10 Children's Definitions of "Pretending"

This book focuses on the development of scientific thinking out of the foundation of causal reasoning and on how children's concepts of science change over the early elementary-school years. Talking about pretending and imagination, as we do in this chapter, might seem like a radical departure from this focus. Imaginative activities often appear to be in opposition to scientific thinking, involving unfettered flights of fancy that break the rules of reality. Part of growing up, the common wisdom goes, is moving away from imagination in favor of the kind of more serious reasoning needed for activities like science. So what place do imaginative activities like pretending have in this book?

To begin answering that question, we must first define "imagination." The use of this word in everyday language conjures up scenarios that are wildly different from reality; being imaginative is often thought of as equivalent to being creative. While that is certainly something that imagination can do, and that is the part of imagination focused on in our typical discourse, that is not how "imagination" is defined in psychological science.

Imagination is the mental tool that allows us to think about anything outside of current reality. As such, it can be used for any kind of event or process or entity, not just fantastical or creative[1] ones. Understood in this way, most of our imaginative activities are actually quite mundane, like daydreaming about our next vacation, thinking about what could have gone better in a past encounter with our family, or practicing what we are going to say to our boss when asking for a raise. All of those scenarios involve elements that do not reflect the truth of current reality. Imagination is simply the ability to think about those kinds of scenarios. One of the key aspects of scientific thinking is the ability to predict events before observing them. This is what imagination allows us to do.

In this chapter, we continue our investigation of children's category-based intensions by asking how children conceptualize pretending, one kind of imaginative process. We first consider how the development of children's explicit understanding of this abstract concept might parallel the development of the other concepts we have considered so far (science, learning, teaching, and play). Then we broaden our discussion to consider various ways in which pretense and imagination relate to causal reasoning and scientific thinking.

"What Is Pretending?"

Pretending is a kind of imaginative activity. When children pretend, they represent the world not as it is, but as something different: a banana becomes a telephone, a parent becomes a fairy princess, they themselves become grown-ups. While the underlying mental states involved in making these substitutions or in conjuring these invisible entities are the same as in other types of imaginative activities, a key feature that distinguishes pretend play from other kinds of imaginative thought is that pretense is acted out. Unlike day-dreaming, counterfactual inference, or making up stories, pretend play does not merely take place in the child's head; it is embodied in some way in the world (see Weisberg, 2015).

Pretend play is also one of the earliest forms of imaginative activity that we can reliably observe.[2] Children begin to engage in simple object-substitution pretense (e.g., pretending to eat a block as if it were a cookie) around 15 to 18 months, and their repertoire of pretend actions and scenarios gradually expands over the course of the preschool years (Piaget, 1962). Social pretense—understanding the pretend worlds of others and being able to share in those worlds—emerges a little later in development, at roughly 2.5 years (Harris & Kavanaugh, 1993). Children can explicitly report on ways that pretense is different from reality by the age of 3 (Morison & Gardner, 1978; Woolley, 1997). Around the age of 4, children start to engage in object representation: Instead of it being necessary to interpret one object as another, children can simply act as if objects that are not there are present (Overton & Jackson, 1973). The emergence of this capacity correlates with children's performance on standard measures of false belief (Taylor & Carlson, 1997), suggesting a relation between pretend play and social-cognitive abilities.

Piaget (1962) posited that the emergence of pretend play was a hallmark of moving from the sensorimotor to the preoperational stages of development; pretense reflects children's abilities to reason about more than what they directly observe. Similarly, Leslie (1988) hypothesized that the emergence of pretense indicated that children possess broader representational mechanisms, which serve as the basis of other developments in their social cognition, such as their understanding of belief and knowledge. In contrast, although Lillard (2001) argued that pretense could be fruitfully understood as a way for children to explore solutions to problems or to enact impossible scenarios in ways that could help them understand reality, she also strongly cautioned against interpreting pretend play as necessary for the development of other cognitive skills (see Lillard et al., 2013).

Regardless of which of these theories of children's pretend play is correct, all of them describe pretending from an external, scientific point of view; they do not provide any information about how children conceptualize their own pretending or the act of pretending in general. But unlike the cases of children's understanding of science and learning covered in the previous chapters, there has been work on this topic. Some of this work has shown that infants recognize that others are pretending (Lillard & Witherington, 2004; Onishi et al., 2007). But most of the studies in this area have focused on whether preschool-age children understand that pretending involves mental states.

In order to make up a scenario or to imbue an object with properties that it does not actually have (i.e., to pretend), one must (1) know what those scenarios or properties are, (2) intentionally think about those scenarios or properties, and (3) be aware that one is engaged in this activity so that one does not come to confuse the pretend representation with reality. Several studies suggest that preschool-age children lack an understanding of all three of these features of pretending. For example, in one set of studies, 4- and 5-year-old children were shown a character, Moe, who was hopping like a kangaroo even though he did not know anything about kangaroos. Children tended to report that Moe was nevertheless pretending to be a kangaroo, seeming to ignore the fact that knowledge of kangaroos is a necessary prerequisite to pretending to be a kangaroo (Lillard, 1993). In another set of studies, preschoolers were shown that Moe was again hopping like a kangaroo, but he was not intending to look like a kangaroo. Again, children tended to report that Moe was pretending to be a kangaroo, even though he lacked the intention to act in this way (Lillard, 1998; Sobel, 2007). In a third set of studies, preschoolers were shown characters who, unbeknownst to them, took on particular appearances (e.g., a boy slipped in the mud and got muddy stripes on his orange shirt, making him look like a tiger, even though he didn't know he looked this way). Again, the majority of preschoolers reported that the character was pretending to be what he looked like (Sobel, 2004a). In each of these cases, young children misunderstand the representational nature of pretense, suggesting that they view pretense merely as a physical activity.

One can examine this conclusion further by asking how children view the relations among the different mental states involved in pretending. Specifically, the causal relation between knowing and intention is an enabling condition: One must first possess a certain kind of knowledge (e.g., what a kangaroo is and how it acts) in order to form the intention to pretend a particular thing (e.g., to jump like a kangaroo). It is impossible to do the latter without the former. In contrast, the causal relation between intention and action is generative: Forming the intention to pretend a particular thing leads to the action, but the surface action is possible without that particular intention. Children might struggle more to understand the former relation than the latter, because they lack a general ability to conceptualize enabling conditions. Indeed, when the enabling condition relation between knowledge and the intention to pretend was made more accessible to preschoolers, their performance on the Moe task improved considerably (Sobel 2009).

Although this line of work using the Moe task generally finds that children think of pretending as a series of actions, we have to contend with the fact that these studies are a bit strange.[3] They all present children with characters and then explicitly tell children about those character's mental states and physical activities. But children rarely, if ever, have access to exactly what another person is thinking or intending. Because of this, we think that it may be more productive—or at least as productive—to ask children to report on what they think pretending is.

Taylor et al. (2003) did this, as part of a larger study on children's understanding of the difference between pretending and lying (if you think about it, these concepts are pretty similar). These researchers categorized children's definitions of "pretending" based on whether they referred to general principles (e.g., "It's where you make something up that can't really happen") or specific examples (e.g., "When you slide and pretend to be a worm"). Younger children (4- and 5-year-olds) generated more of the latter, while older children (6- and 7-year-olds) provided responses that were more evenly distributed between the two categories. Overall, though, the majority of children in their study defined "pretending" in terms of taking the role of someone else or acting like something else.

Unfortunately, that study didn't probe children's understanding of pretending further, nor did it consider how children's definitions of "pretending" related to their knowledge of pretense. To do so, we (Sobel & Letourneau, 2019) first asked 4- to 7-year-olds to define "pretending" (i.e., "What does it mean to pretend?"). A few children said that they did not know or did not want to give a definition. A few other children simply defined "pretending" as pretending ("It means that something is pretend" or "Pretending is when you pretend"). These definitions, like the Identity definitions for "learning" and "teaching" described in chapter 9, were not considered further in our analyses.

The rest of the definitions were coded in three ways, based on some of the definitions of "pretending" described by Lillard (1993) and Austin (1979). We considered whether children talked about pretending being *not real* (e.g., "it means it's not real and you do it," "to make up something"), talked about pretending as involving *agency* (e.g., "it means you're acting," "doing what you want"), or used *mental state* words such as "think," "try," or "believe" (e.g., "you're thinking of something"). These codes were not mutually exclusive, so children's definitions could involve all three or none of them. Table 10.1 gives a few examples taken from this corpus.

Children's age positively correlated with the number of features they used in their definitions, so older children were more likely to define "pretending" using all three types of features. This correlation held when controlling for the length of children's utterances, demonstrating that this relation was not simply a result of the older children talking more. In fact, each of these features alone correlated with children's age. This suggests that, between the ages of 4 and 7, children are more able to articulate pretending in terms of its defining features. What is interesting is that, although all three of these features develop with age, they start at different places and have different developmental trajectories. Most children in the sample generated a definition that included agency, and this feature changed the least over time. Generating a mental state or a reference to something that is not real emerged

Table 10.1
Examples of children's definitions of "pretending" from Sobel & Letourneau (2019) (age in years and gender in brackets)

Response type	Transcribed responses
Not Real Only	Something not real. [5F] Pretending means not real. [7M]
Agency Only	Pretending means that you are playing with toys. [4F] It means when you're sneaky. It means you're a spy. [4M] To play something . . . whatever's part of the game. [6F]
Not Real and Agency	Doing something that's just make-believe. It means it's not real and you do it. [5M] It means you're something else, but you're not really that, but you're playing in a game that you're that. [6M] Pretending means like acting something that is not real. [7M]
Mental State and Agency	To think of your own thing that you like to do. You have to use your imagination and think about strange things and kind things. [7F] Pretending means like you're thinking, and you're thinking and making something happen, but with a costume and stuff. [7M]
Mental State, Not Real, and Agency	Pretending means something's not real and visualizing it and imagining it, I guess, so like if you have a room and then pretending it's a castle. [6F] It means thinking of something that isn't real, thinking of it and learning it. [7M] Using your imagination to make up stuff. [7F]

later and had a steeper developmental trajectory; these features exhibited much more change over time.[4]

In the same study, we asked this group of children to reflect on their own pretending and others' pretending in two ways. First, we gave these children a battery of tasks like the Moe task described above, in which a character is performing an action that appears as though he's pretending to be something, but cannot be pretending because he lacks the appropriate knowledge. We also asked children to reflect on times they pretended by themselves and with others, and how they know others were pretending. These latter questions aim to get at the same information as the Moe task, but in a more naturalistic way.

We found that the number of features that children generated in their definition correlated with their performance on the battery of pretend tasks (including the Moe task), controlling for age and the amount they talked in their definitions. But these definitions did not relate to children's reflections of their own or others' pretending. For the most part, in response to this interview, children emphasized others' actions and appearances when asked how they knew someone else was pretending. For example, one 7-year-old boy was asked how he knew that another person was pretending to be a mommy; he said that he knew because "she [was] pulling up her cell phone." Similarly, a 6-year-old boy said that he knew his cousin was pretending to be Spider-Man because "he was wearing a mask." So young children may understand that someone is pretending given different combinations of appearance, knowledge, and intentions (as probed by the laboratory tasks and the pretending battery we used), but only later begin to spontaneously reference mental states when describing how one pretends. In line with Lillard's arguments, then, young children seem to have an action-based or activity-based understanding of what pretense is, at least for others' pretense (see Lillard 2001; Stich & Tarzia, 2015).

These results bear striking similarity to our findings on children's definitions of "science" and "learning." In all three cases, younger children tend to be more swayed by the outward signs of these activities or by their outcomes: Science is characterized by actions like mixing things together, or outcomes like learning the correct answer; learning does not necessarily involve knowledge change for younger children. As they move through the early elementary-school years, children are more likely to integrate a mentalistic understanding of these activities into their definitions and conceptions. They come to understand science as being a process of learning, and they come to understanding learning and pretending as requiring a certain set of intentions and beliefs.

The Continued Adventures of Moe the Troll

The Moe studies reviewed above shows that children tend to think of pretending as an activity, misunderstanding its reliance on mental states like knowledge and intention. But there was a curious anomaly in the data from the original paper on this task (Lillard, 1993): On one item, children were more likely to correctly report that Moe couldn't be pretending to be something he didn't know about. That item involved Moe running like Simba from The *Lion King*. It was a small effect (about a 15% boost in performance), but it stood out. To investigate this more deeply, we ran a study in which we systematically varied whether the potential pretense was about a fantasy character (e.g., Simba from *The Lion King*) or an ordinary animal (e.g., a cat). Confirming the earlier finding, 4-year-olds in this new study were slightly better at saying that they needed their brains to pretend to be Simba than to pretend to be a cat (Lillard & Sobel, 1999). We also extended this finding to the Moe task. Once again, 4-year-olds were more likely to say that Moe was not pretending to be Simba when he was running like a lion but had no knowledge of lions than to say that Moe was not pretending to be running like a cat even though he had no knowledge of cats (Sobel & Lillard, 2001). As we reviewed in chapter 6, there are some circumstances in which fantastical contexts can bolster children's learning and reasoning; this is another example of that phenomenon.

But why should this be the case? For these data, we believe that we can pinpoint the reason that children were more likely to think maturely about fictional characters than ordinary creatures by drawing a parallel with children's thinking about causality. When children are told that a character is running like Simba, children might think about all of the things that Simba does. For instance, he talks with other animals. Real lions don't do that, and they especially don't spontaneously burst into song with meercats and warthogs. Mufasa (Simba's father) has a supernatural roar that blows hyenas over;[5] real lions roar, but not like that. Simba also communicates with dead relatives, whereas real lions don't do that—at least as far as we know. Given all of this, even though Simba can run, running is not really representative of what makes Simba special or unique. Pretending to be Simba by running thus does not seem to be a good fit with that task. Put another way, if you are going to pretend to be Spider-Man, you are going to act as if you can swing from a web, shoot webbing at bad guys, climb a wall, or generally try to help people; you are not going to worry about paying your rent (even though Peter Parker does, and this is often represented in the comic—why else would he work at the *Daily Bugle*?). You want your action to be representative of what the character can do.

This is related to an old idea in cognitive psychology: the *representativeness heuristic* (Kahneman & Tversky, 1972). "Heuristic" here refers to a rule of thumb, or a shortcut in reasoning. These rules generally work, but they might not be the most rational rules or the best possible mechanisms to use all the time. "Representativeness" here refers to the idea that we jump to a particular conclusion in thinking that a sample is a pure reflection of a population. To illustrate with a brief example, during the Super Bowl between San Francisco and Kansas City in 2020, San Francisco was winning 20–10 with about seven minutes to go. A reputable website put out a tweet that suggested the 49ers had a 95% probability of winning at that point in the game. But Kansas City came back and won the game 31–20. Many people were angry at this tweet in retrospect, and mocked the website that forecasted victory for San Francisco. But 95% isn't 100%; the website wasn't wrong. This example reveals these fans' use of the representativeness heuristic:[6] People represent numbers that are close to 100% as being 100%, because 100% is just easier to think about.

To test whether something about representativeness was involved in children's better performance with the fantasy characters, we introduced 4-year-olds to a new character in a storybook: Zoltron from the planet Zolnar, who looked like an anthropomorphic purple carrot (Sobel, 2006). Zoltron was described as "being from another planet" to establish the fantastical nature of the scenario (following Dias & Harris, 1988).

In one condition, the story revealed that Zoltron engaged in mostly fantastical actions (i.e., actions that violated real-world causal structure), like walking through walls or never having to sleep. In the other condition, the story revealed that Zoltron engaged in a set of ordinary actions, like walking through a door or sleeping through the night. One of Zoltron's actions (playing in the sandbox) was identical across the two storybooks, and the picture of this action was also identical across the two storybooks.

After children were read the story, they were introduced to Moe the troll, who was acting in the same manner to the one action that was common across both Zoltron stories. That is, Moe was playing in the sandbox, which we represented by having the troll doll play in a cardboard sandbox we created for the experiment. Children were then told that Moe had not read the story, so he had no knowledge of Zoltron. They were asked whether Moe was pretending to be Zoltron. Children routinely were more successful on this test question (i.e., denied that Moe was pretending to be Zoltron) when Zoltron had engaged in mostly fantastical actions in the story as opposed to ordinary ones.

What's going on here? To determine whether Moe is pretending to be Zoltron, children must reason about a particular kind of counterfactual: They must compare whether the action/appearance of Moe (the potential pretender) is representative of the action/appearance of Zoltron (the target of the pretense). The more that children believe that Moe's action and appearance are like Zoltron's, the more likely they should be to say that Moe is pretending. That is, fantasy itself might not be the driver of the benefit in performance for these cases. Rather, the fantastical actions performed by Zoltron in the story indicate that, when a potential pretender (Moe) engages in an ordinary action, that action is insufficient to indicate the character is pretending. But when Zoltron only engages in ordinary actions in the story, Moe's ordinary action is more representative, and thus more likely to be intended as pretense. In general, then, when making judgments about pretending, children must learn to use the representativeness of the pretend action in order to decide whether the character is pretending.

Building Fictional Worlds

When children engage in a pretend game or when they hear or watch a narrative story, they build a representation of the world that this game or story describes. This representation allows them to make judgments about the game or story and the characters within it, like how realistic or fantastical it is. How do children do this?

To answer that question, it is helpful to start with adults, because they also need to create mental representations of the stories they consume. How do adults do this? As an example, consider the world of Star Trek. In the show *Star Trek: The Next Generation*, the starship *Enterprise* has a tractor beam, which "employ[s] superimposed subspace/gravitation force beams" to allow for the "direct manipulation of relatively large objects in proximity to a starship. Such operations can take the form of towing another ship, modifying the speed or trajectory of a small asteroid, or holding a piece of instrumentation at a fixed position relative to the ship" (Sternbach & Okuda, 1991, p. 89). The tractor beam is pretty useful, and there are a number of cases where it could have been used (or at least tried) as a solution to a problem that threatened the *Enterprise*. A journey into the bowels of the internet reveals whole threads dedicated to this idea; we are not alone in suspecting that the writers of the show tended to forget that the *Enterprise* had it.[7] But, when it does make an appearance, consumers of this kind of fiction tend to shrug their shoulders—in a world that already contains transporters, replicators, holodecks, and faster-than-light travel, a tractor beam sounds reasonable. But for all the technological marvels of *Star Trek*, we assume that the *Enterprise* has bathrooms and that the human beings on board the *Enterprise* need to eliminate waste.[8]

In contrast, consider *The Love Boat*, the late-1970s TV show about people finding love aboard a cruise ship. It ran for nine seasons and had 249 episodes, so it must have had some staying power. If you were a consumer of this kind of fiction, and you saw Captain Stubing deploy a tractor beam on the *Pacific Princess*, you likely would not have simply shrugged. In fact, you may have felt the need to completely rethink the nature of the show you were watching.[9]

What these examples show is that adults are quite adept at constructing different types of fictional worlds from sparse information (Weisberg, 2016). Adults understand (and tend to gravitate toward) different genres of fiction, recognizing that the rules of a story in the genre of magical realism will be different from the rules of a detective novel. In support of this idea, we (Weisberg & Goodstein, 2009) showed that adults fill in the gaps of fictional worlds based both on their real-world knowledge and on their understanding of the kind of story that they are consuming. In this study, adult participants were presented with three possibilities for a story: entirely realistic, containing a few impossible events, or containing many impossible events. These participants used the degree of similarity of the fictional world to the real world as the basis for their judgments about whether to extend novel facts into that world. For example, in a story in which characters engaged in no violations of real-world causal structure, adults were likely to say that the world of that story resembled the real world quite a bit. In contrast, when a story did violate several aspects of real-world causal structure, adults were less likely to agree that facts that were true of the real world were also true in the world of that story.

These results demonstrate that understanding a fictional story is quite similar to navigating the real world. Both reality and fiction have gaps: Adults do not know everything that there is to know about the structure of reality, and no story is ever long enough to fully describe the world in which it takes place. Luckily, neither engaging in everyday activities nor engaging with fiction requires knowing everything there is to know about the world. In both cases, we can use our existing knowledge and reasoning abilities to fill in gaps when they arise (see Schacter, 2012). This argument further suggests that, as one's knowledge changes and develops, the way in which one understands fictional stories changes and develops with it. Just as children's causal knowledge constrains the kinds of inferences they make about new real-world causal systems, the same knowledge constrains how they construct fictional worlds.

So how do children think about fictional worlds and make judgments about new elements within them? To begin to answer this question, we followed up our work with adults by investigating preschoolers' inferences about novel stories (Weisberg, Sobel, Goodstein & Bloom, 2013). We presented 4-year-olds with one of two kinds of stories. Both had the same basic structure, but one presented several violations of real-world causal laws (e.g., a character who teleported to the ice cream store) while the other presented no real-world causal violations (e.g., a character who walked to the ice cream store). In each case, children were told that some pages of the story were missing, and they were asked to fill in the blanks of the story with new pages. At the points where they had to fill in the story, children were always given the choice between an entirely realistic event and an event that broke some real-world law. Regardless of which story they saw, children were significantly more likely to choose the realistic events. That is, rather than being indiscriminately attracted to fantasy, as popular ideas of children tend to assume, and rather than matching events to their story contexts, as adults tend to do, children are *reality-prone*.

Critically, children in these studies were not reality-prone under all circumstances. When shown the three pairs of choice pictures from this study without any story context and asked to choose which one they liked, children tended to pick a mix of fantastical and realistic events. Further, in a follow-up study, an experimenter told a new group of 4-year-olds that she liked a set of events that were either all realistic or all fantastical. She then asked children which new event she would also like: a novel realistic one or a novel fantastical one. In this case, children correctly chose the event whose ontological structure matched the experimenter's preference. These control studies demonstrate that children do not have a general preference for real-world events; they only showed this preference when asked about which events belong in a story.

Indeed, in another set of follow-up studies, we asked 4-year-olds to construct stories completely from scratch, choosing each time between a fantastical and realistic element to move the plot forward (Sobel & Weisberg, 2014). We found that children were highly consistent in their choices. If they started with a fantastical element, they tended to pick fantastical elements throughout their story construction; if they started with a realistic element, they tended to pick realistic elements throughout their construction. This indicates an understanding that stories need to be internally consistent in the worlds they describe, as in the *Star Trek/Love Boat* example above. But, critically, 80% of children generated all or mostly realistic stories, while only 20% generated all or mostly fantastical ones, replicating the tendency to choose realistic story events that we had found in prior work. And when asked whether unusual events in stories (like the existence of paint that never dried) should be used as the basis for further inferences about that story, preschoolers tended deny that later events would have the same unusual structure. Instead, they tended to say that the story world would match reality more closely (Weisberg & Hopkins, 2020).

These results do not mean that children lack all sensitivity to the structure of fictional worlds. In the study in which children were conservative about extending unusual premises within the world of a story, they were willing to license some familiar impossible premises, like talking animals (Weisberg & Hopkins, 2020; see also Van de Vondervoort & Friedman, 2014). In addition, when asked to choose between two different types of impossible events to continue a story (fantasy and science fiction), 4- to 6-year-olds were able to correctly match these events by genre, choosing fantasy events to continue fantasy stories and science-fiction events to continue science-fiction stories (Kibbe et al., 2018). Nevertheless, when compared to adults, children are generally much less sensitive to the structure of story worlds and much more reality-prone.

But why should this be the case? Before answering that question, it is important to note that children's tendency to continue fantastical stories with realistic events is not an error. Events that are consistent with real-world causal structure occur in all kinds of stories. While fantastical stories can introduce novel violations of causal structure (like the tractor beam in *Star Trek*), even highly unrealistic fictional stories contain many realistic elements (like characters needing to use the bathroom). One cannot necessarily infer that stories containing many violations of real-world rules should contain additional violations. But children's tendency to use real-world causal structure to construct fictional worlds does reflect a certain kind of conservatism in their thinking about possibility.

So how can we explain this conservatism? It is possible that preschoolers (unlike adults) reason according to the *principle of minimal departure* (Ryan, 1980; see also Lewis, 1978; Walton, 1990). This principle states that the construction of a fictional world involves (by default) everything that is possible in the real world, unless the story explicitly forbids it. Although this is not the only possible way to construct fictional worlds (see Weisberg, 2016), if young children follow this principle, it could explain why they fill in stories the way that they do. Adults, by contrast, have a more nuanced view of how much of reality belongs in a story. They are able to flexibly accept and reject premises based on a more holistic assessment of the kind of fictional world they are encountering, rather than assuming that the entirety of reality belongs within the fictional world as a default. What develops over the course of the lifespan, then, is not just the causal and domain knowledge on which fictional worlds are based, but also a higher-order set of assumptions about how that knowledge should be applied within a given fictional world.

Imagination and Causal Reasoning

How children interpret fictional worlds nicely illustrates an important point of connection between imagination and scientific thinking. One of the main goals of scientific inquiry is to determine causal structure, specifically separating genuine causal relations among events from factors that are merely correlates, as the control of variables strategy allows one to do. The causal graphical model framework that we introduced in part I of this book is a way of describing a representation of such knowledge, and we showed there that children can reason according to its principles in a variety of settings.

One of the appealing facets of this framework is its explanation of counterfactual reasoning (Glymour, 2001; Pearl, 2000; Woodward, 2003). Counterfactuals involve constructing a hypothetical representation of a causal structure that is different in some way from the original representation. One can then reason about that modified structure using one's general inference-making abilities. To do so, one must quarantine the original representation (or decouple it from reality; see Leslie, 1987, 1994). This allows the original representation to be retained independently of a new representation on which a counterfactual inference is performed (via reasoning about interventions on certain nodes in the model). The counterfactual is calculated by reasoning about the results of these (hypothetical) interventions. The actual representation of the world, because it has been quarantined, is restored when the counterfactual inference is complete.

But thinking counterfactually crucially involves imagination. For example, we may be able to observe only cases where two events (A and B) occur together. Nevertheless, we can mentally construct scenarios in which A is removed, or in which A and B are related in different ways than they are in reality. Being able to think about *possible* causal structures and the results of various interventions on them is, at its heart, an imaginative process, and one that is vital to causal reasoning (e.g., Gopnik & Walker, 2013; Weisberg & Gopnik, 2013).

These arguments draw a deep connection between causal reasoning and imagination in general, and between causal reasoning and pretend play in particular (see Leslie, 1987, 1994). When children engage in a pretend scenario, they are demonstrating their ability to copy a representation of the world and modify it, while keeping this representation separate from their original representation of the real world. This allows children to draw inferences within the pretend scenario that do not affect their understanding of reality. For example, when a child engages in simple object substitution to pretend a banana is a telephone, their representation of real-world bananas is maintained. Actions within the pretend game that imply that the banana can be used for communication do not affect children's understanding that, in reality, bananas are not communication devices. This way, children do not confuse telephones with bananas (or pretense with reality, more generally). This description makes clear that pretending and counterfactual reasoning involve the same mental capacities. Both require an individual to take an existing representation, copy it, quarantine the original, modify the copy, and then draw conclusions about the modified representation.

One of our studies directly tested this relation, finding evidence that counterfactual thinking and pretending are indeed linked in young children (Buchsbaum, Bridgers, Weisberg & Gopnik, 2012). Specifically, this study taught 3- and 4-year-olds a new causal relation: Putting a special object called a zando on a machine made the machine play the song "Happy Birthday." Once children learned this causal relation, we found that they were able to think counterfactually about it. To test this, we asked them what would happen if the zando were not a zando and we put it on the machine. Children tended to say that putting it on the machine would not make the machine play music. This is a rather complex piece of reasoning. To answer this question correctly, children must suppress what they know to be true in reality (the object really was a zando) and think about an imagined (non-real) scenario in which the zando did not have its usual causal powers.

Even more impressively, the preschoolers in this study were able to transfer this newly learned causal relation into a pretend game. When they were given the opportunity to pretend that a box was the machine and a block was the zando, they chose to put the pretend zando (rather than a second object) on the pretend machine to make it play music in the pretend game. And these preschoolers' tendencies to respond in this way in the pretend scenario were significantly related to their tendencies to correctly answer the counterfactual questions about the real zando and the real machine, even when controlling for other factors like age and executive function abilities. This evidence suggests that imaginative abilities underlie both children's playful actions in pretend games and their counterfactual reasoning abilities in general.

Counterfactual Thinking in Development

The arguments in the previous section lead to the strong conclusion that pretending and imagining are deeply related to counterfactual reasoning, and hence to both causal reasoning and scientific thinking. Although we believe that this theory is sound, aside from the one study reviewed above, there is little direct evidence for it. Here, we review prior work on children's understanding of counterfactual reasoning in general, aiming to illustrate how it relates to both imaginative activities and causal reasoning.

First, there is a long literature on infants' causal perception, suggesting that infants can perceive causal relations among events based on their spatiotemporal relations sometime during the second half of the first year of life (e.g., Leslie & Keeble, 1987; Oakes & Cohen, 1990; Saxe et al., 2005; Saxe et al., 2007; Sobel & Kirkham, 2007). Perceptual information can be a powerful clue to causality, so much so that even adults can experience illusions of causality, which act much like visual illusions. Take, for example, the blicket detector, which we have discussed throughout this book. Most versions of the detector actually present a causal illusion: The block is not making the machine activate. Rather, the experimenter is pressing a button, hidden to the child, at the same time as the block is placed on top of the machine. The button is depressed as long as the block is on the machine and the experimenter stops pressing the button when the block is lifted off. This gives the appearance that the block is causing the machine to turn on.[10] This spatiotemporal relation gives the illusion of causality, much like visual illusions (such as the Ponzo illusion) afford an illusion of depth. Even if you know how the machine works, the illusion stands: Placing a block on the machine appears to cause it to activate.

However, whether infants are genuinely thinking causally on the basis of these perceptual cues is a matter of interpretation (see, e.g., Sommerville & Woodward, 2005). Because we believe that thinking causally goes hand in hand with the ability to think counterfactually, one way to resolve this issue would be to test whether infants can do so. This is an understandably tricky challenge; how could we tell if preverbal babies are thinking about states of affairs that reflect possibilities rather than reality? For this reason, studies on counterfactual thinking tend to focus on older children.

This body of work suggests that children starting around the age of 3 or 4 can engage in certain kinds of counterfactual inferences (e.g., Beck et al., 2006; Guajardo & Turley-Ames, 2004; Harris et al., 1996; Nyhout & Ganea, 2019; Rafetseder et al., 2010; Rafetseder & Perner, 2014; Riggs et al., 1998; Robinson & Beck, 2000). For example, Beck et al. (2006, Study 2) showed 4-year-olds an apparatus with a forked slide, so that a toy could slide down either the spotted side of the slide or the striped side of the slide. After sending the toy down the top of the slide and seeing on which side of the fork the toy ended up, children were asked, "What if it had gone the other way, where would it be?" Children were able to correctly indicate the bottom of the other slide, suggesting that they could consider this counterfactual situation.

There is disagreement, however, about the role of counterfactual reasoning in causal inference. Some researchers have claimed that children understand causal relations among events by reasoning about the absence of candidate causes—that is, by genuinely reasoning counterfactually. In support of this view, Harris et al. (1996) claimed to show that children were capable of engaging in a form of counterfactual inference at the age of 3. In one of their tasks, they first showed children a representation of a clean white floor. Then, a character comes home and doesn't take her muddy shoes off, so she makes the floor all dirty (represented by placing a set of tracks on the "floor"). Children were asked about what the floor would look like if the character had taken off her shoes before she walked on it. They were successfully able to answer that the floor would be clean in this case.

On this basis, and on the basis of the fact that pretend behavior emerges early in development, Harris and his colleagues suggested that counterfactual reasoning was a natural form of causal inference (following suggestions from Mackie, 1974).

In contrast, most of the other studies cited above suggest that counterfactual inference might be a more difficult form of inference than other kinds of causal inferences, such as making predictions. For example, Riggs et al. (1998, Experiment 4) contrasted preschoolers' ability to make an inference about a future hypothetical and about a counterfactual. In this study, children were shown a box with items that had pictures on them and another box with items that did not have pictures on them and were told about this categorization scheme. In one condition (future hypothetical), children were shown a blank piece of paper and were asked which box it would go into if the experimenter drew on it. In the other condition (counterfactual), they were shown a piece of paper with a picture on it and were asked which box if would go into if the experimenter had not drawn on it. Children were more accurate at answering the future hypothetical question than the counterfactual one.

Interestingly, Riggs et al. (1998) also suggested that the false belief task was a measure of counterfactual reasoning, and that the developmental progression that many researchers have documented between ages 3 and 4 (e.g., Wellman et al., 2001) was due to children's developing counterfactual reasoning capacities. Consider, for example, a standard unexpected transfer task (Wimmer & Perner, 1983). In this type of task, children are introduced to a character (Sally) who has a chocolate. Sally does not want her chocolate right now and puts it in a location (such as a drawer) and then leaves the room to do another activity. While she is away, another character (Anne) finds the chocolate and moves it to another location (such as a cabinet). This sets up a situation where Sally has a false belief: The chocolate is now in the cabinet, but Sally thinks that the chocolate is in the drawer, because that is where she last saw it. After children hear this story, they are asked where Sally will look for her chocolate when she returns (alternately, some researchers ask where Sally thinks the chocolate is). Typically, 3-year-olds do not succeed on this task; they tend to say that Sally will look for the chocolate where it currently is (the cabinet). In contrast, 4-year-olds (and hopefully you as well, dear reader) correctly report that Sally will look for the chocolate where she left it (the drawer).

The way that researchers have typically interpreted this pattern of responses over the past thirty-five or so years is by saying that, in order to give the latter (correct) response, children have to make an inference about the content of Sally's beliefs. In contrast, as noted above, Riggs et al. (1998) observed that this measure is also a test of counterfactual inference: If Anne had not moved the chocolate, then Sally's beliefs would be correct. These researchers argued that the mental state aspect of the inference might not be as relevant as the counterfactual; remove the mental state but preserve the counterfactual, and children should still show the same developmental trajectory.

To test this interpretation, these researchers presented children with a version of an unexpected transfer task in which children could be asked to reason about a character's false belief or about a counterfactual state of affairs that did not involve any mental states. In their procedure, two characters were together in their house. One wasn't feeling well and went to bed. The other went to get medicine for the first. While the second character was away, the first character was called away from the house to help put out a fire. Children were equally accurate at answering a counterfactual question about the character's whereabouts that involved no mental state inference ("If there had been no fire, where would the first character be?") as they were about answering a question about the belief states of the second character ("While the first character is out of the house, where does the second character think the first character is?"). These data imply that counterfactual reasoning is a domain-general cognitive capacity, one that underlies or contributes to many different kinds of inferences, including children's abilities to think about false beliefs.

We agree with the idea that causal inferences are related to and sometimes even performed on the basis of counterfactual inferences. But we would like to make a slightly more nuanced view of the relation between these abilities—a view that can explain why counterfactual inferences are sometimes difficult for children. One of the main features of the causal graphical model framework is its ability to support counterfactual inferences (Pearl, 2000). If children's representations of causal knowledge are well-described by this framework (as we argued in part I of the book), then if they can make causal inferences, they can also make counterfactual inferences. However, the studies reviewed above suggest that this is not always the case, and that some kinds of inferences (e.g., counterfactuals) are more difficult than others (e.g., hypotheticals). One reason that this is sometimes the case (such as in Riggs et al.'s 1998 procedure) might have to do with the development of domain-general cognitive capacities (such as inhibitory control, which appears to correlate with counterfactual reasoning measures; see also Beck et al., 2009; Drayton et al., 2011). As we argued in chapter 1, these other cognitive capacities can constrain children's performance on these tasks.

Similarly, counterfactual and future hypothetical questions are usually asked in different ways. Counterfactual questions typically take the form of "What if X had (or had not) happened, would Y [still] have happened?" Future hypothetical questions typically take the form of "What if X happens, then will Y happen?" The different modal verbs used in these questions might contribute to the different levels of linguistic difficulty that children might have with these questions, because these verbs have different developmental trajectories in their comprehension and production (Coates, 1983; Kuczaj & Daly, 1979).

To investigate this issue, we (Sobel, 2001) constructed a measure of future hypothetical and counterfactual inference that removed some of these demands (particularly the linguistic ones). Specifically, we asked 3- and 4-year-olds to talk about a picture book instead of to answer direct future hypothetical and counterfactual questions. In this study, children were shown the first three pictures of a story that depicted a future hypothetical situation, and then were asked to fill in the fourth picture in the storybook. Or, children were shown all four pictures, and then a change was made to the third picture, and then children were asked to fill in a new fourth picture to represent a counterfactual.[11] We based the initial stories on the measures used by Harris et al. (1996) and Riggs et al. (1998), and we found that children were equally good at reasoning about counterfactuals as they were about future hypotheticals.

We also varied what the stories were about. When we used similar stories to Riggs et al. (1998), we found that there was some development between the ages of 3 and 4, which is similar to the developmental trajectory one sees when one studies performance on the false belief task (Wellman et al., 2001). But when the stories were changed to be about whether a character would be happy or sad based on their desire being fulfilled or unfulfilled, both 3- and 4-year-olds were able to reason accurately about both the future hypotheticals and counterfactuals. In contrast, when the story was about whether someone would be surprised, both 3- and 4-year-olds struggled to reason accurately about both future hypotheticals and counterfactuals; they performed no different from chance on both types of stories.

These findings are reminiscent of the effects of contextualization that we discussed in chapter 6. As a reminder, we found that the way that a problem is framed or described can influence children's and adults' reasoning abilities. We suspect that the same kind of mechanism is at play here, and that the type of causal knowledge that a child possesses could affect their ability to reason. So both 3- and 4-year-olds are good at counterfactuals about desire-based situations because they possess a pretty good understanding of the causal relations involved in reasoning about their own and others' desires (see Repacholi & Gopnik, 1997; Wellman & Woolley, 1990; see also Wellman & Liu, 2004). The mental state of surprise, on the other hand, is a more complex concept, and the causal relations involved inferring when someone is surprised might not be available to children until after the age of 4 (see e.g., Hadwin & Perner, 1991).

Studies like this one support our argument that children's counterfactual reasoning abilities are connected to their causal reasoning capacities. They also begin to suggest an answer to the question of directionality: The existence of context effects suggests that children's causal reasoning abilities and their general knowledge support their counterfactual reasoning, rather than children having a fully domain-general counterfactual ability that operates on any type of causal inference.

Another of our studies (Sobel, 2004b) tried to resolve this question more directly by presenting 3- and 4-year-olds with stories about impossible events. In one set of stories, we asked children whether those events were possible. For example, a character wanted to throw a ball up in the air and have it float—is that possible? In another set of stories, we showed the same children a character who tried to do one of these events and failed. Then, we asked about a counterfactual: Was there anything that the character could have done differently to bring about this event? This study also varied the domain of the story, so sometimes the impossible event broke a physical law (like the floating example above), sometimes a biological law (like wanting to never go to sleep again), and sometimes a psychological law (like causing someone to know the location of an object they have never seen). Children's judgments about whether these events were possible in the first set of stories related to their ability to state that the character could not do anything different because the event was impossible in the second set of stories; if children judged that the events were impossible in the first set of stories, they were more likely to say that nothing could be done differently to accomplish an impossible goal. Importantly, this relation was domain-specific: Judgments that physical events were impossible related to counterfactual inferences about physical events, but not to counterfactual inferences about biological events, for example. Again, this suggests that counterfactual thinking might depend on one's causal knowledge, not the other way around.

This work, however, may still present an incomplete view of counterfactual reasoning. As Rafetseder and Perner (2010, 2014) note, the tasks presented in all these studies could potentially be solved if one were only thinking conditionally (i.e., considering "if . . . then" statements or statements of general rules). That is, the work discussed so far does not provide direct evidence that preschoolers are genuinely thinking counterfactually as opposed to making a series of conditional inferences. To demonstrate this, they presented children a version of the task from Harris et al. (1996), but with two characters. Both of these characters have muddy shoes and they both walk across the clean floor, making it dirty. Children are then asked whether the floor would be dirty or clean if only one of the characters had taken off her shoes before she walked across the floor. Preschoolers tend to incorrectly say that the floor would be clean, and it is not until later in development (age 7 or potentially even adolescence, depending on the nature of the study) that children reliably answer correctly (Rafetseder et al., 2013). Unlike younger children, what these older children seem to be doing is reasoning about the "nearest possible world," as Lewis (1973) suggested, taking more of the causal structure of the antecedents into account (see also Leahy et al., 2014). That is, in this view, the older children in these studies are genuinely reasoning counterfactually, while the younger children seem to be attempting to solve the problem by translating it into a conditional statement.

Interestingly, in the same paper, these researchers also speculate on the relation between the developmental trajectory of causal reasoning (particularly as it relates to counterfactual reasoning) and scientific thinking. They write,

> One could also expect a parallel development between [the kind of counterfactual reasoning that takes causal structure into account] and scientific reasoning abilities. A fundamental element in scientific reasoning is differentiating variables

> that are causally relevant for the observed outcome from variables that are not. For example, to determine whether the piece of metal was the only causally relevant factor for the Concorde to crash, one would need to manipulate this factor while holding all other independent variables constant. This amounts to the nearest possible world constraint. (Rafetseder & Perner, 2014, p. 57)

While we believe that counterfactual reasoning does rely on one's existing causal knowledge, as Sobel (2011) suggested, we also accept some of the conclusions from Rafetseder and Perner (2014) about a more prolonged developmental trajectory for counterfactual reasoning, particularly given the complexity of some of their tasks. But it also seems reasonable to conclude that causal knowledge is necessary for the kind of counterfactual reasoning that Rafetseder and Perner tested, as well as the capacity to reason about possible worlds in order to represent a hypothetical intervention on the antecedent.

There's a broader point here. In chapter 2, we introduced the idea that Bayesian inference is a good description of how children might make causal inferences and learn causal structure. Bayesian inference starts with a representation of a hypothesis space, but there are no physical tokens or manifestations of that hypothesis space. That representation is in the mind. This means that making inferences using a Bayesian process requires the ability to imagine. Imagination is thus part of the domain-general mechanism of causal inference, which governs not only counterfactual reasoning, but aspects of causal reasoning as well.

These connections can be seen in some recent empirical work. For example, McCormack et al. (2013) showed that encouraging 5-year-olds to think counterfactually improved their reasoning about a form of blocking, similar to the Gopnik et al. (2001) procedure used to test children's use of the Markov assumption described in chapter 2. Similarly, Engle and Walker (2021) showed that asking counterfactual questions to 5-year-olds helped them determine what data disambiguated competing interpretations. In a synthesis of this literature, Walker and Nyhout (2020) argue that counterfactual questions allow children to "perform mental simulations and interventions on causal models . . . to consider and test alternatives (particularly those with lower prior probability) to an initial hypothesis" (p. 269). So while having a representation of the causal structure of a set of events might allow children to reason counterfactually, it is also the case that the domain-general capacity for imagination helps to guide some forms of causal reasoning. Because children have the capacity to imagine, they can learn not only from statistical regularity, but also from considering what might have been.

There is a corollary to this hypothesis. In chapter 3, we argued that children are not born with the capacity for causal inference, but that it emerges from their statistical learning capacities during the second half of the first year of life, as they begin to integrate their ability to understand statistical regularity with their ability to understand the importance of intervention on the world. The emergence of the capacity to imagine—which seems to begin in earnest in the first half of the second year of life—is another domain-general capacity that plays an important role in the cascading development of causal reasoning and causal knowledge. Describing the developmental process in this way suggests that there is a period of time in development during which children represent causal knowledge, make causal inferences, and learn new pieces of causal structure, but cannot yet engage in counterfactual reasoning. This probably occurs between the second half of the first year of life (when we think children start genuinely reasoning about causality beyond mere statistical regularity) and the middle of the second year of life (when children start pretending). This is an open question for investigation.[12]

Possibility and Probability

Based on the work reviewed above, we conclude that counterfactual thinking and reasoning about imaginary worlds depend both on a domain-general capacity for imagination and domain-specific causal knowledge. This conclusion is supported by another line of work on children's understanding of possibility. For a long time, researchers have documented that even preschoolers have a good understanding of the difference between fantasy and reality (e.g., Corriveau et al., 2009; Morison & Gardner, 1978; Woolley, 1997) or between what is possible and what is impossible (e.g., Schult & Wellman, 1997; see Weisberg, 2013, for review). Although many have taken this as the end of the story, Shtulman and colleagues noted that most of this work contrasts fantastic or impossible events with relatively ordinary ones. Simba the Lion King is fictional; lions are real. But what about events that are neither completely impossible nor totally ordinary, like having a lion or a tiger for a pet? This kind of event is possible, just unlikely (*Tiger King* and Siegfried & Roy notwithstanding). Do children understand that there is a distinction between impossibility and improbability, just as they understand the difference between impossibility and possibility?

To answer this question, Shtulman and Carey (2007) presented 4- to 8-year-olds with ordinary events (eating an apple), impossible events (eating lightning), and improbable events (drinking onion juice). They asked children whether these events could happen in real life. All of the children said that the ordinary events could happen in real life and the impossible events could not, as in previous work using such events. For the improbable events, there was a developmental trajectory. Four-year-olds treated the improbable events like the impossible ones, saying that they could not happen. By the time that children were 8, they correctly judged that the improbable events could happen in real life, like the ordinary ones.

Shtulman and Carey argued that the reason that young children were confused by improbable events was not that they lacked imagination, but rather that they lacked the experience to recognize that such events could be possible (although see Lane et al., 2016, for an alternative interpretation). Given that preschoolers had never experienced drinking onion juice or having a lion for a pet, or any of their other improbable events, the children judged them as impossible. Older children, in contrast, were better able to distinguish between what they had personally experienced and whether an event was possible. One related interpretation of these data is that 4-year-olds genuinely struggle with this kind of question, interpreting "could it happen" as "has it happened," while older children interpret the question in a more mature way, as about whether something is possible in the modal sense.

We (Weisberg & Sobel, 2012) supplemented this interpretation by testing 4-year-olds' understanding of improbable stimuli in two ways. First, we replicated Shtulman and Carey's method, directly asking these children whether improbable events could happen in real life. We found, as they had, that these young children tended to mischaracterize improbable events as impossible. Second, we presented these events in the context of a story, in which a character experienced only improbable events. We then asked children to choose how the story should continue: with a novel improbable event, a novel impossible event, or a novel ordinary event. These three events were presented in pairs, so children's choices were between an improbable and an impossible event or between an improbable and an ordinary event. Children usually chose the improbable event over the impossible one to continue the story, but they were at chance at choosing between the improbable and ordinary events. This suggests that in the context of fiction—where 4-year-olds do not have to rely on their experience—they can accurately distinguish between the improbable and impossible actions. Further, these 4-year-olds correctly treated the improbable actions more like ordinary, possible ones than like impossible ones.

What these data suggest is that, even at these young ages, children are not just responding on the basis of their experience. Rather, children are engaging their causal knowledge to reason about imagined situations. This again suggests that children's causal knowledge is the basis of their counterfactual reasoning capacities. In order to reason about a counterfactual, children must first be able to represent the causal structure they are to reason about. They might use counterfactuality to confirm causal knowledge, but the causal knowledge comes first.

The Role of Inhibition

Before we conclude, we want to consider whether everything we have just said about counterfactual reasoning could be wrong. Another interpretation of the relation between causal and counterfactual reasoning is that counterfactual reasoning actually has little to do with the causal knowledge that one possesses. Rather, making a counterfactual inference is a more domain-general process that is heavily reliant on inhibitory control. In this argument, causal knowledge appears to be relevant to counterfactual reasoning because young children have difficulty suppressing their existing knowledge in order to reason on the basis of counterfactual antecedents rather than on the basis of what they know to be true. Indeed, many studies show that preschoolers' counterfactual reasoning abilities are correlated with their performance on various inhibitory control measures (e.g., Beck et al., 2009; see also Beck, Riggs & Burns, 2011). Moreover, in the adult literature, working memory plays a clear role in counterfactual inferences (e.g., Byrne, 2005).

There is little doubt that inhibition plays a role in counterfactual reasoning, especially because thinking about counterfactuals often requires one to inhibit one's current real-world knowledge. But talking about the role of inhibitory control in development requires unpacking what is specifically meant by the "increasing evidence that domain-general executive functions underpin children's counterfactual thinking" (Beck, Riggs & Burns, 2011, p. 111). Is causal knowledge truly irrelevant to the picture, and can all of children's failures or mistakes be explained by inhibitory processes?

We do not think so. To clarify our position, we borrow an argument from Benson et al. (2013), who discuss the possible ways in which inhibitory control might relate to theory of mind development. One possibility is that children's developing inhibitory control underlies their social cognitive development. The false belief task, for example, requires reasoning not on the basis of one's knowledge of the actual state of the world (there are candles inside a crayon box), but rather on the basis of a different representation (the crayon box should contain crayons, so an ignorant reasoner will think there are crayons inside, not candles). Inhibitory control is necessary for successful performance on this task. Different kinds of inhibitory control, which develop on different timescales based on task complexity and context, allow for the expression of various cognitive and social cognitive capacities throughout development (e.g., the A-not-B task, the false belief task, various measures of understanding pretense; see e.g., Davidson et al., 2006).

In contrast to this standard story that inhibitory control allows for the *expression* of false belief capacities, Benson et al. (2013) suggest that there is another way of interpreting the role of inhibitory control in cognitive development. Specifically, the development of inhibitory control allows for the *emergence* of conceptual change. In this view, children's developing inhibitory control is necessary for reasoning, but not sufficient. To support this argument, these researchers examined the relation between children's developing theory of mind and inhibitory control. They found that 3-year-olds who scored high on inhibitory control measures were not necessarily better at the false belief task than children who scored low on such measures at the outset of their training, but they were more amenable to training on the false belief task. In their view, having better inhibitory control capacities allow children to better process information relevant to learning.

We suggest that something similar is happening with respect to the relation between causal knowledge and counterfactual abilities. Having better inhibitory control capacities does not, on its own, allow children to reason counterfactually. Instead, inhibitory control capacities provide children with improved access to their causal knowledge and greater capacity to reason about the alternate, non-real representations that they construct in order to reason counterfactually.

Imagination and Science

When using a broad definition of "imagination," as any representation that is not meant to reflect the current truth of reality, it is easy to see how imagination has a crucial role to play in scientific thinking (see Weisberg, 2020). A large part of scientific practice involves thinking about possible explanations for patterns of data, alternative ways that experiments could have turned out, and hypotheses for why things happened in a certain way. But these possible explanations and hypotheses are really just imagined scenarios. For example, we may not know exactly why a particular population of frogs suddenly developed a series of deformities on their legs. But we can use the information that we have to imagine an explanation that could fit the facts: A nearby company might have started dumping chemicals in the water, or there might have been unusual fluctuations in temperature recently (similar to what Walker & Nyhout, 2020, call "why else" reasoning). We can think of the process of constructing a hypothesis in parallel to the process of creating a pretend scenario or writing a story. In the science cases, these are stories that are inspired by and connected to real events. Nevertheless, these stories are not necessarily real, and so they require imagination.

We believe that participants in the diagnostic reasoning task we introduced in chapter 5 go through the same sort of imaginative thought process. When they first encounter the blicket detector, they need to come up with some idea of how it works in order to solve the puzzle. Maybe the detector senses number, so it needs four blocks on it to turn green. This hypothesis might or might not be true, so it has to be imagined. As participants gain further information about the machine (e.g., it can turn green with only two blocks on it), they need to update this imagined representation so that it more closely fits the facts.

This example and the work reviewed throughout this chapter make it clear that children's (and adults') causal knowledge constrains their imagination. The framework of causal graphical models that we introduced in chapter 2 provides a way to think about this process. As a quick reminder, causal graphical models are ways of representing different causal structures and different types of relations between causes and effects. In combination with Bayes' rule, or some other formalism for drawing inferences from observed data, they can be used to model how people think about causal systems in the world. More importantly for the current purposes, though, is the fact that these models can be represented and manipulated independently of each other and independently of the structure of the world. This means that they can be used to represent imagined or counterfactual structures as well.

On the flip side, imagination can also be used to manipulate representations of causal structure. In situations where participants do not know the correct underlying structure, they can construct multiple possible models that match the data that they have observed. As new information comes in, they can test out different versions of these models and intervene on them to see which ones can be made to match the new observations (sometimes called "graph surgery"; see Pearl, 2000). Imagination and causal counterfactual reasoning are thus intimately linked in how we think about the world. However, as we have seen across the chapters in this book, explicitly reasoning in this way might have a prolonged developmental trajectory.

To conclude, at the outset of this chapter, we considered the standard view whereby pretending and imagining are unrelated to (perhaps even antithetical to) causal reasoning and scientific thinking. What we hope to have shown is that engaging in and understanding imagination might provide children with insight into the power of possibility—insight that they can use when thinking scientifically. Further, children's causal knowledge provides a foundation on which their cognitive capacities build. Reasoning about pretense, possibility, and counterfactuals thus all emanate from children's developing causal knowledge, and all affect the ways in which children reason about science.

Constructing Science

Connecting Causal Reasoning to Scientific Thinking in Young Children

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