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Preschoolers' ability to navigate communicative interactions in guiding their inductive inferences

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Abstract

Evaluating whether information is generalizable, essential knowledge about a novel category is a critical component of conceptual development. In previous work (Butler & Markman, 2012) 4-year-old children were able to use their understanding of whether information was explicitly communicated for their benefit to guide such reasoning, while 3-year-olds were not. In two experiments, we further investigate this finding. Four-year-olds were adept at navigating pedagogical interactions, judiciously identifying which specific actions in an ongoing interaction were meant as communicative demonstrations for their benefit, while 3-year-olds did not distinguish between the manners of demonstration even in a simpler context. Taken together, these experiments illustrate that this powerful learning mechanism for facilitating children's conceptual development is under construction during the preschool years.

Keywords: Social cognition; inductive inference; generalization; pedagogy; communication.

Introduction

A foundational developmental process is the acquisition of generic knowledge about kinds and categories that supports the construction of a coherent conceptual understanding of the world (Gelman, 2003; Gelman & Wellman, 1991; Keil, 1989; Markman, 1989). But acquiring such knowledge often requires making inductive inferences on the basis of limited information. For example, imagine that a person learns a new fact about an individual animal, say that a bird has a particular shape of feather. Should this person infer that all birds of this kind have similar feathers? That *all* birds have similar feathers? Or alternatively, that these feathers are unusual and idiosyncratic to only this individual, or to a limited set of related birds? One could arguably make each of these generalizations with equal legitimacy based on the given evidence (cf., Goodman, 1965).

Determining the scope of a generalization is a challenge for young children, who experience a flood of new information and must rapidly construct a conceptual framework for understanding the world (Lopez, Gelman, Gutheil, & Smith, 1992). Although in many cases children can tackle this problem by relying on linguistic cues that mark generic knowledge (e.g., Cimpian & Markman, 2009,

2011; Gelman, Star, and Flukes 2002; Hollander, Gelman, & Raman, 2009), there are many potential non-linguistic contexts in which children observe others' actions and must evaluate whether the information those actions produce is generic. How do children carry out this process?

Previous research with infants suggests that even infants are sensitive to cues that someone is deliberately communicating information for their benefit (see Cisbra, 2010), and that this sensitivity appears to change how infants process that information. Specifically, they appear to encode information conveyed communicatively as more kind-relevant and stable than information produced non-communicatively (Gergely, Egyed, & Király, 2007; Futó, Téglás, Csibra, & Gergely, 2010; Yoon, Johnson, and Csibra, 2008). Does this early sensitivity to communicative cues also play a role in older children's ability to assess whether information is generic?

In recent research, Butler and Markman (2012) demonstrated that by age 4 children utilize cues that someone is deliberately communicating information for their benefit to guide such inductive inferences. Three- and 4-year-old children were first taught a label ("blicket") for a novel object. Children then observed perceptually identical evidence that this object was magnetic, but produced with subtly different actions: the experimenter *accidentally* used the object as a magnet; did so *intentionally*; or did so while conveying that they were acting *communicatively* and *pedagogically* for the child's benefit.

Importantly, after being taught the object's name, children engaged in a short, unrelated distractor task. This was done in an attempt to create a clear break between the pedagogical word-learning phase and the experimental manipulation so that children would not interpret every action as meant "for them," simply because the adult had previously been teaching them something about this kind.

After seeing this evidence, children were given 10 additional blickets that were identical, but which upon exploration turned out not to be magnetic. To assess the strength of children's inductive inferences, we measured their continued exploration of the inert objects when they discovered that they failed to have the novel property (after Schulz, Standing, & Bonawitz, 2008): specifically how long and how many attempts children made to try get the inert

blickets to pick up paperclips. This persistence in the face of such negative evidence is an index of how strongly children inferred that the property should generalize.

Four-year-olds showed significantly more such exploration in the pedagogical condition, suggesting they made stronger inductive generalizations about the property when it was demonstrated communicatively. So by age 4 preschoolers are able to use communicative cues to guide their reasoning about whether information represents generic knowledge about a kind. Interestingly, 3-year-olds also based their inferences on the intentions of the adult, but did so purely on the basis of whether the evidence was produced intentionally rather than accidentally. That is, 3 year olds treated intentional and pedagogical actions as warranting similarly strong inferences, more so than an accidental action. Thus there appears to be a developmental difference in how children identify and make use of communicative acts in guiding their inductive inferences.

This developmental difference is intriguing. It seems unlikely that 3-year-old children fail to recognize the communicative cues that signal that an action is meant for their benefit. Indeed, infants as young as 10 months appear to recognize such cues, and having information conveyed with those communicative cues *does* appear to impact how they treat new information. (Csibra, 2010; Csibra & Gergely, 2009). The hypothesis we consider here is whether there may be a developmental difference in the ability to assess, in real time, which actions within a given context are pedagogical. Even within a pedagogical interaction adults may perform a number of actions that are not meant to carry meaningful information, but which could potentially be misinterpreted as acts of teaching. Imagine that a child is watching her mother or father preparing a snack. The adult is interacting with a number of kitchen tools, occasionally interrupting an action to attend to a forgotten item or ingredient, and then returning to the task at hand. In such a dynamic, flowing context, if a child is going to utilize her sensitivity to whether or not an action is meant *for* her, she needs to be able to identify which actions are truly meant as demonstrations, and which are merely incidental, unnecessary, or part of a different embedded event.

The current research aims to shed initial light on this issue, taking two complementary approaches. First, we ask what factors might play a role in driving the effect seen previously in older children. How best can we characterize 4 year olds' use of communicative cues to guide their inferences, and how nuanced is this learning mechanism? Second, what might be preventing younger children from using this distinction to guide their inferences? Does a manipulation that might make it easier for children to draw the distinction between the conditions reveal a similar pattern of inferences at a younger age?

Experiment 1

In utilizing their sensitivity to communicative cues to guide their inductive inference, children need to be able to do so while navigating ongoing interactions with adults,

discriminating those actions that are truly meant for their learning benefit from those that are not.

As discussed earlier, in Butler and Markman's (2012) task, in which children learned that an object was called a "blicket," and then saw that it was magnetic, they were given an unrelated distractor task between the word learning and evidence phases, in an attempt to distance the pedagogical teaching of the word from the experimental manipulation of how the key evidence was produced. Thus the distractor task was meant to provide a clear interruption of the ongoing pedagogical interaction, potentially implying that the subsequent actions were not necessarily meant for the child's benefit, unless they were clearly marked as communicative acts. This opens up a question about the nature of 4-year-olds' ability to selectively use communicative cues to guide their inferences about novel information. How adept are they at identifying an action meant for their benefit when the target action is embedded within a still-continuing pedagogical interaction?

Method

The procedure for Experiment 1 was closely modeled after Butler and Markman (2012), in which children were presented with evidence that a novel object had a novel function, in one of three subtly different ways: communicatively, intentionally, or accidentally. In order to directly address the question of how adept 4-year-olds are at applying their sensitivity to communicative cues in an ongoing context, we manipulated the the position of the distractor task within the continuous stream of events (see Figure 1), thus varying whether or not the ongoing pedagogical interaction was clearly interrupted prior to the evidence phase. If 4-year-olds are truly conducting a nuanced, moment-by-moment analysis of an adult's communicative intentions at each particular point in time, they may distinguish between pedagogical and intentional actions even within an ongoing pedagogical interaction, regardless of the position of the distractor task.

Materials The materials in Experiment 1 were 11 PVC pipes, 5 cm in diameter and 7.5 cm tall. The active object had a noisemaker inside that made an animal noise when it was flipped upside down. The 10 inert objects had several pebbles taped to the inside of the PVC piping in order to give them an equivalent weight and feel as the active object. All 11 objects were covered with blue duct tape, on one end and around the sides, and had yellow duct tape covering one end. The objects were perceptually indistinguishable.

Participants The participants were 96 children from a university preschool ($M_{\text{age}} = 4$ years, 8 months). An additional 9 children were excluded because of experimenter error, or because they did not attend to or finish the procedure. Participants were randomly assigned to one of two orders and three experimental conditions, with the constraint that all six condition-order groups were matched for gender and age.

Procedure The procedure was modeled after that used in Butler and Markman (2012) and described above, but the order of the procedure was manipulated (see Figure 1). In the *interruption* order, the sequence of events was identical to that used previously. The experimenter brought out the target object and four distractor objects, and proceeded to teach the child a novel word (“femo”) for the target object. All children successfully picked out the target object when asked for it by name on two successive trials. The experimenter then said, “Now let’s do something really fun! We can make a boat out of colored paper!” and then proceeded with the distractor task. In the *no interruption* order, the placement of the word learning and distractor phases was switched. Children first participated in the boat-making task as a warm-up game. The experimenter then brought out the target object and the four distractors and conducted the word learning procedure. In both orders, after the second phase of the procedure the experimenter then said, “I’m going to put a few of my things away” and proceeded to put away each of the distractor objects, finally picking up the target object.

In the evidence phase, the experimenter moved the object from one hand into the other, flipping it upside down in the process and placing it yellow-side-down on the table, all in one continuous action. This action was identical in the pedagogical and intentional conditions, except that in the pedagogical condition the experimenter made eye contact with the child and said, “Look, watch this.” The action in the accidental condition was nearly identical, but the experimenter appeared to lose her grip on the object as she was picking it up and moving it, saying, “Oops!” and then appeared to catch it with her other hand and place it on the table. In all three conditions the experimenter then said, “Wow!” after placing the object on the table.

Interruption Order (replication of Butler & Markman, 2012)

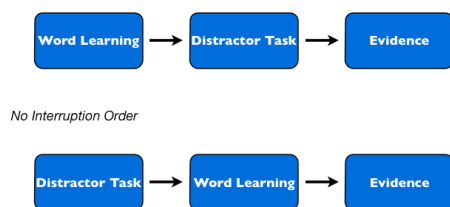


Figure 1: Overview of task structure in the two orders of Experiment 1.

Coding & Data Analysis Two independent judges watched only the exploration phase of each video, and coded both the

amount of time children spent exploring the inert objects, and how many times they attempted to elicit the property from those inert objects.

Children’s exploration violated assumptions of normality and homogeneity of variance. Thus we used non-parametric Mann-Whitney tests to conduct pairwise comparisons between conditions, and ordinal logistic regressions (see Cimpian & Cadena, 2010; Cimpian & Markman, 2009) to assess the overall impact of condition and order.

Results

In order to assess the overall impact of condition and order on children’s exploration, we conducted ordinal logistic regressions (OLR) on our two principal measures exploration (number of attempts to elicit the property from the inert objects and time exploring the inert objects), with condition and order as predictors. There was a significant effect of condition on both number of attempts (Wald $\chi^2 = 16.06$, $p < 0.001$) and time exploring (Wald $\chi^2 = 16.67$, $p < 0.001$). There was no effect of order of the distractor task on number of attempts (Wald $\chi^2 = .064$, $p = .801$), nor was there an interaction between order and condition (Wald $\chi^2 = .345$, $p = .841$). There was a marginal effect of order on time exploring (Wald $\chi^2 = 3.52$, $p = .061$), but there was no interaction between order and condition (Wald $\chi^2 = .255$, $p = .880$). Overall, these analyses suggest that the experimental condition (pedagogical, intentional, or accidental) had a significant effect on 4 year olds’ exploration, and that while the order might have had an effect, it did not alter the effect of condition. To explore these results further, we now compare the results across condition for each order.

Interruption Order The patterns of exploration across conditions in the interruption order clearly replicated the findings of Butler and Markman (2012).

Four-year-olds made significantly more attempts to elicit the property from the inert objects in the pedagogical condition ($M_{\text{pedagogical}} = 9.37$, $SD = 7.20$) than in either the intentional ($M_{\text{intentional}} = 2.69$, $SD = 3.77$; Mann-Whitney $Z = 3.07$, $p = .002$) or accidental ($M_{\text{accidental}} = 3.94$, $SD = 5.20$; Mann-Whitney $Z = 2.38$, $p = .017$) conditions (see Figure 2). There was no difference between the intentional and accidental conditions (Mann-Whitney $Z = .218$, $p = .828$).

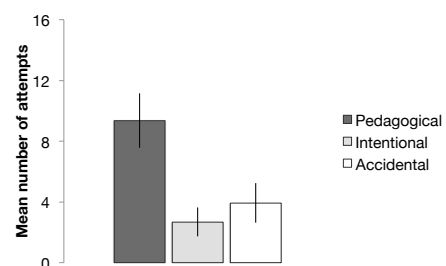


Figure 2: Mean number of attempts in each condition in the *interruption* order of Experiment 1. $N = 64$ (16 per condition). Error bars represent ± 1 SEM.

Four-year-olds also spent significantly longer exploring the inert objects in the pedagogical condition ($M_{\text{pedagogical}} = 13.94$ s, $SD = 10.54$) than in either the intentional ($M_{\text{intentional}} = 3.87$ s, $SD = 5.05$; Mann-Whitney $Z = 2.97$, $p = .003$) or accidental ($M_{\text{accidental}} = 5.44$ s, $SD = 9.03$; Mann-Whitney $Z = 2.59$, $p = .010$) conditions. There was no difference between the intentional and accidental conditions (Mann-Whitney $Z = .276$, $p = .783$).

No-Interruption Order Despite the marginal overall effect of order on time exploring seen in the OLR analyses, the patterns of exploration by children who saw the distractor first, and then learned the word, followed immediately by the evidence phase with no interruption, were nearly identical to those who saw a clear interruption between these phases.

Four-year-olds made significantly more attempts to elicit the property from the inert blickets in the pedagogical condition ($M_{\text{pedagogical}} = 10.37$, $SD = 10.12$) than in either the intentional ($M_{\text{intentional}} = 3.94$, $SD = 4.22$; Mann-Whitney $Z = 1.97$, $p = .048$) or accidental ($M_{\text{accidental}} = 3.67$, $SD = 4.98$; Mann-Whitney $Z = 2.07$, $p = .038$) conditions (see Figure 3). There was no difference between the intentional and accidental conditions (Mann-Whitney $Z = .270$, $p = .787$).

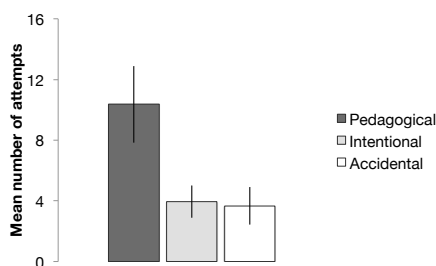


Figure 3: Mean number of attempts in each condition in the *no interruption* order of Experiment 1. $N = 64$ (16 per condition). Error bars represent ± 1 SEM.

Four-year-olds also spent significantly longer exploring the inert blickets in the pedagogical condition ($M_{\text{pedagogical}} = 24.50$ s, $SD = 20.65$) than in either the intentional ($M_{\text{intentional}} = 10.31$ s, $SD = 11.72$; Mann-Whitney $Z = 2.11$, $p = .035$) or accidental ($M_{\text{accidental}} = 8.07$ s, $SD = 9.92$; Mann-Whitney $Z = 2.35$, $p = .019$) conditions. There was no difference between the intentional and accidental conditions (Mann-Whitney $Z = .353$, $p = .724$).

Discussion

The results of Experiment 1 help clarify how older preschoolers use communicative cues to guide their inductive inferences. Regardless of whether or not they were given a clear interruption in the overarching pedagogical interaction, a deliberate break between engaging in an overarching pedagogical interaction and seeing the target action producing the evidence, children selectively

modulated the strength of their inductive generalizations on the basis of whether or not the experimenter explicitly demonstrated that action for their benefit. This suggests that 4-year-olds' inferences are driven a moment-by-moment analysis of whether or not each individual action or series of actions is meant *for* them.

A judicious application of this learning mechanism is important for the accuracy of young children's developing conceptual representations. If children simply made a broad inference about whether an adult is currently teaching them or not, they might be misled about the importance of various pieces of information that they might witness in such contexts. If children did not engage in a moment-by-moment analysis of which actions were deliberately meant for them, they might mistakenly generalize even an incidental action as what one does with this kind of object, even though in fact this is an idiosyncratic, unusual way to use this kind of object. Simply put, it is helpful for children to use their understanding of others' communicative intentions to guide the inferences if they can do so selectively. The results of this experiment suggest that, at least by age 4, children appear to be capable of using communicative cues to guard against such over interpretation, ensuring that the information that does make it into their representations is likely to be important, generic information about the kind.

Experiment 2

The results of Experiment 1 shed light on the sophistication of 4-year-olds' ability to navigate ongoing interactions in order to identify which actions are meant as communicative acts for their benefit, and thus what information ought to be taken as important and generalizable. Even when children have to conduct a more nuanced moment-by-moment analysis of the interaction, 4-year-olds show a consistent pattern of making stronger inferences about evidence that is demonstrated communicatively for their benefit.

This contrasts with the findings with 3-year-olds from Butler and Markman (2012). In three experiments, 3-year-olds consistently showed an analogous effect for pedagogical demonstration compared to seeing the same action done accidentally. However, 3-year-olds did *not* distinguish between the pedagogical and intentional actions, making similarly strong inferences in both conditions. What might account for this developmental difference? Moreover, as we have suggested this inference requires that children not only recognize that an action is *for* them, but have to be able to navigate an ongoing interaction, assessing moment-by-moment whether or not particular actions are indeed meant for them, even when they occur within a communicative context. If younger children struggle with identifying individual pedagogical actions within an overarching stream of actions, it might take a more explicit demarcation of the specific actions that produce the relevant evidence in order to elicit the pattern of reasoning seen in older children.

In Experiment 2, we take a first step at asking whether presenting this manipulation in a context that might make it *easier* for children to navigate the ongoing interaction and identify which actions are truly made for their benefit, might lead 3-year-olds to be more successful at selectively using communicative cues to guide their inferences.

Method

Recall that in Experiment 1, we investigated the importance of the distractor task in potentially facilitating children's ability to navigate the ongoing interaction and identify which actions were and were not meant for them. For older children this did not seem to have any tangible impact—even without any clear interruption between the word learning and evidence phases, 4-year-olds were readily able to selectively use the communicatively demonstrated evidence to make a stronger inference about the novel property. But this interruption seems like a logical place to start in asking whether manipulating the complexity of the context might help facilitate 3-year-olds' ability to engage in the same inference process.

In Experiment 2, we attempted to boost the clarity of the break provided by the distractor task by making it clearly non-pedagogical, non-communicative, and even non-interactive. We hypothesized that 3-year-olds have a more global sense of whether or not they are engaged in a pedagogical interaction, and that this may be leading them to over interpret everything that occurs in this context as likely pedagogical unless otherwise marked. If so, then establishing a clearer break between the pedagogical word learning and the evidence phase might help them distinguish between the pedagogical and intentional actions.

Materials Having established in Experiment 1 that previous findings were not an artifact of the materials used in those studies, in Experiment 2 we returned to using materials identical to those used in Butler and Markman (2012): 1 target magnetic object, 10 identical inert objects, and metal paperclips.

Participants The participants were an additional 24 children from a university preschool ($M_{\text{age}} = 3$ years, 5 months). Participants were randomly assigned to one of two experimental conditions (Pedagogical or Intentional), with the constraint that the conditions be equated for gender and age.

Procedure As in Butler & Markman (2012) and the Interruption order of Experiment 1, children were first explicitly taught a label for the target object. After children were taught the novel word and had successfully indicated the target object on two successive trials, the experimenter brought out the paperclips, colored pencils, and a sheet of paper with a simple triangle outline on it, and said, ““And here’s a picture to color! Why don’t pick out your favorite color to color the triangle with, and then I can write your name on your picture!” The experimenter then let the child

color for 60 s while she pretended to write something down, not making eye contact or otherwise engaging with the child during this distractor task. The experimenter then said “I’m going to put these away” and began to clean up each of the distractor objects, finally picking up the target object and using the object to magnetically pick up the paperclips. This evidence was produced one of two three subtly different ways, as in Experiment 1: pedagogically or intentionally (but non-communicatively). As our main interest was in whether these younger children would distinguish between the pedagogical and intentional conditions (and not whether patterns of exploration in these two conditions would differ from the accidental condition), only these two conditions were run..

The key change from previous studies was the use of this non-interactive distractor task. This was done as an attempt to provide children with a clearer interruption in the ongoing pedagogical interaction. If 3-year-olds’ failure to distinguish between the intentional and pedagogical conditions in previous studies was due to an overall sense of being in a pedagogical interaction, this change might help them disengage from this and discriminate whether or not the target action is truly meant as an act of communication.

Results

Replicating the findings from Butler & Markman (2012), 3-year-olds did not appear to make any distinction between the pedagogical and intentional conditions. Children were equally likely to explore the inert objects in both the pedagogical (8 children, 75%) and intentional (7 children, 58%). Moreover, children made similar numbers of attempts to elicit the property from the inert objects in both the pedagogical ($M_{\text{pedagogical}} = 3.17$, $SD = 3.49$) and intentional ($M_{\text{intentional}} = 4.08$, $SD = 4.80$, Mann Whitney $Z = .240$, $p = .810$). Children also spent a similar amount of time exploring the inert objects in both the pedagogical ($M_{\text{pedagogical}} = 8.67$ s, $SD = 10.31$) and intentional ($M_{\text{intentional}} = 8.42$ s, $SD = 11.76$, Mann Whitney $Z = .090$, $p = .928$).

Discussion

Providing younger children with a clearer break between the pedagogical word learning and evidence phases did not facilitate their ability to selectively use communicative cues to guide their inferences. Even when we had a 60 s break in which the experimenter did not interact with the children, these children still failed to distinguish the pedagogical demonstration and the intentional, but non-pedagogical, action, making similarly strong inferences in both cases. Although we cannot compare children’s inferences in these conditions to an accidental condition, across three studies in Butler & Markman (2012), 3-year-olds consistently distinguished between intentional or pedagogical and accidental conditions, and there is little reason to expect them not to do so in this experiment. Moreover, the key point for our conclusion is that children failed to distinguish between a pedagogical and identical, but non-pedagogical, action, even given a clearer break.

However, it should be noted that there was still an overarching pedagogical context. That is, children still came to the room with a knowledgeable adult and engaged in a brief pedagogical interaction with them. If the distinction between pedagogical and intentional is more global for these younger children, happening on the level of the overarching context rather than moment-by-moment actions, this may explain why having the ongoing pedagogical interaction interrupted by a clearly non-communicative, non-interactive distractor task was not enough to enable them to fully disengage from the pedagogical expectation and evaluate whether the individual instrumental action was deliberately done for their benefit.

General Discussion

To return to our original research question, how best to we characterize preschoolers' ability to use communicative cues to guide their inductive inferences? Our perspective is that although younger children most certainly are capable of recognizing communicative cues (Cisbra, 2010), they may be less adept at navigating pedagogical interactions in order to identify which actions are meant for their benefit. On this account, younger children may have a more global sense of whether or not they are currently engaged in a pedagogical interaction with a knowledgeable adult, and may interpret, or even over-interpret, a variety of intentional actions as *for* them, even if they are not clearly meant as such, and only disengage from this interpretation when an action is clearly marked otherwise, for example as accidental.

The results of these experiments are consistent with this interpretation. Although 4-year-olds judiciously identified which actions were meant for them even when embedded in an ongoing pedagogical interaction, even when 3-year-olds were given a clear break between being taught the word and seeing the evidence produced either communicatively or non-communicatively, they did not use that distinction to guide their inferences. Thus simply interrupting the pedagogical interaction does not seem to be enough to disengage children's overall pedagogical interpretation of the situation.

More broadly, the learning mechanism explored in this paper clearly has powerful implications. Preschoolers are highly sensitive to communicative cues that indicate a particular action is meant for their benefit, and use this to guide stronger and inferences about novel information. But important questions remain about how best to characterize this learning mechanism, what inferential processes are children engaged in, and how this develops over the preschool years.

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