CHAPTER THREE

What Children Learn About Things

We seem to exist in a world of three-dimensional objects moving through space in regular ways, objects that are outside us and would continue to be there even if we weren't looking at them. Some of these objects are people, some are animals, some are plants, and some are just stuff. Some of the objects are similar to one another, and some are different. And yet all of this banal, everyday experience is somehow based on tiny events on the edges of our bodies, photons bombarding our retinas, molecules of air vibrating at our eardrums, flickers of pressure on our fingertips. How do we bridge this apparently insuperable gap between our rich everyday experience of the world and the impoverished information of our senses?

While versions of the Other Minds problem still engage us every day, the External World problem is curiously invisible. We take our ability to perceive and understand objects for granted. It's the groundwork for everything we do. It's a philosophical purloined letter, so simple and in such plain view that we have a hard time seeing it.

One way of making these deep assumptions visible is to think about what happens in a magic show. All magicians, from the moonlighting student in the tuxedo at the children's party to David Copperfield, produce similar effects (the main differences are in the patter and the stage setting). The magician's stock-in-trade is to produce (or seem to produce) events that violate our usually unquestioned beliefs about how objects work. Our almost visceral experience of shock and wonder reflects the strength of those beliefs. Magicians make objects move from one point to another without traversing the space in between: the white rabbit was in the box, and now it's in the top hat. They make what looks like one object into two objects: the single silver ring becomes two rings as we watch. They make objects seem to influence each other from a distance: the magician waves his magic wand, and the box on the other side of the stage wiggles back and forth. They transform objects from one state to another: the water turns into orange juice. They even turn an inanimate object into a living one: the silk scarf becomes a dove.

Why are magicians so surprising and interesting? And why are we so sure that the rabbit really didn't disappear from the box and reappear in the hat? It must be because we are quite certain that things can't actually disappear, or turn into two objects, or be influenced by a magic wand, or change from one thing into another. In fact, we are so certain that, as we say, "we don't believe our eyes." Magic shows make us realize the complicated, abstract set of principles of everyday physics that we usually take for granted. Those beliefs are so deeply ingrained and so important to us that they even override what we actually see. We know that the rabbit can't actually just appear in the top hat. Even little kids "get" magic; the teenager in the tuxedo gets just as excited a response as David Copperfield in Las Vegas.

Nobody ever explicitly teaches us that the magician's tricks are impossible: no one tells us that the rabbit can't be in the hat. Yet it doesn't seem feasible that we could learn these principles directly from our sensory experience either, from the bombardment of photons and sound waves. In fact, as we've learned more and more about how our senses work, we've realized how complicated and tortuous the path is from the world to our brains.

Aristotle could still think that the true essence of objects sailed through our eyes and into our minds, and that that was how we saw the world. It was as if each time you glanced at a page of this book, you were inhaling a tiny, perfect piece of "bookness." But by the seventeenth century we had begun to understand that vision was the result of light that was reflected off objects and into our eyes. Scientists (like Bishop Berkeley and René Descartes) were making advances in optics, the science of light and vision, at the same time that philosophers (like Bishop Berkeley and René Descartes) puzzled over how optical phenomena could ever lead us to know what objects were really like. How could patterns of light bouncing off our retinas tell us that objects can't disappear into thin air or that space is three-dimensional?

The modern answer to the question is that we have a special kind of knowledge that enables us to translate the information at our senses into representations of objects. Our brain takes sensory information, the patterns of stimulation at our retinas and eardrums, and systematically transforms that information. It rearranges and changes it in a way somewhat similar to the way your word processor can rearrange and change the sequence of symbols you type (though, of course, the brain produces much more complicated rearrangements than the word processor). The outcome of this process is the coherent, complex network of beliefs that are so shockingly challenged by magicians.

The evolutionary trick is that these beliefs—that is, the representations we finally end up with after all these transformations and rearrangements—really do tell us about the world out there. The brain ends up with a picture that is actually closer to the real structure of the world than the raw sensory information it started out with. The world really is populated by objects moving in space in regular ways, and evolution ensures that we eventually understand this.

Just as it's important to infer the nature of other people's minds in order to survive, it's also important to infer the nature of the physical world. Determining that your neighbor is sexually interested may improve your reproductive success, but not if you can't figure out how to negotiate your way through the forest trees to get to his hut. Determining whether your neighbor's mate is likely to throw a rock at you is important for your survival, but so is dodging the rock.

So you, as a grown-up, know how to decode the chaotic, ever-shifting patterns of light, touch, sound, and smell that surround you into a book, a couch, a Mozart CD, and a convenient cup of coffee. But where does that knowledge come from?

The broad lines of the answer are similar to the answer to the Other Minds problem: we know a lot to begin with; we learn much more; other people unconsciously teach us. Some kinds of knowledge are there at the start. Even newborns seem to know that we live in a three-dimensional world and that something that looks curved will feel curved, too. But other kinds of knowledge emerge only gradually. Babies don't, at first, seem to understand how objects can be hidden by other objects. Just as babies have to learn things about people that we take for granted, they also have to learn a surprising amount about simple physical objects. Finally, some kinds of information about objects seem to be unconsciously conveyed by grown-ups. We unconsciously "teach" babies about objects even in the language we use to talk to them.

What Newborns Know

The Irresistible Allure of Stripes

Let's go back to the small, warm creature in the hospital room. That brand-new baby is already deeply connected to other people, but that's not all that goes on in the baby's world. Babies love human voices and faces more than anything, but they also love stripes and edges. Babies only a few days old will gaze with focused, cross-eyed intensity at the corner of the ceiling or a striped shopping bag while they ignore all the expensive toys, with their bright colors and soft prints, that Grandma brought along. We can show this systematically in the types of experiments we talked about in the last chapter. You can show babies different kinds of pictures and see where they look. Babies will turn toward complex patterns of high contrast and away from simple patterns with little contrast. Checkerboards and bull's-eyes appear to be at the peak of newborn aesthetic sensibility. In fact, manufacturers of baby toys have taken advantage of this research: the patterns on mobiles designed for very young babies are often taken straight from the pages of academic developmental psychology journals.

Why do babies love stripes? It turns out that this question is as important to cognitive scientists as it is to toy makers because it helps answer another question: How do we divide up the continuous visual image in front of us into separate things? When you look at the book in front of you, how do you know where to draw the line between the book and the background of couch fabric behind it, or the edge of the hand that is holding it? Although this might seem like a simple ability, in fact, the most sophisticated computer vision systems have a very hard time doing it.

Images such as stripes, where there is a sharp contrast between the brightness and texture of two surfaces, are important because they usually indicate where objects begin and end. If you hold this book up against a background, you'll see that the areas of greatest contrast in the image you see, the edges, correspond to the real boundaries of the book. Camouflage works by introducing edges to the inside of an object and obscuring the edges between an object and its background.

If you give young babies a complicated picture and record their eye movements as they look at the scene, you'll see them tracing the outside edges of objects. Newborns are already imposing order on what William James called the "blooming, buzzing confusion" of their senses. They're already organizing the world into a bunch of different things. Paying attention to edges is the best way of dividing a static picture into separate objects.

The Importance of Movement

But, of course, the baby's world isn't static. Even in the hospital room, things are constantly moving. And even newborns will follow a moving object with their eyes. (Alison's older sons found great amusement in "hypnotizing" their baby brother by slowly moving a toy back and forth in front of him.) Movement provides even better cues about where objects begin and end than do just edges alone. Imagine a baby looking at a Big Bird doll lying on a bunny quilt. The doll may have a number of different parts, each of which has specific edges—the head is visually separate from the body, which is separate from the feet. In the same way, each of the bunnies on the quilt also has its own separate edge. But if you pull the quilt out from under Big Bird, all the quilt's edges will move together, and they will move on a different path from all the parts of Big Bird. Psychologists, with uncharacteristic poetry, call this the principle of common fate. When things move together on the same path, they must be part of the same object.

You can demonstrate systematically that babies pay attention to this sort of information. If you show very young babies a video of a static Big Bird that then explodes into its separately defined parts, they won't be perturbed. Because all the parts had separate edges anyway, they may, for all the babies know, have been separate objects to begin with. But if you show them Big Bird moving first, so that they see that all the parts of the object move together, and then show them the exploding Big Bird, they'll look much longer and more attentively, as if they recognize that something is wrong. Seeing the parts move together, seeing their common fate, seems to tell the babies that this is just one object and that its parts are eternally joined together. So babies already have some principles they can use to impose order on a chaotic world.

Movement seems to be important for babies in other ways, too. Very young babies already know a surprising amount about how objects characteristically move. Young babies not only can follow the movements of an object in front of them, they seem to be able to predict how an object will move in the future. Suppose you show the babies an object following a particular trajectory—that is, moving in a particular path at a particular speed—say, a ball rolling on the table. Now the ball rolls behind a screen. They will look ahead to the far edge of the screen, to the place where the object ought to appear if it keeps moving at the same rate and on the same path. If the object does appear there, the babies are unperturbed and keep following the object. But if the object doesn't appear there, or if it appears at the wrong spot or too quickly or too slowly, they look intently at the edge of the screen for much longer. Sometimes, in fact, they look back to the other edge of the screen, or look farther ahead along the path the object should have taken. They seem able to predict where the object should be and when it should get there.

Seeing the World Through 3-D Glasses

Objects have edges and objects move, but another important thing to know about objects is that they are three-dimensional. One of the classic philosophical debates of the eighteenth and nineteenth centuries was about how we turn the two-dimensional, flat image projected onto our retinas into a three-dimensional world. With a little effort (it helps to close one eye and cup your hand around your other eye to make a frame), you can almost see the world around you as a flat picture, admittedly a very well painted one. It's not quite as unsettling as seeing your loved ones as bags of skin, but it is pretty weird and very different from your ordinary experience. But that flat picture is what the image that reaches your eye actually is like.

The great British philosopher Bishop Berkeley argued that we had to learn that space was three-dimensional by coordinating our visual experience and our tactile experience of moving through the world. Berkeley thought that touch was the only sense that gave us direct information about distance and solidity; somehow that information had to be associated with the two-dimensional information we got from vision. Babies demonstrate that Berkeley was wrong.

For one thing, even tiny babies who can't yet walk or crawl act in ways that indicate they understand distance. If you show babies a "looming" ball—a ball that looks as if it's rapidly approaching them—the babies will shrink back and even put their hands protectively in front of them. In much the same way, if you show babies a seductively interesting toy within arm's reach, they'll extend their arms clumsily toward it, even though they're far too little to grab it successfully. When they're a bit older, they'll reach toward a toy that is within reach, but not toward a toy that's out of reach.

Even very young babies have what's called size constancy. Suppose we show you a ball and then show you the same ball twice as far away. The new image on your retina will be only half as large, but you'll have no trouble identifying it as the same ball. On the other hand, if we now show you a ball that's twice as far away and also twice as big, you'll think it's a new ball, even though this time the image on your retina is the same size it was at first. It's as if you implicitly calculate that objects that are farther away look smaller.

Young babies seem to do this as well. Remember that babies perk up and look longer when they see something new and stop looking if it's the same old thing. Suppose you show them the first sequence of events: the close ball followed by the faraway ball. Even though the image on their retinas has changed, they show no particular interest; they act as if the faraway ball is more of the same. However, they do perk up and pay attention when they see the big ball from far away, despite the fact that this time the size of the image on their retinas did not change. Babies, like us, seem able to go beyond the image on their retinas and perceive something about the real ball out there.

Another great English philosopher, John Locke, posed another classical epistemological problem. What would happen if you miraculously restored the sight of someone who had been blind from birth? Would that person recognize all the objects he had known so intimately through touch, or would he have to painstakingly learn that the smooth, hard, curved

surface looked like a porcelain teacup, or that the familiar, soft, yielding swells and silky hairs translated into a visual wife? Locke thought that the blind man would have to learn to make connections between the two types of experience.

Babies are a more common miracle than suddenly cured blind men, and it turns out you can ask them Locke's question, too. They think Locke, like Berkeley, got it wrong. Andy gave one-month-old babies one of two pacifiers to suck on, either a bumpy one or a smooth one. The babies never saw the pacifiers. They just felt them. Then he let the babies look at bumpy and smooth objects, without letting them feel them. The babies looked longer at the object that was the same shape as the one they had just been sucking on. Somehow, they could relate the feel of the pacifier in their mouths with its visual image.

You can ask the same question about the relationship between sound and vision. Even newborns will turn their heads and look toward an interesting noise, suggesting that they already expect to see something in the direction of the noise. You can do more systematic experiments to test this, too. For instance, you can show babies two objects bouncing at different times and play an audiotape of a *boing, boing, boing* sound that is synchronous with only one of them. Babies can tell which visual display matches what they hear; they look longer at the one that bounces in sync with the audiotape.

Even more startling, Andy and Pat showed babies a silent video of a face saying either *ahhh* or *eeee,* and then they played the babies audiotapes of each vowel sound. Five-month-olds could tell which face went with which sound. They looked at the face with the wide-open mouth when they heard the *ahhh* sound and at the face with pulled-back lips when they heard the *eeee* sound. Babies evidently have a primitive ability to lip-read, at least for simple vowels. (This was a provocative experiment—all those wide-open mouths and *ahhhs*. Soon after they finished doing the study together, Andy and Pat got married.)

So in the first few months of life, babies already seem to have solved a number of deep philosophical conundrums. They know how to use edges and patterns of movement to segregate the world into separate objects. They know something about how those objects characteristically move. They know that those objects are part of a three-dimensional space. And they know the relationship between information that comes from their different senses—they can link the feel of a nipple and its pink protuberance, the sound of a voice and the moving lips they see, the ball's exuberant bounce and its accompanying *boing*.

The Tree in the Quad and the Keys in the Washcloth

If babies know all this, what's left to learn? Quite a lot, it turns out. One classic epistemological dilemma is how we know that objects are still there even when we don't see them. As you read this, only a small portion of the room is actually in view. The book itself is probably occupying most of your vision. But you have no doubt that you're in a room full of other things even if you can't see them right at this moment. A pair of philosophical limericks capture the problem:

> There was a young man who said, God
> Must find it exceedingly odd
> To think that this tree
> Continues to be
> When there's no one about in the quad.

One philosopher's answer was:

> Dear Sir, Your astonishment's odd,
> *I* am always about in the quad,
> And that's why the tree
> Continues to be,
> Since observed by, yours faithfully, God.

Modern cognitive scientists can't be satisfied with this answer, but we can still ask the question. How do we come to be so sure that the tree is still there when we aren't looking at it?

We've noted that babies can already make some predictions about where an object will reappear once it vanishes from sight. For instance, if you show babies a rolling ball that disappears at one end of a screen, they predict that it will reappear at the far edge of the screen at the right time. To do this, babies have to be able to think about the object even when they can't actually see it. Another way of testing this capacity is to show them a sort of magician's trick. Suppose you show young babies the object disappearing behind the screen, and the object fails to reappear or shows up in an odd location. Babies in the first six months of life look at this sort of scene for much longer than a scene in which the object reappears where it should.

In other circumstances, though, babies act as if they don't know very much about what has happened to objects that disappear. Suppose you show a six-month-old some wonderfully fascinating thing, a watch or a bunch of keys. He grins and bounces excitedly and starts to reach for it. Now cover the keys with a washcloth. The baby stops dead in his tracks. The excited glee is replaced by a sort of blank puzzlement. Pull off the washcloth and the glee returns.

Piaget tried this first, and he articulated the puzzle: If the baby wants the keys so much, why doesn't he just pull off the washcloth and find them? Maybe it's because he just isn't well coordinated enough. But you can test that by covering the keys with a transparent cover. The baby has no trouble whisking off the cover then. Maybe the baby doesn't remember that the keys are there. But you can show that babies this age remember other events for days or weeks. Instead, it seems the baby genuinely doesn't think that the keys are still there under the washcloth. For him the keys' reappearance from under the washcloth is like the magician's rabbit in the hat for us, a mystifying act of legerdemain.

In fact, babies only gradually learn about hidden objects. By the time they're around nine months old, they can easily find the keys under the cloth, but there are other, more complicated hiding games they still will not understand. Suppose you take a fifteen-month-old and you show her the following sequence of events. You put the keys in your hand and carefully close your hand around them. Then you put your hand under a cloth and leave the keys there. Finally, you take your hand out and show her that your hand is now empty. To us, the conclusion seems obvious—the keys must be under the cloth. Surprisingly, though, the same baby who can confidently find the keys when you simply cover them with a washcloth is, once again, a picture of stupefaction and puzzlement. Babies don't exactly have jaws, more just extended cheeks, but if they did, this baby's jaw would drop. She searches your empty hand, turning it over and over, as if those darned keys must be there somewhere. She looks on the floor. She shrugs, makes an empty-handed gesture, and even says "Where?" or "All gone." She has no idea where the keys could be if they are not in your hand, where she saw them disappear.

It isn't as simple as saying that for the younger baby "out of sight is out of mind." Even the youngest babies can keep some aspects of objects in mind when they're out of sight. But

it does seem that the young baby's conception of what happens during disappearances is very different from our grown-up conception. And that means the baby lives in a universe that is profoundly different from our own. For us, it seems absolutely obvious that the keys must be under the cloth no matter how they're put there—where else could they be? But this is not only not obvious to the baby; it's something that has to be painstakingly learned. The baby, at first, lives in a perpetual magic show, where objects often seem to whirl about from one place to another with no rhyme or reason. Figuring out how it's all really done is one of the most important and difficult intellectual challenges of infancy.

Making Things Happen

Yet another great eighteenth-century philosopher, David Hume, posed a classical philosophical puzzle. When we see that one event always follows another event, we're likely to conclude that the first event caused the second. If every time you drink a cappuccino after dinner, you find yourself locked in a 3:00 A.M. crisis of existential dread, you may eventually work out that it is the coffee, and not the fundamental meaninglessness of the cosmos, that is responsible. We draw these sorts of causal conclusions all the time, and they play an absolutely essential role in what we actually do. You may very well switch to drinking green tea if you would prefer to cultivate a Zen-like serenity, or, for that matter, take up late-night espresso if you want to avoid suburban complacency. But Hume pointed out that we have no intrinsic reason for thinking that one event caused the other, just as we have no intrinsic reason for thinking that other people have minds, that space is three-dimensional, or that sounds and sight are linked. We never actually see one event make another happen. All we see is that the occurrence of one event is consistently followed by the occurrence of another. Why do we conclude that one event causes the other?

It turns out that even very young babies make some assumptions about causal connections between events. Three-month-olds already know about one very important type of cause and effect: they know that their own actions can influence events in the world. In fact, in some ways the causal power of our own actions is the primordial type of causation. Perhaps that's why we are all convinced we have free will. It's as if we think of our own decision to act as the most basic kind of cause, that we are ourselves the real prime movers.

You can give even a tiny, helpless baby artificially enhanced causal powers. You simply tie one end of a ribbon to her foot and the other end to a mobile. When the baby kicks, the mobile moves. Even very young babies rapidly learn to kick the foot with the ribbon to make the mobile turn. If you present them with the same mobile a week later, they will immediately start kicking the appropriate foot. They won't kick if you show them a new mobile. So babies make some assumptions about how their actions will influence the world. Just as important, those assumptions allow them to learn genuinely new things about how the world works.

Some of the very young babies' assumptions about causality, however, seem pretty strange. Suppose you disconnect the ribbon from the mobile, right in front of the babies' eyes. Three-month-olds will go right on kicking, as if they expect their actions will do the trick all by themselves. Moreover, even when the babies are connected by the ribbon, they not only kick but also smile and coo at the mobile, as if they think winsome charm is just as likely to be effective as crude direct action. The babies seem to understand that doing something can make other things happen, but they don't yet understand that this needs to be done through intermediary physical processes. They don't seem to appreciate, for example, that they must be in direct contact with the object in order to make it move.

Piaget called actions like kicking your foot even when the ribbon is disconnected magical procedures, and they do seem to have a sort of superstitious quality. At the same time, though, you could also argue that the babies' behavior is perfectly rational, given the babies' experience. Very young babies may simply be mixing up two different types of causal processes, the kind that influence things (like kicking) and the kind that influence other people (like smiling and cooing).

As scientists we think that everything is mediated by physical causality of some sort, including our interactions with other people. There are, in fact, light and sound waves that go from one person to another even if we can't see them with the naked eye. But from our everyday point of view, it appears we are able to influence people without any direct physical contact at all. (It's probably that fact that makes telepathy seem plausible to so many people.) After all, just looking at someone across a crowded room can set quite a dramatic chain of events in motion. We influence people psychologically by communicating, talking, gesturing, and making faces—we don't have to touch them. In fact, trying to physically manipulate other people to get them to do what we want is usually quite counterproductive, if not actually illegal. Psychological causality is often our most powerful tool.

Psychological causality is particularly important for babies, not only because they can't push things around as much as we can, but because they have to get other people to satisfy most of their needs. When very young babies first try to influence the external world, they may not differentiate between physical and psychological causality, and this may lead to the apparently magical and irrational quality of many of their actions. They make the mistake of using psychological means to try to influence the physical world. Smiling and cooing can get a reaction from Mom even though you're not physically attached to her. It's as if they think maybe they'll have the same effect on the mobile.

In fact, much of what we think of as magical, irrational thinking in adult life may really reflect the same sort of confusion between physical and psychological causality. Shamans and magicians say special words, wave their hands in particular ways, and take care in choosing particular garments in order to influence events in their world. This may seem odd and irrational, but when you think about it, all of us do this when we're trying to influence other people (well, two out of three of us for the garments). If you can use words to get someone into a white-hot rage or into bed with you, why not try to use words to give someone a disease or make her pregnant? "Magical procedures" of this type, whether in children or in adults, are, in fact, ineffective, but believing in them may not really be irrational—just mistaken. They may be based on a confusion about where psychological causality leaves off and ordinary physical causality begins.

By the time babies are about a year old, there seems to be an important change in their understanding of causes. They seem to have learned something about the differences between psychological and physical causality, and they understand more about how physical causation works. They also know something about how events or objects can influence each other. Younger babies can learn to produce an action that has an effect in the world. For example, they can pull a cloth that has a toy on top of it toward them. The peculiarities and limitations of that understanding become clear, though, when you present the babies with a new, slightly different problem by putting the toy to one side of the cloth. The babies

pull on the cloth just as intently and are startled to see that nothing happens, just as they keep kicking even when the ribbon is disconnected. By the end of the first year, though, babies no longer make this mistake; they seem to know right away that the object has to be on top of the cloth. They won't pull the cloth if the object is to one side of it. (In fact, they may give the experimenter a definite "Are you kidding?" look.) This greater understanding of physical causality means their actions look much less magical and are much more effective. This allows them to really plan and scheme and use physical objects as tools.

By the time babies are eighteen months old, they understand quite complicated things about how objects affect each other. Alison and Andy showed babies a toy that was out of reach and then offered them a toy rake. Younger babies would try to reach directly for the object or else would flail around with the rake more or less randomly. But after they reach the age of about eighteen months, babies behaved very differently. They would reach for the out-of-reach object futilely a couple of times, look with a combination of pleading and indignation at their mothers (who were strictly enjoined not to help), stare at the rake, suddenly give a big smile, and then immediately flip the rake over on its side and use it to snag the toy and pull it toward them. You could practically see the lightbulb switching on over their heads. (Of course, these are the same babies who are going through the terrible twos, so their first use of this newfound knowledge about tools is likely to be to pull down all the forbidden objects you put on the high shelves. It does seem perverse of Nature to endow children with new motivations for mischief just when she also endows them with greatly enhanced abilities to get into trouble effectively. It's sort of like letting teenagers get a driver's license.)

There are other reasons to think that, at about a year, babies understand how objects can influence each other. You can show babies a classic case of "billiard ball" causality: a toy car rolling along and bumping into another toy car, which then moves off. Or you can show them almost the same sequence, with just a slight difference—the first car gets close to the second car, and the second car rolls away, but the two cars don't actually touch. Although this is very similar to the first sequence, it violates a basic causal principle. Usually, at least, objects can't act on each other at a distance. Ten-month-olds look longer at the second scene than the first one. This suggests that they recognize just how peculiar it really is. And this, in turn, suggests that they know something about how objects can causally influence each other, quite independent of their own actions.

Children continue to learn about causal relations among objects throughout their toddler years. Before they are three, children are already giving appropriate explanations about what caused what. They say things like "The bench wiggles because these are loose" or "The nail broke because it got bent." By three or four, they can make quite explicit predictions about how simple mechanical systems will work. For instance you can show them a sort of Rube Goldberg apparatus of pipes and tubes through which a ball rolls. Three-year-olds can predict that the ball will have to travel a certain distance before it can bump into another ball and make the machine move.

So, just as babies start out knowing some things about invisible objects but then learn much more, they also start out knowing some things about how events make other events happen but learn much more. Children seem to start out making some assumptions about how they themselves can influence the world, but they gradually have to learn all the many

complex ways in which things in the world can influence one another.

Kinds of Things

Try to just tell someone about the objects around you. You'll find that with very few exceptions (such as people and pets) you do this by saying what kinds of things they are, what kinds of categories they belong to. Here on the table are some sweet peas in a glass, four dollar bills, and a cup of coffee. Just by saying that you've already said that these particular things are like a whole bunch of other flowers, or currency, or beverages. You've said that they belong to a particular category.

But there's a paradox here, one that Plato first articulated. All you ever see are individual objects: this particular sweet pea, this individual dollar bill. There is no "sweet-peaness" or "dollarhood" in the world. So how could it ever be informative to say that this individual thing belongs to this nonexistent, mythical category, when the individual thing itself is all we ever actually experience? Plato himself thought the only answer was that there was another universe, a kind of heaven in which the ideal forms of things, the essential sweet-peaness, the ultimate dollarhood, lived. The individual objects in this universe somehow dimly reflected those forms. (Platonic love, for example, was supposed to be the ideal form to which earthly love aspired. Even Plato's followers were skeptical about that one.) That answer won't do for modern cognitive science: categories can't live in heaven any more than objects can be permanent because God is always looking at them.

Another idea might be that something belongs in the same category as another thing because the two things are similar. But the idea of similarity turns out to be impossible to define with any precision. Each individual sweet pea is, after all, different from every other (this one is lavender and this other is more magenta, this stalk has two blooms while the other has three), and each sweet pea is like each individual dollar in some ways (they both are papery and partly green and curl up at the edges and are viewed with greed by those who feel they can never have enough of them).

In fact, the more you think about categories, the more peculiar and complicated they seem. Scientists are always telling us that things we once thought were in one category are really in another. Whales aren't fish. Pandas keep switching back and forth from the bear to the raccoon category (they seem to be back to being bears now, to the relief of all of us gardeners who hate the thought of finding any type of raccoon cute). We're willing to take the scientists' word for it even if we might not be able to say what it is about a panda that makes it a bear (or not). For most of us, it seems that we think there is some deep but vague underlying nature of an object, some essence that makes it belong to a certain category.

How do we learn all this? Like disappearance and causality, categorization seems to be a particularly important problem for babies in the first three years. Even very young infants already can discriminate between different objects and make generalizations about them in some ways. We saw that babies will get bored if they are shown a succession of similar things and perk up if they are shown something different. That, all by itself, means the babies are already categorizing.

In other respects, though, babies don't seem to understand categories in the same way that we do. We noted before that very young babies will track the trajectory of a moving object and that they pay attention to the principle of common fate. Initially, in fact, they seem to use this principle as their main way of identifying objects. We described how babies predict that objects will stay on the same trajectory and move at the

same rate of speed. If a toy car moves behind a screen and emerges at the wrong speed or on the wrong path, babies look back toward the screen, as if they think this is a new car and the original must be there somewhere. They assume that an object that traces a particular path of movement is the same object.

However, there is some surprising evidence that young babies are actually not particularly interested if a blue toy car goes in one edge of the screen and a yellow toy duck emerges at the far edge on the same trajectory! A grown-up would assume the duck that came out was brand-new and the other toy was still there behind the screen. But young babies seem content to think the toy somehow magically became a new kind of thing behind the screen. The particular kind of category-crossing magic trick in which the scarf turns into a dove wouldn't be surprising to them. Although young babies can discriminate between yellow and blue, and between the duck shape and car shape, they don't seem to rely on these features to determine which object this is. By the time babies are a year old, however, it is easy to show that across a wide range of situations they are surprised when the car turns into a duck, which suggests they have developed a new view of categorization.

Babies do other things that suggest they have a new view of categories. Alison and Andy gave babies a mixed-up bunch of objects: four different toy horses and four different pencils. Alison would put her hands palm up on the table and watch what the babies did with the objects. Nine- and ten-month-olds picked up the horses and pencils, played with them, and often put them in her hands, but they did so pretty much at random. But twelve-month-olds would sometimes pick all the objects of one group, all the horses or all the pencils, and put them in a hand or in a single pile on the table. By the time they were eighteen months old, babies would quite systematically and tidily sort the objects into two separate groups, carefully placing a horse in one hand and then a pencil in the other. In one experiment a particularly fastidious and precise little girl (there actually are fastidious eighteen-month-olds) noticed that one of the pencils had lost its point. She looked carefully at both hands and then reached for her mother's hand to make a separate spot for this peculiar and defective object.

By the time they are two or three years old, children already seem to have a deeper conception of what it means for an object to belong to a category. They can go beyond the superficial appearance of an object and comprehend something about its essential nature. And they begin to understand that knowing an object's category lets you predict specific new things about the object. For instance, you can tell three-year-olds some new fact about a particular object, you can point to a rhinoceros and say, "This rhinoceros has warm blood." If you then tell them that another animal is a rhinoceros, they will say that it has warm blood, too. But they won't extend their new discovery to a triceratops, which looks like a rhinoceros, if you describe it as a dinosaur.

In a similar study, Alison invented a machine that lit up when you put certain blocks on it but not when you put other apparently identical blocks on it. Then she showed two-year-olds the way the objects influenced the machine. Finally, she picked up one of the blocks that had made the machine go off and said, "This is a blicket. Can you show me the other blicket?" The two-year-olds picked the other block that had made the machine go off, not the blocks that just looked like the "blicket."

These two studies together suggest that even two-year-olds are in some ways like the scientists who reclassify pandas and

whales. They look beyond the superficial features of the object to try to determine the deeper laws that govern what the object will do.

By the time children are three or four, we have quite convincing evidence that they look, literally, under the surface of things. Suppose you show three- and four-year-olds natural-looking objects, like plants or rocks. Then you do a kind of cross section, slicing the objects open to show what they look like inside. The children will say that the objects with the same insides are the same kind of thing, even if they look quite different on the surface. Objects with similar outside surfaces but different insides are not the same kind of thing.

These young children, quite surprisingly, even seem to know some things about how animals and plants differ from rocks. They think that living things are more likely to have highly structured insides, while the insides of rocks are more likely to be uniform. They know that baby animals are the same kind of thing as the animals' parents, even though they look very different. They know that tiger cubs, however kittenish they appear, are the same sort of animal as their large and ferocious mothers and quite different from apparently more similar cute and cuddly puppies. They even seem to have a primitive understanding of heredity—they know that a pig who was raised by cows would grow up with a curly tail, like his biological pig parents, and not a straight one, like his adoptive cow parents. These children have barely reached preschool, yet they already seem to have the rudiments of an understanding of biology.

How Do They Do It?

The question, as always, is how do they do it? The answer, as in the last chapter, is that they are born knowing a great deal, they learn more, and we are designed to teach them.

World-Blindness

In the last chapter we talked about how children with autism seem to be blind to other people's minds. They have great difficulty understanding people and often also have difficulty learning how to use language. Another, even rarer genetically determined disorder, Williams syndrome, presents what is in some ways the opposite picture. Children with Williams syndrome are preternaturally sensitive to other people. They are charming and affectionate, even to strangers, and though their language is initially delayed, they develop surprisingly complicated and fluent speech with quite elaborate syntax. But they are terribly bad at comprehending the physical world. They don't even understand hidden objects, use tools, or sort objects into groups until they are three or four years old, although normally developing children work all this out in infancy. As adults, they often can't make their way across a street safely or figure out how to get home. And while they talk about biological and physical phenomena at great length and in some detail, there is a striking superficiality to what they say. A Williams syndrome teenager who can rattle off the names of one hundred different kinds of animals, including pterodactyls and jaguars, nevertheless may fail to understand simple biological processes like growth, inheritance, and death. (Alison's eight-year-old son, who had just painfully worked out the concept of death and was trying to deal with the psychological consequences, heard a visitor talk about Williams syndrome and wistfully remarked that there might be advantages to having only a limited understanding of biology.)

People who study Williams syndrome children often compare their elaborate, fluent speech to cocktail-party talk, the kind of language we use to establish a social connection with other people rather than to achieve a deeper understanding of the world. Whereas children with autism are clueless and frightened in a social setting, children with Williams syndrome are confident but superficial.

We know even less about Williams syndrome than about autism, and there are still many puzzles about just what capacities are spared or damaged in these children. But Williams syndrome suggests there is some genetic basis for our ability to go beyond the surface of things and come to a deeper understanding of the physical world. This ability may be at least partly separate from our ability to speak and to get along in the social world.

The Explanatory Drive

We saw in the last chapter that babies, like scientists, pay attention to counterevidence when they are trying to construct theories of how people work. But there are other similarities between babies and scientists that become particularly vivid when we consider how babies learn about things. In science, and even in ordinary life, we look beyond the surfaces of the world and try to infer its deeper patterns. We look for the underlying, hidden causes of events. We try to figure out the nature of things.

It's not just that we human beings *can* do this; we *need* to do it. We seem to have a kind of explanatory drive, like our drive for food or sex. When we're presented with a puzzle, a mystery, a hint of a pattern, something that doesn't quite make sense, we work until we find a solution. In fact, we intentionally set ourselves such problems, even the quite trivial ones that divert us from the horror of airplane travel, like crossword puzzles, video games, or detective stories. As scientists, we may stay up all night in the grip of a problem, even forgetting to eat, and it seems rather unlikely that our paltry salaries are the sole motivation.

We see this same drive to understand the world in its purest form in children. Human children in the first three years of life are consumed by a desire to explore and experiment with objects. In fact, we take this for granted as a sometimes exhausting fact of parenting. We childproof our houses and say, with a sigh, that the baby is "always getting into things." Clever mothers from time immemorial have discovered that the best way to get a chance to actually cook dinner is to give the baby free rein in the pots-and-pans cupboard.

From the time human babies can move around, they are torn between the safety of a grown-up embrace and the irresistible drive to explore. A toddler in the park seems attached to his mother by an invisible bungee cord: he ventures out to explore and then, in a sudden panic, races back to the safe haven, only to venture forth again some few minutes later. Indeed, we probably never quite escape the bungee cord even as grown-ups; it seems part of the human condition to be perpetually torn between home and away, the desire for comfort and the dread of boredom, the peace of domesticity and the thrill of adventure.

If you think about it from an evolutionary point of view, children's exploratory behavior is rather peculiar. Not only do babies expend enormous energy in exploring the world, their explorations often endanger their very reproductive success (they do have to make it to puberty in one piece, after all). The explanation seems to be that for our species the dangers of exploration are offset by the benefits of learning. The rapid and profound changes in children's understanding of the world seem related to the ways they explore and experiment. Children actively do things to promote their understanding of disappearances, causes, and categories.

Fortunately, these aspects of the physical world are so ubiquitous that babies can do their experiments quite easily and for the most part safely. The crib, the house, the backyard are

excellent laboratories. For instance, we can see babies become interested in, almost obsessed with, hiding-and-finding games when they are about a year old. There is the timeless appeal of peekaboo, that irresistibly funny surefire daddy routine that never seems to go stale. Babies also spontaneously undertake solo investigations of the mysterious Case of the Disappearing Object. Alison once recorded a baby putting the same ring under a cloth and finding it seventeen times in succession, saying "All gone" each time. In our experiments, babies often begin by protesting when we take the toy to hide it. But after one or two turns, they often start hiding the toy themselves or give the cloth and toy to us with instructions to hide it again. Eighteen-month-olds, who are not renowned for their long attention span, will play this game for half an hour.

Babies are similarly fascinated by causal relations between objects. Babies in the ribbon-and-mobile experiments actually get bored after a while with the spectacle of the mobile moving, but they don't get bored with the sensation of their own power. After a while, they only occasionally glance at the mobile, but they keep on kicking. The ubiquitous baby "busy box" is another toy that depends on babies' fascination with what happens in the world. By the time babies are one or two years old, they will quite systematically explore the way one object can influence another object. The babies in our rake experiments forget all about getting the toy after a trial or two. They often deliberately put the toy back far out of reach and experiment with using the rake to draw it toward them. The toy itself isn't nearly as interesting as the fact that the rake moves it closer.

Similarly, babies persistently explore the properties of objects. Six- or seven-month-olds will systematically examine a new object with every sense they have at their command (including taste, of course). By a year or so, they will systematically vary the actions they perform on an object: they might tap a new toy car gently against the floor, listening to the sound it makes, then try banging it loudly, and then try banging it against the soft sofa. By eighteen months, if you show them an object with some unexpected property, like a can that makes a mooing noise, they will systematically test to see if it will do other unexpected things. And, as we saw, children this age will quite spontaneously sort different kinds of objects into different piles.

We think this kind of playing around with the world actually contributes to babies' ability to solve the big, deep problems of disappearance, causality, and categorization. Before science became a separate, socially defined field, it was called experimental philosophy. The grown-ups who chat about real-estate prices while the baby is, thank heaven, busy playing with her toys, don't realize they are witnessing positive miracles of experimental philosophy.

Grown-ups as Teachers

The grown-ups, though, like biblical shepherds, may be contributing to the miracle even if they don't quite recognize it. When babies are about a year old, grown-ups start talking to them in a distinctive way. They start giving a sort of sportscaster's play-by-play of everything the baby does. "There, you picked up the cup, oh, now you're putting it down again. Whoops, there it goes. Oh, dear." And so on. It may not seem quite as silly as the "Aren't you a pretty bunny" talk, but if you think about it, it still seems pretty silly. It's not, after all, as if you're telling the baby something he doesn't already know.

The silliness, however, may be only on the surface. We have reason to think this kind of early language helps organize the world for babies. In the last chapter, we described a sort of

natural experiment to test the effects of other people on children's understanding of the mind: we compared children with older siblings to those without them. We can do a similar sort of natural experiment by comparing children who hear parents describe the world in different ways.

It turns out that, just by the nature of the grammar of their languages, Korean- and English-speaking parents talk about the world quite differently. Korean (like Latin or French) uses an elaborate system of different verb endings to convey different meanings. As a consequence, Korean-speaking parents can, and often do, omit nouns altogether when they talk to their children. A Korean mother can say the equivalent of "moving in" when she sees the baby put a block in a cup, without saying anything about who or what is doing the moving or what it's moving into. In English, on the other hand, we must include at least one noun in almost every intelligible sentence. Moreover, English-speaking parents spend a lot of time pointing to objects and giving them names: "There's a dog! Look at the bird! Car! Airplane!"

Alison and a Korean colleague, Soonja Choi, looked at the kinds of things English-speaking mothers and Korean-speaking mothers said to their eighteen-month-old babies and found that this was indeed true: English-speaking mothers used more nouns and fewer verbs than Korean-speaking mothers. English-speaking mothers tended to name objects a lot, while Korean-speaking mothers were more likely to talk about actions.

When Alison and Soonja looked at what the eighteen-month-old children understood about the world, they found there were consistent differences between the Korean and English speakers. Like their parents, the Korean children used more verbs than the English-speaking kids, while the English-speaking kids used more nouns. But in addition, the Korean-speaking children learned how to solve problems like using the rake to get the out-of-reach toy well before the English-speaking children. English speakers, though, started categorizing objects earlier than the Korean speakers. For instance, they were more likely to put the toy horses and the pencils into two separate piles. It was as if the Korean-speaking children paid more attention to how their actions influenced the world, while the English-speaking children paid more attention to how objects fit into different categories. The likeliest explanation for this is that the children were influenced by what the grown-ups around them said, which in turn was shaped by the grown-ups' language.

This may sound a bit more radical than it actually is. Many years ago the linguist Benjamin Lee Whorf suggested that the grammar of our language influenced the way we thought. The Whorfian hypothesis, as it is called, fell into scientific disrepute quite quickly. (It kept a lasting appeal in the popular imagination, however. In the 1980s a high American official said the Russians would never really negotiate a peace because they didn't even have a word for détente in their language. The fact that *détente* is a French word didn't seem to occur to him.) For one thing the idea is logically incoherent. How do we know that another language even has a concept that ours doesn't have, unless we can somehow express that concept in our language, too?

What we found (and a number of other people have recently found) is rather different from Whorf's idea. Both the Korean- and the English-speaking children understood actions and object categories by the time they were two. Still, the difference in emphasis in the two languages seems to have made one problem easier to solve for one group, while the other problem was easier for the other group. It's like the difference between children who grow up in a house where they talk

about music all the time (like Andy and Pat's house) and children who grow up in a house where they talk about politics (Alison's husband is a public-radio journalist). The children in each home may have the capacity to understand music or politics, but they naturally know more about the topic they hear about a lot.

The interesting thing is that even quite tiny children, just beginning to say their first words, already seem to be influenced by what the people around them are talking about. And, of course, the parents are exercising this influence completely unconsciously, just by talking to their babies. In fact, it would probably be impossible for an English-speaking parent to consciously start to talk like a Korean speaker or vice versa. Nature wisely doesn't rely just on the conscious resolutions and good intentions of parents. The most potent influences on babies—the nouns they hear in a sentence or the unwitting lessons of their siblings—are influences that no one consciously wields.

Babies seem to learn about the external world in much the way they learn about other minds. They start out with some crucial assumptions, assumptions that seem to be built in. But, just as important, they are endowed with powerful abilities to learn, and even more powerful motivations. They are as driven to explore the alien physical world around them as they are to make first contact with the local species. A one-year-old set loose to crawl around a new living room will have the unmistakable gleam in her eye of one who boldly goes where no one has gone before. Fortunately, the life-forms they encounter are benign and quite genuinely, if unconsciously, dedicated to bringing the fruits of their wisdom and civilization to these intrepid small voyagers.