What is a good question asker better at?
From unsystematic generalization to overgeneralization to adult-like selectivity across childhood

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Abstract

From an early age, children prefer to query and rely on informants who are knowledgeable, informative and reliable. Recent research suggests that, when deciding whom to ask for help, children also take into account the *process* by which an informant had learned, from which they infer an active learning competence that signals the ability to solve similar novel task. This project explores across three experiments to what extent adults and 3- to 9-year-old children (N = 229) generalize the ability to ask informative questions to more or less-related abilities or characteristics (Study 1a and 1b), and use question-asking competence as a cue to assess informants' reliability as potential teachers (Study 2). Our results show a clear developmental trend: Three- and 4-year-olds draw unsystematic inferences from the monsters' question-asking expertise; Five- and 6-year-olds identified the better question asker as better at nearly every characteristic presented; Seven- to 9-year-olds showed adult-like response patterns, selectively associating the ability to ask good questions to related characteristics. We also found that all children and adults preferentially seek help from a knowledgeable informant when the problem is related to her domain of expertise. However, only older children and adults preferred seeking help from the good question asker on novel problems, whereas younger children were at chance. This project is a first step in understanding whether and how children use their sensitivity to others' active learning competence to navigate the social world, identifying good role models to *learn how to learn* from.

Keywords: active learning, social cognition, cognitive development, question asking, selective trust

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Children start grasping the complex laws of physics and the mechanics underlying causal relations very early on. By actively exploring and observing the environment around them, infants quickly learn that when they throw an object, it falls, and that an object cannot go through a wall, no matter how hard you bang it against it. Indeed, they are utterly surprised when this does not happen. However, some other kinds of knowledge strongly depend and build on social interactions: How your parents met, that a certain object is called "ball," and that it’s not nice to throw it in someone’s face.

A vast body of research suggests that children are *programmed* to learn from others from the very beginning. Already at 6 months, infants are equipped with special attentional mechanisms to detect when a social partner is willing to convey information (Csibra & Gergely, 2009; Senju & Csibra, 2008), and by the age of nine months, infants use gestures and vocalizations (e.g., babbling) to elicit information about unfamiliar objects from their caregivers (Goldstein & Schwade, 2009; Kovács, Tauzin, Téglás, Gergely, & Csibra, 2014; Walden, Kim, McCoy, & Karrass, 2007; Southgate, Van Maanen, & Csibra, 2007). As soon as children start talking, question asking becomes one of the most powerful tool to enlarge, deepen, enrich, and dynamically revise their knowledge about the physical and social world (Callanan & Oakes, 1992; Campos & Stenberg, 1981; Chouinard, Harris, & Maratsos, 2007; Meltzoff, 1988a, 1988b, 1990). Indeed, according to the verbal transcripts analyzed by Chouinard et al., (2007) preschoolers ask an impressive number of questions when engaged in conversations with adults—about 80 per hour. Research with 3- to 5-year-olds shows that, as children get better at monitoring and recognizing gaps in their own knowledge (Coughlin, Hembacher, Lyons, & Ghetti, 2015; Was & Warneken, 2017), their interrogative stance becomes increasingly more sophisticated (see Ronfard, Zambrana, Hermansen, & Kelemen, 2018 for a review). For instance, around age 2, children start requesting causal explanations rather than just facts or labels (as they do during the first and second years of life; Callanan & Oakes, 1992; Chouinard et al., 2007;

Hickling & Wellman, 2001), and by age 3 they seem to have clear expectations about what answers are satisfactory (Frazier, Gelman, & Wellman, 2009; Kurkul & Corriveau, 2018). Despite this striking early improvement, children still struggle to generate informative questions. On the one hand, analyses of naturalistic and semi-structured adult-child conversations have shown that the scope of children's questions is often constrained by their pre-existing knowledge and intuitions (e.g., focusing on social and biological phenomena rather than artifacts; Kelemen, Callanan, Casler, & Pérez-Granados, 2005), and that their inquires are often unclear and imprecise with respect to the specific kind of information they want to acquire. For instance, when presented with novel artifacts, 3- to 5-year-olds tend to ask ambiguous questions (e.g., "What is it?," that could refer to both the object's name, category or function), rather than expressing their specific interest in the object's function ("How does it work?"; Deborah, Louisa Chan, & Holt, 2004). On the other hand, behavioral and computational work suggests that, although already by age 7 children begin to generate the most effective questions from scratch, only by age 10 they reliably implement the most efficient question-asking strategies, echoing adult-level patterns of performance (see Herwig, 1982; Legare, Mills, Souza, Plummer, & Yasskin, 2013; Mosher, Hornsby, Bruner, & Oliver, 1966; Ruggeri & Feufel, 2015; Ruggeri & Lombrozo, 2015; Ruggeri, Lombrozo, Griffiths, & Xu, 2016; Ruggeri, Sim, & Xu, 2017). For example, when presented with a 20-questions-game, in which one has to identify a target object by asking as few yes-no questions as possible, younger children tend to ask exclusively "hypothesis-scanning" questions, which rule out individual possibilities one by one (e.g., "Is it the dog?" or "is it the parrot?"). In contrast, from around age 7 children start asking "constraint-seeking" questions, which more efficiently partition the hypothesis space by targeting higher-level categories or features that are shared by multiple hypotheses (e.g., "Is it an animal?"), until this becomes the most prominent strategy by age 10. The factors driving this developmental shift have not been systematically investigated yet, but previous work suggested that categorization skills and general verbal abilities might play a crucial role in question asking, supporting the generation of object-general features that can be used to cluster similar objects into categories at different levels of abstraction (Ruggeri & Feufel, 2015; Legare et al., 2013).

Supporting this idea, Ruggeri et al. (2017) found that, when eliminating the need to generate questions from scratch, even 5-, and to some extent 4-year-olds are able to *identify* the most informative between two given questions. The authors presented preschoolers with a storybook describing the reasons why the monster Toma had been late for school over several days. In the Uniform condition, Toma had been late equally often for different reasons, whereas in the Skewed condition, Toma had been late for one particular reason more often (e.g., on five out of eight days he had been late because he had overslept). Children then learned that Toma was late yet again, and that two of his monster friends wanted to find out why. One of the friends asked a constraint-seeking question and the other asked a hypothesis-scanning question, and children had to indicate which of Toma's friends would find out first why Toma had been late——that is, which friend asked the most informative question. Crucially, the constraint-seeking question was more effective in the Uniform condition, but the hypothesis-scanning question, targeting the most likely hypothesis, was more effective in the Skewed condition. In both conditions, the majority of children selected the monster asking the most informative question, regardless of the question type. These results suggest that preschoolers have the computational foundations for developing successful question-asking strategies, and interestingly lay the ground for the current project: Why can preschoolers *identify* informative questions so much earlier than then they can *generate* those informative questions on their own? One intriguing possibility is that children use their sensitivity to questions' informativeness as a way to assess other people's reliability as potential informants or role models. For example, children might assume that someone who asks informative questions might be smarter, better at solving problems, or even more knowledgeable than someone who asks redundant, uninformative questions, and therefore a more reliable source of information. Along these lines, a recent study found that preschoolers attributed problem-solving competence to informants who learned through independent, active exploration (Bridgers, Gweon, Bretzke, & Ruggeri, 2018).

Children's ability to discriminate between sources of information

A significant body of literature has examined young children's strategies when discriminating between reliable and unreliable sources of information (see Mills, 2013 and Sobel & Kushnir, 2013 for reviews). This research demonstrates that children's trust is driven by a complicated mixture of inferences drawn from the *quality* of the information provided (e.g., accuracy, completeness; see Jaswal, Croft, Setia, & Cole, 2010; Koenig, Clément, & Harris, 2004; Koenig & Jaswal, 2011; Pasquini, Corriveau, Koenig, & Harris, 2007) and the characteristics of the *agent* providing the information (e.g., expertise, age, familiarity, culture; see Kinzler & Spelke, 2011; Lutz & Keil, 2002; VanderBorght & Jaswal, 2009). Generally, results from these studies suggest that over the preschool years there are developmental improvements in how children understand the necessary characteristics for being a reliable informant. As an example, children younger than 4 discount claims made by informants that lack relevant episodic knowledge (e.g., Robinson, Champion, & Mitchell, 1999), who possess negative characteristics (e.g., mean; Mascaro & Sperber, 2009), who expressed absolute uncertainity (e.g., Sabbagh & Baldwin, 2001) and showed a stable history of inaccuracy (Koenig & Harris, 2005). Yet, only around age 6 do they take into account the *degree* of inaccuracy, the number of past errors or even the deceptive intentions that an informant might demonstrate (e.g., Einav & Robinson, 2010; Vanderbilt, Liu, & Heyman, 2011). Over the preschool years there can be observed developmental improvements also in children's ability to recognize that different individuals possess different kind of knowledge. For instance, 4- and 5-year-olds, but not 3-year-olds, ask their peers when they want to know how to play with a novel toy, but refer to a car mechanic when they want to fix it (see also Lutz & Keil, 2002; VanderBorght & Jaswal, 2009). Furthermore, although already by age 5 children focus on the relevant clues when deciding whom to trust, they still struggle at age 6 to direct questions to the proper experts (Aguiar, Stoess, & Taylor, 2012; Fitneva, Lam, & Dunfield, 2013; Robinson, Butterfill, & Nurmsoo, 2011). Along these lines, although 5- to 8 -year-old children distinguish between knowable and unknowable pieces of information (e.g., the number of leaves on all the trees in the world), they fail to use this information to discount an informant that very confidently claims to know unknowable things before age 7 (Kominsky, Langthorne, & Keil, 2016).

What inferences do children draw based on the informants' characteristics?

Most of the paradigms used to investigate selective trust focus on children's selection of informants. However, only few studies have examined the inferences children make about the presented informants, that is, the extent to which children attribute other positive (potentially irrelevant) characteristics to informants who have provided reliable information or demonstrated expertise. These studies have implemented several different paradigms: Some manipulated the informants' characteristics, such as gender (Ma & Woolley, 2013), accent (Kinzler, Corriveau, & Harris, 2011), attractiveness (Bascandziev & Harris, 2014, 2016), physical disabilities (Jaffer & Ma, 2015), or honesty (Li, Heyman, Xu, & Lee, 2014), while others varied the type and quality of the information that the informants provided (e.g., claims referring to episodic or semantic knowledge, Esbensen, Taylor, & Stoess, 1997; Nurmsoo & Robinson, 2009; accurate or inaccurate labels of familiar objects, Brosseau-Liard & Birch, 2011; Rakoczy, Warneken, & Tomasello, 2009; Sobel & Corriveau, 2010). Because of this diversity, and because very few of these studies have considered a broad developmental range, it is difficult to trace a clear developmental trajectory of children's inferences. Nonetheless, some researchers have suggested that the extent of children's generalizations depend on the *kind* of knowledge or expertise an informant exhibits or lacks (Mills, 2013). For instance, when an informant lacks situation-specific knowledge, children do not necessarily infer that that the informant also lacks semantic knowledge (Zmyj, Buttelmann, Carpenter, & Daum, 2010). On the contrary, when an informant exhibits semantic knowledge, children tend to make broader generalizations. For instance, 5-year-olds make explicit predictions about a puppet's knowledge of words, facts and prosocial behavior based on its past accuracy in labeling familiar objects (Brosseau-Liard & Birch, 2010). Children at this age also indicate that an informant who correctly labeled objects in the past would know the rules of a novel game (Rakoczy et al., 2009), and assume that someone who knows the causal properties of a novel object would also know the name of that object (Sobel & Corriveau, 2010).

Generally, children younger than 6 seem to be particularly generous in the extent of their generalizations when they are presented with an informant that displays positive personality traits and characteristics. Lane, Wellman & Gelman (2013) found that 3- to 5-year-olds, but not older children, tended to wrongly attribute knowledge about the content of a box to an agent that was described as nice but did not have visual access to the box. Similarly, Landrum, Pflaum & Mills (2016) found that 4- and 5-year-old children inferred that a nice bird expert would be more knowledgeable about near domains (e.g., plants and fruits) than a mean expert, although they were presented with the same relevant expertise (Landrum, Pflaum, & Mills, 2016).

The current project

The studies mentioned above have examined children's ability to identify reliable sources of information based on the knowledge, expertise and confidence that informants exhibit. However, the *origins* of this knowledge, that is, *how* an informant has learned, might also have implications for their reliability and trustworthiness. This project investigates across three experiments the inferences people make based on the active learning competence an informant demonstrated. In particular, we explore to what extent adults and 3- to 9-year-old children generalize the ability to ask informative questions to more or less-related abilities or characteristics (Study 1a and 1b), and use question-asking competence as a cue to assess informants' reliability as potential teachers (Study 2). Based on the findings discussed above, suggesting that 5-year-olds possess the computational foundations to develop successful question-asking strategies, we might expect them, but not younger children, to be able to draw selective and meaningful inferences based on the informant's question-asking competence. However, it is also possible that the ability to make such selective, rich inferences requires more advanced active learning competences, for example, mastery of effective question generation. In this sense, we might observe that adult-like generalization patterns emerge only from age 7.

Study 1a

Method

Participants. Thirty adults (19 female; M_{age} = 28.09 years; *SD* = 7.63) participated in this study. All participants were recruited and tested at the Museum für Naturkunde in Berlin, Germany. They were mostly white european, native German speakers or fluent in German and belonged to diverse social classes. Institutional Review Board (IRB) approval was obtained by the Max Planck Institute for Human Development in Berlin, and participants gave informed consent to participate in the study. One additional participant was excluded from the analyses due to missing data.

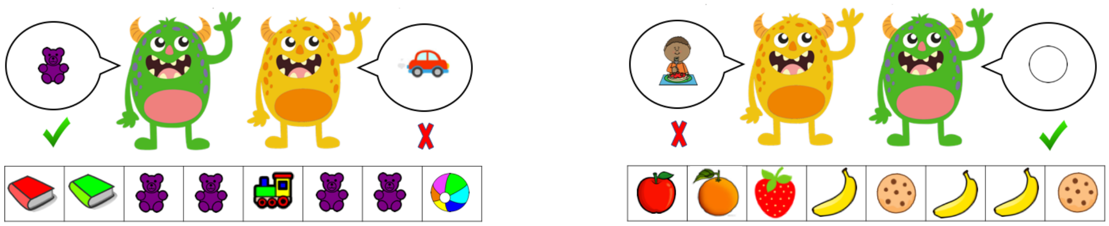
Design and procedure. Participants were tested individually in a secluded area of the museum. The procedure consisted of two phases: familiarization and test.

Familiarization phase. In the familiarization phase, participants were presented with a six-page storybook. The first page introduced two monsters, Bobo and Kila, who wanted to find out what had happened to their friend Toma on her first day of school and so asked her some questions. The following four pages illustrated different episodes (scenarios) taking place on Toma's first day of school (e.g., Toma drew a surprise welcome gift from a bag), together with the questions that Bobo and Kila asked Toma to find out what happened (e.g., "Did you get a teddy bear?" or "Did you get a red toy car?"). On the bottom of the page, eight images, arranged in a row, illustrated the options that the monsters considered (the hypothesis space; e.g., "Bobo and Kila knew what was inside the bag"; see Figure 1). Across the four scenarios, one of the monsters (counterbalanced across participants) always asked informative questions, whereas the other always asked uninformative questions. The informative questions targeted half of the hypotheses considered, either by referring to a single hypothesis presented four times (hypothesis-scanning question; e.g., "Did you get a teddy bear?", when four out of the eight objects in the gift bag were teddy bears; see Figure 1a), or by addressing a feature shared by four of the hypotheses (constraint-seeking question; e.g., "Did you get a round-shaped snack?", when four out of the eight snacks in the bag were round-shaped; see Figure 1b). The uninformative questions targeted either an object that was not included in the hypothesis space (e.g., the red toy car; hypothesis-scanning question; see Figure 1a) or a feature shared by all the objects (e.g., something to eat; constraint-seeking question; see Figure 1b). A sixth page presented the two monsters again and summarized the lesson to be learned from the familiarization phase, reminding participants that "Bobo/Kila always asks good/bad questions, because they are very informative/not informative at all. She is a good/bad question asker!".

Test phase. In the test phase, participants were asked to complete a paper-and-pencil survey consisting of 12 questions, asking participants to rate how much the 12 abilities, traits, or characteristics listed in Table 1 related to the ability to ask informative questions, as exemplified by the familiarization scenarios, on a scale of 0 (*not related at all*) to 10 (*strongly related*). Questions were presented in random order. Given the exploratory character of this study, the questions presented had been selected to include a broad range of abilities, traits, and characteristics (i.e., intellectual skills, physical abilities, individual preferences) that, according to pilot survey data (N = 13), were more or less related to the ability to ask informative questions, involving a stronger or weaker strategic component. As an example, the pilot data indicated that being good at treasure hunting (i.e., solving riddles) suggests competence in searching effectively and exploring strategically, whereas knowing many animal names, being a rather specific semantic knowledge, does not. As a memory check, at the end of the survey participants were asked to indicate again which monster was best at asking questions.

Results and Discussion

All participants (N = 30) answered the memory check question correctly and were included in the analysis. We used a hierarchical clustering algorithm to assess how participants' ratings about the relatedness of question-asking competence to the 12 different kinds of abilities, traits and characteristics cluster together. The similarity between ratings was calculated using the Minkowski distance measure. Clusters were created with the between-group average linkage method (UPGMA), which calculates the mean Minkowski distance between all possible intra -



(a) Scenario 1. Hypothesis-scanning questions (b) Scenario 2. Constraint-seeking questions

Figure 1. Two different scenarios of the familiarization phase: Bobo, the green monster, asks informative questions that either target a single hypothesis (a: "Did you get a teddy bear?") or features shared by half of the hypotheses (b: "Did you get a round-shaped snack?"), whereas Kila, the yellow monster, asks uninformative questions that either target a hypothesis that is not part of the hypothesis space (a: "Did you get a toy car?") or a feature shared by all the hypotheses (b: "Did you get something to eat ?").

and inter-cluster object pairs and define the clusters to minimize the average distance between the included objects. The optimal number of clusters to retain was determined with the "elbow criterion", that is, the point on a scree plot where the marginal gain of variance explained by the first clusters drops. If further examination of the cluster characteristics revealed no meaningful differences between two clusters, the clusters were combined. As a result, participants' ratings clustered across 4 dimensions, each including a subset of those traits, characteristics and abilities sharing similar ratings (i.e., judged as similarly ralated to question-asking competence). Participants rated intellectual abilities such as being clever and being good at school as the *strong* related to the ability to ask informative questions ($n = 2$, $M_{rating} = 8.33$). Abilities with a strategic component (i.e., being good at treasure hunting and being fast at completing jigsaw puzzles) were rated as having a *moderately strong* association with question-asking ability ($n = 2$, $M_{rating} = 6.26$). The association with semantic knowledge (i.e., knowing many animal names) and with being friendly was judged as *moderately weak* ($n = 2$, $M_{rating} = 3.88$), although this latter social trait had the highest between-subjects variability (see Table 1). This seems to suggest that a person who is good at asking questions might be considered socially smart, sociable, or just generally more likely to interact with others and have more friends. Physical abilities, independent of whether they were more likely to involve a strategic component (being good at playing soccer) or not (i.e., kicking a ball the farthest), individual preferences (e.g., liking ice cream) and irrelevant characteristics (e.g., seeing the farthest, having siblings) were clustered together and judged as not at all related to the ability to ask informative questions (*weak*: ($n = 6$, $M_{rating} = 1.37$). Taken together, these results suggest that the adults made distinct, graded, meaningful, and fairly consistent inferences and generalizations based on the ability to ask good questions.

In Study 1b we used a similar paradigm to explore to what extent such inferences and generalizations undergo a developmental change across childhood, and when adult-like intuitions might emerge.

Table 1
Study 1a: Mean Adults' Ratings of the Strength of the Association Between Question-Asking Competence and 12 Abilities, Traits, and Characteristics

Ability/trait/characteristic	Mean	*SD*
Being good at school	8.36	1.83
Being clever	8.30	1.91
Being good at treasure hunting	6.76	2.21
Being fast at completing jigsaw puzzles	5.76	2.67
Knowing lots of animal names	4.20	2.68
Being friendly	3.56	3.16
Having siblings	2.13	2.53
Being good at playing soccer	1.63	2.08
Seeing the farthest	1.37	2.35
Scoring lots of goals in soccer	1.33	2.22
Kicking a ball the farthest	1.10	2.19
Liking ice cream	0.67	1.39

Study 1b

Method

Participants. Participants were forty 3- to 4-year-old children (19 female; $M_{age} = 48.41$ months; $SD = 7.19$), forty 5- to 6-year-olds (21 female; $M_{age} = 70.18$ months; $SD = 6.52$), and forty 7- to 9-year-olds (22 female; $M_{age} = 101.59$ months; $SD = 9.74$). Participants were recruited and tested at local museums or preschools in Berlin, Germany; they were mostly white european from diverse social classes and were native German speakers or fluent in German. IRB approval was obtained and parents gave informed consent for their children to participate before the study. Twenty-four additional participants were excluded from the analyses due to technical issues (n = 2) or for failing the attention check (n = 7), the memory check (n = 9), or both (n = 6; see below).

Design and procedure. The design and procedure of Study 1b were identical to those in Study 1a, with the following exceptions: First, the task was implemented on a 10-inch tablet, and the script was read aloud to participants by an experimenter, who also reminded them, at the end of each scenario, which monster was a "good" and which one was a "bad" question asker. Second, instead of being asked to rate the strength of the association between the given abilities, traits, and characteristics and question-asking effectiveness as in Study 1a, participants were asked to select the one monster they thought was more likely to possess or was better at the presented abilities, traits, and characteristics. Two cards illustrating the monsters were used to help participants indicate their selection. Finally, participants were asked both at the beginning (attention check) and at the end (memory check) of the test phase to indicate which monster was best at asking questions.

Results

Participants' selections were coded as "1" when they indicated the competent question asker or "0" when they indicated the incompetent question asker. We performed a multivariate regression to to assess the similarity between adults' mean ratings in Study 1a and children's selections in Study 1b. This analysis revealed that adults' ratings predicted the 7- to 9-year-old children's response pattern, $\beta = .025$, $p = .01$, 95% confidence interval (CI) [0.008, 0.043], but not the 5- to 6-year-olds', $\beta = .018$, $p = .12$, 95%CI [-0.006, 0.042], or the 3- to 4-year-olds', $\beta = .010$, $p = .41$, 95% CI [-0.017, 0.037]. As illustrated in Figure 2, the extent of children's generalizations followed a clear developmental trend toward selective attribution patterns. Seven- to 9-year-olds made systematic and meaningful attributions of relevant abilities, traits, and characteristics to the good question asker, resembling the trend found with adults in Study 1a. However, a series of binomial tests revealed that even older children had different intuitions from those of adults for some characteristics and abilities (see Table 2). In particular, 7- to 9-year-old children generalized question asking to intellectual abilities involving a strategic component (e.g., being good at treasure hunting and being fast at completing jigsaw puzzles) to a lesser extent than adults, who rated these abilities as strongly related to question asking in Study 1a. Five- to 6-year-olds deemed question-asking competence as related to most (10 of 12) of the abilities, traits, and characteristics included in the study, even the ones that adults in Study 1a rated as completely unrelated. The selections of 3- to 4-year-olds were pretty unsystematic with respect to the abilities, traits, and characteristics that adults in Study 1a deemed strongly related to question-asking competence.

Table 2
Study 1b: Mean Proportion of Participants Who Indicated the Best Question Asker as More Likely to Possess Each Ability, Trait and Characteristic

	7- to 9-year-olds			5- to 6-year-olds			3- to 4-year-olds		
Ability/trait/characteristic	Mean	95% CI	*p*	Mean	95% CI	*p*	Mean	95% CI	*p*
Being good at school	.83	[0.67, 0.92]	<.001	.83	[0.67, 0.92]	<.001	.60	[0.43, 0.75]	.20
Being clever	.78	[0.61, 0.89]	.001	.80	[0.64, 0.90]	<.001	.68	[0.50, 0.81]	.03
Being good at treasure hunting	.68	[0.50, 0.81]	.03	.65	[0.48, 0.79]	.05	.58	[0.48, 0.73]	.34
Being fast at completing jigsaw puzzles	.58	[0.40, 0.73]	.34	.83	[0.67, 0.93]	<.001	.68	[0.50, 0.81]	.03
Knowing lots of animal names	.75	[0.58, 0.87]	.002	.78	[0.61, 0.89]	<.001	.78	[0.61, 0.89]	.001
Being friendly	.73	[0.56, 0.85]	.006	.93	[0.80, 0.98]	<.001	.70	[0.53, 0.83]	.01
Having siblings	.68	[0.50, 0.81]	.03	.65	[0.48, 0.79]	.05	.73	[0.56, 0.85]	.006
Being good at playing soccer	.68	[0.50, 0.81]	.03	.75	[0.59, 0.87]	.002	.45	[0.29, 0.62]	.52
Seeing the farthest	.63	[0.45, 0.77]	.11	.68	[0.50, 0.81]	.03	.75	[0.58, 0.86]	.002
Scoring lots of goals	.55	[0.38, 0.70]	.52	.55	[0.39, 0.71]	.52	.45	[0.29, 0.62]	.52
Kicking a ball the furthest	.55	[0.38, 0.70]	.52	.60	[0.43, 0.75]	.20	.60	[0.43, 0.75]	.20
Liking ice cream	.50	[0.33, 0.66]	1	.75	[0.58, 0.87]	.002	.50	[0.33, 0.66]	1

P values refer to binomial tests against chance level (50%). CI = confidence interval.

Discussion

In Study 1b we assessed whether children's intuitions about question-asking competence and its relatedness to other skills and abilities change across development, and thus when adult-like attribution patterns might emerge. Taken together, our results suggest a clear developmental trend. Three- to 4-year-olds drew unsystematic inferences from the monsters'

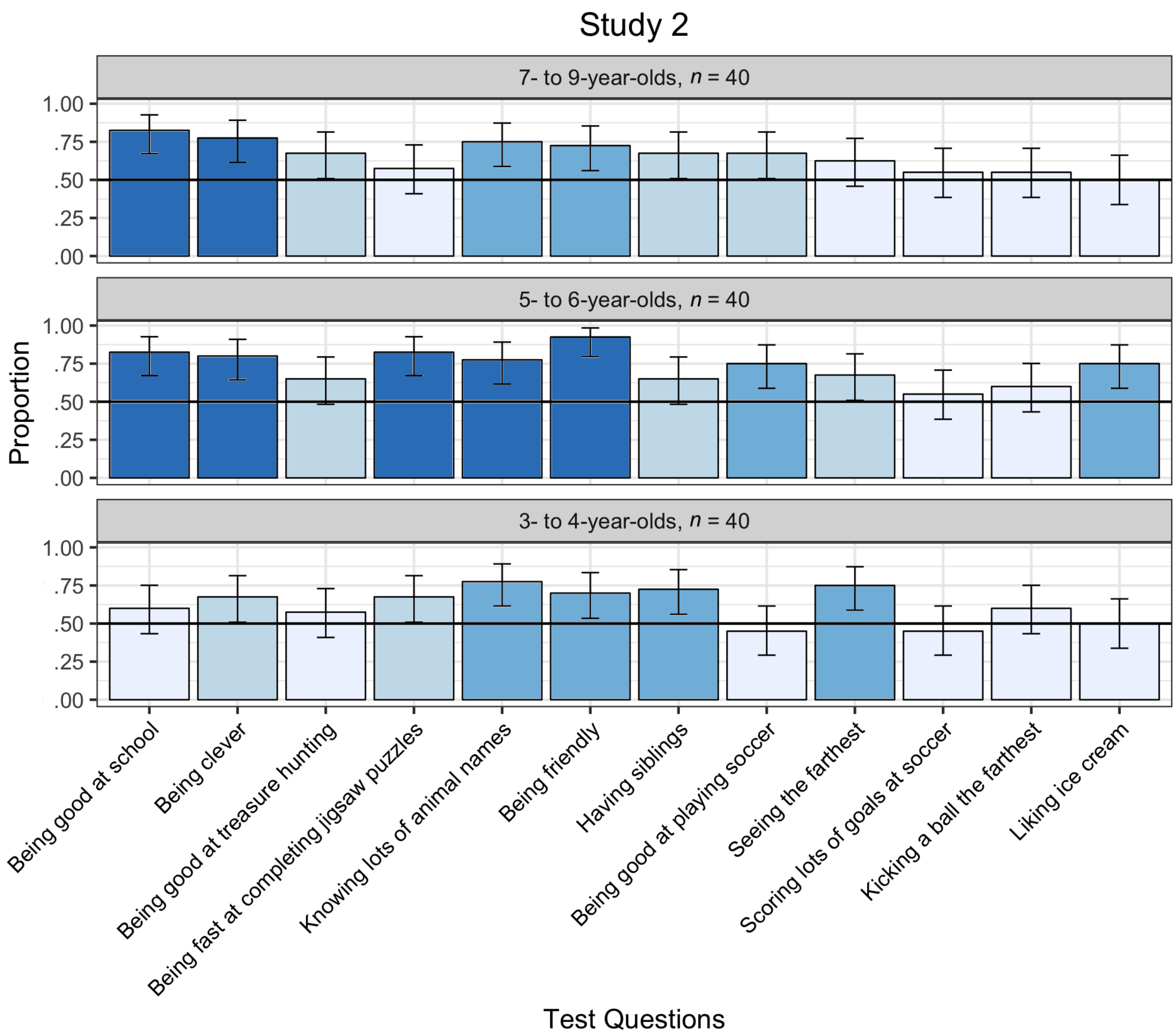


Figure 2. Proportion of participants in each age group who indicated the good question asker as more likely to possess the 12 abilities, traits, and characteristics chosen for the study, presented in descending order with respect to the ratings provided by adults in Study 1 (see Table 1). The color shading reflects significance level as indicated by binomial tests: darkest ($p < .001$), dark ($p < .01$), light ($p > .01$), lightest ($p > .05$). Chance level is 50%. Bars represent 95% bootstrapped confidence intervals.

question-asking expertise, showing no preference for the good question asker when evaluating abilities, traits, and characteristics that both adults and older children deemed strongly related to question asking (i.e., “being good at school”, “being clever”, “being good at treasure hunting”). At the same time, they showed a strong preference for the good question asker on some clearly irrelevant abilities such as seeing the farthest or characteristics related to the social character of the informant, such as being friendly or having siblings. This is maybe surprising in light of the literature suggesting that 4-year-olds are already quite good at evaluating the necessary characteristics for being a reliable source of information (e.g., Danovitch & Keil, 2004; Koenig & Jaswal, 2011, Kushnir et al., 2013, Lutz & Keil, 2002; Sobel & Corriveau, 2010).

Nevertheless, results from studies looking at how far do young children generalize informants' traits or knowledge seem to suggest that preschoolers' tendency to draw local rather than global inferences might depend on the nature and salience of the characteristics or competences demonstrated by the informants (e.g., intellectual or physical and episodic or semantic knowledge; see Csibra & Gergely, 2009; Esbensen et al., 1997; Nurmsoo & Robinson, 2009), or the extent to which these differences are polarized when presented to children (e.g., see Heyman, Gee, & Giles, 2003). For example, Fusaro, Corriveau, and Harris (2011) found that 3- and 4-year-olds inferred that a puppet who labeled familiar objects accurately would have been smarter but not stronger or nicer than an inaccurate puppet. They also predicted that the accurate puppet would have been more competent at labeling unknown objects but not at lifting things, sharing cookies, throwing a basketball, or knowing what animals eat, although this last would have been consistent with being smart. Interestingly, when children in this study were presented with two informants differing in physical strength (i.e., successfully or unsuccessfully lifting different items), they made general rather than local attributions. Thus, they inferred that the strong puppet would have been smarter, stronger, and nicer than the weak one, and they also predicted that she would have been more competent in the behaviors listed above (e.g., labeling objects, sharing cookies, or knowing animals' habits; Fusaro et al., 2011). In line with this evidence, we might interpret the trend observed in this study as an indicator of the salience preschoolers gave to question-asking competence. Thus, it is plausible that their understanding of this ability is limited to a primarily social function (Graesser, Person, & Huber, 1992), so that a person asking informative questions is only seen as someone who's friendly, generally sociable and therefore is more likely to have grown up with siblings.

Brosseau-Liard and Birch (2010) also suggested that the tendency to draw local rather than global attributions might also be an effect of age. In their study, children were presented with an individual's brief history of accuracy in labeling common objects and were asked to make explicit judgments about that individual's future word knowledge as well as broader factual knowledge, talents, or prosocial behavior. Their results show that 4-year-olds do not make the type of explicit attributions that 5-year-olds make, or do so only to a very limited extent, within the same domain as the informants' prior accuracy (i.e., word knowledge; Brosseau-Liard & Birch, 2010). In this sense, the unsystematic trend we found with 3- to 4-year-olds in this study might also just reflect their underdeveloped question-asking abilities, so that it might have just been hard for them to grasp what it means to be good at asking questions. Indeed, previous studies demonstrated that the ability to ask effective questions matures rather late, around 10 years of age (see Ronfard et al., 2018, for a review). Finally, we should also consider that children this young might not be familiar yet with some of the abilities, traits, and characteristics we presented them with. For example, they probably do not have yet a clear idea of what "being good at school" means, as they are not in school yet. Also, they might not appreciate the strategic component underlying the ability of being good at treasure hunting. This component seems to be more evident for them in the ability of solving puzzles. Similarly, they might struggle to understand what intelligence means, but interestingly, as suggested by their preference response for "knowing many animal names", they link question-asking competence to semantic knowledge.

Five- to 6-year-olds identified the good question asker as more likely to have nearly every presented ability, trait, and characteristic, suggesting that they considered effective question asking as an indicator of global expertise and general likability. This overgeneralization trend is in line with some findings suggesting that children this age tend to make broad inferences, sometimes even to unrelated domains, when they observe an informant demonstrating specific knowledge (e.g., labeling familiar objects accurately, Brosseau-Liard & Birch, 2010; knowing causal properties of an object, Sobel & Corriveau, 2010) or showing sociomoral understanding (Cain, Heyman, & Walker, 1997). For instance, Rakoczy, Warneken, and Tomasello (2009) found that 5-year-olds deemed an accurate informant (i.e., one who had correctly labeled familiar objects) as more likely than an inaccurate informant to know the rules for a novel game (Rakoczy et al., 2009). Moreover, some studies suggest that when an informant is presented as possessing epistemic knowledge (e.g., Jaswal & Malone, 2007; Koenig & Harris, 2005; Lane, Wellman, & Gelman, 2013) and shows prosocial traits (e.g., Heyman & Gelman, 1999; Liu, Gelman, & Wellman, 2007), children at this age tend to make global rather than local attributions.

Finally, 7- to 9-year-olds showed adult-like response patterns, selectively associating question-asking competence with some relevant abilities, traits, and characteristics but not others. This selectivity is in line with some of the results obtained in previous studies (e.g., Danovitch & Keil, 2004; Lane et al., 2013) with this age group. For example, Danovitch and Keil (2007) presented 6-, 8-, and 9-year-olds with four short vignettes illustrating a character facing a moral dilemma (e.g., respecting another's privacy) or involved in a scientific problem (e.g., building a rocket). Following each vignette, participants were asked to choose what characteristics the character would have needed to solve the problem (e.g., if the character needed to be nice to other people or if the character needed to be smart). Their results show that only starting at age 8 did children consistently indicate that scientific skills were necessary to solve scientific problems and that moral characteristics were needed to solve moral dilemmas (Danovitch & Keil, 2007). Generally, it is probably not a coincidence that the ability to make selective, meaningful inferences about question asking seems to emerge at the age when children start becoming more effective at generating questions themselves (Herwig, 1982; Mosher et al., 1966; Ruggeri & Feufel, 2015; Ruggeri et al., 2016).

In many studies focusing on generalizations, including some of those reviewed above, two informants are presented as experts in different domains (e.g., Jaswal et al., 2010; Koenig, 2012; Kushnir et al., 2013; Lutz & Keil, 2002). However, in our studies, the good question asker was contrasted with a *bad* question asker, to whom no other positive or neutral features were attributed. In this scenario, children may fall prey to a sort of *halo effect*: Children may attribute all characteristics to the one informant who was presented with a positive feature only to avoid the *bad* one. To address this limitation, in Study 2 we pitted an effective question asker against a *knowledgeable* informant: When is it more important to know things, and when to know *how to* *find out* things? This contrast is particularly interesting because results from Studies 1a and 1b suggest that both children and (to a lesser extent) adults believe that being good at asking questions also implies being more knowledgeable, for example about animal names.

Study 2

Method

Participants. Pilot testing strongly indicated that the paradigm developed for Study 2 was too demanding for 3- to 4-year-olds, of whom more than half (69%) failed both the attention and the memory check (see Design and procedure section below). We therefore decided to discontinue testing this age group. Participants included in the analysis were twenty-three 5- to 6-year-old children (7 female; M_{age} = 74.71 months; *SD* = 6.63), thirty-six 7- to 9-year-old children (16 female; M_{age} = 102.69 months; *SD* = 10.94), and 20 adults (11 female; M_{age} = 34.50 years; *SD* = 12.27), recruited and tested at the museum für Naturkunde and the Labyrinth Kindermuseum in Berlin. They were mostly white european from diverse social classes and were native speakers or fluent in German. IRB approval was obtained by the Max Planck Institute for Human Development in Berlin, and all participants (and participants' parents) gave informed consent to participate before the study. An additional 27 participants were excluded from the analysis for failing the memory check (three 5- to 6-year-olds, one 7- to 9-year-old), both the attention and memory check (thirteen 5- to 6-year-olds, three 7- to 9-year-olds, three adults), for quitting the session prematurely (one 5- to 6-year-old), having a learning disability (one 7- to 9-year-old) or an intellectual disability (one adult) and technical issues (one adult).

Design and procedure. The procedure consisted of three phases, all implemented on a 10-inch tablet. During the familiarization phase, participants were showed four videos introducing two informants: One was really good at finding out things by asking informative questions (the *question asker*) but did not know anything about fish; the other one was knowledgeable about fish (the *fish expert*) but was bad at asking questions (e.g., always asked uninformative questions; see the Appendix for additional details on the familiarization procedure).

In a first test phase, participants were asked three quiz questions, presented in random order, differently related to the expert's domain of expertise: One of the questions referred to fish (*same-domain question*: "Do you know which of these fish can fly?"); one referred to a related domain (animals; *related-domain question*: "Do you know which of these animals is the pangolin?"); and one referred to an unrelated domain (houses; *unrelated-domain question*: "Do you know which of these houses is in Germany?"). For each question, the options to be considered were presented in a 3 x 4 grid (see Figure 3). Two colored frames (blue and yellow, positions counterbalanced across trials) placed below the grid were used to illustrate the two informants to be selected. As expected, most participants did not know the answer to any of the questions. In this case, the experimenter suggested asking one of the informants for help (i.e., "Hmmm, I don't know this either, but we can ask one of my friends for help. Whom do you want to ask?"). Participants were not given any feedback until all questions has been asked. In a few cases participants knew the answers already (Fish: two adults, two 7- to 9-year-olds, five 5- to 6-year-olds; Animals: one adult, one 7-to 9-year-old; Houses: six 7- to 9-year-olds, eight 5- to 6-year-olds). These participants were asked to indicate which of the two informants they would have asked for help if they had not known the answer. Both at the beginning (attention check) and at the end (memory check) of the test phase, we also asked participants to indicate which informant was good at asking questions and which was a fish expert, but also which one was *not good* at asking questions and which one *was not* a fish expert.

In a second test phase, participants were asked to indicate which of the two informants was more likely to possess or be good at some of the abilities, traits, and characteristics presented to participants in Studies 1a and 1b. In particular, we selected "being good at treasure hunting", an ability that was rated by both children (Study 1b) and adults (Study 1a) as strongly related to question-asking competence; "knowing many animal names", to examine whether participants would attribute more factual knowledge to the good question asker (as they did in the previous studies) when contrasted to someone knowledgeable in a related domain; "being clever", to explore whether participants would be more likely to relate intelligence to knowledgeability or effectiveness in search; and finally, "liking ice cream", as a control question. At the end of the session, participants were given the solutions to the quiz questions presented earlier.

(a) Which of these fish can fly? (b) Which of these animals is the pangolin? (c) Which of these houses is in Germany?

Figure 3. Stimuli used for the quiz questions, varying in how much the topic related to the domain of expertise (fish) of the expert: (a) same, (b) related, and (c) unrelated.

Results and Discussion

Whom did participants ask for help? Results are illustrated in Figure 4. A series of chi-square tests confirmed that the two informants were not equally preferred across questions. Generally, participants preferred the fish expert (n = 61 of 79) for the same-domain question, $\chi^2(1, 79) = 23.40$, $p < .001$, but they preferred the question asker (n = 55 of 79) for the related-domain question, $\chi^2(1, 79) = 12.16$, $p = .001$, and for the unrelated-domain question (n = 58 of 79), $\chi^2(1, 79) = 17.32$, $p = .001$. We explored the results further by using binomial tests to assess whether participants' selections differed from chance (50%). For the same-domain question, the majority of adults and children preferred the fish expert (5- to 6-year-olds: 73.9%, $p = .03$; 7- to 9-year-olds: 77.8%, $p < .001$; adults: 80%, $p = .01$), with no differences between age groups, $\chi^2(2) = .23$, $p = .88$. However, when they had to seek help in the related and unrelated domains, participants' selections were not equally distributed across age groups (related: $\chi^2(2) = 13.63$, $p = .001$; unrelated: $\chi^2(2) = 8.48$, $p = .01$). We used a Wilcoxon rank-sum test to compare participants' selections on the related and unrelated domains between age groups. Both adults and 7- to 9-year-olds were significantly more likely than 5- to 6-year-olds to ask the question asker for help in the related (7- to 9-year-olds: $Z = -2.18$, $p = .02$; adults: $Z = -3.55$, $p < .001$) and unrelated (7- to 9-year-olds: $Z = -2.03$, $p = .04$; adults: $Z = -2.66$, $p < .01$) domains. Furthermore, adults preferred the question asker to a greater extent than 7- to 9-year-olds when they had to ask for help in the related domain, $Z = -2.03$, $p = .04$, but not in the unrelated domain, $Z = -1.13$, $p < .25$. Indeed, for the related-domain question, both 7- to 9-year-old children and adults preferred to ask the question asker for help, although to different extents (7- to 9-year-olds: 72.2%, $p = .01$; adults: 95%, $p < .001$), whereas 5- to 6-year-olds' selections did not differ from chance ($p = .67$; 43.5%). Similarly, for the unrelated-domain question, both adults and 7- to 9-year-old children preferred the question asker (7- to 9-year-olds: 77.8%, $p < .001$; adults: 90%, $p < .001$), and again, 5- to 6-year-olds' selections did not differ from chance (52.2%, $p = 1$).

Summarizing, our results show that participants considered expertise as domain specific. Thus, both children and adults preferred to team up with someone possessing specific factual knowledge only if this knowledge was strictly relevant to the domain of knowledge they wanted to learn about. On the other hand, they perceived someone who is good at finding out things as a better informant to learn about more generic domains of knowledge, such as animals or houses. Interestingly, our results suggest that this intuition starts emerging only later in childhood. Indeed, 5- to 6-year-old children did not show any preference for the question asker in any domain, suggesting again that to perceive a good question asker as a reliable source of information, one probably has to be effective at generating questions oneself (e.g., Ruggeri & Feufel, 2015).

How far do informants' competences generalize? As illustrated in Figure 5, participants' generalizations were mostly at chance level, suggesting that the overgeneralization trend found with younger children in Study 1b was due to a sort of halo effect. In fact, when presented with the informants demonstrating different kinds of expertise (e.g., factual-specific vs. strategic-global), neither adults nor children drew systematic inferences; that is, they made no clear distinctions between knowledgeability and question-asking competence. The only exceptions are adults' attribution of being good at treasure hunting to question-asking competence ($M = 75\%$, $p = .04$) and older children's attribution of intelligence to the fish expert (84%, $p < .001$).

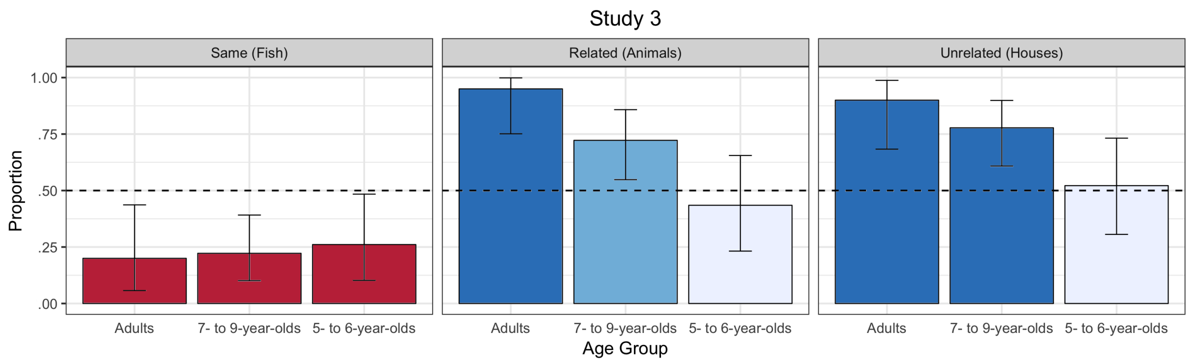


Figure 4. Mean proportion of participants' preferences for the question asker when they had to ask for help on the three quiz questions. The color shading reflects significance level as indicated by binomial tests: darkest ($p < .001$), dark ($p < .01$), light ($p > .01$), lightest ($p > .05$), red (significantly below chance). Chance level is 50%. Bars represent 95% bootstrapped confidence intervals.

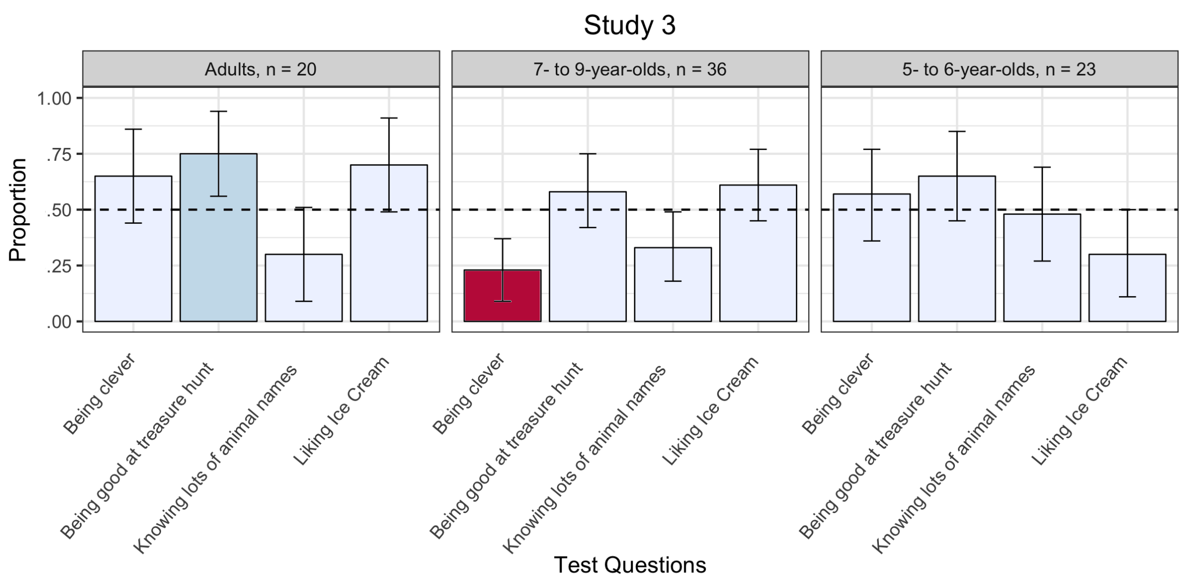


Figure 5. Mean proportion of participants' attributions of question-asking competence to a subset of the abilities, traits, and characteristics used in Studies 1a and 1b. The color shading reflects significance level as indicated by binomial tests: light ($p > .01$), lightest ($p > .05$), red (significantly below chance). Chance level is 50%. Bars represent 95% bootstrapped confidence intervals.

Conclusion

To conclude, this series of studies was a first attempt to explore what children infer from an agent's ability to ask effective questions. In Studies 1a and 1b we found an interesting developmental pattern from unsystematic generalization at age 3–4 years, to overgeneralization at age 5–6 years, to adult-like selective generalization from age 7 onward. Along these lines, Study 2 showed that only older children and adults preferentially sought help from a good question asker over someone exhibiting specific domain expertise, and interestingly, they did so even when they needed to learn about a domain that might have been only related to the knowledgeable expert's competence. Overall, this developmental pattern might reflect the emergence of mature question-asking competence. However, neither children nor adults made distinct, consistent inferences from question-asking competence versus knowledgeability. This is not too surprising if one considers that after all, in real life, differentiating the potential for learning from knowledgeability might not always be straightforward. On the one hand, being more knowledgeable might result in developing a high potential for learning. For example, someone who is very knowledgeable might have gained expertise in the process of searching for information, becoming an effective active learner. On the other hand, being an effective active learner might result in being more knowledgeable. Further research is needed to understand whether it is possible to disentangle these two interpretations and their directionality, for example, by exploring whether boosting one aspect will affect the other. Moreover, the impact of motivational factors in such processes should also be addressed, for example, by investigating the possibility that greater motivation to learn might drive the development of active learning strategies, knowledge acquisition, or both.

This project is a first step in understanding whether and how children use their sensitivity to others' active learning competence to navigate the social world, identifying good role models to learn from and to *learn how to learn* from. Future work should also investigate the impact of such inferences and generalizations on children's learning and social behavior, for example, by examining under what conditions and to what extent children prefer to imitate, learn, or ask for help from someone they identify as an effective active learner. In this sense, it would also be interesting to investigate the kind of inferences children make based on the *nature* of the agent, comparing, for example, robots, voice assistants, and humans, and whether they are selective in a systematic way, asking different questions of different agents.

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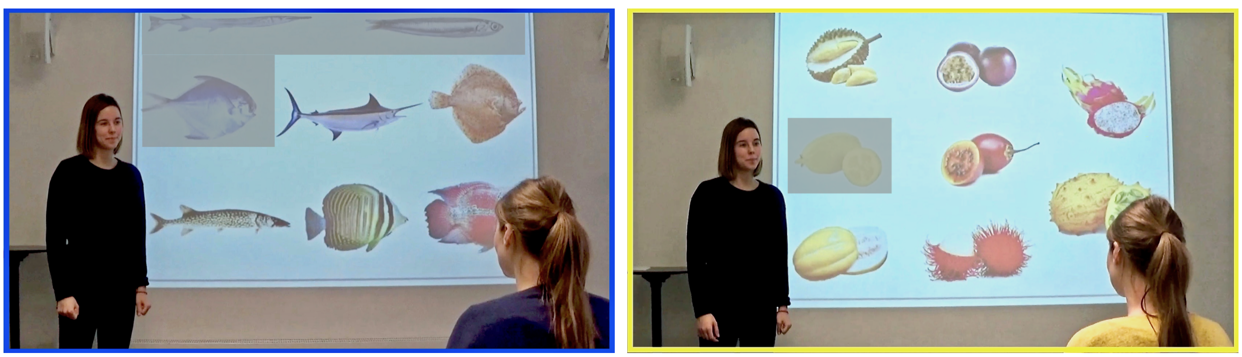
Appendix

Materials Used in Study 3

Familiarization

Four videos were used to introduce the two female informants (one at the time), who could only be distinguished by the color of their shirt (blue and yellow; counterbalanced order). The videos captured the informants from the back while they were sitting at a desk (see Figure A1a and A1b), facing an image projected onto a wall. In two of the four videos, a third neutral agent pointed at the images of 8 fishes onto the wall and asked each informant separately "Which one is fastest?" In one video the question asker replies asking three constraint-seeking questions, each ruling out the half of the options left under consideration, and therefore maximally informative (i.e., "Is the fastest fish long?" when there were eight fish and just four of them had an oblong shape, "Is the fastest fish silver?" when two of the four remaining fish were silver and the other two were blue and yellow, and "Is the fastest fish the one with the long nose?" when there were only two options left, consisting of one blue fish with a long nose, the target, and one yellow fish. In the other video the fish expert replies expressing her expertise about the topic (e.g., "I know which one is the fastest. It's the one with the long nose, the black marlin! It's very big and can swim at 129km/h."), without the need to ask any question. In the remaining two videos, both informants were questioned about a neutral topic (unrelated to the informants' expertise). The third neutral agent pointed at the images of 8 exotic fruits onto a wall and asked: "Which one comes from Mexico?" Again, in one video the question asker identified the answer by asking three maximally informative constraint-seeking questions (i.e., "Is it yellow?" when only four of the eight fruits presented were yellow, two were red, and two were pink, "Is it smooth?" when two of the four remaining fruits had a smooth shiny peel and the other two were covered with thorns, and "Is it the pink one?" when the two remaining options were a red and a pink fruit). In the other video, the fish expert asked three hypothesis-scanning questions, each ruling out only one hypothesis at each step (i.e., "Is it the one that looks like a lemon?" then "Is it the one that looks like a melon?" and finally "Is it the pink one?" targeting the right fruit but when there were still five open unexplored options). Animations were used to cover the options that were ruled out (and highlight the ones that were still open), as well as to highlight the target at the end. In all videos both informants eventually identified the target fish and fruit. However, the process they used to find the answer differed according to the domain of knowledge each question targeted. The question asker found out by asking effective questions in two domains she did not have knowledge of (fish and fruit). The fish expert went straight to the solution when she was questioned about her domain of expertise (fish) and guessed the right solution by asking ineffective questions when she was questioned about a domain that was unrelated to her knowledge (fruit).



(a) Question asker asks a constraint-seeking question (b) Fish expert asks a hypothesis-scanning question

Figure A1. The two scenarios of the familiarization phase.