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Success does not imply knowledge: Preschoolers believe that accurate predictions reveal prior knowledge, but accurate observations do not

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Abstract

Much research has investigated how children track and reason about accuracy when deciding who to trust. The majority of this work assumes a static link between accuracy and knowledge; that is, children are expected to attribute greater knowledge to accurate agents. But while accuracy often reveals knowledge, the two are not deterministically related. Ignorant agents can be accurate (for example, one could take a lucky guess), and knowledgeable agents can be inaccurate (for example, one could accidentally err). Given this, how do children reason about the relation between knowledge and accuracy? Across three experiments, we show that four- and five-year-olds are sensitive to the distinction between knowledge and accuracy. Specifically, children judge that an agent who accurately predicts an outcome is knowledgeable, but an agent who merely observes and then accurately describes the same outcome is not. Our findings show that when children gauge agents' knowledge, they do not rely on accuracy alone; they infer knowledge only when an agent is right in the *right kind* of way.

Keywords: Testimony; Social Learning; Knowledge

Background

The ability to learn from others is one of the most powerful features of human cognition. Acquiring information for oneself can be costly. By relying on others, we can learn that the stove will burn us *without* testing it out; that other countries exist *without* having seen them; or that pangolins have four legs *without* going to the trouble of finding one. In the span of minutes, we can learn about phenomena that took humankind centuries to uncover.

Although this feature of testimony is perhaps its greatest advantage, it may simultaneously be its greatest limitation. If we are told rather than shown, how can we know whether the information we're learning is true? Agents can be misinformed, unreliable, or even malicious. Thus, while the ability to learn from testimony ameliorates the cost of acquiring knowledge firsthand, it imposes a different challenge: deciding whether informants are knowledgeable.

One obvious way to determine what others know is by tracking whether they have been right about similar things in the past. Indeed, there is extensive evidence that children track accuracy over time (Corriveau, Meints, & Harris, 2009; Pasquini et al., 2007), and trust accurate over inaccurate informants (Koenig Clément, & Harris, 2004; Koenig & Harris, 2005). The bulk of this research has used a labeling paradigm, where two informants label common objects before providing conflicting labels for a novel object. An informant who labels common objects correctly is likely knowledgeable and trustworthy; an informant who labels them incorrectly is probably not.

Nonetheless, the relation between accuracy and knowledge is not straightforward. Agents can be inaccurate because they lack attention, motivation, or competence, and they can be accurate for the wrong reasons (e.g., due to luck). Consider, for example, a lifelong Californian who can name their state capital only after consulting a map. Although this agent may be accurate, her knowledge appears newly acquired. Thus, her accuracy is not evidence for any further geographical knowledge.

If accuracy alone does not reliably reveal knowledge, how do we attribute knowledge to others? Perhaps children equate knowledge with performance: being successful or correct implies that an agent is knowledgeable, whereas being unsuccessful or wrong implies that an agent is ignorant. Thus children may equate ignorance with failure (Ruffman, 1996) and knowledge with success.

Alternatively, young children may use accuracy as a cue to knowledge because it is generally useful. But they might still have an intuitive theory that distinguishes between knowledge and accuracy. Although many studies have examined the cues that children rely on when endorsing testimony (see Harris, 2012 for review), these studies do not reveal why children rely on these cues. Children may rely on simple cues such as familiarity (Corriveau et al., 2009; Corriveau & Harris, 2009), accent (Kinzler, Corriveau, & Harris, 2011), and accuracy (Koenig et al., 2004), because they have not yet developed a nuanced understanding of the relationship between belief and action. Or children may rely on these cues because they generally allow for accurate inferences, without requiring the additional (costly) work of explicit representation and reasoning about beliefs (see Begus, Gliga, & Southgate, 2017).

Here, we investigate whether children can distinguish between different degrees of knowledge when two agents are equally accurate. Specifically, we ask whether children are sensitive to the distinction between accurate predictions vs. accurate observations, and we investigate children's intuitions about how these types of knowledge generalize. In Experiment 1, we investigate whether children prefer to attribute knowledge to an agent who can accurately predict an outcome, rather than an agent who correctly describes an outcome they have observed. In Experiment 2, we ask whether children generalize knowledge rationally. And in Experiment 3, we test whether children's intuitions about the relation between belief and action hold spontaneously, when endorsing testimony.

Experiment 1

In Experiment 1, children were introduced to two puppets: one who accurately predicted what was underneath two cups, and one who accurately stated what was underneath the same cups after revealing their contents (see Figure 1). Children were asked to infer which puppet had already known what was under the cups, and which puppet knew what was underneath a third cup (that neither puppet had interacted with). If children understand that only a knowledgeable agent could have told them what was under each cup without looking, they should select the predicting agent in response to both questions. But if children attribute knowledge only on the basis of accuracy, they should show no preference between the two puppets.

Method

Participants 32 four- and five-year-olds (mean age: 5.0 years, range: 4.1 – 6.0 years; n = 16 participants per age group) were recruited at a local children's museum. Five additional participants were recruited but not included in the study, as decided by two blind coders (see Results).

Stimuli Stimuli consisted of two male puppets (named Sam and Max), three paper cups (red, blue and yellow), and three small animal figurines (a fox, a hippo, and a deer).

Procedure The procedure, predictions, and analyses were pre-registered, unless marked with a superscript †. Children were first presented with three inverted cups, and were shown that a toy animal was hidden underneath each cup. The experimenter then introduced two puppets (Sam and Max), explaining that one of them had peeked under the cups (knowledgeable agent) and one had not (ignorant agent). Children were told that the goal of the experiment was to figure out which puppet had peeked under the cups, by asking each puppet what was underneath.

Children were allowed to choose which puppet they wanted to hear from first, and which cup they wanted to ask the puppet about (the role of each puppet was pre-determined, to counterbalance the order in which the agents were introduced). The knowledgeable agent stated what was under the cup the child selected, and then lifted the cup, revealing its contents (e.g. saying 'a hippo' and then revealing a toy hippo). By contrast, the ignorant agent first lifted the cup, revealing its contents, and then stated what animal was underneath (e.g. revealing a toy hippo and then saying 'a hippo'). Thus, both puppets performed identical actions, but in the opposite order: the knowledgeable puppet predicted what was under the cup and then looked; the ignorant puppet checked what was under the cup and then described it. Each puppet predicted or observed the contents of the first cup the child chose. Then, children chose a second cup to ask the puppets about, and each puppet played his role again.

Children's understanding was evaluated via two test questions. Children were asked which puppet had peeked underneath all the cups before the beginning of the game. And children were asked which puppet would know what was under the third cup (which neither of the agents had interacted with). Question order was counterbalanced across participants. Finally, to ensure that they remembered each puppet's role, children answered a memory check question: Children were asked which puppet had told them what was under the cup *before* he looked, and which puppet had told them what was under the cup *after* he looked. Only children who answered both parts of the question correctly were scored as having given the right answer. Because pilot work suggested that the check question was more linguistically demanding than the test questions, this question was not pre-registered as an inclusion measure. It was instead included as a potential variable of interest.

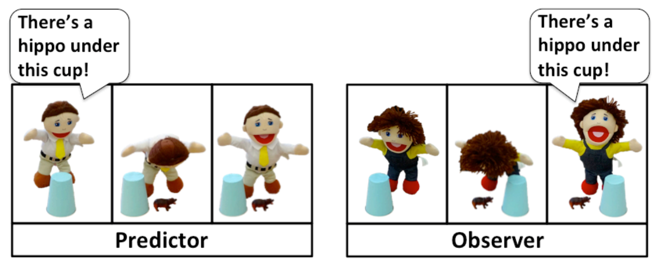

Figure 1: Procedure in Experiments 1-3. The "predictor" puppet first stated the contents of the cup, and then revealed them. The "observer" puppet first revealed the contents of the same cup, and then stated them.

Results and Discussion

Two coders who had not been involved in data collection determined exclusions. The first coder, blind to children's final answers, determined whether the experiment was run correctly. The second coder, blind to condition, coded children's answers. Five participants were excluded from the study because: the child did not attend to the task (n = 1), did not want to continue (n = 1), did not answer the test questions within 30 seconds (n = 1), interfered with the study by revealing the contents of the cups to the puppets (n = 1), or due to experimenter error (n = 1).

Overall, 23 out of the 32 participants identified the predicting puppet as the one who had peeked under the cups (71.9%; 95% CI: 56.3 - 87.5). The same qualitative pattern appeared in both age groups, with 62.5% of four-year olds responding correctly (n = 10 of 16; 95% CI: 38 - 88) and 81.3% of five-year olds responding correctly (n = 13 of 16; 95% CI: 62.5 - 100). Although only five-year-olds were reliably above chance, a logistic regression predicting performance based on age did not reveal any significant difference ($\beta = 0.54$, $p = .47$)†, and the two age groups did not perform reliably different from each other (95% CI on performance difference: -50 - 13).

Consistent with children's judgments about the predicting puppet's knowledge, 84% of participants also inferred that this puppet knew the contents of the last remaining cup (95% CI: 72 - 97). This preference was reliable in both age groups, with 81.2% of four-year olds (n = 13 of 16, 95% CI: 63 - 100) and 87.5% of five-year olds (n = 14 of 16, 95% CI: 75 - 100) giving the predicted answer.

Finally, 68.8% of participants answered the memory check question correctly (95% CI: 53.1 – 84.4), with children in both age groups displaying a weak but consistent effect (both four- and five-year-olds: n = 11 of 16, 95% CI: 50 - 94). Because performance was weaker on the memory check question than on the test questions, this implies that some participants responded to the test questions correctly but failed the memory check questions. Note, however, that these check questions ("Who told us what was under the cups before he looked? And who told us what was under the cups after he looked?") were linguistically complex relative to the test questions ("which one peeked?" and "which one knows what's under this cup?"), and used time words, which four- and five-year-olds have not yet mastered (Trosborg, 1981; Piaget 1969).

Although the knowledge manipulation in our task was subtle (both puppets performed the exact same actions, just in the opposite order), four- and five-year-olds did not attribute knowledge on the basis of mere accuracy. Instead, children recognized that correct predictions (and not observations) mark knowledge. But how nuanced is children's representation of these agents' knowledge states, and how do children decide whether this knowledge should generalize? Perhaps children rationally infer that the puppet who peeked also knows about the contents of the third cup (precisely *because* he peeked under all the cups). Alternatively, children may blindly assume that an agent who makes predictions has more overall knowledge, without a nuanced understanding of the source of this knowledge.

Experiment 2

In Experiment 2, children were introduced to the same predicting and observing agents. But before the test questions were asked, the contents of the third cup were switched without either puppet's knowledge. If children have a nuanced representation of puppets' knowledge states, they should still infer that the predictor was the one who peeked – but they should not judge that he will know what is under the third cup. But if children assume that a knowledgeable agent should know everything, they may still select the predictor in response to this question.

Method

Participants 32 four- and five-year-olds (mean age: 5.0 years, range: 4.0 – 6.0 years; n = 16 participants per age group) participated at a local children's museum. Eight additional participants were recruited but not included in the study, as decided by two blind coders (see Results).

Stimuli Materials were identical to those of Study 1, with the addition of a small box containing six animal figurines: a cat, a duck, a penguin, a parakeet, a rabbit, and an ostrich.

Procedure The procedure was nearly identical to that of Study 1. The two puppets again predicted or observed the contents of the first two cups the child chose. However, right before the test questions, the puppets were briefly put away, and the experimenter removed the animal that was under the last remaining cup. She asked children to choose a new animal (from the box of animals) to put under this cup. The puppets were then brought back, and children were asked the same test questions (Who peeked? Who knows what's under the last cup?; order counterbalanced) and memory check questions (Who told us what was under the cup before/after he looked?; order counterbalanced). As before, children always needed to select one of the two puppets in response to each question.

Results and Discussion

Results were coded in the same way as Experiment 1. Eight children were excluded from analyses and replaced because: the child interfered with the study by revealing the contents of the cups to the puppets (n = 4), due to experimenter error (n = 2), because the child was developmentally delayed (n = 1), or because the child was distracted (n = 1).

Overall, 24 of the 32 participants identified the predicting puppet as the one who had peeked under the cups (75%; 95% CI: 59.4 – 91). This preference was reliably above chance, and identical in both age groups (both four- and five-year-olds: 12 of 16, 95% CI: 56.3 - 100).

As predicted, children did not reliably judge that the predictor knew the contents of the third cup. Only 20 of the 32 participants selected the predictor as the one who would know what was under this cup (62.5%, 95% CI: 47 – 78.1). However, children's responses varied across age groups. 75% of four-year-olds judged that the predicting puppet would know what was under the third cup (12 of 16, 95% CI: 56.3 – 100), but only 50% of five-year-olds selected the predicting puppet in response to the same question (8 of 16; 95% CI: 25 – 75). Although only four-year-olds responded reliably above chance, a logistic regression predicting performance based on age did not reveal any significant difference ($\beta = -1.04$, $p = .12$)[†], and the two age groups did not perform reliably differently (95% CI on performance difference: -5.0 - 56.3).

Finally, 65.6% of participants answered the memory check question correctly (95% CI: 50 - 81.3), with 68.8% of four-year olds (n = 11 of 16, 95% CI: 50 - 93.8) and 62.5% of five-year olds (n = 10 of 16, 95% CI: 37.5 - 87.5) appropriately matching puppets with their actions.

As in Experiment 1, children in both age groups attributed prior knowledge only to agents who made correct predictions (and not correct observations). However, we found an age difference when asking children to reason about the boundaries of the predictor's knowledge. In this experiment, both puppets were ignorant of the contents of the last remaining cup – because those contents had been switched out. Only five-year-olds demonstrated the expected pattern of behavior. Four-year-olds persisted in selecting the predictor in response to this question, perhaps not yet sensitive to the boundaries of this agent's knowledge.

Together, Experiments 1-2 suggest that by age five, children distinguish between knowledge and accuracy, and generalize knowledge rationally. However, both experiments explicitly prompted children to reason about knowledge. In more naturalistic scenarios, children are rarely asked to reason about others' knowledge. Instead, they must decide whom to trust on their own, which requires children to not only spontaneously reason about others' knowledge, but also to use these inferences to decide whom to trust. Do children both infer knowledge from accurate predictions spontaneously, and also apply this belief when deciding whose testimony to endorse?

Experiment 3

In Experiment 3, children observed the same procedure as in Experiment 1. However, children were never explicitly asked to reason about agents' knowledge. Instead, at the end of the task, the two puppets provided conflicting testimony about the contents of the third cup. Children were asked to decide what animal was actually under that cup, thus indirectly probing their inferences about the puppets' knowledge. If children spontaneously infer knowledge from agents' behavior, they should respond consistently with their explicit knowledge judgments in Study 1.

Method

Participants 32 four- and five-year-olds (mean age: 5.0 years, range: 4.1 – 6.0 years; n = 16 participants per age group) participated at a local children's museum. Seven additional participants were recruited but not included in the study, as decided by two blind coders (see Results).

Stimuli Materials were identical to those of Experiment 1.

Procedure The procedure was nearly identical to that of Experiment 1. However, children were not shown the contents of the cups at the beginning. Children watched the puppets predicting and observing the contents of the first two cups the child chose. Then, the puppets provided conflicting testimony about the contents of the least remaining cup. Children were asked what animal was under this cup. Last, children were asked the standard memory check questions ("Who told us what was under the cups before/after he looked?").

Results and Discussion

Results were coded in the same way as Experiments 1-2. Seven participants were excluded from analyses and replaced because: the child did not provide an answer to the test question (n = 5), the child's first language was not English (n = 1), or due to experimenter error (n = 1).

24 of the 32 participants endorsed the testimony of the predicting agent (75%; 95% CI: 59.4 – 90.6). The same qualitative pattern appeared in both age groups, with 68.8% of four-year olds responding correctly (n = 11 of 16; 95% CI: 50 – 93.8) and 81.3% of five-year olds responding correctly (n = 13 of 16; 95% CI: 62.5 – 100). Although only five-year-olds were reliably above chance, a logistic regression predicting performance based on age did not reveal any significant difference ($\beta = 0.50$, $p = .48$)†, and the two age groups did not perform reliably different (95% CI on performance difference: -43.8 – 18.8).

59.4% of participants answered the memory check question correctly (95% CI: 43.8 – 78.1), with 68.8% of four-year olds (n = 11 of 16, 95% CI: 50 – 93.8) and 50% of five-year olds (n = 8 of 16, 95% CI: 25 – 75) matching puppets with their actions appropriately. A logistic regression predicting performance based on age did not reveal any significant difference ($\beta = -0.38$, $p = .54$)†,

In Experiments 1 and 2, when children were prompted to reason about agents' knowledge states explicitly, they attributed prior knowledge only to the agent who made accurate predictions. In the current study, we find that children will also spontaneously attribute prior knowledge to the predicting agent, and will furthermore apply these beliefs when reasoning about possible states of the world (e.g., when deciding which animal is under the cup). This finding provides even stronger evidence that children pay attention to the source of agents' knowledge (that is, the root causes of their accuracy) when selecting informants.

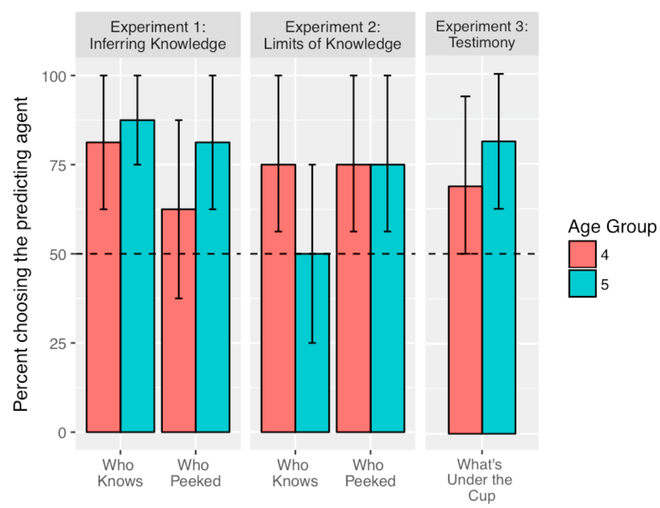

Figure 2: Results from all three experiments. The error bars are bootstrapped 95% confidence intervals, and the dotted line indicates chance performance (50%). Error bars that do not cross chance indicate performance that is reliably above chance.

General Discussion

While accuracy and knowledge are tightly linked, one does not necessarily imply the other. Across three studies, we find that young children are sensitive to this distinction, judging that an accurate prediction reveals prior knowledge, but an accurate observation does not. In Experiment 1, four-and five-year-olds selectively attributed prior knowledge to an agent who made accurate predictions, and not to an agent who made accurate observations. This ability seems to develop with age (with five-year-olds performing more robustly). In Experiment 2, five-year-olds (but not four-year-olds) both inferred that the predicting agent was more knowledgeable, and were simultaneously sensitive to the boundaries of this agent's knowledge. And in Experiment 3, four- and five-year-olds (again, five-year-olds more robustly) attributed knowledge even without explicit prompting to do so. Children spontaneously inferred that the predicting agent was knowledgeable, using that knowledge to evaluate informants' claims and reason about states of the world. These results are especially striking given prior findings that children sometimes succeed in reasoning about knowledge explicitly, but fail to apply the same insights spontaneously (e.g., Lutz & Keil, 2002; Landrum, Mills & Johnston 2013).

Four-year-olds' weaker preferences for the predicting agent suggest that sensitivity to the distinction between predictions and observations (and perhaps to the distinction between knowledge and accuracy) may develop with age. However, it is also possible that four-year-olds struggled not from any confusion about the boundaries of the predictor's knowledge, but due to task demands (as with related explicit social cognition tasks; e.g., Wellman, Cross & Watson, 2001). Alternatively, four-year-olds may have also struggled with the pragmatics of our tasks. In Experiment 2, for instance, children were explicitly asked which puppet knew the contents of the third cup, when in reality neither knew. Because the question presupposed that one of the puppets was knowledgeable, children may have thus preferred the previously knowledgeable agent. Future work will test whether children undergo a conceptual change in their ability to represent the limits of others' knowledge between the ages of four and five – or whether four-year-olds simply struggled due to task demands.

In addition, although our pre-registered sample in each experiment was substantial (n = 32 per study), analyzing children's responses within each age group resulted in reduced power (n = 16 per age group). However, it is important to note that each one of our experiments is in some way a direct or conceptual replication of the same fundamental question. In future work we will perform a meta-analysis to obtain better estimates of our effect sizes.

Our results are consistent with related work showing that children track informants' abilities to produce knowledge independently. When two agents successfully label common animals, but one needs help producing the answers, children prefer to learn novel labels from the agent who answered without help (Einav & Robinson, 2011). While this suggests that children reason about accuracy and knowledge separately, it is also possible that children in that task ascribed both knowledge and accuracy to the helper, rather than to the agent who received help. Moreover, in this study, the ignorant agent gave additional cues to ignorance: she was initially silent when asked for the object's name, and she explicitly said that she wanted help when it was offered. Thus, children may have endorsed the knowledgeable agent without a robust distinction between knowledge and accuracy (see also Lucas & Lewis, 2010, for a critique of the classic Koenig Clément, & Harris, 2004 labeling paradigm). By contrast, in our tasks children did not have additional cues to knowledge or ignorance, as both puppets produced identical actions (differing only in the order with which they were performed). Thus, our work provides evidence that children reason about accuracy and knowledge separately.

Our work stands in contrast to related work suggesting that young children equate ignorance with error, relying on an "ignorance = getting it wrong" heuristic (Ruffman, 1996). Although it is possible that children have an asymmetry in their intuitions about knowledge and accuracy, as well as ignorance and error, recent work suggests that the "ignorance = getting it wrong" heuristic is either limited in its scope, or non-existent (Friedman & Leslie, 2004a, 2004b; Friedman & Petrashek, 2009; German & Leslie, 2001; Jara-Ettinger et al., 2017).

Several further questions remain. First, were children succeeding in our task (and past tasks) by using simple, yet generally accurate heuristics? Or do children have a naïve theory of knowledge that enables them to reason appropriately in situations where knowledge and accuracy do not dovetail?

While accuracy does not necessarily imply knowledge, the two generally go together. By the age of four, children have probably encountered very few accurate (but ignorant) agents. Therefore, it is unlikely that children could have learned a rule through experience that allows them to determine the relationship between accuracy and knowledge. The fact that children nonetheless reason in a sophisticated way about this relationship provides support for the naïve theory account. The combination of our findings with those from Einav & Robinson (2011) lends further weight to the naïve theory account.

Our work focused on one particular distinction between accuracy and knowledge. However, there are many ways a person can be right without being knowledgeable, or wrong without being ignorant. For example, one can take a lucky guess, or accidentally choose the correct response. On the other hand, one can forget or confuse a specific piece of information while still being generally quite knowledgeable. Future work will explore whether children are sensitive to such distinctions.

A second open question is the extent to which children's intuitive theory of knowledge consists of expectations about how knowledgeable agents act, expectations about how ignorant agents act, or combined expectations about both types of agents. In our task, children could have succeeded by identifying the knowledgeable agent (and inferring that the other agent was ignorant through mutual exclusivity), by identifying the ignorant agent (and inferring that the other agent was knowledgeable), or by identifying both. Thus, while our studies show that children can distinguish between knowledge and ignorance, they do not reveal how children infer who is knowledgeable and who is ignorant. Future work will investigate this.

Overall, across three separate experiments, we find that accuracy alone is not enough for four- and five-year-olds to attribute knowledge. For knowledge to be attributed, accuracy must be accompanied by the right kinds of behaviors. For example, knowledgeable agents should not need to observe a possible outcome in order to describe it – they should already know the answer. Although children's ability to license knowledge from accurate predictions (but not observations) develops with age, even four-year-olds generally preferred to attribute knowledge to the predicting agent. In conclusion, our findings suggest that simply being accurate is not enough for children to impute knowledge; truly knowledgeable agents need to be right in the right kind of way.

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