What Babies Know

What Babies Know

Core Knowledge and Composition

Volume 1

ELIZABETH S. SPELKE

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Advance Praise for *What Babies Know*

"Elizabeth Spelke is one of the great scholars of the human mind, and *What Babies Know* is a masterpiece. Brilliant, provocative, and important—this is the book that anyone interested in the origins of cognition simply has to read."

—Paul Bloom, Professor of Psychology, University of Toronto

"This book is an intellectual gift from one of the most important cognitive scientists alive today, whose unmatched combination of experimental ingenuity and theoretical depth have culminated in this thrilling new picture of the nature of the human mind and the origins of human knowledge. Spelke flips around the classical picture of development that starts with sensorimotor experience, to argue that human intelligence is built upon a small number of core cognitive systems that are highly abstract, and also innate, unconscious, evolutionarily ancient, and present in all humans. This book will be of great interest to anyone interested in the nature of intelligence, what it means to be human, or what the very best empirical and theoretical science looks like."

—Nancy Kanwisher, Department of Brain and Cognitive
Sciences and McGovern Institute for Brain Research, MIT

"Core knowledge—human infants' cognitive startup toolkit—is a fundamental concept of contemporary cognitive science. No one could explain it better than its foremost explorer, Professor Elizabeth Spelke. In this essential volume, she lays down the history, principal findings and latest developments of this burgeoning field, with unmatched clarity and gusto. A long-awaited masterpiece!"

—Stanislas Dehaene, Professor of Cognitive
Psychology, Collège de France

Through her elegant empirical work and her incisive theoretical syntheses, Elizabeth Spelke has done more than anyone else alive to characterize the nature, structure and origins of human beings' basic ways of understanding the world. She has shown us the significance of what young babies know, and also what they do not know, integrating both their successes and failures into a view of foundational cognitive architecture that any computational account of the mind—or any attempt to build human-like forms of artificial intelligence—should draw deep inspiration from. This book is volume I of her magnum opus, presenting her most important statement to date and a magisterial overview of both classic and recent work in infant cognition. It is also brilliantly written. Anyone interested in learning about the origins of human intelligence should start by reading it, from cover to cover.

—Joshua B. Tenenbaum, Professor of Computational
Cognitive Science, MIT

For Bridget and Joe

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I've saved the most important acknowledgements for last. Not a word of this book could have been written without the families who have participated in the research it describes. Without parents who trust in science and are willing to contribute to it, experiments on infants would not exist. Moreover, I view the infant participants in this research as the book's true authors and my most valued collaborators and challengers. Special thanks to two sets of families: the infants and parents who participated in my first experiments, patiently putting up with my errors and false starts, and those who were willing, over the past two years and under the stresses of the pandemic, to spend time on Zoom, contributing to basic research on infant minds.

Prologue

How do we grasp abstract concepts like *circle, six, wish,* or *good*? What is special about human cognition? With perceptions and actions so similar to those of other animals, why do we alone develop new systems of knowledge, like astrophysics and medicine, and new technologies that remake the world? What is universal about human cognition? Beneath the variable knowledge and skills that support our diverse languages, cultures, religions, ideologies, and passions, is there a bedrock of assumptions, beliefs, and values that we all share? In this book and its sequel, *How Children Learn*, I aim to shed light on these questions by focusing on two others. First, what do human infants know at the time when their learning begins? And second, how do infants and children learn about the particular places, things, people, and events they encounter, and what makes their learning go so well?

Questions concerning the nature and sources of our abstract concepts have a long history, because such concepts present a puzzle. Many of them are so simple that preschool children talk about them, and so important that they stand at the foundations of a host of fundamental cultural achievements, including mathematics, technology, ethics, and the arts, but the concepts themselves are elusive. A perfect circle has no thickness and so cannot be drawn or touched. Six, a natural number, belongs to infinitely many sets with surprising properties: How can there be as many even numbers as integers, for example? Wishes are mental states that both are and are not part of the material world. And good knives, novels, liars, and deeds have little in common. How do we arrive at these concepts, given the limits to our experience? Neither we, nor the ablest machine we can build, will ever see a perfect circle, count to infinity, or touch a person's thoughts.

The uses we make of our abstract concepts reveal a striking feature of human cognition: We likely are the only animals who create new systems of knowledge over our cultural history and learn them over our lifetimes. Yet our minds and brains are so similar to those of other animals that much of our knowledge of our own capacities for perception, learning, memory, and action comes from research on other species: from the pioneering studies of Eleanor Gibson on visual space perception in newborn goats, and of David Hubel and Torsten Wiesel on the organization and development of visual cortex in cats and monkeys (chapter 1), to the landmark research of Edward Chase Tolman and John O'Keefe on the cognitive and brain processes supporting navigation and spatial memory in rats (chapter 3). These observations suggest a more focused version of my second question: What are the distinctive qualities of our minds that allow us to use the experiences and neural systems that we largely share with other animals to develop new concepts and beliefs that are so different from theirs?

Our capacity to master new knowledge systems creates diversity within our species: People who live in different cultures, or who have lived at different times, have widely differing concepts, beliefs, skills, interests, and opinions. Consider, for example, how much attitudes toward child labor, capital punishment, homosexuality, or the role of women in public life have changed over just the last century, and how variable, across people, some of these attitudes are today. In the face of this variability, my third question also can be rephrased: Are there core cognitive capacities that stand at the foundations of human life in all cultures, and that allow a newborn infant to learn the language, concepts, values, and skills that structure life in the society she finds herself in?

That question brings me to the topic of this book and its successor. Human infants and young children face a formidable learning challenge. Equipped only with the universal capacities of our species, they must master all the commonsense knowledge required for life in the society and culture into which they were born. Strikingly, children accomplish a good part of this task without being taught. Preschool children learn their language, develop a commonsense understanding of how the world works, and take on many of the beliefs and values of the people in their culture before they enter school. Infants begin to learn these things before they begin to speak, even in cultures in which adults rarely speak to them. Infants and children learn not only in families with rich adult-child interactions but also in communities in which young children spend most of their time with peers. Even in cultures like ours, where parents widely believe that their children should be stimulated and instructed as well as nurtured and loved, infants learn all sorts of things that adults do not intend to teach them.

Of course, children are not the only adaptive learners. Many animals show exquisitely rapid and effective learning in biologically significant domains. Chicks, ducks, and geese learn to identify their mother through a rapid process of imprinting; birds learn to migrate over long distances from their winter grounds to the summer habitat in which they were born, building mental maps of the movements of the stars and of the local terrain at their birthplace; and rats learn, in a single, unpleasant trial, to avoid a poisonous food. These learning processes, however, are not flexible: The mechanisms by which chicks learn to identify Mom do not serve to identify the path home or the poisonous plant that abuts it.

Animals also have a remarkably general ability to learn whatever contingencies their local environment presents, even when those contingencies are arbitrary, like the bell rung by Pavlov to announce the arrival of food for his dogs. This general learning process, however, is slow, as it depends on the gradual accumulation of information that one event reliably heralds another. In recent years, the field of artificial intelligence has produced machines that speed up some of the slow, general learning processes found in humans and animals. As a result, the capabilities of the biggest and fastest machines now exceed those of humans in domains like chess and Go, by processing far more information than any person could accumulate in a lifetime. In contrast both to animals and to these machines, however, human infants and preschool children gain a commonsense understanding of their environment through learning processes that require far less information, and that are both fast and flexible. How do they do this?

This book presents my best attempt to answer a piece of this question, focusing only on children's knowledge and learning in infancy. My answer comes in two parts. First, infants' learning rests on a set of cognitive systems that we share with animals and that evolved over hundreds of millions of years. At least six distinct systems serve to represent highly abstract properties of the unchanging navigable environment, of movable objects, of number, and of the living, animate, and social beings who populate our world. The systems share a constellation of properties and limits that distinguishes them from the cognitive systems that philosophers and psychologists have traditionally recognized: perceptual systems, action systems, and belief systems. I call them systems of *core knowledge.*

Second, humans have evolved one set of cognitive capacities that are unique to us: capacities to learn a natural language and to use that language for thinking, for communicating, and for grasping the thoughts of others. During the year this book covers, infants do not use language for communication, but they are continually engaged in learning their native language. The language that infants learn, beginning in the womb and ending just before most of them start to speak intelligibly, allows them to compose new concepts from the concepts of core knowledge. And the language infants hear, from the people in their social world who speak to one another (and in many cultures, to them), provides guideposts for organizing and using these new concepts.

By the end of the infancy period, children have gained the basic tools they need to develop the commonsense knowledge that life in their culture requires. In *How Children Learn*, I will ask how children accomplish this task, beginning at 1 year of age and continuing over the years that separate infancy from the onset of formal schooling. That book will focus on children's developing knowledge of object forms and functions—knowledge that underlies our prolific invention and mastery of tools; of spatial symbols including pictures, maps, and the alphanumeric characters supporting reading and calculation; of the natural numbers; of Euclidean geometry; of mental states as propositional attitudes; and of the structure of the social world. This book ends where the second will begin. It focuses primarily on cognitive development over the course of the first year: a time when infants' learning is propelled by a penchant for observing, exploring, experimenting, and engaging with others, guided first and foremost by their systems of core knowledge.

Core Knowledge

Drawing on more than 40 years of research, this book introduces six core systems (figure P.1).[1] The most richly studied core system focuses on *places* in the persisting, navigable surface layout. It provides us with a sense of where we are, supports the construction of mental maps of the terrain through which we move, and anchors our memory for the events we experience. Another core system focuses on *objects:* nonliving bodies and their motions. It is the foundation for our commonsense understanding of the physical world. A third system focuses on *number* and represents the approximate numerical magnitudes of sets of objects or events. Among other functions, it supports learning about the statistical properties of the things and events we experience. Core knowledge of places, objects, and number has been widely studied in animals as well as humans, using the methods and perspectives of diverse disciplines in the cognitive, brain, and computational sciences, including experimental psychology, systems and cognitive neuroscience, and artificial intelligence and robotics. These are the simplest, best understood core cognitive systems, so I begin the book with them.

Using the methods and findings from studies of these systems, I hypothesize that infants have three more systems of core knowledge. The *form* system evolved, I believe, to represent the forms and functions of living beings that grow, provide our food, and defend themselves against us. For human groups living in close contact with nature, this system gives rise to commonsense knowledge of botany and ecology. For children and adults in industrialized societies, it is diverted to support learning of the forms and functions of artifact objects: learning at the foundations of tool use and technology. I have given it a name that applies in both these contexts. The *agent* system focuses on animate beings, including people, who act on objects and cause changes in them. It underlies our action understanding, action planning, causal reasoning, and grasp of people's intentions. The last system focuses on *social beings* who engage with one another, share their experiences, and form enduring bonds. For our species, this system supports learning about individual people and the network of social relationships that connects them to one another and to us. The agent and social systems together support children's learning about people and their mental states, and they form the core of our commonsense understanding of human societies and ethics.

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[1] I thank Shari Liu for creating this figure.

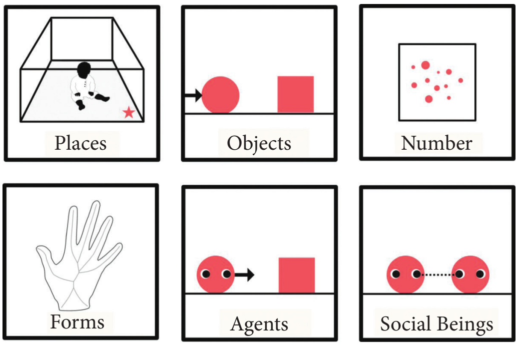

Figure P.1 Six domains of core knowledge.

Core knowledge systems have useful properties. First, each system captures a distinct, interconnected set of abstract concepts. For example, the place system represents the geometric structure of the navigable terrain over which animals move and objects reside, and the traversible paths that connect individual places to one another, and the social system represents the people in one's social world as having experiences like one's own that they share in states of engagement. I believe the core systems provide the foundations for the abstract concepts at the center of all our explicit knowledge. Second, core knowledge functions throughout life. Because each core system centers on abstract concepts, the systems capture fundamental, generalizable properties of the world, like the continuity of time and motion, the geometric properties of space, and the causal powers of animate beings. These systems give rise to our deepest intuitions, as adults, about the nature of the world and ourselves. The core systems, therefore, provide a common ground for communication between people in different cultures, with different beliefs and values.

Where relevant evidence is available, the core systems have been found to be innate, in a straightforward and unproblematic sense of this much-maligned term: They are present and functional on an infant's first informative encounters with the entities that they serve to represent. As a result, these systems support acting, exploring, and learning as soon as the need arises. In humans, moreover, the core systems support the development and use of new systems of knowledge. Although the core number system lacks the power and scope of the natural numbers, for example, children use it, together with other systems, to construct the natural number concepts at the foundations of mathematics. Core systems are more than scaffolds, however: Adults whose core number system is impaired by injury no longer can calculate with natural numbers as they did before.

Core knowledge systems have further properties. First and foremost, each system singles out entities in a distinct cognitive domain: The place system, for example, represents the continuous, unchanging, extended surface layout, but not the objects within it. Similarly, the object system represents inanimate, cohesive, solid, and persisting bodies that move only on contact, but not animals, who have the power to generate their own motion, to perceive things at a distance, and to direct their actions to distant objects. The behavior of animals cannot be fully captured by the rules of contact mechanics in the domain of the object system. Together, the six systems carve our cognitive territory into more manageable units.

Second, the core systems are astonishingly ancient: They have been shaped by hundreds of millions of years of cognitive evolution. Some core systems are shared by animals as remotely related to us as fish, and aspects of these systems are shared by flies and worms. These ancient systems, found even in animals who lack a cerebral cortex, give rise to mental representations that are deeply inaccessible to our human, conscious minds. We can discover them through experiments, but not by introspection.

The ancient origins of the core systems limit the properties they serve to represent. Core systems capture deeply important, general properties of the entities in their domain, but they mostly fail to capture what those entities look like or how, in detail, they behave. To give just two examples, the place system represents the ridges, hills, valleys, and impassable borders of the ground surface over which we and other animals navigate, but it doesn't represent the walls of the infant's house, the objects that furnish it, or even the colors and patterns on the floors on which people walk. The youngest child navigators, eager to find their favorite toy that has been hidden in a room, will retrieve the toy by detecting highly subtle spatial perturbations on the room's floor but will fail to retrieve it by noting its proximity to a brightly colored wall or a salient visual pattern. Similarly, the social system represents the direction of gaze of a face with striking precision but fails to specify the physical characteristics that distinguish faces of the infant's species from those of other species. As a result, newborn human infants look longer at a still face whose eyes are looking at them than at an otherwise identical face looking elsewhere, but they are equally attracted by the direct gaze of a person, a sheep, or a bird.

These ancient core systems have a further property: They are modular, in all the respects described by the philosopher and pioneering cognitive scientist Jerry Fodor in his *Modularity of Mind.* In particular, core knowledge systems operate automatically, regardless of our intentions, thoughts, and beliefs, although their operation does require attention to entities or events that lie within their domain. Finally, human infants and nonhuman animals of all ages fail to combine the outputs of the core knowledge systems flexibly and productively. Neither young infants nor nonhuman animals are capable of fast, flexible learning when faced with tasks that require new combinations of information from different core domains.

If one considers all these properties together, it becomes clear that core knowledge systems do not fit within the categories that appear in traditional treatments of human psychology. They are not sensory or perceptual systems, because they serve to represent abstract properties and relations. They also are not the central cognitive systems that underlie our explicit beliefs, decisions, and reasoning. For example, our actions and stated beliefs do not abide by the core principle that inanimate objects only change their motion on contact with other objects. Indeed, we believe otherwise, and we act on our explicit beliefs when we explain to our children how the earth moves around the sun. Core knowledge systems occupy a middle ground between perceptual systems and belief systems. Cognitive science needs this middle ground, I believe, to understand both human and animal minds.

Although core knowledge exists and functions in the minds and brains of animals and adults (and I will draw heavily on studies of those populations to elucidate its properties), I focus on human infants from birth to 12 months, for two reasons. First, studies of infants shed light on the contents and functioning of human minds before they are filled with culture-specific beliefs and attitudes. Infants are hard to study, because we have no intuitive access to what they know and they have limited means for expressing their knowledge. Nevertheless, experiments on infants provide the most direct access to the earliest emerging cognitive capacities at the foundations of our knowledge. Second, infants' learning lays the groundwork for a constellation of remarkable changes that occur toward the end of the first year: Infants begin to learn not only from others' actions but from their words, and they begin to communicate with others through gestures and patterns of shared attention to objects and events. One-year-old infants have begun to view people, and the objects that people talk about, in new ways.

These changes usher in a period of learning that has no parallel in the living world: the period to be covered in *How Children Learn*. Throughout this period, however, hidden but ever-present systems of core knowledge provide the central abstract concepts that children build on in later years. By using young infants' exceedingly limited behavioral repertoire for all that it is worth, developmental cognitive scientists can discover these concepts and trace the earliest learning they support. Young infants' minds reside in cognitive territory, between perception and belief, that is opaque to our mature, conscious experience. But as adults, our unconscious minds also inhabit that cognitive territory, and so the seeds that we discover in infants, through experiments using the multidisciplinary methods of cognitive science, bring us insight into ourselves.

Organization

This book has 10 chapters. The first chapter isn't about core knowledge; it focuses on infants' visual perception of surfaces and depth. I begin with this topic because research on perceptual development in infancy provided the primary methods by which cognitive scientists have discovered what infants know. Chapter 1 centers on the work of two extraordinary psychologists, Eleanor J. Gibson and Richard Held, whose work from the 1950s to the 1980s tackled ancient questions concerning the nature and origins of perception of the visible spatial layout. From distinct theoretical perspectives, but with converging methods, Held and Gibson turned a long-standing philosophical and scientific debate into a set of empirical questions that they, and other experimental psychologists, proceeded to answer. In doing so, they solved some dicey problems: How can one tease apart the roles of innate capacities and learning in development? How can evidence from the behavior of nonverbal infants and animals support conclusions about the content of their perceptual experience?

The chapter ends with research by more recent computational cognitive scientists, beginning with David Marr, whose work in the 1970s complemented and expanded on the work of Gibson, Held, and others. Together, these scientists created a vibrant interdisciplinary approach to vision that bridges psychophysics, animal behavior, systems and cognitive neuroscience, artificial intelligence, and machine learning. The research this approach has fostered is beginning to suggest how innate knowledge of the visible world might arise, prior to an animal's first encounters with it. The chapter therefore introduces many of the methods and ideas that guide research on core knowledge.

Chapter 2 focuses on studies of infants' knowledge of objects: the movable bodies that we see, grasp, and act on. Before infants can reach for and manipulate objects, they organize perceptual arrays into bodies that are cohesive, bounded, solid, persisting, and movable on contact. Young infants use these abstract, interconnected properties to detect the boundaries of each object in a scene, to track objects over occlusion, and to infer their interactions with other objects. Nevertheless, there are striking limits to young infants' object representations: Infants have little ability to track hidden objects by their shapes, colors, or textures, although they do detect and remember these properties.

Above all, research reveals that infants' early-emerging representations of objects are the product of a single cognitive system that operates as an integrated whole. This system emerges early in development, it remains present and functional in children and adults, and it guides infants' learning. The system combines some, but not all, of the properties of mature perceptual systems and belief systems, and it therefore appears to occupy a middle ground between our immediate perceptual experiences on the one hand and our explicit reasoning on the other. Research probing infants' expectations about objects suggests hypotheses concerning the mechanisms by which a system of knowledge might emerge, function, and guide infants' learning about the kinds of objects their environment provides and the kinds of events that occur when different objects interact. Research described in this chapter also reveals that infants' knowledge of objects is at least partly innate. It suggests how innate knowledge of objects might arise prior to birth, preparing infants for their first perceptual encounters with movable, solid, inanimate bodies.

Chapter 3 turns to core knowledge of places. The core place system underlies our sense of where we are, where other things are, and what paths will take us from one place to another. Studies of animals and young children reveal that navigation depends, first and foremost, on representations of abstract geometric properties of the ground surface over which we travel: the distances and directions of its boundaries, ridges, cliffs, and crevices. This research also reveals sharp limits to the features of the environment that guide children's and animals' sense of place, and it provides evidence that the place system, like the object system, is unitary, emerges early, functions throughout life, and supports learning about the navigable environment.

More than seven decades of research on place representations demonstrates how scientists can determine whether the same cognitive system exists and functions in the same manner in different animal species. The achievement is important, because studies of nonhuman animals provide a panoply of tools for probing the nature, evolution, and development of the cognitive capacities we share with them. Research provides evidence that our place system is ancient: It is largely shared by animals as distantly related to us as fish, from whom we diverged some 500 million years ago. Building on these findings, research on navigating animals, using methods of controlled rearing, provides the clearest evidence that core knowledge of places is innate.

Meanwhile, research on navigating human adults sheds light on the minds of animals and human infants. This research reveals that the place system is modular: It operates automatically, regardless of our intentions and beliefs, and its internal workings are deeply inaccessible to our conscious minds. Studies of adult humans and animals reveal that both the place and object systems are resource-limited and compete for attention. As a consequence, they are not readily combined into a unitary representation, but they complement each other. The same processes that single out movable bodies for the object system serve to remove these bodies from the representations that guide our navigation, allowing us to track our location and travels relative to the enduring and unchanging terrain over which we move. Although children and animals learn to navigate by landmarks, they do not form a comprehensive Euclidean map of their environment. Finally, research applying methods of cognitive neuroscience to studies of animals and human adults, but not yet to studies of young children, provides evidence that navigation is aided by processes of mental simulation of different paths through the environment. Throughout this book, I speculate that core systems give rise to simulations that prepare infants for learning from their encounters with objects, places, and other entities.

Chapter 4 focuses on core knowledge of number. Research on human infants, children, adults in diverse cultures, and nonhuman animals all converges on evidence for an early-emerging ability to represent and combine numerical magnitudes with approximate, ratio-limited precision. This ability depends on a core system with most of the properties of the core object and place systems: it is present in newborn infants and functions throughout life, and it is ancient, unitary, and limited in the types of information it provides. The core number system also is modular, unconscious, and yet dependent on attention, and it competes for attention with the core system that represents the individual objects that we enumerate. Despite its modularity, studies of older children and adults provide evidence that the core number system contributes to children's learning of mathematics in school, to adults' reasoning about mathematics in everyday life, and to the thinking of professional mathematicians when they are challenged with difficult questions in diverse mathematical fields. Thus, even the most abstract and abstruse feats of human reasoning draw, in part, on ancient, early-emerging cognitive systems.

Chapter 4 completes my exposition of the general properties of core knowledge. In chapter 5, I argue that these properties go together: A cognitive system that has some of them is likely to have all of them. The most important of these properties are their ancient origins, their persistence over vast stretches of time, and their resilience despite the innumerable changes wrought by subsequent cognitive evolution. Such systems can only focus on the most abstract and highly general properties of the entities in their domain, and they can only survive within highly encapsulated brain systems, for they must function in creatures who live in very different environments, with very different brains and cognitive capacities. As the beneficiaries of hundreds of millions of years of cognitive evolution, these systems will operate with high efficiency in diverse environments.

In the next three chapters, I propose three more core cognitive systems with these properties. Chapter 6 draws on a large body of research investigating the abilities of animals, infants, children, and adults to categorize objects on the basis of their forms and functions. After reviewing a wealth of research on form perception and shape-based object recognition, I hypothesize that humans and animals are endowed with an ancient core system for perceiving, tracking, categorizing, and reasoning about the branching forms and varied functions of natural objects: especially plants. Plants are the primary sources of food for humans and other animals, and in natural environments, they remain prominent sources of the poisons, irritants, and thorns that threaten animals' health. Like the place system, the form system centers on abstract, interconnected geometric properties, but its properties are distinct from, and complementary to, those captured by the place system.

If the form system evolved to support reasoning and learning about the shapes and functions of living kinds, however, it must be repurposed for most of the world's people, who now live in industrialized environments. This chapter therefore considers how a core form system that evolved for learning the forms and functions of plants might be harnessed by young children to support their learning about the forms and functions of artifacts. Finally, I ask whether the place and form systems together come to support children's mastery of spatial symbols. Research provides evidence that they do, but with conspicuous limits that children only overcome when they learn formal geometry in school.

Chapter 7 focuses on core knowledge of agents: beings who cause their own motion and, by moving, cause changes in the state of the world. I review research providing evidence that young human infants represent the movements of other animals and people in accord with the interconnected, abstract concepts of *cause*, *intention*, *action cost*, and *goal value.* Moreover, infants use agent representations both to guide their own actions on objects and to interpret the object-directed actions of others. Research on young infants and newborn or controlled-reared animals provides evidence that the agent system is unitary, ancient, and at least partly innate; research on older children and adults suggests that it functions throughout life, is modular, and serves as a foundation for the development of children's action planning and causal reasoning. Finally, agent representations show signature limits that distinguish them from representations of places, objects, and plants. Core representations in these four domains compete for attention as they capture complementary aspects of the environment.

Chapter 8 focuses on core knowledge of social beings: entities who endow one another with experiences like their own and who share their experiences in states of engagement. I review research providing evidence that young human infants and nonhuman primates represent both the social interactions in which they participate and those they observe, in accord with the interconnected, abstract concepts of *shareable experience* and *engagement.* Research suggests that these representations are unitary, ancient, developmentally invariant, innate, modular, and foundational for later social and moral reasoning. Adults and children view themselves and others as simultaneously social (because we engage with one another) and agentive (because we act for our own and our partners' benefit). Until 10 months of age, however, I suggest that the core agent and social systems are not readily combined. Like the core number and object systems, these systems compete for attention, allowing infants to represent people either as agents who act and cause changes in the world or as social beings who engage and share experiences, but not both at once. Young infants lack our concepts of people as social agents, whose behavior is both social and causal, guided by mental states that are both phenomenal and intentional. I discuss the development of new concepts of people and their mental states in chapter 10.

As infants engage with other people, they begin to learn the language or languages by which people communicate with the infant and with one another. In chapter 9, I consider infants' language learning in the first year. Research reveals that infants begin to learn the rhythms and sounds of their native language even before birth. By 4 months, infants have begun to learn some of the words and phrases with which speakers convey meaning. As their learning proceeds, infants come to discern how words and part-words combine in phrases, and how speakers use these combinations to share their experiences with others. Remarkably, infants detect and use the ordering of abstract categories of words both to learn individual word meanings and to discover the specific sound contrasts that distinguish one word from another in their native language.

Research suggests that infants' language learning depends, in part, on core knowledge of the people who speak to them and core knowledge of the things and events that people talk about. The connections between language and core knowledge are especially clear in studies of newly emerging languages and of *homesign*: the gestural communication system invented by deaf children with no access to a conventional signed or spoken language. Further connections between language and core knowledge are revealed by studies of universal patterns in the functional vocabulary of mature languages. The most frequent, short, and unstressed function words and part-words in the world's languages tend to convey meanings that map to core knowledge, because adult speakers and listeners access core concepts frequently, rapidly, and automatically.

In chapter 10, I turn to two new systems of concepts that emerge, I believe, at the end of the first year. At about 10 months, infants come to combine representations from the core agent and social systems into a unitary set of concepts of people as social agents, whose object-directed actions fulfill social goals. This new conception of human action appears to arise when infants decipher the first sentences with which their social partners invite them to share attention to objects.

About 2 months later, infants come to combine representations of the action plans of agents and the shareable experiences of social beings into a unitary set of concepts of mental states as both phenomenal and intentional: states that convey people's shareable experiences of things and events. This new conception arises, I suggest, as infants decipher the distinctive meanings of the diverse content words that convey distinct perspectives on the same individuals: words like *animal, dog,* and *Rover*, applied to the same pet, or words like *give* and *take,* applied to the same exchange. These conceptual developments give infants new ways of learning about the world and thinking about other people. They provide foundations for the prodigious learning capacities of older children.

Coda

This book is aimed at a broad community of readers. I assume no knowledge of any particular discipline, but I try to back each factual claim with evidence. I take a broad view of the evidence that bears on these claims: In each chapter, I consider how the findings of behavioral studies on infants mesh, or fail to mesh, with one another, and with experiments that test for the same capacities in other animals, in children and adults in diverse cultures, in the brains of all these creatures, and even, in some cases, in intelligent machines. To achieve this aim, I have written a longer book than you may want to read. Despite its length, however, I have had to leave out much of the beautiful work on infants that has emerged from the many fields of developmental cognitive science. I hope my colleagues will forgive me.

This book has many flaws. First, it is full of language that may mislead. Unfortunately, natural languages have no words for any of the representations that core knowledge systems deliver. When we talk to each other, what we say is informed by core knowledge, but nothing we say expresses that knowledge directly. Core knowledge is taken for granted: Its concepts and assumptions can be left unsaid. This fact has presented me with a lifelong problem: How do I talk or write about it?

The problem was first pointed out to me in 1978 by Henry Gleitman, who was then my senior colleague, one of many brilliant and valued mentors at the University of Pennsylvania, and the greatest teacher and expositor of psychology I have ever known. When I excitedly described to him the findings (by a wonderful student, Phil Kellman) of our first studies of infants' perception of objects, Henry gently but decisively deflated my claims. "Those are interesting findings, but your babies do not see objects. At best, they see schmobjects." Henry was right: Infants start out knowing almost nothing about the chairs, cups, and cars that pop into our minds when we think about objects. Similarly, infants know almost nothing about places, forms, animals, people, or number.

On every page of this book, I bend the English language in ways that invite misreadings, for I have found no happy solution to this problem. Some authors, following Piaget, adopt a new, invented vocabulary for describing the contents of infants' minds, but as a student, I found his writings about "schemas," "assimilation," and "secondary circular reactions" less illuminating than his beautifully clear descriptions, in plain language, of his infants' responses to the challenges their investigator-parents presented to them. Here I opt for ordinary language, but you are welcome, reader, to think “schmobject” or “schnumber” as you proceed through this book.

Second, each chapter of the book is dense with information, twists, and turns. Here is why: I aim to describe what we learn when we study the minds of infants. The first thing we learn, in embarking on such studies, is that our intuitions about infants’ minds are wrong. To learn how infants think, we have to listen to what the infants in our studies tell us. This book is a portrait of the lessons learned from infants who have responded to the often-misguided questions that psychologists like me have put to them. Within this body of research, there are no “silver bullet,” stand-alone experiments that capture the contents of infants’ minds. Insights come instead when a chorus of voices, from the participants in many studies, starts to harmonize, revealing how infants are construing the events experimenters present to them.

Can one digestible book describe the minds of infants for a critical and curious reader with finite time, who will want to know what infants do in laboratory experiments, and to consider whether their behavior in these experiments supports the conclusions I draw? I hope this book achieves that goal, but in case it doesn’t, each of its chapters—exploring infants’ initial and developing knowledge of objects, places, number, forms, agents, social beings, language, and social agents—begins with a road map of the research to be presented and ends with a portrait of the cognitive capacities the research illuminates. The heart of the work lies in between, where specific experiments address specific questions that together converge on a more general understanding of infants’ minds. You, reader, may choose how deeply to delve into this material.

Although this book and its successor address questions that are straightforwardly empirical—Where does knowledge begin in human infancy? How does it grow in childhood?—a passion and a hope lie behind the effort to answer these questions. By gaining a better understanding of infants and children, we gain insight into our own minds: how all people are the same and how we differ; what aspects of our thoughts and actions can be changed and what aspects we likely must live with forever; and how we can adapt our actions to leverage our cognitive capacities effectively. By coming to understand our own minds better, we will better equip ourselves to deal with the prodigious set of challenges that our endlessly inventive species has created.

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