

Can Children Balance the Size of a Majority with the Quality of their Information?

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Abstract

We investigate how children balance the quality of informants' knowledge with the number of endorsements when deciding which of two boxes contains the better option. When group numbers are equal, children choose boxes endorsed by informants with visual access over informants with hearsay (Experiment 1), but are at chance when group size conflicts with quality of knowledge (Experiments 2 and 3). This suggests that children tend to conform to a majority opinion, compared to adults (Experiment 4) and a normative computational model. These studies suggest that preschoolers consider the testimony of multiple informants and evaluate their knowledge sources, but may assume that informants are more individually informative than they are.

Introduction

Social learning is the cornerstone of human society. It has been proposed that our propensity for learning from others, rather than our intelligence or ingenuity, is responsible for our success as a species (Boyd & Richerson, 1985; Boyd, Richerson, & Henrich, 2011). However, not all information from others is equally dependable. A large body of literature about children's epistemic trust has found that children selectively trust informants, and prefer those with a past history of accuracy (e.g., Koenig & Harris, 2005; Pasquini et al., 2007), those with expertise in a topic (e.g., Aguiar, Stoess, & Taylor, 2012; Boseovski & Thurman, 2014; Kushnir, Vredenburgh & Schneider, 2013; Einav, 2014), and those who have first hand knowledge (e.g., Sodian & Wimmer, 1987; O'Neill, Astington, & Flavell, 1992; but see Palmquist & Jaswal, 2012).

In many cases, information on an informant's previous accuracy or expertise may not be available. In this case, Corriveau, Fusaro, and Harris (2009) argue that children could instead evaluate consensus among different informants. They found that preschoolers prefer informants

whose opinions received support from others (Fusaro & Harris, 2008), and endorse object labels given by a majority (Corriveau, Fusaro, & Harris, 2009).

However, groups can also provide unreliable information. To learn accurately, children should consider not just the number of informants, but also the quality of each person's information. In a series of three studies, we explore how children extend trust to informants based on the quality of their knowledge source, and how they weigh this information against majority or minority opinions. We compare children's responses to the performance of adults on these same tasks, and to a computational model of learning preferences from testimony. This model was created to provide a normative baseline showing how a rational learner would balance the opinion of a majority against the quality of each informant's information. Comparing the model's predictions with children's responses can illuminate the extent to which their behavior is rational, and under which conditions it is not.

Experiment 1: Direct knowledge vs. hearsay

In Experiment 1, participants watched as informants gave opinions about which of two boxes contained the better option. Equal numbers of informants endorsed each box, but one box was endorsed by informants who had looked in the boxes and had direct knowledge of what was inside, whereas the other box was endorsed by only one informant with direct knowledge while the other three received hearsay about which box was better.

Methods

Participants Participants were 22 preschoolers (mean age = 4 years 1 month; range = 43 – 66 months). An additional child was excluded due to fussiness.

Materials Materials included two black boxes, each of which contained a toy (a plastic cement truck or stuffed leopard) or a snack (Goldfish cracker or Froot Loop™).

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Table 1. Children's and Adults' choices in Experiments 1-3 compared. * indicates a significant result, $p < .05$

	Children's average score for choosing direct group, out of 2 (standard error)	Adults' average score for choosing direct group, out of 2 (standard error)
Experiment 1	1.45* (0.14)	1.69* (0.06)
Experiment 2	0.83 (0.18)	1.70* (0.08)
Experiment 3	1.10 (0.14)	1.71* (0.08)

Informants were eight 7" tall paper dolls (four male, four female), glued to a wood block base.

Procedure Children participated in two trials: a snack trial and a toy trial. Trial order was counterbalanced across participants. To begin the first trial, the experimenter showed the participant the two boxes and explained that each box contained a [toy/snack], but that she did not know what was inside. Then, the child watched as dolls gave opinions about which box contained the better option.

A group of four dolls endorsed one box and a second group of four endorsed the other. In the direct group, all four dolls received direct (visual) knowledge before giving their opinions. One at a time, each doll walked over to each box and looked inside, then stood beside the same box and said, "I think this [toy/snack] is better!"

In the indirect group, only the first doll in the group received direct knowledge of the box's contents. The first doll looked inside both of the boxes, then stood next to the box not endorsed by the direct group and said, "I think this [toy/snack] is better!" This doll then crossed paths with a second doll, and the experimenter made indiscriminate whispering sounds to convey that the two dolls were conversing. The second doll gave their opinion, saying, "[S]he said this [toy/snack] was better, so I think this [toy/snack] is better," and passed on their hearsay to a third doll, who stated his or her opinion, and then passed the hearsay on to the fourth doll. Each group included equal numbers of male and female dolls, and group order (direct or indirect first) was counterbalanced. The side of the box endorsed by the direct group was also counterbalanced.

After all dolls gave opinions, the experimenter brought all eight dolls back on stage and placed them in front of the box they endorsed, and reminded children that the dolls were all standing in front of the box they had said was better. The experimenter then asked the child to choose the box they wanted to try. Once children selected a box, they were presented with the object inside. They were not shown the contents of the unchosen box. The experimenter cleared all materials from the table, and proceeded to the second trial. The procedure of the second trial was identical to the first.

Results and Discussion

Results for Experiment 1 are summarized in Table 1. Children were scored on the number of trials (0-2) in which they picked the box endorsed by informants with direct knowledge. Children were significantly more likely to choose the direct box over the indirect box, $t(21) = 3.18, p < .01, d = 0.67$. There was no significant difference in

responses for the two trial types (snack vs toy), $p = .31$ (odds ratio = 0.39).

When choosing between two boxes, each endorsed by four informants, children prefer the box endorsed by informants with direct knowledge of the boxes' contents. This suggests that children monitor individual informants' knowledge quality and not just group size. Additionally, this suggests that they understand that visual access is a more reliable source of information than hearsay, even when learning about non-factual domains like preferences.

Experiments 2 and 3: Source versus consensus

In Experiment 1, children chose the box endorsed by the group of informants with direct knowledge of the box's contents. Given that both the indirect and direct groups had the same number of informants, Experiment 1 leaves open the question of how children reconcile source knowledge with consensus information. Previous studies have found that children are sensitive to majority opinions, and often conform to endorsements made by a consensus, so it is possible that consensus endorsements could override children's assessment of informants' source knowledge. In Experiments 2 and 3, children are faced with a decision between a minority of informants who all have higher quality (direct) knowledge, versus a majority of informants who give opinions based on indirect knowledge.

Methods

Participants Participants in Experiment 2 were 24 preschoolers (mean age = 4 years 3 months; range = 42 to 61 months). Three additional children were tested but were excluded due to experimenter error. Participants in Experiment 3 were 31 preschoolers (mean age = 4 years 6 months; range = 44 to 62 months; 18 female, 13 male). Two additional children were tested but excluded due to experimenter error.

Materials were the same as in Experiment 1, except for the addition of two dolls in Experiment 2.

Procedure The procedure of Experiment 2 was identical to Experiment 1, except that there were four informants in the direct group and six in the indirect group. The procedure for Experiment 3 was identical to Experiment 2, but with three informants in the direct group and five in the indirect group.

Results and Discussion

Results for Experiments 2 and 3 are summarized in Table 1. Children were scored on the number of trials (0-2) in which

they picked the box endorsed by informants with direct knowledge.

Experiment 2 Children were at chance in choosing between the box endorsed by the direct group and the box endorsed by the indirect group, $t(23) = -0.94$, $p = .36$, $d = -0.19$. Children chose the box endorsed by the direct group significantly less than in Experiment 1, $t(44) = -2.7$, $p < .01$, $d = -.80$. The majority of children consistently chose either the direct group (7/24) or the indirect group (11/24) on both trials. There was no significant difference in responses for the two trial types, $p = .77$ (odds ratio = 0.71).

One possible explanation for children's at-chance responses in Experiment 2 is the higher number of dolls used in the study compared with Experiment 1 which may place additional demands on the child's memory leading to at-chance performance. To control for the total number of demonstrators, Experiment 3 replicates Experiment 2, but with the same overall number of dolls used in Experiment 1.

Experiment 3 Results are summarized in Table 1. Children were scored on the number of trials (0-2) in which they picked the box endorsed by the informants with direct knowledge. Children were at chance in choosing between the box endorsed by the direct group and the box endorsed by the indirect group, $t(30) = 0.68$, $p = .50$, $d = 0.12$. These responses were not significantly different from those of Experiment 2, $t(53) = -1.17$, $p = .25$, $d = 0.32$, but were marginally different from those of Experiment 1, $t(51) = 1.73$, $p = .09$, $d = -0.49$. There was no significant difference in responses for the two trial types, $p = .07$ (odds ratio = 0.36). The majority of children consistently chose either the box endorsed by the direct group (8/31) or the indirect group (11/31) on both trials

Unlike children's responses in Experiment 1, these two studies found that children were at chance when choosing between the boxes endorsed by the direct and indirect groups. When a majority of informants with indirect knowledge is contrasted with a minority with direct knowledge, children's preference for the box endorsed by the direct informants decreases. These results suggest that a consensus has the power to diminish children's preferences for sources with higher quality knowledge, but does not shift children's judgments entirely—they do not simply endorse the majority's choice. There were also no significant differences between Experiments 2 and 3, suggesting that children's at-chance performance in Experiment 2 was not driven by cognitive load issues (i.e., being overwhelmed by the large number of informants).

Modeling Direct and Indirect Testimony

Given that Experiment 1 suggests that children are sensitive to the quality of informants' knowledge, the results of Experiments 2 and 3 are striking, and may suggest that children have a bias to conform to the majority. Intuitively this behavior seems irrational. However, such behavior could be rational; although indirect informants provide less information than direct informants, they may still provide *some* information. Theoretically, as long as each member of

the indirect group provides some information, a larger group of indirect informants could provide more evidence than a smaller group of direct informants. To assess whether children have a conformity bias, analyze how a rational learner might learn preferences from multiple demonstrators with varying levels of knowledge.

We build a computational model following from previous Bayesian models of learning from testimony by modeling the problem that learners face as an inference problem (e.g., Shafto et al., 2012). Learners then use Bayes' rule to perform inference and select a behavior. Bayes' rule indicates that the probability that a hypothesis, h , is true, given some data, such as informant testimony t , is proportional to the probability of the testimony given the hypothesis times the prior probability of the hypothesis, or

$$p(h|t) \propto p(t|h)p(h). \quad (1)$$

$p(h|t)$ is the posterior probability and $p(t|h)$ is the likelihood.

Normally, hypotheses represent claims about the world, and the data represents observations. In this case, the hypotheses represent beliefs about which item is in which box, and the data are the testimonies given by the informants. Unlike previous models of learning from testimony, here the informants make claims about their preferences rather than factual claims. To capture differing preferences, we assume that a proportion λ of the population prefers one item, while the rest prefer the other. We call the item preferred by the proportion λ the target item.

Under this setup, the learner evaluates two hypotheses, h_d , that the target item is in the box endorsed by the direct group, and h_i , that the target item is in the box endorsed by the indirect group. The probability of each hypothesis can be calculated via Bayes rule, giving the posterior probability

$$p(h_i|t_d, t_i) \propto p(t_d|h_i)p(t_i|h_i)p(h_i) \quad (2)$$

where $t_i = (t_{i1}, \dots, t_{in})$ refers to the testimony of the indirect group, and $t_d = (t_{d1}, \dots, t_{dn})$ refers to the testimony of the direct group. We assume that the prior probability of the preferred item being in either box is equal.

The likelihood term—the probability of observing a particular set of testimony given a hypothesis—depends critically on how the learner assumes informants generate their testimony. We assume a simple generative process, outlined below, for informants who have access to direct evidence, and for those who must rely on indirect evidence.

Finally, we assume that the learner, like the informants, also has a preference, preferring the target item with probability λ . To choose a box, learners first infer the probability that each box holds the target item, and then use their preference to determine which box they select. The probability that the learner chooses the box endorsed by the direct informants is just the probability that the box contains the learner's preferred item given the testimony.

Direct Evidence

We assume that informants who receive direct evidence make decisions based on a two-step process. First, they observe the items in each box (with a small error probability ϵ of incorrectly observing the object, accounting for visual

error), and then they express a preference for the box that contains the object they prefer. For simplicity, we assume that all informants report their preferences accurately. This means that the probability that an informant with direct evidence endorses the box containing the target item given their observation is

$$p(t_j | t_{j,obs}, h_{t_j}) = (1 - \varepsilon)\lambda + \varepsilon(1 - \lambda), \quad (3)$$

where h_{t_j} refers to the hypothesis that the target item is in the box endorsed by informant j 's testimony, t_j , and $t_{j,obs}$ is the informant's observation of the box contents (where they think they saw the target item). In Equation 3, the first term represents the probability that the informant observed the contents accurately and prefers the target item. The second term represents the probability they incorrectly observed the contents and do not prefer the target item. The probability of endorsing the box not containing the target item can be computed similarly. Since the direct informants do not hear any other information, their testimony is not based on the testimony of others, which means that $p(t_d | h_i)$ is just the product of the probability of the individual testimonies.

Indirect Evidence

In the case where informants receive indirect evidence, their testimony is based solely on the information provided by other informants. In these experiments, the information each indirect informant receives from the previous informant is in the form of "whispers." However, what is whispered is not clear. We consider two cases: one where only the preference was passed (each informant whispers only which box they prefer) the other where the contents of each box were passed (each informant whispers what they believe is in each of the two boxes). As in the direct case, all informants give testimony about their preference to the learner, and we assume that informants report their preferences accurately.

Preference Passing In the case where informants whisper their preferences, future informants must use that information to first infer which item is in which box, and then endorse a box according to their own preference. However, if the learner is also told each informant's preference, they are already aware of all the information that each indirect informant had to make their decision, so that subsequent informants provide no new information. The learner should therefore disregard all but the first informant in the chain. This is the case in Experiments 1, 2, and 3; the learner observes the testimony of the first informant, who has direct evidence, and so subsequent informants who receive only indirect evidence can be disregarded.

Object Passing Individuals may whisper more than just their preference; they may whisper which objects they believe are in the boxes. Unlike the previous case where indirect informants provided no new insight, in this case, each indirect informant has knowledge about the boxes' contents that is hidden from the learner. We assume each informant treats the informant whispering to them as having direct knowledge of the box contents, and that informants whisper their beliefs accurately. This is equivalent to all

indirect informants getting their information from the first informant in the chain (who has direct knowledge),

$$p(t_i | t_{1,obs}, h) = p(t_1 | t_{1,obs}, h) \cdot \prod_{j=2}^n p(t_j | t_1, t_{1,obs}, h) \quad (4)$$

where $t_{1,obs}$ is the first informant's observation of the box contents, which he whispers to the next individual in the chain. The first informant's observation corresponds to what is actually inside each box with probability $1 - \varepsilon$ (due to visual error). If the first informant says that the target item is in the box they endorsed, the probability that the next informant agrees with the first informant is,

$$p(t_j = t_1 | t_1, t_{1,obs}, h_{t_1}) = (1 - \varepsilon)\lambda + \varepsilon(1 - \lambda), \quad (5)$$

where the first term accounts for the case where informant j infers that the target item is in the box where the first informant indicated, and prefers the target item, and the second term accounts for the case where the informant infers the target item is not where the first informant indicated, but does not prefer the target item. The case where the first informant whispers that the target item is not in the box they endorsed can be computed similarly.

Object passing represents the other extreme from preference passing—this is the most informative case for a chain of indirect informants. Since we assume that information is accurately transmitted between individuals, the difference between direct testimony and testimony accumulated indirectly through object passing stems from the initial errors in observation. In the case of learning from multiple direct informants, perceptual error is uncorrelated, so that agreement between the informants provides stronger evidence. However, in the case of learning from a string of indirect learners, a single error in the beginning of the chain may propagate errors along the chain.

Results

Both models have two parameters, an error rate ε and a preference parameter λ . We fixed the error rate to $\varepsilon = 0.01$, and fit the preference parameter to children's performance in Experiment 1. We fit λ by maximizing the log-likelihood of the participants' responses in Experiment 1 under the model, producing a best-fitting value of $\lambda = .75$ in the preference passing model, and a value of $\lambda = .78$ in the object passing model. Experiment 1 was used to fit the model alone because it provided a baseline where both the indirect and direct groups had the same number of informants, allowing the model to be sensitive to the relative weighting of direct and indirect testimony, without the potential confound of a conformity bias. This model fit was used to create predictions for Experiments 2 and 3.

Model results are shown in Figure 1. In Experiment 1, both models provide a good fit to the data. The object-passing model provides a better fit to Experiment 3 than the preference-passing model, suggesting children may believe that informants' whispers carry additional (unheard) information, so that five indirect informants are almost as informative as three direct informants.

Critically, in Experiment 2, we found that both models predicted that normative learners should endorse the majority response substantially more than was found

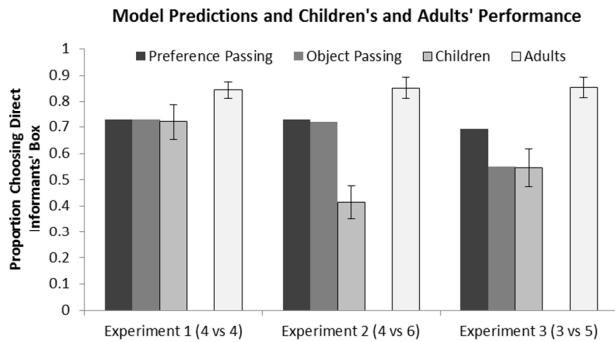


Figure 1. *Model predictions and children's and adults' choices for Experiments 1, 2, and 3. The model was fit to child performance in Experiment 1.*

experimentally. In the object-passing model, we find that the model predicts that learners in Experiment 2 will choose the direct informant's box more than in Experiment 3: the additional direct informant provides substantially more evidence than the additional indirect informant.

Although these model predictions were fit to the data from Experiment 1, both models predict that learners should choose the direct group's box in each experiment for a wide range of parameter values. No matter the values for ϵ and λ , the preference passing model predicts that individuals' performance in Experiment 1 and 2 should be identical; under the preference passing model indirect informants provide no information and so the two additional indirect informants in Experiment 2 should not change the learner's behavior. Changing the parameter values in the object passing model leads to more variation in predictions, but the qualitative results remained the same: in all experiments a rational learner should go with the direct group.

Since the object-passing model represents the maximally informative case, this means that differences in how children interpret the knowledge indirect informants transmit cannot account for their performance. This confirms that, when the quality of informants' knowledge source is in conflict with the majority endorsement, children conform to the majority more than predicted by a range of normative models, suggesting that they believe individual informants provide more evidence than they actually do.

Experiment 4: Adults

Given that children appear to be overconforming to the testimony of the majority when compared to our normative model, a natural question is whether adults also overconform. We explore this by examining how adults make decisions in tasks similar to Experiments 1, 2, and 3.

Methods

Participants Participants were 177 adult US residents, recruited through Amazon Mechanical Turk (MTurk) and paid \$0.50 for their time. Participants were randomly assigned to one of three conditions: 61 participants to a four direct/four indirect condition (a version of Experiment 1), 61 participants to a four direct/six indirect condition (a

version of Experiment 2), and 58 participants to a three direct/five indirect condition (a version of Experiment 3).

Materials The experiment was an online survey administered using Qualtrics survey software, with custom animations inserted using Javascript. The informants were a set of 10 distinct cartoon clip art characters (5 male, 5 female). There were also two pairs of cartoon boxes that differed only in color: a red and blue pair, which participants were told contained games, and a green and yellow pair, which participants were told contained snacks.

Procedure The procedure closely matched that used with children in Experiments 1-3, with the clip art characters replacing the dolls that children saw. Like children, adults each participated in two trials, a snack trial and a game trial, with the order of trials counterbalanced.

Adults saw two boxes on opposite sides of the screen. For the direct group, each member of the group was shown one at a time. A character appeared on the screen, then moved to each box while the cartoon text “*Looks inside box*” flashed above the character's head. Then, the character stood by one box and said, “I think this [game/snack] is better!” For the indirect group, the first member was shown looking inside the boxes, declaring his or her opinion, and moving to stand next to another indirect group member who appeared on screen. The cartoon text “*whisper*” appeared above both their heads. The second doll then moved to stand by one box, and gave their opinion, “[S]he said this [game/snack] was better, so I think this [game/snack] is better”. This process repeated for the remaining characters.

After all characters gave opinions, participants were shown an image with each group of characters placed under the box they endorsed, with a reminder that this was the box each character thought was better. Participants were then asked to “Please select the box with the [game/snack] that you would like to try”. Group order and side/color of box endorsed by the direct group were counterbalanced. In game trials, the red box always appeared on the left, and in snack trials the green box always appeared on the left. For each participant, characters' group assignments were randomized.

Results and Discussion

Results are shown in Table 1. Overall, in all three conditions, adults chose the box endorsed by the direct group significantly more than chance ($t \geq 8.66$, $p < .001$ in all cases). A one-way ANOVA showed no significant differences in performance between the three adult conditions $F(2,177) = 0.02$, $p = .98$. In comparing adult and child performance, a 2 (age group: adults or children) x 3 (Experiment: 1, 2, and 3) ANOVA revealed a main effect for age group; adults' and children's responses differed significantly, $F(1,251) = 43.72$, $p < .01$. There was also an interaction effect between age group and experiment, $F(2,251) = 3.75$, $p < .05$. Planned comparisons between age groups in each experiment condition suggest that this interaction was driven largely by differences in Experiments 2 and 3. Adults and children provided significantly different responses in Experiment 2, $t(83) = -5.21$, $p < .001$, and in

Experiment 3, $t(87) = 4.01$, $p < .001$, but there was only a marginal difference in Experiment 1, $p = .09$.

These results indicate that adults, unlike children, balance the number of informants and the quality of their knowledge source in a manner qualitatively consistent with our model.

General Discussion

These studies provide the first empirical evidence that preschoolers weigh multiple informants' opinions using the quality of their knowledge source to assess the reliability of their testimony. We find that with equal numbers of informant endorsements, children favored a box recommended by informants who received knowledge directly (visual access) over informants who had received knowledge indirectly (hearsay from other informants).

This complements previous work that suggests children understand that not all testimony is equal. To succeed in this task, children had to evaluate opinions from multiple informants at once, and to consider each informant's source knowledge. Furthermore, while previous studies asked children to make factual judgments (e.g., what's in a box) from testimony, children in this study were asked to make a preferential choice based on others' opinions. This suggests that children look to others for social information to inform their preferences, as well as facts.

However, when the box endorsed by a consensus of informants and the box endorsed by informants with a higher quality knowledge source were pitted against one another, children were at chance in choosing between the boxes. From a knowledge-acquisition perspective, additional informants in the indirect group provide limited new information; model predictions indicate that across conditions a rational learner should choose the box endorsed by the informants with the better knowledge source, not the majority. Adults behaved in accordance with model predictions, but the fact that children did not could indicate that children overestimate the usefulness of informants' opinions by assuming that each informant's testimony provides more independent evidence than is statistically the case. Children may assume that each informant has additional information that would make them more accurate than simply receiving the previous informant's testimony. This is consistent with previous work suggesting that children are biased to interpret adults as knowledgeable, helpful teachers (Bonawitz et al., 2011).

The presence of a conformity bias in children may have striking implications for the development of human culture. Many cultural traits, including language and societal norms, are learned at an early age. Formal models suggest that a conformity bias may lead to the stability of such traits over time (Boyd & Richerson 1985; Henrich & Boyd, 1998). If children demonstrate a conformity bias at an early age, it may allow them to quickly learn in-group norms, but may allow neutrally beneficial or even detrimental behaviors to persist in the population. Given that a behavior learned from a majority in childhood may persist through adulthood, a bias towards conformity in children that stems from

incorrectly estimating the independence of demonstrators would lead to systematic changes in the adoption and maintenance of cultural traits through a population. Though the results from this study do not directly address the transmission of social norms based on informant reliability, future work can explore this issue. Additionally, follow-up studies could explore the developmental trajectory of identifying higher quality knowledge sources.

In sum, these experiments shed light on how children learn from others. Four- and five-year-old children demonstrate an emerging ability to consider and integrate several types of information—directness of knowledge and consensus—when assessing the reliability of testimony.

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