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What Could You Really Learn on Your Own?: Understanding the Epistemic Limitations of Knowledge Acquisition

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Abstract

Three studies explored the abilities of 205 children (5–11 years) and 74 adults (18–72 years) to distinguish directly vs. indirectly acquired information in a scenario where an individual grew up in isolation from human culture. Directly acquired information is knowledge acquired through first-hand experience. Indirectly acquired information is knowledge that requires input from others. All children distinguished directly from indirectly acquired knowledge (Studies 1–3), even when the indirectly acquired knowledge was highly familiar (Study 2). All children also distinguished difficult-to-acquire direct knowledge from simple-to-acquire direct knowledge (Study 3). The major developmental change was the increasing ability to completely rule out indirect knowledge as possible for an isolated individual to acquire.

Keywords

naïve epistemology; *testimony*; *metacognition*

Although we all certainly learn some things on our own through direct commerce with the world, much of what we learn comes secondhand to us through the minds of others, who themselves may have learned through others in a series of chains potentially spanning thousands of steps before they end in the firsthand experience of an individual. Knowledge propagates through social contacts, sometimes through one-to-one encounters, often through real-time, one-to-many broadcasts, and other times through time-delayed means (i.e., books). Technological innovations over the years, such as television, the Internet, and mobile technologies, have continued to amplify access to such information (Richert, Robb, & Smith, 2011). The trust and testimony literature has uncovered the many ways in which even preschoolers are skilled at learning from others and making evaluations about the quality of sources (Harris, 2012; Robinson & Einav, 2014) and is part of a broader surge of interest in the ways we learn from others (Gelman, 2009).

Even adults have difficulty distinguishing between directly and indirectly acquired knowledge, as is well documented in source-monitoring failures and the legal witness

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literatures (Ceci, Huffman, Smith, & Loftus, 1994; Johnson, Hashtroudi, & Lindsay, 1993). Over time, it is all too easy to forget if one learned a piece of information as an eyewitness or through another's testimony. These source-monitoring failures are more frequent in children (Ackil & Zaragoza, 1995; Drummey & Newcombe, 2002; Gopnik & Graf, 1988; O'Neill & Gopnik, 1991; Roberts, 2002) and raise the possibility that even as children massively rely on knowledge transmitted by others, they might not have much awareness of the distinctions between knowledge acquired through others, knowledge acquired through direct interactions with the world, and knowledge acquired merely through inference.

Certain progressions in the child's developing theory of mind may also be related to the emergence of the ability to distinguish indirectly from directly acquired information. In the classic "unexpected contents" task (Gopnik & Astington, 1988), children who make false predictions about what a protagonist thinks is inside, for example, a Smarties container, will also insist they knew the contents of the container all along despite having earlier guessed incorrectly, a phenomenon that robustly occurs across cultures (Wellman, Cross, & Watson 2001). In addition, performance on theory of mind tasks is related to the broader ability to understand the relations between having access to information and having specific forms of knowledge (Evans & Roberts, 2008). For example, 3- to 5-year-old children who pass classic false-belief tasks or succeed in the "tunnel task" where they have to infer if they acquired their knowledge through touch, vision, or testimony (O'Neill & Gopnik, 1991; Whitcombe & Robinson, 2000) are also more likely to incorporate misinformation (along with good information) from an adult who clearly had access to the relevant information source rather than from an adult who did not (Evans & Roberts, 2008). Children who scored lower on theory of mind tasks did not differentiate between naïve and knowledgeable adults. In the same study, theory of mind skills were linked to differences in source monitoring skills as well.

Theory of mind development has also been linked to the hindsight bias in which information that one currently knows can influence what one thinks was known at an earlier time (Roese & Vohs, 2012). In particular, children who show stronger hindsight biases also show more immaturity on theory of mind tasks (Bernstein, Atance, Meltzoff, & Loftus, 2007). Younger children's less developed theory of mind has been proposed to arise at least partly from a fundamental constraint on perspective taking that is also found in hindsight bias, namely a tendency to be influenced by one's current knowledge when trying to recall or evaluate a more naive cognitive state, whether that state is one's own earlier state or that of another mind (Birch & Bernstein, 2007). Similarly, children and adults (to a lesser extent) have been described as laboring under a "curse of knowledge" in which one believes the knowledge in other minds is similar to one's own knowledge (Birch & Bloom, 2007). Given that both the hindsight bias and curse of knowledge continue in diminished forms throughout the lifespan (Bernstein, Erdfelder, Meltzoff, Peria, & Loftus, 2011; Roese & Vohs, 2012), school age children might also be expected to have greater challenges distinguishing direct from indirect knowledge.

Such challenges, however, may not mean that the distinction between directly and indirectly acquired knowledge is hard to understand at a more implicit level. Indeed, the grammatical marking by many languages of directly acquired vs. indirectly acquired knowledge

(Aikhenvald, 2004; Papafragou, Li, Choi, & Han, 2007) suggests that rapid automatic representation of such relations may be commonplace, especially given that over one fourth of the world's languages have such grammatical markers (Aikhenvald, 2004). These “evidentiality” markers clearly convey information that a speaker has either directly experienced information or only acquired it through another. Many languages, such as Turkish, also mark a third route to knowledge, namely acquiring information through inference; here, the speaker acknowledges that a new insight is entailed by other elements of knowledge one possesses (Aksu-Koç, 1988). The ubiquity of such markers raises the possibility that even quite young members of such linguistic communities might also have at least a tacit understanding of such source distinctions as shown by their evaluations of sources who use different markers. It now appears that preschoolers have some abilities to draw such contrasts, even as they also may take years to master all the nuances (Matsui & Fitneva, 2009).

The ability to understand distinctions among sources of knowledge relies in part on grasping the different routes that are possible for acquiring knowledge and the implications and limitations of taking specific routes. Here, children's abilities converge with the evidentiality literature: preschoolers have some sense of perception's special advantages as a source for perception-related understanding (O'Neill, Astington & Flavell, 1992; Taylor, 1988) and, by age four, they understand how different information is transmitted by different sensory modalities (Pillow, 1989; O'Neill & Chong, 2001). Even young children appreciate that someone who has had visual experience has knowledge that another without that experience would not have (Nurmsoo & Robinson, 2009; Poulin-Dubois, Sodian, Metz, Tilden, & Schoeppner, 2007). By age six, children start to integrate this knowledge with a sense of when it is better to choose learning new information by looking directly or by asking others, choosing to look more for knowledge that is based on vision (e.g., color) than for knowledge that is not ascertainable through vision (e.g., if a person knows French; Fitneva, Lam, & Dunfield, 2013). These abilities suggest that, by the early school years, children might be capable of inferring knowledge that must be acquired directly vs. indirectly.

However, an early ability to distinguish direct from indirectly acquired information may be clouded by a bias to assume that more information is learned firsthand than actually is. This may be one reason why even adult researchers traditionally tended to romanticize young learners as “stubborn autodidacts” who resolutely teach themselves through first-hand experience when in fact they acquire massive amounts of knowledge through second-hand means (Harris, 2002). This bias to assume more is learned on one's own than really is may not only be strong in children, but may also endure in adults as the “individualism bias,” in which adults inflate their own roles in gaining understanding (Gelfert, 2011). We often have to remind ourselves of the extent to which we “stand on the shoulders of giants” (Newton, 1676) to support our knowledge acquisition. This bias may have early developmental roots and may be especially strong in younger children because of their bias to be overoptimistic about their present and future competencies (Lockhart, Chang, & Story, 2002) and because of a tendency to assume that even recently acquired information has been known all along (Taylor, Esbensen, & Bennett, 1994).

Assessing the Difficulty of Directly Acquired Knowledge

In addition to the distinction between direct and indirect knowledge, a second potentially more subtle contrast occurs between “easy to acquire” direct knowledge and knowledge that is “difficult but not impossible to acquire” directly. Thus, while in principle, one might be able to directly learn information such as which bees in a garden are capable of flying the fastest, the actual gathering of such information might pose major challenges for any one person who would have great difficulty keeping track and making detailed comparisons. Young children would know less about the logistical challenges inherent in gathering some kinds of directly acquired knowledge and might therefore make quite different judgments from adults about the plausibility of single individuals directly acquiring logistically challenging information on their own.

Classic studies on metacognition also suggest that young children might have difficulty understanding the challenges of certain forms of information acquisition when that information is, in principle, directly acquirable. For example, preschoolers and young school children tend to grossly overestimate their working memory capacities and will cheerfully assume they can remember an unrealistically large number of serially presented pictures (Yussen & Levy, 1975). Such misestimates result in not dedicating enough time to studying information and therefore having a worse memory performance (Dufresne & Kobasigawa, 1989). This prediction error may be influenced by the overoptimism bias described earlier, but it also may reflect the difficulties faced by young children when introspecting about the challenges of cognitive tasks and examining their own knowledge independently from simply using it. These metacognitive skills are also related to early emerging theory of mind skills (Lockl & Schneider, 2007) and show how more sophisticated senses of the mind may be required to understand why some forms of knowledge may be difficult to acquire on one's own.

The ability to assess one's own knowledge accurately is an important component in the ability to comprehend both spoken and written discourse (Flavell, Speer, Green, August, & Whitehurst, 1981; Markman, 1977). If one fails to assess the degree to which one's knowledge is incomplete, one may fail to ask for clarifications when needed or draw unwarranted inferences based on too little information (Robinson & Robinson, 1982; Robinson, Rowley, Beck, Carroll & Apperly, 2006). Adults also fail to understand the shallowness of their own explanatory understanding (Alter, Oppenheimer, & Zemla, 2010; Rozenblit & Keil, 2002), and children show an even larger mismatch between estimated and actual understanding (Mills & Keil, 2004). Young children may have special difficulties with partial knowledge. They may understand the consequences of complete ignorance but may have difficulty calibrating the extent to which knowledge is complete when there is clearly some knowledge present, perhaps because they use immature heuristics that give them a false sense of competence (Rohwer, Kloo & Perner, 2012).

Taken together, the literature on children's knowledge self-assessment abilities points to limited skills early on that grow considerably during the early school years, growth that may be mediated by an increasingly sophisticated understanding of how the mind acquires knowledge and the logistical challenges that certain tasks can impose on attentional, reasoning, and memory skills. This pattern then leaves open the question of just how much understanding is needed to evaluate cases of "easy to acquire" vs. "hard to acquire" direct knowledge. Would young children simply accept all cases of direct knowledge as attainable regardless of difficulty or, even with more limited insights, would they nonetheless be able to take into account the variable difficulty levels of direct knowledge? This question also relates to whether young children are capable of intellectual humility. If children have difficulties distinguishing the learnability of easy from hard direct knowledge and if they also have a youthful overoptimism, the resulting combination might result in intellectual arrogance about both themselves and their peers.

To explore these questions, we developed a new task that specifically focused on the contrast between a completely self-taught person and a culturally embedded person. Our goal was to try to make as clear as possible a situation where a person could only acquire knowledge directly and to then see how easily participants could rule out indirectly acquired knowledge. Studies 1 and 2 explore the developing ability to distinguish direct from indirect knowledge through a "deserted island" scenario in which a healthy child grows up on an island without any input from others. Study 3 then asks if children can also distinguish easy from difficult to acquire direct knowledge at the same time as direct from indirect knowledge, or whether that skill takes more time to develop. Based on the literatures showing that even preschoolers have some sense of the distinct ways that perception guides one towards particular forms of knowledge, we predicted that young children would be able to distinguish direct from indirect knowledge but that they would be more error-prone for indirect knowledge that was very familiar to them. With respect to easy- vs. difficult-to-acquire direct knowledge, given that even 5-year-olds make consistent judgments about the relative difficulty of understanding different domains of phenomena (Keil, Lockhart, & Schlegel, 2010), we predicted that they would have fragile, but present skills—skills that would show improvement as the children come to understand more clearly the challenges of acquiring some forms of direct knowledge.

Study 1: Direct vs. Indirectly Acquired Knowledge

Study 1 explored the simplest contrast between direct and indirectly acquired knowledge with a particular focus on whether the ability to judge the feasibility of successful knowledge acquisition emerged earlier for direct or for indirectly acquired knowledge. We predicted more developmental growth for judgments about indirectly acquired knowledge. In cases where both forms of knowledge were highly familiar to young children, they might see even clearly indirect knowledge as somehow acquirable through first hand experience by focusing too heavily on familiarity as a heuristic for inferring that another person must also have that knowledge.

Method

Participants—Twenty-five kindergarteners (12 females; M_{age}=5:7, age range: 5:0–6:2), twenty-five second graders (18 females; M_{age}=7:7, age range: 7:1–7:8), twenty-four fourth graders (13 females; M_{age}=9:8, age range: 9:2–10:6), and twenty-five university students (17 females; M_{age}=18:5, age range: 18–20) participated in the study, conducted from October–December 2007. The children were recruited from elementary and middle schools in a northeastern metropolitan area with a median family income of $62,000. The child sample included approximately 75% European American children, 13% African American children, 6% Asian American children, and 6% children of other ethnicities. The adult sample was approximately 57% European American, 9% African American, 20% Asian American, and 14% other ethnicities.

Materials—A total of 31 stimulus items were prepared, 18 of which described knowledge that can only be acquired secondhand, such as knowledge about invisible processes or things (e.g., germs), historical figures or events (e.g., dinosaurs or George Washington) and 13 of which described knowledge that could be acquired first-hand through perception (e.g., that the sky is blue) or through personal experience (e.g., that one sleeps when one is tired). Knowledge that could be acquired first-hand through perception is hereafter described as a "direct item" and knowledge that could only be acquired secondhand is hereafter described as an "indirect item." The indirect items covered topics ranging from natural phenomena to artificial phenomena to social institutions and included both procedural (e.g., how to read) and declarative forms of knowledge (e.g., that the earth is round). A larger number of indirect items were included in the stimulus set to ensure that younger children had a rich array of indirect cases to consider and to counter potential floor effects if the younger children found it more challenging to see indirect knowledge as unknowable. All direct and indirect items were piloted with eight adults who uniformly judged them in the intended manner. The full set of stimuli is shown in Appendix S1.

Procedure—Each session started with a practice period during which the experimenter described a scenario in which a boy was a baby when the plane he was in crashed on a deserted island where no other people had ever been. His mother was the only other survivor, and although she could take care of him and get him all the food he needed, she suffered injuries such that she could not communicate with her child in any way. The story then described the individual after twenty years as full grown, very healthy, very smart, and very happy as a young man. The participant was then taken through a series of three practice questions asking if the deserted island man would or would not know things, the first of which he would know (knowing it was harder to see things when it was dark out) and the last two he would not know (that iPods play music and how to speak Spanish). For all practice questions, regardless of whether the child answered in a manner consistent with adult intuitions, the experimenter gave adult-normed feedback indicating that the young man in fact would know or would not know the item followed by a very brief explanation that he either could not have encountered the information or would have encountered it (e.g., "He would not know for sure that iPods play music because there are no iPods on the island and no one to tell him about them"). Four members of the youngest age group of participants were dropped from the study and replaced either because of perseverative responding or an unwillingness to complete the task. No participants in any of the older age groups were dropped and replaced.

The test items were assessed using a two-step procedure: (1) the experimenter asked if the young man would know or not know the information conveyed by the item; and (2) if participants said that the deserted island man would know the information, they were asked if he would "probably know" the information or if he would "know it for sure." Those participants who said that the young man would not know the information were asked if he "probably would not know" the information or if he "would not know it for sure." After developing familiarity with the three practice items, each participant was then given the 31 stimulus items in a random order using the two-step procedure. All participants were interviewed individually, with the experimenter reading each stimulus item aloud and then asking about the item using the two-step procedure. Adults were interviewed in the experimenters' laboratory, and interviews lasted approximately 15 minutes each. Children were interviewed outside of their classroom with each session lasting approximately 30 minutes.

Scoring—Participants' "would know" responses were scored either 4 (*would know for sure*) or 3 (*would probably know*) and their "wouldn't know" responses were scored either 2 (*would probably not know*) or 1 (*would not know for sure*). These scores were then averaged for both direct and indirect items, resulting in two scores for each participant ranging from 1 to 4.

Results

A 2×4 repeated measures ANOVA was used to analyze the data, with knowledge type (Direct, Indirect) as the within-subject factor and grade (K, 2, 4, Adults) as the between-subject factor. Effect size estimates were computed using partial eta squared.

The ANOVA yielded a main effect of grade, $F(3,95) = 6.27$, $p < .001$, $\eta 2 = .165$. The youngest children were the most optimistic, believing that the deserted island man would know more overall than the fourth graders and adults believed he would know, K*M* (2.83, *SD* =.51)) > 4^{th} *M* (2.55, *SD* =.33) = Adult *M* (2.51, *SD* =.19), K = 2^{nd} *M* (2.63, *SD* =.37), *Bonferroni*, $p < .007$. A main effect of knowledge type revealed that overall participants expected the deserted island man to know more direct knowledge items than indirect knowledge items, $F(1,95) = 1253.28$, $p < .001$, $\eta 2 = .930$, Direct *M* (3.50, *SD* =.39) > Indirect *M* (1.78, *SD* =.56). Follow-up paired sample t-tests indicated that participants at all grade levels—even the youngest age group—clearly distinguished the ease of knowing direct from indirect items, all *t*s (22,24,23,24) > 6.88, all *p*s < .001, Direct > Indirect (see Figure 1). In fact, 17 out of 18 items judged by adults as indirectly acquired were judged by the kindergarten age group as less likely to be learned firsthand than the lowest scoring of the 13 items judged likely to be learned directly—almost a perfect non-overlap of judgments for the 31 items.

A significant Grade x Knowledge interaction was also found, $F(3,95) = 46.75$, $p < .001$, $\eta 2 = .596$. Subsequent ANOVAs examining age differences for the two knowledge types showed that scores for direct knowledge increased moderately with age, Direct Knowledge: $F(3, 95) = 7.29$, $p < .001$, $\eta 2 = .187$, K < 4^{th} = Adult; K = 2^{nd}, *Bonferroni*, $p < .05$ (see Figure 1), while the scores for the indirect items fell sharply over development, Indirect Knowledge: $F(3,95) = 37.13$, $p < .001$, $\eta 2 = .540$, K > 2^{nd} > 4^{th} = Adult, *Bonferroni*, $p < .03$ (see Figure 1). Overall, the ability to distinguish between direct and indirect knowledge acquisition was more robust with increasing age, an effect mediated primarily by the decrease in indirect knowledge scores.

Discussion

Study 1 shows that the youngest children were the most optimistic about how much knowledge overall could be acquired on the deserted island. However, even the youngest participants agreed strongly with adults about what kinds of knowledge could be learned on one's own. Mean judgments for the 18 indirect items only overlapped in one case with the lowest scoring of judgments for the 13 direct items, suggesting that children differentiated between these two types of knowledge. As expected, the distinction made between directly acquired and indirectly acquired knowledge became more robust with age. In addition, although the indirect items were not systematically selected for high vs. low familiarity, the two indirect items that kindergarteners rated as most knowable ("Your body needs vitamins to stay healthy" [$M = 3.04$] and "Germs make people sick" [$M = 2.80$]) may well have been more familiar to young children than the two items rated as least knowable ("Stars are very hot" [$M = 1.88$] and "There are 7 continents" [M: 2.00]). This difference suggests that young children might believe highly familiar indirect knowledge can be acquired first hand, which is explored in Study 2.

Study 2: Contrasting Known and Unknown Indirect Knowledge with Direct Knowledge

Study 1 found an early ability to understand what kinds of knowledge are acquired first hand as opposed to acquired from the testimony from others. In addition, there was a suggestion that younger children sometimes see familiar adult-judged indirect knowledge as direct. Study 2 pursued these findings through three modifications of the stimuli: First, the indirect stimuli were divided into two kinds: (a) Unknown Indirect: items for which an average child would have minimal knowledge (e.g., how to build a roller coaster) and (b) Known Indirect: items for which an average child would have ample knowledge (e.g., how to play video games). This contrast was included to see if the success of younger children was driven by their introspecting on things they knew a lot about versus things they knew nothing about. Their judgments would be much more impressive if they could make the direct/indirect contrast even for indirect knowledge that they were intimately familiar with. This is a way of testing biases introduced by factors related to "curse of knowledge" and hindsight bias effects. Second, the training was simplified to two examples and the deserted island was described as heavily populated with naturally occurring plants and animals to ensure that children were not thinking about a barren environment. Finally, all new items were created to test the generality of the results found in Study 1.

Method

Participants—Twenty-seven kindergarteners (13 females; M_{age}=5:11; age range 4:11–6:8), twenty-eight second graders (16 females; M_{age}=7:5, age range 7:1–8:2), twenty-five fourth graders (10 females; M_{age}=9:6; age range 8:11–11:2), and twenty-six university students (18 females; M_{age}=18:8; age range 18–21) participated in this study, conducted from January to May 2008. Children were recruited from schools in a northeastern metropolitan area with a median family income of $62,000. The child sample included approximately 75% European American children, 13% African American children, 6% Asian American children, and 6% children of other ethnicities. The adult sample was 57% European American, 9% African American, 20% Asian American, and 14% other ethnicities.

Materials—A total of 24 stimulus items were prepared, 6 that described knowledge that could only be acquired second hand and which young children knew well, such as “How to say the Pledge of Allegiance” (Known Indirect); 6 that described indirect knowledge that children would not know well, such as “How to fly a helicopter” (Unknown Indirect); and 12 items that described knowledge that could be acquired first-hand through perception—e.g., “That birds fly”—or through personal experience—e.g., “How to run” (Direct). Given the high levels of performance on indirect items by even the youngest children in Study 1, there was no perceived need to have more indirect items and thus the total number of indirect items was the same as the total number of direct items. All direct and indirect items were piloted with eight adults who uniformly judged them in the three ways. The full set of stimuli is shown in Appendix S2.

Procedure—The procedure was the same as that used in Study 1 except that two practice questions were used instead of three. The first item deserted island man would know (knowing that he couldn't hold his breath for an entire day) and the second he would not know (knowing how to play dodge ball). These were different practice items from the practice items used in Study 1 and served to check whether particular practice items had an effect on the results. Only two practice items were used because most children in the first study seemed to fully grasp the task and a shorter practice session made the overall task briefer. Three members of the youngest age group of participants were dropped from the study and replaced because of either perseverative responding or an unwillingness to complete the task. No participants in any of the older age groups were dropped and replaced. Each participant was interviewed individually and presented with all 24 stimuli items in a random order. Adults' interviews lasted approximately 15 minutes and children's interviews lasted approximately 30 minutes.

Scoring—Responses were scored in the same way as in Study 1. Average scores for all the direct items, all known indirect items, and all unknown indirect items were calculated for each child. Thus, each child had three average scores that could vary from a value of 1(*would not know for sure*) to a value of 4 (*would know for sure*).

Results

A 3×4 repeated measures ANOVA was used to analyze the scores, with knowledge type (Direct, Known Indirect, Unknown Indirect) as the within-subjects factor and grade (K, 2, 4, Adults) as the between-subject factor. Effect sizes were computed using partial eta squared.

A main effect of grade, $F(3, 102) = 9.82$, $p < .001$, $\eta 2= .224$, showed that the youngest children were once again the most optimistic about how much deserted island man would know. Kindergarteners were more likely than the second graders, fourth graders and adults to believe that deserted island man would know more of the items, K *M* (2.25, *SD* = .46) > 2nd *M* (2.06, *SD* =.32) = 4th *M* (1.96, *SD* =.25) = Adult *M* (1.99, *SD* = .18), *Bonferroni*, $p < .01$.

As in the previous study, there was a main effect of knowledge type, $F(2, 102) = 1646.34$, $p < .001$, η2 = .94, and a significant Grade x Knowledge Type interaction, $F(6, 102) = 21.66$, $p < .001$, η2 = .39. Overall, participants expected deserted island man to know more direct knowledge items than known indirect and unknown indirect knowledge items, which did not differ from one another, Direct *M* (3.43, *SD* =.35) > Known Indirect *M* (1.43, *SD* = .46) = Unknown Indirect *M* (1.35, *SD* =.35), *Bonferroni*, $p < .001$. Subsequent analyses using repeated measures ANOVAs (Knowledge Types) at each grade level showed that all ages, even the kindergarteners, easily grasped the contrast between directly acquired knowledge and indirectly acquired knowledge, all *F*s (2, 52/54/48/50) > 114.41, all *p*s < .001, all η2 > .814, All grades: Direct > Known Indirect, Unknown Indirect (See Figure 2). All grades did not distinguish between the difficulty of acquiring known indirect v. unknown indirect knowledge, with the exception of fourth graders, who believed the deserted island man would have more knowledge of known indirect than unknown indirect items, 4th grade: Known Indirect *M* (1.27, *SD* =.29) > Unknown Indirect *M* (1.15, *SD* =.19), $p = .04$, *Bonferroni* (see Figure 2).

Consistent with the first study, the Grade X Knowledge Type interaction reflected a greater tendency of the younger children to judge some indirect items as learnable on one's own. Thus, the overall ability to make the contrast between directly and indirectly acquired knowledge improved with age. Subsequent ANOVAs comparing grade differences within types of knowledge showed that with increasing age, participants believed the deserted island man would acquire less indirect knowledge of both types, and by fourth grade, there was no difference between the scores of the children and adults for both types of indirect knowledge, Known Indirect: $F(3,102) = 15.94$, $p < .001$, η2 = .319, *K* > 2nd, 4th, and Adult, 2nd > Adult, 4th = Adult; Unknown Indirect, $F(3,102) = 24.29$, $p < .001$, η2 = .417, K > 2nd, 4th, and Adult, 4th = Adult, *Bonferroni*, all *p*s < .05 (see Figure 2). For direct knowledge, there was a slight increase with age: The adults believed the deserted island man would know more direct knowledge items than the children thought he would, Direct: $F(3, 102) = 11.21$, $p < .001$, η2 = .248, Adults > 4th = 2nd = K, *Bonferroni*, $p < .05$.

Discussion

Study 2 shows again that even kindergartners differentiate information one could acquire through direct experience with the world from information one could only learn from outside sources. This finding stands in contrast to children's documented challenges in sensing the difference between being experts on causally dense and causally empty categories (Keil, 2010). Additionally, the results of Study 2 suggest that children are not relying on a simple heuristic of judging anything they know well as something they could acquire on their own, a pattern that might be predicted by strong versions of the curse of knowledge and hindsight bias effects. Instead, they look past how well they know something at the moment to ask how it might be acquired and whether it does or does not need support from other minds. The results also indicate that young children can reason quite accurately about knowledge abilities in a specific context, namely, the inputs that a person would receive on a deserted island. Finally, the primary developmental change of more strongly rejecting the indirect items as knowable was largely complete in fourth graders, who were similar to the adults in their judgments.

Study 3: Contrasting Indirect Knowledge with Easy- and Difficult-to-Acquire Direct Knowledge

Studies 1 and 2 show that, in the deserted island scenario, young children were able to detect knowledge one could acquire directly on one's own vs. indirectly through cultural transmission, even when the second-hand knowledge was highly familiar to most children. Yet, young children might still misunderstand the extent to which one could acquire knowledge on one's own either in terms of breadth, depth, or both. They could be using a heuristic that checks whether information is capable of being acquired solely on one's own in an environment free of culturally transmitted information. To be sure, this is not a trivial skill as it requires a sense of how knowledge is acquired and must override mere familiarity of known information by considering the route that was needed to acquire such information; however, a sole focus on indirect vs. direct routes would be insensitive to the actual challenges of acquiring some forms of direct knowledge. Thus, there is a second dimension of evaluation consisting of an appreciation of information that is technically learnable on one's own but which is pragmatically unlikely due to factors such as cognitive load, attentional challenges and information availability. As noted earlier, young children may have only limited grasps of the logistical challenges inherent to knowledge acquisition; thus, they might be able to accurately judge that the deserted island man could not know indirectly acquired information while being relatively insensitive to the distinction between easy-to-learn versus difficult-to-learn directly acquired information.

Even though younger children surely have a cruder sense of the logistical, cognitive and perceptual challenges of directly acquiring some forms of knowledge, they still might have coarser hunches about information that while in principle is directly acquirable, might be especially difficult to learn on one's own. Young school children, and even preschoolers, do detect relevant areas of deference to experts (Danovitch & Keil, 2004; Lutz & Keil, 2002; Koenig & Jaswal, 2011), suggesting an appreciation that expertise leads to greater knowledge about more complex information in a domain. In addition, young school children consistently make evaluations of the relative difficulty of having knowledge in different broad domains such as the physical and biological sciences (Keil et al., 2010) and, while they rate relative difficulties somewhat differently from adults, they clearly believe that some forms of information are more difficult to acquire than others.

These strands of research suggest that young children might distinguish hard from easy-to-acquire direct information while also judging both to be more plausibly acquired by the deserted island man than indirect information. However, given that young children know less about the nature of learning and its associated challenges, we also predicted that they would not see as large a contrast between easy- and hard-to-acquire information as older children would.

Method

Participants—Twenty-six 5- to 7-year-old children (15 females; M_{age}=6:4; age range: 5:1–7:8), twenty-five 8- to 10-year-old children (13 females; M_{age}=9:2; age range: 7:11–11:0), and twenty-five adults (9 females; M_{age}=33:0, age range: 18–72) participated in the study, conducted from January to June 2014. The children were recruited at local science and children's museums in a northeastern suburban area with a median family income of $77,000. The child sample included 65% European American children, 8% Asian American children, 6% Hispanic children, 4% African American children, and 17% children of other ethnicities. Adults were from the United States and run online through Amazon's Mechanical Turk Interface. The adult sample was approximately 72% European American, 20% African American, 4% Asian American, and 4% other ethnicities.

The two children's age groups were chosen because Studies 1 and 2 suggested that the strongest developmental transition happened between children 7 and younger and those 8 and older and because the children were run during the summer months when grade assignment is more difficult. The use of adults who were Mechanical Turk workers further tested the generality of our findings by moving away from college student populations.

Materials—A total of 12 stimulus items related to biological knowledge were prepared: 4 of which described knowledge that could easily be acquired first hand (e.g., “Some animals are awake during the day but sleep at night while other animals are awake in the night but sleep during the day.”), 4 of which described direct knowledge that could be acquired first hand but with difficulty (e.g., “Ants walk in a zigzag when searching for food but walk in a straight line when going back home.”), and 4 items that described knowledge that could only be acquired indirectly (e.g., “Bats hear really high pitched sounds that people can't hear at all.”). The stimulus items differed from Studies 1 and 2 in order to further test the generality of the results. The 4, 4, 4 distribution of item types was designed to evenly sample each of the three types of knowledge.

All items were piloted with 25 adults who uniformly judged the easy direct as easiest to acquire on one's own, followed by the hard direct, followed by the indirect which were judged by adults as essentially impossible to acquire on one's own. All items were from the domain of biology to minimize any differences among items other than complexity and directness.

As a further check to ensure that all knowledge items were judged as easy to learn in terms of intrinsic complexity of the phenomena themselves, a study was conducted with 25 adults using a scenario of a blind child growing up in a contemporary Western culture who was in essence learning all the items indirectly, through non-visual means. All three types of items were judged to be “easy” to learn through testimony by a 12 year old blind child who had exposure before age 4 to shapes and colors (1 = *very hard to learn* to 4 = *very easy to learn*; Easy Direct M (3.22, SD =.542); Hard Direct M (2.92, SD = .636); Indirect M (3.08, SD = .706), all one-sample ts (24) > 3.30, p < .004, 2.5 = test value). The full set of stimuli is shown in Appendix S3.

Procedure—Each session started with a training period during which a scenario was described in which the participant was asked to imagine a man who grew up all alone on an island ever since he was a tiny baby with nobody else to talk to or teach him things. This scenario varied from that used in Study 1 and Study 2 because piloting with young children revealed that the information about the injured mother was not needed to keep the story plausible. The story then described the boy after twenty years as a full grown young man, who was very healthy, and very happy on the island, which was full of plants, animals, and insects. The participant was taken through a series of three practice questions asking whether the island man would or would not know things, one of which he would know (knowing that he couldn't hold his breath for entire day) and two that he would not know (knowing how to play basketball and knowing who Spongebob Squarepants was). Because we had modified the scenario and because the overall task had fewer items, we decided to use three practice items once again to ensure that the task was clear to the children. Eight of the youngest children were eliminated from the study and replaced because of purely perseverative responding (4) or a desire to stop the task before completion (4). No other participants were replaced in the other age groups.

Following the practice phase, participants were asked to rate the 12 knowledge items using the same two-step procedure employed in Studies 1 and 2 with the small change that “for sure” was changed to “definitely” in the second step (i.e., 1 = *he definitely wouldn't know*; 2 = *he probably wouldn't know*; 3 = *he probably would know*; 4 = *he definitely would know*). Piloting with young children revealed that they easily understood the “definitely” phrasing, which seemed a more natural and colloquial way of speaking than the “for sure” phrasing used in Studies 1 and 2. Each participant was given all 12 stimuli items in a random order.

Children were interviewed individually with each session lasting approximately 15 to 20 minutes. Adults completed the survey online through Amazon's Mechanical Turk. The average survey completion time was 16 minutes.

Scoring—Responses were scored in the same way as in the other two studies. Average overall scores for the easy direct items, the difficult direct items, and the indirect items were calculated for each child. Thus, each child had three scores that could vary from a value of 1 (*definitely wouldn't know*) to a value of 4 (*definitely would know*).

Results

A 3X3 repeated measures ANOVA was used to analyze the scores, with knowledge type (Easy Direct, Hard Direct, Indirect) as the within-subject factor and age (5 -7, 8 -10, Adults) as the between-subject factor. Effect size estimates were computed using partial eta squared.

The ANOVA revealed a significant main effect of knowledge type, $F(2,146) = 273.84$, $p < .001$, $\eta 2 = .790$, a significant main effect of age, $F(2, 73) = 4.99$, $p < .01$, $\eta 2 = .12$, as well as a significant Age x Knowledge Type interaction, $F(4,146) = 13.16$, $p < .001$, $\eta 2 = .265$. Participants overall believed the deserted island man would acquire more “easy direct” knowledge items than “hard direct” knowledge items; moreover, they judged “indirect” knowledge items as the hardest to acquire on one's own, Easy Direct *M* (3.41, *SD* = .45) > Hard Direct *M* (2.64, *SD* =.56) > Indirect *M* (1.79, *SD* =.77), *Bonferroni*, all *p*s < .001.

Separate repeated measure ANOVAs by age group found that all ages distinguished between the three types of knowledge in this same way, all *F*s (2,50/48/48) > 31.66, $p < .001$, Easy Direct > Hard Direct > Indirect, *Bonferroni*, all *p*s < .007 (see Figure 3).

The significant age effect showed that the youngest children gave higher overall ratings of how much could be learned by the deserted island man, 5-7 *M* (2.83, *SD* =.57) > 8-10 *M* (2.53, *SD* =.37) = Adult *M* (2.47, *SD* =.32), *Bonferroni*, $p < .05$). However, as shown by the significant Age X Knowledge interaction, this main effect of age was primarily driven by age differences in judging the indirect knowledge items.

Separate ANOVAs for the three types of knowledge revealed a strong age effect for "indirect" knowledge, $F(2,73) = 14.76$, $p < .001$, $\eta 2 = .288$, a modest age effect for "easy direct" knowledge, $F(2,73) = 3.53$, $p = .03$, $\eta 2 = .09$, and no age effect for "hard direct" knowledge, $F(2,73) = 2.00$, $p = .15$, $\eta 2 = .05$. As seen in Figure 3, the tendency to judge indirect items as learnable on one's own decreased sharply with age, Indirect: 5-7 > 8-10 > Adults, *Bonferroni*, $p < .05$. In contrast, the age differences in judgments about direct knowledge were minimal, Easy Direct: Adults > 8-10, p = .03; 5-7 = 8-10, Adults, *Bonferroni*, $p > .470$; Hard Direct: 5-7 = 8 -10 = Adults, *Bonferroni*, $p > .209$ (see Figure 3).

Discussion

Study 3 again demonstrates that young school children are able to distinguish directly acquired from indirectly acquired forms of knowledge when evaluating what a culturally isolated child might learn over development. The predominant developmental shift was an increasingly stringent exclusion of the learnability of indirect information, with the youngest group of children making more judgments of indirect knowledge learnability than the two older groups, but with the 8–10 year olds also making considerably higher learnability judgments than adults.

The ability to fully rule out the learnability of indirectly acquired knowledge therefore seems to take many years to fully develop. There were no major developmental differences in judgments of the deserted island man's ability to acquire hard direct knowledge. We expected that younger children might treat easy direct and hard direct items more similarly than the older participants would. However, all age groups clearly saw a contrast between the learnability of easy direct and hard direct knowledge, and moreover, within each knowledge type, there were minimal developmental differences. Except for a modest age difference between 8–10 year olds and adults on the easy direct items, there were no differences between age groups in their judgments of how much easy direct knowledge the deserted island man could learn nor were there age differences in how much hard direct knowledge the deserted island man could acquire.

General Discussion

Even young school children have a clear sense of the kinds of direct knowledge an individual could acquire growing up on their own in isolation from any cultural influences as opposed to indirect information that requires cultural transmission of some sort. They do so for a wide variety of topics that cut across domains such as biology, physics, and psychology and that can be either declarative or procedural in nature. The contrast becomes somewhat stronger with age, but that developmental change is modest in comparison to the contrast itself. The developmental change that does occur consists primarily of the increased exclusion of indirect items as at all learnable by the culturally isolated protagonist; little changes over development with respect to judgments about directly acquired knowledge. Furthermore, young children do not seem to be making the contrast between direct and indirect knowledge on the basis of a familiarity heuristic in which they judge information that they know well themselves to be learnable by the isolated protagonist. Thus, in Study 2, indirect items that were highly familiar to U.S. school children (e.g., how to say the Pledge of Allegiance) were judged just as unlikely to be learned as were highly unfamiliar items (e.g., how to fly a helicopter), with both types of indirect items showing a strong contrast to the direct items (e.g., how to cool himself off if he is hot). The direct/indirect contrast is therefore obvious to young children even when pitted against competing factors. Young children easily distinguish culturally transmitted knowledge from culture-free knowledge, at least in scenarios that clearly contrast the two and where they are acting as third party judges.

A different dimension of knowledge evaluation concerns complexity of the learning process itself. Thus, for directly acquired knowledge, some kinds of knowledge would be exceedingly challenging to acquire on one's own whereas other kinds would be trivial. We thought that the ability to see such a complexity-based contrast might be present but more limited in younger children because of an immature ability to think about the technical demands of knowledge acquisition, such as memory and attentional loads. To our surprise, young children were just as adept as older children and adults in distinguishing the easy- to-learn direct knowledge items from the hard-to-learn ones while at the same time clearly seeing both forms of direct knowledge as more feasible to learn than indirectly acquired knowledge. Certainly, subtly complex learning tasks might be contrived that could cause children to overestimate the ease of learning hard-direct knowledge, but these same items might also be overestimated by most adults. Assessing learning tasks that require more complex theory of mind skills might be one case where developmental differences could appear. Higher order recursive theory of mind skills that develop during early and middle school years (e.g., Liddle & Neddle, 2006) might be needed for understanding the cognitive demands of acquiring information that depends on multiple interactive cycles (such as appreciating the difficulty of knowing how a rumor started in a town).

Two major questions arise from these results: What are the cognitive competencies that enable young children to do so well on these tasks, and what explains the developmental changes that are observed with respect to indirect knowledge? Answers to these two questions have implications that extend far beyond the deserted island task.

The first area of competency, contrasting direct from indirect knowledge, would seem to require a careful monitoring of the situation in which the isolated protagonist is embedded and drawing inferences about what information would not be available in that situation. At first, this seems relatively straightforward—one has simply to realize that entities such as video games are not present—but such realizations must arise from inferences based on the simple statement that the protagonist is on an island where no other people have ever been.

To then rule out the learnability of video game playing, the Pledge of Allegiance, the presence of germs and countless other items, participants have to have a clear idea of all the different sorts of information that are cultural constructions and to override the strong sense of knowing that accompanies highly familiar but indirect information. This requires knowing not only objects that are made by other humans, but also knowledge that requires tools not available to an isolated individual. Apparently, these multiple facets of the problem are easily available to children right at the beginning of formal schooling.

Children at least as young as four years are quite sensitive to the distinction between artifacts and natural kinds and know that artifacts and their properties originate in different ways than natural kinds (Gelman & Kremer, 1991; Keil, 1989). Even more subtly, four-year-olds refer to human histories associated with some objects to explain their ownership but not their use, suggesting an ability to track how different facets of entities came into being (Nancekivell & Friedman, 2014). Here, children were able to combine these inferences about human contributions to origins of entities with reasoning about human histories of access to that information as well. To understand that the deserted island man would not know about germs or that the earth is round requires knowing that, although these facts exist independently of human activity, cultural artifacts and groups are required to have that knowledge.

The ability to distinguish easy direct from hard direct items would seem to require different cognitive abilities of the young child. All of the direct items were naturally available patterns to the isolated protagonist and were in principle learnable on one's own. In practice, however, the hard direct items were implausible to learn by a single individual. Given that children have more limited insights into the workings of the mind, their ability to successfully contrast the easy direct items from the hard direct items at the same level as adults is impressive. Based on comments made by some child participants, they seemed to imagine themselves in the isolated context and then consider step-by-step the challenges of collecting the relevant information. Thus, one six-year-old child said that deserted island man would not know that ants walk in a zigzag when searching for food but walk in a straight line when going back home because “He probably just thinks ants walk all over the place”; another six-year-old said the man would not know the difference between the island monkeys' alarm calls because “He knows the three calls are different but would not know the meaning, like another language.” Their ability to engage in such reasoning suggests a possible way to leverage children into other metacognitive insights relevant to educational contexts. For example, a child who is not fully aware of the metacognitive challenges of a memory task might be helped into such an awareness by asking her to imagine a peer who has to keep track of a complex array of information in a highly constrained environment. Apparently, reasoning about such factors in other minds is easier, especially in situations such as the deserted island scenario that makes more salient the challenges of difficult direct knowledge as well as the direct vs. indirect knowledge contrast.

The major developmental shift across all three studies was that of younger children showing a stronger tendency to allow for the possibility of some indirect knowledge being acquired directly. While clearly distinguishing the two forms of knowledge, younger children nonetheless sometimes thought that indirect forms were learnable by the isolated child. One reason for such judgments may be reduced executive processing in younger school children, a limitation that has not only been well documented across many tasks (Zelazo, Carter, Rezinck & Frye, 1997), but that has been increasingly implicated in the testimony literature (Jaswal & Pérez-Edgar, 2014; Jaswal, Pérez-Edgar, Kondrad, Palmquist, Cole & Cole, 2014). In that context, much of the discussion has focused on the development of inhibitory control over what one observes and/or believes and what one hears through testimony. Here, one might extend that idea to conflicts between what one clearly knows oneself and what another could know given a more limited environment. Sometimes, younger children may find highly well-known indirect information to be so immediately available that they have difficulty inhibiting that feeling of their own knowing when taking into account another's situation. This process is, of course, also closely related to the previously discussed curse of knowledge and hindsight bias effects in which false belief task performance has been described as influenced by the “curse” of knowing something oneself and being unable to inhibit extending that attribution to others. This explanation, however, is somewhat weakened by the lack of a familiarity effect in Study 2.

The finding that young children contemplating the deserted island scenario are able to easily contrast both direct and indirect knowledge as well as easy and hard direct knowledge does not mean that children, and adults for that matter, might not also be highly susceptible to an individualism bias in which they assume that they learned far more on their own than they actually did. The cases here sharply contrasted direct with indirect knowledge, but in the real world, many instances of knowledge could be learned either directly or indirectly and sophisticated source monitoring may be needed to know what actually happened. It may be that engaging in thought about scenarios involving individuals isolated from cultural influences can help sharpen such insights, but there still may be a strong bias to infer self-taught knowledge even when that is highly improbable. This bias could lead to younger children possessing far less intellectual humility than older children about the extent to which their understanding of the world depends on others.

The developing ability to distinguish one's own capacity for knowledge from others has implications for a wide variety of situations, especially in more naturalistic settings where both direct and indirect ways of acquiring certain information are plausible. Thus, developmental and individual differences in this ability might influence the effectiveness of teacher-student interactions where the student is miscalibrated about what is learnable on one's own. Fortunately, because even the youngest children in this study were able to easily distinguish most direct items from indirect ones, such miscalibrations should not completely overwhelm school children at any age even if they are a factor. In the social realm there might also be consequences for differences in the ability to clearly know one's own knowledge capacities from those of others. Because younger children may think that social phenomena are especially easy to grasp through direct experience (Keil et al., 2010), they might be especially overconfident about their abilities to anticipate and understand the psychological states of others. Inaccurate assessments of this sort might influence peer relationships, bullying, empathic responses and how others are evaluated. Given that theory of mind skills are related to peer acceptance even in preschool children (Slaughter, Imuta, K., Peterson, & Henry, 2015), it is possible that more subtle effects may continue into the school years that involve relations between knowledge assessment skills and social functioning. All of these possible linkages are intriguing areas of future investigation.

One possible limitation of these studies was that the stimulus items did not have the same average length across item types, especially in Study 3. When measured as word length, item complexity did vary across category types. In Study 1, direct items averaged 8.5 words in length and indirect items 6.2 words. In Study 2, direct items averaged 7.0 words in length, 6.5 words for indirect familiar, and 6.0 for indirect unfamiliar. For Study 3, direct easy items averaged 10.8 words per item, 16.25 for direct difficult, and 7.8 for indirect impossible. It is not obvious, however, how these differing values contaminated the results given the patterns in the data. In addition, there is no relation between item length and scores within any item category despite considerable variation. For example, in Study 3 there was no significant difference in scores between the shortest difficult direct item (dolphins, 11 words) and the longest (monkeys, 20 words). Nonetheless, more precisely balanced item lengths would be a desirable component in future studies. Another limitation is the use of online MTurk adult participants in Study 3 who participated by reading written descriptions of the stimuli as opposed to hearing verbal stimuli as the adults in Studies 1 and 2 did. Conceivably better adult performance could be partially attributed to the lower memory load of a written presentation of the stimuli. This does not seem to be a major factor given comparable results for adults across the three studies, but it is a factor to consider in designing future studies.

Understanding what sorts of knowledge are typically acquired first hand vs. second hand may be a critical component also of knowing when one needs to defer and where to allocate cognitive effort. As discussed earlier, young children do sense the division of cognitive labor around them, but to benefit most profitably from that division, they need to also have some sense of what kinds of information must involve others or should involve others because it is so labor intensive to acquire and assimilate on one's own. One aspect of early folk science—knowing how to look at the causal patterns inherent (or not) in a domain and using them to infer the reasonableness of that domain or category as an area of expertise—is an early emerging skill (Keil et al., 2010). Here we suggest that another, perhaps simpler, way to know when one might need to defer to experts, is to have some sense of how individual bits of knowledge are likely to depend on others for their origins as opposed to being directly available through firsthand experience. Thus, if one knows that some bits of knowledge can simply be acquired by growing up in the world, one would not think of those as the sorts of knowledge that depend on testimony by others. One can then focus more specifically on information that is not normally acquired firsthand and engage evaluation metrics concerning the sources of that information, such as the source's competence, motivations, and point of view. Having a sense of the ways in which particular pieces of knowledge are typically acquired would help guide decisions about where to allocate one's efforts to build up chains of deference and ground one's beliefs on firmer footing.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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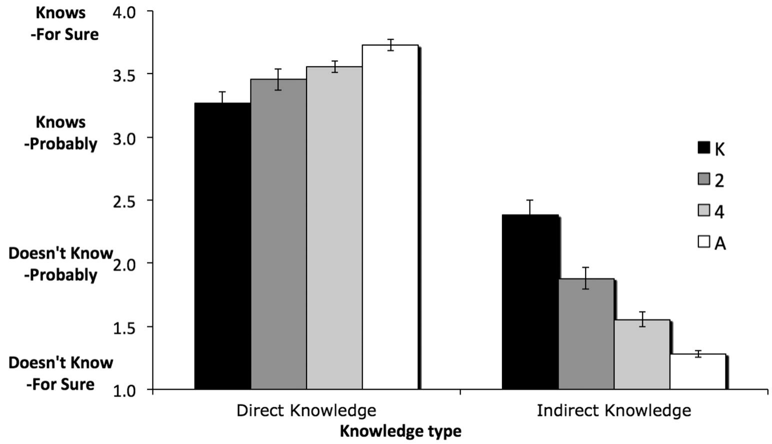

Figure 1.

Judgments of the extent to which directly acquired knowledge and indirectly acquired knowledge could be acquired on one's own, with standard errors shown. Children at all ages saw a clear contrast.

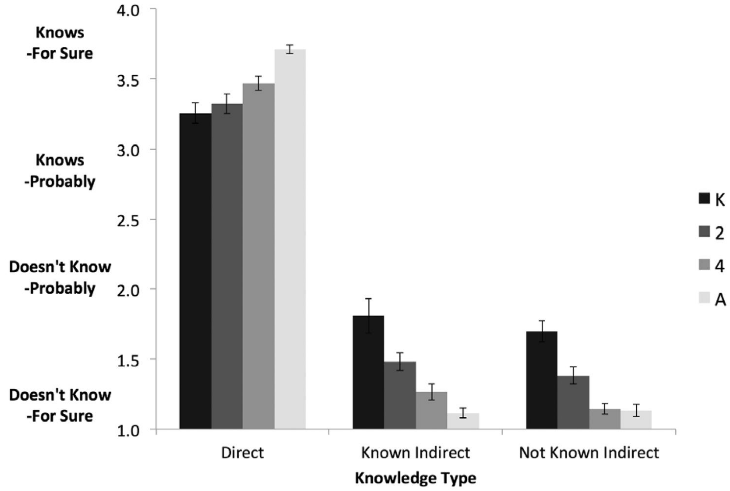

Figure 2.

Judgments of the extent to which directly acquired knowledge and familiar indirectly acquired knowledge and unfamiliar indirectly acquired knowledge could be acquired on one's own. Children at all ages saw a clear contrast between directly acquired information and the indirectly acquired information and no difference between the two forms of indirect information.

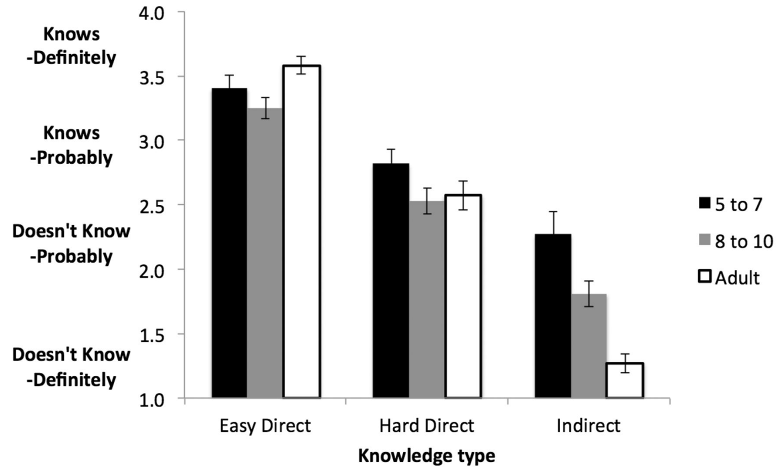

Figure 3.

Judgments of likelihood of knowing easy-to-acquire direct knowledge, difficult-to-acquire direct knowledge, and impossible-to-acquire indirect knowledge. Children at all ages saw a clear contrast between the three types of knowledge, with even the youngest children showing the same overall pattern of responding as adults.