

THE KNOWLEDGE
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illusion

Why We Never Think Alone

STEVEN SLOMAN
AND
PHILIP FERNBACH

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2017

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Introduction: Ignorance and the Community of Knowledge

Three soldiers sat in a bunker surrounded by three-foot-thick concrete walls, chatting about home. The conversation slowed and then stopped. The cement walls shook and the ground wobbled like Jell-O. Thirty thousand feet above them in a B-36, crew members coughed and sputtered as heat and smoke filled their cabin and dozens of lights and alarms blared. Meanwhile, eighty miles due east, the crew of a Japanese fishing trawler, the not-so-lucky *Lucky Dragon Number Five* (*Daigo Fukuryū Maru*), stood on deck, staring with terror and wonder at the horizon.

The date was March 1, 1954, and they were all in a remote part of the Pacific Ocean witnessing the largest explosion in the history of humankind: the detonation of a thermonuclear fusion bomb nicknamed “Shrimp,” code-named Castle Bravo. But something was terribly wrong. The military men, sitting in a bunker on Bikini Atoll, close to ground zero, had witnessed nuclear detonations before and had expected a shock wave to pass by about 45 seconds after the blast. Instead the earth shook. That was not supposed to happen. The crew of the B-36, flying a scientific mission to sample the fallout

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cloud and take radiological measurements, were supposed to be at a safe altitude, yet their plane blistered in the heat.

All these people were lucky compared to the crew of the *Daigo Fukuryū Maru*. Two hours after the blast, a cloud of fallout blew over the boat and rained radioactive debris on the fishermen for several hours. Almost immediately the crew exhibited symptoms of acute radiation sickness—bleeding gums, nausea, burns—and one of them died a few days later in a Tokyo hospital. Before the blast, the U.S. Navy had escorted several fishing vessels beyond the danger zone. But the *Daigo Fukuryū Maru* was already outside the area the Navy considered dangerous. Most distressing of all, a few hours later, the fallout cloud passed over the inhabited atolls Rongelap and Utirik, irradiating the native populations. Those people have never been the same. They were evacuated three days later after suffering acute radiation sickness and temporarily moved to another island. They were returned to the atoll three years later but were evacuated again after rates of cancer spiked. The children got the worst of it. They are still waiting to go home.

The explanation for all this horror is that the blast force was much larger than expected. The power of nuclear weapons is measured in terms of TNT equivalents. The “Little Boy” fission bomb dropped on Hiroshima in 1945 exploded with a force of sixteen kilotons of TNT, enough to completely obliterate much of the city and kill about 100,000 people. The scientists behind Shrimp expected it to have a blast force of about six megatons, around three hundred times as powerful as Little Boy. But Shrimp exploded with a force of fifteen megatons, nearly a thousand times as powerful as Little Boy. The scientists knew the explosion would be big, but they were off by a factor of about 3.

The error was due to a misunderstanding of the properties of one of the major components of the bomb, an element called lithium-7.

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Before Castle Bravo, lithium-7 was believed to be relatively inert. In fact, lithium-7 reacts strongly when bombarded with neutrons, often decaying into an unstable isotope of hydrogen, which fuses with other hydrogen atoms, giving off more neutrons and releasing a great deal of energy. Compounding the error, the teams in charge of evaluating the wind patterns failed to predict the easterly direction of winds at higher altitudes that pushed the fallout cloud over the inhabited atolls.

This story illustrates a fundamental paradox of humankind. The human mind is both genius and pathetic, brilliant and idiotic. People are capable of the most remarkable feats, achievements that defy the gods. We went from discovering the atomic nucleus in 1911 to megaton nuclear weapons in just over forty years. We have mastered fire, created democratic institutions, stood on the moon, and developed genetically modified tomatoes. And yet we are equally capable of the most remarkable demonstrations of hubris and foolhardiness. Each of us is error-prone, sometimes irrational, and often ignorant. It is incredible that humans are capable of building thermonuclear bombs. It is equally incredible that humans do in fact build thermonuclear bombs (and blow them up even when they don't fully understand how they work). It is incredible that we have developed governance systems and economies that provide the comforts of modern life even though most of us have only a vague sense of how those systems work. And yet human society works amazingly well, at least when we're not irradiating native populations.

How is it that people can simultaneously bowl us over with their ingenuity and disappoint us with their ignorance? How have we mastered so much despite how limited our understanding often is? These are the questions we will try to answer in this book.

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Thinking as Collective Action

The field of cognitive science emerged in the 1950s in a noble effort to understand the workings of the human mind, the most extraordinary phenomenon in the known universe. How is thinking possible? What goes on inside the head that allows sentient beings to do math, understand their mortality, act virtuously and (sometimes) selflessly, and even do simple things, like eat with a knife and fork? No machine, and probably no other animal, is capable of these acts.

We have spent our careers studying the mind. Steven is a professor of cognitive science who has been researching this topic for over twenty-five years. Phil has a doctorate in cognitive science and is a professor of marketing whose work focuses on trying to understand how people make decisions. We have seen directly that the history of cognitive science has not been a steady march toward a conception of how the human mind is capable of amazing feats. Rather, a good chunk of what cognitive science has taught us over the years is what individual humans *can't* do—what our limitations are.

The darker side of cognitive science is a series of revelations that human capacity is not all that it seems, that most people are highly constrained in how they work and what they can achieve. There are severe limits on how much information an individual can process (that's why we can forget someone's name seconds after being introduced). People often lack skills that seem basic, like evaluating how risky an action is, and it's not clear they can ever be learned (hence many of us—one of the authors included—are absurdly scared of flying, one of the safest modes of transportation available). Perhaps most important, individual knowledge is remarkably shallow, only scratching the surface of the true complexity of the world, and yet we often don't realize how little we understand. The result is that we

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are often overconfident, sure we are right about things we know little about.

Our story will take you on a journey through the fields of psychology, computer science, robotics, evolutionary theory, political science, and education, all with the goal of illuminating how the mind works and what it is for—and why the answers to these questions explain how human thinking can be so shallow and so powerful at the same time.

The human mind is not like a desktop computer, designed to hold reams of information. The mind is a flexible problem solver that evolved to extract only the most useful information to guide decisions in new situations. As a consequence, individuals store very little detailed information about the world in their heads. In that sense, people are like bees and society a beehive: Our intelligence resides not in individual brains but in the collective mind. To function, individuals rely not only on knowledge stored within our skulls but also on knowledge stored elsewhere: in our bodies, in the environment, and especially in other people. When you put it all together, human thought is incredibly impressive. But it is a product of a community, not of any individual alone.

The Castle Bravo nuclear testing program is an extreme example of the hive mind. It was a complex undertaking requiring the collaboration of about ten thousand people who worked directly on the project and countless others who were indirectly involved but absolutely necessary, like politicians who raised funds and contractors who built barracks and laboratories. There were hundreds of scientists responsible for different components of the bomb, dozens of people responsible for understanding the weather, and medical teams responsible for studying the ill effects of handling radioactive elements. There were counterintelligence teams making sure that communications were encrypted and no Russian submarines were close

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enough to Bikini Atoll to compromise secrecy. There were cooks to feed all these people, janitors to clean up after them, and plumbers to keep the toilets working. No one individual had one one-thousandth of the knowledge necessary to fully understand it all. Our ability to collaborate, to jointly pursue such a complex undertaking by putting our minds together, made possible the seemingly impossible.

That's the sunny side of the story. In the shadows of Castle Bravo are the nuclear arms race and the cold war. What we will focus on is the hubris that it exemplifies: the willingness to blow up a fifteen-megaton bomb that was not adequately understood.

Ignorance and Illusion

Most things are complicated, even things that seem simple. You would not be shocked to learn that modern cars or computers or air traffic control systems are complicated. But what about toilets?

There are luxuries, there are useful things, and then there are things that are utterly essential, those things you just cannot do without. Flush toilets surely belong in the latter category. When you need a toilet, you really need it. Just about every house in the developed world has at least one, restaurants must have them by law, and—thank goodness—they are generally available in gas stations and Starbucks. They are wonders of functionality and marvels of simplicity. Everyone understands how a toilet works. Certainly most people feel like they do. Don't you?

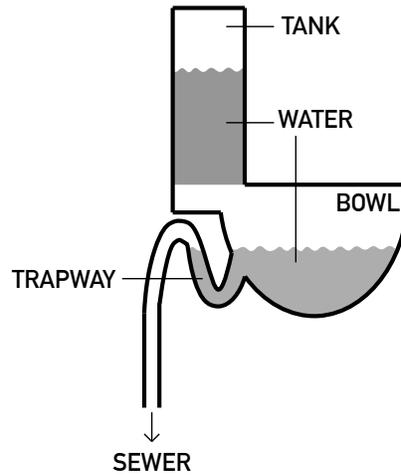
Take a minute and try to explain what happens when you flush a toilet. Do you even know the general principle that governs its operation? It turns out that most people don't.

The toilet is actually a simple device whose basic design has been around for a few hundred years. (Despite popular myth, Thomas Crapper did not invent the flush toilet. He just improved the design

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and made a lot of money selling them.) The most popular flush toilet in North America is the siphoning toilet. Its most important components are a tank, a bowl, and a trapway. The trapway is usually S- or U-shaped and curves up higher than the outlet of the bowl before descending into a drainpipe that eventually feeds the sewer. The tank is initially full of water:



When the toilet is flushed, the water flows from the tank quickly into the bowl, raising the water level above the highest curve of the trapway. This purges the trapway of air, filling it with water. As soon as the trapway fills, the magic occurs: A siphon effect is created that sucks the water out of the bowl and sends it through the trapway down the drain. It is the same siphon action that you can use to steal gasoline out of a car by placing one end in the tank and sucking on the other end. The siphon action stops when the water level in the bowl is lower than the first bend of the trapway, allowing air to interrupt the process. Once the water in the bowl has been siphoned away, water is pumped back up into the tank to wait for next time. It is quite an elegant mechanical process, requiring only minimal effort by the user. Is it simple? Well, it is simple enough to describe in a paragraph but not so simple that everyone understands it. In fact, you are now one of the few people who do.

To fully understand toilets requires more than a short description of its mechanism. It requires knowledge of ceramics, metal, and plastic to know how the toilet is made; of chemistry to understand

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how the seal works so the toilet doesn't leak onto the bathroom floor; of the human body to understand the size and shape of the toilet. One might argue that a complete understanding of toilets requires a knowledge of economics to appreciate how they are priced and which components are chosen to make them. The quality of those components depends on consumers' demand and willingness to pay. Understanding psychology is important for understanding why consumers prefer their toilets to be one color and not another.

Nobody could be a master of every facet of even a single thing. Even the simplest objects require complex webs of knowledge to manufacture and use. We haven't even mentioned really complicated things that arise in nature such as bacteria, trees, hurricanes, love, and the process of reproduction. How do those work? Most people can't tell you how a coffeemaker works, how glue holds paper together, or how the focus works on a camera, let alone something as complex as love.

Our point is not that people are ignorant. It's that people are more ignorant than they think they are. We all suffer, to a greater or lesser extent, from an illusion of understanding, an illusion that we understand how things work when in fact our understanding is meager.

Some of you might be thinking, "Well, I don't know much about how stuff works, but I don't live in an illusion. I'm not a scientist and I'm not an engineer. It's not important for me to know those things. I know what I have to know to get along and make good decisions." What domain do you know a lot about? History? Politics? Economic policy? Do you really understand things within your area of specialty in great detail?

The Japanese attacked Pearl Harbor on December 7, 1941. The world was at war, Japan was an ally of Germany, and while the United States was not yet a participant, it was clear whose side it was on—the heroic Allies and not the evil Axis. These facts surrounding the attack are familiar and give us a sense that we understand the

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event. But how well do you really understand why Japan attacked, and specifically why they attacked a naval base on the Hawaiian Islands? Can you explain what actually happened and why?

It turns out that the United States and Japan were on the verge of war at the time of the attack. Japan was on the march, having invaded Manchuria in 1931, massacred the population of Nanking, China, in 1937, and invaded French Indochina in 1940. The reason that a naval base even existed in Hawaii was to stop perceived Japanese aggression. U.S. president Franklin D. Roosevelt moved the Pacific Fleet to Hawaii from its base in San Diego in 1941. So an attack by Japan was not a huge surprise. According to a Gallup poll, 52 percent of Americans expected war with Japan a week before the attack occurred.

So the attack on Pearl Harbor was more a consequence of a long-standing struggle in Southeast Asia than a result of the European war. It might well have happened even if Hitler had never invented the blitzkrieg and invaded Poland in 1939. The attack on Pearl Harbor certainly influenced the course of events in Europe during World War II, but it was not caused directly by them.

History is full of events like this, events that seem familiar, that elicit a sense of mild to deep understanding, but whose true historical context is different than we imagine. The complex details get lost in the mist of time while myths emerge that simplify and make stories digestible, in part to service one interest group or another.

Of course, if you have carefully studied the attack on Pearl Harbor, then we're wrong; you do have a lot to say. But such cases are the exception. They have to be because nobody has time to study very many events. We wager that, except for a few areas that you've developed expertise in, your level of knowledge about the causal mechanisms that control not only devices, but the mechanisms that determine how events begin, how they unfold, and how one event leads to another is relatively shallow. But before you stopped to

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consider what you actually know, you may not have appreciated how shallow it is.

We can't possibly understand everything, and the sane among us don't even try. We rely on abstract knowledge, vague and unanalyzed. We've all seen the exceptions—people who cherish detail and love to talk about it at great length, sometimes in fascinating ways. And we all have domains in which we are experts, in which we know a lot in exquisite detail. But on most subjects, we connect only abstract bits of information, and what we know is little more than a feeling of understanding we can't really unpack. In fact, most knowledge is little more than a bunch of associations, high-level links between objects or people that aren't broken down into detailed stories.

So why don't we realize the depth of our ignorance? Why do we think we understand things deeply, that we have systematic webs of knowledge that make sense of everything, when the reality is so different? Why do we live in an illusion of understanding?



What Thinking Is For

To get a better sense of why this illusion is central to how we think, it helps to understand why we think. Thought could have evolved to serve several functions. The function of thought could be to represent the world—to construct a model in our heads that corresponds in critical ways to the way the world is. Or thought could be there to make language possible so we can communicate with others. Or thought could be for problem-solving or decision-making. Or maybe it evolved for a specific purpose such as building tools or showing off to potential mates. All of these ideas may have something to them, but thought surely evolved to serve a larger purpose, a purpose common to all these proposals: Thought is for action. Thinking evolved as an extension of the ability to act effectively; it evolved to make us

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better at doing what's necessary to achieve our goals. Thought allows us to select from among a set of possible actions by predicting the effects of each action and by imagining how the world would be if we had taken different actions in the past.

One reason to believe that this is why we think is that action came before thought. Even the earliest organisms were capable of action. Single-celled organisms that arose early in the evolutionary cycle ate and moved and reproduced. They did things; they acted on the world and changed it. Evolution selected those organisms whose actions best supported their survival. And the organisms whose actions were most effective were the ones best tuned to the changing conditions of a complex world. If you're an organism that sucks the blood of passing fauna, it's great to be able to latch onto whatever brushes against you. But it's even better to be able to tell whether the object brushing against you is a delicious rodent or bird, not a bloodless leaf blowing in the wind.

The best tools for identifying the appropriate action in a given circumstance are mental faculties that can process information. Visual systems must be able to do a fair amount of sophisticated processing to distinguish a rat from a leaf. Other mental processes are also critical for selecting the appropriate action. Memory can help indicate which actions have been most effective under similar conditions in the past, and reasoning can help predict what will happen under new conditions. The ability to think vastly increases the effectiveness of action. In that sense, thought is an extension of action.

Understanding how thought operates is not so simple. How do people engage in thinking for action? What mental faculties do people need to allow them to pursue their goals using memory and reason? We will see that humans specialize in reasoning about how the world works, about *causality*. Predicting the effects of action requires reasoning about how causes produce effects, and figuring out why something happened requires reasoning about which causes are

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likely to have produced an effect. This is what the mind is designed to do. Whether we are thinking about physical objects, social systems, other individuals, our pet dog—whatever—our expertise is in determining how actions and other causes produce effects. We know that kicking a ball will send it flying, but kicking a dog will cause pain. Our thought processes, our language, and our emotions are all designed to engage causal reasoning to help us to act in reasonable ways.

This makes human ignorance all the more surprising. If causality is so critical to selecting the best actions, why do individuals have so little detailed knowledge about how the world works? It's because thought is masterful at extracting only what it needs and filtering out everything else. When you hear a sentence uttered, your speech recognition system goes to work extracting the gist, the underlying meaning of the utterance, and forgetting the specific words. When you encounter a complicated causal system, you similarly extract the gist and forget the details. If you're someone who likes figuring out how things work, you might open up an old appliance on occasion, perhaps a coffee machine. If you do, then you don't memorize the shape, color, and location of each individual part. Instead, you look for the major components and try to figure out how they are connected to one another so that you can answer big questions like how the water gets heated. If you're like most people and you're not interested in investigating the insides of a coffee machine, then you know even less detail about how it works. Your causal understanding is limited to only what you need to know: how to make the thing work (with any luck you've mastered that).

The mind is not built to acquire details about every individual object or situation. We learn from experience so that we can generalize to new objects and situations. The ability to act in a new context requires understanding only the deep regularities in the way the world works, not the superficial details.

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The Community of Knowledge

We would not be such competent thinkers if we had to rely only on the limited knowledge stored in our heads and our facility for causal reasoning. The secret to our success is that we live in a world in which knowledge is all around us. It is in the things we make, in our bodies and workspaces, and in other people. We live in a community of knowledge.

We have access to huge amounts of knowledge that sit in other people's heads: We have our friends and family who each have their little domains of expertise. We have experts that we can contact to, say, fix our dishwasher when it breaks down for the umpteenth time. We have professors and talking heads on television to inform us about events and how things work. We have books, and we have the richest source of information of all time at our fingertips, the Internet.

On top of that, we have things themselves. Sometimes we can fix an appliance or a bicycle by looking at it to see how it works. On occasion, what's broken is obvious when we take a look (if only this were more common!). You might not know how a guitar works, but a couple of minutes playing with one, seeing what happens when the strings resonate and how their pitch changes when their lengths are changed, might be enough to give you at least a basic understanding of its operation. In that sense, knowledge of a guitar can be found in the guitar itself. There is no better way to discover a city than to travel around it. The city itself holds the knowledge about how it is laid out, where the interesting places to go are, and what you can see from various vantage points.

We have access to more knowledge today than ever before. Not only can we learn how things are made or how the universe came to be by watching TV, we can answer almost any factual question by typing a few characters on a keyboard and enlisting a search engine.

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We can frequently find the information we need in Wikipedia or somewhere else on the web. But the ability to access knowledge outside our own heads is not true only of life in the modern world.

There has always been what cognitive scientists like to call a division of cognitive labor. From the beginning of civilization, people have developed distinctive expertise within their group, clan, or society. They have become the local expert on agriculture, medicine, manufacturing, navigating, music, storytelling, cooking, hunting, fighting, or one of many other specialties. One individual may have some expertise in more than one skill, perhaps several, but never all, and never in every aspect of any one thing. No chef can cook all dishes. Though some are mighty impressive, no musician can play every instrument or every type of music. No one has ever been able to do everything.

So we collaborate. That's a major benefit of living in social groups, to make it easy to share our skills and knowledge. It's not surprising that we fail to identify what's in our heads versus what's in others', because we're generally—perhaps always—doing things that involve both. Whenever either of us washes the dishes, we thank heaven that someone knows how to make dish soap and someone else knows how to provide warm water from the faucet. We wouldn't have a clue.

Sharing skills and knowledge is more sophisticated than it sounds. Human beings don't merely make individual contributions to a project, like machines operating in an assembly line. Rather, we are able to work together, aware of others and what they are trying to accomplish. We pay attention together and we share goals. In the language of cognitive science, we share intentionality. This is a form of collaboration that you don't see in other animals. We actually enjoy sharing our mind space with others. In one form, it's called playing.

Our skulls may delimit the frontier of our brains, but they do

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not delimit the frontier of our knowledge. The mind stretches beyond the brain to include the body, the environment, and people other than oneself, so the study of the mind cannot be reduced to the study of the brain. Cognitive science is not the same as neuroscience.

Representing knowledge is hard, but representing it in a way that respects what you don't know is very hard. This is one of the hidden talents of human beings. To participate in a community of knowledge—that is to say, to engage in a world in which only some of the knowledge you have resides in your head—requires that you know what information is available, even when it is not stored in memory. Knowing what's available is no mean feat. The separation between what's inside your head and what's outside of it must be seamless. Our minds have to be designed to treat information that resides in the external environment as continuous with the information that resides in our brains. That we are designed this way is one of evolution's remarkable achievements.

You now have the background you need to understand the origin of the knowledge illusion. The nature of thought is to seamlessly draw on knowledge wherever it can be found, inside and outside of our own heads. We live under the knowledge illusion because we fail to draw an accurate line between what is inside and outside our heads. And we fail because there is no sharp line. So we frequently don't know what we don't know.

Why It Matters

Understanding the mind in this way can offer us improved ways of approaching our most complex problems. Recognizing the limits of our understanding should make us more humble, opening our minds to other people's ideas and ways of thinking. It offers lessons about how to avoid things like financial meltdowns. It can enable us to

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improve our political system and help us assess how much reliance we should have on experts versus how much decision-making power should be given to individual voters.

This book is being written at a time of immense polarization on the American political scene. Liberals and conservatives find each other's views repugnant, and as a result, Democrats and Republicans cannot find common ground or compromise. The U.S. Congress is unable to pass even benign legislation; the Senate is preventing the administration from making important judicial and administrative appointments merely because the appointments are coming from the other side.

One reason for this gridlock is that both politicians and voters don't realize how little they understand. Whenever an issue is important enough for public debate, it is also complicated enough to be difficult to understand. Reading a newspaper article or two just isn't enough. Social issues have complex causes and unpredictable consequences. It takes a lot of expertise to really understand the implications of a position, and even expertise may not be enough. Conflicts between, say, police and minorities cannot be reduced to simple fear or racism or even to both. Along with fear and racism, conflicts arise because of individual experiences and expectations, because of the dynamics of a specific situation, because of misguided training and misunderstandings. Complexity abounds. If everybody understood this, our society would likely be less polarized.

Instead of appreciating complexity, people tend to affiliate with one or another social dogma. Because our knowledge is enmeshed with that of others, the community shapes our beliefs and attitudes. It is so hard to reject an opinion shared by our peers that too often we don't even try to evaluate claims based on their merits. We let our group do our thinking for us. Appreciating the communal nature of knowledge should make us more realistic about what's determining our beliefs and values.

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This would improve how we make decisions. We all make decisions that we're not proud of. These include mistakes like failing to save for retirement, as well as regrets like giving in to temptation when we really should know better. We'll see that we can deploy the community of knowledge to help people overcome their natural limitations in ways that increase the well-being of the community at large.

Appreciating the communal nature of knowledge can reveal biases in how we see the world. People love heroes. We glorify individual strength, talent, and good looks. Our movies and books idolize characters who, like Superman, can save the planet all by themselves. TV dramas present brilliant but understated detectives who both solve the crime and make the climactic final arrest after a flash of insight. Individuals are given credit for major breakthroughs. Marie Curie is treated as if she worked alone to discover radioactivity, Newton as if he discovered the laws of motion in a bubble. All the successes of the Mongols in the twelfth and thirteenth century are attributed to Genghis Khan, and all the evils of Rome during the time of Jesus are often identified with a single person, Pontius Pilate.

The truth is that in the real world, nobody operates in a vacuum. Detectives have teams who attend meetings and think and act as a group. Scientists not only have labs with students who contribute critical ideas, but also have colleagues, friends and nemeses who are doing similar work, thinking similar thoughts, and without whom the scientist would get nowhere. And then there are other scientists who are working on different problems, sometimes in different fields, but nevertheless set the stage through their own findings and ideas. Once we start appreciating that knowledge isn't all in the head, that it's shared within a community, our heroes change. Instead of focusing on the individual, we begin to focus on a larger group.

The knowledge illusion also has important implications for the evolution of society and the future of technology. As technological

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systems become more and more complex, no individual fully understands them. Modern airplanes are a good example. Flying is now a collaborative effort between the pilot and the automated systems in control most of the time. Knowledge about how to operate a plane is distributed across the pilots, the instruments, and the system designers. The knowledge is shared so seamlessly that pilots may not realize the gaps in their understanding. This can make it hard to see catastrophe coming, and we have seen the unfortunate consequences. Understanding ourselves better may help to create better safeguards. The knowledge illusion also affects how we should think about the most transformative technology of our age, the Internet. As the Internet becomes ever more integrated into our lives, the community of knowledge has never been richer, as vast, or as easily accessible.

There are other implications too. Because we think communally, we tend to operate in teams. This means that the contributions we make as individuals depend more on our ability to work with others than on our individual mental horsepower. Individual intelligence is overrated. It also means that we learn best when we're thinking with others. Some of the best teaching techniques at every level of education have students learning as a team. This isn't news to education researchers, but the insight is not implemented in the classroom as widely as it could be.

We hope that this book will leave you with a richer understanding of the mind, one in which you have a greater appreciation for how much of your own knowledge and thought depends on the things and people around you. What goes on between our ears is extraordinary, but it intimately depends on what goes on elsewhere.

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