

## EMPIRICAL ARTICLE

# Children's Understanding of How Past Experience Shapes Future Expectations

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## ABSTRACT

As adults, we do not expect ignorant agents to behave randomly or always get things wrong. Instead, we expect them to act reasonably, guided by past experiences. We test whether 4-to-6-year-olds share this intuition and use it to infer others' knowledge, or whether they rely on a simple "ignorance = error" heuristic identified in past work. Across three pre-registered experiments ( $n = 264$  4-to-6-year-olds recruited in the US between 2018-2022; demographic data not collected), we find that 4-year-olds expect agents to draw on past experiences when acting in new situations. However, only 6-year-olds reliably use this expectation to infer others' knowledge from behavior. These findings suggest that by age 6, children use a causal model of how ignorance shapes behavior, and not just a cue-based understanding of epistemic states.

The ability to represent other people's mental states—such as their desires, beliefs, and knowledge—underlies many of our most important social interactions. It shapes how we interpret other people's behavior (Baker et al. 2017); predict their future actions (Wellman et al. 1990; Wellman 2014); communicate and share knowledge (Shafto et al. 2014; Bridgers et al. 2020); and even judge their moral standing (Young et al. 2007).

Yet, these mental states are not directly observable, so we must develop a capacity to infer them by watching other people's behavior. As adults, this capacity is remarkably sophisticated: we can infer another person's goal from just a few movements in space (Baker et al. 2009), their preferences from a single choice (Jern et al. 2017), and their knowledge or beliefs from minimal evidence—such as seeing an agent check behind a wall (Baker et al. 2017) or hearing them use a particular adjective in a communicative interaction (Jara-Ettinger and Rubio-Fernandez 2021). These inferences are supported by a mental causal model of how other people's unobservable mental states cause their behavior, called a Theory of Mind (Gopnik and

Meltzoff 1997; Dennett 1989). Equipped with this causal model, adults can then invert it, working backwards from observed behavior to make inferences about others' likely underlying mental states.

For example, suppose your friend usually leaves their car keys in a bowl by the door but often forgets to take them out of their jacket pocket. If your friend wanted to go out, we can use our causal model to predict their behavior. For instance, we might expect them to first check the bowl and, if the keys are not there, to then try to remember which jacket they wore yesterday and check its pockets. This model of how mental states guide behavior can then be inverted, allowing us to also work backwards from observed actions to the unobservable beliefs and desires that best explain them. In this example, if you just watched your friend put on their shoes, go check the bowl next to the door, and then walk to the coat rack and think for a moment before grabbing a jacket and checking its pockets, you can infer they want their keys and believe they may be in their jacket. This theoretical proposal for how we reason

about other minds, where mental-state inference is performed by inverting our mental causal models of other minds, can be formalized and implemented as a computational model. Recent research suggests that models formalized based on this account capture a variety of human mental-state inferences with quantitative accuracy, including how adults infer other people's goals (Baker et al. 2009), beliefs (Baker et al. 2017), preferences (Jern et al. 2017), and competence (Jara-Ettinger and Rubio-Fernandez 2021). Taken together, this work provides some evidence that adults may in fact infer others' mental states following a similar theoretical-level process, observing others' actions and inverting their causal models of other minds to infer what mental states likely gave rise to the observed actions.

This capacity to infer mental states from behavior is not just important for adults and might be particularly critical in early childhood. Since children frequently rely on others to learn about the world, they benefit from distinguishing people who are knowledgeable and trustworthy from those who are not (Sperber et al. 2010), and evidence suggests that their learning is powerful in part thanks to their capacity to reason about other people's minds (Gweon 2021). Studies into the development of action understanding reveal that young children can also infer mental states by inverting a causal model of other minds (Lucas et al. 2014; Jara-Ettinger et al. 2016). This capacity emerges in infancy (Liu et al. 2017; Gergely and Csibra 2003), and it allows children to solve complex social challenges like interpreting ambiguous speech (Jara-Ettinger 2019) and judging whether other people's behavior is justifiable or condemnable (Jara-Ettinger et al. 2015).

Although children appear to rely on a causal model of other minds to infer goals and desires, this capacity might not extend to inferences about beliefs and knowledge (called epistemic states). When inferring epistemic states, children's inferences do not follow the predictions that a causal model inversion would predict (Richardson et al. 2018). Instead, children appear to rely on two complementary assumptions: that knowledgeable people get things right, and that ignorant people get things wrong. These assumptions offer a practical shortcut, allowing children to associate observable behavior with epistemic states in a reliable way, avoiding the more complex kind of reasoning that is characteristic of adults' inferences.

Evidence for the first assumption—knowledge implies accuracy—comes from studies showing that children readily track other people's previous accuracy and then use this to make social decisions and predictions, preferring to learn from those who have been previously correct and expecting them to continue being accurate in the future (Birch et al. 2008; Koenig et al. 2004; Koenig and Harris 2005). Critically, this expectation is applied in a rigid way, suggesting it is a simple heuristic. For example, 3-year-olds are equally dismissive of someone who makes one error out of four and someone who gets all four wrong. It is not until age 4 that they begin to distinguish between these behaviors (Pasquini et al. 2007), and not until age 6 that they can reliably consider not just whether someone was wrong, but how wrong they were (Einav and Robinson 2010).

In recent years, however, a growing body of research has revealed that children's expectations about knowledgeable agents are more sophisticated than a simple accuracy expectation. By the end of preschool, children distinguish agents who can produce accurate statements independently from those who do so with help (Einav and Robinson 2011); they distinguish agents who make accurate predictions from agents who merely make accurate observations (Aboody et al. 2022); they understand that knowledgeable agents are less likely to seek out information (Aboody et al. 2021); and they track the knowledge limits of accurate agents (i.e., understanding that being accurate in one domain does not imply you will always be accurate; Aboody et al. 2022). Children at this age even know that some facts are, in principle, unknowable (Lockhart et al. 2016). Together, this research suggests that 6-year-olds have a causal understanding of how and why knowledge produces accurate behavior.

What about children's second hypothesized heuristic, where they equate ignorance with getting things wrong? This heuristic was proposed based on studies showing that children predict that an agent who is ignorant will always get things wrong (Ruffman 1996; Saxe 2005). Conversely, when children watch an agent make an inaccurate statement, they treat the agent as being generally ignorant, even when the inaccuracy was justifiable (e.g., failing to correctly name an object they cannot see; Nurmsoo and Robinson 2009), and they struggle to understand that an ignorant person can get things right by chance (Aboody et al. 2025).

In the same way that the “knowledge = accuracy” heuristic has been called into question, some research suggests that the “ignorance = error” expectation might also be an over-simplified picture of children's understanding of other minds. 4- and 5-year-olds do not always expect ignorant agents to get things wrong (Friedman and Petrashek 2009; Jara-Ettinger et al. 2017). This research suggests that children have more nuanced expectations, but it does not yet reveal exactly what children believe about how ignorant agents act.

What kind of expectation might distinguish a simple “ignorance = error” assumption from a causal understanding of why others do what they do? Here, we suggest that a key adult intuition is that we do not expect ignorant agents to behave randomly or to always be wrong. Instead, we expect them to make reasonable attempts to succeed in their goals by drawing on any relevant past experiences that might give a clue for how to act.

To illustrate this, imagine that a new ice cream shop opens near your house, and you invite a friend to check it out. Even if you know your friend has never been there, you would not expect them to be completely at a loss. Intuitively, you would expect them to rely on past experiences to guide their actions: walking up to the counter, checking the available flavors, waiting for a server, ordering, and then paying at the cashier. Their ability to flawlessly navigate this new setting would be unremarkable. But now imagine this shop uses a peculiar system. You first buy tokens from a machine, use those tokens to pay, and then hand the receipt to a server in exchange for your ice cream. If your friend walked in and took all

the right steps in the right order, you might now suspect they knew something about this ice cream shop and their system in advance.

This example highlights how our representations of ignorant agents are more nuanced than a simple expectation for error or randomness. Intuitively, we understand that agents accumulate experiences that shape their expectations in new situations. These expectations then allow us to predict how others will act (e.g., predicting that a friend who has never been to the unusual ice cream parlor may initially struggle), and to infer what others know (e.g., inferring prior knowledge when someone acts in a way that deviates from expected reasonable behavior under ignorance).

Our paper aims to reveal at what age children begin to expect ignorant agents to act reasonably based on past experiences, and whether they use this expectation to infer epistemic states. Clarifying the age at which this ability emerges is important for several reasons. First, to understand why children may not show adult-like behavior, we need to determine whether they lack a causal model of how epistemic states drive behavior, or whether they struggle to invert this model. Second, this research can help us understand why children rely on simpler heuristics. One possibility is that young children use heuristics like “ignorance = error” because they have no other available strategies, and they abandon heuristics as soon as they are able to do more causal-based reasoning. Alternatively, there might be a developmental period in which children can infer mental states through a causal model but still prefer heuristics as reasoning shortcuts. Finally, this study contributes important data for understanding the general trajectory of Theory of Mind development. Identifying when children form expectations for how ignorant agents ought to act, and when they can use those expectations to reason backwards—inferring what others know from what they do—poses a contribution to the overall literature on Theory of Mind milestones. We return to these three points in the General Discussion.

In Experiment 1, we begin by testing the basic causal expectation that ignorant agents should make reasonable guesses in new situations. Experiments 2 and 3 then test whether children can use this causal expectation to work backwards from someone’s behavior to recover their knowledge. Throughout, we focus on 4- to 6-year-olds because the ability to explicitly reason about and infer others’ epistemic states undergoes substantial development during these years (Aboody et al. 2025; Wellman et al. 2001; Wellman and Liu 2004; Wu and Schulz 2018), and past work suggests that reasoning about ignorance without relying on heuristics may not emerge until age 6 or beyond (Chen et al. 2015; Fabricius et al. 2021; Friedman and Petrashek 2009; German and Leslie 2001; Ruffman 1996; Saxe 2005). Moreover, it is in this age range that children show an improved understanding of how past experience can be used to predict people’s future behavior (explored in the domain of visual perception; Krachun and Lurz 2016), and it is by age 6 that children can understand how ignorant agents transition to becoming knowledgeable based on evidence (Huang et al. 2019). We therefore expected that older children might be able to succeed at this task (helping us ensure our task was designed appropriately), but it might also reveal when children gain these intuitions.

## 1 | General Methods, Approach to Analyses, and Demographic Information

Consistent with current recommendations for statistical best practices, we primarily take an estimation approach to data analysis, rather than relying on null-hypothesis significance testing (Cohen 1994; Cumming 2014). We estimate effect sizes by bootstrapping our data and obtaining 95% confidence intervals; we take confidence intervals that do not cross chance as evidence of a reliable effect. To test for effects of age continuously, we use binomial logistic regression models, reporting  $\beta$ -coefficients and  $p$ -values.

All experiments’ procedures, predictions, exclusion criteria, and analyses were preregistered; see [Supporting Information](#) for details on deviations from preregistration. All preregistrations, stimuli, data, and analysis files are available in the OSF project page: <https://osf.io/5vzkq/>. All experiments were IRB-approved. Note that while our analysis plan was not exploratory (all analyses were preregistered) our research question could be considered exploratory because we did not have exact predictions about the precise developmental trajectory or age at which children would begin to succeed.

All data were collected between 2018 and 2022, and children were tested online (always US participants), in Connecticut, or in California. We did not preregister collecting demographic information because there was no reason to expect basic Theory of Mind capacities could vary as a function of gender, ethnicity, or race (see Doebel and Frank 2023). However, aggregate statistics over visitors at (museums) or residents near (schools) our in-person recruitment sites suggest that our sample was drawn from a diverse population both in terms of race/ethnicity as well as SES; see [Supporting Information](#) for details.

## 2 | Experiment 1

Experiment 1 tests whether 4- to 6-year-olds have a basic expectation that ignorant agents draw on their past experiences when facing relevant novel situations.

### 2.1 | Method

#### 2.1.1 | Participants

120 4-, 5-, and 6-year-olds (mean age: 5.48 years, range: 4.01–6.90 years;  $n = 40$  participants per age group) were recruited and tested online (determined via a power analysis, see [Supporting Information](#)). Twelve additional participants were recruited but not included in the study (see Section 2.3).

#### 2.1.2 | Stimuli

Stimuli consisted of a brief picture story with simple animations, implemented as a PowerPoint presentation. In the story, participants were introduced to a male puppet, Max, and two identical-looking toys: both were dark gray boxes with a white

heart on the front, and each had two buttons on top: a black button to the left and a red button to the right (see Figure 1). When activated, the heart on the front of the toys lit up yellow and spun around. For the “training” toy, only one of the buttons activated the toy (either the red or the black button; counterbalanced across participants) and for the “test” toy, both buttons activated the toy.

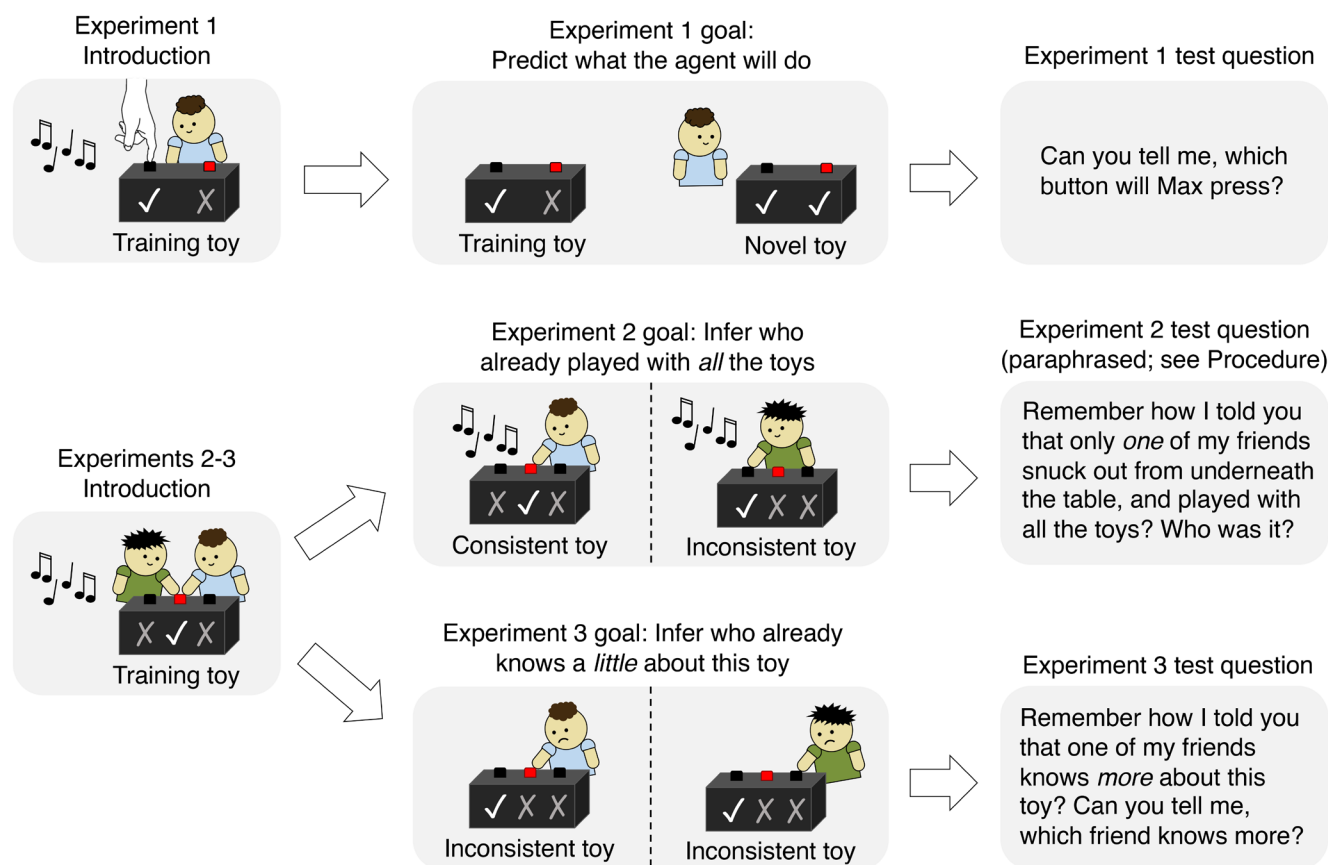
## 2.2 | Procedure

The experiment consisted of three phases. We describe these phases concisely below, including key parts of the script, but see [Supporting Information](#) for the detailed procedure and full script. In the first phase, the experimenter introduced children to two new toys and showed them how each toy worked; participants learned that only one button activated the first training toy (the black button or the red button, counterbalanced across participants), but *both* buttons activated the second test toy. In the second phase, children were introduced to an agent called Max, and they learned that Max had never seen these toys before and did not know how they worked. The experimenter then proceeded to teach Max how the training

toy worked, demonstrating that only one of the buttons activated this toy, and the other one did nothing. Toys were always illustrated via a hand icon that sequentially pressed each button (see Figure 1).

In the third and final phase, the experimenter then introduced the task, saying “Max! Guess what! It’s your turn. You can press *one button* to make this toy go.” The hand icon moved to point to the second toy, and Max turned to look at it. The experimenter explained that “...you only have one chance to make the toy go. If you can make the toy go on your first try, I’ll give you a *sticker!*” The promise of a sticker was intended to establish that Max would be motivated to get it right on the first try, to minimize the possibility that children would expect Max to be exploratory.

Max turned to look at the training toy, and the experimenter narrated his response, “And Max says, ‘Hmm! Well, the black button *made* this toy go, and the red button did *not* make this toy go (counterbalanced). So, I’ll press...” Max turned to look at the second toy, and the experimenter asked the test question: “[Participant name], can you tell me, which button will Max press? The *black* button, or the *red* button? What do you think—will he press the black button, or the red button?” The



**FIGURE 1** | Procedure schematic of Experiments 1–3; note that the check-marks and x’s on the boxes are only for illustrative purposes, and were not present in the experiment; music notes represent a toy activating. In Experiment 1, an agent learned how the training toy worked, and was then given one chance to activate a new, outwardly-identical toy. Participants knew this toy worked differently, but were asked to predict what the agent would do. In Experiments 2 and 3, two agents learned how a different training toy worked. Each was then given one chance to activate a new, outwardly-identical toy. One agent always acted consistently with his experience with the training toy (pressing the red button); the other always acted inconsistently (pressing a black button). In Experiment 2, both agents succeeded in activating their respective toys. Participants were asked to infer who had added prior experience, having already played with all the toys. In Experiment 3, both agents failed to activate the new toy. Participants were asked to infer who had some added prior experience, and knew *more* about the new toy.

experimenter then asked participants to explain their response, and asked participants to recall whether each button had activated its respective toy, a simple preregistered inclusion question designed to ensure participants had understood the task (see [Supporting Information](#)).

## 2.3 | Results

For this study, we hypothesized that, if children only have an expectation that ignorant agents get things wrong or behave randomly, they should perform at chance, as our design controls for this. If children are also simply drawn by simpler heuristics like visual salience, they should show a significant preference for a red button and should again perform at chance, as we counterbalanced which button activated the first toy. However, if children expect ignorant agents to act reasonably based on past experiences, we predicted that they should expect the agent to try the same button that had activated the first toy.

For the 71.2% of participants whose sessions were video or audio taped ( $n=94/132$ ), two coders who were not involved in data collection determined exclusions according to preregistered criteria. The first coder was blind to participants' final answers, checking for any experimenter errors, family interference, internet connectivity issues, and ensuring that the participant was attentive. The second coder was blind to counterbalance and thus could not determine whether a participant's answer was right or wrong. The second coder checked for the same issues as the first coder and additionally checked whether participants answered the test question within 30s. Twelve participants were excluded from the analyses and replaced because they did not pass the preregistered inclusion questions ( $n=10$ ), because they did not provide a codable answer to the test question ( $n=1$ ), or because they had already participated in the past ( $n=1$ ).

Overall, 65.8% of participants ( $n=79$  of 120) predicted that Max would leverage his experience with the training toy when

deciding how to activate a new visually-identical toy, pressing the same button he'd learned made the first toy go. This proportion is reliably above chance (95% CI: 57.5–74.2); see [Figure 2](#). A logistic regression predicting dummy-coded performance based on age revealed no significant age difference ( $\beta = -0.29$ ,  $p = 0.21$ ); see [Figure 2](#). These results suggest that, when making action predictions, 4-year-olds already expect an agent to leverage relevant prior experience when deciding how to act in a new situation.

## 3 | Experiment 2

Having found that 4- to 6-year-olds do expect ignorant agents to leverage relevant experiences when deciding how to act, we next sought to test whether children can use this expectation when inferring knowledge from action; all while controlling for accuracy.

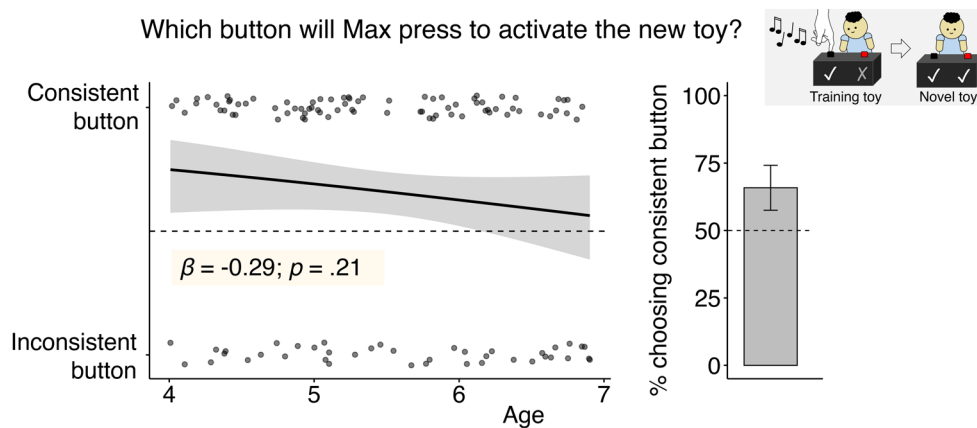
### 3.1 | Method

#### 3.1.1 | Participants

72 4-, 5-, and 6-year-olds (mean age: 5.45 years, range: 4.05–6.995 years;  $n=24$  participants per age group) were recruited and tested in Connecticut or California (see [Supporting Information](#) for full details). Sample size was determined via a power analysis (see [Supporting Information](#)). Twenty-one additional participants were recruited but not included in the study for failing inclusion criteria (see [Section 3.3](#)).

#### 3.1.2 | Stimuli

Stimuli consisted of two male puppets, Sam and Max, and three novel toys. All three toys were externally identical, each covered in dark gray construction paper and measuring



**FIGURE 2** | Results of Experiment 1. At left are participant predictions over which button Max would press (acting consistently or inconsistently with his experience with the training toy) plotted as a function of age, along with a logistic regression fit to the dataset. Points are jittered along the Y axis (but not the X axis). The gray band shows a 95% confidence interval in the regression. At right, we plot the proportion of participants predicting Max would act consistently with his prior experience, pressing the black button, by age group. The dotted line indicates chance performance; vertical bars show 95% bootstrapped confidence intervals. The gray box at top right is a procedure schematic (note that we counterbalanced which button activated the training toy).

approximately  $5 \times 3 \times 2.75$  in. Each toy had three buttons on top: a red button in the middle, flanked by a black button to either side (see Figure 1).

Although all three toys looked the same, they worked in different ways. The first “training” toy activated and played music only when the central red button was pressed. Of the remaining toys, the “consistent” one worked the same way. However, the “inconsistent” one worked differently: only pressing the black button to the participant’s far left made it activate and play music. The other black button did not make this toy activate, and neither did the red button.

### 3.2 | Procedure

The experiment consisted of four phases, which we describe concisely, including key parts of the script; see [Supporting Information](#) for detailed procedure and full script. In the first phase of the experiment, the experimenter introduced children to a new toy, the “training toy,” and showed them how it worked. Participants learned that the central red button activated this toy, causing it to play music—but the flanking black buttons were inert and did nothing. After the experimenter’s demonstration, participants were encouraged to press the red button for themselves. In the second phase, participants were introduced to two new puppets, Sam and Max. The experimenter taught Sam and Max how to activate the training toy, demonstrating that only the red button caused this toy to activate and both black buttons were inert.

In the third phase, the experimenter introduced two new toys, visually-identical to the first. Participants learned that one puppet had snuck out and already played with all the toys, so he already knew how all of the toys worked. Meanwhile, the other puppet had not seen anything. The experimenter explained the task, proposing to “ask our friends some questions, to figure out which friend snuck out from underneath the table, and played with *all* the toys.” One at a time, each puppet was asked to activate one of the new toys (this occurred while the other puppet was removed from sight and placed underneath the table). Each puppet always looked at the toy nearest to him and chose a button to press, explaining his reasoning. For the consistent toy, which worked the same as the training toy, the puppet would say, “Hmm. Well, the red button made this toy go [touching the training toy], so the red button [pointing to button on consistent toy] makes this toy go too!” Then he would press the red button he had indicated, successfully causing the consistent toy to activate and play music. For the inconsistent toy, which worked differently from the training toy, the puppet would say, “Hmm. Well, the red button made this toy go [touching the training toy], but this black button [pointing to leftmost button on inconsistent toy] makes this toy go.” Then he would press the black button he had indicated, successfully causing the inconsistent toy to activate and play music. The experimenter would always recap what a puppet had done, saying, “And [puppet] was right; the [red/black] button makes this toy go! So [puppet] showed us how to make this toy go.”

After participants had observed both puppets activate one of the new toys, in the fourth and final phase of the experiment, the experimenter asked the test question, saying: “[Participant name], remember how I told you at the beginning of the game, that only *one* of my friends snuck out from underneath the table, and played with all the toys? Can you tell me, which one of my friends snuck out and played with all the toys?” The experimenter then asked participants to explain their response, and asked participants to recall which toy each puppet had activated, a simple pre-registered inclusion question designed to ensure participants had understood the task (see [Supporting Information](#)).

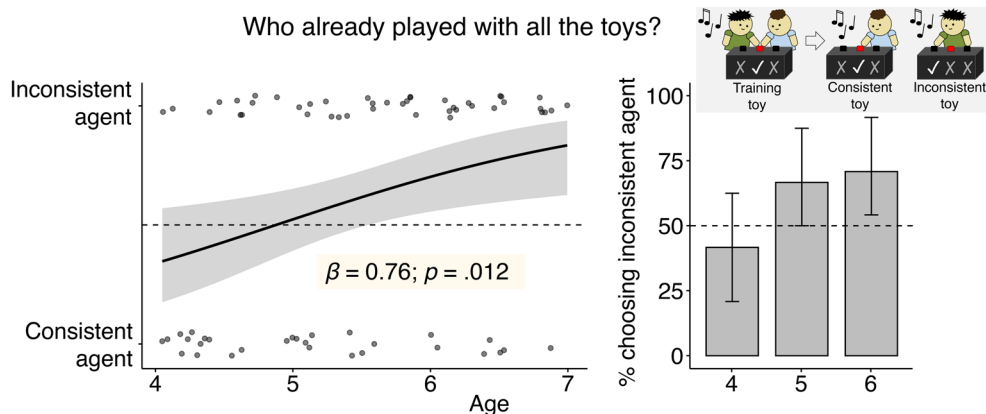
Note that puppets always demonstrated the toy they were standing closest to. This was to avoid pragmatic concerns that could arise if puppets undertook a cost to demonstrate a particular toy. The identity of the puppet whose turn was first (Max/Sam) and the toy this agent acted on (consistent/inconsistent) was counterbalanced. Additionally, the side each puppet was presented on (left/right) was randomized. Finally, note that three participants were tested using different puppets, Adrienne and Sophie, because Max and Sam were not available.

### 3.3 | Results

If children are inferring knowledge and ignorance through simple success and failure expectations, they should perform at chance, as our experiment matched the success of both agents. By contrast, if children have an expectation that ignorant agents act by drawing on past experiences, we hypothesized that they would attribute added knowledge to the agent whose actions could not be explained by his experience with the first toy.

For the 93.5% of participants whose sessions were video or audio taped ( $n = 87/93$ ), two coders who were not involved in data collection determined exclusions according to preregistered criteria. The first coder was blind to participants’ final answers, checking for any experimenter errors, family interference, and ensuring that the participant was attentive. The second coder was blind to counterbalance, and thus could not determine whether a participant’s answer was right or wrong. The second coder checked whether participants answered the test questions, and whether the experimenter or family members behaved in any way that could affect participants’ choices. Twenty-one participants were excluded from analyses and replaced because they did not pass the preregistered inclusion questions ( $n = 8$ ), due to experimenter error ( $n = 5$ ), participant inattention ( $n = 4$ ), because the participant did not answer the test question within 30s ( $n = 2$ ), interference with the procedure ( $n = 1$ ), or because the participant was non-neurotypical ( $n = 1$ ).

Overall, 59.7% of participants judged that the agent who pressed the black button on the new toy (acting inconsistently with his prior experience with the training toy) was more likely to have had additional knowledge. This proportion is not reliably different from chance (43 of 72; 95% CI: 48.6–70.8). However, a logistic regression predicting dummy-coded performance based on age (continuous) revealed a significant age difference ( $\beta = 0.76$ ,  $p = 0.012$ ); see Figure 3. While only 41.7% of 4-year-olds judged



**FIGURE 3** | Results of Experiment 2. At left are participant inferences over who had added prior experience with the toys (the agent who acted consistently or inconsistently with his experience with the training toy) plotted as a function of age, along with a logistic regression fit to the dataset. Points are jittered along the Y axis (but not the X axis). The gray band shows a 95% confidence interval in the regression. At right, we plot the proportion of participants inferring the inconsistent agent had prior experience with the toys (explaining why he did not rely on his experience with the training toy) by age group. The dotted line indicates chance performance; vertical bars show 95% bootstrapped confidence intervals. The gray box at top right is a procedure schematic (note that agents' roles were counterbalanced).

that the agent who activated the inconsistent toy had prior knowledge (10 of 24; 95% CI: 20.8–62.5), 66.7% of 5-year-olds (16 of 24; 95% CI: 50–87.5) and 70.8% of 6-year-olds (17 of 24; 95% CI: 54.2–91.7) selected this agent; see Figure 3.

### 3.4 | Discussion, Experiments 1 and 2

In Experiment 1, even 4-year-olds expected an ignorant agent to leverage relevant prior knowledge when deciding how to act in a new situation, predicting he would act consistently with his prior experience. In Experiment 2, however, it was not until age 5 or 6 that children's inferences about what others know appeared to be grounded in this expectation. Specifically, 6-year-olds judged that an agent who appeared to reject his prior experience—and succeeded—must have had some additional knowledge, compared to an agent whose actions were perfectly explained by his prior experience.

However, 5- and 6-year-olds might have succeeded in Experiment 2 through a different strategy. In this experiment, children only knew how the training toy worked, and they might have assumed that the new toys worked the same way. If so, children could attribute knowledge when they see successful actions that are inconsistent with their own personal expectations, rather than reasoning about the expectations the agent should have built from experience. In other words, children might simply attribute knowledge to agents who teach them something new or unexpected. We test for this possibility in Experiment 3.

## 4 | Experiment 3

Experiment 3 served as a conceptual replication and extension of Experiment 2 that also controls for the possibility that children simply infer knowledge from any action that they personally find novel.

## 4.1 | Method

### 4.1.1 | Participants

72 4-, 5-, and 6-year-olds (mean age: 5.56 years, range: 3.99–6.93 years;  $n=24$  participants per age group) were recruited and tested in Connecticut (sample size determined by power analysis, see [Supporting Information](#)). Twenty-five additional participants were recruited but not included in the study due to preregistered exclusion criteria.

### 4.1.2 | Stimuli

Materials were identical to those of Experiment 2, except that now only two toys were used: the training toy and the inconsistent toy.

## 4.2 | Procedure

The procedure of Experiment 3 was very similar to that of Experiment 2. Specifically, the first two phases were identical (in the first phase, participants learned how to activate the “training toy,” and in the second phase the puppets were introduced and learned the same; see Procedure of Experiment 2 for added details, and see [Supporting Information](#) for detailed procedure and full script). In the third phase, however, instead of producing two new toys, the experimenter only brought out the “inconsistent” toy and followed up by teaching participants how it worked, in the puppets' absence. The experimenter explained that this toy worked differently from the other toy and demonstrated that only the leftmost black button activated the toy. Participants were encouraged to press this button for themselves to observe that it indeed caused the toy to activate.

The third phase then proceeded similarly in structure to that of Experiment 2, with the experimenter explaining that one of the

puppets knew *more* about the inconsistent toy, having seen it before and therefore knowing a little about it, whereas the other puppet had never seen or played with the toy before. The experimenter proposed she and the participant “ask our friends some questions to figure out which one knows *more* about this [inconsistent] toy!” One at a time, each puppet was asked to activate the new toy (this occurred while the other puppet was removed from sight and placed underneath the table). Each puppet always looked at the new toy and chose a button to press, explaining his reasoning. The consistent puppet would say, “Hmm. Well, the red button made this toy go [touching the training toy], so the red button [pointing to button on inconsistent toy] makes this toy go too!” Then he would press the red button he had indicated, look down, and make a surprised “oh!” sound when the toy failed to activate. The inconsistent puppet would say, “Hmm. Well, the red button makes this toy go [touching the training toy], but this black button [pointing to the rightmost, incorrect button on the inconsistent toy] makes this toy go.” Then he would press the black button he had indicated, look down, and make a surprised “oh!” sound when the toy failed to activate. The experimenter would always recap what a puppet had done, saying, “So [puppet] pressed this [red/black] button.”

After participants had observed both puppets attempt to activate the “inconsistent toy”, in the fourth and final phase of the experiment, the experimenter asked the test question, saying: “[Participant name], remember how I told you that one of my friends knows *more* about this toy? Can you tell me, which friend knows more?” The experimenter then asked participants to explain their response, and asked participants to recall which button each puppet had pressed on the inconsistent toy, a simple preregistered inclusion question designed to ensure participants had understood the task (see [Supporting Information](#)).

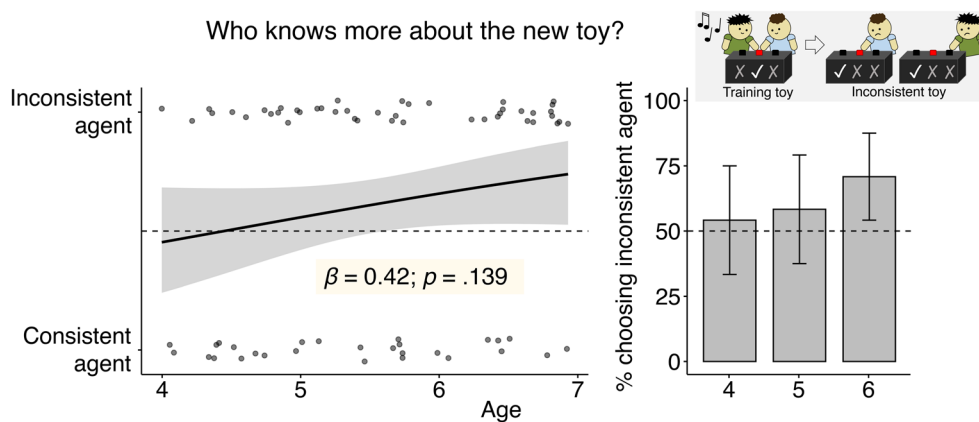
Note that the puppet whose turn was first (Max/Sam) and their role (consistent/inconsistent) was counterbalanced. Additionally, the side each puppet was presented on (left/right) was randomized.

### 4.3 | Results

Our predictions were similar to Experiment 2. If children rely on simple success and failure cues, they should perform at chance since both agents failed at activating the toy. But an expectation that ignorant agents draw on relevant past experiences should lead them to infer that the agent that went against past experiences was more knowledgeable, despite ultimately having made an incorrect choice.

For the 85.6% of participants whose sessions were video or audio taped ( $n = 83/97$ ), two coders who were not involved in data collection determined exclusions according to preregistered criteria, as in the previous experiments. Twenty-five participants were excluded from analyses and replaced because: they did not pass the preregistered inclusion questions ( $n = 11$ ), due to experimenter error ( $n = 5$ ), because the participant did not answer the test question within 30 s ( $n = 3$ ), interfered with the procedure by revealing to the puppets how the toys worked ( $n = 2$ ), did so and also failed inclusion ( $n = 2$ ), due to participant inattention ( $n = 1$ ), or because the participant was non-neurotypical ( $n = 1$ ).

Overall, 61.1% of participants judged that the agent who pressed the black button (acting inconsistently with his prior experience) was more likely to have had *some* added prior knowledge. This proportion includes but does not cross chance ( $n = 44$  of 72; 95% CI: 50–72.2). A logistic regression predicting performance based on age did not reveal a significant age difference ( $\beta = 0.42$ ,  $p = 0.139$ ); see Figure 4. However, there is little evidence that the reduced task demands (as compared to Experiment 2) improved younger children’s performance. Indeed, only 6-year-olds’ preferences were robust: While 70.8% of 6-year-olds judged that the agent who pressed the black button was more knowledgeable (17 of 24; 95% CI: 54.2–87.5), only 54.2% of 4-year-olds (13 of 24; 95% CI: 33.3–75) and 58.3% of 5-year-olds (14 of 24; 95% CI: 37.5–79.2) also made this judgment; see Figure 4.



**FIGURE 4** | Results of Experiment 3. At left are participant inferences over who knew more about the new toy (the agent who acted consistently with his experience with the training toy, or the agent who acted inconsistently), plotted as a function of age, along with a logistic regression fit to the dataset. Points are jittered along the Y axis (but not the X axis). The gray band shows a 95% confidence interval in the regression. At right we plot the proportion of participants inferring the inconsistent agent already had some prior knowledge about the new toy (explaining why he did not rely on his experience with the training toy) by age group. The dotted line indicates chance performance; vertical bars show 95% bootstrapped confidence intervals. The gray box at top right is a procedure schematic (note that agents’ roles were counterbalanced).

## 4.4 | Discussion

Experiment 3 makes two contributions. First, it conceptually replicates Experiment 2 and confirms that children's increased difficulty making inferences (relative to predictions in Experiment 1) could not be explained by children relying on first-person surprise to attribute knowledge. In addition, it shows that, by age 6, children can still use deviations from expected behavior to infer who has more knowledge, even in a case where neither of the two agents had full prior knowledge.

## 5 | General Discussion

To successfully interact with others, we often need to figure out what they know, as well as what they do not. These representations underlie a broad range of our social behavior, from selective learning to pedagogy to moral evaluation (e.g., Goodman and Frank 2016; Shafto et al. 2014; Young et al. 2007). Here we investigated young children's intuitions about how ignorant agents behave. Our work was inspired by the tension between two bodies of evidence. The first suggests that children often use simple "knowledge = accuracy" and "ignorance = error" heuristics (e.g., Chen et al. 2015; Fabricius et al. 2021; Friedman and Petrashek 2009; Fusaro et al. 2011; Kominsky et al. 2016; Ruffman 1996). The second suggests that children do have a causal understanding of why and when knowledge implies accuracy (Aboody et al. 2022; Einav and Robinson 2011; Jara-Ettinger et al. 2017), but with persistent failures in making sense of ignorant agents (Aboody et al. 2025).

Our work tested what we suggest is one of the most basic expectations of a causal understanding of how ignorant agents act. Specifically, we explored whether children go beyond expecting ignorant agents to get things wrong or to behave randomly and instead expect them to draw on relevant past experiences when deciding how to act. That is, we tested for an expectation of reasonable action. Note that in our experiment, we did so by having children infer a complementary mental state: who is knowledgeable? This decision was due to methodological considerations where it is easier to ask children who has knowledge than who is ignorant—a word that many children might not know and would require us to use more complex linguistic structures like negation. Nonetheless, this inference could only be resolved if children had an expectation about how ignorant agents tend to act, as explained in the results section of each experiment.

Our work revealed that by age 4, children expect that an agent who encounters a new toy (and is therefore ignorant about it) will rely on relevant past experiences to decide how to act (Experiment 1). This result adds further evidence that children do not expect ignorance to always imply error, or to produce random behavior. It is also consistent with research suggesting that children can integrate others' past experiences to predict behavior (Krachun and Lurz 2016), but it goes beyond this work by identifying a specific expectation children have over how ignorant agents make decisions in new situations. At the same time, Experiments 2 and 3 revealed that it takes children between one and two additional years to rely on this expectation when

inferring epistemic states from action. These results suggest that predicting behavior precedes the ability to infer knowledge via an expectation that actions are guided by prior knowledge.

The finding that children make causal predictions before mental state inferences is consistent with one of the most popular frameworks for Theory of Mind, where children and adults recover mental states by starting with a causal model of how others' mental states lead to action, and then work backwards to infer others' mental states from their actions (e.g., Baker et al. 2017; Jara-Ettinger et al. 2016; Jern et al. 2017; Lucas et al. 2014). According to this view, successful mental-state inference requires both a causal expectation for how mental states shape behavior and mechanisms for inverting this model to work backwards from observable behavior to the underlying mental states. In the context of this view, our work suggests that the capacity to invert these mental causal models undergoes important development in 4- and 5-year-olds.

What exactly develops when children become able to invert this causal model? Our work does not decisively answer this question, but by identifying the approximate age of success, we can raise several possibilities. The first possibility is that 4-year-olds are actually already able to invert their expectations about how ignorant agents act, but did not show this capacity in our task. This would be consistent with related research showing children can invert causal models of other minds to infer goals, desires, and preferences from early in life (Gergely and Csibra 2003; Liu et al. 2017; Lucas et al. 2014). Why would children fail to show this capacity in our study? One hypothesis is that these inferences might still be difficult and effortful for young children, perhaps especially in relation to ignorance, leading them to prefer to rely on simpler shortcuts when possible. Indeed, related work suggests that 5- and perhaps even 6-year-olds do still rely on heuristics when reasoning about ignorance (Chen et al. 2015; Fabricius et al. 2021; Ruffman 1996). Thus, when confronted with our tasks that controlled for accuracy, a lack of practice with this particular type of inference may have caused children to struggle and thus default to relying on heuristics.

Another possibility is that children do not yet know how to work backwards in their causal model to recover mental states. Why would they be able to do so for desires but not ignorance? One possibility is because the causal model for desires is, in some ways, less ambiguous. Upon observing an agent pursuing an item or outcome, and the costs they incurred in doing so, children can use a basic expectation that others trade off costs and rewards to infer how much they wanted it (inferring that someone really wanted an object they went to great lengths to pursue, and really did not want an object they skipped when it was easily obtainable; Jara-Ettinger et al. 2016). By contrast, hypotheses about knowledge and ignorance can be harder to evaluate. Intuitively, an expectation that ignorant agents will draw on past experiences to take some reasonable action does not always result in a single obvious clear choice: there are many ways to be ignorant and reasonable. Thus, evaluating different hypotheses over what others know might be harder in the epistemic domain.

Although not the main purpose of our study, our work also contributes some initial evidence about children's reasoning about intermediate epistemic states, in between full knowledge and

full ignorance, which have been understudied. In particular, Experiment 3 suggests that 6-year-olds can make inferences about relative knowledge, inferring which of two agents knows *more*, even when neither is fully knowledgeable and both fail to achieve their goal. This opens the door for future research to investigate the breadth of children's ability to reason about intermediate epistemic states, and the extent to which children represent epistemic states in a graded manner.

Our work also has several limitations that open questions for future work. First, we suggest that children expect agents to act consistently with their past experiences in new but relevant situations and that they use this expectation to infer what others know based on their actions. However, there were two sources of information participants could have used when making epistemic inferences in Experiments 2 and 3: what agents did (which button they chose to press), and what they said (how they explained their actions). Agents' explanations differed by two words, with the agent who chose the red button saying, "Hmm. Well, the red button made this [training] toy go, **so** the red button makes this toy go **too**," and the agent who chose the black button saying, "Hmm. Well, the red button made this [training] toy go, **but** this black button makes this toy go." If children attended to these subtle linguistic differences when inferring who knew more, this would still be consistent with our account, showing that children attribute knowledge to those who explicitly note they rejected their past experience. However, our work does not reveal to what extent children may need to explicitly hear agents declare they are rejecting past experiences, or whether they can detect this from action alone (although note that in Experiment 1 such linguistic cues were not present and children correctly predicted that an agent would act according to his prior experience in a relevant new situation). Future work should investigate how children weight and use different sources of information (linguistic; behavioral) when inferring what others know.

Second, the fact that older children succeed in our tasks does not imply that they would also succeed outside a laboratory setting. This is because our experimental designs attempted to minimize task demands, and it is possible that our experimental task demands were equal to or lesser than the demands of making these inferences in our everyday lives: everyday situations are often noisier and with more to track than simple, well-controlled experiments. Although we do not conclusively know to what extent task demands can explain our developmental trajectory, our work suggests that at least in a simple, well-controlled experiment, children fail to infer agents' past experiences from their actions before age 6. Future work should continue to investigate the development of children's ability to do so.

Finally, although there is little evidence that the most basic Theory of Mind capacities (like the ones we study here) vary meaningfully across populations, note that our sample was US-based, mostly recruited in either Connecticut or in Los Angeles, California. White participants as well as participants from the upper middle class were likely over-represented. Given that we did not collect individual-level information such as SES, IQ, or race/ethnicity, our data do not reveal how such variables could have affected our findings (although the little work on this suggests they have no effect; Rajkumar et al. 2008). Future work

should investigate to what extent these capacities vary across samples and cultures.

## 6 | Conclusion

To navigate the social world, we must be able to figure out what other people know about the situation they're in, and how that will affect their behavior. Although past work suggests that preschoolers sometimes rely on outcome-based rules to predict ignorant agents' actions (e.g., Chen et al. 2015; Fabricius et al. 2021; Ruffman 1996), our work shows that children at this age can also make principled judgments when such heuristics cannot do. Specifically, even 4-year-olds have expectations for how knowledge and action relate, expecting ignorant agents to draw on relevant past experiences when deciding how to act in new situations. And by age 6, children use these expectations to infer others' past experiences from their actions (no matter if agents succeed or fail at achieving their goals). Taken together, these results highlight the importance of going beyond children's representations of extreme mental states (such as complete knowledge or ignorance) to also study intermediate mental states (such as partial knowledge), which might help reveal important intermediate stages in children's developing Theory of Mind (characterizing how different components of Theory of Mind develop; e.g., Gopnik and Wellman 1992; Wellman and Liu 2004).

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### Data Availability Statement

The data that support the findings of this study are available at the project OSF page linked in-text.

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### Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** cdev70032-sup-0001-supinfo.docx.