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Determining who to question, what to ask, and how much information to ask for: The development of inquiry in young children

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ABSTRACT

To obtain reliable information, it is important to identify and effectively question knowledgeable informants. Two experiments examined how age and the ease of distinguishing between reliable and unreliable sources influence children's ability to effectively question those sources to solve problems. A sample of 3- to 5-year-olds was introduced to a knowledgeable informant contrasted with an informant who always gave inaccurate answers or one who always indicated ignorance. Children were generally better at determining which informant to question when a knowledgeable informant was contrasted with an ignorant informant than when a knowledgeable informant was contrasted with an inaccurate informant. In some cases, age also influenced the ability to determine who to question and what to ask. Importantly, in both experiments, the strongest predictor of accuracy was whether children had acquired sufficient information; successful problem solving required integrating knowledge of who to question, what to ask, and how much information to ask for.

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Introduction

Much of what children learn is based on information acquired through the testimony of others (e.g., Bergstrom, Moehmann, & Boyer, 2006; Harris, 2007; Harris & Koenig, 2006). In some situations,

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children are provided with information from others with pedagogic intent; for instance, parents and teachers scaffold learning by providing children with new information to solve problems. However, in many other situations, children must actively seek information from others by asking questions. This complex cognitive process involves at least three steps: determining the appropriate informant to question, deciding how to use questions as a tool to acquire information related to the problem at hand, and determining how to apply the information received to solve the problem. For any given problem, if children falter at any step in this process, their success may be stymied. The current research examined the developmental trajectory of the use of questions as problem-solving tools. In particular, how does the capacity to ask a sufficient number of effective questions to a knowledgeable informant facilitate problem-solving success?

Children frequently ask questions, and their questions take many forms (Callanan & Oakes, 1992; Chouinard, 2007; Greif, Kemler Nelson, Keil, & Gutierrez, 2006; Kemler Nelson & O'Neil, 2005; Wellman, Hickling, & Schult, 1997). For instance, preschoolers can tailor their questions to different conceptual categories (Greif et al., 2006), or they can ask questions to determine which of two objects is hidden inside a box (Chouinard, 2007). Yet little is known about children's ability to effectively direct their questions to informants who vary in how knowledgeable, and thus how informative, they are.

Indeed, just the task of recognizing that different informants may have access to different kinds of information or have different degrees of knowledge about a given topic may take considerable cognitive resources because young children may need to override the assumption that all sources are accurate (Heyman, 2008; Heyman & Legare, in press; Vanderbilt, Liu, & Heyman, in press; Wilson & Sperber, 2002). Presumably, the ease of identifying a source's knowledge status may influence children's ability to effectively question that source. For instance, for clearly labeled experts in familiar domains (e.g., doctors, car mechanics), even 3-year-olds can recognize some of the distinctions in experts' knowledge (Lutz & Keil, 2002). However, when it comes to applying this knowledge to problem solving, there are developmental improvements. For instance, 4-year-olds are better than 3-year-olds at considering prior demonstrations of expertise when determining who knows the correct answer to a new problem (Sobel & Corriveau, 2010). When asking questions of experts with different domains of knowledge (e.g., color experts vs. shape experts), 5-year-olds are more successful than younger children at identifying the appropriate source to question and generating effective questions (Mills, Legare, Bills, & Mejias, 2010).

Notably, in everyday life, informants do not always have readily identifiable and easily distinguishable kinds of expertise. Instead, informants often have overlapping and/or varied amounts of knowledge about a variety of topics, and we must ascertain which source will be more or less informative based on inferences about the source's experience or competency. In some cases, we can look for explicit cues of ignorance (e.g., someone shrugs his shoulders or professes a lack of knowledge). In other cases, we may need to evaluate the informant's claims over time (e.g., examine the informant's history of answering related questions and look for potential inaccuracies). Although the extent to which informants profess their lack of knowledge explicitly (e.g., providing verbal cues) makes it easier for both children and adults to identify them, comparing an informant's claims with one's own knowledge in order to draw conclusions may be a more difficult task.

How successful are children at distinguishing between knowledgeable and less knowledgeable informants, and can they keep this distinction in mind when asking questions? Most of the research to date supports the possibility that although preschoolers can make the distinction among knowledgeable, ignorant, and inaccurate informants, there are substantial developmental improvements in the capacity to do so (Birch, Vauthier, & Bloom, 2008; Corriveau & Harris, 2009; Corriveau, Meints, & Harris, 2009; Harris, Pasquini, Duke, Asscher, & Pons, 2006; Jaswal & Malone, 2007; Koenig, Clément, & Harris, 2004; Koenig & Harris, 2005; Koenig & Jaswal, in press; Nurmsoo & Robinson, 2009a, 2009b; Pasquini, Corriveau, Koenig, & Harris, 2007; Sabbagh & Baldwin, 2001). Some improvements relate to the difficulty of distinguishing between the informants; whereas 3-year-olds struggle to differentiate between knowledgeable and inaccurate informants, older children often have less difficulty in making this distinction (Koenig & Harris, 2005).

Importantly, the capacity to distinguish between more and less knowledgeable sources does not ensure that children can apply this understanding to guide inquiry. There is some evidence that

children can indicate which of two informants they would like to ask for information regarding the label of a new object or new function. However, in previous research on this topic, children did not actually generate the questions themselves and experimenters generally had both informants provide a response regardless of children's preferences (e.g., Koenig & Harris, 2005). Therefore, the developmental trajectory of the complex capacity to direct questions to knowledgeable informants (and ignore less knowledgeable ones) is underspecified.

On determining which informant to question, children need to determine what kinds of questions to ask to obtain the information they need to solve the problem at hand. Preschoolers could falter at this stage in the inquiry process for several reasons, including insufficient linguistic skills, metacognitive difficulties in assessing what they do not know, and limited working memory capacity and processing speed (e.g., Kail, 1991, 2007). Given that these skills improve over the preschool years, children should also show improvements in their questioning skills. Evidence to date supports the claim that over development, children gradually ask a greater proportion of questions that would be classified as effective (i.e., appropriately worded to obtain the information needed to solve problems) as opposed to ineffective (i.e., vague, irrelevant, or otherwise inappropriate) (Mills et al., 2010).

In addition to identifying who to question and what to ask, there is more to do; children also need to ask *enough* effective questions to the appropriate informants to obtain the information needed to solve their problem. Indeed, it is plausible (and perhaps quite common) to successfully identify the most knowledgeable informant, ask effective questions, but fail to obtain enough information to solve a problem or fail to systematically review the gathered information to draw a conclusion for problem solving. Research examining hypothesis testing indicates that both children and adults have difficulty in determining when they have gathered enough information for problem solving. Children, like adults (Schauble, 1996), often manipulate too many variables to sufficiently test their hypotheses, failing to recognize how to appropriately narrow the options to solve a problem (Chen & Klahr, 1999). Preschoolers and elementary school-age children also often cease to examine additional and relevant evidence once they find evidence to support their hypothesis (Klahr & Chen, 2003; Klahr, Fay, & Dunbar, 1993). Although children can design better experiments with explicit training (Chen & Klahr, 1999; Klahr & Chen, 2003), they do not seem to do so easily. Thus, this research indicates that children (and adults) sometimes assume that they have the solution to the problem before they have adequately explored all of the possible options.

That said, new research on the development of questioning indicates that preschoolers can sometimes determine when they have gathered sufficient information to address their questions (e.g., Frazier, Gelman, & Wellman, 2009; Kemler Nelson, Egan, & Holt, 2004). In addition, when children are successful at asking enough effective questions to identify a solution, children are more accurate in their problem solving (Chouinard, 2007; Mills et al., 2010). In fact, one study showed that if children asked enough questions to acquire the needed information, they were more successful at problem solving than those who had not done so regardless of their age (Mills et al., 2010). Yet much remains to be understood about how successful children are at effectively and efficiently questioning informants who vary in their degree of knowledge when seeking information for problem solving.

To examine these issues, in two experiments, 3- to 5-year-olds were presented with pairs of informants with contrasting levels of knowledge. For each experiment, there were two within-participants conditions. In one condition, a knowledgeable informant was contrasted with another who verbally indicated his own ignorance (the *ignorant condition*). In the other condition, a knowledgeable informant was contrasted with another who was consistently and clearly inaccurate (the *inaccurate condition*). Notably, ignorance and inaccuracy were demonstrated differently in the two experiments; Experiment 1 involved informants who were blatantly ignorant (i.e., stating ignorance and not providing an answer at all) and inaccurate (i.e., providing an impossible and incorrect answer), whereas Experiment 2 involved informants who were more subtly ignorant (i.e., verbally indicating uncertainty before providing a plausible but incorrect answer) and inaccurate (i.e., providing a plausible but incorrect answer). For both experiments in each condition, after being introduced to the two informants, children were instructed to question the informants to determine which of two or four target cards was inside a box.

There were three primary research questions. First, are there differences in children's ability to know who to question and what to ask based on age and/or the ease of distinguishing between the

informants? Developmental differences were anticipated because older children generally have more experience than younger children both in distinguishing between different types of informants and in asking questions. In addition, working memory capacity and processing speed improve over development (Kail, 1991, 2007); thus, older children generally have more information processing capacity. Therefore, we expected that older preschoolers would direct a greater proportion of questions to the knowledgeable informants than younger preschoolers and that older preschoolers would ask more effective questions than younger preschoolers. We also anticipated differences based on the ease of distinguishing between informants given previous research supporting the possibility that it may be easier to discount an informant who clearly indicates ignorance than one who provides inaccurate answers. As a result, children should then have greater capacity to engage in other aspects of the problem-solving process (e.g., generating effective questions, integrating the answers to questions to solve a problem). We expected that children would direct a greater proportion of questions to knowledgeable informants in the ignorant condition than in the inaccurate condition and that children would ask more effective questions in the ignorant condition than in the inaccurate condition.

Second, are there differences in children's problem-solving accuracy based on age and/or the ease of distinguishing between the informants? We predicted that older children would obtain more correct answers than younger children and that children overall would obtain more correct answers in the ignorant condition than in the inaccurate condition.

Finally, which factors contribute to successful performance on this task? We predicted that the most important predictor of the ability to accurately solve problems would be children's success at asking enough questions of the appropriate source to obtain the information needed for problem solving. Specifically, we anticipated that regardless of age and the ease of distinguishing between informants, the more trials in which children were successful at asking enough effective questions of the most knowledgeable source to obtain the information needed to solve the problem, the more successful children would be at problem solving overall.

Experiment 1

Method

Participants

Participants were 20 3- and 4-year-olds ($M = 4.24$ years, range = 3.40–4.99, 9 girls and 11 boys) and 22 5-year-olds ($M = 5.5$ years, range = 5.05–6.03, 10 girls and 12 boys) who were recruited from preschools in local communities. The sample was predominantly from middle- and upper-class backgrounds. Children were tested in a quiet room by an experimenter and an assistant, with each session taking 10 to 15 min.

An additional 10 3-year-olds ($M = 3.71$ years), 14 4-year-olds ($M = 4.42$ years), and 4 5-year-olds ($M = 5.54$ years) were excluded from the study, including approximately equal numbers of boys and girls overall and within each age group. Of these 28 children, 21 were excluded because they were unable to generate a task-related question during the warm-up task after repeated prompting and encouragement.¹ The other 7 were excluded because they needed the experimenters' help to ask a question at some point during the task.

Materials

In total, 14 simple line drawings of pictures on small note cards were used in the study. There was 1 training pair of pictures (pig vs. crayon) and 6 pairs of pictures divided into two sets (Set 1: sun vs. block, tree vs. cup, and car vs. butterfly; Set 2: apple vs. truck, bottle vs. flower, and ball vs. cat).

¹ The protocol of our study was designed so that participants who were unable to generate a task-related question during training were instead asked to participate in an alternative task in which they received more scaffolding. The data from this alternate task are not included in the current experiment. That said, it is also important to note that of these 28 children who were excluded, only 8 were never able to ask a task-related question throughout the study; the other 20 asked a task-related question at some point. Nonetheless, because these 28 children did not generate all of the questions themselves and, in fact, may have benefited from hearing the assistant ask effective questions, we excluded all participants who did not ask all questions themselves.

The first item of each pair was inside the box. Four animal puppets were used as the informants for the study (a lion and a bear; a horse and a cow).

Design

Each experimental session consisted of a warm-up phase and a test phase. The test phase included two within-participants conditions: an *inaccurate condition*, in which a knowledgeable puppet was contrasted with one who always gave inaccurate answers, and an *ignorant condition*, in which a knowledgeable puppet was contrasted with one who always admitted ignorance. For each condition, children were familiarized with the puppets before continuing to the test trials. The puppet pairs, the stimulus sets, and the order of conditions were counterbalanced.

Two experimenters were used in running this study: an experimenter who interacted with the children and an assistant who monitored the stimuli and recorded the data.

Warm-up phase

After several minutes of rapport building, the experimenter told the participants that they would be playing a question game. The experimenter explained that the objective of the game was to determine the contents of some special boxes by questioning some puppet friends.

Next, the experimenter placed a sample box on the table along with two pictures (a pig and a crayon). Children were told that one of the pictures was inside the box and that they could ask questions to the puppet friends to determine what was inside the box. Children were told that they could ask questions about “what the special thing looks like, or sounds like, or feels like, or does, or anything you want that will help you figure out what’s in the box.” Children were then prompted to ask questions. If a child asked what was inside the box, the experimenter reminded the child that the puppets could not answer such a question specifically and then stated what questions the puppets could answer.

Test phase

Puppet familiarization. The familiarization phase was designed so that children could meet the puppets and get a sense of how they answer questions without biasing them toward the specific questions used for solving the problems in the test trials.

After the warm-up phase, children were introduced to the first pair of puppets who would help them to figure out what was inside the box. Children were introduced to the two puppets by name (e.g., “Lion” and “Bear”) and were encouraged to say hello. The only indication of a difference between the puppets was the experimenter’s statement, “I’ve heard that one of them is very helpful at answering questions, and the other isn’t as helpful. Let’s ask them some questions to get to know a little more about them.”

The experimenter asked two questions: one regarding why people wear coats in the winter and one regarding why people brush their teeth. Each puppet responded according to its knowledge status; the knowledgeable puppet responded accurately, the inaccurate puppet responded with something clearly incorrect (e.g., people wear coats when it is hot outside to keep cool), and the ignorant puppet responded by indicating a lack of knowledge (e.g., “I don’t know why, I just don’t know”). The experimenter then ended the familiarization period by saying that now that the children knew a little more about the two puppets, it was time to play the game. There was no reminder of who knew what at the end of the familiarization period. Thus, after being forewarned that one informant might be more helpful than the other informant, children needed to infer the knowledge status of each puppet based on the answers to the two “why” questions.

Test trials. There were three test trials in each condition. At the beginning of the test trials for each condition, a box and two pictures for the first trial of the set were placed on the table and children were reminded, “One of these things is inside the box. You can ask our puppet friends questions to figure out what is inside the box. Say their names when you want to ask them a question. When you think you’ve figured out what is inside the box, you can guess. Are you ready? Who do you want to ask first?”

The experimenter had prepared responses to questions developed from methods used in previous research (Mills et al., 2010) and through piloting the current study. In general, the experimenter encouraged the children to ask questions about the item inside the box and redirected ineffective

Table 1

Examples of children's questions and responses to specific questions in Experiments 1 and 2.

Question type	Example question(s)	Puppets	Responses
Effective (Experiment 1)	"Does it fly?" (Options: car and butterfly; correct answer: car)	Knowledgeable	"No, it doesn't fly."
		Ignorant	"I don't know, I just don't know."
		Inaccurate	"It doesn't fly, it swims,"
Effective (Experiment 2)	"Is it red?" (Options: blue shoe and red shoe; correct answer: blue shoe)	Knowledgeable	"No, it is not red."
		Guesser	"Hmm, I'm not sure. I'll guess it is red,"
		Plausibly inaccurate	"Yes, it is red."
Ineffective (both experiments)	Off-task: "Is your father a fireman?"	Puppet answers accurately, and then experimenter reminds child of the purpose of the game	
	Irrelevant: "Why aren't there gold cars?"	Puppet answers accurately, and then experimenter reminds child of the purpose of the game	
	Vague (pointing): "Is it this one?"	Experimenter prompts that children need to ask questions about the item, for instance, asking whether they could ask a question about the picture at which they were pointing	
Clarification (both experiments)	"Am I supposed to pick a puppet first?"	Experimenter answers accurately	

questions. See Table 1 for specific example questions and responses for Experiment 1 (as well as Experiment 2).

Each child's question was answered by the informant according to its knowledge status; the knowledgeable puppet gave the correct answer, the inaccurate puppet gave a clearly inaccurate answer (e.g., if the child asked what color the thing in the box was, the puppet would respond with a color that was not on either card), and the ignorant puppet always expressed ignorance (e.g., "I don't know, I just don't know"). After each question and answer exchange, the experimenter asked the child if he or she wanted to ask another question or guess, reminding the child that the point of the game was to figure out what was inside the box.

Overview of coding scheme

Each session was transcribed verbatim. Transcripts were examined to identify children's questions. Any utterance that began with typical question words (e.g., who, what, when, does, is) and any phrase that indicated the child might have been searching for information (e.g., "this one?") was recorded. Each question was then coded for two types of information. First, each question was coded for whether it was directed to the knowledgeable, inaccurate, or ignorant informant. Second, each question was coded for whether it was *effective* (i.e., worded in a way that the child could obtain information that could help to solve the problem if the question were directed to the appropriate source), *ineffective* (i.e., not able to obtain information that could help with problem solving due to being too vague, irrelevant, or off-task), or a *clarification* of the protocol. See Table 1 for examples of questions of each kind.² It is important to note that the codes regarding the informant who

² Children asked a wide variety of effective questions in this study. Sometimes children focused on specific features of the items such as the color (e.g., "Is it pink?"), the sound they made (e.g., "Does it meow?" "Does the thing in the box go flitter flitter?"), the function (e.g., "Does the thing in the box grow?" "Can you drive it?"), and the parts (e.g., "Does it have wings?" "Does it have a lid?"). Other times children asked broader questions that required more than a "yes" or "no" answer (e.g., "What color is it?" "What does it sound like?"). At times children even integrated different features in a single multipart question (e.g., "Is the thing blue and does it fly?"). For the purpose of the current research, we focused on categorizing each question for whether or not it was effective regardless of the complexity of the question. Future research may seek to examine whether the *kind* of effective question reveals important insight into children's problem-solving abilities.

was questioned and the type of question asked were independent; for instance, a child could ask an effective question to the knowledgeable informant or to the uninformative informants. Interrater reliability was 100%.

Results

All analyses were originally conducted to examine order effects by condition (ignorant vs. inaccurate). Because there were no significant effects, order was excluded from further analyses.

Are there age and/or condition differences in children's ability to know who to question and what to ask?

For each child, the number and type of questions directed to each informant for each condition were calculated. Fewer than 4% of children's questions were for clarification. Because these clarification questions were not of central interest to the problem-solving task, for these and all other analyses, clarification questions were excluded.

To examine age and condition differences in children's ability to direct effective and ineffective questions to different informants, a 2 (Condition: ignorant vs. inaccurate) \times 2 (Informant: knowledgeable vs. other) \times 2 (Question Type: effective vs. ineffective) mixed design analysis of variance (ANOVA) was conducted on the number of questions asked with age group (younger [3- and 4-year-olds] vs. older [5-year-olds]) as a between-participants variable. See Table 2 for means and standard errors.

There was a main effect of informant, $F(1, 40) = 20.87, p < .001$, partial $\eta^2 = .34$, a significant interaction between question type and age group, $F(1, 40) = 4.94, p = .03$, partial $\eta^2 = .11$, and a significant interaction between question type and informant, $F(1, 40) = 12.07, p = .001$, partial $\eta^2 = .23$. These effects need to be taken in light of the three-way interaction among question type, informant, and age group, $F(1, 40) = 10.24, p = .003$, partial $\eta^2 = .20$. A simple effects test of this interaction revealed different patterns of responses for the two age groups. There were significant differences in the number of questions asked by older children to the informants, $F(1, 21) = 21.43, p < .001$, partial $\eta^2 = .51$. Specifically, they most frequently asked effective questions to the knowledgeable informant ($M = 5.73, SE = 0.81$). They less frequently asked the other three types of questions: effective questions to the other informant ($M = 2.14, SE = 0.47$), ineffective questions to the other informant ($M = 2.05, SE = 0.73$), and ineffective questions to the knowledgeable informant ($M = 2.00, SE = 0.62$). In contrast, for younger children, there was no significant distinction in the number of questions (effective and ineffective) directed to the two informants (knowledgeable informant: $M = 2.30, SE = 0.59$ [effective] vs. $M = 3.60, SE = 0.56$ [ineffective]; other informant: $M = 1.40, SE = 0.38$ [effective] vs. $M = 2.85, SE = 0.68$ [ineffective]), $F(1, 19) = 0.04, p = .84$, partial $\eta^2 < .01$ (see Fig. 1).

Finally, there was an interaction between condition and informant, $F(1, 40) = 7.46, p = .01$, partial $\eta^2 = .16$. Children made a larger distinction in the number of questions directed to each informant in the ignorant condition compared with the inaccurate condition. In other words, children were better at recognizing the most knowledgeable source to question in the ignorant condition than in the inaccurate condition.

Table 2

Experiment 1: Numbers of effective and ineffective questions by age, condition, and informant.

		Ignorant condition			Inaccurate condition		
		Knowledgeable	Ignorant	Total	Knowledgeable	Inaccurate	Total
4-year-olds	Effective	1.20 (0.31)	0.45 (0.15)	1.65 (0.41)	1.10 (0.32)	0.95 (0.25)	2.05 (0.45)
	Ineffective	1.95 (0.39)	1.05 (0.32)	3.00 (0.61)	1.65 (0.31)	1.80 (0.45)	3.45 (0.58)
	Total	3.15 (0.23)	1.50 (0.30)	4.65 (0.33)	2.75 (0.41)	2.75 (0.36)	5.50 (0.51)
5-year-olds	Effective	2.95 (0.46)	0.95 (0.24)	3.90 (0.61)	2.77 (0.44)	1.18 (0.24)	3.95 (0.55)
	Ineffective	1.00 (0.35)	0.91 (0.36)	1.91 (0.71)	1.00 (0.32)	1.14 (0.41)	2.14 (0.70)
	Total	3.95 (0.37)	1.86 (0.34)	5.82 (0.58)	3.77 (0.35)	2.32 (0.39)	6.09 (0.50)

Note. Values are means with standard errors in parentheses.

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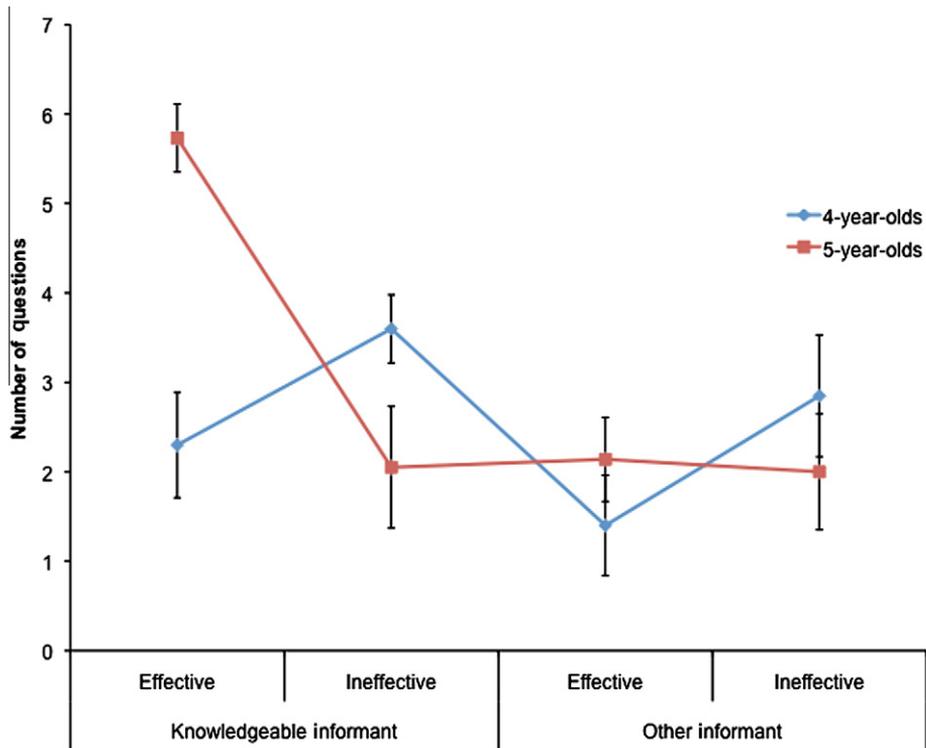


Fig. 1. Interaction among question type, informant, and age group in Experiment 1.

Did children successfully solve the problems?

The number of trials (out of 3) in which children obtained the correct answer for the ignorant condition and for the inaccurate condition were calculated. A mixed design ANOVA compared the number of correct answers for the two conditions (ignorant and inaccurate) between age groups. There was no main effect of age and no interaction between condition and age. However, there was a trend of condition, $F(1, 40) = 4.06$, $p = .05$, partial $\eta^2 = .09$; overall, participants obtained slightly more correct answers for the ignorant condition ($M = 2.38$, $SE = 0.11$) compared with the inaccurate condition ($M = 2.09$, $SE = 0.14$). Although there were some condition differences in accuracy, one-sample t tests comparing the number of correct answers with chance ($M = 1.50$) indicated that children obtained more answers than would be expected by chance in both the ignorant condition, $t(41) = 7.81$, $p < .001$, $d = 1.20$, and the inaccurate condition, $t(41) = 4.39$, $p < .001$, $d = 0.67$.

What mattered most for performance?

In successful problem solving, it is important for children to be able to integrate their understanding of who to question and what to ask and then keep asking questions until all of the needed information is gathered. Indeed, in some cases, it is possible to have identified the most knowledgeable source and be able to ask effective questions but not to ask enough effective questions to have the information needed to solve the problem. In fact, it is even possible to ask enough questions to solve the problem but still not use that information appropriately. To examine how important asking enough questions is for accurate problem solving, for each trial, we coded whether children asked enough effective questions to the knowledgeable source to obtain the right answer. That is, we examined the transcripts of the question-and-answer exchanges for each trial to determine whether

Table 3

Experiment 1 ignorant condition: descriptive statistics and correlations between variables.

	Descriptive statistics							
	<i>M</i>	<i>SD</i>	1	2	3	4	5	6
1. Accuracy	2.38	0.73	–	–	–	–	–	–
2. Age	4.90	0.75	.17	–	–	–	–	–
3. Number of questions to knowledgeable source	3.57	1.50	.26 [†]	.25	–	–	–	–
4. Number of effective questions	2.83	2.65	.41**	.43**	.47**	–	–	–
5. Number of total questions	5.26	2.27	–.08	.21	.77**	.23	–	–
6. Number of trials in which enough questions were asked	1.52	1.29	.51**	.32*	.21	.76**	–.15	–

[†] $p < .10$.* $p < .05$.** $p < .01$.**Table 4**

Experiment 1 inaccurate condition: descriptive statistics and correlations between variables.

	Descriptive statistics							
	<i>M</i>	<i>SD</i>	1	2	3	4	5	6
1. Accuracy	2.10	0.88	–	–	–	–	–	–
2. Age	4.90	0.75	.16	–	–	–	–	–
3. Number of questions to knowledgeable source	3.29	1.80	.35*	.43**	–	–	–	–
4. Number of effective questions	3.05	2.49	.49**	.45**	.57**	–	–	–
5. Number of total questions	5.81	2.29	–.07	.33*	.67**	.21	–	–
6. Number of trials in which enough questions were asked	1.38	1.23	.66**	.46**	.56**	.82**	.06	–

* $p < .05$.** $p < .01$.

children had asked enough effective questions to obtain the information needed to eliminate all but one option for determining the correct answer. We then calculated the number of trials (out of 3) for each condition in which children asked enough questions to the knowledgeable source.

Next, to better understand what correlated most highly with children's performance in each condition, we examined the correlations between the accuracy in each condition and several other measures, including age, the number of questions directed to the knowledgeable source (regardless of effectiveness), the number of effective questions (regardless of the source), the number of total questions, and the number of trials in which children asked enough questions to the appropriate source to obtain the information needed to solve the problems. The correlations and p values, as well as the descriptive statistics for each measure, are provided in Tables 3 and 4. For both conditions, although there was a direct relationship between accuracy and the number of questions asked to the knowledgeable source as well as the number of effective questions, the strongest relationship to accuracy was with the number of trials in which enough questions were asked to obtain the information needed for problem solving. Note, however, that the relationship between age and accuracy was quite low ($r_s < .17$) and insignificant.

We also examined what mattered most for performance with multiple regression analysis. For each condition, accuracy was entered as the dependent variable and the three most significantly correlated variables were entered in one block: (a) the number of questions directed to the knowledgeable source, (b) the number of effective questions, and (c) the number of trials in which enough questions were asked. For the ignorant condition, the overall model was significant, $F(3, 41) = 5.05, p = .005$. The regression standard coefficients revealed that the only significant predictor was the number of trials in which enough questions were asked ($\beta = .53, t = 2.42, p = .02$). For the inaccurate condition, the overall model was also significant, $F(3, 41) = 10.57, p < .001$. Again, the regression standard coefficients revealed that the only significant predictor was how many trials in which enough questions were asked ($\beta = .82, t = 3.81, p < .001$).

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Discussion

In the current study, we hypothesized that both age and the ease of distinguishing between informants (i.e., condition) would influence who children questioned, what they asked, and how accurate they were at problem solving. We found partial support for this hypothesis. Age played a role in both who children questioned and what they asked; in the current study, older preschoolers were better than younger children at directing questions to the most knowledgeable informant (primarily when contrasted with an inaccurate informant) and were better at coming up with effective questions. However, age did not correlate with accuracy; older children were not significantly more accurate than younger children at solving problems in this study. Perhaps because the problems in this study were simple (with children having a 50% chance of being accurate just by guessing), children could end up choosing the correct answer without being successful at questioning.

Whether the knowledgeable informant was paired with the inaccurate or ignorant informant played a role in both who children questioned and accuracy. Despite having information regarding each informant's knowledge status before beginning problem solving, children had more difficulty in determining who to question when distinguishing between a knowledgeable informant and an inaccurate one than when distinguishing between a knowledgeable informant and an ignorant one. Children also obtained slightly more correct answers in the ignorant condition than in the inaccurate condition. However, condition mattered less for question efficacy. This suggests that the cognitive resources required to determine who to question did not interfere with children's ability to determine what to ask with these simple problems. Importantly, however, regardless of a child's age or how difficult it was to distinguish between the potential sources of information, children's ability to direct effective questions to the appropriate informant related to their problem-solving success (see also Legare, Mills, Yasskin, & Clayton, 2011). Taken together, the data from Experiment 1 support the proposal that both age and the ability to distinguish between informants matter for problem solving. Yet beyond these factors, asking enough questions matters more.

Experiment 1 also leaves a number of open questions that we address in Experiment 2. First, in Experiment 1, children learned about the knowledge status of the puppets by observing their answers to "why" questions, which were different from the kinds of questions that children needed to ask to solve the problems during the task. This may have led to less generalization from the puppet familiarization task to the test trials and may partially explain why younger children asked more ineffective questions than effective ones (and sometimes asked no questions at all, leading to them being excluded from the study).

To address these concerns with puppet familiarization, a different method was used in Experiment 2. Instead of the puppets responding to unrelated "why" questions, the puppets were asked questions about the contents of boxes (i.e., the same type of problem faced by the children during the rest of the trials). One potential shortcoming of this manipulation is that children's ability to generate effective questions without modeling would not be able to be assessed because children would hear questions modeled that related to their problem-solving task. However, notably, the manipulation also has important strengths. This demonstration of the knowledge status of the puppets is more related to the problems during test, and this should lead to better generalization. In addition, modeling effective question asking may make the task easier for younger children, allowing the possibility of testing a group of 3-year-olds. Indeed, many of the developmental changes reported in the information-seeking literature focus on shifts between 3- and 4-year-olds (e.g., Koenig & Harris, 2005; Pasquini, Corriveau, Koenig, & Harris, 2007), suggesting that it may be important to include 3-year-olds in other work related to information seeking. Yet because tasks that require children to generate their own questions are more difficult than traditional information-seeking tasks (which typically involve having children point to an informant or repeat back a word), 3-year-olds often struggle (Chouinard, 2007; Mills et al., 2010; see also Experiment 1 of the current article). Nonetheless, witnessing someone else ask questions related to the task (i.e., modeling questions) may help 3-year-olds to feel more comfortable asking questions themselves.

Second, although in everyday life people can sometimes determine that an answer to a question is inaccurate just by listening to the response (e.g., the inaccurate puppet's clearly wrong response during training in Experiment 1), more frequently we need to gather evidence to evaluate someone's

response and determine its accuracy. Thus, the ignorance and inaccuracy of the informants was slightly different in Experiment 2 to make the demonstration of knowledge status less explicit and, potentially, closer to everyday life. Instead of having an ignorant condition in which the ignorant puppet answered “I don’t know” in response to each question, Experiment 2 involved a “guesser” condition in which the ignorant puppet actually guessed (e.g., “Hmm, I’m not sure. I’ll guess [inaccurate but plausible response]”). Thus, the guesser is indicating uncertainty but providing an answer, and this may make its knowledge status more difficult to detect than the knowledge status of the ignorant puppet in Experiment 1. Likewise, instead of having an inaccurate condition in which the inaccurate puppet provided answers that were obviously impossible (e.g., stating that the thing inside the box was blue when that was not one of the options), Experiment 2 involved a “plausibly inaccurate” condition in which the puppet provided answers that were inaccurate but possible (e.g., stating that the thing inside the box was blue when one item, the wrong item, was blue). In other words, the only distinction between these two informants is that the guesser indicated uncertainty with paralinguistic cues. Aside from those cues, both informants consistently provided incorrect answers. Therefore, to succeed at determining who to question, children needed to compare the informant’s response with the evidence (the actual item in the box) to detect the inaccuracy both during training and throughout the trials. We predicted that this should be easier to assess when interacting with the guesser than when interacting with the plausibly inaccurate informant given that the guesser indicated some uncertainty before providing an incorrect answer. This may be particularly true for the older preschoolers, who in previous research have been more adept than 3-year-olds at recognizing mental terms and verbal expressions indicating doubt (Moore, Bryant, & Furrow, 1989; Robinson, Haigh, & Nurmsoo, 2008).

Third, it is unclear from Experiment 1 whether or not children explicitly recognized which source was most knowledgeable. Indeed, it is possible that explicit understanding (i.e., the ability to state which puppet is more knowledgeable) is related to better performance on the task. Therefore, in Experiment 2, to better understand what attributions children were making about the informants, a metacognitive question was added after each set of trials to determine whether children recognized which informant provided the most correct answers. This allows a comparison of performance on the metacognitive question with performance on the experimental task.

Finally, given that some research has found that problem difficulty is an important factor to consider as it relates to children’s question-asking ability (e.g., Mills et al., 2010), Experiment 2 involved two types of trials for each condition: two simple trials with two options for what could be inside the box (as in Experiment 1) and two complex trials with four options for what could be inside the box.

Experiment 2

Method

Participants

Participants were 17 3-year-olds ($M = 3.41$ years, range = 2.96–3.84, 10 girls and 7 boys), 18 4-year-olds ($M = 4.48$ years, range = 4.05–4.99, 10 girls and 8 boys), and 16 5-year-olds ($M = 5.38$ years, range = 5.00–5.93, 11 girls and 5 boys) who were recruited from preschools in local communities. The sample was predominantly from middle- and upper-class backgrounds. Children were tested in a quiet room by two experimenters, with each session taking 10 to 15 min. An additional 11 children participated but were dropped from the final sample due to potential developmental delay (1 4-year-old), experimenter error (2 3-year-olds and 3 5-year-olds), classroom interruptions (2 5-year-olds), and reluctance to talk (3 3-year-olds).

Materials

In total, 32 simple line drawings of pictures on small note cards were used in Experiment 2. There were two sets of pictures, and each set was created so that each color was used in only one pair of items. The first set of pictures consisted of two training pairs (white hat and pink pig; gray spoon and purple lizard), two simple test pairs (green truck and green apple; black horse and brown horse),

and two complex test pairs (orange block, yellow block, orange sun, and yellow sun; blue bird, red bird, blue bike, and red bike). The second set of pictures also consisted of two training pairs (yellow car and green frog; orange leaf and gray ball), two simple test pairs (purple butterfly and purple umbrella; blue shoe and red shoe), and two complex test pairs (black dog, brown dog, black crayon, and brown crayon; pink cup, white cup, pink flower, and white flower). The first item of each pair was inside the box. The same four animal puppets were used as the informants as in Experiment 1 (a lion and a bear; a horse and a cow).

Design

As in Experiment 1, each experimental session consisted of a warm-up phase and a test phase. However, the two within-participants conditions differed from those in Experiment 1. In the *plausibly inaccurate condition*, a knowledgeable source was contrasted with one that provided answers that were plausible given the options but that turned out to be inaccurate. In the *guesser condition*, a knowledgeable source was contrasted with one that indicated a lack of certainty and then provided a response that was plausible given the options but that turned out to be inaccurate.

For each condition, children were first familiarized with the puppets before continuing to the test trials. The puppet pairs, the stimulus sets, and the order of the conditions were counterbalanced. Two experimenters were used in running this study: an experimenter and an assistant.

Warm-up phase

Similar to Experiment 1, after several minutes of rapport building, children participated in a short warm-up task designed to help children learn the rules for the experimental task. In particular, the task modeled asking questions about the item inside the box (e.g., is the thing in the box pink?) but not exactly what was inside the box (e.g., is it the pink pig?). For the task, the experimenter and the child hid one of two objects (i.e., a red pencil or a yellow rubber duck) inside a paper bag and the assistant asked questions to figure out the contents of the bag. During the warm-up task, the assistant modeled asking a question that was against the rules and an effective question, and the experimenter responded according to the script (see Table 1). Finally, the assistant indicated that she was ready to take a guess about what was inside the bag, and the experimenter prompted the child to share the contents of the bag. After completion of the warm-up task, the experimenter explained that they would play another game with some puppet friends.

Test phase

Puppet familiarization. Like Experiment 1, the familiarization task demonstrated the knowledge status of the puppets to children. Unlike Experiment 1, children observed task-relevant questions. Children were introduced to the puppets and the task using the same method as in Experiment 1. Two training pairs were used during puppet familiarization, with the puppets responding according to their knowledge status (see Table 1); the knowledgeable puppet responded accurately, the plausibly inaccurate puppet responded inaccurately, and the guesser puppet expressed doubt and then responded inaccurately. The same question was directed to each puppet of the pair, and then the assistant opened the box so that the child could see the contents. The assistant asked about different features of the items in the two trials (e.g., function, sound). For one trial the knowledgeable puppet gave an accurate “yes” response, and for the other trial the knowledgeable puppet gave an accurate “no” response.

The experimenter ended the familiarization period by saying that now that the children knew a little more about the two puppets, it was time to play the game. There was no reminder or explicit statement regarding which puppet knew what at the end of the familiarization period. Thus, children needed to infer the knowledge status of each puppet from tracking whether the claims matched the evidence.

Test trials. There were four test trials in each condition: two simple trials (two pictures) followed by two complex trials (four pictures). The method was otherwise the same as in Experiment 1.

Metacognitive question. After completing all four trials for one condition, children were asked a metacognitive question to determine whether they recognized who provided more right answers. The

experimenter asked the child which puppet gave more right answers, reminded the child of his or her choice, and asked the child to indicate his or her level of certainty on a scale with facial images used in previous research: *really sure*, *a little sure*, or *not so sure* (Woolley, Boerger, & Markman, 2004). The same procedure was used after each condition.

Overview of coding scheme

Sessions were transcribed and coded as in Experiment 1. Each question was coded for whether it was directed to the knowledgeable, plausibly inaccurate, or guesser informant. Then questions were coded as effective, ineffective, or clarification. Again fewer than 4% of the questions were clarification questions. Interrater reliability was 100%.

Results

All analyses were originally conducted to examine order effects by condition (plausibly inaccurate vs. guesser). Because there were no significant effects, order was excluded from further analyses.

Are there age, condition, and/or trial type differences in children's ability to know who to question and what to ask?

For each child, both the number and type of questions directed to each informant for each condition and each trial type (simple or complex) were calculated. For this and all other analyses, clarification questions were excluded because they were not related to the problem-solving task (fewer than 5% of questions were for clarification in this study).

Experiment 2 involved two types of trials: simple trials, in which children had only two possible options, and complex trials, in which children had four possible options. To allow direct comparison between Experiment 1 (which involved only simple trials) and Experiment 2 (which involved both simple and complex trials), we conducted separate ANOVAs for each trial type. To examine age and condition differences in children's ability to direct effective and ineffective questions to the different informants, a 2 (Condition: plausibly inaccurate vs. guesser) \times 2 (Informant: knowledgeable vs. other) \times 2 (Question Type: effective vs. ineffective) mixed design ANOVA was conducted with age group as a between-participants variable for each trial type (see Table 5 for means and standard errors).

First, for simple trials, there was a main effect of informant; children asked more questions to the knowledgeable informant ($M = 3.78$, $SE = 0.26$) than to the other informant ($M = 2.76$, $SE = 0.25$), $F(1, 48) = 9.46$, $p = .003$, partial $\eta^2 = .17$. Unlike Experiment 1, there was also a main effect of question type, $F(1, 48) = 31.43$, $p < .001$, partial $\eta^2 = .40$. Overall, children asked more effective questions than ineffective ones, presumably because of the more relevant training session in which the experimenter modeled questions. That said, similar to Experiment 1, there was also an interaction between question type and informant, $F(1, 48) = 6.06$, $p = .017$, partial $\eta^2 = .11$. Although the vast majority of the questions were effective and directed to the knowledgeable informant ($M = 2.74$, $SE = 0.12$), children did

Table 5

Experiment 2: numbers of effective and ineffective questions by trial type, condition, and informant.

		Guesser condition			Plausibly inaccurate condition		
		Knowledgeable	Guesser	Total	Knowledgeable	Inaccurate	Total
Simple trials	Effective	1.27 (0.12)	0.82 (0.11)	2.09 (0.17)	1.47 (0.11)	1.08 (0.15)	2.55 (0.23)
	Ineffective	0.55 (0.11)	0.35 (0.08)	0.90 (0.17)	0.49 (0.10)	0.51 (0.12)	1.00 (0.19)
	Total	1.82 (0.14)	1.17 (0.13)	2.99 (0.20)	1.96 (0.17)	1.59 (0.20)	3.55 (0.28)
Complex trials	Effective	1.92 (0.19)	1.10 (0.16)	3.02 (0.24)	1.94 (0.18)	1.18 (0.18)	3.12 (0.31)
	Ineffective	0.22 (0.08)	0.16 (0.07)	0.38 (0.11)	0.28 (0.08)	0.25 (0.08)	0.53 (0.13)
	Total	2.14 (0.20)	1.26 (0.17)	3.40 (0.25)	2.22 (0.21)	1.43 (0.20)	3.65 (0.33)

Note. Values are means with standard errors in parentheses.

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occasionally ask the other informant effective questions ($M = 1.90$, $SE = 0.10$). Fewer ineffective questions were asked ($M = 1.04$, $SE = 0.08$, to the knowledgeable informant; $M = 0.86$, $SE = 0.08$, to the other informant). There were no other significant main effects or interactions for simple trials.

Findings for complex trials mirrored the main findings for simple trials. First, there was a main effect of informant; children asked more questions to the knowledgeable informant ($M = 4.35$, $SE = 0.36$) than to the other informant ($M = 2.68$, $SE = 0.31$), $F(1, 48) = 16.33$, $p < .001$, partial $\eta^2 = .25$. There was also a main effect of question type, $F(1, 48) = 89.85$, $p < .001$, partial $\eta^2 = .65$, as well as an interaction between question type and informant, $F(1, 48) = 12.16$, $p = .001$, partial $\eta^2 = .20$. These findings should be considered in light of a trend toward a three-way interaction among informant, question type, and age group, $F(2, 48) = 3.07$, $p = .056$, partial $\eta^2 = .11$ (see Fig. 2). This interaction was not significant for simple trials in this experiment but was significant in Experiment 1. A simple effects test of this interaction revealed different patterns of responses for the three age groups. The 3-year-olds showed no significant interaction between informant and question type, $F(1, 16) = 0.09$, $p = .77$, partial $\eta^2 = .00$. In contrast, the 4-year-olds showed a significant interaction, $F(1, 17) = 12.22$, $p = .003$, partial $\eta^2 = .42$, and the 5-year-olds showed a trend in that direction, $F(1, 15) = 9.77$, $p = .078$, partial $\eta^2 = .19$. In other words, for complex trials, both 4- and 5-year-olds asked primarily effective questions directed to the knowledgeable informant. In contrast, for 3-year-olds, there was no significant difference between the number of effective and ineffective questions directed to either source.

There was also a significant three-way interaction among condition, informant, and age group, $F(2, 48) = 3.91$, $p = .03$, partial $\eta^2 = .14$ (see Fig. 3). A simple effects test of this interaction again revealed different patterns of responses for the three age groups. Both 3- and 4-year-olds showed no significant interaction between informant and condition, $F(1, 16) = 2.00$, $p = .18$, partial $\eta^2 = .11$, and $F(1, 17) = 1.07$, $p = .32$, partial $\eta^2 = .06$, respectively. In contrast, 5-year-olds showed a significant interaction, $F(1, 15) = 7.09$, $p = .018$, partial $\eta^2 = .32$. Unlike the younger children, 5-year-olds showed

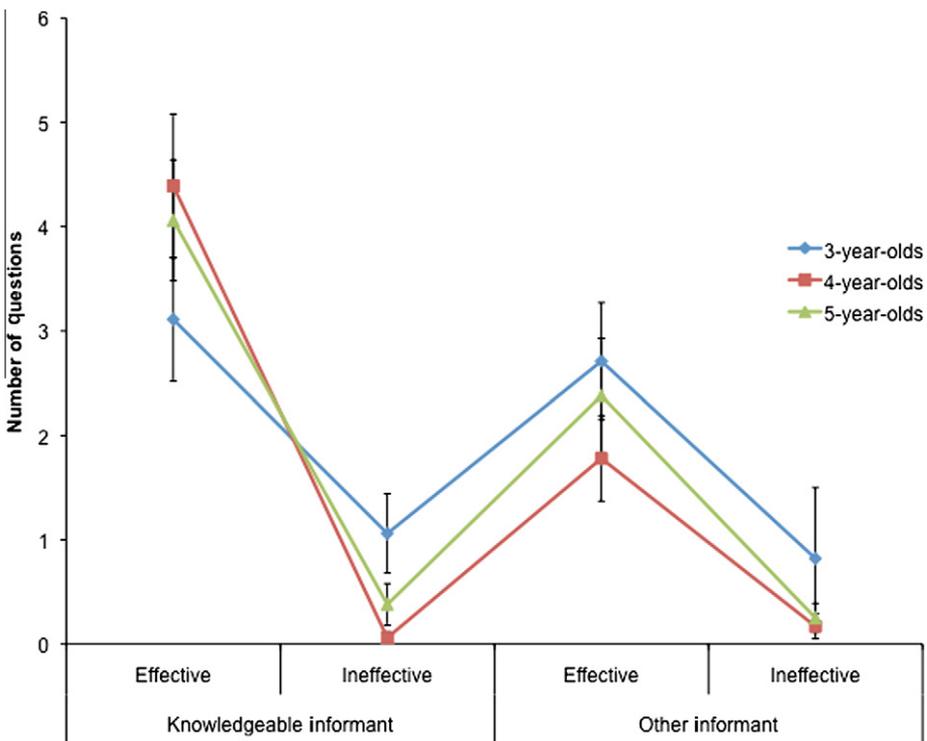


Fig. 2. Interaction among question type, informant, and age group for complex trials in Experiment 2.

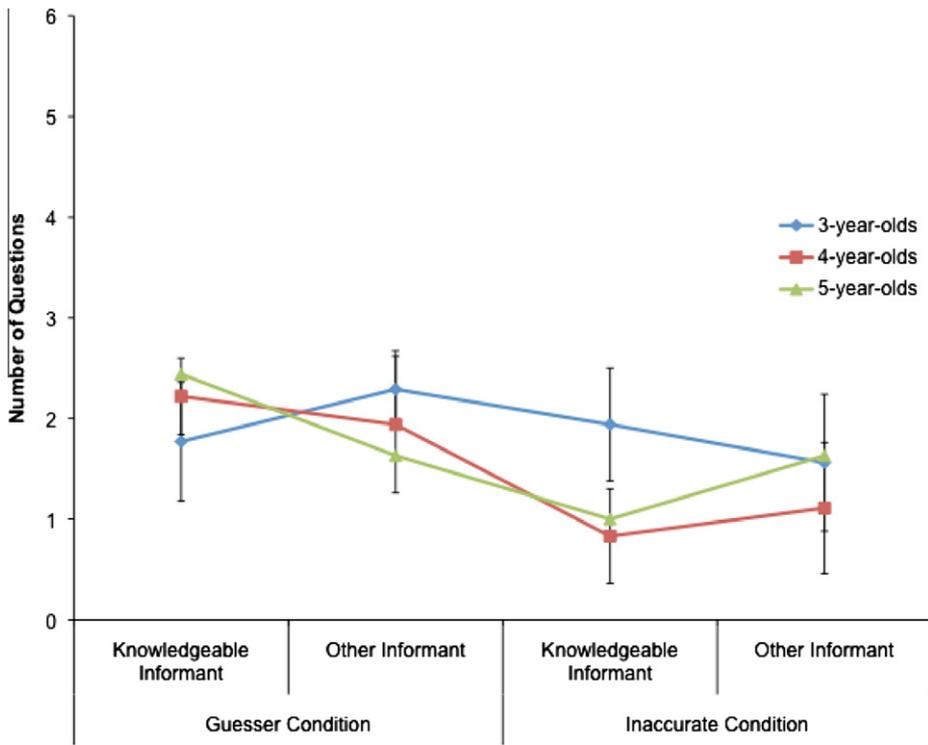


Fig. 3. Interaction among condition, informant, and age group for complex trials in Experiment 2.

different patterns of questioning depending on the condition; they asked more questions to the knowledgeable informant than to the other informant in the guesser condition, $t(15) = 3.16$, $p = .006$, $d = 0.79$, but not in the plausibly inaccurate condition, $t(15) = 0.565$, $p = .58$.

Finally, to examine age and condition differences in children's ability to direct effective and ineffective questions to the different informants between the simple and complex trials, a 2 (Condition: plausibly inaccurate vs. guesser) \times 2 (Informant: knowledgeable vs. other) \times 2 (Trial Type: simple vs. complex) \times 2 (Question Type: effective vs. ineffective) mixed design ANOVA was conducted with age group as a between-participants variable. Having already examined each trial type separately in previous analyses, we concentrated on potential effects of trial type or interactions with trial type here.

Although there was no main effect of trial type (children asked approximately the same number of questions in simple trials as in complex trials), there were two interactions. First, there was an interaction between trial type and question type, $F(1, 48) = 27.39$, $p < .001$, partial $\eta^2 = .36$. Children asked more effective questions and fewer ineffective questions in the complex trials (effective: $M = 6.14$, $SE = 0.51$; ineffective: $M = 0.91$, $SE = 0.19$) than in the simple trials (effective: $M = 4.64$, $SE = 0.35$; ineffective: $M = 1.90$, $SE = 0.29$). Second, there was an interaction among trial type, informant, and question type, $F(1, 48) = 4.35$, $p = .04$, partial $\eta^2 = .08$. As discussed earlier, for both simple and complex trials, children directed a greater number of effective questions to the knowledgeable informant than to the other informant.

Are there age and/or condition differences in children's responses to the metacognitive question, and how did metacognitive response relate to accuracy?

For the metacognitive question after each condition, children were asked who they thought provided more right answers to their questions and indicated their certainty. Children's responses were

converted to a 6-point scale, with 6 indicating certainty that the knowledgeable informant provided the most right answers and 1 indicating certainty that the other informant (either plausibly inaccurate or inaccurate guesser) provided the most right answers. An ANOVA was used to compare the rating for the two conditions across age groups. There was a trend for children to be more confident about the correct answer in the guesser condition ($M = 4.51$, $SE = 0.28$) than in the plausibly inaccurate condition ($M = 3.85$, $SE = 0.31$), $F(1, 48) = 3.61$, $p = .06$, partial $\eta^2 = .07$.

Because children might not have used the certainty scale appropriately but still may have comprehended the difference between the two informants, we also examined the percentage of children per age group who indicated that the knowledgeable informant gave more right answers (i.e., we disregarded the certainty rating in this analysis). For the guesser condition, 76% of 3-year-olds, 61% of 4-year-olds, and 81% of 5-year-olds endorsed the correct informant. For the plausibly inaccurate condition, 71% of 3-year-olds, 61% of 4-year-olds, and 50% of 5-year-olds endorsed the correct informant. A chi-square analysis to compare the patterns of data for the three age groups for each condition revealed no significant differences. However, binomial tests comparing the number of children indicating the correct informant for each age group and condition with chance revealed significant differences in the guesser condition. In that condition, a greater proportion of 3- and 5-year-olds than chance identified the correct informant as providing more right answers ($ps = .05$ and $.02$, respectively).

To examine the relationship between metacognitive awareness and performance on the task, we conducted several follow-up tests. First, Pearson correlations were calculated between accuracy on the task (out of 4) and confidence on the metacognitive scale (out of 6) for each condition. This correlation was significant for the plausibly inaccurate condition ($r = .51$, $p < .001$) but not for the guesser condition ($r = -.03$, $p = .86$). Interestingly, the metacognitive scale rating for the plausibly inaccurate condition also correlated with performance in the guesser condition ($r = .28$, $p = .046$). This suggests that being able to accurately and confidently detect which informant is most knowledgeable by tracking the accuracy of the sources is a sign of a deeper understanding of how to use informants for problem solving.

Second, given that children may have had difficulty in using the certainty scale, we also compared accuracy on the task for children who identified the correct informant as providing more right answers with that for children who did not by using independent samples t tests. In the plausibly inaccurate condition, children who knew which informant provided more right answers were significantly more accurate than children who did not ($M = 2.42$, $SE = 0.16$ vs. $M = 1.35$, $SE = 0.22$ [out of 4]), $t(49) = 4.02$, $p < .001$, $d = 1.14$. In contrast, in the guesser condition, there were no significant differences between the groups ($M = 2.00$, $SE = 0.21$ vs. $M = 2.00$, $SE = 0.31$), $t(49) = 0$, $p = 1.00$, $d = 0$.

Did children successfully solve the problems?

The number of simple trials (out of 2) and the number of complex trials (out of 2) in which each child obtained the correct answers for the plausibly inaccurate condition and for the guesser condition were calculated. A mixed design ANOVA compared the numbers of correct answers for the two conditions for the two types of trials between age groups. There was no main effect of condition; children obtained the same number of correct answers for the guesser and plausibly inaccurate conditions (guesser condition: $M = 2.00$, $SE = 0.17$; plausibly inaccurate condition: $M = 2.00$, $SE = 0.15$), $F(1, 48) = .001$, $p = .98$. However, there was a significant difference in accuracy for the simple and complex trials, $F(1, 48) = 15.68$, $p < .001$, partial $\eta^2 = .25$. Averaged across condition, children obtained more correct answers for the simple trials ($M = 1.19$, $SE = 0.09$) than for the complex trials ($M = 0.80$, $SE = 0.08$).

Planned post hoc tests comparing the number of correct answers with chance in each condition ($M = 1.5$) found that children obtained more correct answers than chance for both the guesser condition and the plausibly inaccurate condition, $t(50) = 2.94$, $p = .005$, $d = 0.41$, and $t(50) = 3.37$, $p = .001$, $d = 0.47$, respectively. Planned post hoc tests also examined differences in the number of correct answers to questions per trial type added across conditions (i.e., out of 4 possible for each trial type). First, paired t tests showed that children obtained significantly more correct answers for the simple trials ($M = 2.39$, $SE = 0.17$) than for the complex trials ($M = 1.61$, $SE = 0.16$), $t(50) = 4.03$, $p < .001$, $d = 0.56$. Second, one-sample t tests compared the number of correct answers for each trial type with

chance (2 out of 4 for simple trials and 1 out of 4 for complex trials). For the simple trials, this was a significant difference, $t(50) = 2.33$, $p = .024$, $d = 0.33$; for the complex trials, this was also a significant difference, $t(50) = 3.83$, $p < .001$, $d = 0.54$.

What mattered most for performance?

To better understand what related most highly with children's performance in each condition, we examined the correlations between accuracy in each condition and the following measures: age, the number of questions directed to the knowledgeable source (regardless of effectiveness), the number of effective questions (regardless of the source), the number of total questions, the response to the meta-cognitive question on the 6-point scale, and the number of trials in which children asked enough questions to the appropriate source to obtain the information needed to solve the problems. The correlations and p values, as well as the descriptive statistics, are provided in Tables 6 and 7.

Multiple regression analyses were then conducted to predict accuracy based on the three primary measures of interest in Experiment 1 (number of questions directed to knowledgeable source, number of effective questions, and number of trials in which enough questions were asked) as well as the new measure added to Experiment 2 (metacognitive scale rating). All of the above variables were entered into one block.

For the guesser condition, the overall model was significant, $F(4, 50) = 5.15$, $p = .002$. The regression standard coefficients revealed that the only significant predictor was asking enough effective questions ($\beta = .65$, $t = 3.52$, $p = .001$). For the plausibly inaccurate condition, the overall model was also significant, $F(4, 50) = 9.66$, $p < .001$. The regression standard coefficients revealed two significant

Table 6

Experiment 2 guesser condition: descriptive statistics and correlations between variables.

	Descriptive statistics								
	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7
1. Accuracy	2.00	1.22	–	–	–	–	–	–	–
2. Age	4.42	0.84	.05	–	–	–	–	–	–
3. Number of questions to knowledgeable source	3.96	2.16	.33*	.16	–	–	–	–	–
4. Number of effective questions	5.12	2.60	.23†	.19	.67**	–	–	–	–
5. Number of total questions	6.39	2.94	.08	–.04	.77**	.81**	–	–	–
6. Number of trials in which enough questions were asked	1.25	1.18	.50**	.41**	.68**	.67**	.43**	–	–
7. Metacognitive scale rating	4.49	1.98	–.03	.10	.30*	.21	.23	.30*	–

† $p < .10$.

* $p < .05$.

** $p < .01$.

Table 7

Experiment 2 plausibly inaccurate condition: descriptive statistics and correlations between variables.

	Descriptive statistics								
	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7
1. Accuracy	2.00	1.06	–	–	–	–	–	–	–
2. Age	4.42	0.84	–.01	–	–	–	–	–	–
3. Number of questions to knowledgeable source	4.18	2.41	.47**	–.13	–	–	–	–	–
4. Number of effective questions	5.67	3.50	.28†	.12	.72**	–	–	–	–
5. Number of total questions	7.20	3.88	.14	–.04	.76**	.88**	–	–	–
6. Number of trials in which enough questions were asked	1.31	1.24	.58**	.27†	.60**	.47**	.25†	–	–
7. Metacognitive scale rating	3.86	2.17	.51**	–.06	.20	.03	–.12	.42**	–

† $p < .10$.

* $p < .05$.

** $p < .01$.

predictors: asking enough effective questions ($\beta = .31, t = 2.11, p = .04$) and certainty on the metacognitive scale ($\beta = .33, t = 2.71, p = .009$).

Discussion

Experiment 2 was different from Experiment 1 in several ways; a separate group of 3-year-olds was included, the training related more closely to the test trials and involved modeling of questions, the informants were more difficult to distinguish (because both provided plausible answers), and two trial types were used (simple trials like the ones used in Experiment 1 as well as complex trials). As in Experiment 1, we hypothesized that both age and the ease of distinguishing between informants (i.e., condition) would influence who children questioned, what they asked, and how accurate they were at problem solving. That said, we also expected key differences based on our additional experimental manipulations. We expected that children would be more successful at asking effective questions in Experiment 2 than in Experiment 1 given that effective questions were modeled during training. We also expected that trial type would influence performance, with children performing better for simple trials than for complex trials.

We found partial support for these hypotheses. Beginning with the findings related to age, despite the addition of a separate group of only 3-year-olds in this study, age did not correlate significantly with accuracy (similar to Experiment 1). There were also no differences between age groups in the number of effective questions asked for either simple or complex trials. This was in contrast to Experiment 1, which found that 5-year-olds asked more effective questions than younger children (a group of 3- and 4-year-olds). Presumably because the training session for Experiment 2 was more related to the task than the training session for Experiment 1, children had a better understanding of how to ask effective questions during the task itself, minimizing age differences in generating effective questions.

Age did matter, however, in the ease of distinguishing between informants (i.e., condition) for Experiment 2. More specifically, in Experiment 1, children of all age groups were better at determining which informant to question when a knowledgeable informant was contrasted with one who indicated uncertainty (the ignorant condition) as opposed to when the informant was contrasted with one who was inaccurate (the inaccurate condition). In contrast, in Experiment 2, only 5-year-olds showed this pattern, asking more questions to the knowledgeable informant in the guesser condition (similar to the ignorant condition in Experiment 1) than in the plausibly inaccurate condition (similar to the inaccurate condition in Experiment 1). One possible explanation for this finding is that the contrast between the knowledgeable, guesser, and plausibly inaccurate informants was more difficult to discern in this experiment. Unlike Experiment 1, all informants provided answers that were plausible; thus, children needed to attend even more closely to determine which informant was most helpful.

Also in contrast to Experiment 1, there were no differences in accuracy based on the ease of distinguishing between the informants, and this may be due in part to the differences in informants as discussed above. That said, in general, accuracy was much lower in Experiment 2 than in Experiment 1. The increased difficulty in Experiment 2 may have contributed to this result. Whereas Experiment 1 included three simple trials per condition, Experiment 2 included two simple trials and two complex trials per condition. In addition, unlike Experiment 1, all informants in Experiment 2 provided some sort of answer. Thus, the task in Experiment 2 was more difficult, leading to lower overall performance.

Still, despite these differences in performance between the two experiments, it was clear in both experiments that factors other than age were important in children's success at problem solving. Like Experiment 1, our regression analyses for Experiment 2 demonstrated that asking enough effective questions was more important than other variables for performing well (although metacognitive ability played a role as well [see below]).

As described earlier, Experiment 2 included several additional contributions to understanding of children's question-asking behavior for problem solving. First, the complexity of the problems varied in this study, and this related to who children questioned, what they asked, and how accurate they were. Overall, children asked a greater number of effective questions in complex trials than in simple trials. They also directed a greater number of effective questions to the knowledgeable informant than to the other informant, especially for complex questions. Because the complex trials were always after

two simple trials for each condition, children may have had sufficient experience by the time they reached the complex trials to know who to question and what kinds of questions to ask. They also needed to ask more effective questions to determine the answers to the problems. Importantly, however, asking more effective questions in complex trials did not ensure that children could successfully ask enough questions to obtain the correct answers; children obtained fewer correct answers for the complex trials than for the simple trials. They typically did not ask *enough* effective questions to the informants to obtain the information needed to solve the complex problems correctly. For instance, many children asked about just one dimension (e.g., color) and stopped there, even though they also needed to ask about the second dimension (e.g., object type) to obtain enough information to solve the problems. This is additional evidence that being able to ask effective questions to a knowledgeable source is not enough for problem solving; it is also necessary to recognize when one has asked enough questions to reach a solution.

Second, the metacognitive question (“Who gave you more right answers?”) examining whether children identified the most accurate informant was somewhat difficult for children; the average accuracy across conditions was 74% for 3-year-olds, 61% for 4-year-olds, and 65% for 5-year-olds, lower than metacognitive performance in some other experiments examining how children evaluate informants (e.g., Birch, Akmal, & Frampton 2010; Corriveau & Harris, 2009). We discuss this finding in more detail in the General discussion.

Despite children’s general difficulty in identifying which of the two informants was most accurate, there were still several interesting findings related to metacognition. Children were more confident at indicating the correct informant for the guesser condition than for the plausibly inaccurate condition. In addition, a greater proportion of 3- and 5-year-olds than chance correctly identified the most accurate informant in the guesser condition (but all age groups were at chance for the plausibly inaccurate condition). These findings suggest that it was easier for children to determine who was most accurate when the informant clearly marked his lack of certainty with paralinguistic cues (the guesser condition) than when he did not (the plausibly inaccurate condition).

That said, it is intriguing that correctly identifying the most accurate informant correlated with performance in the plausibly inaccurate condition but not in the guesser condition and that identifying the most accurate informant in the plausibly inaccurate condition correlated with performance in *both* conditions. In fact, in the plausibly inaccurate condition, the ability to recognize the most accurate informant was the only other factor besides asking enough questions to predict accuracy on the task. The children who were able to identify the most accurate informant in the plausibly inaccurate condition were also able to track each informant’s history of responses and infer who was most knowledgeable without needing any paralinguistic cues available to guide them. This ability to effectively evaluate potential sources of information may indicate more sophisticated reasoning skills and could connect to other aspects of children’s problem-solving skills.

General discussion

In a world filled with potential sources of information, it is important for children to be able to recognize that some informants are more knowledgeable than others and to use this understanding to guide inquiry-based problem solving. Age can influence this ability; at least in some cases, older preschoolers are better than younger ones at directing questions to the most knowledgeable informant and better at coming up with effective questions. In addition, the ease of distinguishing between potential sources of information can influence this ability; children sometimes struggle more to discount an inaccurate informant than an ignorant one. Importantly, however, there is more to success at problem solving than age or the ease of distinguishing between sources; children’s ability to direct enough effective questions to the appropriate informant relates most strongly to their problem-solving success. Thus, the extent to which children successfully integrate these skills is crucial for effective inquiry; children must be able to apply their knowledge of who to question, what to ask, and how much information to ask for.

To better understand what changes across development in the ability to successfully use inquiry for problem solving, it is useful to first reflect on what may influence each component of the process as

well as how children begin to integrate these pieces. The first crucial component relates to what influences children's ability to know who to question. In some ways, it is surprising in the current study that even 5-year-olds sometimes struggled to recognize the most knowledgeable informant and that preschoolers often struggled to explicitly identify the most accurate source. Indeed, as mentioned earlier, the average accuracy on the metacognitive question was lower than in some other experiments examining how children evaluate informants (e.g., Birch et al., 2010; Corriveau & Harris, 2009).

There are several reasons why children may have struggled more to recognize the most knowledgeable informant in the current experiment compared with some prior research. One possibility is that the ease of determining each informant's knowledge status played a role. For instance, in other research demonstrating that even 3-year-olds can monitor informants for inaccuracy, the inaccuracies were easier to detect; the knowledge status of each informant could be readily determined either from observing the body language or from listening to the informant provide an incorrect label several times (e.g., Birch et al., 2010; Corriveau & Harris, 2009; Corriveau et al., 2009; Koenig & Harris, 2005; Nurmsoo & Robinson, 2009a, 2009b). In contrast, in our research, children needed to track what each informant said over time to match it with the correct answer, and this may have been more difficult. The number of exemplars also varied between children; they received only two examples during training, but they could have received any number of examples during the test trials, depending on how they questioned each source and how successful they were at tracking the responses given to the correct answers.

In addition, in our research, the ease of distinguishing between informants differed, and this mattered for their understanding of who to question. Indeed, children were generally more successful at determining the most accurate informant when he was somehow ignorant (Experiment 1, ignorant condition) or explicitly indicating a lack of certainty before guessing (Experiment 2, guesser condition) than when he was in some way inaccurate (Experiment 1, inaccurate condition, and Experiment 2, plausibly inaccurate condition). These differences highlight the importance of continuing to examine how the ease of detecting someone's knowledge status can influence problem-solving success.

Another possible influence on children's ability to recognize the most knowledgeable informant relates to the cognitive load placed on children. Unlike previous research in which children needed to point to which informant they thought would be most helpful, in our task children needed to generate their own questions. Given the development of question-asking skills during early childhood (e.g., Chouinard, 2007), it seems likely that for many children generating effective questions is difficult and, thus, there are fewer mental resources available to reflect on which informant may be most helpful. Future research needs to examine the potential role that cognitive load plays in evaluating informants.

Regardless of how the ability to distinguish between sources is encouraged, it is clear that the ability to recognize the most accurate informant has important implications for problem solving. In Experiment 2, the children who could explicitly recognize that the knowledgeable informant provided more right answers than the plausibly inaccurate informant performed better overall. From this research alone, we cannot determine whether explicitly knowing who to question reduces cognitive load and makes thorough questioning easier or whether children who are capable of effectively gathering information for problem solving generally have rich enough reasoning abilities to distinguish between different kinds of informants. This is an open question for future research to address.

Returning to the issue of understanding what changes across development in the ability to successfully use inquiry for problem solving, a second crucial component is the ability to ask effective questions. In Experiment 1, older children were better at asking effective questions than younger children, presumably because of older children's more sophisticated language skills. That said, there are also ways to encourage younger children to ask more effective questions. In Experiment 2, modeling effective questions during the warm-up and familiarization phases seemed to help children ask more effective questions; whereas the majority of 4-year-olds asked ineffective questions in Experiment 1, the majority asked effective questions in Experiment 2. Moreover, modeling questions allowed even 3-year-olds to participate in Experiment 2. Thus, modeling different kinds of effective questions can be useful in helping children to learn how to ask effective questions themselves.

The third crucial component is determining how much information is needed and assessing the extent to which sufficient information has been acquired. Given the difficulty that both children and

adults have at monitoring the status of their information gathering (e.g., Chen & Klahr, 1999; Klahr & Chen, 2003; Klahr et al., 1993; Kuhn, Pease, & Wirkala, 2009; Schauble, 1996), it is foreseeable that preschoolers would have difficulty in recognizing when they have asked enough questions to obtain the information they need to solve problems. For instance, in our research, when presented with complex problems involving multiple options for a correct answer, it was common for children to stop after receiving the answer to one question, neglecting to recognize that more information was needed. To help them better monitor their information-gathering efforts, it may help to reduce the cognitive demands from other aspects of problem solving such as determining who to question and what to ask. Modeling questions in different problem-solving situations may also contribute to the development of this skill because knowing what types of questions to ask may help children (and adults) to recognize when they are missing information. Consistent with this possibility is research demonstrating that listening to questions asked by others helps children and adults to recognize gaps in their own knowledge (Chin & Brown, 2002; Choi, Land, & Turgeon, 2005; Mills & Keil, 2004; Rozenblit & Keil, 2002). Future research can examine how children develop strategies to cope with the complexity of problems during the inquiry process.

Given that children and adults are inundated with potential sources of misinformation, it can be difficult to find the right source of information—one who is both willing and able to share accurate information—and to know exactly what to ask to help us solve our problems. To some extent, people willing to share advice are so readily available that we could continue asking questions ceaselessly, but that would hardly be efficient or effective. It is an open question how we can best encourage effective inquiry, but it is certain that the development of inquiry involves a complex integration of a set of skills—determining the best sources, forming questions, and monitoring the status of our knowledge—in which the sum (success at problem solving) is greater than the parts.

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