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Accentuate the negative: Expectations about sampling procedures determine the impact of negative evidence on children's inductive judgments

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Abstract

Young children rely on sparse samples of evidence to make broad generalizations. For example, they will readily use evidence that *robins have hollow bones* to predict that all birds have hollow bones. Most of what we know about the development of generalization comes from studies on children's reasoning from positive evidence (e.g., evidence of other birds with hollow bones). The present study examined the significance of negative evidence (e.g., evidence of animals that <u>do not</u> have hollow bones). Three-, 4-, and 5-year-olds (*N*=98) were asked to generalize from samples with negative evidence and samples with positive evidence that were selected either deliberately or incidentally. Children from all three age groups made a higher rate of generalizations from samples that included negative evidence than from samples that included positive evidence, but only when evidence was described as having been selected deliberately by the experimenter. Furthermore, older children were more sensitive than younger children to the contrasts highlighted by negative evidence: Five-year-olds generalized from samples in which negative evidence presented either an explicit contrast with the category in question (e.g., sheep <u>do not</u> have hollow bones) or an implicit contrast with the category in question (e.g., sheep have dense bones). Three- and four-year-olds generalized only when samples presented explicit contrasts. These results are discussed in light of other work on inductive reasoning that emphasizes the role of dyadic factors on generalization, such as the expectation that informants intend to share relevant information.

Keywords: add your choice of indexing terms or keywords; kindly use a semicolon; between each term

Introduction

Inductive reasoning – the ability to generalize from a specific case to general cases – is an essential component of human cognition. Learning that *robins have hollow bones* can be useful evidence to support the inference that other, and perhaps all, birds have hollow bones. Most research on the development of inductive reasoning has focused on how children reason as they accumulate positive evidence – that is, cases that confirm that a property is shared by other category members (Gutheil & Gelman, 1997; Hayes *et al*., 2007). However, positive evidence is not without limits. For example, while learning that *robins have hollow bones* and *sparrows have hollow bones* is likely to increase our willingness to generalize the property to other birds, it may leave us uncertain about the extent to which the property is shared by only birds or a subset of birds (e.g., songbirds), and not other animals. One solution to this uncertainty is to consider negative evidence – that is, cases that highlight the absence of a property for a certain category. Learning that *robins have hollow bones* and *mice <u>do not</u> have hollow bones* establishes a contrast between the types of things that have the property (e.g., other birds have hollow bones) and those that do not (e.g., mammals), and therefore can be a strong guide for which generalizations are warranted. This study examines some factors that may contribute to children's use of negative evidence to make inductive inferences.

Negative evidence has been shown to impact generalization in several areas of development such as language learning and categorization (Ankowski *et al*., 2013; Au & Markman, 1987; Carey & Bartlett, 1978). For example, Ankowski and colleagues (2013) found that when asked to identify which member of an array of stimuli was a "wug", 3-year-olds performed better when they were presented additional negative evidence (i.e., contrasting evidence) about a case that was not a "wug" ("e.g., "This is a wug one. This is <u>not</u> a wug one.") than when they were given additional positive evidence about a case that was a "wug" ("e.g., "This is a wug one. This is a wug one."). Similarly, Au and Markman (1987) found that providing contrasting labels of known colors was useful for helping children as young as 3 years learn a novel color word (e.g., "Can you bring me the mauve thing? See, it's <u>not</u> green and it's <u>not</u> yellow. It's mauve."). These cases illustrate the important role of negative evidence in placing constraints on learning; providing negative evidence about a known color term ("it's not yellow") as a contrast to an unknown term (e.g., "mauve") directs a learner's attention to color as the relevant feature to which to attach the meaning of the novel word.

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Similar results were demonstrated in a study of inductive reasoning in children (Kalish & Lawson, 2007; Waxman *et al*., 1997). In a property projection task Kalish and Lawson (2007) found that 4-year-olds showed a greater willingness to generalize a property attributed to an individual to another individual from the same category when presented a mixed sample of positive evidence and negative evidence than when presented a sample with two pieces of positive evidence.

To understand why negative evidence promotes generalization it is important to consider that evidence is often presented in information-sharing contexts, such as an experimental setting, a classroom lesson, or an everyday conversation. In conditions such as these people often expect that an informant has provided relevant and generalizable information (Csibra & Gergely, 2009; Harris *et al*., 2008; Medin *et al*., 2003; Sperber & Wilson, 1986). In the context of inductive reasoning, when presented with negative evidence such as *robins have ulnar bones* and *donkeys <u>do not</u> have ulnar bone*s, one might assume that evidence about *donkeys* was chosen as a contrast to what is known about *robins* to communicate that the property generalizes (exclusively) to other birds, but not non-birds. From this perspective the contrastive effects of negative evidence are likely to depend on whether one believes that an informant has purposefully selected the evidence. Voorspoels and colleagues (2015) demonstrated this to be the case for adults. In their study adults exhibited a greater willingness to endorse a conclusion for mixed samples of negative evidence and positive evidence than samples with a single piece of positive evidence, but only when the samples were described as having been selected deliberately compared to when they were descried as having been selected randomly.

The present study examined the extent to which children rely on their expectations about the sampling procedure used by the experimenter when generalizing from samples that include negative evidence. There are several reasons to expect they will. Before they reach the age of 5 years children consider a number of factors when deciding whether to trust the information provided by an informant, such as the informant's past accuracy (Gweon *et al*., 2014), their knowledge within a domain (VanderBorght & Jaswal, 2009), and their identity or status (Rhodes *et al*., 2010; Lawson, 2018). Children as young as 3 years rely on the method used to select the examples presented to them when deciding how to generalize labels (Xu & Tenenbaum, 2007; see also Xu & Denison, 2009). For example, Xu and Tenenbaum (2007) found that 3-year-olds restricted their label generalizations to the narrowest category (e.g., peppers) implicated by a sample (e.g., 3 types of peppers) when the items were believed to have been selected deliberately, but generalized labels more broadly when the items were believed to have been selected randomly. Thus, it is clear that young children pay close attention to the procedures that were used to select examples when determining whether (and how) to generalize the evidence provided by informants.

In this study we assessed generalization by using a property projection task (e.g., Gelman, 1988). Participants were presented samples of evidence that included a base premise (e.g., *Hawks have ulnar bones*) and either positive evidence (e.g., *Donkeys have ulnar bones*) or negative evidence (e.g., *Donkeys <u>do not</u> have ulnar bones*). Children were then asked whether they were willing to project the property attributed to the base premise to a different target (e.g., *Do you think Larks have ulnar bones?*).

Critically, we manipulated the method by which the evidence was selected by describing that the samples were chosen either deliberately, "to help you learn about animals", or incidentally, when the experimenter merely "grabbed some pictures from a box in my office". This method of manipulating the cover stories was modeled after Voorspoels *et al*. (2015). We expected that children would show a greater willingness to project properties from samples that included negative evidence than samples with positive evidence, and that they would be especially prone to show this pattern when they were led to believe the samples were selected to help them learn about the items (i.e., deliberate sampling).

We included three age groups (3-, 4-, and 5-year-olds) to explore possible developmental differences in children's responses. Prior work indicates that children as young as 3 years will use negative evidence to generalize properties to category members (e.g., Waxman *et al*., 1997). Thus, we expected a common pattern of generalizations in all three age groups. However, there are some reasons to expect developmental differences. First, while children have been shown to have a general bias to trust others (e.g., Mills, 2013), younger children tend to rely more heavily on this bias even when available evidence suggest they should be more judicious. For example, Scofield and Behrend (2008) found that while both 3- and 4-year-olds preferred reliable informants over unreliable informants, only the older group modified their willingness to trust a previously reliable informant after they proved to be unreliable. Similarly, Mascaro and Sperber (2009) found that 3-year-olds were more willing than 4- and 5-year-olds to accept information provided by an informant who was trying to be deceptive. These developmental patterns suggest that in the current study older children might be more likely to recognize that when samples were purposefully selected the negative evidence provides stronger support for generalization than positive evidence, whereas younger children might show an overall preference to generalize when evidence was deliberately selected, regardless of evidence type.

Finally, we manipulated the type of contrasts established by the negative evidence. In addition to receiving some items with positive evidence children were also presented two types of negative evidence, each of which differed in the type of contrast they established. Those that provided an explicit contrast included negation (e.g., "*donkey <u>do not</u> have ulnar bones*"), whereas the others presented an implicit contrast (e.g., "*donkeys have omat bones"*). Prior research suggests there is reason to expect differences in generalizations from implicit contrasts and explicit contrasts. While children learn from explicit contrasts from a very young age (Au & Markman, 1987; Waxman *et al*., 1997), the ability to learn from implicit contrasts appears a bit later. For example, Gelman and Markman (1985) found that 4-year-olds, but not 3-year-olds, were able recognize that when adjectives are used to qualify the meaning of nouns (e.g., the *red* car) they imply a contrast from other category members (e.g., non-red cars; Horowitz & Frank, 2016 reported similar findings). Implicit contrasts are more ambiguous, and therefore can cast doubt on whether an informant has chosen the most felicitous example (e.g., Nordmeyer & Frank, 2018). Thus, if there are any differences between age groups we expected those to emerge for implicit contrasts, which might pose a challenge for younger participants for whom the ambiguity might make these items confusing.

Experiment

Method

Participants Ninety-seven children participated in this study. There were 33 three-year-olds (M_{Age}=3.42 years, SD=.42; 19 females; 14 males), 33 four-year-olds (M_{Age}=4.61 years, SD=.42; 21 females; 12 males), and 32 five-year-olds (M_{Age}=5.57 years, SD=.37; 17 females; 15 males). Children were recruited from preschools in a medium-sized Midwestern US city. Overall, the racial/ethnic breakdown was representative of the city from which the children were selected: 64% White, 19% Black, 10% Latino/Hispanic, and 7% Other. Participating schools were given a small monetary donation for their support of this research.

Design & Materials This experiment used a 2 (Sampling condition: Incidental sampling, Deliberate sampling) by 3 (Evidence type: Negative-explicit, Negative-implicit, Positive) design with the first factor manipulated between subjects and the second factor manipulated within subjects. There were an approximately equal number of participants from each age group randomly assigned to the two Sampling conditions: Incidental sampling ($N_{\text{3-year-olds}}$=16, $N_{\text{4-year-olds}}$=16, $N_{\text{5-year-olds}}$=16) and Deliberate sampling ($N_{\text{3-year-olds}}$=17, $N_{\text{4-year-olds}}$=17, $N_{\text{5-year-olds}}$=16).

In both conditions participants were presented 15 items each of which included a base premise, an additional piece of evidence, and a conclusion. The base premise involved the attribution of a novel biological property to a category (e.g., "Hawks have omat bones") and the additional piece of evidence involved attribution of a novel biological property to a different category (e.g., donkey). The Evidence type manipulation involved modifications to the properties that were attributed to the categories in the additional evidence. For *Positive* trials the categories were attributed the same property that was attributed to the base premise (e.g., "Donkeys have omat bones"). The *Negative-explicit* trials involved negation of the property that was attributed to the base premise (e.g., "Donkeys do not have omat bones"). For *Negative-implicit* trials the additional evidence involved attribution of a different property than was attributed to the base premise (e.g. "Donkeys have ulnar bones"). Participants were presented 5 items from each of the three evidence types. After presentation of the base premise and the additional evidence participants were asked to project the property attributed to the base premise to a different target (e.g., seagulls).

The base premise and conclusion target were always represented by items from the same basic-level category (e.g., birds) and the additional evidence was drawn from a different superordinate category (e.g., mammals). We did not expect children would have knowledge about the particular items (e.g., "hawks" or "seagulls"), but rather that they would understand that the items represented distinct members of the "bird" category (see e.g., Rosch *et al.,* 1976). Likewise, children might not be familiar with some of the items from the superordinate categories (e.g., "donkey"), yet we expected they would recognize that those items were from a different category than the base premise and conclusion targets (e.g., birds). All items were represented by a picture of an animal from the category (mounted on a 4cm by 4cm index card). The assignment of evidence type was pseudo-randomized to ensure that each set of items was represented by each evidence type an approximately equal number of times.

The novel biological properties were drawn from prior studies on the development of induction. The properties used for the *Negative-implicit* items were intended to offer clear alternatives to the property attributed to the base premise such that the presence of this alternative property would reasonably imply the absence of the property that was attributed to the base premise (e.g., ulnar bones vs. omat bones).

Procedure Participants were interviewed individually in a quiet location at their preschool or daycare center. At the beginning of the interview each participant was told that the experimenter was going to "show you some pictures and ask some questions". Sampling condition was manipulated by modifying the subsequent task descriptions. Each of the descriptions are presented below:

> *Incidental sampling condition* "Before I left my office I grabbed these pictures of different animals from a box; I didn't even look in the box when I grabbed the pictures! Each picture includes a fact about each animal. I am going to read the facts about these animals and then ask some questions".

> *Deliberate sampling condition* "Before I left my office I grabbed these pictures of different animals from a box; I picked these pictures to help me teach you some things about these animals. Each picture includes a fact about each animal. I am going to read the facts about these animals and then ask some questions".

For the youngest group of participants we repeated the sampling method 4 times during the experiment to ensure they did not forget the sampling procedure (e.g., "Remember these are pictures of animals I just grabbed from a box..", "Remember, these are pictures I picked to help you learn about animals.."). Children were randomly assigned to one of these two sampling conditions.

After these instructions the experimenter presented each item by first placing a photograph of the base premise approximately 40 cm in front of the participant, pointing to the item in the photograph, and attributing the appropriate property to the category represented in the picture. Next, the photograph depicting the category in the additional evidence was placed beside the base premise and the experimenter pointed to this item and made the appropriate property attribution. The experimenter then placed the photograph of the conclusion item below the two evidence items (approximately 25 cm from the child) and asked the child if they would project the property attributed to the base premise to this category (e.g., "Do you think seagulls have omat bones?"). In the rare case in which children did not offer a "yes" or "no" response we provided an additional prompt to assure them they should make their best guess (e.g., "there are no right or wrong answers, just make your best guess"). Responses were recorded and the next item was then presented. Overall the task lasted approximately 10 minutes.

Results

Responses in which participants projected a property from the base premise to the conclusion target (i.e., responded "yes" to the projection question) were scored "1", whereas responses in which they did not (i.e., responded "no" to the projection question) were scored "0".

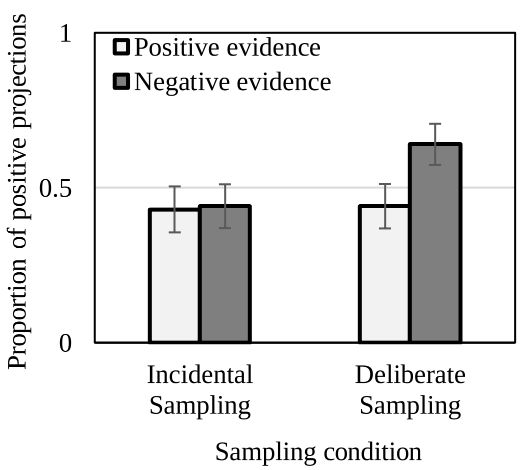

Figure 1. Proportion of projections for Positive evidence and Negative evidence in the Incidental sampling and Deliberate sampling conditions. Bars represent 1+/- SE from the mean.

The first analysis tested whether sampling procedures had unique effects on projections of positive evidence and negative evidence (overall). For this analysis we calculated an average for projections in both negative evidence conditions (implicit and explicit). Next, we conducted a mixed ANOVA with Sampling condition (Incidental, Deliberate) and Age (3-year-olds, 4-year-olds, 5-year-olds) as between subjects variables and Evidence type (Positive evidence, Negative evidence) as the within subjects variable. There was not a significant effect of Age (F<.43, p=.64). However, there was a main effect of sampling condition, $F(1,92)=3.91$, $p=.05$, $\eta^2=.04$, which was qualified by an interaction with Evidence type, $F(1,92)=6.51$, $p=.01$, $\eta^2=.07$. In support of our main hypothesis there was a higher rate of projections under deliberate sampling than incidental sampling for Negative evidence ($M_{Deliberate}=.70$, $SD=.25$; $M_{Incidental}=.52$, $SD=.33$), $F(1,96)=9.84$, $p=.002$, but not for Positive evidence (Deliberate sampling, $M=.57$, $SD=.33$; Incidental sampling, $M=.52$, $SD=.35$), $F<.57$, $p=.45$. (See Figure 1). Thus, all three groups of children exhibited a greater willingness to generalize from samples of negative evidence when the evidence was selected deliberately than when it was selected incidentally.

Our second set of analyses assessed potential developmental differences in projections for samples that included either an implicit contrast or an explicit contrast. To test our developmental prediction we focused on responses in the Deliberate sampling condition. An Age by Evidence type (Implicit, Explicit) ANOVA yielded a significant interaction, $F(2,47)=4.33$, $p=.02$, $\eta^2=.16$, due to differences in projections for the Negative-implicit items, $F(2,47)=3.73$, $p=.03$, $\eta^2=.09$. As suggested by Figure 2, under deliberate sampling five-year-olds made a significantly higher proportion of projections for Negative-implicit items than both 4-year-olds and 3-year-olds, both Tukey's HSD, $p<.05$. There were no age differences in projections for explicit contrasts, all Fs<1.0, *ns*.

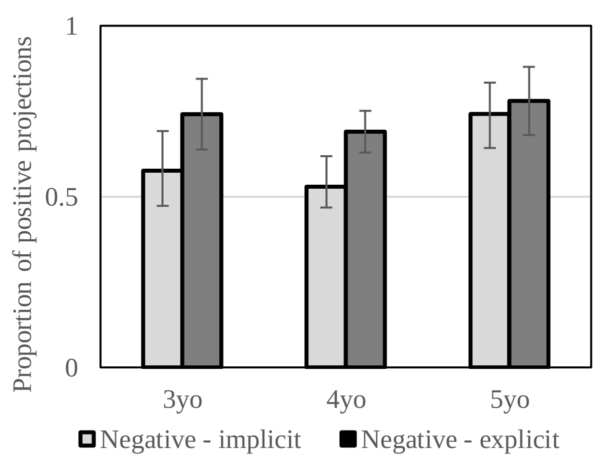

Figure 2. Proportion of projections for Negative-implicit and Negative-explicit items in the Deliberate sampling condition for 3-, 4-, and 5-year-olds. Bars represent 1+/- SE from the mean.

Paired-samples *t*-tests of responses in the Deliberate sampling condition revealed that for both younger groups the proportion of projections for the Negative-explicit items was significantly higher than the proportion of projections for the Negative-implicit items, both *t*s>3.46, *p*s<.003 (two-tailed), *d*s>.42. For 5-year-olds there was not a significant difference in projections for Negative-implicit and Negative-explicit items, $t(15)=.94$, $p=.36$. *ns*.

Finally, we conducted a set of one-sample *t*-tests to assess whether participants responses were significantly different from chance ($M=.50$). These analyses revealed that children's responses were significantly greater than chance for Negative evidence under deliberate sampling $t(95)=5.63$, $p<.001$, $d=.97$. Moreover, in the Deliberate sampling condition all groups of children responded at rates significantly greater than chance for the Negative-explicit items, all *t*s>4.23, *p*s<.002, but only the 5-year-olds showed a consistently high rate of projections for the Negative-implicit items, $t(16)=3.45$, $p=.007$, $d=.57$.

General Discussion

Research on the development of inductive reasoning tends to focus on how positive evidence influences children's generalizations (e.g., Gutheil & Gelman, 1997; Hayes *et al*., 2007). The goal of the current study was to examine the significance of negative evidence: To what extent does learning about cases that lack a property in question support inductive decisions? Our results indicate that children as young as three years of age prefer to generalize from samples that include negative evidence, compared to those that include positive evidence, but only when evidence is described as having been selected deliberately by an informant who has purposefully selected evidence to help them learn.

These findings replicate other work that has found that negative evidence supports inductive generalization in young children (Kalish & Lawson, 2007; Waxman et al., 1997). Our results build on this work by showing that the contrast effect established by negative evidence depends on children's understanding of why evidence was selected. Thus, in addition to building on prior developmental work in this area, our findings provide a conceptual replication of the work by Voorspoels *et al*. (2015) who showed that adults favored inductive arguments with negative evidence (over those without negative evidence) when the arguments were chosen deliberately but not when they were selected randomly.

Taken together these results are consistent a relevance-based view of induction (e.g., Medin *et al*., 2003), which suggests that we consider, perhaps foremost, the purpose with which an informant has selected evidence when we make inductive decisions. Children, like adults, assess a range of factors when determining whether to trust the testimony provided to them by others (e.g., Harris *et al*., 2018; Mills, 2013; for similar insights about adult cognition see Sperber *et al*., 2010). By the age of 3 years children consider the method used by informants to select evidence when determining the extent to which a generalization is warranted (Xu & Tenenbaum, 2007; see also Butler & Tomasello, 2016). The current findings suggest that children's expectations about the goals that underlie evidence selection cause them to interpret negative evidence as presenting a meaningful contrast intended to support generalization about a category and property in question.

One might wish to argue that the high rate of projections from explicit contrasts indicates that the negated statements had an information-processing advantage (see e.g., Just & Carpenter, 1971). However, it is important to emphasize that the inflated generalizations for explicit contrasts were only present under deliberate sampling, and therefore the information-processing advantage does not adequately explain the findings observed here and elsewhere (Voorspoels *et al*., 2015). Yet we believe the two accounts are not mutually exclusive; children's expectations about their communicative partner along with the processing demands of the task likely played a role in the higher rate of generalizations for explicit contrasts. Indeed, providing negative evidence in the form of negation of the category in question satisfies two expectations of communication: the expectation that a communicator will be precise and that they will provide us with the most helpful information possible (Grice, 1975).

While there was a common pattern of projections for explicit contrasts, this study revealed developmental differences in responses to implicit contrasts. Three-and four-year-olds preferred to generalize from explicit contrasts over implicit contrasts, and 5-year-olds made a higher proportion of projections from implicit contrasts than both younger groups, at least when samples were deliberately chosen. These results seem to be at odds with the findings reported by Kalish and Lawson who found that 4-year-olds generalized when negative evidence was presented as an implicit contrast. However, their study included a relatively old group of 4-year-olds (judging from their report, *M* age was approximately 4 years and 10 months across experiments). Post-hoc inspection of responses from our study suggests that under deliberate sampling older 4-year-olds (above 4.5 years, n=8) made a higher proportion of projections for implicit contrasts ($M=.70$) than did the younger 4-year-olds (below 4.5 years, n=9) ($M=.49$). These age trends are generally consistent with findings on implicit contrasts in word learning (Gelman & Markman, 1985; Horowitz & Frank, 2016), and suggest that the greater ambiguity provided by implicit contrast was likely to have presented a challenge for 3- and young 4-year-olds. Just why this was the case remains a matter of speculation. One possibility is that older children are simply more flexible in their ability to integrate information about informants with their evaluation of the available evidence (e.g., Mascaro & Sperber, 2009; Scofield & Behrend, 2008; see Mills, 2013 for review). Consider that projecting from implicit contrasts required that participants first recognize that the evidence was generalizable despite being less felicitous (e.g., Nordmeyer & Frank, 2018), and then understand that informants, even those who intend to be helpful, can sometimes provide ambiguous evidence. That 5-year-olds only generalized from implicit contrasts in the deliberate sampling conditions indicates that they were able to effectively use both of these pieces of information. However, it remains unclear whether younger children were simply unable to recognize the implied contrast or if they were not able to accept that an otherwise helpful informant could have provided ambiguous evidence.

Additional aspects of the results warrant some further discussion. Notably, because we focused on children's expectations about evidence selection we held constant the category from which the evidence was drawn. However, just which category serves as negative evidence influences children generalizations. For example, Kalish and Lawson (2007) found that children showed a greater willingness to generalize from samples when the negative evidence was from the closest superordinate category, such as it was in the present study (see also Waxman et al., 1997, and Voorspoels et al., 2015 for similar results with adults). From this perspective the suppressed rate of projections from positive evidence was likely due to the categories presented in the evidence. When deciding whether to generalize evidence from one category of birds to another category of birds, the addition of positive evidence about a mammal does not provide especially strong support; the evidence is ambiguous about which inferences are permitted. In contrast, negative evidence attributed to a target from an immediately superordinate category (e.g., mammals) provides an optimal contrast to support generalizations to members within the category in question (e.g., birds). These concerns suggest that future work will need to examine how children balance evidence from a range of negative cases with information about the way an informant has selected evidence.

In sum, we showed that an early emerging expectation that informants provide relevant and generalizable information can explain children's willingness to generalize from samples of negative evidence. This interpretation situates the present studies within a broader body of research that has detailed the degree to which young reasoners exercise vigilance when assessing the evidence provided to them by others (e.g., Harris *et al.,* 2018; Mills, 2013). Moreover, these findings provide some insight into how young reasoners solve a prominent riddle in the study of induction: How is it possible that negative evidence can support our inferences? Children, like adults, seem to solve this apparent riddle by simply trusting that the negative cases that support induction are those that have been selected for them by a helpful informant.

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