Cognitive pragmatism: Children flexibly choose between facts and conjectures.

Junyi Chu
junyichu@mit.edu
Department of Brain and Cognitive Sciences, MIT

Laura Schulz, PhD
lauraschulz@mit.edu
Department of Brain and Cognitive Sciences, MIT

Abstract

Abundant work has looked at children's ability to appropriately reject testimonies and unverified claims (Butler et al, 2017; Frazier, Gelman, & Wellman, 2009; Koenig, Clement, & Harris, 2004). However, sometimes our current knowledge is insufficient for solving a problem. In these cases, we should reject unsatisfying facts and prefer satisfying, if speculative, conjectures. In two studies, we gave 4-7 year-old children (Study 1, N=66; Study 2, N=32) questions that either could or could not be answered with available information. For each question, children made a binary choice between a factual answer citing information from the story or a conjectural answer that made unverified claims. Across age groups, children successfully chose the more satisfying response regardless of its truth value: children chose facts for questions with known answers and conjectures for questions with unknown answers. These findings suggest that children will go beyond known information to endorse unverified claims when they satisfy the question-under-discussion.

Keywords: Cognitive Development; Explanations

Introduction

Questions with unknown answers lie at the heart of scientific inquiry. Often we can answer our questions by advancing hypotheses consistent with our prior knowledge and considering the evidence in their favor. Sometimes however, we do not have sufficient evidence to establish the truth of a claim and must entertain speculative conjectures ("Maybe there is an ether?" "Maybe there is dark matter?"). The value of such speculations lies not in how certain we are of their truth but in how certain we are that if the conjectures were true, they would solve our problems.

When in development do we begin to value unverified hypotheses and speculations? Critically, the truth status of conjectural claims is unknown, thus they cannot be evaluated on their accuracy. The learner must first understand that the available information is insufficient or irrelevant to the question under discussion and that a speculative claim is warranted. Second, the learner must decide whether a given conjecture, if true, would provide a satisfying answer to the problem. Although many other considerations might factor into the evaluation of any proposal (including its plausibility, simplicity, falsifiability, or feasibility, as well as the reputation and credibility of its source) the pre-eminent criterion for a good response to a query is that it provides an answer to the question at hand.

As we review below, abundant work has looked at how children explore and ask questions in the face of unresolved problems, and how they evaluate both the quality of their explanations they receive and the reliability of their information sources. However, such work has focused almost uniformly on whether children correctly reject improbable, unreliable, or unsubstantiated claims in favor of information that is trustworthy, verified, or consistent with respect to evidence and prior knowledge. Far fewer studies have looked at situations in which children might (rightly) reject known information in favor of the unknown. This study is thus a first attempt to investigate children's endorsement of conjectural claims.

Research suggests that children are sensitive to unresolved questions. When they see events that conflict with their prior knowledge, or evidence that fails to distinguish competing hypotheses, children are motivated to explore (Buchsbaum et al., 2012; Legare, 2012; 2014; Gweon et al., 2014; van Schijndel et al., 2015; Schulz & Bonawitz, 2007; Schulz, Standing, & Bonawitz, 2008; Stahl & Feigenson, 2015).

Children are also notorious for asking questions (asking as many as 76 an hour; Chouinard, 2007). Moreover, children are sensitive both to the reliability of their informants and the quality of the answers they receive. Children as young as three track speakers' accuracy (Koenig et al., 2004) and prefer to learn novel information from previously accurate informants (e.g. Corriveau & Harris, 2009). With age, the preference for accuracy increases: older children are more likely to reject confident but inaccurate sources in favor of hesitant but accurate ones (Kominsky, Langthorne, & Keil, 2016).

Children also evaluate claims independently of their source. Preschoolers favor claims supported by strong arguments over circular ones, and circular arguments over unsupported opinions (Mercier, Bernard, & Clement, 2014), although the preference becomes stronger over development (e.g. Mills et al., 2017). If a respondent simply restates a child's question, asserts norms, describes the event, or reacts personally instead of responding to the query, the child is likely to repeat the question (Frazier et al., 2009). By age five, children are sensitive to "explanatory virtues" (Lombrozo, 2011), evaluating explanations based on how many observations they account for, how simple and internally coherent they are, and how probable they are given observed data and prior knowledge (Bonawitz & Lombrozo, 2012; Walker, Bonawitz, & Lombrozo, 2017).

Children also spontaneously try to generate their own explanations for surprising events (Legare, 2012; Legare, Gelman, & Wellman, 2010), often positing unobserved causes including "invisible batteries", hidden buttons, or hidden agents to explain artifacts that move or change state spontaneously or stochastically (Gelman & Gottfried, 1996; Saxe, Tenenbaum, & Carey, 2005; Schulz & Sommerville, 2006; Wu, Muentener, & Schulz, 2016). Children also seek to explain others' behavior (Bartsch & Wellman, 1989; Wellman & Banerjee, 1991) and will posit changes in others' desires or goals to explain why a character did something unexpected

(Wimmer & Woolley, 1990). Collectively, these studies suggest that children can and do ”go beyond the data” to make inferences about the world. When expectations are violated, children are willing to advance conjectures that, if true, would satisfy their goals of maintaining their beliefs about the world (Schulz et al., 2008).

Often however, problems and questions arise without any violation of expectation. Absent any ambiguity or conflict with prior beliefs, we may still face questions that require answers we do not yet have. How might children go about evaluating answers to questions of this nature? Although children are reliably vigilant against inaccurate information, less is known about how children evaluate claims whose truth status is unknown. Children can clearly entertain speculative, imaginary, hypotheses in their pretend play, and they do so in ways that are both informed by (Harris, 2000), and arguably informative about, events in the real world (Buchsbaum et al., 2012; Gopnik & Walker, 2013). Nonetheless, children systematically distinguish pretense and fantasy (Flavell, Flavell, & Green, 1987; Woolley & Ghossainy, 2013). One hypothesis therefore, is that they might systematically reject conjectural claims that contain unverified information.

Some research suggests this is the case. By age four, children are aware of the importance of verification for the validity of a claim, and prefer verified claims. For instance, when asked to evaluate puppets' claims regarding the content of a set of boxes after the puppets had looked inside all, some, or none of the boxes, 4- to 7- year old children rated fully verified claims as more acceptable than partially verified claims, and these in turn were considered more acceptable than unverified claims (Butler, 2017). Critically, in this context, the children themselves did not see inside any of the boxes, and thus could not use accuracy as a means of evaluation.

However, children can also distinguish between two conjectural claims when neither of them are verified. For instance, when asked to decide which of two devices controlled which of two effects, in the absence of any covariation data, preschoolers expected discrete and continuous affordances to control discrete and continuous phenomena respectively (Magid, Sheskin, & Schulz, 2015; see also Tsividis, Tenenbaum, & Schulz, 2015). This suggests that children are sensitive to abstract features of causes and effects, and use these features to constrain their generation and evaluation of candidate causes, in the absence of any distinguishing evidence.

Previous work leaves open the question of whether children might flexibly reject known facts and choose conjectures to answer questions with no known answer. In the current study, we tell children stories and ask questions that either can or cannot be answered by appealing to known events in the story. We ask children to choose between factual responses that repeat information in the story, and conjectural responses that go beyond available information. If children systematically prefer reliable verified information to speculative conjectures, they should always choose the known facts; if they systematically prefer fanciful, speculative conjectures they should always pick those. However, we predict that children will flexibly select responses; choosing verified facts for questions with known answers but preferring the unverified conjectures for questions with no known answers. Critically, both the factual and conjectural answers contain the same content-bearing words used in the questions. Thus, both responses are semantically associated with the question. If children choose flexibly in response to the question, they must do so by considering the meaning of the question as a whole and what makes a more satisfying response. Because we often need to go beyond available facts to answer both causal “why” questions and problem-solving “how” questions, here we ask children both kinds of questions.

Study 1

Methods

Participants and materials Sixty-six children (M = 6.04 years, range: 48-95 months) were recruited from an urban children's museum. Seven additional children participated but were excluded for either responding inaccurately on a practice question (n = 5), not speaking English as a native language (n = 1) or for incomplete participation (n = 1).

Participants completed six trials consisting of two training trials and four test trials. Each trial began with an illustrated story presented as three animated slides on a laptop computer. Figure 1 displays the final slide for each story. After narrating each story, the experimenter asked a question and two puppets (Elmo and Cookie Monster) presented their answers. These answers were pre-recorded audio clips activated by the experimenter. Elmo always provided his answer first, followed by Cookie Monster (see Table 1 for items used).

The training trials were designed to ensure that participants were paying attention and understood the task. These stories depicted human characters performing common daily activities embedded in a simple narrative (e.g. riding a bike, or eating ice cream). The training questions could always be answered using information from the story (i.e. they were factual questions). To avoid biasing children towards either puppet, Elmo and Cookie Monster each got one question correct.

The test trials involved novel creatures engaging in different activities (making a hat, sneezing from allergies, dropping a toy down a deep hole, juggling; see Figure 1). Two question-answer pairs were developed for each story: a factual question that could be answered with information from the story and a conjectural question for which any information from the story would be irrelevant. Elmo always provided a fact and Cookie Monster always provided a conjecture. Participants listened to all stories and answered 2 factual and 2 conjectural questions; the question type alternated with each trial so as to eliminate response bias. We counterbalanced two between-subjects factors: (1) item order (whether the first test trial was a factual or conjectural question) and (2) story-question match, resulting in four story sequences. Thus, while all participants heard all stories and all answers, half the participants heard each story with a factual question

Table 1: Stories, questions, and answer choices used in both studies. See Figure 1 for illustrations.

Story	Question	Answer
Training 1	How did Tommy get to the castle?	**Conjecture**: He walked to the castle **Fact**: He rode a bike to the castle
Training 2	What is Tommy's favorite ice cream?	**Fact**: Chocolate **Conjecture**: Strawberry
Why 1	**Factual**: Why are the Wugs sneezing? **Conjectural**: Why are the Feps furry?	**Fact**: Because the Wugs are allergic to the Fep's fur. **Conjecture**: Because the Feps go up to the mountains and the fur keeps the Feps warm.
Why 2	**Factual**: Why are the small Daxes wearing hats? **Conjectural**: Why are the hat-making Blickets bigger than the Daxes?	**Fact**: Because the big Blickets made the hats for them. **Conjecture**: Because the Blickets are older than the Daxes.
How 1	**Factual**: How did the banana eating Gazzers learn to juggle? **Conjectural**: How did the Gazzers get the bananas?	**Fact**: Because Bozo the clown taught the banana eating Gazzers how to juggle. **Conjecture**: Because the Gazzers threw their balls up into the trees and knocked down the bananas.
How 2	**Factual**: How did the Duff's toy fall into the deep hole? **Conjectural**: How did the Duffs rescue their toy?	**Fact**: Because the Duffs' hair was in their eyes and they couldn't see and they tripped and dropped their toy. **Conjecture**: Because the Duffs tied their long hair into a rope and made a ladder with it and used it to climb down and get the toy.

and half the participants heard it with a conjectural question.

Procedure Children were tested individually in a quiet room. The experimenter began by introducing participants to the computer display and to the two puppets (Elmo on the left and Cookie Monster on the right). The experimenter explained the task, saying: "Every time I tell you a story, I need you to remember what happened because I'm going to ask a question at the end. Elmo and Cookie Monster will tell us their answers and your job is to choose who had the better answer." For each trial, the experimenter first narrated the story and presented her question ("My question is,. . . "). She then directed the question at one puppet (e.g. "Elmo, can you tell us, . . . "), played its' pre-recorded answer, and repeated (e.g. "Elmo said because . . . "). The experimenter then repeated the question-answer sequence with the other puppet before repeating the question and inviting the child to make a choice ("Who do you think had the better answer for [question]?"). Positive feedback was given on the practice trials ("That's right, Elmo had the better answer this time.") and neutral, encouraging feedback was given on the test trials ("Alright, let's see what's next"). Children who correctly answered both practice questions continued to complete the four test trials.

Figure 1: Illustrations of practice (A-B) and test stories (C-F).

Results and Discussion

Our primary effect of interest is whether participants responded appropriately, that is, choosing facts in the stories for questions with known answers and choosing relevant conjectures for questions with no known answers. On average, participants responded appropriately on 3.17 out of 4 test trials (SD = 0.71). This was significantly better than chance responding ($t(65)$=13.3, p <.001). Twenty-three children (35%) chose the corresponding answer on all 4 trials, significantly above chance (binomial p <.001). Overall performance did not differ by counterbalanced conditions so we collapsed the responses throughout ($F < 1$).

We conducted a logistic mixed-effects regression with age and question type as fixed effects, and random intercepts for subject and story. There was no effect of age (β=0.037,

z=1.76, *n.s.*), suggesting that children as young as four succeed at matching informative facts and appropriate conjectures to questions with known and unknown answers, respectively (see Figure 2). There was a main effect of question type (β=-1.23, z=-3.5, p=<.001). Conjectural questions elicited fewer appropriate responses (M = 1.41 of 2 trials) than factual questions (M = 1.76; $t(65)$ = 3.86, p <.001).

Finally, recall that two stories involved "why" questions (see Table 1) and two stories involved "how" questions. While this contrast was designed to cover a broad range of explanatory questions, the random effect coefficients from the previous analysis suggested that participants were more likely to endorse the corresponding answers on the last two trials (involving "how" questions). Thus we conducted a post-hoc analysis to examine how potential story effects and interaction between story and question type on participant's response. We conducted a logistic mixed-effects model with story and question type as fixed effects, and random intercepts for subject. As before, we found a significant main effect of question type (β=-2.7, z=-3.3, p <.001). Unexpectedly, there were significant story by question type interactions (χ^2=16.94, p <.001). To explore these interactions, we conducted Tukey-adjusted pairwise comparisons on the proportion of appropriate answers chosen for factual versus conjectural questions on each story. We found that while performance was similar across question type for the two "how" questions, children chose at significantly lower rates on the two "why" questions when the questions required choosing the unknown, conjectural answer. Figure 2 shows the mean proportion of appropriate answers chosen by story and question type.

Discussion In this study, we asked four to seven-year-old children to choose the better of two explanations. Across age groups, children endorsed verified, true solutions for questions with known answers and unverified, but appropriate, conjectures for questions with unknown answers. Rather than rely on a general preference for either facts or conjectures, we found that children are able to consider the abstract features of the problems when evaluating possible solutions.

However, children responded somewhat differently depending on question type. For factual questions, children were equally likely to choose the appropriate, verified fact across all four test trials. However, for conjectural questions,

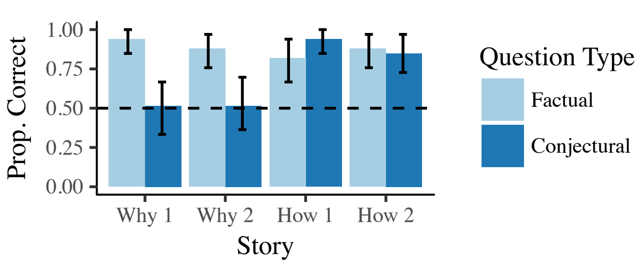

Figure 2: Study 1, Proportion of children choosing appropriate explanations. Error bars show bootstrapped 95% CIs.

children chose the appropriate conjectural answer above chance only on the two "how" items and not the two "why" items. Because the "why" questions always came first, children may simply have gotten better at reasoning about conjectural questions over the trials. In particular, because children had just referred to information available in the story to answer the training questions, they may have carried over this response to the first two test questions. We test this possibility in the next study by asking "how" questions before "why" questions.

Study 2

Method

Thirty-two children (M = 5.03 years, range: 49-71 months) were recruited from an urban children's museum. Fourteen additional children did not pass the inclusion criteria (see Study 1 for details). Materials were the same as Experiment 1, except that the two "How" questions came before the two "Why" questions. As in Study 1, participants were randomly assigned to one of four counterbalanced orders.

Results and Discussion

First, we test for a replication of the overall success in Study 1. Here, participants responded appropriately on an average of 2.84 out of 4 test trials (SD = 1.14), significantly above chance ($t(31)$=4.19, p <.001). Twelve children (38%) chose the corresponding answer on all 4 trials, significantly above chance (binomial p <.001). Overall performance did not differ by counterbalanced conditions so we collapsed the responses for the following analyses(F <1).

Next, we conducted a logistic mixed-effects regression with fixed effects of story type (Why vs. How) and question type (Known vs. Unknown), and random intercepts for subject. No significant main effects were found. Replicating Study 1, there was a significant story type by question type interaction, (β=-2.6, z=-2.7, p=0.008). Tukey-adjusted pairwise comparisons reveal that on conjectural questions, children showed greater accuracy on 'How' questions than 'Why' questions (z=2.67, p= 0.038). Figure 3 shows the proportion of children choosing appropriate explanations in Study 2.

Finally, we were interested in whether children's weaker performance on stories involving "why" questions in Study 1 was due to an order effect or due to differences in story type. Thus, we pooled data for 4-5-year olds in Study 1 with the data from Study 2 (total N = 65) and conducted a logistic mixed-effects model with study (1 or 2), story type (Why vs. How) and question type (Known vs. Unknown) as fixed effects, and random intercepts for subject. The only significant effect was an interaction of story type and question type (β=-2.5, z=-2.7, p=0.008). Pairwise comparisons indicate that across both studies, children were more likely to choose the appropriate conjectural response to a How question than a Why question (z=4.34, p<.001). Within 'Why' questions, participants were more likely to choose appropriately on factual than conjectural questions (z=3.64, p=0.002). Figure 4 shows the mean proportion of appropriate answers chosen by story and question type, pooled across both studies.

Discussion We replicated the main findings from Study 1 showing that 4-5-year-old children flexibly endorse both facts and conjectures in response to different questions. We also replicated the finding that children are especially likely to accept conjectures as responses to questions about how to achieve a goal. There are numerous potential differences between "why" and "how" questions both in our study and more generally. For example, "how" questions may invite explanations about the *manner* of events, whereas "why" questions may focus on the *reason for* some event. Perhaps "how" questions may be more frequently associated with conjectural solutions, or the specific content of the stories we used may have made conjectural solutions seem more plausible for the "how" questions than the "why" questions. Future work could ask why children treat "why" and "how" questions differently.

General Discussion

Children are often faced with unresolved questions and unverified answers. The current experiment looked at whether children could go beyond known information to evaluate speculative claims, and whether these evaluations were sensitive to the type of question under discussion. Children as young as four chose verified, true solutions for questions with known answers and unverified, but appropriate, conjectures for questions with unknown answers. Children did not show systematic preferences for either fact or conjectures; instead, they chose answers that matched the question type, suggesting that they are able to consider the abstract features of the problems, and chose flexibly between conjectural and factual explanations depending on the type of question being asked.

In this study, we asked children to choose between facts and conjectures in response to questions with or without known answers. By and large, children chose successfully. Because these were forced-choice responses, we cannot be sure whether children preferred the factual answer for the factual questions, rejected the conjectural answer for the factual questions, or both. Similarly, we do not know if children preferred the conjectural answers for the conjectural questions or simply rejected the factual answers as irrelevant. However, the fact that children were more likely to opt for conjectures on the conjectural "how" questions than the "why" questions provides some grounds for believing that children actively preferred the conjectural answers (rather than simply rejecting the factual answers). The known answers were equally unsatisfying responses to the "how" and "why" questions but children may have had an easier time representing the conjectural responses to how questions (i.e., imagining how throwing balls up in a tree would knock down bananas or climbing down a rope could let you retrieve a ball) than calling on the less vivid background knowledge required to answer the why questions (i.e., recalling that height correlates with age or that fur keeps you warm). However, future research might investigate children's evaluation of conjectural and factual responses independently.

Here, although we pit unverified conjectures against verified facts, the conjectures did not conflict with any known information or prior beliefs. In the real world however, solving our problems does sometimes require us to set aside previously acquired knowledge. Our data hints at children's willingness to do so: in one conjecture, creatures descended down a rope ladder made of their own hair in order to rescue a toy (see Table 1, Story *How 2*). Children robustly endorsed this explanation when appropriate. Future studies might look at whether young learners will endorse explanatory speculations that contradict other information or *threaten* other beliefs. Additionally, although this study looked at how children might choose between competing hypotheses, we could also ask how children generate novel hypotheses in response to questions they can't otherwise answer.

We suggest that when we try to answer questions or solve problems, we are fundamentally constrained by the goal of doing just that: we evaluate proposals based on how well they achieve those ends before we even consider data-dependent criteria such as accuracy, validity or the verification process. This kind of "cognitive pragmatism" may be a critical part of our cognitive repertoire, and a reflection of how explanatory goals can usefully constrain hypothesis generation, problem-solving, and creativity.

The current results suggest that although young children recognize the value of reliable information and appeal to it when it provides a satisfying answer to their queries, they are also willing to go beyond available data and entertain relevant conjectures. This distinctively human trait may allow

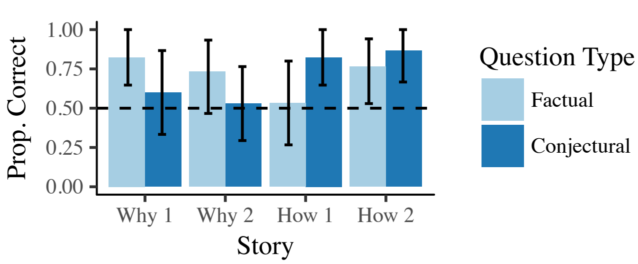

Figure 3: Study 2, Proportion of children choosing appropriate explanations. Error bars show bootstrapped 95% CIs.

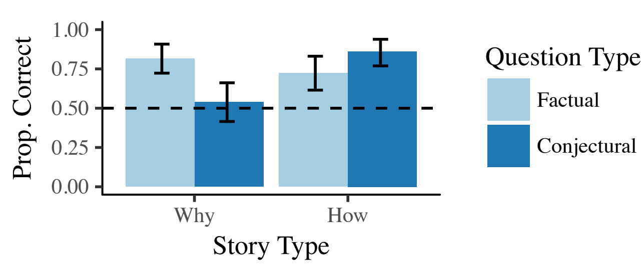

Figure 4: Proportion of 4-5 year olds across both studies choosing appropriately. Error bars are bootstrapped 95% CIs.

children to imagine solutions to problems well in advance of their ability to test them, and perhaps, to imagine new problems that expand the bounds of human inquiry.

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