurs not once but many times over, as theories and evidence repeatedly come into contact with one another. It is also, however, a development that is incompletely realized in most people. (Kuhn, 1989, p. 688)

Scientific reasoning, then, has its roots in early childhood, but it continues to develop long beyond that (Klahr, 2000; Kuhn, 2000; Zimmerman, 2000). Adolescents and adults are far from perfect, but they do show forms or levels of scientific reasoning not seen in children. The development of scientific reasoning is largely a matter of increasing consciousness of and control over theories, evidence, and inferential processes.

**Argumentation**

Argumentation involves processes of reciprocal justification. Particular arguments can be logical, in the strict sense of formal and deductive, but argument, as Deanna Kuhn (2009) noted, lies squarely in “the realm of everyday, informal reasoning. If there were a single intellectual skill that would serve adolescents well in their lives … this would seem to be it” (p. 171). Beyond the value of skillful argument to individuals, moreover, argumentation is central to societal ideals such as rational jury deliberation (Warren, Kuhn, & Weinstock, 2010) and democratic governance (Habermas, 1990; Sen, 2009). Thus argumentation has been of longstanding interest to philosophers (Cohen, 2001), and Deanna Kuhn and other developmental psychologists have extensively studied its development (De Fuccio, Kuhn, Udell, & Callender, 2009; Felton, 2004; Iordanou, 2010; Kuhn, 1991, 2009; Kuhn, Goh, Iordanou, & Shaenfield, 2008; Kuhn, Shaw, & Felton, 1997; Kuhn & Udell, 2003; Leitao, 2000; Udell, 2007).

Argumentation begins with providing reasons to justify one’s claims, positions, or actions, but ideally it goes far beyond this. It includes coordinating reasons and elaborating evidence to
produce convincing arguments. It includes evaluating the arguments of others. In its most social aspect, argumentation involves refuting arguments with counterarguments and refuting counterarguments with rebuttals. At its highest levels it involves understanding that sometimes there is not a right and a wrong view, but neither are all views and arguments equally good; rather, some views and arguments may be better or worse than others (see the discussion of epistemic cognition and development in Chapter 3). It is possible, moreover, that some combination of views, or an alternative not yet considered, may end up being accepted by consensus as the best yet.

Consistent with other research on reasoning, research on argumentation shows that adolescents are capable of arguing at a level beyond that of children but that the skills of argument in people of all ages leave much to be desired. Research with individuals ranging from adolescence to adults beyond age 60 showed that education, but not age, correlated strongly with argument skill (Kuhn, 1991). Development of argumentation skills beyond early adolescence appears possible but not inevitable or universal. Extensive research by Deanna Kuhn and her associates has shown that interventions designed to promote and support argumentation can enhance developmental progress over a period of months (De Fuccio et al., 2009; Felton, 2004; Iordanou, 2010; Kuhn, Goh, et al., 2008; Kuhn et al., 1997; Kuhn & Udell, 2003; Udell, 2007).

**Diversity in Thinking and Reasoning**

Rationality for Piaget reaches its culmination in formal operations, which he took to be the universal state of cognitive maturity. As we have seen throughout this chapter, however, there are multiple types of thinking and forms of reasoning. If we are to understand the nature and development of rationality, we must understand its diversity. As we will now see, although claims of cognitive diversity have been made with regard to group differences, dual processing research shows that the primary locus of cognitive diversity is within individuals.

**Group Differences**

Richard Nisbett, Kaiping Peng, and their associates (Nisbett, Peng, Choi, & Norenzayan, 2001; Peng & Nisbett, 1999), on the
basis of their own research and a review of other studies, concluded that the primary locus of diversity is between cultures:

The authors find East Asians to be holistic, attending to the entire field and assigning causality to it, making relatively little use of categories and formal logic, and relying on “dialectical” reasoning, whereas Westerners are more analytic, paying attention primarily to the object and the categories to which it belongs and using rules, including formal logic, to understand its behavior. The 2 types of cognitive processes are embedded in different naive metaphysical systems and tacit epistemologies. (Nisbett et al., 2001, p. 291)

Others agree there are group differences in thinking and reasoning but see the primary locus of such diversity in gender. In many cases, forms of cognition seen by culture theorists as Western are attributed by gender theorists to men; forms seen as non-Western are attributed to women. Research consistently shows, however, that diverse forms and aspects of thinking and reasoning are commonly seen among women and men in diverse cultural contexts (Hyde, 2005). There are indeed individual differences in the use of these processes, and some of these differences may be related to culture or gender, but research does not support a categorical distinction between cultural or gender groups in thinking or reasoning. No gender or cultural group has ever been shown to rely on a particular kind of thinking or reasoning to the exclusion of some other kind. On the contrary, human thinking and reasoning in men and women in all cultures involve the coordination of multiple processes.

Nisbett et al. (2001) maintained that people use different types of cognitive processes because their cultures represent distinct epistemologies (theories of knowledge; see Chapter 3). East Asians, they claimed, use holistic and dialectical cognitive processes reflecting an East Asian epistemology, whereas Westerners use analytic and logical processes reflecting a Western epistemology. Here again, switching the focus from culture to gender, gender theorists have proposed gendered epistemologies, often making similar distinctions. However, although the title of a classic work referred specifically to “women’s ways of knowing” (Belenky, Clinchy, Goldberger, & Tarule, 1986), there is no evidence in this book or, to my knowledge, anywhere else that women have epistemologies distinct from those of men. Since
the 1990s, gender difference theorists have generally written of “gender-related” (rather than gender-exclusive) epistemologies (Baxter Magolda, 1992, 2002; Clinchy, 2002), but even this claim may be too strong. Systematic reviews of research on gender differences in epistemic cognition show such differences to be negligible or nonexistent (Brabeck & Shore, 2003; King & Kitchener, 1994, 2002). The question of cultural differences in epistemic cognition is more complex and less investigated. Whatever statistical differences there may be across cultures in the prevalence of various epistemic beliefs and orientations, however, it seems highly unlikely that the various cultures of the world will turn out to have distinct epistemologies of their own or that individual epistemologies will simply be a reflection of culture. On the contrary, as we will see in Chapter 3, major differences in epistemic cognition are a function of level of development and domain of reasoning, not gender or culture.

**Dual Processing Theories**

Dual processing researchers have made cognitive distinctions similar to those of culture and gender theorists but have provided substantial and convincing evidence that the locus of diversity lies within individuals—adolescents and adults, regardless of culture or gender, use both analytic (formal) and heuristic (contextual) processes (Amsel et al., 2008; Evans, 2002, 2007; Kahneman, 2003; Klaczynski, 2000, 2001, 2004, 2005, 2009; Stanovich, 1999; Stanovich & West, 2000). Others have suggested and provided evidence for even more complex forms of internal diversity in thinking and reasoning (Kuhn et al., 1995; Siegler, 1996). In the realm of advanced cognition, we are each a multitude.

To simplify, however, we process at no fewer than two levels. Dual processing theories are compatible with common conceptions of Piaget’s theory of formal operations as a competence theory (Overton, 1990; see Chapter 1). Deliberate application of logical norms does not replace earlier modes of functioning but rather supplements them. Given Piaget’s concern with development, it is reasonable that he focused especially on formal and analytic processes, which show important developmental change. Dual processing theories, as applied to development, help us see how such developmental changes interact with the heuristic and contextual processes that produce automatic inferences throughout our lives.
In summary, research on advanced cognition indicates that the major locus of diversity is *within* individuals rather than across individuals or groups. Interestingly, if this sort of diversity is universal, our focus on diversity has illuminated a universal aspect of human rationality: We all coordinate diverse processes, strategies, and perspectives.

**Conclusion**

Research shows that adolescents often make progress in their thinking and reasoning, thus enhancing the quality of their inferences. But what is developing in the development of reasoning? From the universality of internal cognitive diversity, another human universal likely follows: Given the demands of cognitive coordination, we all, to varying degrees, develop metacognitive understanding and control of our diverse inferential processes. Thus we turn now to the development of metacognition.