Adolescence

Twelfth Edition

Adolescence

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For Wendy and Ben

About the Author

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LAURENCE STEINBERG, Ph.D., is the Distinguished University Professor and Laura H. Carnell Professor of Psychology at Temple University. He graduated from Vassar College in 1974 and from Cornell University in 1977, where he received his Ph.D. in human development and family studies. He is a Fellow of the American Psychological Association, the Association for Psychological Science, and the American Academy of Arts and Sciences and former President of the Society for Research on Adolescence and the Division of Developmental Psychology of the American Psychological Association. Dr. Steinberg has been on the editorial boards of many major journals, including *Developmental Psychology* and *Child Development,* where he served as Associate Editor. He chaired the National Academies' Committee on the Science of Adolescence and has been a frequent consultant to state and federal agencies and lawmakers on child labor, secondary education, and juvenile justice policy. His work was cited numerous times by the U.S. Supreme Court in its landmark decisions that abolished the juvenile death penalty and mandatory sentences of life without parole for juveniles.

Dr. Steinberg is one of the most highly cited scholars in the field of developmental psychology. His own research has focused on a range of topics in the study of contemporary adolescence, including parent–adolescent relationships, risk taking and decision making, mental health, adolescent brain development, school-year employment, academic achievement, and juvenile crime and justice. He has been the recipient of numerous honors, including the John P. Hill Award for Outstanding Contributions to the Study of Adolescence, given by the Society for Research on Adolescence; the Society for Adolescent Medicine's Gallagher Lectureship; and, from the American Psychological Association, the Urie Bronfenbrenner Award for Lifetime Contribution to Developmental Psychology in the Service of Science and Society, the Award for Distinguished Contributions to Research in Public Policy, and the APA Presidential Citation. In 2009, he was named as the first recipient of the Klaus J. Jacobs Research Prize for Productive Youth Development.

Dr. Steinberg also has been recognized for excellence in research and teaching by the University of California, the University of Wisconsin, and Temple University, where he was honored in 1994 as one of that university's Great Teachers. He has taught undergraduate and graduate courses in adolescence for more than 40 years and has served as the primary advisor to more than 40 graduate students, many of whom have gone on to become influential scholars in their own right in the field of adolescence. In 2013,

he received the Elizabeth Hurlock Beckman Award, a national prize given to college professors who have "inspired their former students to achieve greatness."

In addition to *Adolescence,* Dr. Steinberg is the author or co-author of approximately 400 scholarly articles on growth and development during the teenage years, as well as the books *You and Your Adolescent; When Teenagers Work: The Psychological and Social Costs of Adolescent Employment* (with Ellen Greenberger); *Crossing Paths: How Your Child's Adolescence Triggers Your Own Crisis* (with Wendy Steinberg); *Beyond the Classroom: Why School Reform Has Failed and What Parents Need to Do* (with B. Bradford Brown and Sanford Dornbusch); *The 10 Basic Principles of Good Parenting* (which has been published in 10 languages); *Rethinking Juvenile Justice* (with Elizabeth Scott); and *Age of Opportunity: Lessons From the New Science of Adolescence.* He is co-editor of *Studying Minority Adolescents: Conceptual, Methodological, and Theoretical Issues* (with Vonnie McLoyd) and the *Handbook of Adolescent Psychology* (with Richard Lerner).

Brief Contents

Contents

A Note from the Author

Two psychopathic killers persuaded me to abandon my dreams to someday become a comedy writer and study psychology instead. I did not enter college intending to become either a psychologist or a professor. I majored in English, hoping to study creative writing. I became interested in psychology during the second semester of my freshman year, because of an introductory course in personality theory. My professor had assigned the book *In Cold Blood,* and our task was to analyze the personalities of Dick and Perry, the two murderers. I was hooked. I followed this interest in personality development to graduate school in developmental psychology, where I learned that if you really wanted to understand how we develop into the people we ultimately become, you have got to know something about adolescence. That was 45 years ago, and I'm still as passionate about studying this period of life as I was then.

I hope that this book gets you more excited about adolescence, too.

One reason I like teaching and writing about adolescence is that most students find it inherently interesting, in part because pretty much everyone has such vivid recollections of what it was like to be a teenager. In fact, researchers have discovered that people actually remember events from adolescence more intensely than events from other times, something that has been referred to as the "reminiscence bump."

The reminiscence bump makes teaching adolescence both fun and frustrating. Fun, because it isn't hard to get students interested in the topic. Frustrating, though, because it's a challenge to get students to look at adolescence from a scientific, as well as personal, perspective. That, above all, is my goal for this book. I don't want you to forget or set aside your own experience as an adolescent. (I couldn't make that happen, anyway.) But what I hope I can do is to help you understand adolescence—your own adolescence as well as the adolescence that is experienced by others around the world—more deeply and more intelligently, by introducing you to the latest science on the subject. I still maintain a very active program of research of my own, and that necessitates staying on top of the field's most recent and important developments. There is a lot of exciting work being done on adolescence these days (one of my interests is the adolescent brain), and I want to share this excitement with you. Who knows, maybe you'll become hooked, too.

I've tried to do my best at covering the most important topics and writing about them in a way that is not only informative, but fun and interesting to read. If there's something I could have done better, please let me know.

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Preface

Cutting-edge Science, Personalized for Today's Students

As a well-respected researcher, Laurence Steinberg connects current research with real-world application, helping students see the similarities and differences in adolescent development across different social, economic, and cultural backgrounds.

Through an integrated, personalized digital learning program, students gain the insight they need to study smarter, stay focused, and improve their performance.

Personalized Study, Better Data, Improved Results

McGraw-Hill Education's SmartBook® is an adaptive learning program designed to help students stay focused and maximize their study time. Based on metacognition and powered by McGraw-Hill LearnSmart, SmartBook's adaptive capabilities provide students with a personalized reading and learning experience that helps them identify the concepts they know, and more importantly, the concepts they don't know.

Make It Effective. Unlike other eBooks, SmartBook is adaptive. SmartBook creates a personalized reading experience by highlighting the most impactful concepts a student needs to learn at that moment in time. This ensures that every minute spent with SmartBook is returned to the student as the most value-added minute possible.

Make It Informed. SmartBook continuously adapts, highlighting content based on what the student knows and doesn't know. Real-time reports quickly identify the concepts that require more attention from individual students—or the entire class. Because SmartBook is personalized, it detects the content individual students are most likely to forget and refreshes them, helping improve retention.

New to this edition, SmartBook is now optimized for mobile and tablet and is accessible for students with disabilities. Content-wise, it has been enhanced with improved learning objectives that are measurable and observable to improve student outcomes. SmartBook personalizes learning to individual student needs, continually adapting to pinpoint knowledge gaps and focus learning on topics that need the most attention. Study time is more productive and, as a result, students are better prepared for class and coursework. For instructors, SmartBook tracks student progress and provides insights that can help guide teaching strategies.

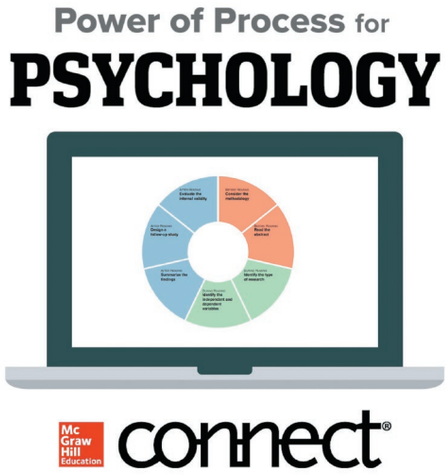
Informed by Students. Content revisions are informed by data collected anonymously through McGraw-Hill Education's SmartBook.

STEP 1. Over the course of three years, data points showing concepts that caused students the most difficulty were anonymously collected from Connect for Adolescence's SmartBook.

STEP 2. The data from SmartBook were provided to the author in the form of a **Heat Map**, which graphically illustrates "hot spots" in the text that affect student learning.

STEP 3. The author used the **Heat Map** data to refine the content and reinforce student comprehension in the new edition. Additional quiz questions and assignable activities were created for use in Connect to further support student success.

RESULT: Because the **Heat Map** gave the author empirically based feedback at the paragraph and even sentence level, he was able to develop the new edition using precise student data that pinpointed concepts that gave students the most difficulty.



Preparing Students for Higher-Level Thinking

At the higher end of Bloom's taxonomy, **Power of Process** helps students improve critical-thinking skills and allows instructors to assess these skills efficiently and effectively in an online environment. Available through Connect, preloaded journal articles are available for instructors to assign. Using a scaffolded framework such as understanding, synthesizing, and analyzing, Power of Process moves students toward higher-level thinking and analysis.

Real People, Real World, Real Life

McGraw-Hill Education's Milestones is a powerful video-based learning tool that allows students to experience life as it unfolds, from infancy through emerging adulthood. A limited number of Milestones videos are now available for viewing within the McGraw-Hill Connect Media Bank for Adolescence, 12e.

Chapter-by-Chapter Changes

The Twelfth Edition of *Adolescence* features updated and expanded coverage of key issues in development in every chapter. And as mentioned earlier, the author revised the text in response to student heat map data that pinpointed the topics and concepts with which students struggle the most. This heat-map-directed revision is reflected primarily in Chapters 2, 4, 8, 11, and 12.

Below is a complete list of changes in each chapter:

Chapter 1

- Thorough update of all content (more than 70 new citations)
- Simplified discussion of hormonal regulation of puberty
- Expanded discussion of body dissatisfaction among adolescent girls
- Expanded discussion of adolescent sleep
- Expanded discussion of eating disorders, adding binge eating disorder
- Dropped discussion of adolescent health care

Chapter 2

- Thorough update of all content (more than 90 new citations)
- Expanded discussion of memory during adolescence and the "reminiscence bump"
- Condensed discussion of intelligence
- Greatly expanded discussion of structural and functional changes in the adolescent brain
- Added discussion of brain development in young adulthood
- Expansion of material on "the social brain"
- Expanded discussion of risk taking in adolescence

Chapter 3

- Thorough update of all content (more than 60 new citations)
- Addition of discussion of late adolescents living at home
- Expanded discussion of terminology used to refer to this age group
- Expanded discussion of impact of poverty on mental health and brain development

Chapter 4

- Thorough update of all content (more than 110 new citations)
- Expanded discussion of acculturation
- Greatly expanded discussion of behavioral genetics
- Added discussion of differential susceptibility theory
- Expanded discussion of homeless adolescents

Chapter 5

- Thorough update of all content (more than 100 new citations)
- Dropped dated discussion of "youth culture"
- Added entirely new section on the need for peer groups in modern society, including Margaret Mead's work on societal change
- Simplified discussion of clique structure
- Dropped dated discussion of racial tension in peer groups
- Greatly expanded discussion of bullying and victimization
- Added new section on cyberbullying

Chapter 6

- Thorough update of all content (more than 50 new citations)
- Added discussion of education policy under President Trump
- Dropped dated examples of minority student school experiences
- Added discussion of school climate and bullying
- Updated discussion of differential treatment of minority adolescents in schools
- Updated material on ADHD and medication for the condition

Chapter 7

- Thorough update of all content (more than 90 new citations)
- Greatly condensed discussion of part-time employment
- Dropped dated material on youth unemployment
- Expanded discussion of risky online behavior, like sexting
- Thoroughly revised discussion of "screen time"
- Added entirely new section on social media

Chapter 8

- Thorough update of all content (more than 80 new citations)
- Added discussion of future orientation
- Updated and expanded material on ethnic identity development and discrimination
- Added discussion of differences among sexual identity, sexual orientation, and gender roles
- Added additional discussion of the development of sexual identity, including mental health of transgender youth

Chapter 9

- Thorough update of all content (more than 50 new citations)
- Condensed discussion of emotional autonomy
- Expanded discussion of self-regulation
- Updated discussion on the reasons for the increase in peer influence in adolescence
- Added material on declines in social responsibility in adolescence

Chapter 10

- Thorough update of all content (more than 70 new citations)
- Added entire section on the impact of social media on the development of Intimacy
- Expanded discussion of dating
- Expanded discussion of dating violence

Chapter 11

- Thorough update of all content (more than 70 new citations)
- Update of all statistics on sexual activity
- Expanded discussion of sexual harassment, especially of LGBTQ youth
- Expanded discussion of the effects of casual sex on mental health
- Expanded discussion of peer influences on sexual activity

Chapter 12

- Thorough update of all content (more than 50 new citations)
- New discussion of interventions to enhance noncognitive contributors to academic success
- Expanded discussion of factors affecting student engagement during transition to secondary school
- Updated statistics on U.S. high school achievement (SAT, NAEP, and PISA)

Chapter 13

- Thorough update of all content (more than 150 new citations)
- Expanded discussion of comorbidity of internalizing and externalizing problems
- Expanded discussion of interplay between genes and environment as contributors to psychosocial problems
- New discussion of e-cigarettes
- Expanded discussion of neurobiological differences between conduct disordered and nondisordered adolescents
- Expanded discussion of drugs and the adolescent brain

- Updated all statistics on prevalence and demographic differences in substance abuse, crime, and depression
- Expanded discussion of neurobiological differences between depressed and nondepressed adolescents
- New discussion of school shootings

Online Instructor Resources

The resources listed here accompany *Adolescence*, 12e. Please contact your McGraw-Hill representative for details concerning the availability of these and other valuable materials that can help you design and enhance your course.

Instructor's Manual Broken down by chapter, the Instructor's Manual includes chapter outlines, suggested lecture topics, classroom activities and demonstrations, suggested student research projects, essay questions, and critical thinking questions.

Test Bank and Computerized Test Bank This comprehensive Test Bank includes multiple choice and essay questions. Organized by chapter, the questions are designed to test factual, applied, and conceptual understanding. All test questions are available within TestGen™ software.

PowerPoint Slides The PowerPoint presentations, now WCAG compliant, highlight the key points of the chapter and include supporting visuals. All of the slides can be modified to meet individual needs.

Acknowledgments

Revising *Adolescence* at a time when so much new information is available is a challenge that requires much assistance. For this new edition, McGraw-Hill Education commissioned a broad survey of the course and I am grateful to the more than 150 instructors who provided feedback on trends in the field and challenges in the classroom.

In addition, I am grateful to the many colleagues and students across the country who took the time during the past 35 years to send me comments and suggestions based on their firsthand experiences using Adolescence in the classroom. They have improved the text with each edition.

2 Cognitive Transitions

Changes in cognition, or thinking, represent the second of three fundamental changes that occur during adolescence—in addition to puberty and the transition into new social roles. Like developments in the other two domains, the cognitive transitions of adolescence have far-reaching implications for the young person's psychological development and social relations. Indeed, the expansion of thought during adolescence represents as significant an event and as important an influence on the adolescent's development and behavior as puberty.

During the last two decades, scientists have made tremendous gains in understanding brain maturation during adolescence through the use of imaging techniques that permit us to look inside the adolescent brain, just as an X-ray permits physicians to look directly at bones. We now have a good idea of how the brain's structure and patterns of activity change during the adolescent years and the implications of these changes for behavioral, emotional, and, of course, cognitive development. Later in this chapter, we'll look at brain maturation in adolescence in detail. But let's begin by simply describing how adolescents think and, more importantly, how their thinking differs from that of children and adults.

Changes in Cognition

Most people would agree that adolescents are "smarter" than children. Teenagers clearly *know* more than children—after all, the longer we live, the more opportunities we have to acquire new information. But adolescents also *think* in ways that are more advanced, more efficient, and generally more effective than children (Keating, 2011; Kuhn, 2009). Compared to children:

- Adolescents are better at thinking about what is possible, instead of limiting their thought to what is real.
- Adolescents are better at thinking about abstract things.
- Adolescents think more often about the process of thinking itself.
- Adolescents' thinking is more often multidimensional, rather than limited to a single issue.
- Adolescents are more likely to see things as relative, rather than as absolute.

Let's look at each of these advantages—and some of their implications for adolescents' behavior—in greater detail.

Thinking About Possibilities

Children's thinking is oriented to the here and now—to things and events that they can observe directly. But adolescents are able to consider what they observe against a backdrop of what is possible. Put another way, for the child, what is possible is what is real; for the adolescent, what is real is just a subset of what is possible. This allows adolescents to think "counterfactually"—to think not only about how things actually are, but to think about what might have been (Beck & Riggs, 2014).

Consider how individuals think about themselves. Children don't wonder, the way adolescents often do, about how their personalities might change in the future, or how they might have been different had they grown up under different circumstances. When you are a child, you simply are who you are. In adolescence, though, who you are is just one possibility of who you could be.

This does not mean that children are incapable of imagination or fantasy. Nor does it mean that children are unable to conceive of things being different from what they observe. But adolescents are able to move easily between the actual and the possible, to generate alternative possibilities and explanations systematically, and to compare the ways things are with the way they might be under different circumstances.

The adolescent's ability to reason systematically in terms of what is possible comes in handy when learning math and science. The study of mathematics in junior and senior high school (algebra, geometry, and trigonometry) often requires that you begin with an abstract or theoretical formulation—for example, "the square of a right triangle's hypotenuse is equal to the sum of the squares

Although many parents believe that their children become more argumentative during adolescence, what is more likely going on is that the cognitive changes of the period enable them to be better arguers. ©Tetra Images/Getty Images

deductive reasoning
A type of logical reasoning in which one draws logically necessary conclusions from a general set of premises, or givens.

of the other two sides" (the Pythagorean theorem). This theorem is a proposition about all *possible* right triangles, not just triangles that you might actually observe. In mathematics, you learn how to apply these theorems to concrete examples (that is, real triangles). You understand that the theorem still holds true even for right triangles you have never seen. Scientific experimentation also involves the ability to generate possibilities systematically. In a chemistry experiment in which you are trying to identify an unknown substance by performing various tests, you must first be able to imagine alternative possibilities for the substance's identity in order to know what tests to conduct.

The adolescent's use of this sort of thinking is not limited to scientific problem solving. We see it in the types of arguments adolescents employ, in which they are better able than children to envision and anticipate the possible responses of an opponent and to have one or more counterarguments handy. Many parents believe that their children become more argumentative during adolescence. What probably happens, though, is that their children become *better arguers* (Steinberg, 2011). Adolescents don't accept other people's points of view unquestioningly–including their parents' viewpoints. They evaluate them against other theoretically possible beliefs. This improvement in the adolescent's intellectual ability likely contributes to the bickering and squabbling that often occur between teenagers and their parents (Smetana, 1989).

making the practical connection

In what ways did your high school classes take advantage of the advanced thinking abilities that develop in adolescence? In what ways were opportunities to do this missed? What might teachers do to stimulate more advanced thinking?

Deductive Reasoning One manifestation of the adolescent's increased facility with thinking about possibilities is the development of **deductive reasoning.** Deductive reasoning is a type of logical reasoning in which you draw logically necessary conclusions from a general set of premises, or givens. Consider the following problem:

All hockey players wear mouth guards.
Kim is a hockey player.
Does Kim wear a mouth guard?

Individuals who reason deductively understand that the correct conclusion (*Kim wears a mouth guard*) necessarily follows from the first two statements. No additional knowledge about hockey or about Kim is necessary to come up with the correct answer. Deductive reasoning is seldom used before adolescence, and its development is one of the major intellectual accomplishments of the period (Morris & Sloutsky, 2001).

Adolescents are also better able than children to recognize when a logical problem *doesn't* provide sufficient information and to respond by saying that the question can't be answered with any certainty. Suppose we were to change the problem to this:

All hockey players wear mouth guards.
Kim is wearing a mouth guard.
Is Kim a hockey player?

If you answer this type of question quickly, without thinking it through, you might say that Kim is indeed a hockey player. But, in fact, this isn't necessarily the case. Whereas children are easily fooled by such problems, adolescents are more likely to say that there is no way of knowing whether Kim plays hockey, because we are not told that the *only* people who wear mouth guards are hockey players.

One reason for their superior performance on these sorts of problems is that adolescents are better able to catch themselves before they incorrectly answer the question and pause a moment before responding (Daniel & Klaczynski, 2006). As you will read later in this chapter, the ability to stop yourself before acting automatically (and perhaps incorrectly) is controlled by a region of the brain that has been shown to mature during adolescence (Casey & Caudle, 2013; Luna, Paulsen, Padmanabhan, & Geier, 2013).

Hypothetical Thinking Related to the development of deductive reasoning is the emergence of hypothetical, or "if-then," thinking. In order to think hypothetically, you need to see beyond what is directly observable and apply logical reasoning to anticipate what might be possible. Being able to plan ahead, to see the future consequences of an action, and to provide alternative explanations of events all require being able to think hypothetically.

Thinking hypothetically also permits us to suspend our beliefs about something in order to argue in the abstract. If you have ever been in a debate, you know that being capable of assuming a hypothetical stance is important, because doing so permits us to understand the logic behind another person's argument without necessarily agreeing with it. Playing "devil's advocate," for example–when you take a position contrary to what you really believe in order to challenge someone else's reasoning–requires hypothetical thinking.

Hypothetical thinking also has implications for the adolescent's social behavior. Taking the perspective of others enables the adolescent to think through what someone else might be thinking or feeling ("If I were in her situation, I'd be pretty angry"). This helps in formulating and arguing a viewpoint, because it allows adolescents to

think a step ahead of the opposition—a cognitive tool that can come in handy when dealing with parents ("If they come back with 'You have to stay home and clean up the garage,' then I'll remind them about the time they let my sister go out when *she* had chores to do"). And hypothetical thinking plays an important role in decision making, because it permits us to plan ahead and foresee the consequences of choosing one alternative over another ("If I go out for the soccer team, then I am going to have to give up my part-time job"). We become much better at anticipating the future consequences of our decisions during adolescence (Steinberg, Graham, et al., 2009).

Thinking About Abstract Concepts

The appearance of more systematic, abstract thinking is a second notable aspect of cognitive development during adolescence. We noted earlier that children's thinking is more concrete and more bound to observable events and objects than is that of adolescents. This difference is clear when we consider the ability to deal with abstract concepts—things that cannot be experienced directly through the senses.

Abstract thinking is clearly seen in adolescents' ability to think in more advanced ways about interpersonal relationships, politics, philosophy, religion, and morality—topics that involve such abstract concepts as friendship, faith, democracy, fairness, and honesty. The growth of social thinking during adolescence is directly related to the young person's improving ability to think abstractly. Later in this chapter, we'll examine the ways in which social thinking—generally referred to as "social cognition"—improves in adolescence.

Thinking About Thinking

A third gain in cognitive ability during adolescence involves thinking about thinking itself, a process sometimes referred to as **metacognition.** Metacognition often involves monitoring your own cognitive activity during the thinking process—for example, when you consciously use a strategy for remembering something (such as the mnemonic device *Every Good Boy Deserves Fun* to recall that the notes of the treble clef are E-G-B-D-F) or when you make sure you've understood something you're reading before going on to the next paragraph. Interventions designed to improve adolescents' metacognitive skills have been shown to enhance reading, writing, test taking, and performance on homework (Williams et al., 2002). Because adolescents are better at thinking about their own thoughts, they are much better at monitoring their own learning (Crone, Somsen, Zanolie, & Van der Molen, 2006; Kuhn, 2009). While studying, adolescents are able to step back and assess how well they are learning the material. Doing this enables them to pace their studying accordingly—to speed up and skim the material if they feel that they are learning it easily or to slow down and repeat a section if they are having a hard time. Brain systems that are active when individuals are monitoring their own performance continue to mature throughout adolescence and early adulthood, which may help the development of metacognition (Ladouceur, Dahl, & Carter, 2007).

Thinking about thinking also leads to increased introspection and self-consciousness. When we are introspective, we are thinking about our own emotions. When we are self-conscious, we are thinking about how others think about us. These processes permit the sorts of self-examination and exploration that are important tools for establishing a coherent sense of identity.

Adolescent Egocentrism The ability to think about thinking sometimes results in problems for young adolescents, before they adjust to having such powerful cognitive tools. Being able to introspect, for instance, may lead to periods of extreme self-absorption—referred to as "adolescent egocentrism" (Elkind, 1967). Adolescent egocentrism results in two distinct problems in thinking that help to explain some of the seemingly odd beliefs and behaviors of teenagers (Goossens, Seiffge-Krenke, & Marcoen, 1992).

The first, the **imaginary audience,** comes from having such a heightened sense of self-consciousness that you imagine that your behavior is the focus of everyone else's attention. For example, a teenager who is going to a concert with 10,000 other people may worry about dressing the right way because "everybody will notice." Given the cognitive limitations of adolescent egocentrism, it is hard to persuade young adolescents that the "audience" is not all that concerned with their behavior or appearance. We now know that the parts of the brain that process social information—such as perceptions of what others are thinking—undergo significant change during early adolescence, just when self-consciousness is increasing (Burnett, Sebastian, Kadosh, & Blakemore, 2011; Mills, Lalonde, Clasen, Giedd, & Blakemore, 2014; Pfeifer & Blakemore, 2012; Pfeifer et al., 2013; Somerville et al., 2013). Brain imaging studies indicate that adolescents' self-perceptions rely more than adults' on what they believe others think of them (Pfeifer et al., 2009).

metacognition
The process of thinking about thinking itself.

imaginary audience
The belief, often brought on by the heightened self-consciousness of early adolescence, that everyone is watching and evaluating one's behavior.

personal fable
An adolescent's belief that he or she is unique and therefore not subject to the rules that govern other people's behavior.

A second problem resulting from adolescent egocentrism is called the **personal fable.** The personal fable revolves around the adolescent's egocentric (and erroneous) belief that his or her experiences are unique. For instance, an adolescent

teenager whose relationship with a girlfriend has just ended might tell his sympathetic mother that she could not possibly understand what it feels like to break up with someone—even though breaking up is something that most people experience plenty of times in life. Maintaining a personal fable of uniqueness has some benefits, in that it enhances adolescents' self-esteem and feelings of self-importance. But holding on to a personal fable also can be dangerous: think about a sexually active adolescent who believes that pregnancy simply won't happen to her, or a reckless driver who believes that he will defy the laws of nature by taking hairpin turns at breakneck speed.

Although it was once thought that adolescents are especially susceptibile to the personal fable, researchers have found it difficult to confirm that egocentrism actually peaks in early adolescence. In fact, certain aspects of adolescent egocentrism, including the personal fable, persist through the adult years (Frankenberger, 2000; Quadrel, Fischhoff, & Davis, 1993). Ask any *adult* cigarette smoker if she or he is aware of the scientific evidence linking cigarette smoking with heart and lung disease, and you'll see that the personal fable is quite common among many individuals who have long since left adolescence.

making the personal connection

Think back to your own adolescence. Can you recall times when you experienced an imaginary audience? How about more recently? Do you think this happened more when you were younger than it does now?

Thinking in Multiple Dimensions

A fourth way in which thinking changes during adolescence involves the ability to think about things in multiple dimensions (Kuhn, 2009). Whereas children tend to think about things one aspect at a time, adolescents can see things through more complicated lenses. For instance, when a certain batter comes up to the plate in a baseball game, a preadolescent who knows that the player has a good home-run record might exclaim that the batter will hit the ball out of the stadium. An adolescent, however, would consider the hitter's record in relation to the specific pitcher on the mound and would weigh both factors before making a prediction (perhaps this player often hits homers against left-handed pitchers but frequently strikes out against righties).

The ability to think in multidimensional terms is evident in a variety of situations. Adolescents can give much more complicated answers than children to questions such as "Why did the Civil War begin?" or "How did Jane Austen's novels reflect the changing position of women in European society?" Thorough answers to these sorts of questions require thinking about several dimensions simultaneously, because many factors led to the Civil War, just as many factors affected the way in which people reacted to Austen's work.

The development of a more sophisticated understanding of probability is also made possible by an improved ability to think in multiple dimensions. Suppose I give you a set of blue and yellow beads. I ask you to divide them into two containers so that the containers have different numbers of beads overall but that the probability of reaching into a container and picking a blue bead is the same for each. In order to do so, you would have to vary the number of blue beads *and* the number of yellow beads between the two containers, because the probability of drawing a blue bead is a function of both the number of blue beads and the number of yellow beads. It is not until early adolescence that individuals can solve this sort of problem successfully (Falk & Wilkening, 1998).

As is the case with other gains in cognitive ability, the ability of individuals to think in multiple dimensions also has consequences outside of school. Adolescents describe themselves and others in more complicated terms ("I'm shy with strangers, but extroverted with people once I've met them") and find it easier to look at problems from multiple perspectives ("I know that's the way you see it, but try to look at it from her point of view"). Understanding that people's personalities are not one-sided, or that social situations can have different interpretations, permits the adolescent to have far more sophisticated—and far more complicated—self-conceptions and relationships.

Sarcasm and *South Park* Adolescents' ability to look at things in multiple dimensions also enables their understanding of sarcasm. As an adult, you know that the meaning of a speaker's statement is communicated by a combination of what is said, how it is said, and the context in which it is said. If I turned to you during a boring

The development of advanced thinking abilities allows adolescents to appreciate sarcasm, irony, and satire, such as that used in shows like South Park. ©Getty Images/Getty Images

lecture, rolled my eyes, and said, in an exaggeratedly earnest tone, "This is the most interesting lecture I've ever heard," you'd know that I actually meant just the opposite. But you'd know this only if you paid attention to my inflection and to the context, as well as the content, of my statement. Only by attending simultaneously to multiple dimensions of speech can we distinguish between the sincere and the sarcastic. It's no surprise that our ability to use and detect sarcasm and irony improves during preadolescence and adolescence (Glenwright & Pexman, 2010).

Why do young adolescents laugh hysterically when characters in movies aimed at their age group say things like "He said 'erector set'"? Adolescents' ability to think in multiple dimensions also permits them to appreciate satire, metaphor, and the ways in which language can be used to convey multiple messages. Teenagers' ability to use and appreciate sarcasm, irony, and satire helps to explain why shows like *The Simpsons, South Park,* and *Rick and Morty* have always had such strong appeal in this age group. (Not to mention that they are often pretty funny to adults, too. Our son's school once summoned his class's parents to watch an "offensive" episode of *South Park* to show us how our children were being harmed by television; the demonstration ended prematurely, though, because we parents were laughing too hard.)

Adolescent Relativism

A final aspect of cognition that changes during adolescence concerns a shift from seeing things in absolute terms—in black and white—to seeing things as relative. Compared to children, adolescents are more likely to question others' assertions and less likely to accept "facts" as absolute truths.

This increase in relativism can be exasperating to parents, who may feel as though their teenagers question everything just for the sake of argument. Difficulties often arise, for example, when adolescents begin seeing parents' values that they had previously considered absolutely correct ("Moral people do not have sex before they are married") as completely relative ("Welcome to the twenty-first century, Dad").

Theoretical Perspectives on Adolescent Thinking

Although there is general agreement that adolescents' thinking is more advanced than children's, there is far less consensus about the processes underlying this advantage. Part of the lack of agreement stems from the fact that no one single factor distinguishes thinking during adolescence from thinking during childhood (Keating, 2011). And part stems from the different points of view that theorists have taken toward cognitive development in general. Because researchers working from different theoretical perspectives have posed different research questions, used different tasks to measure thinking, and emphasized different aspects of cognitive activity, their studies provide different, but nevertheless compatible, pictures of mental development during adolescence.

Two theoretical viewpoints that have been especially important are the Piagetian perspective and the information-processing perspective. Although these two views of adolescent thinking begin from different assumptions about the nature of cognitive development in general, they each provide valuable insight into why thinking changes during adolescence (Kuhn, 2009).

The Piagetian View of Adolescent Thinking

Theorists who adopt a Piagetian perspective take a **cognitive-developmental view** of intellectual development. They argue that cognitive development proceeds through a fixed sequence of qualitatively distinct stages, that adolescent thinking is fundamentally different from the type of thinking employed by children, and that during adolescence, individuals develop a special type of thinking that they use across a variety of situations.

According to Piaget, cognitive development proceeds through four stages: (1) the **sensorimotor period** (from birth until about age 2), (2) the **preoperational period** (from about age 2 until about age 5), (3) the period of **concrete operations** (from about age 6 until early adolescence), and (4) the period of **formal operations** (from adolescence through adulthood). Each stage is characterized by a particular type of thinking, with earlier stages of thinking being incorporated into new, more advanced, and more adaptive forms of reasoning. Piagetian theorists believe that abstract logical reasoning is the chief feature that differentiates adolescent thinking from that of children (Keating, 2011).

We noted that adolescents' thinking can be distinguished from the thinking of children in several respects—among them, being able to think hypothetically, multidimensionally, and abstractly. The connection between these skills and the development of formal operations is clear: In order to think about alternatives to what really exists, to think in multidimensional terms, and

cognitive-developmental view
A perspective on development, based on the work of Piaget, that takes a qualitative, stage-theory approach.

sensorimotor period
The first stage of cognitive development, according to Piaget, spanning the period roughly between birth and age 2.

preoperational period
The second stage of cognitive development, according to Piaget, spanning roughly ages 2 to 5.

concrete operations
The third stage of cognitive development, according to Piaget, spanning the period roughly between age 6 and early adolescence.

formal operations
The fourth stage of cognitive development, according to Piaget, spanning the period from early adolescence through adulthood.

information-processing perspective
A perspective on cognition that derives from the study of artificial intelligence and attempts to explain cognitive development in terms of the growth of specific components of the thinking process (such as memory).

selective attention
The process by which we focus on one stimulus while tuning out another.

divided attention
The process of paying attention to two or more stimuli at the same time.

working memory
That aspect of memory in which information is held for a short time while a problem is being solved.

long-term memory
The ability to recall something from a long time ago.

autobiographical memory
The recall of personally meaningful past events.

to systematically think about concepts that aren't directly observable, you need a system of reasoning that works just as well in hypothetical situations as it does in actual ones.

There is a difference, of course, between what adolescents are capable of doing and what they actually do. Gaps between people's reasoning abilities and how logically they think in everyday situations are huge, and everyday decision making is fraught with logical errors that cannot be explained by cognitive incompetence (Kahneman, 2011). This is true for adults as well as adolescents. For example, if asked whether they would rather try to pull a lucky lottery ticket from an envelope of 10 tickets, of which only 1 is lucky, versus an envelope of 100 tickets, of which 10 are lucky, most people select the second option—even if they know that the mathematical odds of pulling a lucky ticket are identical in the two scenarios.

Although its influence has waned considerably over the past four decades, the Piagetian perspective on cognitive development during adolescence has stimulated a great deal of research on how young people think, although not all of the perspective's predictions have held up (Keating, 2011). Actually, very little research supports the idea that cognitive development proceeds in a stage-like fashion and that there is a qualitatively unique stage of thinking that is characteristic of adolescence (Keating, 2011; Kuhn, 2009). Rather, advanced reasoning capabilities develop gradually and continuously from childhood through adolescence and beyond, in more of a steady fashion than was proposed by Piaget (that is, more like a ramp than like a staircase). Rather than talking about a distinct stage of cognitive activity characteristic of adolescence, it is more accurate to depict these advanced reasoning capabilities as skills that are employed by older children more often than by younger ones, by some adolescents more often than by others, and by individuals when they are in certain situations (especially familiar ones) more often than when they are in other ones (Kuhn, 2009).

The Information-Processing View of Adolescent Thinking

Piaget attempted to describe adolescent thinking in broad terms, and to use one overarching concept—formal operations—to characterize the period. Other scientists have tried to identify the specific abilities that improve as individuals move from childhood into adolescence and beyond. Just what is it about the ways adolescents think about things that makes them better problem solvers than children? This question has been the focus of researchers working from the **information-processing perspective.**

Studies of changes in specific components of information processing have focused on four areas in which improvement occurs during adolescence: attention, memory, processing speed, and organization. All of these skills improve as individuals move from childhood through adolescence, mainly during the first half of the adolescent decade (Keating, 2004). These gains help to explain why adolescents are better than children at abstract, multidimensional, and hypothetical thinking.

Attention During adolescence, we become better at paying attention (Thillay et al., 2015). Improvements take place both in **selective attention,** in which adolescents must focus on one stimulus (a reading assignment) and tune out another (the electronic beeping of a younger brother's video game), and in **divided attention,** in which adolescents must pay attention to two sets of stimuli at the same time (such as studying while texting with a friend) (Memmert, 2014; Mizuno et al., 2011). Improvements in attention mean that adolescents are better able than children to concentrate and stay focused on complicated tasks, such as reading and comprehending difficult material. There also is considerable evidence that the ability to inhibit an unwanted response (for instance, stopping yourself from looking up at a commercial that suddenly appears on the television in the corner of the room while you are reading) improves during early and middle adolescence (Kuhn, 2009). This improvement is likely linked to maturation of brain systems that govern impulse control (Casey & Caudle, 2013; Church, Bunge, Petersen, & Schlaggar, 2017). One concern that has been raised in recent years is the possible adverse impact that media multitasking has on adolescents' ability to sustain attention on information they need to focus on (Rothbart & Posner, 2015; Uncapher, Thieu, & Wagner, 2016).

Memory Second, memory abilities improve during adolescence. This is reflected both in **working memory,** which involves the ability to remember something for a brief period of time, such as 30 seconds, and in **long-term memory,** which involves being able to recall something from a long time ago (Keating, 2004). Studies of adolescents' ability to remember personally meaningful events from earlier in life, an aspect of long-term memory called **autobiographical memory,** find that our earliest memories, some of which we lose during childhood, stabilize sometime during early adolescence, when most people can remember back to when they were about

Improvements in selective attention and divided attention enable adolescents to tune out interference and focus on the task at hand.
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two and a half years old, but not much earlier than this (Reese, Jack, & White, 2010).

Adults generally remember details about the people, places, and events they encountered during adolescence better than those from other years, a phenomenon called the **reminiscence bump** (Rubin et al., 1986). The reminiscence bump does not appear to result from better memory, because basic memory abilities remain strong until midlife. Nor is it due to the fact that so many important events happen for the first time during adolescence (e.g., first love, first job, first time living away from parents). Even mundane events that took place during adolescence are recalled better than those that happened at other ages. Moreover, we tend to remember other, less personal things from adolescence better, too—things like movies, books, music, and current events (Janssen, Chessa, & Murre, 2007).

Something is different about how everyday experiences are encoded during adolescence, as if the brain's "recording device" is calibrated to be hypersensitive at this age. When certain chemicals in the brain are released at the same time an event is experienced, the event is more easily remembered than when levels of these chemicals are not as high. These chemicals are released when we experience something that elicits strong negative or positive feelings. As we'll see, brain regions responsible for strong emotions are especially sensitive during adolescence. As a result, the adolescent brain is chemically primed to encode memories more deeply (Knutson & Adcock, 2005). As you'll read later in this chapter, brain systems that govern emotion undergo dramatic change in adolescence. The reminiscence bump doesn't exist because more emotional events take place in adolescence, but because ordinary events trigger stronger emotions.

reminiscence bump
The fact that experiences from adolescence are generally recalled more than experiences from other stages of life.

When we think of the importance of memory in problem solving, we typically think of having to retrieve facts that we deliberately have memorized—one aspect of long-term memory. But working memory may be even more important than long-term memory for the sort of problem solving likely encountered in adolescence (Amso, Haas, McShane, & Badre, 2014). For example, in order to answer multiple-choice questions, you need to be able to remember each option long enough to compare it with the other choices as you read them. Think for a moment of how frustrating it would be to try to solve a multiple-choice problem if, by the time you had read the final potential answer, you had forgotten the first one!

Working memory skills increase between childhood and adolescence and over the course of adolescence (Carriedo, Corral, Montor, Herrero, & Rucian, 2016). Improvements in working memory coincide with the continued maturation of brain regions during adolescence that are responsible for this aspect of cognition (Conklin, Luciana, Hooper, & Yarger, 2007; Hanson et al., 2012; Jolles, Kleibeuker, Rombouts, & Crone, 2011). More specifically, advances in working memory during adolescence are linked to the ways in which these areas of the brain are organized and connected, which permits more efficient and powerful information processing (Wendelken, Ferrer, Whitaker, & Bunge, 2016; Sole-Padulles et al., 2016). And because these brain regions are still developing in early adolescence, it is possible to improve individuals' basic cognitive abilities through

training (Schmiedek, Lovden, & Lindenberger, 2014). As is the case with media multitasking and attention, though, concerns have been raised about the impact of multitasking on memory; adolescents who are frequent multitaskers perform worse on tests of both working memory and long-term memory (Uncapher et al., 2016).

Speed A third component of information processing related to the observed improvements in thinking in adolescence is an increase in the sheer speed of information processing (Kail & Ferrer, 2007). Regardless of the task employed, older adolescents process the information necessary to solve the problem faster than early adolescents, who, in turn, process information faster than preadolescents. This increase in the speed of information processing occurs mainly in early adolescence; the difference in speed between a 9-year-old and a 12-year-old is greater than that between a 12-year-old and a 15-year-old, which, in turn, is greater than that between a 15-year-old and an 18-year-old (Kail & Ferrer, 2007). Processing speed does not change very much between middle adolescence and young adulthood (Church et al., 2017).

Organization A fourth information-processing gain in adolescence involves improvements in organizational strategies (Siegler, 2006). Adolescents are more planful than children—they are more likely to approach a problem with an appropriate strategy in mind and are more flexible in their ability to use different strategies in different situations (Albert & Steinberg, 2011a). The use of mnemonic devices (such as using HOMES to remember the names of the Great Lakes—Huron, Ontario, Michigan, Erie, and Superior) and other organizational strategies helps to account for differences in the performance of older and younger children on academic tasks requiring memory (Siegler, 2006).

For instance, think for a moment about how you approach learning the information in a new textbook chapter. After years of studying, you are probably well aware of particular strategies that work well for you (underlining, highlighting, taking notes, writing in the margins), and you begin a reading assignment with these strategies in mind. Because children are not as planful as adolescents, their learning is not as efficient. Developmental differences in levels of planning during childhood and adolescence can be seen quite readily by comparing individuals' approaches to the guessing game 20 Questions. With age, individuals' strategies become increasingly more efficient—when guessing the name of a person, an adolescent might begin by asking whether the person is dead or alive, then male or female, and so forth, whereas a young child might just start randomly throwing out the names of specific people (Drumm & Jackson, 1996).

functional magnetic resonance imaging (fMRI) A technique used to produce images of the brain, often while the subject is performing some sort of mental task.

diffusion tensor imaging (DTI) A technique used to produce images of the brain that shows connections among different regions.

Is Cognitive Development Complete by Age 15? By the time they have turned 15, adolescents are just as proficient as adults in basic cognitive abilities. Working memory, attention, and logical reasoning abilities increase throughout childhood and early adolescence and then level off around this age (Gathercole, Pickering, Ambridge, & Wearing, 2004; Luciana, Conklin, Hooper, & Yarger, 2005). However, at this age people are still developing more sophisticated cognitive skills, such as thinking creatively, planning ahead or judging the relative costs and benefits of a risky decision (Kleibeuker, Koolschijn, Jolles, De Dreu, & Crone, 2013; Albert & Steinberg, 2011b), and in the coordination of cognition and emotion, when feelings might interfere with logical reasoning (for example, when you have to make a decision when you are angry or when faced with peer pressure) (Albert, Chein, & Steinberg, 2013). Much of what we have learned about brain maturation in adolescence—the subject of the next section—helps explain why basic information-processing skills may mature by age 15, but why the development of more advanced abilities may not be complete until individuals reach their mid-20s.

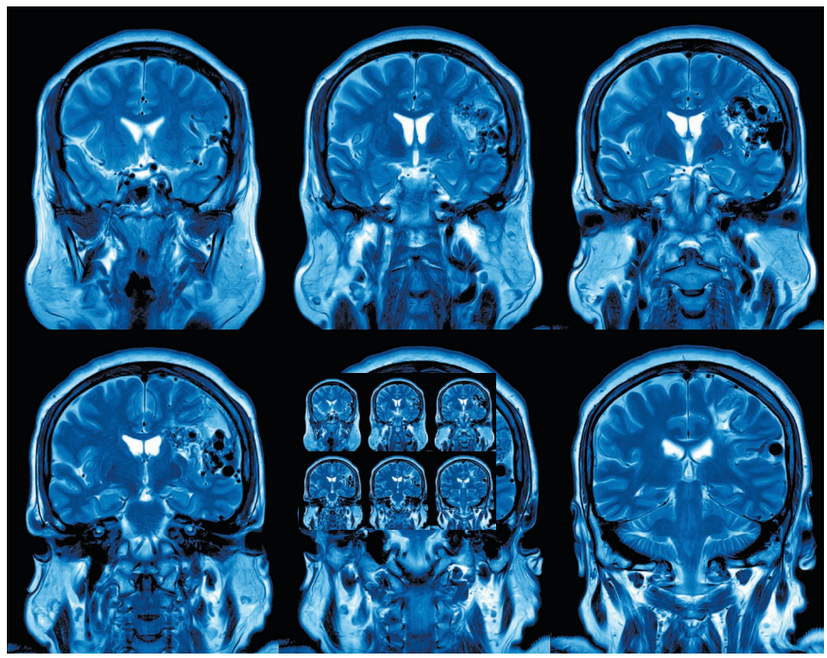
The Adolescent Brain

It was once believed that improved intellectual functioning in adolescence would be reflected in larger brain size. But the brain reaches its adult size by age 10, making it impossible that changes in thinking during adolescence are due to sheer increases in the size of the brain (Paus, 2009). For many years, scientists could not find links between physical changes in the brain and improvements in cognitive functioning during adolescence.

All this changed a little more than 15 years ago. Since 2000, there has been an explosion in research on adolescent brain development, and the speed with which our understanding of adolescent brain development has grown has been absolutely breathtaking (Blakemore, 2018; Dahl, 2016; Spear & Silveri, 2016).

Improvements in the methods used to study brain maturation—including studies of brain growth and development in other animals (because all mammals go through puberty, it is possible to study "adolescent" brain development in other species), studies of changes in brain chemistry, and postmortem studies of brain anatomy—have advanced the field in important ways (Doremus-Fitzwater & Spear, 2016; Mychasiuk & Metz, 2016). But the major contribution to our understanding of what takes place in the brain during adolescence has come from studies using various imaging techniques, especially **functional magnetic resonance imaging (fMRI)** and **diffusion tensor imaging (DTI).** These techniques allow researchers to take pictures of individuals' brains and compare their anatomy and activity. Some aspects of brain development in adolescence are

reflected in changes in **brain structure** (for instance, certain parts of the brain are relatively smaller in childhood than adolescence, while others are relatively larger), whereas others are reflected not so much in the brain's structure but in changes in **brain function** (for instance, adolescents may use different parts of the brain than children when performing the same task) (e.g., Dosenbach et al., 2010; O'Hare, Lu, Houston, Bookheimer, & Sowell, 2008; Wang, Huettel, & De Bellis, 2008).



Advances in brain-imaging technology have contributed to our understanding of how the brain changes at adolescence. These images are created through a process known as functional magnetic resonance imaging, or fMRI. ©AkeSak/Shutterstock

Using DTI, scientists are able to see the ways in which various regions of the brain are connected and compare patterns of interconnections among people at different ages (e.g., Klingberg, 2006). This allows us to better understand how "communication" patterns linking different regions of the brain change with development. Researchers use fMRI to examine patterns of activity in various regions of the brain while individuals are performing different tasks (for example, recalling a list of words, viewing photos of friends, or listening to music).

Participants in an fMRI study are asked to perform tasks on a computer while they are lying inside a brain scanner. With this setup, it is possible to study both how patterns of brain activity differ during different tasks (for example, when we are actively reading versus being read to) and whether people of different ages show different patterns of brain activity while performing the very same task. In our lab, for instance, my collaborators and I study how patterns of brain activity vary when individuals perform tasks either alone or with their friends watching them, and whether the ways in which the impact of an audience of peers on brain activity differs between teenagers and adults (e.g., Smith, Steinberg, Strang, & Chein, 2015).

Scientists have also studied age differences in patterns of brain activity using **electroencephalography (EEG),** which measures electrical activity at different locations on the scalp. EEG can be used to examine changes in electrical activity—called **event-related potentials (ERPs)**—in response to different stimuli or events (Segalowitz & Davies, 2004). Scientists often compare ERPs between people of different ages to determine when, if at all, patterns of brain activity undergo developmental change (e.g., Bishop, Hardiman, Uwer, & von Suchodoletz, 2007; Feinberg & Campbell, 2010).

Are Male and Female Brains Different? Many popular books claim that there are important differences between the brains of adolescent boys and girls (and, for that matter, adult men and women). Research indicates, however, that differences between the genders in brain structure and function are very small and unlikely to explain differences between males and females in the way they behave or think (Paus, 2009; Spear, 2010). In general, male brains are about 10% larger than female brains (even accounting for the fact that male bodies, on average, are bigger than females'), but as noted above, there is no relation between sheer brain size and intellectual functioning, so it is unlikely that this small difference in size has any practical significance. In addition, there are few consistent sex differences in the size of specific brain regions or structures—some parts of the brain are slightly larger among females, and some are slightly larger among males (Ardekani, Figarsky, & Sidtis, 2012; Dennison et al., 2013; Blakemore, 2011; Koolschijn & Crone, 2013).

Several studies have looked specifically for connections between pubertal hormones and brain development, since male and female brains are exposed to different levels of testosterone and estrogen both prenatally and during puberty (Bramen et al., 2012; Herting,

brain structure
The physical form and organization of the brain.

brain function
Patterns of brain activity.

electroencephalography (EEG)
A technique for measuring electrical activity at different locations on the scalp.

event-related potentials (ERPs)
Changes in electrical activity in areas of the brain in response to specific stimuli or events.

neurons
Nerve cells.

synapse
The gap in space between neurons, across which neurotransmitters carry electrical impulses.

neurotransmitters
Specialized chemicals that carry electrical impulses between neurons.

Maxwell, Irvine, & Nagel, 2012). It is clear that the structure of the brain is changed by exposure to sex hormones, but the ways in which the brains of adolescent boys and girls differ as a result of sex hormones is enormously complicated (Cédric, Koolschijn, Peper, & Crone, 2014). Some studies also show different patterns of connections between brain regions in males and females (Lopez-Larson, Anderson, Ferguson, & Yurgelun-Todd, 2011; Satterthwaite et al., 2015; Tomasi & Volkow, 2012), although the importance of these changes for understanding sex differences in behavior or cognition is not known. By and large, however, the similarities between males and females in brain structure and function—before, during, and after adolescence—are far more striking than the differences (Gur & Gur, 2016). Most experts agree that differences between how males and females think are too small to be of practical significance and do not justify educational curricula or teaching techniques that have been specially geared for boys or girls (Miller & Halpern, 2014). There may be other reasons to prefer single-sex schools over coeducational ones, but sex differences in brain development isn't one of them.

How Your Brain Works

The brain functions by transmitting electrical signals across circuits that are composed of interconnected cells, called **neurons.** Each neuron has three parts—a cell body; a longish projection called an axon, which terminates in many small tips; and thousands of tiny, antennae-like branches, called dendrites, which themselves split off into smaller and smaller spines, like a plant's root system. In the adult brain, each neuron has about 10,000 connections. Collectively, neurons and the projections that connect them are called "gray matter."

When electrical impulses travel along a neural circuit, they leave one neuron through its axon and enter the next one through one of the receiving neuron's dendrites. The transmission of current from one neuron to another can be thought of as the passage of information along that particular pathway, like runners on a track team passing a baton during a relay race. Everything we think, perceive, feel, or do depends on the flow of electrical impulses across the brain's circuits.

The axon of one neuron is not actually connected to the dendrites of another, though, the way an electrical wire in your home is connected to a light switch, or the way the prongs of an appliance plug touch the active contacts inside an outlet. There is a tiny gap, called a **synapse,** between the tip of one neuron's axon and another neuron's dendrite. In order for an impulse to be relayed to a neighboring neuron, the electrical charge has to "jump" across this gap. How does this happen?

The transfer of current across the synapse when a neuron fires is enabled by the release of chemicals called **neurotransmitters.** You've probably heard of some of the most important neurotransmitters, like dopamine or serotonin. Many of the most widely prescribed antidepressants work, for instance, by altering the amount of serotonin in brain circuits that control mood.

When neurotransmitters are released from the "sending" neuron and come into contact with the receptors on the dendrites of the "receiving" neuron, a chemical reaction occurs on the other side of the synapse that triggers a new electrical impulse, which travels on its way to the next neuron in the circuit, jumping across the next synapse with the help of neurotransmitters. This process is repeated whenever information travels through the brain's elaborate circuitry.

Each neurotransmitter has a specific molecular structure that fits into a receptor for which it is precisely designed, the way a key fits into a lock. An impulse that stimulates a neuron to release dopamine will trigger a response in a neuron that has dopamine receptors, but not in one that only has receptors for a different neurotransmitter. This enables the brain to stay organized—if any time a neuron fired it activated every other neuron in the neighborhood, all helter-skelter, it would be impossible to maintain well-defined brain circuits—an enormous challenge in an organ that packs one hundred billion neurons, each with 10,000 connections, into the space inside your skull. This way, when a neuron that is part of a circuit that regulates mood fires, it affects how you feel, not whether you move your big toe.

A key process in early brain development is the development of billions and billions of synapses—the connections between neurons. The formation of some of these synapses is genetically programmed, but others are formed through experience. The rate of synapse formation peaks at about age 1 and slows down in early childhood, but the development of new synapses continues throughout life as we learn new skills, build memories, acquire knowledge, and adapt to changing circumstances. The more a synapse is used, the stronger its electrical pathway becomes.

Gray Matter Initially the brain produces many more connections among cells than it will use. At 1 year of age, the number of synapses in the infant brain is about *twice* the number in the adult brain (Couperus & Nelson, 2006). However, soon after birth unused and

unnecessary synapses start to be eliminated, a process called **synaptic pruning.**

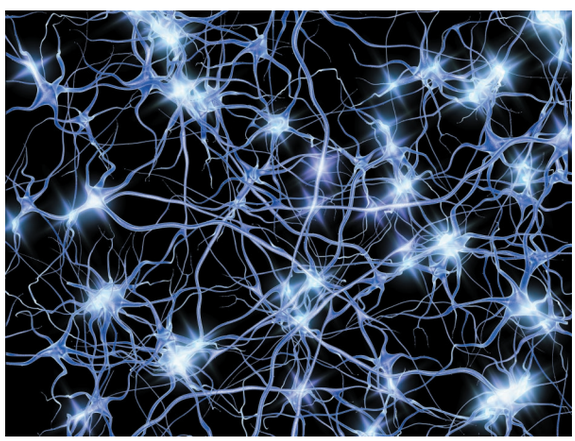
As a general rule, we tend to assume that "more is better," but that's not the case with the number of synapses in the brain. Imagine a meadow between two patches of forest. Hundreds of lightly trodden paths connect one side to the other (the unpruned brain). Over time people discover that one path is more direct than others. More people begin using this path more often, so it becomes wider and deeper. Because the other paths are no longer used, the grass grows back and those paths disappear. That's what synaptic pruning is like—the "paths" we use repeatedly become more and more ingrained, whereas those we do not use disappear. Synaptic pruning results in a decrease in the amount of gray matter in the brain, which is often manifested in a thinning of the areas that have been pruned (Tamnes et al., 2017).

Synaptic pruning continues through adolescence and is normal and necessary to healthy brain development. Just as pruning a rose bush—cutting off weak and misshapen branches—produces a healthier plant with larger flowers, so synaptic pruning enhances the brain's functioning. Synaptic pruning makes the brain more efficient by transforming an unwieldy network of small pathways into a better organized system of "superhighways."

Generally, the development of synapses is characterized by a period of growth (when more and more synapses are created) followed by a period of decline (when more and more synapses are pruned). When we plot the density of synapses over time, we see a ∩-shaped curve—or, more accurately, a series of ∩-shaped curves that peak at different ages, depending on the specific region of the brain, because different regions are pruned at different ages (Tanaka, Matsui, Uematsu, Noguchi, & Miyawaki, 2012). As a rule, the brain regions in which pruning is taking place at a particular point in development are the regions associated with the greatest changes in cognitive functioning during that stage, because as a particular pathway of neural transmission becomes more efficient, the specific cognitive process it supports improves. For example, synaptic pruning in the brain's visual system is most dramatic early in infancy, when our visual abilities are improving the most.

synaptic pruning
The process through which unnecessary connections between neurons are eliminated, improving the efficiency of information processing.

myelination
The process through which brain circuits are insulated with myelin, which improves the efficiency of information processing.



During infancy and childhood, the brain produces more connections between neurons, called synapses, than is necessary. Adolescence is a time when many of these unnecessary synapses are eliminated, a process called "pruning." ©PASIEKA/Brand X/Getty Images

White Matter Cells other than neurons also play a role in transmitting electrical impulses along brain circuits. These cells, known as "white matter," provide support and protection for neurons and compose a fatty substance, called myelin, that surrounds the axons of certain neurons, like the plastic sheath around electrical wires. Myelin insulates brain circuits, keeping the impulses flowing along their intended pathways rather than leaking out. Circuits that are coated in myelin carry impulses about a hundred times faster than circuits that are not myelinated, making them much more efficient, especially if the circuits cover a large distance.

The growth of myelin, called **myelination,** occurs in waves, beginning before birth and continuing into young adulthood (Paus, 2009). Unlike synapses, with their ∩-shaped pattern of growth, white matter increases throughout childhood and adolescence, well into adulthood, although at different rates in different regions of the brain at different points in development (Brain Development Cooperative Group, 2012). As with synaptic pruning, examining *where* myelination is occurring most dramatically at a particular point in development provides clues about the aspects of cognitive functioning that are changing most at that stage.

The Age of Opportunity

One of the most exciting new discoveries in neuroscience is that some areas of the brain may be especially malleable, or "plastic," in adolescence—it is more easily shaped, for better or for worse, by experience during adolescence than at any time other than the first few years of life (Lillard & Erisir, 2011; Selemon, 2013; Zelazo & Carlson, 2012). That's why adolescence has been described as an "age of opportunity" (Steinberg, 2014).

Scientists have known for some time now that the brain is particularly malleable during the first 3 years after birth. But the discovery that adolescence is a second period of heightened brain **plasticity** is a relatively recent development (Selemon, 2013), and one that scientists have become increasingly interested in (Fuhrmann, Knoll, & Blakemore, 2015). Plasticity refers to the capacity of the brain to change in response to experience. It's the process through which the outside world gets inside us and changes us. The brain's remarkable malleability in response to experience enables us to learn and strengthen abilities, from very basic ones (like memory) to very advanced ones (like planning ahead). This is at the heart of brain plasticity. It's not only "use it or lose it." It's also "use it and improve it." This is true at all ages, but it is much more easily and reliably accomplished before adulthood, when the brain is much more plastic.

Why It's Hard for Old Dogs to Learn New Tricks

There are two types of brain plasticity: developmental and adult. **Developmental plasticity** refers to the malleability of the brain during periods in which the brain is being built, when its anatomy is still changing in profound ways, as is the case in adolescence. Some of these changes involve the development or loss of brain cells, but the most important changes involve the brain's "wiring"—that is, how its one hundred billion neurons are interconnected.

The other type of plasticity is **adult plasticity.** Because every time we learn or remember something there must be some enduring biological change in the brain, the brain must possess a certain degree of plasticity at all ages. If this weren't true, it would be impossible to acquire new knowledge or abilities in adulthood. Because we can always learn new things, however, there is always some amount of plasticity in the brain, no matter how old we are. But the two kinds of plasticity differ significantly.

plasticity
The capacity of the brain to change in response to experience.

developmental plasticity
Extensive remodeling of the brain's circuitry in response to experiences during childhood and adolescence, while the brain is still maturing.

adult plasticity
Relatively minor changes in brain circuits as a result of experiences during adulthood, after the brain has matured.

First, adult plasticity doesn't fundamentally alter the neural structure of the brain, whereas developmental plasticity does. Developmental plasticity involves the growth of new brain cells and the formation of new brain circuits. Adult plasticity mainly involves fairly minor modifications to existing circuits. It's like the difference between learning how to read (which is a life-altering change) and reading a new book (which usually is not).

Second, brain systems are far less malleable during periods of adult plasticity than they are during periods of developmental plasticity. In fact, the developing brain is chemically predisposed to be modified by experiences, like clay when it is still soft, whereas the adult brain is predisposed to resist modification—like that same clay once it has hardened (Spear, 2013a). This is the reason we don't become better at seeing or hearing after we have matured beyond infancy, or why we have so much more trouble learning to ski or surf as adults than as children. By the time we are adults, the brain systems that regulate vision, hearing, and coordination have hardened. This is also why it is far easier to learn a foreign language before adolescence than after—brain systems responsible for language acquisition have lost a lot of their plasticity by then.

Finally, because the developing brain is so much more malleable, it can be influenced by a far wider range of experiences than can the mature brain. When the brain is developing, it is shaped by experiences that we aren't even aware of. Once the brain has matured, we need to pay attention to and give meaning to our experiences in order to be affected by them in an enduring way.

In other words, the developing brain is sculpted both by passive exposure and by active experience. That means that before our brain has fully matured, we can be affected, in potentially permanent ways, by *every* experience, whether it's positive or negative, whether we understand it or not—in fact, whether or not we're even aware of it. It's not surprising, then, that we recall things from adolescence more easily than we do from adulthood.

Because plasticity is what allows us to learn from experience, it enables us to adapt to the environment. Without it, our ancestors couldn't have remembered which contexts were safe and desirable, because they supplied food or water, for example, and which were to be avoided, because they were dangerous. The malleability of our brains greatly benefits us because it allows us to acquire new information and abilities. Periods of heightened plasticity, like infancy or adolescence, are therefore good times to intervene in order to promote positive development and ameliorate the negative effects of harmful experiences earlier in life (Weller, Leve, Kim, Bhimji, & Fisher, 2015).

But this malleability is a risk as well, because during these times of heightened sensitivity, the brain is also more vulnerable to damage from physical harms, like drugs or environmental toxins, or psychological ones, like trauma and stress (Sisk & Romeo, in press; Tottenham & Galván, 2016). As you will read later, the plasticity of the adolescent brain is why the adverse effects of using recreational drugs during adolescence (and during early adolescence, in particular) are more lasting than those associated with using the same drugs in adulthood (Giedd, 2015).

making the scientific connection

Advances in neuroscience have revealed that adolescence is a second period of heightened brain plasticity. Why might this be evolutionarily adaptive? What is it about adolescence that might make it an important time for the brain to be malleable?

What Changes in Adolescence?

The brain undergoes significant changes in both structure and function during adolescence. These changes alter the way adolescents think and process information, as well as how they interact with others.

Changes in Brain Structure During Adolescence During adolescence, the brain is "remodeled" through synaptic pruning and myelination in particular brain regions (Spear, 2013a) (see Figure 2.1). One part of the brain that is pruned dramatically in adolescence is the **prefrontal cortex,** the region of the brain most important for sophisticated thinking abilities, such as planning, thinking ahead, weighing risks and rewards, and controlling impulses (Casey, Tottenham, Liston, & Durston, 2005). Pruning also takes place in other parts of the cortex in adolescence (Blakemore, 2012).

prefrontal cortex
The region of the brain most important for sophisticated thinking abilities, such as planning, thinking ahead, weighing risks and rewards, and controlling impulses.

There is also continued myelination of the cortex throughout adolescence, which also leads to many cognitive advances (Darki & Klingberg, 2015; Ferrer et al., 2013; Ordaz, Foran, Velanova, & Luna, 2013). Myelination is stimulated by puberty (Menzies, Goddings, Whitaker, Blakemore, & Viner, 2015), but also by experiences such as education (Noble, Korgaonkar, Grieve, & Brickman, 2013) and exercise (Herting, Colby, Sowell, & Nagel, 2014).

Although scientists initially focused on the thinning of gray matter as the main feature of structural change in the

Figure 2.1 Synaptic pruning (reflected in the thickening of the cortex) and myelination (reflected in increases in white matter) take place in many brain regions during adolescence, including the parietal, temporal, and frontal lobes. (Tamnes et al., 2010)

Improvements in connectivity between the prefrontal cortex and limbic system helps adolescents regulate emotions and navigate the social world. Blend Images - Rolf Bruderer/Getty Images

brain at adolescence, there has been increasing interest in the importance of the increase in white matter, which improves the efficiency of connections within and across brain regions (Khundrakpam, Lewis, Zhao, Chouinard-Decorte, & Evans, 2016; Stevens, 2016). Better connectivity between different parts of the cortex allows us to think faster and better (Wendelken et al., 2017). Better connectivity between the prefrontal cortex and the **limbic system,** an area of the brain involved in the processing of emotions, social information, and reward and punishment, leads to improvements in our ability to regulate our emotions and coordinate our thoughts and feelings (Ladouceur, Peper, Crone, & Dahl, 2012; Silvers et al., 2017a; Vetter, Pilhatsch, Weigelt, Ripke, & Smolka, 2015). Structural maturation of the prefrontal cortex is not complete until the mid-20s (Casey et al., 2005; Hooper, Luciana, Conklin, & Yarger, 2004; Paus, 2009).

limbic system
An area of the brain that plays an important role in the processing of emotional experience, social information, and reward and punishment.

response inhibition
The suppression of a behavior that is inappropriate or no longer required.

executive function
More advanced thinking abilities, enabled chiefly by the maturation of the prefrontal cortex, especially in early adolescence.

functional connectivity
The extent to which multiple brain regions function at the same time, which improves during adolescence.

dopamine
A neurotransmitter especially important in the brain circuits that regulate the experience of reward.

serotonin
A neurotransmitter that is especially important for the experience of different moods.

Changes in Brain Function During Adolescence

The two most important changes in brain function involving the prefrontal cortex in adolescence both lead to greater efficiency in information processing (Spear, 2010). First, patterns of activation *within* the prefrontal cortex generally become more focused. For instance, in experiments in which participants are presented with a rapid succession of images and asked to push a button when a certain image appears, but refrain from pushing it when a different image appears (a process known as **response inhibition**), adolescents are less likely than children to activate prefrontal regions that are not relevant to performing the task well. As adolescents grow into adulthood and these brain systems further mature, self-control improves, as does performance on tests that measure other aspects of advanced thinking, often referred to as **executive function** (Crone & Steinbeis, 2017; Carriedo et al., 2016; Zelazo & Carlson, 2012).

Second, over the course of adolescence, individuals become more likely to use multiple parts of the brain simultaneously and coordinate activity *between* prefrontal regions and other areas, including other portions of the cortex and areas of the limbic system (Casey, Galván, & Somerville, 2016; Casey, Heller, Gee, & Cohen, 2017; Crone & Steinbeis, 2017). This is especially important on difficult tasks, where the task demands may overtax the prefrontal cortex working alone, and especially on tasks that require self-control, where it is necessary to coordinate thinking and feeling (Aite et al., 2017). In fact, when adolescents who are tested for self-control are told that they will be rewarded for controlling themselves, they perform better than when no such rewards are offered (Geier & Luna, 2012; Strang & Pollak, 2014; Teslovich et al., 2014).

This simultaneous recruitment of multiple brain regions working as a "team," referred to as **functional connectivity,** is made possible by the increase in physical connections between brain regions (Dosenbach, Petersen, & Schlaggar, 2013). Children's brains are characterized by a large number of relatively "local" connections (i.e., connections between nearby brain regions), but as individuals mature through adolescence and into adulthood, more distant regions become increasingly interconnected (Baker et al., 2015; Sherman et al., 2014). This is seen even when individuals are lying still, just resting (Stevens, 2016). The maturation of functional connectivity is more or less complete by age 22 (see Figure 2.2).

Risk and Reward A different type of functional change results from changes, especially in the limbic system, in the ways in which the brain is affected by certain neurotransmitters, including **dopamine** (which plays an important role in our experience of reward) and **serotonin** (which plays an important role in the experience of different moods). These changes, which are partly caused by puberty, make adolescents more emotional, more responsive to stress, more sensitive to rewards, and more likely to engage in sensation seeking than either children or adults (Barkley-Levenson & Galván, 2017;

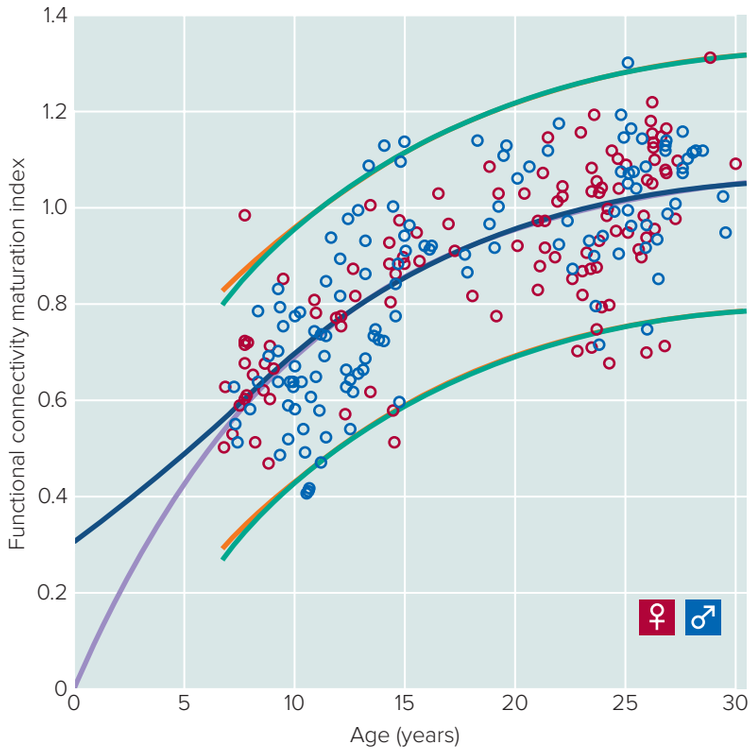


Figure 2.2 The maturation of functional connectivity is more or less complete by age 22. (Dosenbach et al., 2010)

Braams, van Duijvenvoorde, Peper, & Crone, 2015; Galván, 2013; Luciana & Collins, 2012). They are also thought to increase individuals' vulnerability to substance abuse, because they seek higher levels of reward; to depression, because of their increased vulnerability to stress; and to other mental health problems, because of their easily aroused emotions, including anger, anxiety, and sadness (see Figure 2.3) (Casement, Shaw, Sitnick, Musselman, & Forbes, 2015; Guyer, Silk, & Nelson, 2016; Heller & Casey, 2016; Luciana, 2013). One other negative consequence of this increase in emotional reactivity is an increase in adolescents' sensitivity to feeling threatened, which may prompt some adolescents to lash out at others or deliberately seek out experiences that are frightening (Dreyfuss et al., 2014; Spielberg, Olino, Forbes, & Dahl, 2014). As adolescents mature toward adulthood, these trends begin to reverse, and individuals become less easily aroused by positive or negative stimuli, and better able to regulate their emotions (Silvers et al., 2017b; Silvers, Shu, Hubbard, Weber, & Ochsner, 2015).

These changes in the functioning of the limbic system occur relatively early in adolescence, in contrast to developments in the prefrontal cortex, which are still ongoing in early adulthood (Blakemore & Robbins, 2012; Luciana, 2013; Mills, Goddings, Clasen, Giedd, & Blakemore, 2014). Unlike the changes that occur in the limbic system, which have been directly linked to the impact of pubertal hormones on the brain, the development of cognitive control is more or less independent of puberty (Icenogle et al., 2017; Ordaz, Fritz, Forbes, & Luna, 2017). This relatively late maturation of the

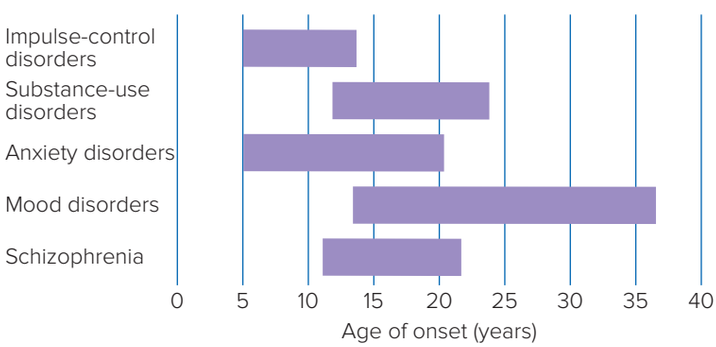


Figure 2.3 The age of onset of most common psychiatric disorders is somewhere between the ages of 10 and 20. New research on adolescent brain development helps explain why this is the case. (Paus, Keshavan, & Giedd, 2008)

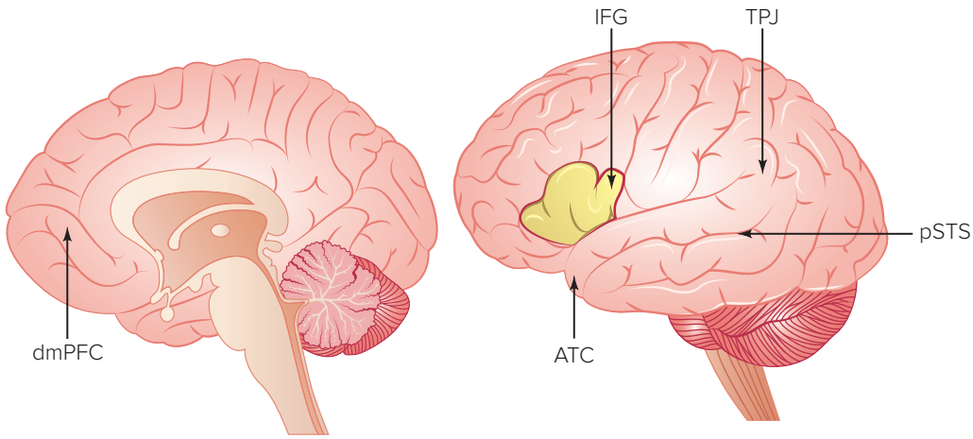


Figure 2.4 Regions of the social brain network: areas of the brain that may be sensitive to social cognitive processes necessary to navigate the adolescent social environment. Regions that are involved in social cognition include the dorsal medial prefrontal cortex (dmPFC) and temporoparietal junction (TPJ), which are involved in thinking about mental states; the posterior superior temporal sulcus (pSTS), which is involved in observing faces and biological motion; the anterior temporal cortex (ATC), which is involved in applying social knowledge; and the inferior frontal gyrus (IFG), which is involved in understanding the actions and emotions of others.

prefrontal cortex, particularly compared to the changes that take place in the limbic system at puberty, has been the subject of much discussion among those interested in risk taking and behavioral problems in adolescence, because this gap in timing may help explain the dramatic increase in risky behavior that takes place between childhood and adolescence, as well as the decline in risk taking that occurs as individuals mature into adulthood (Casey, Jones, & Somerville, 2011; Steinberg, 2008). In essence, the brain changes in ways that may provoke individuals to seek novelty, reward, and stimulation several years before the complete maturation of the brain systems that regulate judgment, decision making, and impulse control (Galván, 2010; Padmanabhan, Geier, Ordaz, Teslovich, & Luna, 2011; Van Leijenhorst et al., 2010). In the words of one team of writers, it's like "starting the engines with an unskilled driver" (C. Nelson et al., 2002, p. 515). As the "braking system" improves, in part because of maturation of the prefrontal cortex and its connections to other brain regions, and as reward seeking declines, individuals become less likely to engage in risky behavior (Steinbeis, Haushofer, Fehr, & Singer, 2016; Peters, Peper, van Duijvenvoorde, Braams, & Crone, 2017).

Many writers have pointed out that adolescents' sensitivity to reward isn't always maladaptive, however (Telzer, 2016). Although sensation seeking may lead some teenagers to do dangerous things, it may lead others to explore the environment in ways that lead them to engage in prosocial behavior, to learn new skills, to be flexible, and to increase their knowledge of the world (van Duijvenvoorde, Peters, Braams, & Crone, 2016). This makes perfect sense given that adolescence evolved as a stage during which individuals venture out on their own; to be successful, they must be both willing to take risks and able to learn from their experience.

The Social Brain Yet another important change in the brain in adolescence involves a network of regions referred to as the "social brain" (Braams & Crone, 2017; Kilford, Garrett, & Blakemore, 2016; Mills, Lalonde, Clasen, Giedd, & Blakemore, 2014) (see Figure 2.4).

In most species of mammals, individuals become more social around the time of puberty, which makes perfect sense, given that adolescence evolved as a stage of development designed to prepare individuals for mating and reproduction (De Lorme, Bell, & Sisk, 2013; Walker et al., 2017). Changes in the social brain in early adolescence, which increase the brain's sensitivity to social cues, like other people's facial expressions and behavior, intensify adolescents' sensitivity to social evaluation (van den Bos, van Duijvenvoorde, & Westenberg, 2016), which is why adolescents are more prone to feel embarrassed than either children or adults (see Figure 2.5) (Guyer, Choate, Pine, & Nelson, 2012; Silk et al., 2012; Somerville, 2013; van den Bos, de Rooij, Miers, Bokhorst, & Westenberg, 2014). This also may be why adolescents are so susceptible to social influence and, especially, peer pressure (Welborn et al., 2016). In one study that tested individuals' ability to exercise response inhibition, adolescents had a harder time controlling themselves than either children or adults when responding to pictures showing peers having a good

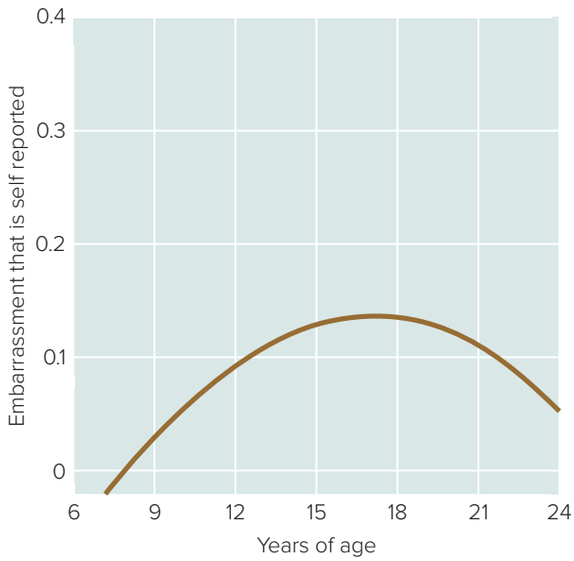


Figure 2.5 **Changes in the social brain during adolescence have both costs and benefits. One downside is that people become more self-conscious. Adolescents report feeling embarrassed more often than either children or adults.** (Somerville, 2013)

time (Perino, Miernicki, & Telzer, 2016). Another study found that being observed by a friend interfered with adolescents' cognitive performance but had no such effect on adults (Wolf, Bazargani, Kilford, Dumontheil, & Blakemore, 2015).

Individuals' ability to recognize subtle changes in others' facial expressions improves during adolescence (Garcia & Scherf, 2015; Kragel, Zucker, Covington, & LaBar, 2015; Shaw et al., 2016). The increase in sex hormones at puberty appears to play a role in influencing this increase in sensitivity to others' facial expressions (Goddings, Heyes, Bird, Viner, & Blakemore, 2012; Moore et al., 2012; Motta-Mena & Scherf, 2017), which makes perfect sense, given the ultimate purpose of adolescence. If your goal is to find a willing sex partner, it helps to pay close attention to other peoples' facial expressions. One fascinating study found that, after going through puberty, individuals were more likely to remember the faces of people who were at the same level of pubertal maturation than those who were either less or more physically advanced (Picci & Scherf, 2016) (see Figure 2.6).

Other research indicates that sensitivity to others' mental states increases during adolescence, a change that also is reflected in changes in patterns of brain activity when individuals observe others (Burnett et al., 2011; Masten, Eisenberger, Pfeifer, & Dapretto, 2013; Pfeifer & Blakemore, 2012). Keep in mind, though, that adolescents vary in how sensitive they are to the influence of others—some are highly aware of the social world, whereas others are close to oblivious (Schriber & Guyer, 2016). Adolescents who are especially responsive to social rewards are more likely to engage in risky sexual behavior, perhaps because their increased sensitivity to such rewards leads them to downplay the costs of this type of risk taking (Eckstrand et al., 2017).

Changes in a region referred to as "the social brain" make adolescents more sensitive to other people's emotional states. ©I love images/city break/Alamy Stock Photo

Figure 2.6 **Mean sensitivity for recognition of each face category, separately for (a) prepubertal children, (b) early-puberty adolescents, (c) late-puberty adolescents, and (d) sexually mature adults. The dark bar in each graph indicates the face category in which that pubertal group exhibited superior performance compared with the average of the three other face categories.** (adapted from Picci & Sherf, 2016). Alfa Photostudio/Shutterstock; Image Source; Ljupco Smokovski/Shutterstock; Alexxndr/Shutterstock; Gelpi/Shutterstock; S_L/Shutterstock

Although this increased attentiveness to other people's mental states likely has a number of benefits (it may make teenagers more socially skilled, for example; Rosen et al., 2018), it also makes adolescents more easily distracted by others' emotional expressions (Cohen-Gilbert & Thomas, 2013). An important implication of this for parents is that yelling at a teenager angrily may not be an effective means of getting the adolescent to listen, because the teenager may end up paying more attention to the angry emotion than to the content of what is being said. Indeed, when adolescents listen to recordings of their mother being critical, this increases activity in emotional regions of the brain, but dampens activity in regions that govern self-regulation and logical reasoning (Lee, Siegle, Dahl, Hooley, & Silk, 2014).

making the cultural connection

New research shows that brain systems governing things like impulse control, planning ahead, and balancing risk and reward are still maturing during late adolescence. Yet, rates of adolescents' risky behavior, such as experimentation with drugs or unprotected sex, vary considerably around the world. If these sorts of behaviors are more common in adolescence because of the way the brain is changing, shouldn't they be more universal?

Implications for Adolescent Behavior

Evidence of a correlation between changes in brain structure or function and changes in adolescent behavior does

not necessarily mean that the first is necessarily causing the second (Kuhn, 2009; Paus, 2009).

We know that adolescents' behavior affects their brain development. An obvious illustration of this relationship involves the impact of alcohol and other drugs on the brain, but there are other, more subtle examples as well. As mentioned earlier, the process of synaptic pruning is influenced by experience: Repeated activation of a specific collection of neurons as a result of engaging in a particular behavior will actually result in structural changes that strengthen the connections among those neurons, which in turn will make them function more efficiently. For example, practicing the same task over and over again makes it easier and easier to perform the task each time. Scientists have grown increasingly interested in seeing whether different sorts of training programs or interventions can improve adolescents' self-control (Crone, 2009; Modecki, Zimmer-Gembeck, & Guerra, 2017) or reduce their tendencies toward sensation seeking (Romer et al., 2011), both of which may reduce risky behavior.

I'm often asked when adolescents start to think like adults, or at what age the adolescent brain becomes the adult brain. As you now know, the answer depends on which aspects of thinking or brain development one is concerned about. When it comes to relatively more sophisticated cognitive abilities, such as thinking ahead, envisioning the future consequences of a decision, balancing risks and rewards, or controlling impulses—all of which are governed mainly by the prefrontal cortex—research on brain maturation certainly suggests that these capabilities are still developing well after individuals enter their 20s. But when it comes to more basic abilities, such as those involving memory, attention, and logical reasoning, especially under optimal conditions, brain and behavioral studies indicate that the average 15-year-old performs no worse than the average adult. In addition, some young adults show patterns of brain activity that is significantly less mature than what one would predict based on their chronological age, whereas others demonstrate patterns of brain activity that are more mature than what one would expect. In one study, the young adults whose estimated "brain age" was lower than their chronological age were more likely than other people their age to report enjoying risk taking (Rudolph et al., 2017). Moreover, patterns of age differences in brain activity depend on the circumstances under which individuals are tested; one recent study found that when 18- to 21-year-olds are emotionally aroused, their cognitive performance and brain activity resembles that of teenagers, but that under more calming conditions, young adults look more like people in their mid-20s (Cohen et al., 2016). Where we draw the boundary between adolescence and adulthood—at least as far as cognitive development is concerned—should probably depend on why the boundary is being drawn and on what specific abilities are relevant to the behavior in question (Steinberg, Cauffman, Woolard, Graham, & Banich, 2009).

Individual Differences in Intelligence in Adolescence

For the most part, theorists who have studied adolescent cognitive development from either a Piagetian or an information-processing framework, or through brain research, have focused on the universals in adolescent intellectual growth. Other theorists have been more interested in studying individual differences in intellectual abilities. How large are individual differences in intelligence in adolescence? Why are some adolescents brighter than others?

The Measurement of IQ

To answer questions about the relative intelligence of individuals, psychologists have had to devise ways of assessing intelligence—no easy feat given the considerable disagreement over what "intelligence" really is. Today, the most widely used measures are intelligence tests, or IQ (for "intelligence quotient") tests. Among these tests are the Stanford-Binet, the Wechsler Intelligence Scale for Children (WISC-IV), and the Wechsler Adult Intelligence Scale (WAIS-III). An individual's IQ is computed by dividing his or her mental age by his or her chronological age and then multiplying the result by 100. A score of 100 is used to designate the midway point. An IQ score below 100 indicates a poorer test performance than the average person of the same age; a score above 100 indicates a better performance than average.

Although someone's score on an intelligence test is often reported in terms of her or his overall IQ, intelligence tests actually comprise a series of tests, and it is usually possible to look at performance in different areas independently. The WISC-IV and the WAIS-III, for example, each contain two groups of tests: verbal tests, which include measures of vocabulary, general information, comprehension, and arithmetic abilities, and performance tests, which include measures of memory, perceptual reasoning, and picture completion.

Changes in specific aspects of IQ performance during adolescence are correlated with synaptic pruning in brain regions known to play a role in those specific types of learning (Ramsden, Richardson, Josse, Thomas, & Ellis, 2011; van den Bos, Crone, & Güroğlu, 2012). And there is a link between intelligence and brain development. More intelligent adolescents have a more dramatic and longer period of production of synapses before adolescence and a more dramatic pruning of them after (P. Shaw et al., 2006), more connections between the prefrontal

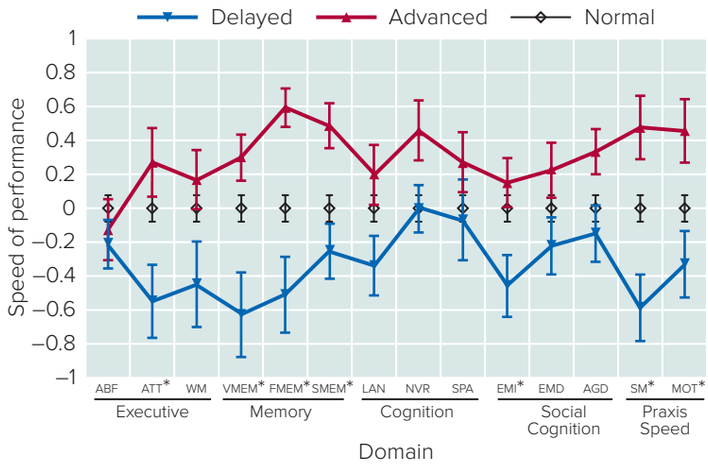


Figure 2.7 Adolescents whose "brain development index" is advanced relative to their chronological age perform tests of cognitive ability faster than those whose brain development index is average or delayed. (From Erus et al., 2015)

cortex and other brain regions (Cole, Yarkoni, Repovš, Anticevic, & Braver, 2012), and a longer period of brain plasticity (van den Bos, Crone, & Güroğlu, 2012). In one recent study, the researchers used brain imaging to construct a "brain development index," which quantified how mature the brain's circuitry was. Not surprisingly, scores on the measure improved steadily between ages 8 and 22 (Erus et al., 2015). The researchers then identified individuals whose level of brain development was more advanced than would be expected based on their chronological age. Individuals with advanced brain development scores performed significantly faster (although not necessarily more accurately) on tests of cognitive ability, including various tests of attention, memory, and reasoning (see Figure 2.7). There is strong evidence that differences among individuals in performance on these sorts of tests are largely (although not entirely) genetic in nature (Friedman et al., 2016).

Mental abilities assessed by conventional IQ tests increase dramatically through childhood and adolescence, reaching a plateau sometime in mid-to-late adolescence. (It is no coincidence that this plateau occurs at around the same age as that for information processing, because IQ test performance depends a lot on information-processing abilities.) This argues strongly in favor of educational interventions prior to mid-adolescence; interventions in early childhood, especially, have been shown to improve intellectual performance during adolescence (Campbell, Pungello, Miller-Johnson, Burchinal, & Ramey, 2001). In addition, research shows that extended schooling during adolescence itself enhances individuals' performance on standardized tests of intelligence (Ceci & Williams, 1999). Whereas individuals who had dropped out of school early showed unchanging—and relatively lower—scores on intelligence tests during adolescence, students who remained in school, especially those in the more advanced tracks, showed impressive gains in verbal ability over time. Another study found that it is possible to facilitate the development of creative thinking in adolescence through training (Kleibeuker et al., 2017).

zone of proximal development
In Vygotsky's theory, the level of challenge that is still within the individual's reach but that forces an individual to develop more advanced skills.

scaffolding
Structuring a learning situation so that it is just within the reach of the student.

Culture and Intelligence

Much of our current thinking about the nature of intelligence has been influenced by the work of the Russian psychologist Lev Vygotsky (1930/1978), who emphasized the broader context in which intellectual development occurs. According to this view, it is essential that we understand the nature of the environment in which an adolescent develops in terms of its demands for intelligent behavior and its opportunities for learning. Individuals develop and use intellectual skills not simply as a function of their cognitive maturation but also in response to the everyday problems they are expected to solve. The very same children who perform poorly on school-based tests of knowledge may excel when faced with an equally challenging test of competence in the real world—such as figuring out the most efficient route between school and home through a dangerous neighborhood.

Vygotsky argued that children and adolescents learn best in everyday situations when they encounter tasks that are neither too simple nor too advanced, but just slightly more challenging than their abilities permit them to solve on their own. Within this **zone of proximal development,** young people, through close collaboration with a more experienced instructor (whether an adult or another child), are stimulated to "reach" for the more advanced level of performance. The role of the instructor is to help structure the learning situation so that it is within the reach of the student—a structuring process called **scaffolding.** If you watch good parents, teachers, or

coaches at work, you will probably observe a great deal of scaffolding.

One fascinating discovery about how adolescents learn is that novelty and challenge are key to maintaining the brain's plasticity (Steinberg, 2014). By encouraging teenagers to learn new things, and by challenging them to work harder, good teachers can use scaffolding to take advantage of the adolescent brain's exceptional malleability. In doing so, not only can teachers help adolescents learn at that time, but they can actually make future learning more likely, by helping to keep the brain plastic. Some research suggests that learning certain skills may be easier in late adolescence than early adolescence, which suggests that the window of opportunity created by heightened brain plasticity may be open longer than one might think (Knoll et al., 2016).

Adolescent Thinking in Context

Just as it is important to ask how the broader context influences adolescents' cognitive development, it is also important to ask how their cognitive development influences their interactions with their environment. Most of the thinking adolescents do occurs in everyday situations, not just when they are taking tests designed to see how smart they are.

As our understanding of adolescent thinking has expanded, researchers have begun to look beyond laboratory experiments and standardized tests to examine how the cognitive changes of adolescence actually affect teenagers' day-to-day thoughts and actions. Do advances in deductive reasoning or information-processing abilities make a difference in the real world? How do the brain changes that take place in adolescence play out in everyday experiences? To answer these questions, psychologists have studied the practical side of adolescent thinking with respect to how people think about social situations and how they think about risk.

Social Cognition in Adolescence

Social cognition involves such cognitive activities as thinking about people, social relationships, and social institutions (Smetana & Villalobos, 2009). Compared with those of children, adolescents' conceptions of interpersonal relationships, their understanding of human behavior, their ideas about social institutions and organizations, and their ability to figure out what other people are thinking is far more developed. Gains in the area of social cognition help account for many of the psychosocial advances typically associated with adolescence—advances in the realms of identity, autonomy, intimacy, sexuality, and achievement. Individual differences in social cognitive abilities also help explain why some adolescents have more social problems than others (Dodge, Coie, & Lynam, 2006; Fontaine, Yang, Dodge, Bates, & Pettit, 2008).

Research on social cognition during adolescence includes many topics, but four of the most often studied concern (1) theory of mind; (2) thinking about social relationships; (3) understanding social conventions; and (4) conceptions of laws, civil liberties, and rights (Rote & Smetana, 2011; Smetana & Villalobos, 2009).

social cognition
The aspect of cognition that concerns thinking about other people, about interpersonal relations, and about social institutions.

mentalizing
The ability to understand someone else's mental state.

theory of mind
The ability to understand that others have beliefs, intentions, and knowledge that may be different from one's own.

Theory of Mind During preadolescence and adolescence, individuals develop a more nuanced understanding of other people's personalities and psychological states, enabled in part by brain maturation in systems that support what is called **mentalizing**—the ability to understand someone else's mental state (Burnett et al., 2011; C. Harenski, K. Harenski, Shane, & Kiehl, 2012; Pfeifer & Peake, 2012). As they develop a more sophisticated **theory of mind,** the ability to understand that others have beliefs, intentions, and knowledge that may be different from one's own, adolescents are better able to interpret the feelings of others and to infer their motives and feelings, even when specific information of this sort is not directly observable (Choudhury, Blakemore, & Charman, 2006; Dumontheil, Apperly, & Blakemore, 2010). Adolescents also become better at lying as a result of these improvements in social cognition (Evans & Lee, 2011).

Not only are adolescents more capable of discerning another person's perspective on some issue or event, they are also better able to understand that person's perspective on their own point of view. They are especially able to take the perspective of someone the same age (Conson, Salzano, Frolli, & Mazzarella, 2017). Ultimately, adolescents' improvements in their ability to figure out what others are thinking lead to improvements in communication, because they become more capable of formulating arguments in terms that are more likely to be understood by someone whose opinion is different. This gain in perspective taking may change the dynamics of adolescents' relationships with their parents—for better (because adolescents are able to see more things from their parents' point of view) and for worse (because adolescents may use these advanced social cognitive abilities to challenge their parents' authority or deceive them) (Gingo, Roded, & Turiel, 2017; Smetana & Villalobos, 2009).

Thinking About Social Relationships Improvements in mentalizing lead to changes in the way that adolescents think about relationships with peers and parents. One topic that researchers have been especially interested in concerns adolescents' beliefs about peer

social conventions
The norms that govern everyday behavior in social situations.

exclusion (Leets & Sunwolf, 2005). All other things equal, children believe that it is wrong to exclude peers from social activities (for example, whether to invite the whole class or just one's close friends to a birthday party). With age, however, as adolescents' understanding of group dynamics becomes more sophisticated, they begin to take into account other considerations, like personality ("She's not open-minded ... we all feel weird around her"), the activity context ("We thought he wasn't good enough to play basketball"), and the reason for excluding some individuals but not others ("[The party] was a team thing") (Recchia, Brehl, & Wainryb, 2012, p. 198). On the other hand, adolescents generally believe that social exclusion on the basis of gender orientation, nationality, race, or ethnicity is wrong (Brenick & Killen, 2014; Ruck, Park, Crystal, & Killen, 2015).

Changes in adolescents' understanding of social relationships also transform their beliefs about authority, which has important implications for their relationships with parents and other adults (Smetana & Villalobos, 2009). With age, adolescents increasingly distinguish between moral issues (such as whether it is acceptable to steal from someone else) and conventional ones (such as whether one eats dessert before or after the main course) (Lahat, Helwig, & Zelazo, 2013). Although the stereotype of adolescents is that they invariably come to reject the authority of adults, research shows that what happens instead is that adolescents increasingly distinguish between issues that authority figures have the right to regulate and issues that are their own personal choices (Gingo et al., 2017). Thus, adolescents by and large are in favor of laws that prohibit stealing and vandalism, but are less accepting of laws concerning curfews and loitering (Oosterhoff & Metzger, 2017).

As adolescents begin to make these distinctions, they often question their parents' authority. Issues that had been viewed as matters of right and wrong start to seem like matters of personal choice and, as such, beyond the bounds of parental authority (Van Petegem et al., 2017). For example, parents' rules about things like the cleanliness of the adolescent's bedroom or bedtimes on school nights, which had been accepted as matters of right and wrong, start to seem like arbitrary conventions that are open to debate. Here's how one girl described it

> *In the beginning their word was law I guess. Whatever they decided together was what we would do regardless of what. . . . Now I will push back if I don't think it's fair. . . . I won't maybe give in as easily which can be good and bad.* Parkin, C. M., & Kuczynski, L. (2012).

One main source of conflict between adolescents and their parents involves which issues parents have legitimate authority over and which they do not. An adolescent boy explained how he handled it:

> *I don't enjoy that they ask me questions all the time and nag me about going out and stuff. . . . I'll give them answers but they're discreet answers. I'll give them little parts of things just to make it sound good, I guess.* Parkin, C. M., & Kuczynski, L. (2012).

Similar changes occur in adolescents' beliefs about their teachers' authority (Smetana & Bitz, 1996) and the authority of groups to dictate how individuals should behave (Helwig, Yang, Tan, Liu, & Shao, 2011). For instance, adolescents understand that teachers have the right to demand that students show up for class on time and sit quietly if asked, but believe that students should be able to decide where they sit in class or during lunch.

Understanding Social Conventions The realization that individuals' perspectives vary, and that their opinions may differ as a result, leads to changes in the ways that adolescents approach issues regarding social conventions (Smetana & Villalobos, 2009). During middle childhood, **social conventions**—the social norms that guide day-to-day behavior, such as waiting in line to buy movie tickets—are seen as arbitrary and changeable, but adherence to them is not; compliance with such conventions is based on rules and on the dictates of authority. When you were 7 years old, you might not have understood why people had to wait in line to buy movie tickets, but when your parents told you to wait in line, you waited. By early adolescence, however, conventions often are seen as arbitrary social expectations. As an adolescent, you begin to realize that people wait in line because they are expected to,

Adolescence is a time of changes in the way we think abut social conventions, like having to wait in a line to buy movie tickets. ©Hero Images/Getty Images

not because they are forced to. Indeed, young adolescents often see social conventions as *nothing but* social expectations and, consequently, as insufficient reasons for compliance. You can probably imagine young teenagers saying something like this: "Why wait in a ticket line simply because other people are lined up? There isn't a *law* that forces you to wait in line, is there?"

Gradually, however, adolescents begin to see social conventions as the means by which society regulates people's behavior. Conventions may be arbitrary, but we follow them because we share an understanding of how people are expected to behave in various situations. We wait in line for theater tickets not because we want to comply with any rule, but because it is something we are accustomed to doing.

Ultimately, individuals come to see that social conventions help to coordinate interactions among people. Social norms and expectations are derived from and maintained by individuals having a common perspective and agreeing that, in given situations, certain behaviors are more desirable than others, because such behaviors help society and its institutions function more smoothly. Without the convention of waiting in line to buy movie tickets, the pushiest people would always get tickets first. Older adolescents can see that waiting in line not only benefits the theater by keeping order but also preserves everyone's right to a fair chance to buy tickets. In other words, we wait in line patiently because we all agree that it is better if tickets are distributed fairly.

Conceptions of Laws, Civil Liberties, and Rights

As is the case with individuals' developing understanding of relationships between people, over the course of adolescence individuals also become more nuanced in the way they think about the relationship between the individual and society. Most research on adolescents' beliefs about rights and civil liberties comes from studies of Western, middle-class youth, and it is important to be cautious about generalizing the findings of these studies to young people from other cultures. Nevertheless, even in collectivist cultures that place less emphasis on the rights of the individual, adolescents become increasingly likely to believe that there are some freedoms—like freedom of speech and freedom of religion—that should not be restricted (Smetana & Villalobos, 2009). That said, research also finds that, with age, teenagers come to believe that there are situations in which it may be legitimate to restrict individual rights to serve the benefit of the community.

Several themes cut across the research findings from studies of different aspects of social cognition—the way we think about people, relationships, conventions, and rights. First, as individuals move into and through adolescence they become better able to step outside themselves and see things from other vantage points. Second, adolescents are better able to see that the social "rules" we follow (in the family, at school, and in broader society) are not absolute and are therefore subject to debate and questioning. Third, with age, adolescents develop a more differentiated, more nuanced understanding of social norms. Yes, individuals are entitled to certain rights, but there are some situations under which it might be appropriate to curtail them. Yes, it is generally wrong to exclude others, but sometimes social exclusion is justifiable (Killen, Rutland, Abrams, Mulvey, & Hitti, 2013).

These gains in social cognition help to account for gains in social competence during adolescence. Adolescents who have more sophisticated social cognitive abilities actually behave in more socially competent ways (Eisenberg, Morris, McDaniel, & Spinrad, 2009). Although there is more to social competence than social cognition, being able to understand social relationships is an important component of social maturity.

Adolescent Risk Taking

A second practical application of research into adolescent thinking involves the study of adolescent risk taking. The main health problems of adolescence are the result of behaviors that can be prevented—behaviors such as substance abuse, reckless driving, and unprotected sex. In

Recent research on cognitive development in adolescence has been aimed at understanding the thinking behind adolescent risk taking. ©Photodisc/Getty Images

behavioral decision theory An approach to understanding adolescent risk taking, in which behaviors are seen as the outcome of systematic decision-making processes.

the real world (IOM and NRC, 2011), and on many laboratory tasks of risky decision making (Burnett, Bault, Coricelli, & Blakemore, 2010; Defoe, Dubas, Figner, & van Aken, 2015; Shulman & Cauffman, 2014; Steinberg et al., 2009), adolescents take more risks than adults, not only in the United States, where much of this research has been conducted, but around the world (Duell et al., 2017). Although of course not all adolescents are risk takers, by and large, adults are more risk avoidant than teenagers are (van Duijvenvoorde et al., 2015).

The Centers for Disease Control and Prevention, a federal agency that monitors the health of Americans, surveys American teenagers annually and asks whether they had engaged in various behaviors during the previous 30 days (Centers for Disease Control and Prevention, 2014). Risk taking is common among adolescents. More than 40% of teen drivers report having texted while driving, one-fifth had ridden with an intoxicated driver, and one-tenth themselves have driven after drinking. Among teenagers who ride bicycles, 88% report rarely or never wearing a helmet (Centers for Disease Control and Prevention, 2014).

Behavioral Decision Theory A number of writers have looked at adolescent risk taking from a perspective called **behavioral decision theory** (Kahneman, 2011). In this perspective, which draws heavily on economics, decision making is a rational process in which individuals calculate the costs and benefits of alternative courses of action and behave in ways that maximize the benefits and minimize the costs. According to this theory, all behaviors, including risky ones, can be analyzed as the outcome of a process involving five steps: (1) identifying alternative choices, (2) identifying the consequences that might follow from each choice, (3) evaluating the costs and benefits of each possible consequence, (4) assessing the likelihood of each possible consequence, and (5) combining all this information according to some decision rule (Beyth-Marom, Austin, Fischhoff, Palmgren, & Jacobs-Quadrel, 1993).

So, for example, an adolescent girl who is trying to decide whether to accept a ride home from a party with friends who have been drinking will (1) identify the choices (to accept the ride or not), (2) identify the consequences ("If I accept the ride, and we get into an accident, I could be seriously hurt, but if I don't accept the ride, my friends will make fun of me for being a 'loser'"), (3) evaluate the desirability of each consequence ("Appearing like a 'loser' to my friends is bad, but being in an accident would be terrible"), (4) assess the likelihood of each consequence ("My friends probably won't really change their opinion of me just because I turn down the ride, and my friend who is driving is so drunk that he really might get into an accident"), and (5) combine all the information according to some decision rule ("All things considered, I think I won't take the ride").

From the perspective of behavioral decision theory, then, it is important to ask whether adolescents use different processes than adults in identifying, estimating, and evaluating behavioral options and consequences. If risky decisions are the result of faulty information processing—in attention or memory, for example—perhaps it would make sense to train adolescents in these basic cognitive abilities as a means of lessening their risk taking.

As we have seen, however, adolescents, at least by the time they are 15 or so, have the same basic cognitive abilities as adults (Beyth-Marom et al., 1993; Furbey & Beyth-Marom, 1992). This is true even for issues as complicated as deciding whether to abort a pregnancy (Steinberg, 2014). The major gains in the cognitive skills that affect decision making appear to occur between childhood and adolescence, rather than between adolescence and adulthood. Thus, educating adolescents in how to make "better" decisions is not likely to reduce risk taking (Steinberg, 2015). There is no evidence, for example, that adolescents are worse at perceiving risks than adults are (Ivers et al., 2009; Van Leijenhorst, Westenberg, & Crone, 2008). However, research indicates that adolescents vary far more than adults in how they interpret words and phrases used to describe risk—words like "probably," "likely," or "a very low chance"—suggesting that health educators and practitioners should not take for granted that an adolescent's understanding of a message about risk is what the educator thinks it is (Mills, Reyna, & Estrada, 2008). Similarly, just because an adolescent says that she knows that having "safe sex" can protect her against sexually transmitted diseases doesn't necessarily mean that she knows the specific behaviors that constitute safe sex (Reyna & Farley, 2006).

Age Differences in Values and Priorities If adolescents use the same decision-making processes as adults, and if adolescents are no more likely than adults to think of themselves as invulnerable, why, then, are adolescents more likely to engage in risky behavior? One answer may involve the different values and priorities that adolescents and adults have. For example, an individual's decision to try cocaine at a party may involve evaluating a number of different consequences, including the legal and health risks, the pleasure the drug may induce, and the way in which he or she will be judged (both positively and negatively) by the other people present. An adult and an adolescent may both consider all these consequences, but the adult may place relatively more weight on the health risks of trying the drug, while the adolescent may place relatively more weight on the social consequences of not trying it. (Young adolescents' risky decision making is especially influenced by the opinions

of their peers; Knoll, Magis-Weinberg, Speekenbrink, & Blakemore, 2015). Although an adult may see an adolescent's decision to value peer acceptance more than health as irrational, an adolescent may see the adult's decision as equally incomprehensible. Behavioral decision theory reminds us that many decisions—even risky ones—can be seen as rational once we understand how an individual estimates and evaluates the consequences of various courses of action.

One very important difference between adolescents and adults is that, when weighing the costs and benefits of engaging in a risky behavior, adolescents are more attuned to the potential rewards than are adults (Modecki, 2016). This difference is consistent with changes that are taking place in the limbic system around the time of puberty, which we discussed earlier in this chapter. Studies of juvenile offenders have found, for instance, that adolescents' criminal activity was more strongly related to their beliefs about the potential rewards of the activity (for example, being seen as "cool") than to their perceptions of the activity's potential costs (for example, the chances of being arrested) (Loughran, Reid, Collins, & Mulvey, 2016; Matsueda, Kreager, & Huizinga, 2006; Shulman, Monahan, & Steinberg, 2017). As several writers have pointed out, this has important implications for the prevention of risky behavior among adolescents (Victor & Hariri, 2016). It may be more important to convince adolescents that the rewards of a risky activity are small (for example, that few people will actually look up to someone for being violent) than to persuade them that the costs are large (for example, that being incarcerated will be terrible).

In all likelihood, of course, neither adolescents' nor adults' decisions are always made in as straightforward or rational a way suggested by behavioral decision theory. Nevertheless, this approach has opened up a new way of thinking about adolescent risk taking. Instead of viewing risky activities as the result of irrational or faulty judgment, experts are now trying to understand where and how adolescents obtain the information they use in reaching their conclusions, and how accurate the information is. If, for example, adolescents underestimate the likelihood of getting pregnant following unprotected sex, sex education efforts might focus on teaching teenagers the actual probability. (Of course, this presumes that adolescents' decisions about whether to have sex are made rationally, which may not be the case [P. Levine, 2001].)

Emotional and Contextual Influences on Risk Taking We should also keep in mind that emotional and contextual factors, as well as cognitive ones, contribute to adolescent risk taking (Dahl, 2008; Rivers, Reyna, & Mills, 2008; Steinberg, 2010). Several researchers have noted that adolescents may differ from adults in important ways that are not captured by measures of logical reasoning, such as susceptibility to peer pressure, impulsivity, orientation to the present rather than the future, or reward seeking (Cauffman et al., 2010; de Water, Cillessen, & Scheres, 2014; Steinberg et al., 2008; Steinberg et al., 2009). A number of studies have shown that adolescents' decision making is as good as adults' when individuals are tested under calm conditions, but that the quality of adolescents' decision making declines more than adults' when they are emotionally aroused (Figner & Weber, 2011; van Duijvenvoorde, Jansen, Visser, & Huizenga, 2010) or fatigued (Silva, Patrianakos, Chein, & Steinberg, 2017).

With respect to emotional factors, for example, studies show that individuals who are high in reward seeking and **sensation seeking**—that is, who seek out novel and intense experiences—are more likely to engage in various types of risky behaviors than their peers (Harden & Mann, 2015) and that both reward seeking and sensation seeking are higher during adolescence than childhood or adulthood (Duckworth & Steinberg, 2015). Similarly, adolescents who are especially impulsive are also more likely to engage in risky behavior (Kim-Spoon et al., 2017; Quinn & Harden, 2013). One reason that middle adolescence is a period of heightened risk taking is that it is a period characterized by a combination of high sensation seeking and high impulsivity (Harden & Tucker-Drob, 2011; Smith, Xiao, & Bechara, 2012), especially among boys (Shulman, Harden, Chein, & Steinberg, 2014), most likely because of the impact of testosterone on sensation seeking (Harden et al., 2017). One recent study of more than 5,000 people from 11 countries found that, around the world, adolescence is a time of heightened reward seeking and immature self-control (Steinberg et al., 2017) (see Figure 2.8). At all ages, people who are high in sensation seeking and low in impulse control are more likely to be risk takers, both in the real world and in laboratory experiments (Duell et al., 2016; Lydon-Staley & Geier, 2017; Wasserman, Crockett, & Hoffman, 2017).

The context in which individuals spend time matters, too (Boyer, 2006). A good deal of adolescents' risk taking takes place in contexts in which they are emotionally aroused (either very positively or very negatively), unsupervised by adults, and with their peers (Kretsch & Harden, 2014). For example, one recent study found that adolescents with mothers who worked nights were more likely to take risks, in part because the parents were less likely to know their teen's whereabouts (Han, Miller, & Waldfogel, 2010). As noted earlier, individuals' susceptibility to peer pressure is higher during early and middle adolescence than later, suggesting that one reason for teenagers' greater risk taking is the fact that they spend so much time in the peer group (Steinberg & Monahan, 2007). Most adolescent risk taking, including delinquency, drinking, and reckless behavior, occurs when other teenagers are present, and adolescents are more likely to take

sensation seeking
The pursuit of experiences that are novel or exciting.

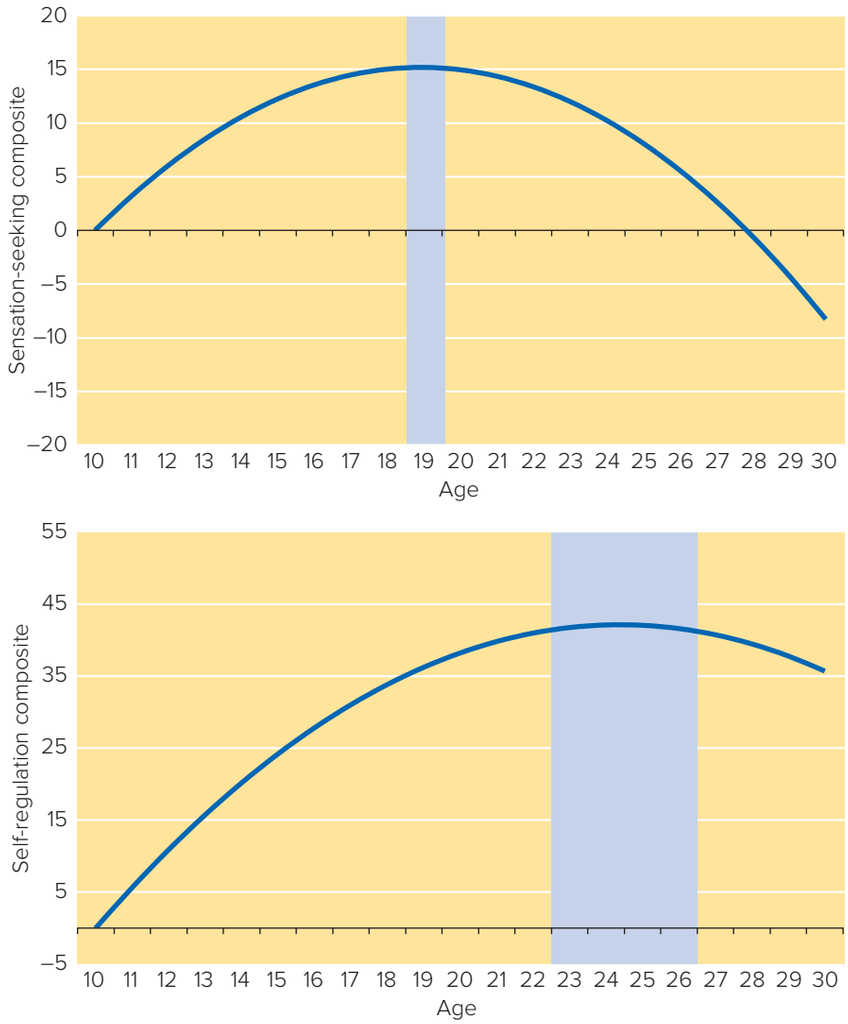


Figure 2.8 Around the world, adolescence is a time of heightened sensation seeking and still developing self-regulation. The gray bars indicate the age at which there is a peak (sensation seeking) or plateau (self-regulation). (Figure 1 from Steinberg et al., 2015)

risks when their friends are around (Steinberg, 2014). Although adolescent drivers, on average, take more chances than adults, how adolescents drive depends on who is in the car; adolescents drive much more safely when their parents are passengers than when they are driving alone or with their friends (Simons-Morton et al., 2011; Telzer, Ichien, & Qu, 2015). One study found that having their mother around actually increases activation in adolescents' reward centers when they are making safe decisions, but decreases it when they are making risky ones (Guassi Moreira & Telzer, 2016). In other words, when your mother is around, it may actually feel better to make prudent choices than dangerous ones! And, when faced with risky choices, teenagers who have relatively more positive relationships with their parents are less likely to take risks (Guassi Moreira & Telzer, 2017) and less likely to show activation of the brain's reward centers (Qu, Fuligni, Galván, & Telzer, 2015).

The effect of peers on adolescent risk taking is clearly evident in studies of driving crashes. As Figure 2.9 shows, having multiple passengers in the car increases the risk of crashes dramatically among 16- and 17-year-old drivers, significantly among 18- and 19-year-old drivers, and not at all among adults. This is both because adolescent passengers can be distracting to new drivers and because adolescents are simply more likely to take risks in the presence of peers (Clentifanti, Modecki, MacLellan, & Gowling, 2014; Foss & Goodwin, 2014; Pradhan et al., 2014). Consistent with this, in one experiment, in which adolescents, college undergraduates, and adults who were either alone or in a room with their friends played a video driving game that permitted risky driving—for instance, driving through an intersection after a traffic light had turned yellow—found that the mere fact of having friends watching their performance increased risk taking among adolescents and undergraduates, but not adults (Gardner & Steinberg, 2005). In a subsequent study, in which the researchers imaged the teens' brains while they played a similar video driving game, the results indicated that the brain regions associated with the experience of reward

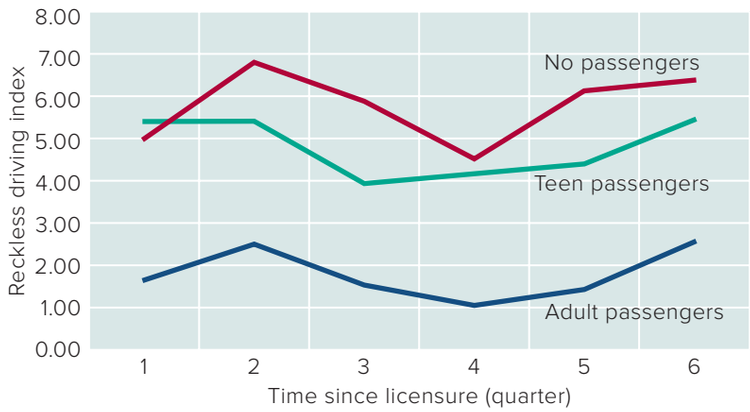


Figure 2.9 **Although adolescents on average are riskier drivers than adults, who is in the car makes a big difference. Teens drive more recklessly when they are alone or with peers than when they have adult passengers.** (Simons-Morton et al., 2011)

were much more likely to be activated when the teenagers were observed by their friends than when they were alone, and that risky driving was correlated with heightened activity in the brain's reward areas. Thus, in the presence of their peers, adolescents may pay more attention to the potential rewards of a risky decision than they do when they are alone (O'Brien, Albert, Chein, & Steinberg, 2011; Smith, Steinberg, Strang, & Chein, 2015). This peer effect on adolescent risk taking is not seen, however, if a slightly older adult is present (Silva, Chein, & Steinberg, 2016) (see Figure 2.10).

Logic and Intuition More recently, several theorists have proposed models of adolescent risk taking that consider the ways in which two different thinking systems—one that is deliberative and logical, and one that is intuitive and gut-level—interact to influence behavior (Reyna, Wilhelms, McCormick, & Weldon, 2015; Romer, Reyna, & Satterthwaite, 2017). According to these perspectives, the heightened risk taking seen during adolescence, and the drop in risk taking in adulthood, can't be entirely due to deficiencies in logical reasoning,

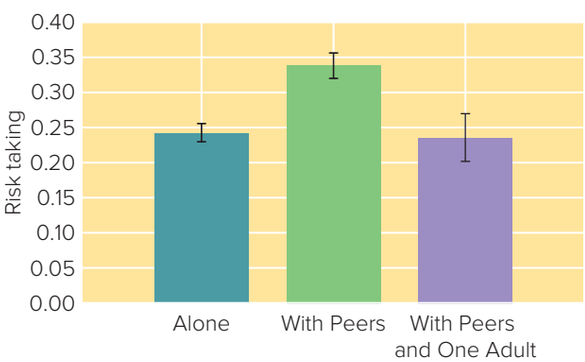


Figure 2.10 **Adolescents make riskier decisions when they are with their peers, but the presence of a slightly older adult eliminates this peer effect on risk taking.** (Figure 1 from Silva, Chein, & Steinberg 2016)

because adults themselves do not always act logically. As the Nobel Prize-winning psychologist Daniel Kahneman has pointed out (2011), we all often behave in ways that defy logic.

For instance, suppose I describe someone to you as quiet, introspective, methodical, and nerdy, and ask you whether that person is more likely to be a mathematician or a waiter. Most people say "mathematician." But this is certainly not correct—since in the United States there are over 7 million people who are waiters or waitresses and only 3,000 people employed as mathematicians! If you answered "mathematician," you were probably using your intuition, rather than logic. In this example, the gut-level choice happens to be wrong, but in many situations in life, our intuitions are correct. Being able to make some decisions intuitively takes advantage of experience and permits us to make decisions much more quickly than we would be able to do if we had to reason everything out.

Although the development of logical thinking may differentiate adolescents from children, the main change to take place between adolescence and adulthood is not the further development of logical decision making (as you read earlier, this is pretty much completed by age 15 or so), but the continued development of intuitive decision making that is based on experience. What stops adults from taking a lot of risks is not that they are good at systematically analyzing the probabilities of various outcomes, but because they get a gut-level feeling that keeps them away from the risky act. If I am standing on a cliff overlooking a dark body of water that I can't see into, the reason I don't jump is not that I've logically assessed my chances of getting hurt and decided that the odds are not in my favor. I don't jump because something inside me immediately tells me that it is a dumb thing to do. I don't even have to think about it. In one study in which adolescents and adults were asked whether some obviously risky things (e.g., "setting your hair on fire," "swimming with sharks,") were bad things to do while their brain was scanned, the researchers found that the adolescents took longer to respond and were more likely

than adults to activate brain regions that are involved in deliberative thinking; adults, in contrast, were more likely than adolescents to activate regions that reflect gut-level responding (Baird, Fugelsang, & Bennett, 2005). One other study has found that improvements in deliberative decision-making abilities are associated with more, not less, risk taking (Wolff & Crockett, 2011).

Reducing Adolescent Risk Taking Generally speaking, the most common approach to reducing adolescent risk taking is through classroom-based education programs designed to teach adolescents about the dangers of various activities (e.g., smoking, unprotected sex, drinking and driving), about making better decisions, and about resisting peer pressure to engage in risky activity. However, the evidence that these programs work is very shaky. For example, one evaluation of laws banning texting while driving found significant reductions in crash-related hospitalizations among adults but not among teenagers (Ferdinand et al., 2015). If, as we have seen, adolescents do not seem to be ignorant about the risks of these activities or deficient in the ways in which they make decisions, it does not seem likely that efforts to change their knowledge or decision making will result in very much risk reduction. Indeed, some writers have argued that enabling adolescents to make more accurate determinations of risk may inadvertently *increase* risky behavior, because the actual probabilities of something bad happening after engaging in a risky act are actually very small (Reyna, Weldon, & McCormick, 2015). Plus, adolescents are more likely than adults to be swayed by their personal experiences than by information alone (Rosenbaum, Venkatraman, Steinberg, & Chein, 2018). And if recent research on brain maturation is pointing to reasons for the inherent vulnerability of adolescence—the combination of heightened sensation seeking and immature impulse control—perhaps it makes sense to rethink our approach to the problem (Reniers, Murphy, Lin, Bartolomé, & Wood, 2016; Steinberg, 2015).

One alternative approach might focus on limiting adolescents' opportunities to put themselves in risky situations. For example, because we know that adolescents are more likely to have automobile accidents when they have teenage passengers in the car or drive at night, limiting the situations under which teenagers are permitted to drive, especially after they are newly licensed, would give adolescents that coveted driver's license but limit risky driving. Many states have found that graduated driver licensing, which phases adolescent drivers into full unrestricted driving privileges over time, lowers the incidence of fatal crashes involving 16-year-old drivers, although it appears to increase the incidence of crashes among 18-year-olds (Masten, Foss, & Marshall, 2011).

It is also possible to reduce adolescent risk taking through economic policies. For example, although anti-tobacco education has met with only limited success, increases in the cost of cigarettes have dramatically reduced the rate of teen smoking. Thus, raising the price of tobacco or alcohol would likely diminish adolescents' use of these products, because adolescents generally do not have a great deal of money and would therefore be sensitive to increases in the cost of smoking or drinking (Chaloupka, 2004). Another possibility would be to make risky things harder for adolescents to obtain, by more strictly enforcing policies that prohibit stores from selling tobacco and alcohol to minors, limiting the supply of illegal drugs, or enforcing laws that limit adolescents' access to firearms (Rowland, Toumbourou, & Livingston, 2015). Yet a third possibility would be to make the penalties for engaging in certain risky behaviors, like reckless or drunk driving, more severe, and in so doing increase the salience of the potential costs of engaging in the risky behavior. Finally, to the extent that sensation seeking may be a normal part of adolescence, perhaps we can figure out how to provide safe outlets for this motivation. Not all risk taking is bad, after all, and many adolescents take risks in order to help others (Do, Guassi Moreira, & Telzer, 2017). The challenge for parents, educators, and policy makers is to find ways to permit adolescents to take risks without putting themselves in situations in which they can hurt themselves.