Violation of epistemic expectations: Children monitor what others know and recognize unexpected sources of knowledge

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Abstract

Humans have an intuitive sense of what others know and how they learned it. These expectations are often latent, but violating them can elicit surprise and curiosity (e.g., a stranger knowing a lot about you). Here we investigate the development of epistemic expectations by measuring young children's sensitivity to such violations. First, parents reported that children typically respond to violations of epistemic expectations by age 4 (Exp.1). In naturalistic dialogue experiments with 4- and 5-year-olds, children were more likely to display surprised expressions and report being surprised when the experimenter's parent knew personal information about them than when their own parent did (Exp.2). However, children showed an opposite pattern when these people knew information about the experimenter's sibling (Exp.3). Together, these results suggest preschool-aged children are sensitive to others' access to information and readily detect violations of their epistemic expectations in casual conversation.

Keywords: Cognitive Development; Theory of Mind; Communication; Epistemic Cognition; Information Access

Introduction

Imagine you are at a job interview playing up your organization skills, when the interviewer responds: "but you were locked out of your apartment twice last week; where were your organizational skills then?". You would likely feel surprised: How could the interviewer possibly know something so personal about you? You might also wonder how they came to know; perhaps the interviewer knows your roommate or lives near you and happened to see your lockouts. Yet, if your roommate made the same comment during a mock interview, you wouldn't be surprised at all; they likely experienced your mistake first-hand or heard about it from you.

Our expectations about others' mental states are central to how we navigate the social world. Representing others' beliefs and knowledge affects how we reason about and predict their behavior (e.g., Baker & Tenenbaum, 2014; Jara-Ettinger et al., 2017), communicate and coordinate (e.g., Fussell & Krauss, 1992; Schober & Clark, 1989; Wilkes-Gibbs & Clark, 1992), whom we approach to request help or information (e.g., Bass et al., 2022; Birch et al., 2008; Einav & Robinson, 2011; Gweon et al., 2018; Koenig & Harris, 2005; Lockhart et al., 2019), and even how we evaluate others' transgressions (e.g., Cushman et al., 2013; Giffin & Lombrozo, 2018). The example above also illustrates the apparent ease with which we represent others' knowledge; as soon as the interviewer mentioned what you did last week, you couldn't help but think about *how* that person came to know. Indeed, recent work has found that people take longer to read scenarios where a stranger, as opposed to a friend, knows something personal about them (Rubio-Fernández et al., 2019), suggesting we draw inferences about about others' beliefs "on the fly" without being explicitly prompted.

As effortless and automatic as these inferences might seem, they nonetheless reflect a rich, causal understanding of how people acquire information. Importantly, this understanding does not require observing *how* others form beliefs. While even infants and young children can use others' visual access (e.g., Kim & Song, 2015; Knudsen & Liszkowski, 2012; Luo & Baillargeon, 2007; Luo & Johnson, 2009; Surian et al., 2007) or communication (e.g., Chuey et al., 2022; Jin et al., 2019; Song et al., 2008; Tauzin & Gergely, 2018; Vouloumanos et al., 2012, 2014) to reason about what they know, opportunities to directly witness others' belief formation are rather infrequent. Instead, we can anticipate what someone might think or know based on factors that influence their access to information, such as their identity or social relationships, and even reason backwards from their mental states to recover these factors; the interviewer's uncanny knowledge suggests that they either know your roommate or have seen the incidents themselves.

Some prior work suggests that children can reason about what others know even without directly witnessing how they came to know. For example, 6-year-olds can infer the broader kinds of knowledge and expertise someone possesses based on a sample of their prior knowledge (Chuey et al., 2020; Lockhart et al., 2019). Children around this age also possess an emerging understanding of how social relationships influence the spread of information; children expect someone to say nice things about their friend but not about their enemy (Liberman & Shaw, 2020), and understand that people know different things about their social partner depending on the nature of their relationship (Liberman et al., 2020). Therefore, by the early school years, children seem to have an abstract understanding of how people acquire certain kinds of information and how it flows between individuals. Existing findings with preschool-aged children suggest that even younger children can monitor and evaluate sources of information based on their reliability (Birch et al., 2008; Koenig et al., 2004; Koenig & Harris, 2005; Pasquini et al., 2007; Scofield & Behrend, 2008), consensus (Corriveau et al., 2009;

Fusaro & Harris, 2008; Haun et al., 2012), and access to information (Aboody et al., 2022; Brosseau-Liard & Birch, 2011; Schillaci & Kelemen, 2014).

These findings, however, involve deliberate epistemic reasoning where children were presented with specific scenarios and explicitly asked who knows what. An important characteristic of our latent expectations about others' informational access is that they go unnoticed until they are violated, prompting more explicit reasoning about the source of others' knowledge in context. Additionally, children struggle to track and differentiate the information possessed by different sources into late childhood (Lindsay et al., 1991; Ruffman et al., 2001). Thus, even though prior work raises the possibility that young children can track others' knowledge given their plausible access to information, evidence is rather limited.

Here we ask whether young children can track what others know without directly observing their information access; do children form epistemic expectations "on the fly" merely based on others' identity or social relationships? To this end, we measured children's response to violations of such expectations in two ways. We examined both their explicit reports of feeling surprised as well as their facial expressions. Prior work has found that young children express surprise (Moll et al., 2016) and tension (Ni et al., 2023) in anticipation of agents acting on their false beliefs, suggesting that children's latent monitoring of others' epistemic states may be evident in their facial expressions.

In order to maximize the possibility that others' unexpected knowledge elicits a robust response, we specifically focus on what others know about the participants themselves. This is similar to the interviewer example above and prior work with adults (Rubio-Fernández et al., 2019). Indeed, recent work finds that preschool-aged children are motivated to learn and shape others' impressions of them (Asaba & Gweon, 2022; Asaba et al., 2022), suggesting that children may notice instances where a stranger knows something about them. In Experiment 1, we use parental surveys to identify when parents first noticed behaviors that reflect violations of children's epistemic expectations. In Experiments 2 and 3, we use a novel conversational paradigm to assess children's responses to epistemic violations in real-time.

Experiment 1

As an initial study, we sought to leverage parental reports to identify when children might start forming and reacting to violations of epistemic expectations about others. Recent work has used parental surveys to collect anecdotes that reflect when children begin to show "loophole" behaviors (Bridgers et al., 2021) and using them to target a specific age range for further studies. Here we take a similar approach by asking a sample of parents about their children's reactions to someone knowing something unexpected about them.

Methods

Participants We recruited 132 adults from Cloud Research (Mean age = 36, 69 males) who reported to be a parent of at least one child aged between 3 to 8 years. Participants provided information about a total of 177 children in this age group (Mean age = 5.6, 90 males, 62% White) and were provided with modest compensation for their time ($2).

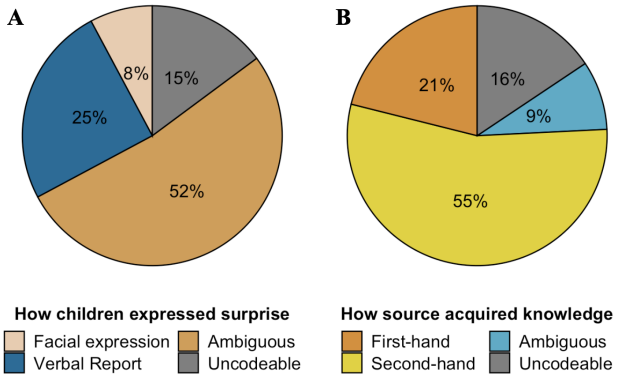

Figure 1: Data from Experiment 1: parental reports detailing instances where children were surprised someone knew something about them. Parents' responses were coded by how children expressed their surprise (A) and how the source of their surprise likely acquired their knowledge (B).

Procedure The study was administered as a self-paced Qualtrics survey. We informed participants that their answers will help developmental psychologists design studies on what children expect others to know about them; we then asked them to list how many children they had between 3 to 8 years of age, and then complete the following procedure for each child.

Participants first provided their child's age (in years), gender, and race. They were then asked "Has your child ever been surprised that someone knew something about them?" and presented with a binary choice: "Yes, they currently engage in such behavior or recently have" or "No, they have never engaged in such behavior". To help participants better understand the question and recall relevant behaviors, we provided three examples obtained from a previous pilot study (e.g., "For Halloween last year, she (the child) was Elsa (a character in the movie Frozen). She was surprised that people were able to figure out that Frozen was her favorite movie. She was floored and kept asking how they knew"). Participants who reported that their child had showed similar behaviors were then asked to provide their best guess at what age their child first demonstrated them, and to briefly describe, if they could, a specific episode that came to mind.

Results and Discussion

Overall, parents reported that a majority of their children (128/177, 72%) had expressed surprise that someone knew something about them. A logistic regression predicting parents' answers by their child's age found a marginal effect of age ($\beta = .18$; $p = .079$); this weak effect is consistent with the relatively early age at which parents first noticed this behavior: 3.78 years on average.

Most parents (126/128, 98%) who reported that their child

had demonstrated this behavior were able to recall and describe a particular instance. For example, one parent reported: "When his grandma gave him a Pikachu toy for his birthday, he was like, how did you know I love Pokemon, grandma?" We were particularly interested in how we might measure children's surprise empirically, as well as what kinds of violations might give rise to them. Therefore, for each report, we coded how the child expressed their surprise (i.e., verbally or via facial expressions) as well as how the person mentioned in the episode acquired their knowledge about the child (See Figure 1).

14% (18/126) stories were uncodeable (e.g., difficult to interpret, not about children's surprise). Among the 109 coded reports, 61% (67/108) did not specify how children expressed surprise, 29% (32/108) mentioned that the child explicitly verbalized their surprise (e.g., by asking how someone knew), and 9% (10/108) mentioned that the child was visibly surprised (e.g., eyes widening) without specifying a verbal reaction. In 65% (70/108) of reports, someone acquired knowledge about the child through someone else (e.g., being told by a parent) whereas the knowledge was based on perceptual information (e.g., knowing that a child likes dinosaurs because they were wearing a dinosaur shirt) in 25% of reports. The origin of knowledge was unclear in the remaining 10% of reports (11/108).

In sum, Experiment 1 provided suggestive evidence that young children demonstrate surprise when someone knows something about them, and by 4 years of age, such responses are readily noticeable by parents. This allowed us to constrain the focus of our empirical investigation to children between ages 4 and 5. Interestingly, children were more likely to express their surprise verbally rather than through their facial expressions alone, and they were most frequently surprised about knowledge someone would have acquired second-hand (i.e., by talking to their parent). In subsequent experiments we explore both children's facial expressions and verbal reports in response to knowledge that would typically be acquired second-hand (e.g., preferences).

Experiment 2

In Experiment 2, we used a naturalistic conversational paradigm to assess how children respond when an expected or an unexpected source possessed personal information about them (i.e., their favorite food or movie). We look at children's explicit reports of feeling surprised at the end of the study as well as their spontaneous expressions at the time of violation.

Methods

Participants We recruited 4- and 5-year-old children (N=49, range: 4.0 - 5.9, mean: 6.1 yrs, 19 males, 43 % white). Parents of potential participants received an email describing the study and asking them to provide at least two pieces of information about their child: their favorite food(s) and their favorite movie/show(s). Those who responded were scheduled for a synchronous study on Zoom (http://zoom.us). Five additional children participated but were excluded due to experimenter error (n=4) or inattention (n=1).

Procedure The study procedure consisted of a conversation between the child and the experimenter (See Figure 2). The experimenter had already obtained some personal facts about the participant based on the parent's email and was prepared to use this information during the conversation.

After greeting the child on Zoom and obtaining parental consent, the experimenter mentioned they had something to tell them. The experimenter first brought up one of the two pieces of information about the child (favorite food or movie/show), describing the source as either the child's parent (i.e. "your mom") or the experimenter's parent (i.e. "my mom"). For example, "I was talking to *your mom*, and your mom said that your favorite food is pizza". The experimenter then engaged the child in brief conversation about the topic [1] (e.g., "what kind of toppings do you like on your pizza?") before bringing up the second piece of information in a similar manner, using the other parent as the source this time: "I was talking to *my mom*, and my mom said that your favorite movie is Frozen". The order of the information and source was counterbalanced across participants.

After a brief conversation about the second topic, the experimenter asked the child a series of questions about each piece of information in the order they were discussed. The first question probed whether children remembered the source of personal information: "Do you remember who told me what your favorite food/movie is? Was it your mom or my mom who told me?". If children responded with the incorrect source or could not remember, the experimenter corrected them by telling them the original source: "actually, it was *my* mom who told me ...". The experimenter then asked the key question: "Were you surprised that your/my mom knows what your favorite food/movie is, or were you not surprised?". Afterwards, the experimenter told children they were actually playing a silly game, and that the experimenter's parent doesn't actually know these things.

Results and Discussion

First, we looked at whether children were more likely to report surprise when an unexpected (vs. an expected) source possessed knowledge about them. We used a mixed effects logistic regression to predict children's reports of surprise, with source (child's parent, experimenter's parent) and age (in months) as fixed effects and target knowledge (favorite food or movie) and source order (child or experimenter's parent first) as random effects.

As expected, children were significantly more likely to report being surprised when the experimenter's parent (41/49, 84%) knew personal information about them than when their

[1] The conversations varied based on the individual participant and their preferences. However, to avoid drastic differences between participants, the experimenter typically asked participants to explain their preferences and tried to keep the conversations around a minute per topic.

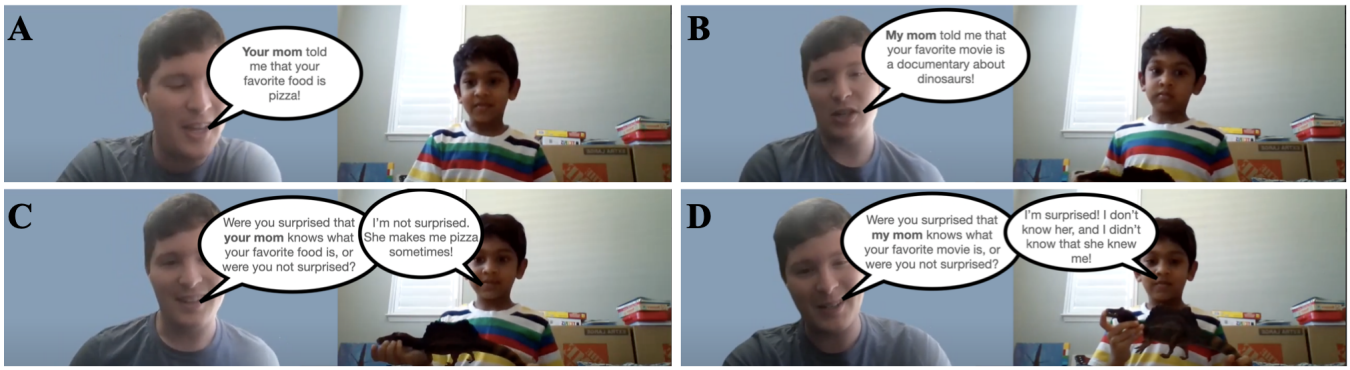

Figure 2: Abridged depiction of an example conversation in Experiment 2. First, the experimenter informs the child that they learned something about them from the child's parent (A), and from their own parent (B). After having a conversation about these topics, the experimenter asked the child if they were surprised that each source possessed knowledge about them (C-D).

own parent (16/49, 33%) had the same knowledge ($\beta = 1.8$, $p < .001$). There was no effect of age ($\beta = .04$, $p = .28$).

Given prior work using children's facial expressions in false belief scenarios (Moll et al., 2016; Ni et al., 2023), we also investigated whether children's facial expressions suggested any initial reaction to the unexpected knowledge source. We coded whether children's facial expression changed (eyebrows raising or furrowing, eyes widening or closing, mouth opening or closing, lips smiling or frowning) after the experimenter mentioned where they had acquired information about them. As expected, out of 43 codeable videos, 16 children (37%) showed a change in their expressions after the experimenter mentioned something they had learned about them from the experimenter's parent, whereas only 1 child (2%) showed a change after the experimenter mentioned something they had learned about them from the child's parent. This difference was statistically significant ($\beta = 3.2$, $p = .002$) and did not vary by age ($\beta = .02$, $p = .64$).

We implemented a memory check to see whether children explicitly remembered who provided each piece of information to the experimenter. Most children provided an answer (44/49, 90%). Rather unexpectedly, however, 23 of 49 children (47%) incorrectly attributed knowledge to their parent when the source of the knowledge was in fact the experimenter's parent, whereas only 9 of 49 (18%) incorrectly attributed knowledge to the experimenter's parent when the actual source was their own. Intrigued by this unexpected error rate, we ran a mixed-effects logistic regression to predict memory error [2] using the same fixed and random effects. Consistent with the pattern of surprise, children were more likely to misattribute knowledge to their own parent when it was actually provided by the experimenter's parent, compared to the reverse ($\beta = 1.39$, $p = .005$). There was no effect of age ($\beta = .04$, $p = .25$). Importantly, children's memory errors did not appear to influence their surprise reports; excluding participants who failed either memory check, children were still significantly more likely to report being surprised when the experimenter's parent knew personal information about them than when their own parent had the same knowledge ($\beta = 2.5$, $p < .001$).

In sum, Experiment 2 provides additional evidence that children, by around 4 years of age, understand who might have access to private information about themselves; both their verbal reports and facial expressions suggest they find it surprising when their expectations are violated, and a subset of children even misattributed the knowledge to a more plausible source (i.e., their parent, instead of the experimenter's parent ; See Figure 3). Critically however, it is possible that children show this pattern simply because they expect their own parent, compared to other adults, to be generally more knowledgeable. Below we report an ongoing experiment that aims to address this concern.

Experiment 3

This ongoing experiment uses the same method as Experiment 2 to examine children's epistemic expectations, with one change: The parents of the child and the experimenter purportedly knew the experimenter's sibling's favorite food/movie, instead of the child's. This manipulation flipped the expected / unexpected source of information, making the experimenter's parent a more plausible source of information than the child's parent. Thus, we expected an opposite pattern of results compared to Experiment 2.

Methods

Participants We plan to recruit the same number of 4- and 5-year-olds as Experiment 2; data collection is ongoing (31/49 planned), and here we report results from 31 children (Mean age = 62 months, 20 males, 45% White)) who participated in the study over Zoom. While obtaining information about the child's preferences was unnecessary in this experiment, we still emailed parents ahead of time requesting the same information and only scheduled a session with those who responded in order to avoid sampling from a meaningfully different population. Four additional children participated but were excluded for not providing clear responses to the key questions (n=3) or technical difficulties (n=1).

[2] We coded explicit misattribution as 1, and 0 otherwise, including correct answers and no answer

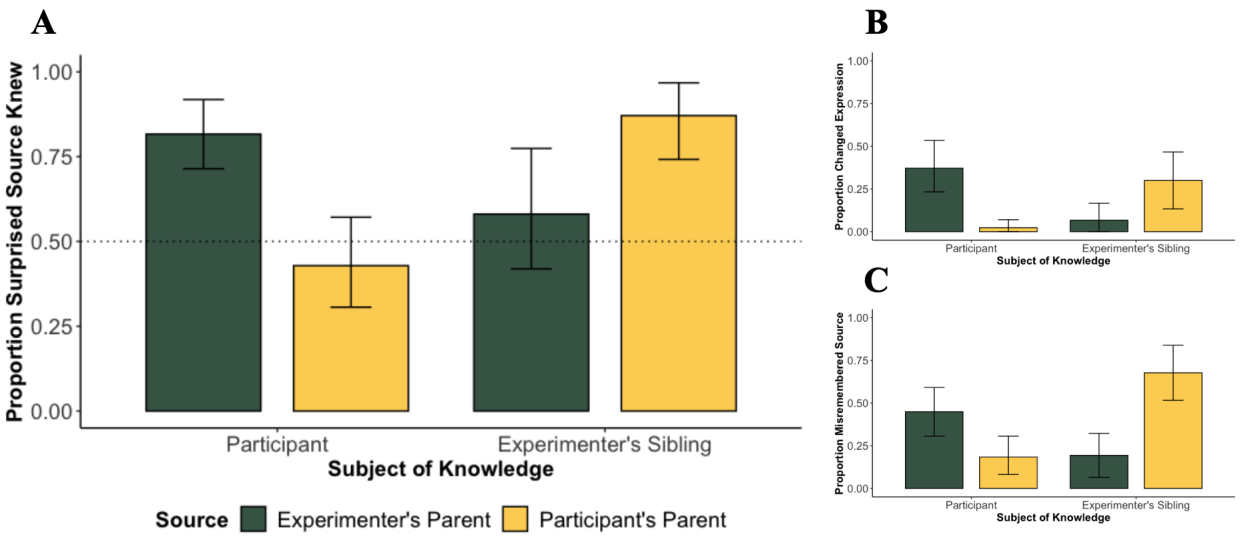

Figure 3: (A) Proportion of children who reported being surprised that a given source possessed knowledge about them (Exp 2) or the experimenter's sibling (Exp 3); results do not differ when excluding participants who exhibited a memory error. (B) Proportion of children whose expression changed after experimenter said a given source possessed knowledge. (C) Proportion of children who misattributed knowledge to the other (incorrect) source. Error bars indicate 95% bootstrapped confidence intervals.

Procedure The procedure was similar to Experiment 2 but knowledge about the child was replaced by knowledge about the experimenter's sibling.

First, the experimenter told the child that they had a sibling (gender matched to the child) just like them, and mentioned something they learned about their sibling from either the child's parent (i.e., "your mom") or their own parent (i.e., "my mom"). For example, the experimenter said: "I was talking to your mom, and your mom told me that my sister's favorite food is pizza!"). Next, the experimenter asked the child what their favorite food or movie was and engaged them in conversation. The experimenter then brought up the second piece of information in a similar manner, describing the source as the other parent this time.

Finally, the experimenter asked the child the same series of questions as Study 2, but about their sibling: "Do you remember who told me what my sister's food/movie is? Was it your mom or my mom who told me?"; "Were you surprised that your mom/my mom knows what my sister's favorite food/movie is, or were you not surprised?".

Results

We conducted the same analysis as Study 2. As expected, children were significantly more surprised when their own parent (27/31, 87%) knew personal information about the experimenter's sibling than when the experimenter's parent (18/31, 58%) had the same knowledge ($\beta = 1.6$, $p = .014$). There was no effect of age ($\beta = .03$, $p = .45$).

Additionally, we coded children's changes in expression after the experimenter mentioned information about their sibling. Out of 30 codeable videos, only 2 (7%) children's expressions changed after the experimenter mentioned something they had learned about their sibling from the experimenter's parent while 9 (30%) children's expressions changed after the experimenter mentioned something they had learned about their sibling from the child's parent. This difference was statistically significant ($\beta = 1.79$, $p = .032$) and did not vary by age ($\beta = .005$, $p = .91$).

As before, we also examined children's memory for who provided the experimenter with a given piece of information. Most children provided an answer (26/31, 84%), showing a reversed pattern of errors from Experiment 2; only a small proportion of children (6/31, 19%) incorrectly attributed knowledge to their parent when the source was in fact the experimenter's parent, while a majority (21/31, 68%) incorrectly attributed knowledge to the experimenter's parent when the source was really their own. Indeed, children were significantly more likely to misattribute knowledge to the experimenter's parent when it was really provided by the child's parent, compared to the reverse ($beta = 2.17$, $p < .001$). There was no effect of age ($beta = .003$, $p = .94$). Unlike in Exp 2, We could not examine whether memory errors influenced children's surprise reports due to low power.

Discussion

The current studies shed light on how we form expectations about others' knowledge, implicitly and explicitly. In Exp 1, parents reported that a majority of their children had been surprised that others knew something about them, beginning to do so on average by around 4-years. Exp 2 investigated these behaviors experimentally by providing children with information about themselves obtained from a likely (the child's parent) or unlikely (the experimenter's parent) source. Both 4- and 5-year-olds explicitly reported that they were surprised that the experimenter's parent, but not their own parent, pos-

sessed this knowledge. Interestingly, children's facial expression were more likely to change following information coming from an unexpected source (the experimenter's parent) and they systematically misattributed this knowledge to their parent, suggesting they possessed an implicit expectation that the experimenter's parent would not possess personal information about them.

Exp 3 suggests these expectations are not limited to knowledge about themselves. When assessing who possessed knowledge about someone else—the experimenter's sibling—whom their own parent was unlikely to have access to, we found an opposite pattern of responses: children's verbal reports and facial expressions suggest they were surprised their parent, but not the experimenter's parent, possessed personal knowledge about the experimenter's sibling. They were also more likely to misattribute the knowledge to the experimenter's parent. Overall, these results demonstrate that by around 4-years, children form expectations about what people know about themselves and others, and that these expectations are guided, at least in part, by a sense of others' access to information.

How implicit are children's epistemic expectations, and how spontaneously do they recognize violations of them? Despite parents' reports of children spontaneously asking how an expected source acquired their knowledge, we rarely observed such behavior in Studies 2 or 3. It is possible that the structured nature of the overall interaction (e.g., a scheduled session with an experimenter where the child only provides responses when asked) discouraged children from asking spontaneous questions.

However, children's memory errors point towards another possibility: Perhaps children made pragmatic repairs, also on the fly, believing the experimenter misspoke when they said their parent possessed knowledge about the child. Indeed, prior work has found that young children reinterpret unexpected utterances based on the quality of the speech signal (i.e., noise) as well as the speaker's past reliability (Yurovsky et al., 2017). While further work is needed to understand the role epistemic expectations play in children's pragmatic inferences, the current work nonetheless demonstrates that children form systematic epistemic expectations: Inferring that the experimenter misspoke when citing an unexpected information source would itself provide evidence that children hold implicit expectations about what such sources know.

Children's expectations about others' knowledge had to be based on some sense of their access to information. How granular and flexible are young children's representations of others' information access? On the one hand, it is possible their understanding of information access is initially quite shallow. Perhaps they simply use familiarity between agents as a proxy for access. For example, because they expect someone to be more familiar with their parent than with a stranger, they expect their own parent to know more about them relative to a stranger, and they expect a stranger's parent to know more about the stranger than themselves. On the other hand, children may represent information access in terms of distinct channels. For example, they might understand that their parent has access to information about them both perceptually (i.e., by observing the child's actions) and communicatively (i.e., by speaking with the child), while a stranger's parent has access to neither of these channels.

The current studies do not differentiate between these possibilities, but future research could tease them apart by introducing a channel of information access. For example, the experimenter could begin Exp 2 by telling the child that their parents actually talk regularly. This provides a communicative channel through which the experimenter's parent could acquire personal information about the child from the child's parent. If children represent information access in terms of distinct channels, children should now be less surprised that the experimenter's parent possesses knowledge about them. Additionally, when asked where they think the experimenter's parent learned it from, they should infer that their own parent likely told the experimenter's parent, who in turn told the experimenter.

Although the nature of how children represent information access is currently unclear, there is some evidence suggesting they are capable of holding richer representations, at least some of the time. Even infants understand others can acquire information perceptually (e.g., Luo & Baillargeon, 2007; Luo & Johnson, 2009; Kim & Song, 2015; Knudsen & Liszkowski, 2012; Surian et al., 2007) and communicatively (e.g., Jin et al., 2019; Song et al., 2008; Tauzin & Gergely, 2018; Vouloumanos et al., 2014, 2012), and preschoolers are able to use communicative access to infer a speaker's knowledge based on a listener's actions (Chuey & Gweon, 2021). Slightly older children also privilege primary sources over those who obtained information secondhand (Aboody et al., 2022), suggesting they have some sense that information can pass through, and be diluted by, chains of communication between multiple agents. Therefore, children's ability to represent diverse channels of information access depends on the extent to which they can encode and track these channels across agents and across time.

When we encounter an unlikely source of knowledge, like a stranger knowing we lost our keys last week, surprise might give way to speculation: Have I met this person before? Do they have access to disturbingly thorough background checks? Even though we are unaware of it most of the time, these instances remind us of our remarkable ability to reason about almost anyone's abstract mental states in the blink of an eye. The current work suggests these inferences reflect a rich understanding of how others acquire knowledge that nonetheless emerges early in life.

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