

# Occam's Rattle: Children's Use of Simplicity and Probability to Constrain Inference

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A growing literature suggests that generating and evaluating explanations is a key mechanism for learning and inference, but little is known about how children generate and select competing explanations. This study investigates whether young children prefer explanations that are simple, where simplicity is quantified as the number of causes invoked in an explanation, and how this preference is reconciled with probability information. Both preschool-aged children and adults were asked to explain an event that could be generated by 1 or 2 causes, where the probabilities of the causes varied across conditions. In 2 experiments, it was found that children preferred explanations involving 1 cause over 2 but were also sensitive to the probability of competing explanations. Adults, in contrast, responded on the basis of probability alone. These data suggest that children employ a principle of parsimony like Occam's razor as an inductive constraint and that this constraint is employed when more reliable bases for inference are unavailable.

*Keywords:* causal reasoning, explanation, inference to the best explanation, simplicity, parsimony

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The process of seeking, generating, and evaluating explanations plays a crucial role in learning and development (Keil, 2006; Lombrozo, 2006). Even young children seek explanations spontaneously (Callanan & Oaks, 1992; Greif, Kemler-Nelson, Keil, Guterrez, 2006; Hickling & Wellman, 2001) and benefit from generating explanations, whether or not they receive feedback on the accuracy of those explanations (Bonawitz, van Schijndel, Friel, & Schulz, in press; Chi, de Leeuw, Chiu, & LaVancher, 1994; Legare, Gelman, & Wellman, 2010; Legare, Wellman, & Gelman, 2009; Siegler, 2002; Wellman & Liu, 2007). Children are also discriminating about what counts as an explanation (Frazier, Gelman, & Wellman, 2009) and prefer some kinds of explanations over others (Kelemen, 1999). Yet little is known about a central aspect of this process: how competing explanations are evaluated.

In this article, we explore whether and how young children employ simplicity as a basis for evaluating explanations. We consider cases in

which more than one explanation is consistent with the observations being explained and which, therefore, require more than consistency with data as a basis for evaluation. Such cases are ubiquitous throughout development. Did Sally look for her marble in the basket by accident or because she had a false belief about its location (e.g., Amsterlaw & Wellman, 2006)? Is the day/night cycle best explained by an orbiting sun or an orbiting Earth (e.g., Vosniadou & Brewer, 1994)? Like scientists, children must draw inferences on the basis of ambiguous data, and a principle of parsimony—such as the well-known stricture not to multiply entities beyond necessity, known as *Occam's razor* (Baker, 2004)—offers one promising approach (see also Harman, 1965; Lipton, 2002).

We also examine whether children's explanations are sensitive to probability and whether simplicity and probability jointly constrain inference. It could be that simplicity is only used as a basis for evaluating explanations when probability information is unknown. Alternatively, simplicity and probability could make independent contributions to the quality of an explanation, such that both factors influence children's preferred explanations.

In what follows, we briefly review previous research on adults' preference for simpler explanations, as well as relevant developmental findings. We then present two novel experiments to investigate whether an explanation involving a single cause is preferred over an explanation involving two causes and how this preference is reconciled with information about the probability of each explanation. We conclude by suggesting that children consider both simplicity and probability in evaluating explanations.

## Simplicity in Adults' Explanations

Previous research on simplicity in explanation evaluation has focused on adults. This work has quantified simplicity in terms of the number of propositions (Lagnado, 1994; Read & Marcus-

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Newhall, 1993; Thagard, 1989) or causes (Lombrozo, 2007) invoked in an explanation. For example, Lombrozo (2007) examined whether adults prefer explanations involving fewer causes and whether this preference informs assessments of probability (see also Lagnado, 1994; Read & Marcus-Newhall, 1993). Participants learned about an alien with two symptoms that could be explained by appeal to one disease or two and were asked to identify the most satisfying explanation for the symptoms. Participants also received information about the base rates of these diseases, and in some conditions, the complex explanation (two diseases) was more likely than the simpler alternative (one disease).

Lombrozo (2007) found that adults were sensitive to base-rate information but only preferred the complex explanation when it was much more probable than the simpler alternative. However, both Lagnado (1994) and Lombrozo (2007) found that when participants were explicitly told that the complex explanation was most likely, rather than having to infer this, simplicity did not influence judgments. These findings suggest that in the face of probabilistic uncertainty, adults employ simplicity as a basis for evaluating explanations.

### Simplicity in Children's Explanations?

If adults appeal to simplicity to constrain inferences when faced with uncertainty, children have all the more reason to do so. However, research on children's explanations has generally focused on explanations' content (e.g., Frazier et al., 2009; Wellman, Hickling, & Schult, 1997), not on the roles of probabilistic evidence or inference. For example, there is evidence that children prefer explanations that are causal (Frazier et al., 2009), teleological (Kelemen, 1999), and appropriate for the domain in question (Greif et al., 2006; Schult & Wellman, 1997). In contrast to this focus on content, research on causal inference has demonstrated that even young children are sensitive to probability (Gopnik, Glymour, Sobel, Schulz, & Danks, 2004; Kushnir & Gopnik, 2007; Schulz & Gopnik, 2004), sampling information (Kushnir, Xu, & Wellman, 2008; Xu & Garcia, 2008), and prior beliefs (e.g., Koslowski, 1996; Schulz, Bonawitz, & Griffiths, 2007) but has not examined simplicity.

Although previous work on causal inference is consistent with a preference for simpler explanations, this research has not attempted to isolate effects of simplicity from those of probability. To illustrate, consider a study in which children were trained that blocks that activate a machine ("blickets") are either rare or common (Sobel, Tenenbaum, & Gopnik, 2004). Children were then presented with a backward blocking paradigm: They were shown that two objects (A and B) activated the machine together and that one object (A) activated the machine by itself. Is the other object (B) a blicket? When children were taught that blickets were rare, they made the correct backward blocking prediction and only extended the blicket label to A, even though B was associated with the machine's activation. However, when children were taught that blickets were common, they also categorized the uncertain object, B, as a blicket.

Backward blocking could reflect a principle like Occam's razor: Why assume both blocks are potential causes of the machine's activation if one is sufficient to explain the effects? However, the findings can be explained on the basis of probability alone: In the condition in which blickets are rare, the probability that both objects are blickets is less than the probability that a single object is a blicket (see also Beckers, Vandorpe, Debeys, & De Houwer, 2009, and Sobel & Munro, 2009, for related examples of such

inferences, where simplicity is not dissociated from probability). Because these tasks were not designed to assess the role of simplicity, simplicity and probability are not manipulated independently. Therefore, we cannot determine whether children do appeal to simplicity and, if so, whether judgments are a function of both simplicity and probabilistic evidence.

To investigate the role of simplicity without confounding simplicity and probabilistic evidence, we present children with an outcome that can be explained by one cause or by two, and vary the relative probabilities of these competing explanations across conditions. In so doing, we create situations in which the simpler explanation (one cause) is *not* the most probable and thereby dissociate a preference for simplicity from probabilistic inference on the basis of frequency information. We thus present the first study, to our knowledge, to directly examine whether simplicity plays a role in constraining children's inferences and how simplicity and probabilistic evidence jointly influence explanations.

### Experiment 1

Children and adults were asked to explain an outcome consistent with both a simple explanation (one cause) and a complex alternative (two causes). To make the task engaging and appropriate for preschool-aged children, we modified the procedure used by Lombrozo (2007) to involve a live event and solicited explanations by asking participants why an outcome occurred.

The task involved a toy for which the simplicity and probability of candidate explanations could be varied independently. Participants learned about colored chips that generated one or two effects when placed in the toy's activator bin: Blue chips activated the toy's light and fan, red chips activated the light, and green chips activated the fan. Participants were asked to explain an event in which a bag of chips accidentally tipped into the toy's activator bin, and the fan and light both activated. Citing a single blue chip was the simplest explanation, but citing a red chip and a green chip was a viable alternative. Varying the numbers of different chips in the tipped bag was equivalent to varying the base rates of diseases in Lombrozo (2007). This task thus allowed us to explore new questions concerning children's explanatory preferences: whether children prefer simpler explanations when simplicity and probability are unconfounded, whether children are sensitive to probability in generating explanations, and how simplicity and probability interact in evaluating competing explanations.

### Method

**Participants.** Eighty-five children (range = 47–72 months;  $M = 58$  months) and 64 adults (range = 18–23 years) participated. There were approximately equal numbers of male and female participants. Although most children were from White, middle-class backgrounds, a range of ethnicities resembling the diversity of the population was represented.

**Design.** We used a between-subjects design in which participants were assigned to one of four conditions: a 1:1 probability condition (in which the probability of the complex explanation was equal to that of the simple explanation), a 1:2 condition (in which the probability of the complex explanation was twice that of the simple explanation), a 1:4 condition, and a 1:6 condition. (See Table 1 for chip totals per condition and Table 2 for the mathematical formulas.) Because some children failed the memory

Table 1  
Types of Explanations Generated as a Function of Condition for Experiments 1 and 2

Experiment 1				
Variable	Condition			
	1:1	1:2	1:4	1:6
No. Chips used	1 Blue 3 Red 3 Green	1 Blue 6 Red 6 Green	1 Blue 12 Red 12 Green	1 Blue 18 Red 18 Green
Children's responses				
No. Simple "a blue chip"	8	10	6	5
No. Complex "red and green chip"	1	3	9	10
No. Other (e.g., "a blue and red chip")	7	3	1	1
Adults' responses				
No. Simple	6	2	3	1
No. Complex	10	14	13	15

Experiment 2		
Variable	Condition	
	1:1	1:6
No. Chips used	5 Yellow 16 Purple 16 Orange	1 Yellow 18 Purple 18 Orange
No. Simple "a yellow chip"	10	6
No. Complex "purple and orange chip"	5	13
No. Other (e.g., "a yellow and purple chip")	5	1

Note. Condition labels indicate the ratio of the probability of the simple explanation (blue) to that of the complex explanation (red and green).

check (see the Procedure section), 18 children participated in the 1:1 condition, 18 in the 1:2 condition, 21 in the 1:4 condition, and 25 in the 1:6 condition. Adults were randomly assigned to each of the four conditions, with 16 adults per condition.

**Materials.** The task involved a toy with a red bulb and a green fan, both of which spun and lit up when activated. These effects appeared to be generated by placing colored chips in an activator bin but were, in fact, controlled with a hidden switch.

Table 2  
Number of Chips of Each Color in Each Condition of Experiments 1 and 2, Along With Calculations for Probability Conditions

No. chip color			All possible outcomes if 1 or 2 chips fell into bucket									Condition (ratio) <sup>d</sup>
B	R	G	B <sup>a</sup>	R <sup>a</sup>	G <sup>a</sup>	BB <sup>b</sup>	RR <sup>b</sup>	GG <sup>b</sup>	BR <sup>c</sup>	BG <sup>c</sup>	RG <sup>c</sup>	
Experiment 1												
1	3	3	0.07	0.21	0.21	0.00	0.07	0.07	0.07	0.07	0.21	1 = 1:1
1	6	6	0.04	0.23	0.23	0.00	0.10	0.10	0.04	0.04	0.23	.5 = 1:2
1	12	12	0.02	0.24	0.24	0.00	0.11	0.11	0.02	0.02	0.24	.25 = 1:4
1	18	18	0.01	0.24	0.24	0.00	0.11	0.11	0.01	0.01	0.24	.167 = 1:6
Experiment 2												
Y	P	O	Y <sup>a</sup>	P <sup>a</sup>	O <sup>a</sup>	YY <sup>b</sup>	PP <sup>b</sup>	OO <sup>b</sup>	YP <sup>c</sup>	YO <sup>c</sup>	PO <sup>c</sup>	
5	16	16	0.07	0.22	0.22	0.01	0.09	0.09	0.06	0.06	0.19	1 = 1:1
1	18	18	0.01	0.24	0.24	0.00	0.11	0.11	0.01	0.01	0.24	.167 = 1:6

Note. B = blue; R = red; G = green; Y = yellow; P = purple; O = orange. We assume that the probabilities of one chip and of two chips falling in the toy's activation bin are equal and that chips are independent and fall without replacement. Outcomes containing the blue chip are counted as simple, whether or not there was a second chip. That is, chip combinations consisting of blue and red, blue and green, and blue alone were all counted as "simple," as this results in a more conservative estimate for the role of simplicity. (Note, however, that in coding participants' explanations, we used a more stringent criterion, to be consistent in our definition of simplicity as appealing to a single cause.)

<sup>a</sup> $p(1 \text{ chip}) = .5 * (\text{no. that chip}) / (\text{Total no. chips})$ . <sup>b</sup> $p(2 \text{ same color chip}) = .5 * [(\text{no. first chip color}) / (\text{Total no. chips})] * [(\text{no. first chip color} - 1) / (\text{Total no. chips} - 1)]$ . <sup>c</sup> $p(2 \text{ chips of different colors}) = .5 * \{[(\text{no. first chip color}) / (\text{Total no. chips})] * [(\text{no. second chip color}) / (\text{Total no. chips} - 1)] + [(\text{no. second chip color}) / (\text{Total no. chips})] * [(\text{no. first chip color}) / (\text{Total no. chips} - 1)]\}$ . <sup>d</sup>ratio = probability of outcomes consistent with simple, blue-chip explanation (i.e. B, BB, BR, BG)/probability of outcomes consistent with complex, red-and-green-chip explanation (i.e. RG) =  $\{\sum [p(B), p(BB), p(BR), p(BG)] / p(RG)\}$ .

**Procedure.** There were three phases: a demonstration, a memory check, and an explanation event (see Figure 1 and the online supplemental materials).

**Demonstration.** Participants were shown that placing a red chip in the activator bin activated the bulb, placing a green chip in the activator bin activated the fan, and placing a blue chip in the activator bin generated both effects. The experimenter then asked the participant to help count chips into a clear container (see Table 1).

**Memory check.** Participants were asked what happened when each kind of chip went in the activator bin. They were also asked to predict what would happen if both a red chip and a green chip went in simultaneously. This ensured that participants realized that a red chip and a green chip could activate both parts of the toy and, thus, generate an outcome identical to a single blue chip. The experimenter also asked participants how many chips of each color were in the container. The questions served to eliminate participants (especially children) unable to attend to the task.

**Explanation event.** After mixing the chips in the container, the experimenter poured them into an opaque, rigid bag that was placed next to the toy's activator bin. The experimenter then "accidentally" knocked the bag toward the activator and away from the participant, and the bulb and fan immediately activated. Participants could not see or hear what actually fell into the activator bin. The experimenter exclaimed, "Oops! I knocked my bag over! I think one or two chips may have fallen into my toy! What do you think fell into the toy?" Explanations were recorded.

The number of chips required to achieve each condition's probability ratio was computed by assuming that accidentally tipping the bag was equally likely to result in one chip or two chips falling. This assumption was reinforced by having the experimenter explicitly note that "one or two chips" fell in the activator bin.

Adults were informed that the procedure was designed for young children; the adult procedure was otherwise equivalent.

## Results and Discussion

**Data from children.** Children's responses on the memory check were coded. Children failing any portion of the check were excluded from analyses, resulting in 16 children per condition. There were no differences in children's ages across the four conditions, Kruskal-Wallis  $h(3) = 1.33, ns$ .

Children's explanations were transcribed and coded by a research assistant, with the first author serving as a second coder (blind to condition). Because participants were asked "what fell into the toy," explanations appealed directly to one or more chip combinations (e.g., "a blue chip," "a red one and a green one") and responses fell unambiguously into one of three categories: simple (blue chip only), complex (red and green chips only), or other<sup>1</sup> (see Table 1). Coder agreement was 100%.

All children generated a single explanation and overwhelmingly provided explanations that were adequate in the sense that they accounted for both observed effects. Of the 64 explanations generated, only four failed to account for both effects (e.g., just "a red chip"). This suggests that children understood the task and the basic requirements for an explanation.

To examine whether the explanation a child generated depended on the relative probabilities of the one- and two-cause explanations, the distribution of explanations was analyzed as a function of condition, revealing a significant effect,  $\chi^2(6, N = 64) = 20.25,$

$p < .01$ .<sup>2</sup> Examining only simple and complex explanation choices, there was a monotonic increase in the proportion of children selecting the complex explanation as it became more likely, and children were significantly more likely to provide a complex explanation in the 1:6 condition than in the 1:1 condition (Fisher exact,  $p = .01$ ; see Figure 2).

When the simple and complex explanations were equally likely (1:1 condition), significantly more children selected the simple explanation,  $\chi^2(1, N = 16) = 7.58, p < .01$ . Even in the 1:6 condition, in which the probability of the simple explanation was under 15%, over 30% of children chose that explanation.

These data suggest that children were sensitive to the probability information conveyed by the relative numbers of chips but had a baseline preference for the simpler explanation. That simplicity and probability both influenced explanation choices suggests that children effectively selected between or integrated these competing explanatory demands.

**Data from adults.** All adults passed the memory check and generated only simple or complex explanations (see Table 1). Overall, the distribution of explanations did not differ as a function of condition,  $\chi^2(3, N = 64) = 5.74, p = ns$ . However, adults were more likely to favor a complex explanation when it was more probable: They were significantly more likely to provide the simple explanation in the 1:1 condition than in the 1:6 condition,  $\chi^2(2, N = 64) = 4.57, p < .05$ .

Adult responses differed significantly from children's responses. Collapsing across all four conditions, children were no more likely to choose the simple explanation or the complex explanation,  $\chi^2(1, N = 64) = 1.17, p = ns$ , but adults were significantly more likely to choose the complex explanation,  $\chi^2(1, N = 64) = 50.0, p < .001$ . In all conditions, adults were more likely than children to generate the complex explanation: 1:1,  $\chi^2(2, N = 32) = 4.57, p < .05$ ; 1:2,  $\chi^2(2, N = 32) = 15.18, p < .01$ ; 1:4,  $\chi^2(2, N = 32) = 4.8, p < .05$ ; 1:6,  $\chi^2(2, N = 32) = 4.57, p < .05$ . And whereas children were significantly more likely to choose the simple explanation over the complex alternative in the 1:1 condition, adults were not ( $N = 16, p = ns$ , by binomial test). The adult response pattern can thus be accounted for by probability alone.

## Experiment 2

Experiment 1 suggests that children prefer simpler explanations but are also responsive to the probabilistic evidence for each explanation. However, several alternative accounts are worth considering before accepting this interpretation.

First, it could be that as the total number of chips involved in the task increased, children became more inclined to cite explanations involving multiple chips. We address this concern in Experiment 2 by matching the total number of chips in a 1:1 condition and a 1:6 condition.

Second, it could be that children generated explanations by "matching" the chip colors cited to the observed effects, as red

<sup>1</sup> Note that only one child (in the 2:1 condition) generated an explanation with all three chips (red, green, and blue), which we coded as "other," although coding it as "complex" does not affect the results.

<sup>2</sup> These results also hold over the distribution of only simple and complex explanations as a function of condition,  $\chi^2(3, N = 52) = 10.93, p = .01$ .

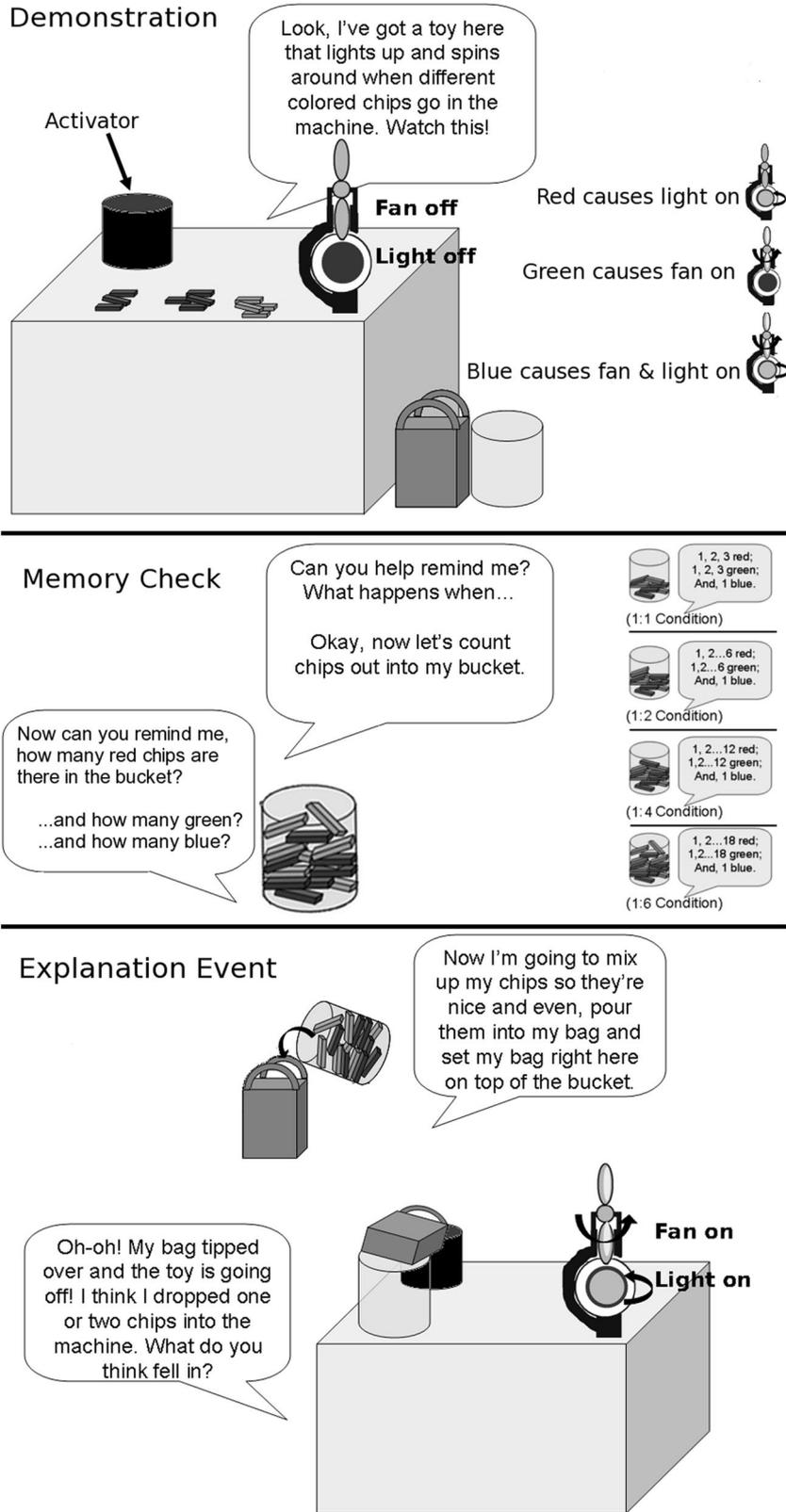


Figure 1. Schematic illustration of the experimental procedure used in Experiment 1.

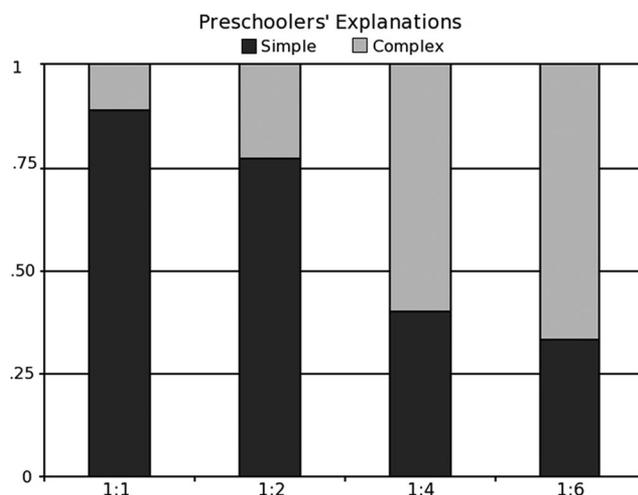


Figure 2. Proportion of children generating simple and complex explanations as a function of condition in Experiment 1, excluding the small number of children who generated “other” explanations. The condition labels along the x-axis indicate the ratio of the probability of the simple explanation (blue chip) to that of the complex explanation (red and green chips).

chips activated a red bulb and green chips a green fan. This could potentially account for the pattern of results if color-matching became more frequent as the total number of chips in the task increased. Experiment 2 addresses this alternative by matching the total number of chips across probability conditions, as noted above, and additionally employs chip colors that do not correspond to parts of the toy.

Finally, it could be that children’s preference for simpler explanations reflected an assumption about how likely it was that the tipped container would spill one chip versus two. Experiment 2 addresses this concern by changing the way in which chips are sampled: We replaced the accidental container-tipping event with a mechanical claw that drew chips and included initial training to demonstrate that the claw was equally likely to draw one or two chips.

## Method

**Participants.** Forty-eight children (range = 50–71 months;  $M = 60$  months) participated. Although most children were from White, middle-class backgrounds, a range of ethnicities resembling the diversity of the population was represented.

**Design.** Children participated in both 1:1 and 1:6 probability conditions (see Tables 1 and 2 for chip counts and probability computations). The conditions were presented with order counterbalanced across participants. However, because there were significant order effects, with more than half of participants simply repeating their response from the first condition, we only report results from the first condition in what follows, effectively treating probability condition as a between-subjects factor. Four children were dropped from the 1:1 condition and four from the 1:6 condition for failing the memory check on the first trial (see the Procedure section),

**Materials.** The task involved the toy from Experiment 1, but the chips used to activate the toy were yellow, purple, and orange. Additionally, there were green training chips and a pink “grabbing claw.”

**Procedure.** The procedure for Experiment 2 was identical to Experiment 1, with exceptions noted below.

**Demonstration.** Children were first introduced to the “grabbing claw” and told that the claw always picks up one or two chips when placed in the bucket, with each outcome (one chip or two chips) occurring equally often. Children were told that the experimenter could not see or control which chips were picked up and were shown two demonstrations (counterbalanced) with a bucket of green chips: One involved the claw grabbing a single chip, and the other involved two chips. The green chips were then removed.

As in Experiment 1, children were shown which chips activated the machine, but the colors were as follows: orange activated the bulb, purple activated the fan, and yellow activated both.<sup>3</sup>

**Explanation event.** After mixing the chips in the container, the experimenter poured them into an opaque, rigid container and, with eyes averted, used the claw to reach into the container, depositing the claw’s contents into the activator. During this procedure, the experimenter reminded children that she could not see or control what the claw grabbed. Upon opening the claw into the activator, the bulb and fan immediately activated. The experimenter then said, “I think one or two chips fell into my toy! What do you think fell into the toy?” Explanations were recorded.

## Results and Discussion

Children’s responses on the memory check were coded. Children failing any portion of the check were excluded from analyses, resulting in 20 children per condition. There were no differences in children’s ages between conditions,  $t(38) = 0.03$ ,  $p = ns$ .

Children’s explanations were transcribed and coded by a research assistant blind to hypotheses, and reliability was coded by a second research assistant blind to condition and hypotheses. As with Experiment 1, responses fell unambiguously into one of three categories: simple (yellow chip only), complex (purple and orange chips only), or other (see Table 1). Seventy-five percent of video clips were reliability coded, with coder agreement of 100% (we did not receive video consent for the remaining clips).

All children generated a single explanation and overwhelmingly provided explanations that were adequate in the sense that they accounted for both observed effects. Of the 40 explanations generated, only three failed to account for both effects (e.g., just “an orange chip”). This suggests that children understood the task and the basic requirements for an explanation.

The distribution of explanations was analyzed as a function of condition, revealing a significant effect: Children were more likely to select the complex explanation in the 1:6 condition than in the

<sup>3</sup> We thank an anonymous reviewer for pointing out the possibility that in the 1:6 condition, children were matching colors based on “warmth” and “coolness” of the color. Although the data reported here cannot definitively rule this out, we think it is unlikely to account for our results; additional testing suggested that children were not more likely to pair warm colors and cool colors than they were to select other color combinations.

1:1 condition, Fisher exact ( $N = 40$ ),  $p < .05$ .<sup>4</sup> In the 1:1 condition, where both explanations were equally likely, significantly more children selected the simple explanation,  $\chi^2(2, N = 20) = 7.5$ ,  $p < .05$ . In the 1:6 condition, in which the probability of the simple explanation was under 15%, 30% of children nonetheless chose that explanation (see Figure 3).

There were no differences between the 1:1 conditions of Experiments 1 and 2 (Fisher exact,  $ps = ns$ ), nor between the 1:6 conditions (Fisher exact,  $ps = ns$ ).

These findings mirror those from Experiment 1 and support the conclusion that children are sensitive to both simplicity and probability in generating explanations. The findings also go beyond Experiment 1 in ruling out alternative interpretations. However, the results of Experiment 2 did not survive the within-subject manipulation. Children tended to simply repeat their response on the second trial, indicating that contextual demands (e.g., a preference for response constancy following the ambiguously positive feedback at the end of the first trial) outweigh the differential effects of simplicity and probability across conditions and suggesting that preschooler's sensitivity to probability and simplicity may be relatively fragile.

### General Discussion

Using a novel method, we find that children's early explanations are sensitive to both simplicity and probability. When faced with two equally probable, competing explanations, children overwhelmingly selected the explanation that was simpler in the sense that it invoked fewer causes. When frequency information suggested that the complex explanation was more probable, this tendency was moderated but not eliminated.

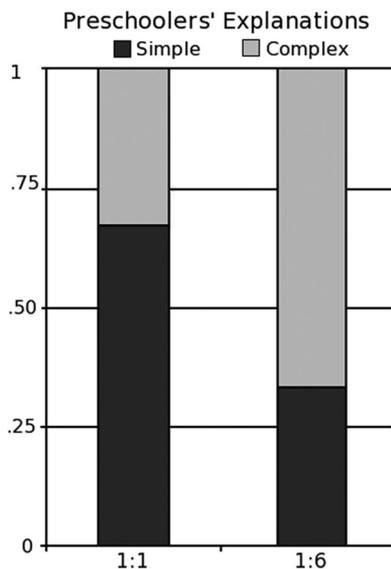


Figure 3. Proportion of children generating simple and complex explanations as a function of condition in Experiment 2, excluding the small number of children who generated “other” explanations. The condition labels along the  $x$ -axis indicate the ratio of the probability of the simple explanation (yellow chip) to that of the complex explanation (purple and orange chips).

These findings are the first to isolate a preference for simpler explanations in young children. By manipulating the probabilistic evidence for each explanation (through the numbers of chips of each color), we removed probabilistic confounds present in previous studies of causal learning. The fact that children's explanations favor simplicity—even when probability is held constant—suggests that children prefer simpler explanations in virtue of their simplicity, not (as could be the case in previous experiments) because such explanations are independently more likely.

Despite a baseline preference for simplicity, explanations also varied as a function of probability. This contributes to an emerging literature suggesting that children are savvy probabilistic reasoners, but it does so using a quite novel task. What makes our data particularly striking is that a small manipulation across conditions—namely, the number of chips of each color—dramatically affected the explanations children (and adults) provided.

The pattern of findings reveals that children are sensitive to both simplicity and probability in generating explanations. Rather than responding on the basis of a single dimension irrespective of probability condition (simplicity alone or probability alone), our population of young children responded as a function of both dimensions, either integrating them to form a composite judgments or evaluating both before deciding which dimension to favor. One possibility is that children use simplicity as a basis for assigning prior probabilities to competing explanations but appropriately update those probabilities in light of probabilistic evidence, yielding an overall preference for simplicity that is nonetheless responsive to evidence (see Lombrozo, 2007, for a similar suggestion with adults).

Unlike Lombrozo (2007), who found that adults used simplicity to inform explanation choices when faced with probabilistic uncertainty, the current experiment found no evidence of a preference for simpler explanations among adults. However, Lagnado (1994) and Lombrozo (2007) both found that adults ignored simplicity when the most probable explanation was clearly identified. In our task, the adult population may have been able to compute relative probabilities, reducing uncertainty concerning which explanation was most likely. It is thus possible that the observed differences between children and adults reflect expertise, rather than a developmental change. Specifically, simplicity may be used as a guide to probability only when more reliable bases for assessing probability are unavailable. This could arise when physical systems are not well understood (as could be the case with the children in this experiment) or when there is uncertainty about how to assess probability (as with adults in some conditions from Lombrozo, 2007). Future work could examine how simplicity and probability interact given more complex or natural conditions, as well as conditions in which mechanism information is well understood.

Why might children and adults rely on simplicity in the face of probabilistic uncertainty? One possibility is that the use of simplicity in inference has a normative justification (Akaike, 1974; Li & Vitanyi, 1997; Rissanen, 1978). Simpler explanations reduce the risk of “overfitting” data and have also been advocated as a

<sup>4</sup> Fisher exact is used because expected cell frequencies are less than five. These results also hold over the distribution of only simple and complex explanations as a function of condition,  $\chi^2(2, N = 40) = 4.14$ ,  $p < .05$ .

rational consequence of Bayesian inference (Jeffreys & Berger, 1992). Most normative justifications for simplicity do not apply to the task presented here, but if a role for simplicity is sometimes warranted, our findings could reflect an overextension of that role. Future work could evaluate how simplicity influences children's and adult's reasoning when simplicity is quantified in ways more consistent with these normative approaches.

Another possibility is that children appeal to the simpler explanation—the single cause—because it participates in a greater number of causal relationships and may therefore be regarded as more salient or central (i.e., the blue chip causes two outcomes and, hence, participates in two causal relationships, whereas the red and green chips each cause only one outcome). In this vein, research on categorization suggests that category features that participate in more relations can be more “central” (see Ahn, Kim, Lassaline, & Dennis, 2000; Rehder, 2003; Sloman, Love, & Ahn, 1998; see also Lombrozo, 2009). Future work can examine whether the aspects of causal structure that make some features central to judgments of category membership likewise influence the quality of explanations.

Finally, a third possibility is that children (and adults) appeal to simplicity as a result of cognitive limitations (see also Halford, Wilson, & Phillips, 1998). Although this may be the case under some conditions, we think it is unlikely to explain the present findings. Neither children nor adults tended to produce the simplest explanation when frequency information overwhelmingly favored a complex alternative, suggesting that they were willing and able to recognize and privilege complex explanations.

## Conclusions

In the course of learning and development, children are constantly faced with situations for which more than one explanation is possible. This occurs not only in explaining isolated events or properties but also in constructing explanatory frameworks such as a theory of mind (e.g., Wellman & Lagattuta, 2004) or a mental model of the Earth (e.g., Vosniadou & Brewer, 1994). Prior beliefs provide one way to leverage limited experience in the service of inference, but our findings suggest an additional resource available to children and adults under uncertainty: domain-general constraints that inform judgment by playing a role in the evaluation of explanations. Specifically, we have provided evidence for a principle of parsimony, such as Occam's razor, and for the claim that children's explanations, like adults', involve multiple sources of constraint in identifying the best explanation.

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