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Collaborative pedagogy: 3-year-olds bring pedagogical cues into alignment with analogical reasoning to extract generic knowledge

Andrea S. Taverna, [1]

Email andtaverna@gmail.com

Migdalia I. Padilla, [2]

María C. Baiocchi, [3]

Olga A. Peralta, [1]

[1] Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Instituto, Rosario de Investigaciones en Ciencias de la Educación (IRICE), Bv. 27 de Febrero 210, Bis, S2000, Rosario, Argentina

[2] Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Instituto, Rosario de Investigaciones en Ciencias de la Educación (IRICE), Bv. 27 de Febrero 210, Bis, S2000, Rosario, Argentina

[3] Facultad de Psicología, Universidad Nacional de Rosario (UNR), Riobamba 250, S2000, Rosario, Argentina

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Abstract

Although there is wide evidence on young children’s category learning, questions concerning how cognitive mechanisms and social mediation work collaboratively in this process remain sparse. Here, we study the impact of pedagogy in young children’s categorization of novel artifacts. A before-and-after micro-genetic study compared 58 3-year-old children’s performance in four learning scenarios which varied in the way category information—the artifact function—was provided: (a) in one single pedagogical demonstration, (b) in several guided pedagogical demonstrations aimed at eliciting analogies and inductions, or (c) employing analogies and inductions, but not in a guided pedagogical way. Results showed that children detected the function as the central conceptual property of the novel artifact only if the information was transmitted analogically (but not inductively) in several pedagogical demonstrations contingent with children categorization performance. These findings expand the role of pedagogy in categorization at an early age, showing that pedagogical cues act in concert with certain inferential learning mechanisms helping children extract generic knowledge.

Keywords

Category knowledge
Artifacts
Pedagogical cues
Inferential mechanisms
Young children

Introduction

Questions concerning how young children come to acquire the conceptual systems that characterize adult’s thinking have been pervasive in developmental psychology. In an effort to answer this question, researchers from different approaches have paid attention to either the cognitive capacities inherent to the child mind or the sociocultural context that shapes conceptual learning.

Some perspectives have focused in the cognitive mechanisms, like analogy and induction, which allow children extract generalizable knowledge (see Newcombe 2011 for a review of this approach). Other perspectives from a sociocultural tradition highlight that human cognitive mechanisms are strongly mediated by semiotic systems in contexts of interactions with more experienced partners (e.g., Cole 1996; Nelson 1996; Rogoff 2003; Saxe 2012; Saxe et al. 1987; see Gauvain et al. 2011, for a review).

Taken together, these perspectives provide routes to better understand the socio-cultural processes that work together with child's cognitive capacities in the construction of meaning. In this research, we seek to expand our knowledge concerning how cognitive mechanisms and social context work collaboratively to extract generalizable knowledge form a novel category. Specifically, we intend to provide evidence on the cognitive mechanisms that act in concert with social mediation helping young children detect the function as the conceptually central property of a novel artifact category.

Children's category learning: the case of artifacts

When asked to classify objects, children typically rely on superficial appearances excluding adult-like criteria, like the conceptually central properties (see Murphy 2002 for a review). This conflict between perceptual features and central properties becomes especially salient in the case of artifacts. Artifacts are human-made objects created to fulfill a specific function. As such, and in contrast to natural kinds, the categorization of artifacts has its roots in our intuitions about the intention of the creator (Bloom 2002; Dennet 1990; Keil 1996). So, extracting generalizable knowledge from artifacts may present a unique cultural learning challenge. Since the perceptual features of artifacts are usually poorly related (see Keil et al. 2007), these features may not be a useful route to extract a conceptual structure. A particularly important issue lays in the need to distinguish between the central property of an artifact from its potential uses, that is, what the artifact is *for* (Dennett 1989). For example, I can use a chair for a number of things, including as a step stool or a door stopper, but that does not change the fact that a chair is *for* sitting (Butler and Markman 2014).

Numerous studies on children's categorization of artifacts have explored whether children's responses were perceptually or functionally based, reporting contradictory results. For example, Gentner's classic study (1978) as well as more recent studies (Sloutsky 2003) showed that children aged from 2 to 5 extend the name of the artifact based on their perceptual aspects, while older children and adults on their function. In contrast, Kemler Nelson et al. (2000) found that 2-, 3-, 4- and 5-year-old children extend a name of an artifact in base of functional aspects.

Research has also focused on the type of information that facilitates children's categorization of artifacts. For example, Diesendruck et al. (2003) as well as Kemler Nelson et al. (2000) reported that 2-, 3- and 4-year-old children extended names in base of the function, as long as the function was emphasized using appropriate materials. Also, young children selected less perceptually similar artifacts when receiving information concerning the intentions the artifacts were designed for (e.g. “This artifact is used for...”), the functions that the objects can do (e.g. “Look what this object does...”) (Truxaw et al. 2006) or by highlighting their similarity-based structure in the frame of an analogical reasoning process (e.g., “This is a blicket (pointing out the novel artifact) and this is also a blicket (pointing out a second novel artifact), ¿do you see how both are blickets?”) (Author 2013). Taken together, this evidence suggests that when there are relatively clear connections between physical affordances and the intended design, young children reason about artifacts in terms of their indented functions.

Routes to extract generalizable knowledge about concepts and kinds

A large body of research has been devoted to explore how children move from the first-hand experience to generalizable knowledge about category membership (see Murphy 2002 for a review). While a group of studies have centered on socio-cognitive mechanisms inherent to the child, others have paid more attention on the mediation processes that shape conceptual development.

As far as the first approach, research has focused on the type of category information that children rely on in association with the cognitive mechanisms they employ. Some studies proposed that very early in development words serve as cues to form taxonomic relations (Markman and Hutchinson 1984; Waxman and Markow 1995) and children pay attention to specific utterances from generic language (e.g. “Dogs have bones inside”) as opposed to utterances referring to individuals (e.g. “This dog has bones inside”) (Butler and Markman 2013; Carlson and Pelletier 1995; Gelman 2003, 2004; Leslie 2007, 2008; Prasada 2000).

Also, young children use different kind of inferential reasoning mechanisms, like induction and analogy. On one hand, children use conceptual information to make category-based inductions, when children are told the category membership of an object they use that category as the basis of further inferences (Booth et al. 2005; Gelman and Coley 1990). On the other hand, children identify similarity-based relations by comparing category members in the frame of the analogical reasoning, including the ones concerning novel artifacts (Author 2012a, 2012b; Gentner and Rattermann 1991; Namy and Gentner 2002).

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Recent studies have focused on the communicative and social abilities displayed by children as a unique way to acquire generic knowledge (Butler and Markman

2014; Csibra and Gergely 2009). From this point of view, a communication system, called 'natural pedagogy', enables fast and efficient learning of cognitively opaque knowledge that would be hard to acquire relying only on observational learning mechanisms. For instance, when an adult points at airplanes and tells a child that 'airplanes fly', the information is not restricted to the particular airplanes in the particular context, but provides generic knowledge generalizable to other members of the category and to variable contexts (Csibra and Gergely 2009). This line of research pointed out that the transmission of such generic knowledge is not constrained to linguistic communication; it is possible via manual demonstration as well.

Recent studies illustrated the effect of pedagogical cues such as eye contact, ostensive demonstrations, in categorization tasks. Butler and Markman (2014) wanted to know whether preschool children categorize artifacts by their function when the information is explicitly transmitted in one-single demonstration. Four- and 5-year-old children were asked to categorize in three conditions. First, in a pedagogical condition where the experimenter made eye contact, provided ostensive demonstrations and established joint attention with the child. Second, in an intentional condition where the novel function was deliberately shown but the experimenter did not make eye contact or established joint attention. Third, in an accidental condition where the experimenter appeared to fortuitously use the novel object function exclaiming "Oops" in order to make clear that the action was not intentional. The results showed that preschool children were significantly more likely to categorize the artifacts when their function was demonstrated in a pedagogical context. These findings show that when children are targeted directly by communicative pedagogical demonstrations even in one single demonstration, their learning pattern changes fundamentally, extracting generalizable knowledge (Butler and Markman 2014).

Concerning mediation processes, a different but complementary body of research investigated the strategies adults use to help children extract generalizable knowledge. Many of these studies rest on the Vygotskian tradition and propose that language and other semiotic tools are much more than vehicles to convey knowledge, as they essentially transform conceptual development in adult-child interactions (Luria 1930; Tulviste 1991; Vygotsky 1986). Several observational studies described how parents naturally use language to help children determine the level of a new word (e.g. superordinate, subordinate, basic level) (Callanan 1985, 1991; Gelman et al. 1998; Nelson 1996), scaffold category knowledge in classification tasks (Rogoff and Gardner 1984) and assist children in the understanding of word meanings (Garton 2001). This evidence emphasizes that the social processes provide a communicative and linguistic model for the construction of meaning.

The present study

In the research we present here, we intend to delve into the learning mechanisms young children rely on to detect the conceptual central property of a novel artifact category. A recent study showed that the “Natural pedagogy” is so potent that 4- and 5-year-old children extract generalizable knowledge and infer the novel category when provided with pedagogical cues—eye contact and ostensive gestures—in one single demonstration (Butler and Markman 2014). In the present study, we hypothesize that younger children, 3-year-olds, need to be engaged not in one but in several pedagogical demonstrations of the novel artifact function in order to extract generalizable knowledge. In addition, we propose that children activate inferential learning mechanisms in a dynamic process in which meanings are established in interaction with an adult. Specifically, we state that the communicational system called “Natural pedagogy” (Csibra and Gergely 2009) needs to adopt, under certain circumstances, a collaborative and mediated format where pedagogy interacts with children’s inferential learning mechanisms to establish common meanings.

In this line, two recent studies on the categorization of familiar objects (Author 2012a, 2012b, 2013) have shown that adult mediation interact collaboratively with inferential mechanisms helping children categorize the objects.

In the present research, we investigated whether 3-year-olds detect the function as the central conceptual property of a novel artifact if transmitted: (a) in one single unguided pedagogical demonstration (making eye contact, ostensive demonstrations) or (b) in several guided pedagogical demonstrations aimed at eliciting analogies and inductions or (c) employing analogies and inductions, but in a not guided pedagogical way. Although the “Natural Pedagogy” approach has been extensively addressed (Csibra and Gergely 2009; Butler and Markman 2014), the extent to which pedagogy interacts with learning mechanisms remains uncertain. Here, we move from approaches of category development that explore separately the effect of pedagogical cues or individual reasoning mechanisms in unguided contexts to an integrative approach incorporating both social and cognitive aspects. We also move from analysis based on differences between participants’ performances to a micro-genetic method (Lacasa 1994), using a within-subject design in order to test the reorganization of the category knowledge in each group. Additionally, we tested differences in the learning process between groups and, finally, we carried out an individual analysis, classifying children as learners and not-learners.

Method

Design

The design consisted of a before-and-after micro-genetic study using a word extension and forced-choice task with three phases (see Table 1).

Table 1

Design of the study

Phase I pedagogical cues	Phase II learning process	Phase III pedagogical cues
1 trial	4 trials (maximum)-1 trial (minimum)	1 trial
Conditions		
Eye contact	1. Analogy + induction Similarity-based among artifacts Functional properties Eye contact Ostensive demonstration Contingence with child's responses	Eye contact Ostensive demonstration
	2. Analogy Similarity-based among artifacts Eye contact Ostensive demonstration Contingence with child's responses	
	3. Induction Functional properties Eye contact Ostensive demonstration Contingence with child's responses	
	4. Not-pedagogy Similarity-based among artifacts Functional properties	

Phase I: pedagogical cues The purpose of this phase was to test children's performance only as a function of pedagogical cues, such as eye contact and ostensive gestures, provided in one-single demonstration.

Phase II: learning process Children were invited to extract generalizable knowledge of the novel category member in a learning process with several demonstrations. Four conditions were manipulated. The conditions differed in the format the experimenter transmitted the artifact function to the children.

1. Analogy + induction: the experimenter demonstrated similarity-based and verbalized conceptual features pedagogically to trigger analogies and inductions, guiding children's category performance contingently.

2. Analogy: the experimenter demonstrated similarity-based features pedagogically assisting children’s category performance contingently.

3. Induction: the experimenter verbalized and demonstrated conceptual features pedagogically guiding children’s category performance contingently.

4. Not pedagogy: the experimenter exposed children to similarity-based and conceptual features about artifact function but neither pedagogical demonstrations (eye contact, ostensive demonstrations) nor contingent guidance was provided. This learning format was intended to work as a control condition.

Phase III: pedagogical cues The purpose of this phase was to test children’s performance after the category learning process. This phase was the same as phase I but new category members were presented to the children.

Participants

Sixty 3-year-old children (age range = 2.6 to 3.11; M_{age} = 3.3) participated in this study. Participants were randomly assigned to one of the four conditions. Two children were excluded because they did not finish the task. The participants were contacted through the pre-schools they attended in the cities of Rosario and Cañada de Gómez, Santa Fe, Argentina. Once authorization to conduct the research was granted by the institutions, we asked for the parental written informed consent. The socio-economic level of the sample can be characterized as middle. The criterion for participant selection was age and absence of developmental disorders; this information was provided by the school and teacher’s reports. The study was conducted in agreement with ethical standards set by the National Research Council of Argentina; these standards are in accordance with the international ones for this type of research.

Materials

We constructed a category—‘Pong’—for unknown novel artifacts, its function was to open and close. We employed 13 three-dimensional cardboard artifacts of 15 × 8″. The artifacts were designed as different exemplars of the category ‘Pong’. They were organized in a set of six trials. Each trial consisted of one artifact that served as a *standard* (e.g. a rectangle cardboard object which opens and close), and two alternatives related to the standard in different ways: *the conceptual choice* shared the conceptual relation but was perceptually different (e.g. a pyramid which opened and closed); *the perceptual choice* was perceptually similar to the standard one but was outside of the target category ‘Pong’ (e.g. a rectangle artifact which function was to pour). The artifacts of the six trials are listed in Table 2. Figure 1 displays a sample of the stimuli. Also, in order to engage children in the task, we used a toy, a Martian called “Marvin” and his planet, a sphere with all the artifacts inside.

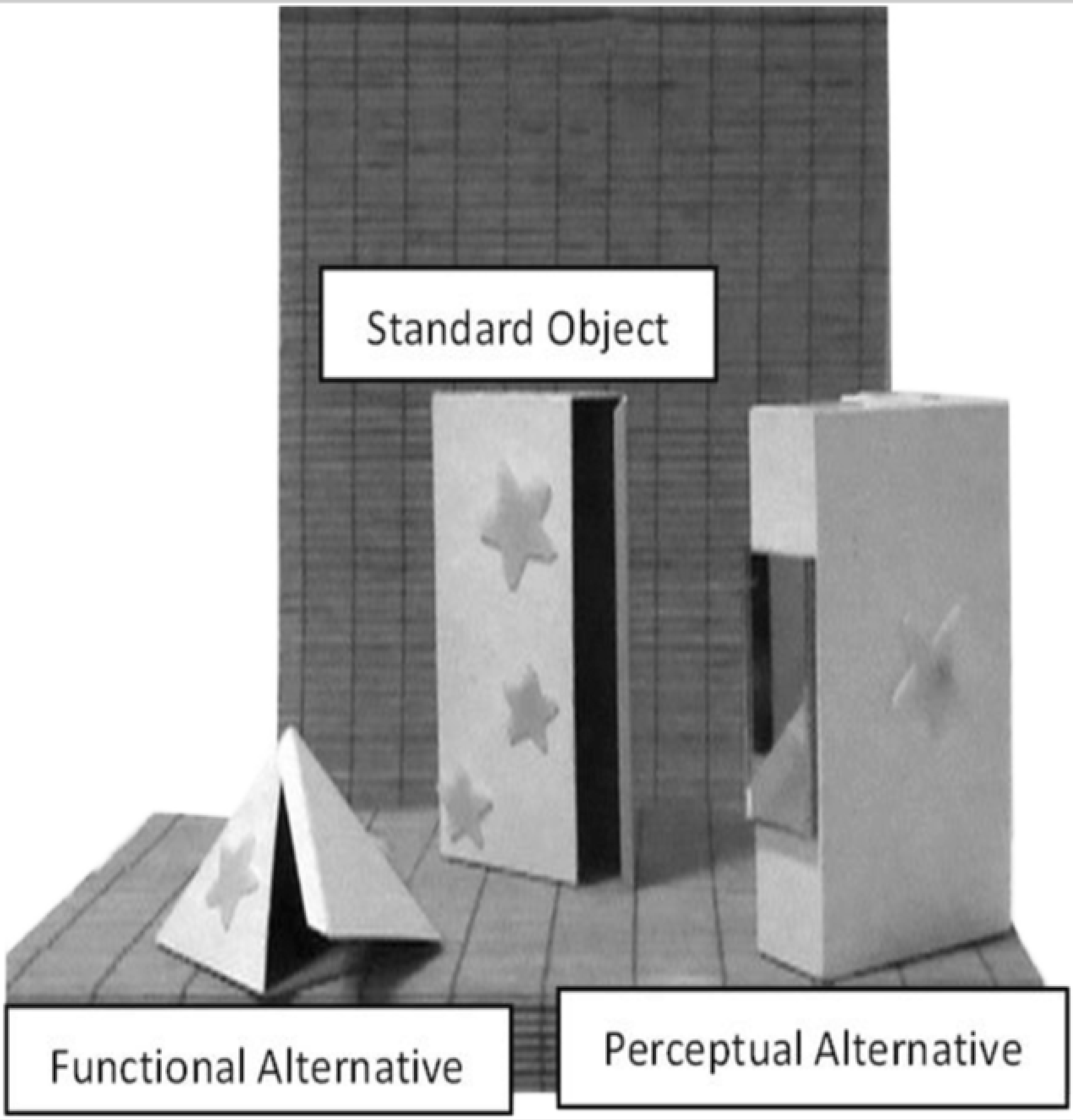
Table 2

List of similarity-based and category-based features provided by condition during the process

Phase I		
	Alternatives	
Standard-artifact: rectangular *Open and close*	Perceptive: rectangular *Pour*	Functional: pyramidal *Open and close*
Phase II		
Conditions: analogy + induction, analogy, not pedagogy		
Standard-artifacts 1. Rectangular 2. Small rectangular 3. Square *Open and close*	Perceptive: 1. Rectangle *Reflect* 2. Square *Make noise* 3.Rectangular *Hang* 4. Small square *Pour*	Functional 1. Pentagon *Open and close* 2. Hexagon *Open and close* 3. Cylinder *Open and close* 4. Long cylinder *Open and close*
Condition: induction		
Standard-artifact: rectangular *Open and close*	Perceptive 1. Rectangle *Reflect* 2. Square *Make noise* 3.Rectangular *Hang* 4. Small square *Pour*	Functional 1. Pentagon *Open and close* 2. Hexagon *Open and close* 3. Cylinder *Open and close* 4. Long cylinder *Open and close*
Phase III		
Alternatives		
Standard-artifacts: rectangular *Open and close*	Perceptive: rectangular *magnetize*	Functional: Double pyramid *Open and close*

Fig. 1

Sample of the stimuli



Procedure

The whole procedure consisted in three phases. Phases I and III were the same for all children. In phase II, children were randomly assigned to one of four conditions with four trials each.

Phase I (*Pedagogical cues*, one trial). All children, regardless of the condition, had to extend the new name applied to an artifact to another artifact member in the frame of pedagogical cues. First, the experimenter introduced the child to "Marvin, the Martian" and his planet, with the artifacts inside, telling the child that she will show him/her all the strange objects that Marvin had. Then, she handed over the first standard artifact (e.g. a rectangle that opens and close), and looking to the child said: "Look, in Marvin's Planet this is a 'Pong' (pointing to the novel artifact), look what ‘Pongs’ do (showing the function: open and close)”. Then, the experimenter requested the child to repeat the novel word. She then laid two new alternatives, showing their different functions, and asked the child: “Can you tell Marvin which of these objects is also a Pong?”. If the child categorized perceptually, the experimenter corrected saying: “Marvin told me that *this* is the Pong”, handing over the conceptual choice. If the child categorized conceptually, the experimenter said: “Marvin told me that *this* one is a Pong” pointing to the child’s choice. No other feedback was provided.

Phase II (*learning process*). In this phase, we manipulated children’s construction of a novel artifact category in response to different learning contexts. In three experimental conditions—*analogy* + *induction*, *analogy*, *induction*—the category information was provided pedagogically and contingently in an interactive context in order to trigger analogical and/or category-based induction. Thus, if the child categorized perceptually, a new piece of category information (either similarity-based and/or functional features) was provided. If the child generalized on the basis of artifact function, the same standard artifact and/or the same category feature was maintained for the next trial. During four trials, we offered a maximum of three pieces of category information and a minimum of no information (see Tables 2 and 3 for the list of similarity based and functional features provided by condition during the process). A fourth condition—*Not pedagogy*—served as a control, children were exposed to similarity-based and functional features but no contingent pedagogical cues were provided.

Table 3

List of functional cues provided in analogical + induction, induction, and not pedagogy conditions

Functional cue 1	“Marvin uses Pongs to open and close”.
Functional cue 2	“Marvin uses Pongs to open and put things in here and then close them”.
Functional cue 3	“Marvin uses the Pongs to open, keep little things in here and close, look!”.

The complete procedure was as follows:

1. *Analogy* + *induction.* The experimenter added a standard object to the one presented in phase I and looking at the child said: “This is a Pong and this is also a Pong, see how both are Pongs? I will tell you something special about Pongs: Pongs like these open and close” (pointing to both objects and demonstrating their function). The purpose was to transmit category

information concerning similarity-based features in order to engage the child in the analogical reasoning process. In addition, both artifacts were presented in a conceptual vignette consisting in a brief piece of information about the artifact function. Pointing both artifacts, the experimenter said: “Marvin uses Pongs to open and close”. The objective was to engage the child to perform an inductive process drawing upon the conceptual property given. Afterwards, two alternatives, one perceptual and one conceptual, were presented showing their corresponding functions (e.g. reflect; open and close) saying: “Can you tell Marvin which one of these is also a Pong”? The experimenter provided feedback to the child’s response

If the child chose the *perceptive alternative*, the experimenter said: “Marvin told me that *this is not* a Pong (pointing the child’s choice). He told me that *this* is a Pong (pointing to the conceptual alternative). Now, I am going to help you find a Pong”. Immediately after, a second trial was presented in order to make the category regularities among the artifacts more explicit. The experimenter added another artifact with the category feature and, pointing to the artifacts, said: “This is a Pong, this is a Pong, and this is also a Pong, see how the three are Pongs?. I will tell you something special about Pongs, Pongs like these are to open and close so Marvin can keep little things inside, see? (The experimenter showed the function and put some little stars inside the object). Look what Pongs do!”. She then displayed two alternatives on the table showing their different functions: “Can you tell Marvin which one of these is also a Pong?”

If the child extended the word to the *conceptual alternative* in the first trial, the experimenter said: “Very good! This is a Pong. Let’s go find another one”. Since the child categorized conceptually, the next trial was introduced repeating same category information of the previous trial. Then, the experimenter presented the third and fourth trials with new alternatives, following the same procedure of the first trial, providing category information, eye contact, ostensive gestures, demonstration and feedback contingent with the child response.

2. Analogy. The experimenter added a standard artifact to the one presented in phase I and, looking at the child, said: “This is a Pong and this is also a Pong, do you see how both are Pongs (demonstrating the artifacts function)”. The purpose was to transmit the similarity-based features pedagogically in order to engage the child in the analogical reasoning process. In this condition, there was no verbal information about the functional properties of the category. Then, the experimenter presented the two alternatives showing their corresponding functions (e.g. reflect; open

and close) and asked the child to extend the word saying: “Can you tell Marvin which one of these is also a Pong?”

If the child extended the word to the *perceptual alternative*, the experimenter said: “Marvin told me *that* it is not a Pong (pointing at the child response) and that *this* is a Pong (pointing at the conceptual response). Now, I am going you help you find another Pong”. Immediately after, the experimenter added a new standard object with the same function in order to make the conceptual structure between objects more explicit saying: “This is a Pong, this is a Pong, and this is also a Pong, see how these are Pongs?” showing the artifacts function. Then, the experimenter presented a new trial following the same procedure saying: “Can you tell Marvin which one of these is also a Pong?”. Children had to extend the word to one of the alternatives displayed.

If children extended the word to the *conceptual alternative* in the first trial, the experimenter said: “Very good! This is a Pong, let’s find another Pong”. Since the child categorized conceptually, the next trial was introduced repeating the same category information of the previous trial. Then, she presented the third and fourth trials following the same procedure, providing pedagogical cues and similarity-based features contingent with the child response.

3. Induction. The experimenter pointed to the standard object already displayed in phase I telling the child: “Marvin says that this is a Pong, I will tell you something special about Pongs: Pongs like this are to open and close, see what Pongs do, did you know that?” showing the function of the artifact. This category information was transmitted pedagogically to engage the child to perform an inductive process on the basis of the property given, the function. Then, the experimenter presented the two alternatives showing their corresponding functions (e.g. reflect; open and close) and asked the child to extend the word saying: “Can you tell Marvin which one of these is also a Pong?” Children had to extend the novel word to the alternatives displayed

   If the child extended the word to the *perceptual alternative*, the experimenter said: “Marvin told me *that* it is not a Pong (pointing at the child response) and that *this* is a Pong (pointing at the conceptual response). Now, I am going you help you find another Pong”. Immediately after, the experimenter pointed to the standard object already displayed in trial 1 and introduced a new functional feature in the frame of a conceptual vignette, pointing to the artifact the experimenter said: “Marvin uses Pongs to open and put things in here and then close them”, showing their function. The objective was to engage the child to perform a new inductive process drawing upon the conceptual property given. Then, the experimenter presented a new trial following the same procedure saying: “Can you tell Marvin which one of these is also a Pong?” Children had to extend the word to one of the alternatives displayed.

If children extended the word to the *conceptual alternative* in the first trial, the experimenter said: “Very good! This is a Pong, let’s find another Pong”. Since the child categorized conceptually, the next trial was introduced repeating the same category information of the previous trial. Then, she presented the third and fourth trials following the same procedure, providing pedagogical cues and functional features contingent with the child response.

4. Not-pedagogy condition: after phase I, the experimenter added a standard object to the one already presented. Seating with the child but without making eye contact she displayed and named the standard objects saying without pointing: “See these? This is a Pong and this is also a Pong, see how both are Pongs? I am going to tell you something special about Pongs: Pongs like these are to open and close, look?” showing the artifacts’ function. Then, without pointing to the standard objects, she said: “So, now that you know that these are Pongs and that Pongs are to open and close, can you tell me which one of these two are also a Pong?” Children were exposed to both category information, similarity-based and function, but this information was not transmitted guiding the child contingently as no category information, pedagogical cues or feedback were provided contingent to the child response. Afterwards, the experimenter presented the second, third and fourth trials, one by one following the same procedure, and children had to extend the word to one of the alternatives displayed

Phase III (*pedagogical cues*, one trial). Immediately after phase II, all children were presented with one trial as in phase I but with other exemplars of the category. This phase followed the procedure described in phase I, but with novel alternatives.

Strategy of analysis

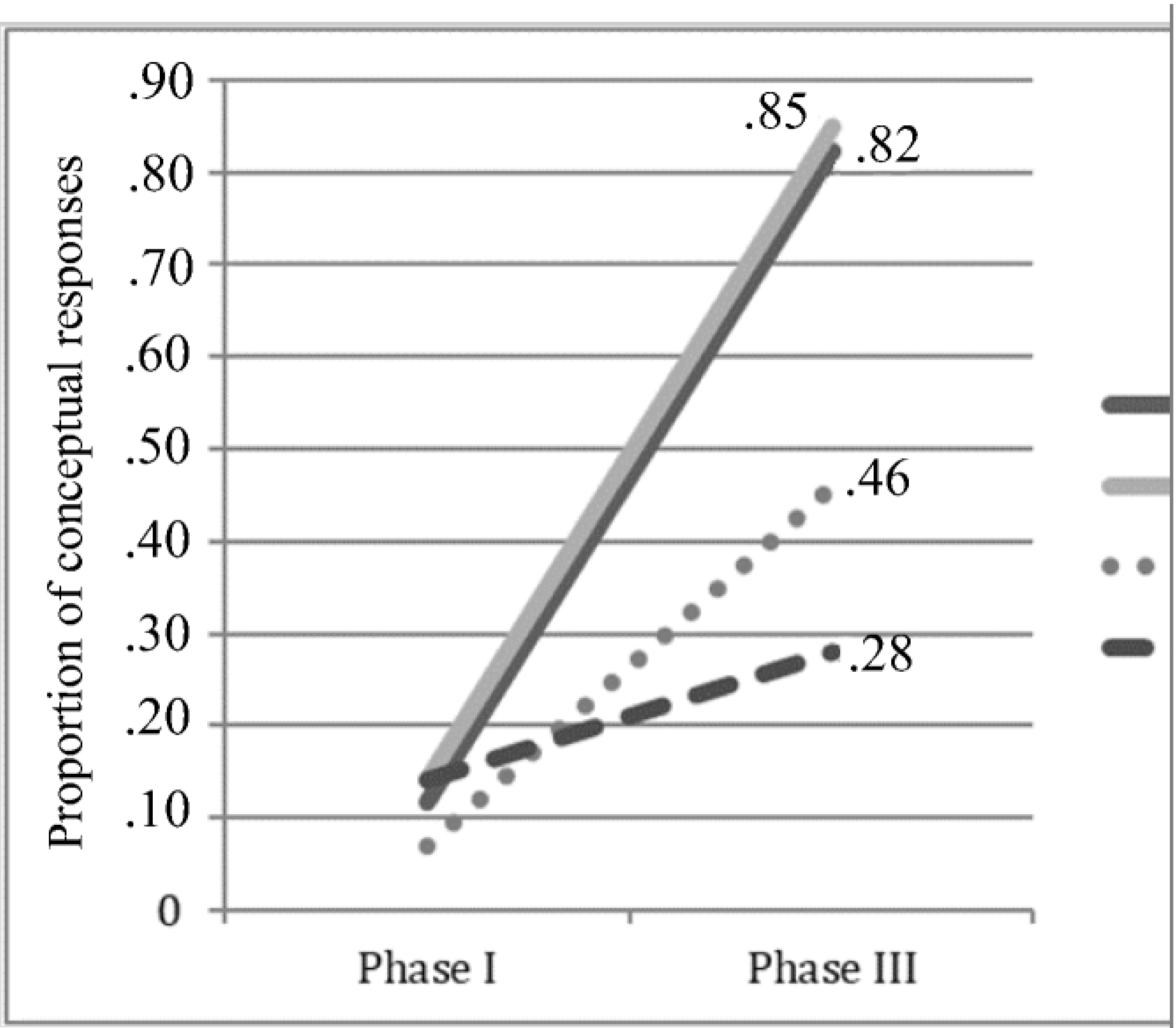
We analyzed our data in two main steps. First, we performed analyses against chance on the number of children’s conceptual responses in all conditions before the learning process (phase I). Second, we tested whether children’s conceptual performance varies as function of the process, that is, from phase I to phase III. Finally, we performed analyses against chance on the number of children's conceptual responses in all conditions after phase III.

Results

Analyses were performed on the number of conceptual responses; percentages are also informed for clarity purposes. In phase I of all conditions, children made less conceptual responses than expected by chance (0.50) (analogy condition, 2/17 (11.7%), x^2 (17) = 9.9, $p < .05$; analogy + induction condition, 2/14 (14%), x^2 (14) = 7.1, $p < .05$; induction condition, 1/13 (7%), x^2 (13) = 9.3, gl. 1, $p < .05$; not-pedagogy condition, 2/14 (14%) x^2 (14) = 7.1, gl. 1, $p < .05$) (Fig. 2). Thus, at 3 years of age, children selected the perceptual choice over the conceptual one when they categorized a novel artifact, suggesting that pedagogical cues in a one-single demonstration were not sufficient to detect the artifact function as a central property of an unknown category.

Fig. 2

Proportion of children's conceptual responses by condition



To test whether the proportion of conceptual responses increased after the process in each condition, we first compared the proportion of conceptual choices in phase I. All children in this phase selected the same proportion of conceptual choices when extending a novel word to an artifact, x^2 (58) = .3, p = .9. Then, we compared the proportion of conceptual choices between phases I and III for each condition. Given that the data were nominal (perceptual/conceptual) and the distribution of scores was not symmetrical, the *McNemar* test for related samples was considered appropriate for statistical analyses.

After the process, children in the analogy condition selected more functional responses (82.4%) than in phase I (11.8%), *McNemar*, $p < 0.001$, and so did children in the analogy + induction (phase II 85% vs. phase I 14%, *McNemar*, $p < 0.002$). In contrast, no significant increase in conceptual responses from phase I to phase III was found either in the induction (7% vs. 46%, *McNemar*, $p = 0.08$) or in the not-pedagogy conditions (14% vs. 28%, *McNemar*, $p = .6$).

In addition, after the process, in phase III, only children in the *analogy* or *analogy + induction* conditions made more conceptual responses than expected by chance (analogy condition, 14/17 (82.4%), x^2 (17) = 7.1, $p < .05$; analogy + induction condition, 12/14 (85%), x^2 (14) = 7.1, $p < .05$). In contrast, in the induction and not-pedagogy conditions, children's conceptual responses continued at chance levels (induction condition, 6/13 (46%), x^2 (13) = .07, $p = .7$; not-pedagogy condition, 4/14 (28%), x^2 (14) = 2.5, $p = .1$).

These outcomes show that before the learning process, children in all conditions did not generalize on the basis of artifact function. However, after the learning process, the detection of conceptual regularities differed by condition. Children were successful only after being involved in an interactive learning process where the category information concerning artifact function was transmitted analogically through sustained and contingent pedagogical demonstrations.

These results confirmed our hypothesis which states that young children do not infer a novel category either solely as a function of pedagogy or in base of inferential learning mechanisms. To infer the novel artifact category, children needed to be explicitly involved in several pedagogical demonstrations, benefiting the most from analogical reasoning mechanisms.

Analysis of individual performance

In phase I, 87.9% of children (51 children) did not extract generalizable knowledge selecting more perceptual responses than expected by chance (.50), ($x^2(1) = 33.3$, $p < .001$); only 12% (7 children) had a successful performance before the process. This analysis further confirms that for most children, pedagogical cues in a one-single pedagogical context were not sufficient to detect function as the central feature of a novel category. Of those 7 children, 6 continued categorizing successfully in all trials of the learning process and in phase III. The remaining child selected a conceptual response in one trial during the process and the perceptual choice in phase III.

We also classified children as learners or non-learners (see Table 4). Children were classified as *learners* when before the process they categorized artifacts perceptually but after the process, conceptually. Children were considered *non-learners* when no change was produced after the process. Considering both successful conditions together, where analogy was present (*analogy + induction and anal*ogy), 23 of 27 children were learners.

Table 4

Frequency distribution of children’s responses as a function of “learners” and “non learners” classification

Conditions	Learners	Non-learners	Total
Analogy + induction	11	3	14
Analogy	10	7	17
Induction	5	8	13
Not pedagogy	3	11	14

A X^2 test of 2 × 4 revealed that the number of learners significantly varied among conditions ($x^2(3) = 10.3$, $p < .05$). A subsequent X^2 analysis showed that the number of learners varied among the successful conditions (*analogy + induction* and *analogy*) and unsuccessful ones (*induction*; *no pedagogy*) ($x^2(1) = 14.3$, $p < .001$).

Overall, four main findings can be drawn from the results of the different analysis performed. First, most 3-year-old children did not use solely pedagogical cues to detect the artifact function in one single demonstration. Second, children were not successful after being exposed to category information about artifact function (analogies, functional features) in a not pedagogical way. Third, they were also unsuccessful by stimulating inductions alone, even in a pedagogical and guided context. Finally, children’s responses shifted from perceptual to conceptual only when the artifact function was transmitted analogically with several demonstrations in a guided pedagogical learning format.

General discussion

The purpose of this research was to study the impact of pedagogy in young children’s categorization of novel artifacts. A before-and-after micro-genetic study showed that children detected the function as the central conceptual property of the novel artifact only if the information was transmitted analogically (but not inductively) in several guided pedagogical demonstrations. These findings expand our knowledge on the role of pedagogy in the development of young children’s categories, showing that pedagogical cues act in concert with certain inferential learning mechanisms helping children extract generic knowledge.

The reported results suggest that at a young age, the communication system called “Natural pedagogy” (Csibra and Gergely 2009) needs to adopt a collaborative format for the construction of meaning where pedagogy interacts with inferential learning mechanism. In this format, the adult transmitted the category information through sustained pedagogical demonstrations providing information concerning the function of the artifact contingently with the child responses.

We illustrated that the learners played more than an ‘observational role’ (Csibra and Gergely 2009); instead, they reasoned analogically about the specific aspects that the adult was drawing their attention on. The communicative tools employed by the adult played much more than a communicative role, as they transformed the child’s conceptual understanding within a micro-genetic process. Therefore, this collaborative pedagogy became a ‘catalyst process’ (Nelson 1996) of conceptual changes at a micro-genetic level.

These findings are consistent with theories centered on the socio-cognitive capacities inherent to the child (Csibra and Gergely 2009; Gelman and Coley 1990; Gentner and Rattermann 1991; Namy and Gentner 2002) as well as on those focused on the social mediation processes that shape representational changes in development (Cole 1996; Garton 2001; Nelson 1996). This research integrated both approaches in a micro-genetic study identifying aspects inherent to the child’s mind as well as to the social context that elicited the emergence of generalizable knowledge. The study illustrated a micro-conceptual change as a result of an interaction.

One possible explanation for the lack of effect of the induction route could be that children did not have a prior knowledge to make contact with. In contrast, by comparing several category members, children extracted deeper commonalities and reasoned about the category features that were central to define the novel category (Gentner and Rattermann 1991; Namy and Gentner 2002). Results from a previous study that showed the effect of collaborative pedagogy in the categorization of familiar kinds support this interpretation (Author 2013). Contrary to the findings of the present study, Author (2013) reported that 3-year olds aligned pedagogical cues with category-based induction. Probably, since children were asked to categorize animals, fruits and vehicles, categories children were already familiar with, they could reason about properties conceptually.

One might argue that children’s conceptual shift between phases I and III was the result of a systematic reiteration of category information or of pedagogical cues, rather than the result of a collaborative pedagogy where children brought those cues into alignment with analogical reasoning. However, if this were the case, children would have been successful in the *not-pedagogy* condition as well, where they were reiteratively exposed to category information. They would also have been successful in the *induction* condition, where they systematically received pedagogical cues contingent to their categorization performance.

Certainly, some to the current work may open new questions for future research. For example, one criterion in the selection of our participants was absence of developmental disorders; it would have been important, however, to count with more fine measures of development, like intelligence or language and their impact on children's performance.

Additionally, since these results are restricted to a sample of children from urban contexts exposed to Western education, it would be interesting to gain further insight into the learning process in children from other cultural backgrounds, like rural populations or indigenous communities. As it has been reported (Author 2012a, 2012b, 2014, 2016, 2019; in press), the concepts that children from diverse cultural backgrounds develop are organized in conceptual systems aligned with their particular epistemological orientations, providing framework theories that organize their knowledge, learning and behavior. For example, in reasoning about the natural world, children and adults from an indigenous population—the Wichí—invoke a pervasive socio-ecology, one that emphasizes social relations (and not solely taxonomic relations) among the inhabitants of their ecosystem.

The results of this research can be instrumental to preschool educational practices. If teacher's actions are directed towards conceptual levels that are beyond what young children already understand, these actions could boost developing conceptual capacities. For example, teachers may not only present young children an environment rich in objects that invites to observe, manipulate and explore, but also display collaboratively strategies aimed at eliciting rich inferential processes, such as analogical reasoning. By means of these strategies, teachers could lead children to integrate objects into new conceptual structures. Access to more abstract concepts that may not only allow children to organize information efficiently, but also put this information at the service of a number of cognitive tasks, such as identifying things, creating analogies, solving problems, going beyond what is already known.

This study underscores the need to adopt a more nuance treatment of children's acquisition of generalizable knowledge as it emphasizes both the child's cognitive strategies as well as the shaping forces of the social contexts that underlie conceptual development in childhood.

Publisher's note

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