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SHORT REPORT

Pedagogical cues encourage toddlers' transmission of recently demonstrated functions to unfamiliar adults

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Abstract

Young children use pedagogical cues as a signal that others' actions are social or cultural conventions. Here we show that children selectively transmit *(enact in a new social situation) causal functions demonstrated pedagogically, even when they have learned and can produce alternative functions as well. Two-year-olds saw two novel toys, each with two functions. One experimenter demonstrated one function using pedagogical cues (eye contact and child-directed speech) and a second experimenter demonstrated the alternative function using intentional actions towards the object, but without pedagogical cues. Children imitated both functions at equal rates initially, indicating equal causal learning from both types of demonstration. However, they were significantly more likely to enact the pedagogical function for a new adult not present during the initial demonstrations. These results indicate that pedagogical cues influence children's transmission of information, perhaps playing a role in the dissemination of cultural conventions from a young age.*

Research highlights

- Demonstrates that the social context in which young children learn novel functions leads to selective social transmission, despite equal causal learning.
- Directly contrasts pedagogical demonstrations of causal functions with equally intentional, but non-pedagogical demonstrations.
- Demonstrates the potential for using unfamiliar third parties to assess children's social behavior and inferences about conventions (e.g. object functions, word learning, etc.).
- Indicates that pedagogical cues influence children's own transmission of culturally relevant information to others.

Introduction

Humans may be unique in the extent to which they transmit and maintain conventions and cultural norms (Tomasello, 1996; Tomasello, Kruger & Ratner, 1993; Whiten, Horner, Litchfield & Marshall-Pescini, 2004). By definition, conventions are manners of speech or action that are common throughout a society, though perhaps arbitrary and to some extent symbolic (Diesendruck, Carmel & Markson, 2010; Kalish & Sabbagh, 2007; Rakoczy Warneken & Tomasello, 2008). Recent research has examined how young children learn conventional behaviors, ranging from words, to object functions, to rules of social behavior (Butler & Markman, 2012; Diesendruck *et al.*, 2010; Diesendruck & Markson, 2001; Graham, Stock & Henderson, 2006; Henderson & Graham, 2005; Rakoczy *et al.*, 2008; Rakoczy, Brosche, Warneken & Tomasello, 2009a; Rakoczy, Warneken & Tomasello, 2009b; Schmidt, Rakoczy & Tomasello, 2011). While this research has highlighted children as rapid learners, or receivers, of conventions, much less attention has been directed at investigating children as disseminators, or transmitters, of conventions in new social situations.

One notable exception is work by Whiten and Flynn (2010; Flynn & Whiten, 2012), who examined the spontaneous dissemination of novel actions in preschool classrooms. Whiten and Flynn (2010) taught child models one of two methods (two causally efficacious

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actions) for extracting a reward from a foraging device, 'lift' or 'poke'. The child models demonstrated the actions in their respective classrooms and other children were permitted to use the device. Initially, children produced the modeled actions exclusively, but with time, children began to produce new efficacious actions, demonstrating innovation. After five days of experience with the device, most of the children in the classroom produced the action that they witnessed other children produce most often, regardless of whether it was one initially modeled or a technique that children innovated on their own. These results show how young children engage in social learning in the context of everyday play, by acting as both observers *and* transmitters of new information. However, in this example, transmission may have been an incidental outcome of children's play with objects in attaining their own goals. Thus, this study leaves open the question of whether children can be both deliberate and selective in transmitting certain types of information over others, and what factors might motivate selective transmission. Most critically, and unique to the present study, addressing this question would highlight the potential role that children themselves play in promoting and transmitting cultural conventions.

Theorists have suggested that infants and young children are predisposed to infer social relevance from demonstrations that include pedagogical (or 'ostensive') cues such as eye contact, child-directed speech, and generic language (Csibra & Gergeley, 2009; Southgate, Chevallier & Csibra, 2009; Schmidt *et al.*, 2011). In many cases, children generalize further (Butler & Markman, 2012), imitate more faithfully (Southgate *et al.*, 2009; Brugger, Lariviere, Mumme & Bushnell, 2007), and even restrict causal exploration (Bonawitz, Shafto, Gweon, Goodman, Spelke & Schulz, 2011) when actions are pedagogically demonstrated. Also, when compared to observational learning from non-pedagogical demonstrations, pedagogical demonstrations serve as a gateway to further social and psychological inferences, such as inferences about a person's familiarity with an object (Moll & Tomasello, 2007) and inferences about the social relevance of particular action sequences (Southgate *et al.*, 2009). These studies (and many others) suggest that pedagogical cues are a likely candidate to induce selective transmission of socially relevant information.

Here, we ask whether 2-year-old toddlers selectively transmit – that is, reproduce for a new person in a new social situation – information that they have learned about an object through a pedagogical demonstration. Critically, we investigate whether this selective transmission occurs despite children having learned other things about that object as well. To this end, we focus on the distinction between causal and conventional functions of objects. As Whiten and Flynn (2010) showed, preschool-aged children can learn to produce causally efficacious actions from incidental observations without explicit pedagogical cues. This result is supported by many studies showing that pedagogical cues are neither necessary (e.g. Matheson, Moore & Akhtar, 2013) nor sufficient (e.g. Gopnik, Sobel, Schulz & Glymour, 2001; Buschbaum, Gopnik, Griffiths & Shafto, 2011) for causal learning in controlled laboratory settings.

One recent study investigated the role of pedagogical cues versus intentional non-pedagogical cues in 3-year-old children's learning of novel conventional functions of objects (Schmidt *et al.*, 2011). This study assessed children's imitation of demonstrated functions and protests in response to a puppet's violations of those functions. The 3-year-old children were sensitive to whether the demonstrations were performed intentionally as opposed to accidentally, but further pedagogical cues were not necessary for them to treat the functions as conventional (Schmidt *et al.*, 2011). These results run contrary to findings mentioned previously, and seem to suggest that pedagogical cues and intentional, non-pedagogical cues both lead children to infer conventionality of object functions. However, it is worth noting that in Schmidt *et al.* (2011), there was no direct comparison between the pedagogical and the intentional cues presented to children. Rather, each type of cue was contrasted with an accidental act, one from which few inferences (social or causal) are warranted. Also, this study did not take the additional step of observing children transmit information in the presence of third parties not present in the initial demonstration (as in Whiten & Flynn, 2010). Thus our question remains.

In order to address this question, we designed a task appropriate for 2-year-old children in which two experimenters each demonstrated, with clear intentions, a distinct action on the same object. We used novel objects that, when acted upon, could each produce two outcomes (i.e. light or sound). The actions therefore represented two causal functions of the object (Diesendruck *et al.*, 2010; Butler & Markman, 2012). In an initial demonstration phase, one experimenter engaged directly with the child using eye contact and child-directed speech while performing one function, whereas the other experimenter performed the alternative function intentionally, but directed their attention only at the object and did not engage with the child. After each demonstration, we measured children's imitation of each function as an index of causal learning. In particular, we coded the *first action* children produced with the object, as a conservative measure of how children understood the request to act on the object. In addition,

we coded the *duration of time* children produced the demonstrated action. We expected children to learn and thus imitate each action following its demonstration first and for longer regardless of whether it was demonstrated in a pedagogical or non-pedagogical fashion. This prediction follows easily from other findings in causal learning from intentional actions.

We then introduced children to a third experimenter, an unfamiliar adult with whom neither the children nor the demonstrators had previously interacted. This new adult made a general request for information about the object. Again we coded both first action and duration of *each* type of demonstrated function produced. Even though actions demonstrated are potentially valid responses to this general request, we predicted that children would selectively transmit the function that was initially demonstrated using pedagogical cues in this new social situation both initially and for longer. This pattern of results would suggest that, in new situations, children transmit pedagogical demonstrated causal functions, perhaps inferring their conventional significance.

Method

Participants

Thirty-two 2-year-old children participated (M = 25.10 months, SD = 1.80 months). The children were all from a rural university town and were predominantly Caucasian and middle class. All participants were native English speakers. Eight additional children were excluded from the final sample, one due to experimenter error and the remaining seven children due to uncooperativeness (i.e. refusal to sit at a table for the demonstration of the functions).

Stimuli

The stimuli were two novel toys, referred to as the Cylinder and the Rectangle (see Figure 1), each of which produced a sound when acted upon in one way and a light when acted upon in another way. Both objects were decorated differently to disguise their original appearance. The Cylinder was 8 inches in length and 1.5 inches in diameter. One end of the object whistled when blown. A button in its center caused a light at the other end to flash. The Rectangle was made of blue Lego© blocks, and was 8 inches in height, 1 inch thick, and 4 inches wide. A crank produced a mechanical sound while a yellow button in the toy's center activated a blinking flashlight at one end.

Figure 1 *The two toys used as the novel objects. The Cylinder is shown on the left and the Rectangle on the right. Each toy made a sound if manipulated in one way, and projected a light if manipulated in another way.*

Apparatus

Sessions took place in a quiet room in the laboratory. The child sat on one side of a child-sized table across from two experimenters. Interactions were recorded with two Sony DCR-SR68 digital cameras. One camera was positioned at the side of the table, capturing both experimenters and the child, and the second camera was positioned behind the experimenters to capture the child's visual attention and movements.

Procedure

Warm-up

The demonstrators played with the child until he/she was sufficiently comfortable to sit alone. The experimenter who conducted the transmission test trials, termed the unfamiliar adult, did not interact with the child or the demonstrators before the experiment began. The child's caretaker sat behind the child and was told to refrain from interacting with the child.

Demonstration phase

Children viewed two experimenters demonstrate a distinct function of the same object. One experimenter was designated the *pedagogical demonstrator* and the other, the *intentional*, *non-pedagogical demonstrator*. Order of demonstrators (pedagogical first versus intentional, non-pedagogical first), the functions (i.e. light vs. sound), and the toys (cylinder first vs. rectangle first) were counterbalanced across participants. In order to control for the type of action, a distinct novel action was used for each

demonstration (i.e. turn crank and then press button versus wave light and then blow the whistle).

Pedagogical demonstration

The pedagogical demonstrator made eye contact with the child, presented one of the toys and commented, 'Look! Do you see this?' She then activated one of the toy's functions, either the sound or light, in a slow, deliberate manner. She repeated this demonstration three times, then placed the toy in front of the child and commented, 'Your turn.' The child had 30 seconds to act upon the toy. If the child did not act upon the toy immediately, the pedagogical demonstrator prompted, 'You try.' Throughout this demonstration, the non-pedagogical demonstrator gazed at a clipboard in her lap.

Intentional, non-pedagogical demonstration

In contrast, the intentional, non-pedagogical demonstrator maintained her attention exclusively on the toy while holding it in front of her. She looked at the toy and commented to herself without making eye contact or directly addressing the child, saying, 'I like this! Nice!' and then activated the remaining function of the toy in the same slow, demonstrative manner. She repeated the demonstration three times, then placed the toy in front of the child and said, 'Your turn.' The child had 30 seconds to act upon the toy. As in the Pedagogical Demonstration, if the child did not act upon the toy, the non-pedagogical demonstrator prompted, 'You try.' Throughout this demonstration, the pedagogical demonstrator gazed downward at a clipboard.

Transmission phase

After both functions had been modeled for the first object, the pedagogical demonstrator and the intentional, non-pedagogical demonstrator left the table, moved to a far corner of the room, and turned their backs to the child. Then the unfamiliar adult, not present in the initial Demonstration phase and blind to the pedagogical status of the actions, entered the room. She smiled, greeted the child, sat down, picked up the toy, and asked the child, 'What is this? What does this do?' She then placed the toy in front of the child and maintained her gaze on the child and toy. If the child did not respond, she repeated the prompt. The unfamiliar adult was careful not to respond to how the child manipulated the toy. After 30 seconds, she thanked the child, took the toy, and left the room.

Next, the original demonstrators returned to the table with the second object and swapped seats to control for possible side preferences. For this second toy, each demonstrator again acted upon this object in the same manner as they had with the first toy (i.e. either pedagogically or intentionally but non-pedagogically), with the ordering counterbalanced as described above. Once both functions and their outcomes had been demonstrated, the demonstrators again left the table and the unfamiliar adult returned and, as she had before, asked the child to show her what the second toy did.

Coding

First action coding

Two condition-blind observers coded children's initial action on the objects during each Demonstration and Transmission phase. The experimenter's demonstrations were edited from the videos such that the coders were unaware of both the function that was demonstrated and the social context in which it was performed. The observers coded which of the two possible functions children performed first on each object immediately following each of the demonstrations (two per object: one pedagogical, one intentional non-pedagogical) and which function they performed first in the Transmission phase. Children received a score of 1 if the first action they produced following the demonstration was the just-demonstrated function and a 0 if not. A condition-blind observer performed reliability coding on a random subset of 50% of the participants' first action responses. Overall agreement between coders was 94% ($\kappa = .88$, $p < .01$).

Action duration coding

The observers also coded the number of seconds that the child spent producing each function during the 30 seconds following each demonstration and in the 30 seconds following the requests in the Transmission phase. Reliability for the continuous duration coding was assessed by means of a Pearson's correlation statistic based on 50% of the participants and was high, $r = .92$, $p < .01$.

Switch and sequence coding

A condition-blind observer counted the number of times children switched between the two functions during each 30-second response interval. This measure was included to capture the range of actions children produced in the

response interval and, critically, to compare whether the sequence of actions, as indexed by the amount of switching relative to the first response, varied between demonstration types, response types, trials, or between Demonstration and Transmission phases. A second observer coded a random subset of 50% of the observations. Reliability was acceptably high (r = .61, $p < .001$).

Social engagement coding

To check whether demonstrations induced differing levels of social engagement (e.g. more eye contact, more faithful imitation), two observers coded children's social engagement with each experimenter during the response period following each Demonstration phase. We gave children more points if they engaged more with the experimenter while manipulating the object. If children did not manipulate the object at all they received a score of 0. Children received a score of 1 if they attempted to reproduce the function without engaging the demonstrator's attention during their reproduction. Finally, children received a score of 2 if they attempted to reproduce the function either while visually attending to and/or directing (i.e. vocally or manually) the demonstrator's attention to their actions. Thus engagement coding was different from action-duration coding in that children could make successful responses (by the criteria in the previous section) but score low on engagement. Agreement between the coders on a subset of 25% of the scores indicated high reliability (94% concordance, $\kappa = .80$, $p < .01$).

Results

First action analyses: Demonstration phase

We began by examining whether children immediately reproduced the demonstrator's function following each demonstration as one indicator of how children understood the request to act upon the object. Since children viewed four functions in total (i.e. two with the first object and two with the second object), they had the opportunity to imitate four functions (i.e. two pedagogical functions and two intentional, non-pedagogical functions). As children were equally likely to reproduce the functions for any given demonstration type (i.e. pedagogical versus non-pedagogical) regardless of trial order (McNemar's, *ns*), within-trial demonstration order (pedagogical first or second), type of toy (i.e. Rectangle and Cylinder), or function type (i.e. button press, whistle, arm crank, flashlight, all paired *t*-tests, *ns*), we combined across these factors for our analysis.

The total number and percentage of children who reproduced each function (pedagogical and non-pedagogical) immediately following each demonstration is displayed in Table 1. Mostly, children reproduced one of each type (31%), but 16% of children imitated both functions of each type. In addition, 12% of children imitated at least one pedagogical function but neither of the non-pedagogical functions, and 9% of children imitated at least one non-pedagogical function but neither of the pedagogical functions. Lastly, 13% did not imitate either function. Thus, children were equally likely to first imitate the pedagogical and intentional, non-pedagogical functions following their respective demonstrations (McNemar-Bowker's, *ns*). Moreover, children's imitation of the pedagogical and intentional, non-pedagogical functions was significantly correlated, $r = .35$, $p = .05$, indicating that children who were likely to imitate pedagogical functions were also likely to imitate non-pedagogical functions.

Action duration analyses: Demonstration phase

We also compared the time children spent producing each of the demonstrated functions across the two types of 30-second post-demonstration intervals. Preliminary analyses failed to reveal any significant effects of toy (i.e. Rectangle and Cylinder), within-trial demonstration order (i.e. pedagogical first or second), trial order (i.e. first object or second object) or function type (i.e. button press, whistle, arm crank, flashlight, all paired *t*-tests, *ns*). We thus combined across these factors, and present the average summed times of the action durations (i.e. across two combined 30-second intervals of each type).

The results are displayed in Figure 2. A paired samples *t*-test showed that children did not differ significantly in reproducing the pedagogical (M = 15.38 s, SD = 12.14 s) and non-pedagogical (M = 13.81 s, SD = 14.08 s) functions following each of their demonstrations, $t(31) = .636$, $p = .53$.[1]

Switch and sequence analyses: Demonstration phase

To further examine the sequence of actions throughout each 30-second response interval, we looked at the number times children switched actions after their first response. There was no effect of within-trial

[1] A comparable analysis of the number of discrete actions (e.g. number of button-presses or crank turns) reproduced also showed no difference; combined across both demonstration objects, children reproduced the pedagogically demonstrated function (M = 6.44, SD = 5.60) and non-pedagogically demonstrated function (M = 5.69, SD = 5.24) at equal rates, $t(31) = .59$, *ns*.

Table 1 *Number (and percentage) of children who reproduced (i.e. imitated) each function (pedagogical and non-pedagogical) immediately following each demonstration (four demonstrations total)*

First action	Did not imitate a pedagogical function	Imitated 1 pedagogical function	Imitated 2 pedagogical functions
Did not imitate a non-pedagogical function	4 (13%)	2 (6%)	2 (6%)
Imitated 1 non-pedagogical function	2 (6%)	10 (31%)	3 (9%)
Imitated 2 non-pedagogical functions	1 (3%)	3 (9%)	5 (16%)

Note: Children who imitated at least one function of each demonstration type as their first response are shaded in dark grey (see the lower right of the table). Light grey shading shows children who imitated only one demonstration type but not the other (thus, they never produced the alternative function). Finally, children who failed to reproduce any of the demonstrated functions are shown in the box that is not shaded (top left).

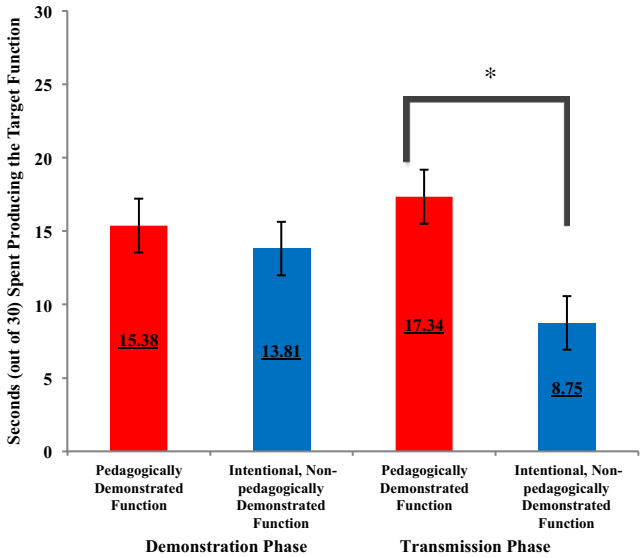

Figure 2 *The time children spent imitating and transmitting the functions for each object and summed across both trials is shown. The two left-most columns display the average number of seconds children spent imitating the just demonstrated function for the pedagogical and intentional, non-pedagogical demonstrators. The two right-most columns display the average number of seconds children spent performing each function for the unfamiliar adult. The bars represent standard error of the mean (*p < .05).*

demonstration order (pedagogical first or second) for either demonstration phase trial (*t*-tests, *ns*) so results were combined. A 2 (Demonstration Type: Pedagogical vs. Intentional, Non- Pedagogical) × 2 (Trial Order: First Demonstration vs. Second Demonstration) revealed an effect of trial order, $F(1, 31) = 30.15$, $p < .001$, but no other effects. Children switched actions frequently during the second round of demonstrations ($M = 3.67$ switches, $SD = 5.17$), but almost never switched in the first round ($M = .27$, $SD = .62$). Critically, we also confirmed that, for each demonstration type and trial order, the number of switches was unrelated to a tendency to imitate the demonstrator (all *t*-tests, *ns*).

First action analyses: Transmission phase

We then assessed which of the demonstrated functions children transmitted first to the unfamiliar adult. Of the 32 children, only one child never complied with the request (on either trial), whereas the remaining children (97%) transmitted at least one demonstrated function on at least one trial, and of those 31, 21 (68%) did so on both trials.

We analyzed the first function transmitted following the unfamiliar adult's prompt ('What does this do?'). In response to this question, children could transmit the pedagogically demonstrated function first, the non-pedagogically demonstrated function first, or neither. There were no differences between the first and second Transmission phases (Wilcoxon's signed-rank test, *ns*) so we combined across the two transmissions phases by counting the number of first responses of each type. Figure 3 shows the distribution of first responses ordered by frequency and exclusivity. Of the 31 children who responded to the unfamiliar adult's request, the majority of them (16/31, 52%) responded by repeating the pedagogically demonstrated function exclusively, either both times (10; 32%) or once with one no-response (6; 19%). Ten (32%) children's first responses were mixed, they performed one action of each demonstration type, and five (16%) only performed the non-pedagogically demonstrated action (either both times or once with one no-response). Scoring these responses (+1, 0, −1 respectively) and comparing to a neutral 0 point (one first response of each demonstration type) shows that the distribution was significantly in favor of the exclusive transmission of the pedagogical function ($M = .34$, $SD = .74$), $t(31) = 2.61$, $p = .014$.

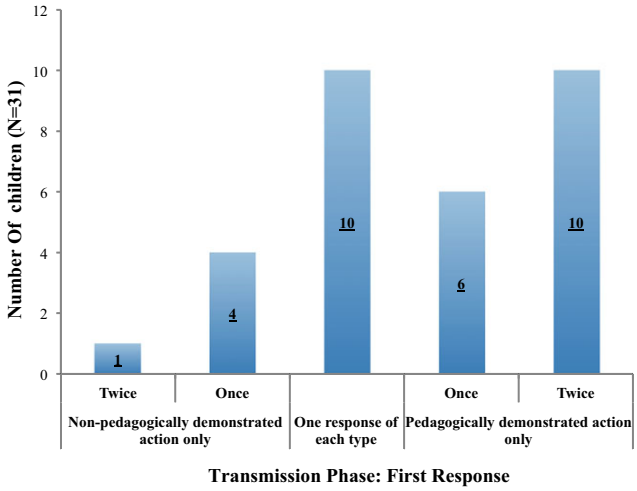

Figure 3 *The distribution of first responses to the unfamiliar adult's request ('What does this do?') across both transmission phases. From left to right, the responses are ordered by frequency and exclusivity; the number of children whose first response was only the non-pedagogically demonstrated action (both times or once only), to those whose first response was mixed (one of each type), to those whose first response was the only pedagogically demonstrated action. One child, who made no response either time, is not included (for a total N = 31).*

Action duration analyses: Transmission phase

We also compared the time children spent producing each type of action across the entire 30-second interval following the unfamiliar adult's request. There were no differences between the first and second Transmission phases (paired samples *t*-tests, *ns*) so we combined across these phases by summing the times spent producing each type of action across both 30-second intervals. The results are shown in Figure 2. A paired sample *t*-test indicated that children spent significantly more time reproducing the pedagogical ($M = 17.34$ s, $SD = 14.51$ s) than the intentional, non-pedagogical function ($M = 8.75$ s, $SD = 9.54$ s; $t(31) = 2.68$, $p = .012$).[2] This analysis combined with the first response data above suggests that children preferentially transmitted the pedagogical function to the unfamiliar adult.

[2] A comparable analysis of the number of discrete actions reproduced also echoed this difference; combined across both demonstration objects, children tended to reproduce the pedagogically demonstrated function ($M = 8.69$, $SD = 10.13$) more often than the non-pedagogically demonstrated function ($M = 4.41$, $SD = 7.61$) at a higher rate, $t(31) = 1.78$, $p = .085$.

Switch and sequence analyses: Transmission phase

As in the Demonstration phase, we examined the sequence of actions throughout each 30-second interval in the Transmission phase. This time there was no difference in the number of times children switched actions between the first and second transmission phases, $t(31) = .92$, *ns*. Children switched actions infrequently during both transmission phases (First: $M = .47$, $SD = 1.16$; Second: $M = .25$, $SD = .51$). In fact, 18/25 (72%) of children who made a response on the first trial never switched actions, and 20/27 (74%) who made a response on the second trial never switched actions. Furthermore, the number of switches was unrelated to which action was transmitted first (*t*-tests, *ns;* $M = .56$, $SD = 1.13$ for pedagogical function first and $M = .19$, $SD = .40$ for non-pedagogical function first).

Child social engagement analyses

It was possible that the pedagogical demonstrations induced more social engagement in children, which may have affected the transmission process. We performed additional analyses to address this possibility. First, we summed each child's level of engagement (i.e. using the 0–2 coding scale of children's engagement) across the two pedagogical demonstration trials (Distribution of Summed Pedagogical Engagement Scores: 0 = 9%, 1 = 0%, 2 = 9%, 3 = 28%, and 4 = 53%) and across the two non-pedagogical demonstration trials (Distribution of Summed Non-pedagogical Engagement Scores: 0 = 9%, 1 = 0%, 2 = 19%, 3 = 25%, and 4 = 47%). A Wilcoxon signed ranks test of children's engagement indicated that children did not differentially engage the attention of the demonstrators across the two types of demonstration (Pedagogical: $M = 3.16$, $SD = 1.22$; Non-pedagogical: $M = 3.00$, $SD = 1.24$, $p = .363$).

Second, we split the children into two groups based on which demonstration (pedagogical versus non-pedagogical) they saw first, and analyzed the 30 seconds of activity after this initial demonstration. This approach allowed us to measure differences in the amount of time children spent engaging when there was only one possible action to imitate. A paired samples *t*-test of the amount of time children spent imitating the just-demonstrated action indicated that children did not engage with the demonstrator of the pedagogical and non-pedagogical functions at different rates in this initial phase (Pedagogical $M = 7.28$, $SD = 8.04$, Non-pedagogical $M = 7.59$, $SD = 9.16$), $t(31) < 1$, *ns*. Thus, together these two analyses failed to provide evidence that children were differentially engaged by the pedagogical and non-pedagogical demonstrations.

Discussion

We began with the question of whether 2-year-olds selectively transmit – that is, reproduce for a new person in a new social situation – information that they have learned about an object through a pedagogical demonstration. We also investigated whether selective transmission occurs despite children having learned other things about that object as well. Our results indicate that the social context in which young children learned novel causal functions influenced what information they enacted in a new social situation. Importantly, this occurred despite equal learning of alternative functions: intentional cues (pedagogical or otherwise) lead children to imitate each demonstrated function immediately after each demonstration. Children also spent equal amounts of time on each function during the Demonstration phase regardless of whether it was demonstrated pedagogically or intentionally but non-pedagogically. Moreover, as the experiment progressed, children began to switch back and forth between demonstrated actions, indicating not only equivalent learning of both causal functions but also increased causal exploration and play. However, in the Transmission phase, children reproduced the pedagogically demonstrated object function first, for longer, and across the 30 seconds following any given request, often without switching in the presence of the unfamiliar adult. Thus, while children's causal learning was not impacted by the use of pedagogical cues, their *transmission* of the functions to a third party soon afterward was.

Our results are consistent with theoretical accounts of cultural learning that emphasize the role of pedagogical or ostensive communication (such as Natural Pedagogy Theory; Csibra & Gergely, 2009), and go one step further in offering a way to reconcile seemingly contradictory findings between these accounts and the research on causal learning. Though observing others' intentional actions is sufficient to learn about causal properties of objects (Flynn & Whiten, 2012; Matheson *et al.*, 2013, Gopnik & Schulz, 2004), observing pedagogical cues over and above intentional ones may give children the sense that those same causal properties are also socially relevant. Our findings therefore suggest that children engage in both types of learning – about the social world and about objects and causality – simultaneously, and often from the same social interactions.

These findings also raise important questions about children's active participation in cultural transmission. What is the mechanism responsible for children's transmission? One possibility is that children processed the novel functions more quickly and easily in the pedagogical demonstrations, resulting in the differential transmission of the pedagogical functions. In line with this possibility, a number of findings show that toddlers process stimuli more quickly and have stronger neural responses to those stimuli following periods of joint attention (Grossman & Johnson, 2010; Striano, Chen, Cleveland & Bradshaw, 2006a; Striano, Kopp, Grossmann & Reid, 2006b). However, it is unlikely that this possibility fully explains our results, as children did not evidence any differential social engagement, interest in the objects, or faithful imitation initially.

Another possibility is that the 2-year-old children in our study made a social inference regarding the relevance of the pedagogical cues when responding to the unfamiliar adult's inquiry. Children may have inferred that the pedagogical cues signal conventionality, or the shared aspect, of the functions being demonstrated. Consistent with Natural Pedagogy Theory (Csibra & Gergely, 2009), children may have used the pedagogical cues as a signal that what they were being taught had social significance, which in turn led them to be more likely to transmit the pedagogical functions. This possibility is in line with studies of word learning in which toddlers show awareness of what types of information should generalize across individuals (e.g. object labels) and what information should not (e.g. individual preferences for an object) (e.g. Graham *et al.*, 2006; Henderson & Graham, 2005).

Yet another possibility concerns the use of pedagogical cues by *the recipient*. In the Transmission phase, the unfamiliar adult established joint attention and used child-directed speech in asking children about the objects functions. Children may have matched the attention and speaking cues of the recipient to those of the pedagogical demonstrator. In this way, children's transmission may also be sensitive to the social cues of people requesting information from them.

These possible mechanisms are not mutually exclusive; thus future research should seek to delineate the cognitive, social, and attentional mechanisms underlying children's learning and transmission of conventions. As described above, manipulating factors associated with both the demonstrations and the recipients (e.g. adult versus child, familiar versus unfamiliar, pedagogical versus non-pedagogical cues) may expand our understanding of what additional cues might lead children to infer that causal actions are also socially relevant.

Our study unites ideas from research focused on how children receive and infer conventionality (e.g. Schmidt *et al.*, 2011; Deisendruck *et al.*, 2010) and diffusion chain studies focused on how children participate in cultural transmission (e.g. Whiten & Flynn, 2010; Flynn & Whiten, 2012). By experimentally controlling cues in the

Demonstration phase, we isolated one factor – pedagogy – that contributes to children's selectivity in reproducing functions in new social situations. Indeed, this manipulation was quite subtle. Demonstrators varied only in their eye gaze and speech towards the child as they acted upon the object. Yet, this difference was sufficient to bias which function children chose to transmit to a new individual. These results raise questions about how such cues might influence transmission in more naturalistic settings, such as classrooms. Relatedly, there is some evidence that pedagogical demonstrations can have detrimental effects on causal learning by restricting the children's exploratory play and causal discovery (Bonawitz *et al.*, 2011). Though there are many methodological differences between our study and this prior work, the parallels suggest that following the guidelines of direct instruction may at times curb exploration but invite (or encourage) cultural participation.

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