Cognitive Development 38 (2016) 27–35

Contents lists available at ScienceDirect

Cognitive Development

Navigating pedagogy: Children's developing capacities for learning from pedagogical interactions

Lucas P. Butler[a,*], Ellen M. Markman[b]

[a] Department of Human Development and Quantitative Methodology, 3942 Campus Drive, University of Maryland, College Park, MD 20742, United States
[b] Department of Psychology, Stanford University, 450 Serra Mall, Stanford, CA 94305, United States

ARTICLE INFO

Article history:
Received 14 October 2014
Received in revised form
16 December 2015
Accepted 8 January 2016
Available online 29 January 2016

Keywords:
Pedagogy
Social learning
Conceptual development
Social cognition

ABSTRACT

Young children can use cues that an adult is pedagogically providing information for their benefit to evaluate its importance and generalizability. But to use pedagogical actions to guide learning, children must learn to navigate ongoing pedagogical interactions, identifying which specific actions within an overarching context are in fact meant as pedagogical. In two experiments ($N = 120$) we illustrate that 3-year-old struggle with this ability, failing to distinguish pedagogical from merely intentional actions unless the endpoints of a pedagogical interaction were clearly demarked. These results shed light on the development of this powerful learning mechanism for facilitating inductive inference.

1. Introduction

The ability to learn from others is an essential learning mechanism to foster cognitive development. Social learning is what enables complex cultural knowledge to be faithfully learned and transmitted from generation to generation (Gergely & Csibra, 2005, 2006; Tomasello, 1999). A large proportion of social learning undoubtedly takes place via language, but children also learn a lot from observing the actions of others. Others' actions, and in particular the underlying intentions that guide them, are potentially rich sources of information about the world. Recognizing that someone is intentionally reaching for a particular object, for example, licenses inferences about a person's visual access, desires, preferences, and possibly even beliefs (Luo & Baillargeon, 2007; Onishi & Baillargeon, 2005; Woodward, 1998). And inferring the underlying goals of an action, even an incomplete or unsuccessful one, allows for rapid and accurate imitation of novel actions (Meltzoff, 1995).

Moreover, recognizing that the goal behind an action is not merely instrumental (for the actor's own benefit) but rather pedagogical (that is, done communicatively for the child's benefit) may allow for further inferences about the intended meaning of that communicative act and why an adult is choosing to communicate this information in this particular context (Gergely & Jacob, 2012; Sperber & Wilson, 1986). Specifically, if children recognize that a communicative act is being done pedagogically, for their benefit, they may reason that the information being communicated is likely important and generalizable beyond the particular individual or situation (Csibra & Gergely, 2009). Thus children may be able to use their reading of the intentions behind others' actions to infer enduring, general knowledge about the world from episodic bits of information, the classic inductive problem (Gelman, 2003; Gelman & Wellman, 1991; Goodman, 1965; Keil, 1989; Markman, 1989).

* Corresponding author.
E-mail address: lpbutler@umd.edu (L.P. Butler).

http://dx.doi.org/10.1016/j.cogdev.2016.01.001
0885-2014/

Preverbal infants appear to recognize ostensive cues that can signal pedagogical intent—most canonically seeing another person make direct eye contact with them and establish joint attention on an object (Csibra, 2010). Moreover, they take information accompanied by ostensive cues such as direct eye contact as more stable, kind relevant, and generalizable than identical information produced intentionally, but with no direct eye contact, joint attention, or other cues to ostension (Egyed, Király, & Gergely, 2013; Gergely, Egyed, & Király, 2007; Futó, Téglás, Csibra, & Gergely, 2010; Yoon, Johnson, and Csibra, 2008). Moreover, by 4 years of age children appear to use this sensitivity to pedagogical intent to guide more calibrated inductive inferences about to what extent novel information is generic, taking information conveyed pedagogically as both more generalizable to a novel kind (Butler & Markman, 2012), and more conceptually central to what it means to be a member of that kind (Butler & Markman, 2014).

However, this research with preschoolers also revealed a potential developmental difference in how children use pedagogical cues to guide their inductive inferences (Butler & Markman, 2012). In that study 4-year-olds made stronger inductive generalizations about a novel object property specifically when it was demonstrated for their benefit, compared both to seeing it produced accidentally and even compared to seeing identical evidence produced in an intentional, but non-pedagogical manner. In contrast, 3-year-olds made equivalently strong inferences on the basis of both the pedagogical demonstration and the intentional, but non-pedagogical, action. This result poses a puzzle, as even preverbal infants show clear effects of pedagogical cues on their encoding and, at least in one study, on their generalization of novel information (Egyed et al., 2013; Gergely et al., 2007; Futó et al., 2010; Yoon et al., 2008). What, then, is preventing 3-year-olds from making use of those cues in guiding their inductive inferences? To answer this question, it is helpful to take a step back and discuss more broadly how this inferential process might play out in actual learning episodes preschoolers might encounter, and how that might map onto the methodology used in prior research.

The effects of pedagogical cues on infants' learning (Egyed et al., 2013; Gergely et al., 2007; Futó et al., 2010; Yoon et al., 2008) may well be driven by a relatively automatic, cue-driven process. But preschoolers appear to be assessing whether others' actions are being carried out with pedagogical intent, and using that assessment to guide inferences about the importance and generalizability of demonstrated information (Butler & Markman, 2012, 2014). This more complex process presents an inductive challenge. Actions do not occur in isolation, but rather occur amidst ongoing, dynamic interactions. And adult–child interactions may often at some level be implicitly pedagogical, in that the child likely assumes that the adult knows more than they do, potentially leading the child to expect to be taught. But even within a pedagogical interaction, adults may perform any number of actions that are not intended to carry meaningful information. To use their sensitivity to pedagogical intent to accurately assess the importance of novel information, children need not only to *recognize* cues to pedagogical intent, they need to be able to *navigate* pedagogical interactions, sorting out which actions in an overarching context are in fact meant as "teaching moments," and which are done merely intentionally, not directed with pedagogical intent toward the child. If children struggle to do this, potentially misinterpreting various intentional actions as acts of teaching this would attenuate the power of learning from pedagogical demonstration.

As an illustrative example, imagine that a young child is watching her father prepare eggs for breakfast. As the child watches, her father takes out a whisk and labels it for her. He then goes about various tasks involved in making eggs—cracking the eggs, chopping some herbs, adding salt and pepper. At one point the phone rings, and the father engages in a short conversation. Afterwards, he absent-mindedly uses a fork (instead of the whisk) to beat the eggs, and later as the eggs are cooking he uses the whisk to brush herbs from the cutting board into the pan.

In this dynamic, flowing context, identifying which actions are meant as pedagogical demonstrations poses a challenge. The child needs to assess, for example, whether her father was showing her that whisks are for brushing things off cutting-boards—or whether he was merely grabbing what was convenient to accomplish this goal. Thus using pedagogical intent to guide inductive inferences requires children to navigate the ongoing situation, actively tracking the adult's intentions over the course of the dynamic interaction, and selectively using only those actions that are clearly meant as pedagogical demonstrations as the basis for their inferences. Given this, we might expect a developmental trajectory in which very young children are capable of broadly recognizing pedagogical contexts, but must learn how to navigate dynamic interactions in order to pinpoint which actions are truly meant for them.

Indeed, we know from the literature on "overimitation" that children have a tendency to assume that any novel action that they see in the context of being shown how to carry out a novel task ought to be imitated (Horner & Whiten, 2005). This phenomenon appears early in development, and appears to increase with age (McGuigan & Whiten, 2009; McGuigan, Whiten, Flynn, & Horner, 2007). There are differing proposals for what psychological mechanisms underlie overimitation. One argument is that children view each intentional action as causally necessary (Lyons, Damrosch, Lin, Macris, & Keil, 2011; Lyons, Young, & Keil, 2007). The other is that children over-imitate for social reasons, such as the drive to affiliate with others (Over & Carpenter, 2012) because they interpret the actions as part of a culturally-relevant ritualistic or normative action (Herrmann, Legare, Harris, & Whitehouse, 2013; Kenward, 2012; Kenward, Karlsson, & Persson, 2011; Keupp, Behne, & Rakoczy, 2013; Nielsen, Moore, & Mohamedally, 2012; Nielsen, Kapitany, & Elkins, 2015). Relatedly, children imitate more faithfully when they do not know the goal or underlying causal structure of an action (Williamson & Markman, 2006; Williamson & Meltzoff, 2011; Williamson, Meltzoff, & Markman, 2008), which could potentially be consistent with either proposal.

Most importantly for our purposes, the extent to which children overimitate depends on various social factors, including whether or not the demonstration is carried out live and with clear pedagogical cues and whether or not the demonstrator had previously engaged with the child (Marsh, Ropar, & Hamilton, 2014; Nielsen, 2006; Nielsen et al., 2012, 2015). This

literature provides at least initial evidence that young children may indeed have a tendency to view individual actions as equally important given that they are in a social situation with some level of pedagogical relevance.

To bring this back to the current research, consider the specific situation preschoolers encounter in Butler and Markman (2012). Children were first taught a label ("blicket") for a novel object. They 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. Children then encountered additional blickets that were not magnetic, and their continued exploration of those inert kind members was taken as an index of how strongly they had generalized the novel property. As mentioned earlier, 4-year-olds made stronger inductive generalizations about the property specifically when it was demonstrated for their benefit, persisting in their exploration significantly more in the pedagogical condition, compared both to the accidental and even to the intentional condition. In contrast, 3-year-olds made equivalently strong inferences on the basis of both the pedagogical demonstration and the intentional (but non-pedagogical) action, exploring equally in the pedagogical and intentional conditions, and less in the accidental condition.

In these experiments, children were in an overarching, potentially pedagogical situation, having been brought from the classroom to a testing room and taught the name of a novel object. They then engaged in an unrelated distractor task (learning how to fold a paper house). The experimenter then started putting away the various objects, and then intentionally used the previously labeled, novel object for a particular function (magnetically picking up paperclips). In this context, children need to monitor the ongoing interaction to assess, moment-by-moment, whether a particular action is meant as an act of teaching. If 3-year-olds are less skilled at this, they may treat the entire situation as globally pedagogical, and thus fail to distinguish between actions with different underlying intentions in guiding the strength of their inferences. Older children, on the other hand, may be more attuned to which actions are truly meant as pedagogical demonstrations of evidence, and which are merely instrumental actions taking place within the overarching context. It is important to note that we are not suggesting 3-year-olds are not sensitive to pedagogical cues, as even infants are clearly capable of distinguishing actions directly accompanied by pedagogical cues and those that are not. Rather, we suggest that 3-year-olds may treat a (merely) intentional action that comes within an overarching pedagogical context as equivalent to an explicitly pedagogical action, unless they have a clear reason to believe otherwise (i.e., if the action appears accidental). Thus there may be a developmental shift from children using a more global distinction between pedagogical and non-pedagogical situations, to beginning to distinguish whether individual actions are pedagogical or not, regardless of the global context in which they occur.

In the current research we aimed to shed light on this issue by asking whether 3-year-olds' prior failure to distinguish between pedagogical and intentional actions was because they tend to treat an intentional action that occurs amidst an ongoing pedagogical interaction as itself pedagogical. To test this, we conducted two experiments in which we test whether manipulations that increased the salience of when a pedagogical interaction begins and ends, or which removed the overarching pedagogical context altogether, would enable younger children to use pedagogical cues to guide their inductive inferences about novel information.

2. Experiment 1

In Butler and Markman (2012), 3-year-olds did not use pedagogical cues to guide their inductive generalizations, instead making equally strong generalizations and exploring equally in both the pedagogical and intentional conditions. We hypothesize that this lack of an effect, compared to the effect seen with the 4-year-olds, was due to these younger children's difficulty navigating the ongoing pedagogical interaction. In particular, children were engaged in an overarching pedagogical context, which was only interrupted by a brief distractor task which served to separate being taught the label for a novel object and seeing evidence that it possessed a novel property. This distractor task (folding houses with colored paper) constituted a shift from one topic to another, but the task itself was still pedagogical. If 3-year-olds struggle with isolating individual pedagogical demonstrations from within an overarching interaction, the pedagogical nature of this distractor task may have led them to continue interpreting subsequent intentional actions as equally pedagogical. In Experiment 1, we tested whether establishing a clearer break between the pedagogical word learning and the evidence phase – one that was not merely a shift in the topic of the pedagogical interaction but rather a clear interruption of that pedagogical interaction – might help 3-year-olds assess whether or not the subsequent actions were truly meant for their benefit. To do this, we attempted to boost the clarity of the break provided by this distractor task by making it clearly non-pedagogical, non-communicative, and even non-interactive.

2.1. Method

The experimental protocol was approved by Stanford University's Institutional Review Board, Protocol # 11315.

2.1.1. Participants

The participants were 24 children from a university-affiliated preschool (M_{age} = 3 years, 5 months; Range: 3 years, 0 months to 3 years, 9 months). One additional child was not included because of experimental error. Participants were randomly assigned to one of the two experimental conditions (pedagogical or intentional), with even numbers of males

and females in each condition. The children were predominately from middle- and upper-SES families. A variety of ethnic backgrounds were represented.

2.1.2. Materials

As in Butler and Markman (2012), the novel objects were 11 small wooden blocks, 2.5 cm × 2.5 cm × 5 cm. The 1 active block was magnetic on one end, while the 10 inert blocks were not. All were covered with black electrical tape, with green electrical tape covering the magnetic or nonmagnetic end. All 11 blocks were perceptually indistinguishable. The objects in the distractor phase were a handful of paperclips, 4 colored pencils, and a sheet of paper with a simple triangle outline.

2.1.3. Procedure

The procedure was identical to that used in Butler and Markman (2012), with identical evidence being produced either pedagogically or intentionally. The only change was in the nature of the distractor phase, as described below. All children were tested in a private room in their preschool by a trained experimenter.

2.1.3.1. Word-learning phase. Children were first explicitly taught a novel label (spoodle) for the novel object. When asked for the spoodle, all children successfully selected it from an array of four distractor objects (e.g., unusual kitchen tools) on two successive trials, without error.

2.1.3.2. Distractor phase. 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 4 distractor objects, finally picking up the target object and using the object to magnetically pick up the paperclips, as described in detail below.

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 teaching.

2.1.3.3. Evidence phase. After picking up the active spoodle, the two conditions diverged. In the pedagogical condition, the experimenter established eye contact with the child and said, "look, watch this," and then deliberately placed the spoodle on the paperclips, picking it up with paperclips attached. In the intentional condition, the experimenter carried out the identical action as in the pedagogical condition, i.e., deliberately placing the spoodle on the paperclips and picking it up with paperclips attached, but never made eye contact or otherwise interacted with the child during this period. The key difference is the lack of any ostensive cues in the intentional condition. In both conditions, the experimenter then picked up the spoodle and looked at it, saying "wow" in a positive tone, and then placed it next to the paperclips.

2.1.3.4. Exploration phase. After producing the functional evidence, the experimenter then placed the 10 inert spoodles on the table, saying, "'and here are some more spoodles," and told the child to "go ahead and play"' while he left table and sat facing away from the child for 60 s. At this point the paperclips were directly in front of the child (as they had been since the distractor phase), the active object was lying on table to the child's left, on its side with paperclips attached, and the inert objects were on table to the child's right. All objects were within easy reach for the child.

2.1.4. Coding and data analysis

Two independent judges coded each child's exploration. Each coder viewed only the portion of the video immediately following the demonstration, and so was blind to condition.

Our primary way of assessing children's inductive inferences was by measuring their exploration of the inert objects. That is, did they generalize the property to the other kind members, and how strongly did they hold on to this inference in the face of evidence that these kind members in fact failed to have the property? Our primary dependent measure of was the *number of attempts* to elicit the property from the inert spoodles. An attempt was coded as any intentional action clearly done to pick up paperclips, including both placing the spoodle on the paperclips as well as placing a paperclip on the spoodle. This measure provides an index of the amount of evidence that children need to *disconfirm the generalization they have made*. This is a critical point. We would expect that children would be equally likely to learn the novel property and to make at least a tentative generalization regardless of whether the property was demonstrated pedagogically or merely intentionally, and indeed this is precisely what was found by Butler and Markman (2012). The key for our purposes, however, is that we looked specifically at children's exploration of the novel kind members in the face of counterevidence—that is, when their initial generalization turned out to be mistaken. This behavior, persistence in the face of counterevidence, provides a test not of children's learning per se, but of how strong or how tentative that generalization is, depending on how the evidence for it was generated.

Children's exploratory play is highly variable, and often resulted in violations of the assumptions of normality and homogeneity of variance. We therefore used planned pairwise Mann–Whitney tests comparing each of the pedagogical conditions separately to the intentional and accidental conditions. We specifically wanted to test whether children's exploration in the pedagogical conditions differed from their performance either in the intentional or accidental conditions.

2.2. Results

Replicating and extending findings from Butler and Markman (2012), 3-year-olds still did not appear to make any distinction between the pedagogical and intentional conditions, even with this clearer break in the overarching pedagogical interaction. Children made similar numbers of attempts to elicit the property form 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).

2.3. Discussion

Providing younger children with a clearer break between the pedagogical word learning and evidence phases did not facilitate their ability to selectively use pedagogical 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 made similarly strong inferences in both the pedagogical and intentional conditions. Thus even with a clearer break in the pedagogical context, 3-year-olds were not using the distinction between explicitly pedagogical and non-pedagogical but intentional actions to modulate the strength of their generalizations.

However, it should be noted even in this study 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. We have suggested that the distinction between pedagogical and instrumental intent may be more global for these younger children, happening more on the level of the overarching context rather than moment-by-moment actions. If so, then children may interpret any intentional action taking place within a pedagogical context as essentially equivalent in terms of the information it may potentially carry, and thus may fail to attend to cues to whether or not specific actions were carried out with pedagogical intent in guiding their inferences. It is important to note here that we are not necessarily suggesting that 3-year-olds take all intentional actions to be explicitly pedagogical. But given an overarching pedagogical context, 3-year-olds may not see the specific intent behind a specific action as relevant in terms of the inferences they ought to draw from it. We test this hypothesis in Experiment 2 by completely stripping away any overarching pedagogical expectation for the situation.

3. Experiment 2

One explanation for younger children's apparent failure to distinguish between pedagogical and intentional actions in guiding their inferences is that they may have a more global, overarching sense of being in a pedagogical situation. That is, unlike the older children, who may be conducting a moment-by-moment analysis of whether a particular action is being deliberately produced for their benefit, younger children may simply gauge whether or not they are in the kind of situation in which a knowledgeable adult might teach them something, and then ignore or fail to notice cues about whether or not a specific intentional action is in fact done with pedagogical intent. If so, then leading children to construe the context as ostensibly non-pedagogical, and thus giving them no reason to expect to be explicitly taught something, might enable even 3-year-olds to now make stronger inferences on the basis of explicitly having that evidence produced for their benefit rather than in a merely instrumental manner. We test this hypothesis by introducing a new, clearly non-pedagogical goal that guides the experimenter's actions prior to the demonstration, and then producing identical evidence for a novel function in either a pedagogical or non-pedagogical manner.

3.1. Method

Given the failure of 3-year-olds to use pedagogical cues even given the clearer interruption in Experiment 1, here we set out to test whether a wholesale change in the overarching scene to one which children were not expecting to learn anything, would be sufficient for 3-year-olds to now use pedagogical cues. Given this large a change, we also tested 4-year-olds in this new version, to ensure that we would replicate their success from Butler and Markman (2012).

3.1.1. Materials

As in Experiment 1, the materials were 11 perceptually identical objects, 2.5 cm × 2.5 cm × 5 cm, covered in black electrical tape. There was one active magnetic object, and 10 inert objects.

3.1.2. Participants

The participants were 48 3-year-olds (M_{age} = 3 year, 6 months; Range: 3 years, 0 months to 3 year, 9 months) and 48 4-year-olds from a university-affiliated preschool (M_{age} = 4 years, 10 months; Range: 4 years, 0 months to 4 years, 11 months). Five additional children were not included in the final sample, either because of experimenter error (4 children) or because

the child's teacher entered the room in the middle of the procedure (1 child). The children were predominately from middle- and upper-SES families. A variety of ethnic backgrounds were represented.

Children within each age group were randomly assigned to one of three experimental conditions (pedagogical, intentional, or accidental), with equal numbers of males and females in each condition.

3.1.3. Procedure

The key change in the current experiment is that instead of establishing a pedagogical situation from the beginning, the experimenter created the sense that the game she intended to play with the child had not yet started. Prior to bringing the child from the classroom to the research room, the experimenter told the child that she had a really fun new kind of puzzle to play. When the experimenter and child entered the room, table was already set up with two piles of colored pencils, a pile of paperclips, and the active target object. The experimenter asked the child to sit down at the table, and pretended not to notice the objects on table while she turned on the camera and prepared to sit down herself. Then, the experimenter appeared to suddenly "notice" what was on the table, and exclaimed, "Oh, it looks like another gameroom teacher didn't clean up the gameroom when she left. It looks like she left her colored pencils out, and her paperclips out, and she left her spoodle out too. Can you hold on for a minute? Before we can start our puzzle game I need to clean these things up." This cover story served two purposes. First, it allowed children to learn the word "spoodle" for the target object, but without the experimenter explicitly teaching it as in Experiment 1, which would have created a pedagogical context. Second, it allowed the experimenter to establish that the game they were supposed to play (the puzzle game) had not yet started, and thus imply that the experimenter's actions were simply with the purpose of cleaning up and getting ready for that game.

After this cover story, the experimenter grabbed a bucket from the floor and moved on to the evidence phase of the experimenter. The evidence and exploration phases were identical to that used in the previous experiments, with the exception that the experimenter remained standing while putting away the objects and carrying out the target action. This was done to reinforce the sense that these actions were not necessarily part of the game that the child had come to play.

The experimenter put away each of the distractors, then picked up the active spoodle. In the *pedagogical* condition, she made eye contact with the child and said, "look, watch this," and then deliberately placed the spoodle on the paperclips, picking it up with paperclips attached. In the *intentional* condition, the experimenter carried out the identical action, deliberately placing the spoodle on the paperclips and picking it up with paperclips attached, but never made eye contact or otherwise interacted with the child during this period. The *accidental* condition was identical to the *intentional* condition (i.e., no ostensive cues), except that the experimenter appeared to accidentally drop the spoodle on the paperclips as he was putting it away, exclaiming "oops!" In all three conditions she then looked at it and said, "wow!"

After producing the functional evidence, the experimenter then placed the 10 inert spoodles on the table, saying, "and here are some more spoodles," and told the child to "'go ahead and play"' while she left table and sat facing away from the child for 60 s. At this point the paperclips were directly in front of the child (as they had been from the beginning of the study), the active object was lying on table to the child's left, on its side with paperclips attached, and the inert objects were on table to the child's right. All objects were within easy reach for the child.

3.1.4. 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.

As in Experiment 1, children's exploration violated assumptions of normality and homogeneity of variance. Thus we used non-parametric Mann–Whitney tests to directly compare the pedagogical condition to the intentional and accidental conditions.

3.2. Results

3.2.1. 4-year-olds

Replicating previous findings (Butler & Markman, 2012), 4-year-olds made significantly more attempts to elicit the property from the inert objects in the pedagogical condition ($M_{\text{pedagogical}} = 11.81$, SD = 11.91) than in either the intentional ($M_{\text{intentional}} = 5.25$, SD = 6.82; Mann–Whitney $Z = 2.01$, $p = .044$) or accidental ($M_{\text{accidental}} = 3.63$, SD = 6.56; Mann–Whitney $Z = 3.00$, $p = .003$) conditions (see Fig. 1). There was no difference between the intentional and accidental conditions (Mann–Whitney $Z = 1.06$, $p = .287$).

3.2.2. 3-year-olds

Unlike in either Experiment 1 or Butler and Markman (2012), in the present study when 3-year-olds had the overarching pedagogical context stripped away, and thus had no expectation of explicitly being taught something, they too made significantly stronger inferences about the generalizability of the property to other members of the kind when it was demonstrated pedagogically, even compared to witnessing an identical, intentional action done in a non-pedagogical manner.

Three-year-olds made significantly more attempts to elicit the property from the inert objects in the pedagogical condition ($M_{\text{pedagogical}} = 6.69$, SD = 6.86) than in either the intentional ($M_{\text{intentional}} = 2.00$, SD = 2.90; Mann–Whitney $Z = 2.01$, $p = .044$) or

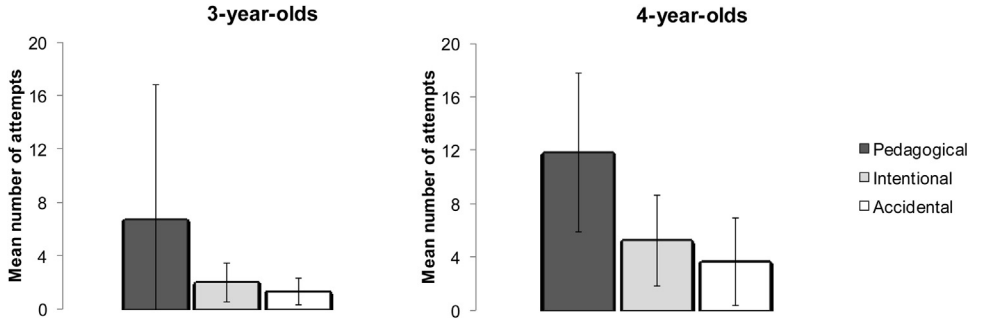

Fig. 1. Mean number of attempts in each condition in Experiment 2. $N = 96$ (16 per condition). Error bars represent 95% confidence intervals.

accidental ($M_{accidental} = 1.31$, SD = 1.96; Mann–Whitney $Z = 2.43$, $p = .015$) conditions (see Fig. 1). There was no difference between the intentional and accidental conditions (Mann–Whitney $Z = 0.58$, $p = .565$).

3.3. Discussion

In Experiment 2, we tested whether stripping away the overarching pedagogical context, and thus removing any general expectation that they might be taught something, led even 3-year-old children to capitalize on pedagogical cues in order to guide their inferences. The results were clear: when there was no overarching pedagogical context, both 3- and 4-year-olds made significantly stronger inferences about evidence that had been explicitly, pedagogically demonstrated for their benefit, even relative to identical evidence that had been produced in an intentional, but non-pedagogical manner. Younger children are in fact capable of using pedagogical cues to guide their inductive inferences about the generalizability of novel information, but only when the overarching pedagogical context is stripped away did 3-year-olds successfully distinguish between pedagogical and intentional action in making inferences about generalizability.

4. General discussion

Young children can use their recognition of whether novel information is being explicitly communicated for their pedagogical benefit to guide inferences about its importance and generalizability (Butler & Markman, 2012, 2014). However, doing so requires that children identify which specific actions in an overarching context are intended as pedagogical demonstrations. Our findings show that there are clear developmental differences in children's ability to do this. Data from prior studies (Butler & Markman, 2012, 2014) suggest that 4-year-olds may be quite adept at navigating ongoing pedagogical interactions. Regardless of how relevant evidence is produced, 4-year-olds learn an object's function and explore to see whether other category members share that function. But they reserve strong generalizations for properties that are demonstrated for their benefit, persistently exploring and trying to elicit that property from additional category members. Moreover, they do so even in an overarching pedagogical situation.

In contrast, 3-year-olds appear to take any intentional action that occurs within a as equally licensing inductive inferences. They appear only to use cues that a particular *action* is meant as pedagogical to modulate the strength of their inferences in a context that removes any general expectation of being taught something by a knowledgeable adult. Even clearly interrupting the pedagogical interaction, as in Experiment 1, does not seem to be enough to disengage children's overall pedagogical interpretation of the situation. Instead the overarching pedagogical expectation itself may need to be eliminated.

Younger children are most certainly capable of recognizing communicative cues (Csibra, 2010). But they have yet to learn how to apply this sensitivity selectively in context, navigating ongoing interactions to identify which actions are being done 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 assume all actions taking place within that interaction to be equally relevant to their learning, regardless of whether or not they are intended as pedagogical demonstrations. That is not to say that younger children aren't capable of selectively learning form others' actions, but rather that they may only constrain their inferences when an action is clearly marked as not relevant for them, for example as accidental. Indeed, they do restrict the inferences they make on the basis of accidental actions that are explicitly marked e.g., by saying "oops" both here in Experiment 2, and in Butler and Markman (2012). That said, they seem to assess mainly whether the overall context is one in which they might expect to learn something, and not whether each specific action is being carried out for their benefit. They also do not appear to treat shifts in the topic of an ongoing pedagogical interaction as relevant to their inferences. Rather, they treat any action that comes within an overarching pedagogical situation as an act of teaching.

It is important to point out that casting a wide net on what might be pedagogical can itself be adaptive for learning. It makes some sense to pay attention and learn from any intentional action that you witness an adult carrying out. And across all the conditions in our experiments children do learn and imitate the novel action regardless of how it is produced.

Being overly sensitive to whether every specific action is carried out pedagogically might in some cases lead children to be overly conservative about the generalizability of novel information (see Bonawitz et al., 2011 Bonawitz, Shafto, Gweo, Goodman, & Spelke, 2011). But what does not seem adaptive – and what younger children may be doing – is treating any action that occurs within a pedagogical context as equally licensing inferences that may be resistant to counterevidence. Learning from and making at least some tentative generalization on the basis of an intentional or even accidental actions seems relatively low-cost, but making a strong inference that is resistant to counterevidence, especially on the basis of limited evidence, could be maladaptive. Children could, for example, mistakenly generalize even idiosyncratic, unusual ways to use an object as typical. Indeed, 3-year-olds do seem to treat any knowing, confident intentional action with a novel tool as not only typical but even normative (Schmidt, Rakoczy, & Tomasello, 2011). Of course, it is an open question whether 3-year-olds truly interpret, or even over-interpret, intentional actions as explicitly done *for* them with pedagogical intent when they come amidst an overarching pedagogical context, or whether they simply fail to attend to specific pedagogical cues unless they have not already been engage in a pedagogical interaction. We know from the literature on over-imitation reviewed earlier that children do have a robust tendency to view novel causal actions as relevant and important (either causally or socially), even when they should not be taken as such (Kenward, 2012; Lyons et al., 2007; Marsh et al., 2014; Nielsen, 2006; Nielsen et al., 2012, 2015). At least by age 4, however, it appears that over-imitation may be more selective (Keupp, Bancken, Schillmoeller, Rakoczy, & Behne, 2015; Keupp, Behne, Zachnow, Kasbohm, & Rakoczy, 2015). Thus it may well be that the developmental progression is one from assuming all actions in a potentially pedagogical learning situation are treated as equally important, and only with further development do children come to be more selective in their inferences. Investigating this developmental progression will be an important avenue for future research digging deeper into children's social learning. Regardless, in considering children's social learning, it is only particularly helpful for children to use their understanding of others' communicative and pedagogical intentions to guide their inferences if they can do so selectively, and this capacity appears to be developing between ages 3 and 4.

The findings of the present research shed new light on the functioning of a powerful mechanism for leveraging the social knowledge of others in the process of constructing a conceptual understanding of novel kinds and categories. Building on previous research, we have found that preschoolers can use pedagogical cues to identify actions meant for them, and that this has powerful consequences for their inductive inferences. But learning to selectively apply this learning mechanism in context requires the capacity to navigate ongoing pedagogical interactions, specifically identifying which actions are meant as pedagogical demonstrations for the child's own benefit, and which are irrelevant or incidental. This skill appears to be in construction at between ages 3 and. 4. This research also opens up an important avenue of research into how children's expectations about being taught may affect their learning. In particular, while the kind of pedagogical demonstration explored here is ubiquitous in Western society, it is notably different or even absent in some other societies (Hewlett, Fouts, Boyette, & Hewlett, 2011; Rogoff, 2003; Shneidman, Gaskins, & Woodward, 2015; Shneidman & Woodward, 2015). Clearly the details of how social learning works will be very different in a society that does not employ clear pedagogical teaching or direct instruction, and capturing those differences is an important goal of current and future research. Although further research is needed to more fully capture the development and application of pedagogical reasoning, the ability to make different inferences on the basis of whether or not information is explicitly conveyed pedagogically represents a powerful tool that children may employ to quickly learn important, generic information about the world from limited exposure to novel information. Our findings highlight how the development of young children's sensitivity to the nuances in others' social behavior can impact their conceptual development.

Acknowledgments

This research was based in part on a doctoral dissertation submitted to Stanford University, and was supported by a NSF Graduate Research Fellowship. The first author was also supported by an Alexander von Humboldt Foundation Fellowship for Postdoctoral Researchers during the preparation of this manuscript. Special thanks to the parents, children, teachers, and staff at the Bing Nursery School. We also thank Ariana Borgaily, Jamie Lawrence, and Kimmy Scheible for assistance with data collection and coding, and Andrei Cimpian and members of our lab for helpful discussion of this work.

References

Butler, L. P., & Markman, E. M. (2012). Preschoolers use intentional and pedagogical cues to guide inductive inferences and exploration. *Child Development*, *83*, 1416–1428.
Butler, L. P., & Markman, E. M. (2014). Preschoolers use pedagogical cues to guide radical reorganization of category knowledge. *Cognition*, *130*, 116–127.
Bonawitz, E., Shafto, P., Gweon, H., Goodman, N. D., Spelke, E., & Schulz, L. (2011). The double-edged sword of pedagogy: instruction limits spontaneous exploration and discovery. *Cognition*, *120*(3), 322–330.
Csibra, G. (2010). Recognizing communicative intentions in infancy. *Mind & Language*, *25*, 141–168.
Csibra, G., & Gergely, G. (2009). Natural pedagogy. *Trends in Cognitive Sciences*, *13*, 148–153.
Egyed, K., Király, I., & Gergely, G. (2013). Communicating shared knowledge in infancy. *Psychological Science*, *24*, 1348–1353.
Futó, J., Téglás, E., Csibra, G., & Gergely, G. (2010). Communicative function demonstration induces kind-based artifact representation in preverbal infants. *Cognition*, *117*, 1–8.
Gelman, S. A. (2003). *The essential child: origins of essentialism in everyday thought*. New York: Oxford University Press.
Gelman, S. A., & Wellman, H. M. (1991). Insides and essences: early understandings of the non-obvious. *Cognition*, *38*(3), 213–244.
Gergely, G., & Csibra, G. (2005). The social construction of the cultural mind: imitative learning as a mechanism of human pedagogy. *Interaction Studies*, *6*, 463–481.

Gergely, G., & Csibra, G. (2006). Social learning and social cognition: the case for pedagogy. In Y. Munakata, & M. H. Johnson (Eds.), *Processes of Change in Brain and Cognitive Development. Attention and Performance, XXI.* (pp. 249–274). Oxford University Press: Oxford.
Gergely, G., & Jacob, P. (2012). Reasoning about instrumental and communicative agency in human infancy. In J. B. Benson, F. Xu, & T. Kushnir (Eds.), *Rational constructivism in cognitive development* (pp. 59–94). New York: Elsevier Inc.: Academic Press.
Goodman, N. (1965). *Fact, fiction, and forecast. Indianapolis*. Bobbs-Merrill Company.
Herrmann, P. A., Legare, C. H., Harris, P. L., & Whitehouse, H. (2013). Stick to the script: the effect of witnessing multiple actors on children's imitation. *Cognition*, *129*, 536–543.
Hewlett, B. S., Fouts, H. N., Boyette, A. H., & Hewlett, B. L. (2011). Social learning among Congo Basin hunter-gatherers. *Philosophical Transactions of the Royal Society B*, *366*, 1168–1178.
Horner, V., & Whiten, A. (2005). Causal knowledge and imitation/emulation switching in chimpanzees (*Pan troglodytes*) and children (*Homo sapiens*). *Animal Cognition*, *8*, 164–181.
Keil, F. C. (1989). *Concepts, kinds and cognitive development*. MA: MIT PressCambridge.
Kenward, B. (2012). Over-imitating preschoolers believe unnecessary actions are normative and enforce their performance by a third party. *Journal of Experimental Child Psychology*, *112*, 195–207.
Kenward, B., Karlsson, M., & Persson, J. (2011). Over-imitation is better explained by norm learning than by distorted causal learning. *Proceedings of the Royal Society of London B: Biological Sciences*, *278*(1709), 1239–1246.
Keupp, S., Behne, T., & Rakoczy, H. (2013). Why do children overimitate? Normativity is crucial. *Journal of Experimental Child Psychology*, *116*(2), 392–406.
Keupp, S., Bancken, C., Schillmoeller, J., Rakoczy, H., & Behne, T. (2015). Rational over-imitation: preschoolers consider material costs and copy causally irrelevant actions selectively. *Cognition*, *147*, 85–92.
Keupp, S., Behne, T., Zachnow, J., Kasbohm, A., & Rakoczy, H. (2015). Over-imitation is not automatic: Context sensitivity in children's overimitation and action interpretation of causally irrelevant actions. *Journal of Experimental Child Psychology*, *130*, 163–175.
Luo, Y., & Baillargeon, R. (2007). Do 12.5-month-old infants consider what objects others can see when interpreting their actions? *Cognition*, *105*, 489–512.
Lyons, D. E., Damrosch, D. H., Lin, J. K., Macris, D. M., & Keil, F. C. (2011). The scope and limits of overimitation in the transmission of artefact culture. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *366*(1567), 1158–1167.
Lyons, D. E., Young, A. G., & Keil, F. C. (2007). The hidden structure of overimitation. *Proceedings of the National Academy of Sciences*, *104*, 19751–19756.
Markman, E. M. (1989). *Categorization and naming in children: problems of induction*. Cambridge, MA: MIT Press.
Marsh, L., Ropar, D., & Hamilton, A. (2014). The social modulation of imitation fidelity in school-age children. *PLoS One*, *9*, e86127.
McGuigan, N., & Whiten, A. (2009). Emulation and overemulation in the social learning of causally opaque versus causally transparent tool use by 23- and 30-month-olds. *Journal of Experimental Child Psychology*, *104*(4), 367–381.
McGuigan, N., Whiten, A., Flynn, E., & Horner, V. (2007). Imitation of causally opaque versus causally transparent tool use by 3- and 5-year-old children. *Cognitive Development*, *22*(3), 353–364.
Meltzoff, A. N. (1995). Understanding the intentions of others: re-enactment of intended acts by 18-month-old children. *Developmental Psychology*, *31*, 838–850.
Nielsen, M. (2006). Copying actions and copying outcomes: social learning through the second year. *Developmental Psychology*, *42*, 555–565.
Nielsen, M., Moore, C., & Mohamedally, J. (2012). Young children overimitate in third-party contexts. *Journal of Experimental Child Psychology*, *112*, 73–83.
Nielsen, M., Kapitany, R., & Elkins, R. (2015). The perpetuation of ritualistic actions as revealed by young children's transmission of normative behavior. *Evolution and Human Behavior*, *36*, 191–198.
Onishi, K. H., & Baillargeon, R. (2005). Do 15-month-old infants understand false beliefs? *Science*, *308*, 255–258.
Over, H., & Carpenter, M. (2012). Putting the social into social learning: explaining both selectivity and fidelity in children's copying behavior. *Journal of Comparative Psychology*, *126*(2), 182–192.
Rogoff, B. (2003). *The cultural nature of human development*. New York: Oxford University Press.
Schmidt, M. F. H., Rakoczy, H., & Tomasello, M. (2011). Young children attribute normativity to novel actions without pedagogy or normative language. *Developmental Science*, *14*(3), 530–539.
Shneidman, L., Gaskins, S., & Woodward, A. (2015). Child-directed teaching and social learning at 18 months of age: evidence from Yucatec Mayan and U. S. infants. *Developmental Science* (in press).
Shneidman, L., & Woodward, A. L. (2015). Are child-directed interactions the cradle of social learning? *Psychological Bulletin* (in press).
Sperber, D., & Wilson, D. (1986). *Relevance: communication and cognition*. Cambridge, MA: Harvard University Press.
Tomasello, M. (1999). *The cultural origins of human cognition*. Cambridge, MA: Harvard University Press.
Williamson, R. A., & Markman, E. M. (2006). Precision of imitation as a function of preschoolers' understanding of the goal of the demonstration. *Developmental Psychology*, *42*, 723–731.
Williamson, R. A., & Meltzoff, A. N. (2011). Own and others' prior experiences influence children's imitation of causal acts. *Cognitive Development*, *26*, 260–268.
Williamson, R. A., Meltzoff, A. N., & Markman, E. M. (2008). Prior experiences and perceived efficacy influence 3-year-olds' imitation. *Developmental Psychology*, *44*, 275–285.
Woodward, A. L. (1998). Infants selectively encode the goal object of an actor's reach. *Cognition*, *69*, 1–34.
Yoon, J. M. D., Johnson, M. H., & Csibra, G. (2008). Communication-induced memory biases in preverbal infants. *Proceedings of the National Academy of Sciences of the USA*, *105*, 13690–13695.