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Young children use probability to infer happiness and the quality of outcomes

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Abstract

Happiness with an outcome often depends on whether better or worse outcomes were initially more likely. In five experiments, we show that young children ($N = 620$, Experiments 1-4) and adults ($N = 254$, Experiment 5) use probability to infer emotions and assess outcome quality. In Experiments 1 and 2, 5-6-year-olds (but not 4-year-olds) inferred that an agent would be less happy with an outcome if a better outcome was initially more likely. In Experiment 3, 4-6-year-olds used probability to assess quality. These findings suggested a developmental lag between 4-year-olds' assessments of quality and happiness. We replicated this lag in Experiment 4. In Experiment 5, adults used probability to assess both quality and happiness. We suggest that children and adults may have used probability to establish a standard against which actual outcomes are compared. Doing so might allow them to make probability-based inferences of happiness without drawing on counterfactual reasoning.

Keywords: emotion attribution, happiness, probability, social cognition, cognitive development

Young children use probability to infer happiness and the quality of outcomes

Our happiness with an outcome depends on the likelihood of better or worse alternatives. For example, in gambling simulations, adults feel worse about not winning any money if their chances of winning were high, rather than low (Mellers, Schwartz, Ho, & Ritov, 1997). Such emotional reactions are widely believed to depend on counterfactual comparisons in which people's emotions are intensified when they know they could have had a better or worse outcome (e.g., Bell, 1985; Loomes & Sugden, 1986; Shepperd & McNulty, 2002; van Dijk & van der Pligt, 1997).

People may also consider the probability of better or worse outcomes when inferring others' happiness. If so, this would suggest that people's intuitive theory of happiness is linked with their understanding of probability. Here we explore this proposal from a developmental perspective.

Much previous work suggests that young children have difficulty seeing the link between alternative outcomes and emotions. Children do not experience counterfactual emotions themselves until they are 5-7 (O'Connor, McCormack, & Feeney, 2012; Weisberg & Beck, 2010). Further, they have difficulty using counterfactual comparisons to anticipate others' emotions (e.g., Guttentag & Ferrell, 2004; see Beck & Riggs, 2014 for a review). In one study, 5-7-year-olds considered an agent who could choose one of two sealed boxes and keep its contents (Weisberg & Beck, 2010). The chosen box was revealed to contain just a few stickers, whereas the unchosen box held many more. Children did not indicate that the agent would feel badly about having chosen the box with fewer stickers, even though children did feel badly when they were the ones to make this worse choice for themselves. Similarly, young children often fail to infer that expectations (which provide counterfactual alternatives) can influence happiness (Lara,

Lagattuta, & Kramer, 2017; but see Asaba, Ong, & Gweon, 2019 for evidence of this ability in children aged 5). Importantly, though, none of these studies specifically manipulated the odds of better or worse outcomes.

Providing young children with information about the probability of better or worse outcomes might allow them to infer happiness. This information may matter because the odds of an alternative outcome affects its impact. For example, children might use probabilistic reasoning to first assess the quality of an outcome (i.e., how good or bad it is), and then use this assessment to infer happiness. When someone with a high probability of winning money does not actually win any, children could first assess that this outcome is bad or unlucky, and then conclude that the person is unhappy. It is plausible that children might make probability-based inferences of happiness because infants and preschoolers make simple probabilistic inferences (e.g., Denison, Konopczynski, Garcia, & Xu, 2006; Denison & Xu, 2010; Téglás, Girotto, Gonzalez, & Bonatti, 2007), and preschoolers also use probability in social judgments (e.g., inferring preferences; Kushnir, Xu, & Wellman, 2010; Ma & Xu, 2011).

To investigate whether children infer other people's happiness by considering the probability of better and worse outcomes, we focussed on children aged 4-6. Children in this age range infer happiness by relying on memorized scripts, such as *people are happy when they receive presents* (e.g., Widen & Russell, 2010, 2011; also see Fehr & Russell, 1984). They also make these inferences by considering people's mental states (e.g., Harris, Johnson, Hutton, Andrews, & Cooke, 1989; Wellman & Woolley, 1990). For example, 5-year-olds predict a boy will be happy if he believes a box contains candy, even if its actual contents are undesirable (Hadwin & Perner, 1991). Perhaps 4-6-year-olds also infer happiness by considering probability.

To investigate this possibility, 4-6-year-olds in Experiment 1 rated how happy a girl felt upon receiving equal numbers of yummy and yucky gumballs from a gumball machine. Across conditions, the girl either had a high chance of getting mostly yummy ones, or a high chance of getting mostly yucky ones. Experiment 2 added a condition where the girl was equally likely to get yummy or yucky gumballs. Experiments 3 and 4 investigated children's judgments about outcome quality. Experiment 5 investigated adults' judgments about outcome quality and people's happiness.

Experiment 1

Methods

Participants. We tested 180 children: 60 4-year-olds ($M = 4;6$ [years; months]; range = 4;0 – 4;11; 29 girls), 60 5-year-olds ($M = 5;5$; range = 5;0 – 5;11; 26 girls), and 60 6-year-olds ($M = 6;5$; range = 6;0 – 6;11; 34 girls). Our sample size of 30 participants per cell means that our experiments may have low power to detect small to medium effects, but we followed it based on our lab stopping rule when this data was collected. Our lab chose this stopping rule because we felt it sufficed to reveal effects in previous developmental experiments using similar designs. Children from all experiments were individually tested at schools and daycares in a mid-sized XXXX city in XXXX with all data collection occurring between April, 2017 and April, 2019.

Materials and procedure. All materials were shown on a laptop computer. Children were told a story about a gumball machine containing yummy red gumballs and yucky black ones. Children in each age range were randomly assigned to see this story in one of two between-subjects conditions. In the Mostly Yummy condition, the gumball machine contained many red gumballs and just a few black ones (46 red; 4 black). In the Mostly Yucky condition, the gumball machine contained the reverse distribution (46 black; 4 red).

A girl appeared beside the gumball machine in both conditions. She wanted red gumballs and children were asked a comprehension question to confirm that they understood. The girl pulled the handle of the machine and received two red and two black gumballs. Children were asked to rate how she felt using a 7-point happy face scale, ranging from extremely sad to extremely happy. See Figure 1 for a sample of the story and script.

In both conditions, the girl had an extremely high chance of mostly or exclusively receiving the more common type of gumball. For example, in the Mostly Yucky condition, she had a 97% chance of getting at least 3 black gumballs. Hence, getting 2 red and 2 black gumballs is a relatively good outcome in the Mostly Yucky condition, and a relatively bad outcome in the Mostly Yummy condition. Thus, if children infer happiness by considering the probability of better or worse outcomes, they should rate the girl as happier in the Mostly Yucky condition than in the Mostly Yummy condition.

(A) Here's a gumball machine. It has red gumballs and it has black gumballs. The red gumballs are very, very yummy and the black gumballs are very, very yucky. (B) And look, here's a girl. She wants a red gumball. *What color gumball does the girl want?* (C) To get some gumballs, the girl pulls down the handle, and the machine shakes up all the gumballs. (D) Look! She got some gumballs. So now I have a question for you. *How does the girl feel about the gumballs that she got?*

Figure 1. Sample slides and script for the Mostly Yucky condition. The Mostly Yummy condition was identical, but the distribution of yummy and yucky gumballs was reversed.

Results

Figure 2 shows children's mean happiness ratings; also see Table 1 for means and standard deviations for all experiments. Data for all experiments are available at

https://osf.io/e3a2k/?view_only=505fab0517914db1b065b2285748d565. A 2 (condition: Mostly

Yummy, Mostly Yucky) x 3 (age: 4, 5, 6) ANOVA revealed a significant age by condition interaction, $F(2,174) = 4.39, p = .014, \eta_p^2 = .048$. There were no main effects of condition, $F(1,174) = 3.40, p = .067, \eta_p^2 = .019$, or of age, $F(2,174) = 2.09, p = .127, \eta_p^2 = .023$. We explored each age group separately and found that both 5- and 6-year-olds rated the girl as significantly happier in the Mostly Yucky condition than in the Mostly Yummy condition, $t(58) = -2.07, p = .043, d = 0.53$, and $t(58) = -3.07, p = .003, d = 0.79$, respectively. However, 4-year-olds did not show differences between the two conditions, $t(58) = 1.18, p = .243, d = 0.31$.

Discussion

These findings suggest that 5- and 6-year-olds can use probability to infer happiness. However, it is unclear whether this effect was mostly driven by one condition (e.g., children inferring disappointment in the Mostly Yummy condition, without inferring relief in the Mostly Yucky condition).

We examine this in Experiment 2 by seeking to replicate Experiment 1 with 5-6-year-olds, and adding a third baseline condition where the girl was equally likely to get yummy and yucky gumballs.

Table 1

Means and standard deviations for children's and adults' ratings in Experiments 1 – 5

Experiment	Judgment-type	Age	Condition		
			Mostly Yummy	Mostly Yucky	50/50
1	Happiness	4	1.07 (2.32)	0.33 (2.50)	--
		5	0.47 (2.45)	1.63 (1.88)	--
		6	0.83 (1.86)	2.13 (1.38)	--
2	Happiness	5	1.00 (2.20)	1.67 (1.83)	1.30 (2.25)
		6	0.17 (1.74)	1.60 (1.22)	1.33 (1.79)
3	Quality	4	0.40 (2.69)	1.87 (1.74)	--
		5	0.40 (2.33)	1.23 (1.79)	--
		6	0.10 (1.49)	1.60 (1.69)	--
4	Happiness	4	1.05 (2.42)	0.80 (2.42)	--
	Quality	4	0.85 (1.85)	1.95 (1.58)	--
5	Happiness	Adults	-0.14 (1.63)	0.36 (1.64)	--
	Quality	Adults	0.00 (1.58)	0.51 (1.42)	--

Figure 2. Children's mean happiness ratings, ranging from -3 (extremely sad) to 3 (extremely happy). Error bars show ± 1 standard error of the mean.

Experiment 2

Methods

Preregistration. This study was conducted after Experiments 1 and 3, and was preregistered at <http://aspredicted.org/blind.php?x=3ae2dy>. The preregistration covered the number of participants, design, and analysis plan.

Participants. We tested 180 children: 90 5-year-olds ($M = 5;6$; range = 5;0 – 5;11; 47 girls), and 90 6-year-olds ($M = 6;6$; range = 6;0 – 6;11; 41 girls). One additional child was tested and excluded because they did not provide a rating.

Materials and procedure. We repeated the procedure from Experiment 1, but added a third 50/50 baseline condition in which the gumball machine contained half yummy and half yucky gumballs (25 red, 25 black). Children in each age range were randomly assigned to one of the three conditions.

Results

Figure 3 shows children's mean happiness ratings. A 3 (condition: Mostly Yummy, Mostly Yucky, 50/50) $\times$ 2 (age: 5, 6) ANOVA revealed a main effect of condition, $F(2,174) = 4.99$, $p = .008$, $\eta_p^2 = .054$. There was no effect of age, $F(1,174) = 1.08$, $p = .301$, $\eta_p^2 = .006$, and no age by condition interaction, $F(2,174) = 0.97$, $p = .382$, $\eta_p^2 = .011$. Follow-up t-tests revealed that children rated the girl as significantly happier in the Mostly Yucky condition than in the Mostly Yummy condition, $t(118) = -3.21$, $p = .002$, $d = 0.59$, and happier in the 50/50 condition than in the Mostly Yummy condition, $t(118) = -2.00$, $p = .048$, $d = 0.37$. Happiness ratings did not significantly differ between the Mostly Yucky and 50/50 conditions, $t(118) = 0.97$, $p = .335$, $d = 0.17$.

Figure 3. Children's mean happiness ratings, ranging from -3 (extremely sad) to 3 (extremely happy). Error bars show ± 1 standard error of the mean.

Discussion

We replicated the findings that 5-6-year-olds use probability to infer happiness. Further, we found this was driven by the understanding that the girl would be relatively upset when she was initially more likely to get a better outcome.

In the remaining experiments, we turn to the finding (from the first experiment) that 4-year-olds did not use probability to infer happiness. Four-year-olds' failure is unlikely to stem from an inability to consider basic probability, as children this age expect a majority item in a distribution to be sampled most often (e.g., Denison et al., 2006; Girotto, Fontanari, Gonzalez, Vallortigara, & Blaye, 2016). One explanation for their failure is that 4-year-olds struggled to give lower happiness ratings for the "good" machine and higher happiness ratings for the "bad" machine. Four-year-olds might find this difficult because it requires inhibiting the impulse to match visually "good" scenes with positive emotions (e.g., Doan, Friedman, & Denison, 2018).

To examine this possibility, we next investigated whether 4-6-year-olds can use probability to assess the quality of an outcome. As noted above, this could be a necessary step in probability-based inferences of happiness. If the 4-year-olds do use probability to assess quality, this would show that their failure does not stem from inhibitory demands, but may instead reflect a deeper breakdown in the inferences linking probability and happiness.

Experiment 3

Methods

Participants. We tested 180 children: 60 4-year-olds ($M = 4;7$; range = 4;0 – 4;11; 27 girls), 60 5-year-olds ($M = 5;5$; range = 5;0 – 5;11; 28 girls), and 60 6-year-olds ($M = 6;5$; range = 6;0 – 6;11; 33 girls). Two additional children were tested and excluded because they did not provide a rating.

Materials and procedure. The materials, procedure, and design were identical to Experiment 1, except that the girl was removed from the stories. We used the same rating scale as in the previous experiments, but children were asked to rate how good the outcome was, and not about happiness. Children were randomly assigned to either the Mostly Yummy condition or the Mostly Yucky condition. See Figure 4 for a sample of the story and script for the Mostly Yucky condition.

(A) Here's a gumball machine. It has red gumballs and it has black gumballs. The red gumballs are very, very yummy and the black gumballs are very, very yucky. (B) Let's pull the handle to see what comes out. The machine shakes up all the gumballs. (C) Look what came out! So now I have a question for you. *How good was that?*

Figure 4. Sample slides and script for the Mostly Yucky condition. The Mostly Yummy condition was identical, but the distribution of yummy and yucky gumballs was reversed.

Results

Figure 5 shows children's mean quality judgments. A 2 (condition: Mostly Yummy, Mostly Yucky) x 3 (age: 4, 5, 6) ANOVA revealed a main effect of condition, $F(1,174) = 18.07$, $p < .001$, $\eta_p^2 = .094$, where children rated the outcome as better in the Mostly Yucky condition than in the Mostly Yummy condition. There was no effect of age, $F(2,174) = 0.46$, $p = .635$, $\eta_p^2 = .005$, and no age by condition interaction, $F(2,174) = 0.53$, $p = .590$, $\eta_p^2 = .006$.

Discussion

These findings demonstrate that by age 4, children can determine the relative quality of an outcome, and can inhibit the impulse to match overwhelmingly “good” visual scenes with good ratings. Together, the experiments so far suggest that 4-year-olds can use probability to assess the relative quality of an outcome, but not to infer happiness. However, we must be cautious about this conclusion because it rests on the results of separate experiments. To provide more certainty, we investigated the potential developmental gap between 4-year-olds' assessments of quality and inferences of happiness within a single experiment.

Figure 5. Children's mean outcome quality judgments, ranging from -3 (extremely bad) to 3 (extremely good). Error bars show ± 1 standard error of the mean.

Experiment 4

Methods

Preregistration. This study was preregistered at <http://aspredicted.org/blind.php?x=e43tu8>. The preregistration covered the number of participants, design, and analysis plan.

Participants. We tested 80 4-year-olds ($M = 4;6$; range = 4;0 – 4;11; 36 girls). Two additional children were tested and excluded because they did not provide a rating. Our preregistered sample size of 40 participants per cell is larger than the stopping rule in the previous experiments because this experiment focussed on just one age group (i.e., meaning that the overall sample of participants was smaller than in the previous experiments).

Materials and procedure. We used a 2X2 design in which condition (Mostly Yummy, Mostly Yucky) was manipulated within-subjects (order counterbalanced across children), and judgment-type (Happiness, Quality) was manipulated between-subjects. In the stories, a girl

approached a gumball machine and received 2 yummy gumballs and 2 yucky ones. A happy face scale then appeared, and children were either asked about the girl's happiness ("How does the girl feel about the gumballs that she got?") or about the quality of the outcome ("How good was that?"). See Figure 6 for a sample of the story and script for the Mostly Yucky condition.

(A) Here's a gumball machine. It has red gumballs and it has black gumballs. The red gumballs are very, very yummy and the black gumballs are very, very yucky. (B) And look, here's a girl. (C) To get some gumballs, the girl pulls down the handle, and the machine shakes up all the gumballs. (D) Look! She got some gumballs. So now I have a question for you. *How does the girl feel about the gumballs that she got?* (Happiness question) OR *How good was that?* (Quality question)

Figure 6. Sample slides and script for the Mostly Yucky condition. The Mostly Yummy condition was identical, but the distribution of yummy and yucky gumballs was reversed.

Results

Figure 7 shows children's mean happiness and quality ratings. A 2 (condition: Mostly Yummy, Mostly Yucky) $\times$ 2 (judgment-type: Happiness, Quality) mixed ANOVA revealed a condition by judgment-type interaction, $F(1,78) = 5.33$, $p = .024$, $\eta_p^2 = .064$. There were no main effects of condition, $F(1,78) = 2.11$, $p = .150$, $\eta_p^2 = .026$, or judgment-type, $F(1,78) = 1.67$, $p = .200$, $\eta_p^2 = .021$.

We conducted follow-up t-tests to better understand the interaction. When rating quality, children gave higher ratings in the Mostly Yucky condition than in the Mostly Yummy condition, $t(39) = -2.83$, $p = .007$, $d = 0.46$. However, when judging happiness, there was no significant difference between the Mostly Yummy and Mostly Yucky conditions, $t(39) = 0.57$, $p = .570$, $d = 0.09$, replicating our previous findings.

Figure 7. Children's mean happiness and outcome quality ratings, ranging from -3 (extremely sad/bad) to 3 (extremely happy/good). Error bars show ± 1 standard error of the mean.

Discussion

The findings replicated the developmental gap in which 4-year-olds succeed in using probability to assess quality, but not to infer happiness. We wondered whether this gap between quality and happiness continues later in the lifespan. If so, this might suggest that probability is linked more closely with quality than with happiness. Our earlier experiments provided some evidence against this possibility. Specifically, they showed that older children use probability to infer both happiness (Experiments 1 and 2) and quality (Experiment 3). But because these were assessed in different studies (which also used slightly different methods), those experiments only provide a weak basis for comparing these judgments. To better examine this possibility, we conducted an online version of this study with adults.

Experiment 5

Methods

Preregistration. This study was preregistered at <http://aspredicted.org/blind.php?x=mt7mz9>. The preregistration covered the number of participants, design, and analysis plan.

Participants. The experiment was successfully completed by 254 adults ($M = 35$; 111 females) recruited using Amazon Mechanical Turk. Based on our preregistration, we originally recruited 300 participants, but excluded participants who failed at least one of our two comprehension check questions ($N = 45$). One additional participant was excluded because they did not provide a rating on one trial, and so their data could not be analyzed. Our decision to recruit 300 participants was based on the assumption that would leave us with at least 100 participants per between-subject condition (i.e., after exclusions for failures of comprehension checks). We felt that 100 participants per condition would suffice to reveal effects given findings from previous online studies of adults that used similar designs.

Materials and procedure. The experiment used the same 2X2 design as Experiment 4: condition (Mostly Yummy, Mostly Yucky) was manipulated within-subjects, and judgment-type (Happiness, Quality) was manipulated between-subjects. The stories were similar to those in Experiment 4, except each was conveyed using two images, each shown on a separate page. The first page showed a girl at a gumball machine, with the script, “Here’s a girl at a gumball machine. There are red gumballs and black gumballs. The red gumballs are very very yummy and the black gumballs are very very yucky”. The second page showed the girl had received two yummy and two yucky gumballs, with the script, “The girl pulled the handle and got some gumballs”. The test question (“How does the girl feel about the gumballs that she got?” or “How

good was that?") appeared lower down on the page, along with the same happy face scale used with children. Participants responded by clicking on one of the faces.

Results

Figure 8 shows adults' mean happiness and quality ratings. A 2 (condition: Mostly Yummy, Mostly Yucky) x 2 (judgment-type: Happiness, Quality) mixed ANOVA revealed a main effect of condition, $F(1,252) = 11.95$, $p = .001$, $\eta_p^2 = .045$, where adults had higher ratings in the Mostly Yucky condition than in the Mostly Yummy condition. There was no main effect of judgment-type, $F(1,252) = 1.22$, $p = .270$, $\eta_p^2 = .005$, and no condition by judgment-type interaction, $F(1,252) = 0.001$, $p = .972$, $\eta_p^2 = .000$.

Figure 8. Adults' mean happiness and outcome quality ratings, ranging from -3 (extremely sad/bad) to 3 (extremely happy/good). Error bars show ± 1 standard error of the mean.

Discussion

These findings suggest that for the stories we showed children, adults use probability to a similar extent when inferring happiness and outcome quality. As such, the findings do not support the conjecture that probability is linked more closely with quality than with happiness.

General Discussion

We examined whether children and adults use probability to infer people's happiness and the quality of outcomes. For children aged 5 and 6 (and for adults), happiness and quality judgments both depended on whether a better outcome was initially more likely. At age 4, children did not use probability to infer the girl's happiness, but did use it to infer the relative quality of the outcome.

We found that children use probability to infer negative emotions (e.g., disappointment), but not positive ones (e.g., relief, elation). In the second experiment, we found that relative to the baseline condition (equal odds of receiving yummy and yucky gumballs), children gave more negative emotional ratings when a better outcome was initially more likely. But they did not give significantly more positive ratings when a worse outcome was initially more likely. This asymmetry is broadly consistent with many previous findings, including those suggesting that: probability more strongly affects adults' negative than positive emotions (e.g., van Dijk & van der Pligt, 1997); children experience the negative emotion regret before they experience the positive emotion relief (Weisberg & Beck, 2010); and children and adults react more strongly to having less than others (disadvantageous inequality) than to having more (advantageous inequality; e.g., Blake & McAuliffe, 2011; Boyce, Brown, & Moore, 2010; Lobue, Nishida, Chiong, DeLoache, & Haidt, 2011).

We also found that children use probability to assess quality before they can use it to infer happiness. This developmental gap is counterintuitive. If 4-year-olds use probability to assess quality, and likewise understand that negative events lead to unhappiness (e.g., Widen & Russell, 2011), why do they struggle to see how probability can affect emotions? One explanation is that 4-year-olds do not *spontaneously* draw both inferences in this chain (i.e.,

probability→quality, quality→happiness). When asked how the girl feels, 4-year-olds might not have realized that they should start by inferring the quality of the outcome. On this account, 4-year-olds might do better if prompted to first assess quality. However, alternative explanations for the developmental gap between inferences of quality and happiness are possible. Perhaps older children use probability to infer happiness, without first assessing quality (e.g., by considering probability in relation to desires). On this account, 4-year-olds might fail because they have not connected the disparate conceptual domains of emotion and probability.

Regardless, these accounts leave open deeper questions about how children and adults use information about probability to infer happiness and assess quality. They could use this information to establish a “standard of comparison” against which actual outcomes are considered (e.g., Cadotte, Woodruff, & Jenkins, 1987). For instance, when a good outcome is highly probable, this establishes a high standard of comparison. Children (and adults) may then judge that a mediocre outcome is bad because it falls short of this standard (e.g., a gumball machine with 90% good gumballs sets this as the standard, and so the outcome of 50% good gumballs is disappointing). Crucially, this does not require counterfactual comparisons—the actual outcome can be compared to a standard without specifically considering that a better or worse outcome could have occurred.

Alternatively, children’s and adults’ inferences could depend on counterfactual comparisons. For example, when the machine mostly contained yummy gumballs, participants may have judged the outcome was relatively bad because they recognized that a better outcome could easily have occurred. We think this is unlikely for children, though. Although young children can reason about counterfactuals (Nyhout & Ganea, 2019; also see German & Nichols,

2003; Harris, German, & Mills, 1996), they may only come to use counterfactuals to infer others' happiness at age 7 (e.g., Guttentag & Ferrell, 2004).

We next consider two broader implications of the findings. First, our findings advance knowledge of the ways in which children attribute happiness. They show that children do not only infer happiness by relying on memorized scripts (e.g., Russell 1990; Widen & Russell, 2010, 2011), or by considering others' mental states (e.g., Hadwin & Perner, 1991; Wellman & Bartsch, 1988). In addition to these methods for inferring happiness, children also draw on their understanding of probability. Second, our findings advance knowledge of how children use probability information to make social inferences. Preschool-aged children use probability to infer preferences (Kushnir et al., 2010; Ma & Xu, 2011), and older children use it to infer others' surprise (Doan et al., 2018). We extend these findings by showing that 4- and 5-year-olds use probability to infer outcome quality and others' happiness. We found evidence for a developmental lag between children's probability-based inferences of outcome quality and happiness. With development, probabilistic understanding may be gradually integrated into children's understanding of the social world.

Constraints on Generality. In all experiments, we tested participants from a Western, educated, industrialized, rich, and democratic (WEIRD; Henrich, Heine, Norenzayan, 2010) society. As such, we must not assume that our results would generalize to non-WEIRD populations. Also, all experiments used similar stimuli involving gumball machines. In choosing gumball machines, we anticipated that children would be familiar with their probabilistic nature. However, it is uncertain whether our findings would replicate using other kinds of probabilistic stimuli (e.g., spinners, dice).

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