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Psychological Science published online 9 July 2010
DOI: 10.1177/0956797610376652

Psychological Science OnlineFirst, published on July 9, 2010 as doi:10.1177/0956797610376652

Research Article

ASSOCIATION FOR PSYCHOLOGICAL SCIENCE

Psychological Science
XX(X) 1–7

DOI: 10.1177/0956797610376652
http://pss.sagepub.com
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Young Children Use Statistical Sampling to Infer the Preferences of Other People

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Abstract

Psychological scientists use statistical information to determine the workings of human behavior. We argue that young children do so as well. Over the course of a few years, children progress from viewing human actions as intentional and goal directed to reasoning about the psychological causes underlying such actions. Here, we show that preschoolers and 20-month-old infants can use statistical information—namely, a violation of random sampling—to infer that an agent is expressing a preference for one type of toy instead of another type of toy. Children saw a person remove five toys of one type from a container of toys. Preschoolers and infants inferred that the person had a preference for that type of toy when there was a mismatch between the sampled toys and the population of toys in the box. Mere outcome consistency, time spent with the toys, and positive attention toward the toys did not lead children to infer a preference. These findings provide an important demonstration of how statistical learning could underpin the rapid acquisition of early psychological knowledge.

Keywords

cognitive development, intuitive psychology, statistical inference, probabilistic reasoning, social cognition, infant cognition

Received 6/23/09; Revision accepted 12/3/09

Young children are intuitive psychologists. Within the first few years of life, children begin to understand the actions of other people in terms of underlying psychological causes, such as desires, preferences, beliefs, emotions, and knowledge states. It remains unclear, however, how children learn about these internal motivations. Perhaps, like psychological scientists, children use statistical evidence to reveal the nature of mind and action. Indeed, children are surrounded by statistical evidence for psychological causality; people's behaviors are often regular, consistent, and contingent on particular contexts. Young children's intuitive statistical abilities have been examined in physical reasoning (Téglás, Girotto, Gonzalez, & Bonatti, 2007; Xu & Garcia, 2008), word and scene segmentation (Kirkham, Slemmer, & Johnson, 2002; Saffran, Aslin, & Newport, 1996), language learning (Lany, Gómez, & Gerken, 2007; Xu & Tenenbaum, 2007a, 2007b), and causal reasoning (Kushnir & Gopnik, 2005, 2007; Schulz, Bonawitz, & Griffiths, 2007). Through two experiments, we investigated whether young children use the statistical properties of human actions to learn about a psychological cause.

What may constitute the right kind of statistical evidence for a psychological cause? Generally, psychologically caused actions are statistically nonrandom. Put another way, humans acting intentionally—in accordance with their own internal motivations—have the ability to dramatically change statistical sequences of events. Recognizing when actions are nonrandom helps children learn about physical causal relations (see Gopnik et al., 2004). Recognizing when actions are nonrandom could similarly allow children to learn about the psychological states of intentional agents. A demonstration of this ability would provide information about the scope of children's attention to statistical information and the manner in which they learn naive psychology.

Consider an action that observers would expect to be statistically random—a person taking toys out of a toy box with his or her eyes closed. Not only adults, but also preschoolers (Denison, Konopczynski, Garcia, & Xu, 2006) and even infants (Téglás et al., 2007; Xu & Garcia, 2008) expect randomly drawn samples to be representative of underlying populations, and vice versa. For example, Xu and Garcia (2008; Xu & Denison, 2009) showed 8- and 11-month-old infants a person taking four red balls and one white ball out of a box with her eyes closed. When the contents of the box were revealed, infants looked longer at an unexpected population (a box full of mostly white balls with some red balls) than at an expected population (mostly red balls and some white balls). However, when 11-month-old infants saw a person with an explicitly

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expressed preference draw the sample intentionally (i.e., with her eyes open and looking in the box), Xu and Denison (2009) found that these infants did not form expectations about the contents of the box. Thus, 11-month-old infants seem to make random-sampling assumptions about random actions, but not intentional actions.

These data leave open two intriguing possibilities. On the one hand, intentional actions might be a signal to children that statistical evidence is not relevant. Young children might instead learn about psychological causes by attending solely to psychological cues—for example, eye gaze, reaching, facial expressions, affect, verbalizations—without regard for the statistical regularity or irregularity of the relevant events. On the other hand, violations of statistical regularity could signal to young children the presence of a psychological cause and also might help these children to discern what that cause could be.

To address these issues, we examined children's reasoning in a scenario in which violations of random sampling provide a meaningful psychological cue by revealing a person's preference. Imagine a person taking five rubber frogs out of a toy box and playing happily with them. Does the intentional act itself—rather than its statistical properties—provide evidence of a preference for frogs? If most or all of the toys in the box are frogs, the statistical information is in keeping with random draws from the box; thus, this situation would provide no evidence that the person prefers rubber frogs to, for example, rubber ducks. If, however, the box is full of rubber ducks with very few rubber frogs in it, then the sample of five frogs is not likely to have been drawn by chance. More likely, the person chose to take only frogs and so is displaying a greater preference for frogs than for ducks. It is important to note that, in this example, psychological cues (e.g., gaze, reach, affect) are insufficient evidence to infer a preference. Generally, determining preferences, unlike determining momentary desires, requires attending to the options not chosen—such as the other toys in the box. To learn about a person's preference therefore requires that children attend to the violation of random sampling and use that statistical evidence to draw psychological conclusions.

In Experiment 1, we asked whether preschool children, who already have a general notion of preferences, can learn about a particular agent's preference from an intentional action that violates random sampling. In Experiment 2, we asked whether statistical evidence plays a role in the emergence of a notion of preferences in 19- to 24-month-old infants.

Experiment 1

In Experiment 1, an agent intentionally sampled five toys of the same type from a box of toys. We manipulated the population of the box across three groups of preschoolers. In the first condition, 18% of the toys were of the selected type, and 82% were of another type. In the second condition, 50% were of the selected type. In the final condition, 100% were of the selected type. After they saw the selections, children assigned to each condition were asked which toy (the selected type, the alternative type, or a third, novel object) the agent preferred. Psychological cues to preference (such as positive affect) were identical across conditions. Thus, if children infer preferences from psychological cues alone, children in each condition should not have differed in their response. However, if children regard a violation of random sampling as a cue to preference, then participants should have inferred preference most strongly in the 18% condition, least strongly in the 100% condition, and with intermediate strength in the 50% condition.

Method

Participants. Seventy-two preschoolers participated: 36 were 3 years old (M = 44.1 months, SD = 3.2 months) and 36 were 4 years old (M = 53.9 months, SD = 3.3 months). Participants were recruited from local preschools in a small, Midwestern city and were predominantly non-Hispanic White and middle class. Children were randomly assigned to the 18%, 50%, or 100% conditions. The average age of both groups of participants combined (M = 49.1 months, SD = 5.9 months) was comparable across conditions, $F(2, 68) = 1.56$, n.s.

Materials. Two sets of toys (with three types per set) were used. In each set, one type of toy was the target chosen by the agent. A second type of toy was placed in the box in the 50% and 18% conditions. A third type of toy was never in the box but provided a novelty control. Set 1 contained foam shapes; red circles and blue flowers alternated as the target, and yellow tubes were always the novel toy. Set 2 contained small balls; soft replica baseballs and soft replica basketballs alternated as the target, and green practice golf balls were the novel toy. Using each set of materials, we created boxes (length = 13 in., width = 5 in., height = 6 in.) to serve as the populations. Boxes were black and opaque. The four boxes used in the 18% condition contained a 7:31 ratio of target to other toy (e.g., 7 red circles and 31 blue flowers). The two boxes used in the 50% condition contained a 19:19 ratio of target to other toy (e.g., 19 red circles and 19 blue flowers). The four boxes used in the 100% condition contained 38 target toys (e.g., 38 red circles). An additional set of five toys of each type were kept in three separate bowls to be used for the preference question at the end of the procedure.

Procedure. Each child sat individually at a table opposite the experimenter, who began by introducing the agent (a puppet named "Squirrel") to the child. Children were told that Squirrel liked some toys but not other toys. The experimenter then removed Squirrel and placed three bowls of toys from the first set on the table. She asked the child to label them; if the child could not identify the toys, labels were provided. Figure 1 depicts the procedure for an example trial.

The experimenter then removed the bowls and brought out the first box. She opened the top so the child could look at the toys. She prompted the child to label toys but made no

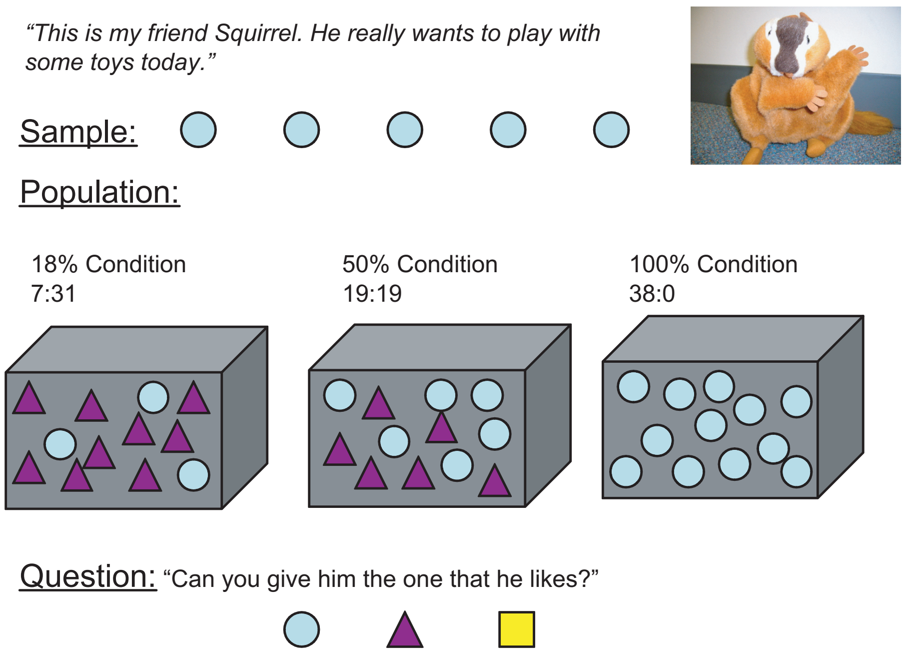

Fig. 1. Procedure for Experiment 1. Children were introduced to Squirrel, who proceeded to take five toys out of a box. The sample always consisted of five toys of the same type—the target toy—which are shown here as circles. Alternate toys also in the box are shown here as triangles. The population of each toy box varied across three conditions (18% target toys, 82% alternate toys; 50% target toys, 50% alternate toys; or 100% target toys). Finally, three bowls were brought out: a bowl of five target toys, a bowl of five alternate toys, and a bowl of five novel toys that were not included in the box. The children were then asked to give Squirrel the toy he liked.

reference to the quantity or proportion of the different toys in the box. The experimenter then brought out Squirrel again and asked Squirrel whether he wanted to take some toys to play with. Squirrel removed a sample of five target toys one at a time and placed them on the table in a pile. After Squirrel removed the fifth toy, the experimenter closed the box; Squirrel played with the toys, and then the experimenter took him away again. The amount of time spent selecting and playing with the toys was kept equal across the conditions. The experimenter put the box away, set out the three bowls, then brought out Squirrel again, and said, "Squirrel is back! He wants some toys again. Can you give him the ones that he likes?" The child's first choice was recorded.

The procedure was repeated with the other set of toys. The proportion of toys in the box varied between subjects but not between trials. The set of toys presented first (foam shapes or balls) was counterbalanced across subjects. The sample drawn from the box was counterbalanced along with the box contents. The order of placement of the bowls (left, right, center) was also counterbalanced.

Results and discussion

The average number of targets children chose (out of two) is shown in Figure 2. The results reveal that children used the statistical cue—the violation of random sampling—to infer that Squirrel was selecting toys based on a preference. A 2 (age: 3, 4) × 3 (condition: 18%, 50%, 100%) analysis of variance revealed a main effect for condition, $F(2, 66) = 4.34$, $p = .017$, $r^2 = .12$, and no other significant effects. As predicted, children chose the target toy most often in the 18% condition ($M = 1.63$, $SE = 0.15$), least often in the 100% condition ($M = 1.00$, $SE = 0.15$), and with intermediate frequency in the 50% condition ($M = 1.31$, $SE = 0.16$). This linear trend was significant ($p = .004$). Directional (one-tailed) t tests showed that children in the 18% condition were significantly more likely to pick the target than children in the 50% condition were, $t(46) = 1.72$, $p = .045$, $d = 0.48$, and children in the 50% condition were marginally more likely to pick the target than children in the 100% condition were, $t(46) = 1.3$, $p = .096$, $d = 0.41$. The difference between the two extreme conditions (18% vs. 100%) was significant, $t(46) = 3.16$, $p = .002$, $d = 0.89$.

We also tallied the number of children who gave Squirrel the target toy on both trials in order to compare responses to chance. In the 18% condition, 16 out of 24 children (67%) gave Squirrel the target toy on both trials. In the 50% condition, 11 out of 24 children (46%) did so, and in the 100% condition, only 7 out of 24 children (29%) chose the target toy on both trials. Responses in the 18% condition were significantly above chance (binomial test, $p < .001$) and significantly different than the responses in the 100% condition (Fischer exact test, $p = .037$). Responses in the 50% condition were also above chance (binomial test, $p = .001$). However, responses in the 100% condition were not different from chance (binomial

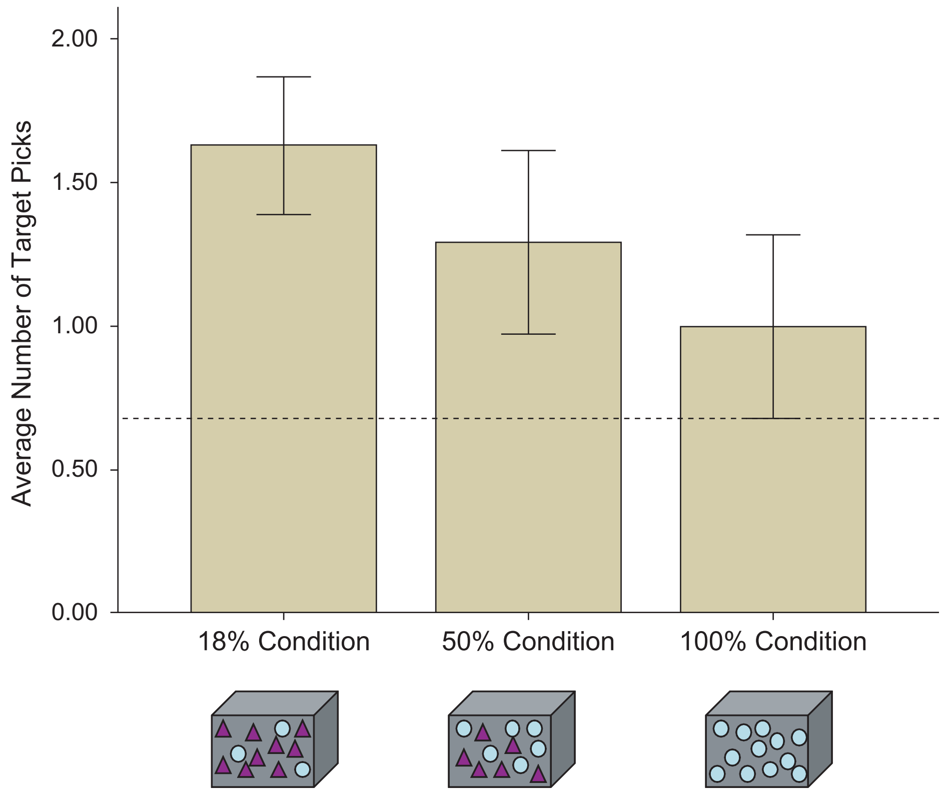

Fig. 2. Average number of times (maximum = 2) that children chose to give Squirrel the target toy in each condition of Experiment 1. The conditions varied in the percentage of target toys (18%, 50%, or 100%) in the box from which Squirrel sampled five target toys. The error bars represent 95% confidence intervals around the means.

test, n.s.). This analysis supports the conclusion that the violation of random-sampling expectations, rather than psychological and linguistic cues, accounted for children's inference that Squirrel had chosen the target because he preferred it.

It is conceivable that children in the 18% and 50% conditions might have selected the target more often not because they inferred that Squirrel had a preference for the target, but because they thought he was avoiding the other toy in the box. An analysis of children's alternative responses reveals that this was not the case. In trials in which children did not give Squirrel the target toy, responses were roughly equally distributed between the alternate toy in the box and the novel toy that was not in the box (18% condition: 5 novel-toy picks, 4 alternate-toy picks; 50% condition: 7 novel-toy picks, 10 alternate-toy picks; 100% condition: 16 novel-toy picks, 8 alternate-toy picks). These results suggest that children were basing their response on Squirrel's preference for the target toy rather than on his avoidance of the alternate toy.

Experiment 2

Experiment 1 demonstrated that preschoolers can use statistical evidence in the form of a violation of random sampling to infer a psychological cause—a preference. Is such reasoning a result of or potentially a contributor to children's emerging understanding of preference? It is generally thought that infants first infer desires and preferences by appealing to emotional cues, such as pleasure and disgust (Repacholi & Gopnik, 1997). Yet, in the case of nonsocial events, intuitive sampling assumptions may be present in infancy. Can infants, like preschoolers, use statistical-sampling information to infer preferences, even when emotional cues are controlled for?

In Experiment 2, we presented infants with a scenario similar to Experiment 1. We concentrated on older infants (average age = 20 months) because previous research has shown that it is around this age that infants understand the link between emotional reactions and desires. We also refined and simplified the experimental procedure in two fashions. First, the agent was changed from a puppet to a live person, in part because the actions of human agents are easier for infants to interpret as intentional (e.g., Woodward, 1998), and also because a live actor can provide real emotional cues to signal desire. Second, we made the procedure less verbal (removing the word "likes" throughout) and less taxing on memory (by making the boxes clear so infants could see the proportions of toys throughout the task). Infant judgments were elicited through a direct but ambiguous request for a toy by the agent. Previous research has shown that infants can interpret an adult's enthusiastic but ambiguous requests as a request for desired objects (Tomasello & Haberl, 2003).

Infants saw a person select five toys of one type out of a box containing a minority of that type (18% of the toys in the box) or a majority of that type (82% of the toys in the box). Since both boxes contained both types of toy, any differences between conditions could not be artificially strengthened by novelty effects. Again, psychological and emotional cues to preference were present, but they were identical across conditions. Thus, if infants infer preferences from a violation of random-sampling expectations, they should do so only when the sample is nonrepresentative—that is, in the 18% condition but not in the 82% condition.

Method

Participants. Participants were 48 infants (M = 20.23 months, age range = 19–24 months) recruited from a baby registry in a small Midwestern city. Twenty-four infants were assigned to the 18% condition, and 24 were assigned to the 82% condition. Mean ages were equivalent in the two conditions, $t(46) = 0.589$, n.s.[1]

Materials. The toys were yellow rubber ducks or green rubber frogs of equal size (diameter = 2 in.) placed in clear plastic boxes (length = 7 3/8 in., width = 6 5/8 in., height = 4 3/4 in.). One box contained a 7:31 ratio of ducks to frogs, and the other box contained a 31:7 ratio. An additional set of five toys of each type were kept in two separate bowls to be used for the preference question at the end of the procedure.

Procedure. Infants sat in a high chair at a table in a laboratory room; the experimenter was seated to the infant's left. The infant's parent sat in a separate chair behind and to the right of the child. The infant was allowed 2 min to play with the bowls of frogs and ducks. Then, the bowls were removed, and the confederate entered. The experimenter introduced the confederate by name and said, "Let's play!"

The confederate sat opposite the infant at the table. The infant, experimenter, and confederate began by playing a turn-taking game with a toy car, a cup, and a ball. This game allowed the infant to become comfortable sharing with the confederate. After the game, the confederate left the room.

The experimenter put the box of toys on the table. She opened the box, labeled the toys, and let the child handle them for a few seconds before calling the confederate to play. The confederate returned to her seat across from the infant and removed five toys (all ducks or all frogs) from the box one at a time. While pulling out each toy, she smiled and vocalized positively, alternating between labeling the toy (e.g., "Wow, frogs!") and making the sound of the animal (e.g., "Ribit, ribit!"). She played with the toys for the remaining time (30 s total, including sampling time), and then left the room.

The experimenter put the box away and put the two bowls of toys on a tray out of reach of the infant so he or she could not touch the toys before response-coding began. The confederate returned and stood on a floor mark slightly away from the table and centered between the two bowls. She held out her hand palm up (centered between the bowls of toys), looked directly at the child, and said, "Oh goody! Just what I wanted! Can you give me one?" The experimenter slid the tray toward the infant, and coding of the response began.

Each infant participated in one trial. The toy designated as the target was counterbalanced (ducks vs. frogs) and was either in the minority or in the majority (18% vs. 82%). The order of placement of the bowls (left vs. right) was also counterbalanced.

Coding. The infant's behavior immediately after the confederate's question was coded for the first toy (or toys) that the infant touched ("first touch") and the first toy (or toys) that she or he handed to the confederate ("first offer"). A subset of the data (20% from each condition) was coded by a second researcher. Intercoder agreement was 100%.

Results and discussion

Results were consistent with the findings from Experiment 1. When the sample was drawn from the minority of toys in the box (18%) but not from the majority (82%), infants were more likely to infer that the confederate had a preference. Table 1

Table 1. Infants' First Touches and First Offers in Experiment 2

	18% condition (sampling violation)		82% condition (no sampling violation)	
Response	First touch	First offer	First touch	First offer
Target toy	13	14	5	9
Alternate toy	10	10	14	13
Both target and alternate	1	0	5	2

Note: n = 24 per condition; data in each column indicate the number of infants who made each type of response. "First touch" refers to the first toy (or toys) that the infant touched; "first offer" refers to the first toy (or toys) that the infant handed to the confederate. The objects available for selection were target toys (i.e., the toys that was produced when the contents of the box were sampled) and alternate toys. The two conditions differed in the percentage of target toys in the boxes from which samples were drawn.

shows infants' responses. Infants' first touches revealed a significant difference between conditions, $\chi^2(2, N = 48) = 6.89$, $p = .032$, $\varphi = .38$. Infants' first offers did not significantly differ across conditions, $\chi^2(2, N = 48) = 3.48$, n.s.

To reconcile this difference and create a fuller picture of infants' responding, we created a composite code combining first touches and first offers; these results are shown in Table 2. In the 18% condition, 14 out of 24 infants (58%) touched and offered the target toy to the confederate. The remaining 10 infants (42%) touched and offered the alternate toy. In the 82% condition, only 5 out of 24 infants (21%) touched and offered the target toy to the confederate, and 13 infants (54%) touched and offered the alternate toy. Four infants (17%) touched the alternate toy but then switched their response to offer the target toy. This change indicates that they considered both toys in their responding (as in studies that examine sequential touching; e.g., Oakes & Madole, 2000). The other 2 infants (8%) touched and offered both toys simultaneously.

The difference in composite responses between conditions was significant, $\chi^2(3, N = 48) = 10.65$, $p = .014$, $\varphi = .47$. A comparison of infants who first touched and first offered the target between conditions was also significant (14 vs. 5; Fischer exact test, $p = .017$). Thus, when there was a violation of random sampling, 19- to 24-month-old infants' first touch alone and in combination with their first offer favored the target toys. However, when there was no violation of random sampling (no statistical cues for preference), it was difficult for infants to interpret the confederates' request; this resulted in more variable responding (including sequential touching) and a tendency to favor the alternate, more novel, toy.

Given that both boxes contained two types of toys, these results were not due to infants simply associating the confederate's selection of one type of toy with her preference. Furthermore, in both conditions, the confederate played excitedly with her choices, so results were not based solely on the confederate's social-emotional reactions. Instead, the infants encoded the proportion of the two types of toys in each box, and in the case of a violation of random sampling, they inferred a preference for that type of toy.

General Discussion

These studies provide the first evidence that young children can use intuitive statistical abilities to infer a psychological cause—a preference. In Experiment 1, preschoolers inferred the preferences of an agent when the sample drawn violated random sampling. Additionally, the less representative the sample, the more likely children were to infer the agent's preference. In Experiment 2, we extended this finding to 20-month-old infants.

We argue that children's inferences were based on sensitivity to statistical sampling, and not based solely on outcome consistency or affective cues, because the only difference between conditions was the proportion of alternate toys in the box that were not sampled. Thus, our results are not consistent with a simple associative-learning mechanism (i.e., if a puppet or a person selects or is associated with one type of toy, then he or she must prefer it over other types of toys). Instead, these results are consistent with a statistical-inference mechanism, according to which the young children noted the representativeness of a sample relative to a larger population and used nonrandom-sampling expectations as the basis for their inference. In the case of preschoolers, the evidence also suggests that the degree of nonrepresentativeness was correlated with the strength of preschoolers' inference about preferences; this correlation is a clear sign that preschoolers are employing a probabilistic-reasoning strategy.

Our results support the intriguing conclusion that statistical inference plays a critical role in early social learning—both as infants form initial notions of psychological causality and later as preschoolers achieve more detailed and sophisticated psychological knowledge. Thus, this initial demonstration sets the stage for future research. Important questions remain about how affective, behavioral, and statistical cues combine in children's social learning. For example, in infants, is the initial construal of actions as intentional and goal directed (Gergely & Csibra, 2003; Phillips & Wellman, 2005; Sommerville & Crane, 2009; Woodward, 1998, 2009) a sufficient starting point? In older children, could statistical evidence enable children to transition from understanding preferences to reasoning about stable personality traits (Heyman & Gelman, 2000; Kalish,

Table 2. Composite Coding of Infants' First Touches and First Offers in Experiment 2

Combined responses	18% condition (sampling violation)	82% condition (no sampling violation)
Category 1: touch and offer target	14	5
Category 2: touch and offer alternate	10	13
Category 3: touch alternate and switch to offer target	0	4
Category 4: touch and offer both	0	2

Note: $n = 24$ per condition; data in each column indicate the number of infants who made each type of response. Coding combined infants' first touches and first offers. The responses of 4 children (1 in the 18% condition and 3 in the 82% condition) who first touched both types of toy together but then offered only one type of toy were coded as Category 1 or 2 depending on whether the toy offered was the target or the alternate.

2002)? In advance of the results from further research, our data already demonstrate that statistical information dovetails with information about intentional-emotional properties of human action to shape children's early learning about the social world.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Funding

This research was supported by a fellowship from the McDonnell Collaborative Initiative on Causal Learning, a National Institute of Child Health and Human Development (NICHD) postdoctoral fellowship to T.K., Grant HD-22149 from NICHD to H.M.W., and a grant from the Natural Sciences and Engineering Research Council, Canada, to F.X.

Note

1. Twelve other tested children (4 in the 18% condition, 8 in the 82% condition) touched toys but refused to hand them to the experimenter. An analysis of all the first-touch data including these infants resulted in a statistically significant difference between the 18% and 82% conditions, $\chi^2(2, N = 60) = 6.16$, $p < .05$.

References

Denison, S., Konopczynski, K., Garcia, V., & Xu, F. (2006). Probabilistic reasoning in preschoolers: Random sampling and base rate. In R. Sun & N. Miyake (Eds.), *Proceedings of the 28th annual conference of the Cognitive Science Society* (pp. 1216–1221). Florence, KY: Psychology Press.

Gergely, G., & Csibra, G. (2003). Teleological reasoning in infancy: The naive theory of rational action. *Trends in Cognitive Sciences*, *7*, 287–292.

Gopnik, A., Glymour, C., Sobel, D.M., Schulz, L.E., Kushnir, T., & Danks, D. (2004). A theory of causal learning in children: Causal maps and Bayes nets. *Psychological Review*, *111*, 1–30.

Heyman, G., & Gelman, S. (2000). Beliefs about the origins of human psychological traits. *Developmental Psychology*, *36*, 663–678.

Kalish, C. (2002). Children's predictions of consistency in people's actions. *Cognition*, *84*, 237–265.

Kirkham, N., Slemmer, J., & Johnson, S. (2002). Visual statistical learning in infancy: Evidence for a domain general learning mechanism. *Cognition*, *83*, B35–B42.

Kushnir, T., & Gopnik, A. (2005). Children infer causal strength from probabilities and interventions. *Psychological Science*, *16*, 678–683.

Kushnir, T., & Gopnik, A. (2007). Conditional probability versus spatial contiguity in causal learning: Preschoolers use new contingency evidence to overcome prior spatial assumptions. *Developmental Psychology*, *44*, 186–196.

Lany, J., Gómez, R., & Gerken, L. (2007). The role of prior experience in language acquisition. *Cognitive Science: A Multidisciplinary Journal*, *31*, 481–507.

Oakes, L., & Madole, K. (2000). The future of infant categorization research: A process-oriented approach. *Child Development*, *71*, 119–126.

Phillips, A., & Wellman, H. (2005). Infants' understanding of object-directed action. *Cognition*, *98*, 137–155.

Repacholi, B., & Gopnik, A. (1997). Early reasoning about desires: Evidence from 14- and 18-month-olds. *Developmental Psychology*, *33*, 12–21.

Saffran, J., Aslin, R., & Newport, E. (1996). Statistical learning by 8-month-old infants. *Science*, *274*, 1926–1928.

Schulz, L., Bonawitz, E., & Griffiths, T. (2007). Can being scared cause tummy aches? Naive theories, ambiguous evidence, and preschoolers' causal inferences. *Developmental Psychology*, *43*, 1124–1139.

Sommerville, J.A., & Crane, C.C. (2009). Ten-month-old infants use prior information to identify an actor's goal. *Developmental Science*, *12*, 314–325.

Téglás, E., Girotto, V., Gonzalez, M., & Bonatti, L.L. (2007). Intuitions of probabilities shape expectations about the future at 12 months and beyond. *Proceedings of the National Academy of Sciences, USA*, *104*, 19156–19159.

Tomasello, M., & Haberl, K. (2003). Understanding attention: 12- and 18-month-olds know what's new for other persons. *Developmental Psychology*, *39*, 906–912.

Woodward, A. (1998). Infants selectively encode the goal object of an actor's reach. *Cognition*, *69*, 1–34.

Woodward, A. (2009). Infants' grasp of others' intentions. *Current Directions in Psychological Science*, *18*, 53–57.

Xu, F., & Denison, S. (2009). Statistical inference and sensitivity to sampling in 11-month-old infants. *Cognition*, *112*, 107–114.

Xu, F., & Garcia, V. (2008). Intuitive statistics by 8-month-old infants. *Proceedings of the National Academy of Sciences, USA*, *105*, 5012–5015.

Xu, F., & Tenenbaum, J. (2007a). Sensitivity to sampling in Bayesian word learning. *Developmental Science*, *10*, 288–297.

Xu, F., & Tenenbaum, J. (2007b). Word learning as Bayesian inference. *Psychological Review*, *114*, 245–272.