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THE RELIANCE ON INCLUSIVE *LIVING THING* IN INDUCTIVE INFERENCE AMONG 5-YEAR-OLDS: THE ROLE OF ACCESS TO NATURE AND THE SIZE OF RECEPTIVE VOCABULARY

The present study employed a serial forced choice inductive inference paradigm to test whether rural and urban 5-year-olds varying in SES rely on the representation of living things in extending new knowledge. Sixty-five children learned that humans possess a novel internal property and, in a series of test trials, had to decide whether to attribute the property to an inanimate living thing or to an artifact. Additionally, the size of children's receptive vocabulary was assessed. This study provides the first evidence that those 5-year-olds who have access to rich nature and who have acquired a high level of receptive vocabulary do rely on *living kinds* in induction in a forced choice task. The study further underscores the necessity to include children with diverse backgrounds in research on the development of biological knowledge. It also provides new evidence that general cognitive ability links to advances in children's biological understanding.

Key words:cognitive development, naive biology, receptive vocabulary, living things, inductive inference

Introduction

The development of biological knowledge relies on two central categories, i.e. *animates* and *living things*. There is a qualitative difference between how these categories are acquired. Animates are readily recognized in early infancy by two highly salient features, namely, goal directed movement and biological pattern of motion (Craighero et al., 2011; Csibra et al., 2003; Simion, Regolin, & Bulf, 2008). Consequently, the category *animates* plays an active role in young children's reasoning (Carey, 1985; Mandler & McDonough, 1996, see Gelman

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& Opfer, 2002 for a review). In contrast to animates, living things, a grouping which contains animals, plants, and fungi[1], seems to be acquired relatively late (Carey, 1985; Hatano et al., 1993; Laurendeau & Pinard, 1962; Piaget, 1929; Stavy & Wax, 1989; Waxman, 2005). This is not surprising. The commonalities between living kinds, which include, among others, response to the environment, energy processing, regulation, ordered structure, reproduction, growth and development, and evolutionary adaptation (Campbell et al., 2008) are far from salient[2]. At the same time the differences between animals, plants, and fungi are large enough to make perceptual learning unviable. Additionally, there is little support for *living things* from language (Anggoro, Waxman, & Medin, 2008; Leddon, Waxman, & Medin, 2008). Because living things are perceptually and linguistically elusive, the acquisition of this category is laborious and depends on an interplay between direct experiences with living kinds, causal reasoning, language, cultural transmission, and other factors (Waxman, 2005).

The acquisition of a mature understanding of *living things* must be construed as a part of the development of a complex system of causal beliefs, naïve biology (Carey, 1985). According to major theoretical accounts, adults attribute life to all and only animals and plants[3]. Interestingly, fungi, the third kingdom that includes multicellular organisms, is hardly ever mentioned in cognitive research on the development of *living things*. Although there is no reason to expect the mature concept to exclude fungi, researchers characterize adults as attributing life to just animals and plants (e.g. Carey, 1985; Goldberg & Thompson-Schill, 2009; Hatano et al., 1993; Laurendeau & Pinard, 1962; Leddon, Waxman, & Medin, 2008).

A mature representation of living kinds includes a set of features and processes that distinguish living from nonliving entities. A recent focus group study (Kerbe, 2016) showed that lay adults consider motion, change, growth, and metabolism as key criteria for the definition of life. It is important to note that change, growth, and metabolism characterize animals, plants, and fungi to an equal extent, but motion is largely confined to animates.

For the purpose of the present analysis I propose that the mature lay representation of *living things* is divided into four components: 1) adults explicitly represent *living things* as a grouping of all biological beings (Carey, 1985;

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[1] Apart from multicellular organisms , that is, most animals, plants and fungi, living kinds include microorganisms, such as bacteria. Lay adults and children have a representation of microorganisms, but the scope of the present study is constrained to the representation of those living things that can be observed with the naked eye.

[2] Mayr (1982) provides a historical perspective and Machery (2012) offers a critical view on attempts to define and demarcate the living world within scientific biology. Providing a review of biological literature in this regard is beyond the scope of the present work.

[3] The form of a mature lay adult representation of living things is mostly assumed rather than tested directly (Carey, 1985; Hatano et al., 1993; Laurendeau & Pinard, 1962; Leddon, Waxman, & Medin, 2008; Piaget, 1929). It is important to note that this literature makes reference to lay adults representation of living things and not to the state of scientific knowledge about living things.

Goldberg & Thompson-Schill, 2009; Hatano et al., 1993; Laurendeau & Pinard, 1962; Leddon, Waxman, & Medin, 2008), 2) they are aware of commonalities within living kinds (Gelman, 2003; Inagaki & Hatano, 2002), 3) they represent these commonalities as central elements of their naïve biological theory, which is a domain specific system of causally interrelated beliefs about biological beings (Carey, 1985), and 4) the representation of *living things* has inductive potential (Carey, 1985; Inagaki & Hatano, 2002). A category has inductive potential when it supports induction, which means that "it is used as the basis for novel inferences about the world" (Gelman, 2003, p. 26), for example, when a person learns a novel fact about an animal and, relying on the representation of living things, generalizes this fact to a plant (Inagaki & Hatano, 2002).

The four components listed above are not inseparable, and each has a different developmental trajectory. It is generally agreed that preschoolers and kindergarteners do not group animals and plants under a common label (e.g. Hatano et al., 1993; Laurendeau & Pinard, 1962), but they are aware of the commonalities between living things (see Inagaki & Hatano, 2002 or Gelman, 2003 for a review). There are mixed views on the role of these commonalities in children's naive biology (e.g. Carey, 1985 vs. Inagaki & Hatano, 2002). Very little is known about the inductive potential of living things in young children's reasoning. In what follows, I will present four major accounts of the development of *living things* with a particular eye on their position regarding children's ability to make inductive inferences based on *living things*. The accounts could be dubbed as *intentionality*, *vitalism*, *teleology*, and *essentialism*.

Intentionality. By Carey's (1985) account, early biological reasoning relies on intentional agency, which characterizes humans and other animals. Key biological properties play no role in this framework, and therefore young children have no reason to group plants with animals. The main source of support for the intentionality view came from inductive inference studies (Carey, 1985). Carey probed the reliance on *living things* in induction by testing inferences from a double premise (a dog and a rose). She proposed that mature biological reasoning should rely on conceptual combination, whereby a feature of two biological entities as disparate as an animal and a plant would be generalized to all living things (Carey, 1985, p. 141). For example, if a person learns that a dog and a rose both have golgi[4], they should assume that all living things have golgi as well. As Carey predicted, adults, but not 6-year-olds, relied on *living things* when making inductions from this double premise. However, there are two problems with Carey's data. First, Carey tested a homogeneous urban population. Later studies (e.g. Ross et al., 2003, or Tarlowski, 2006) undermined the universality of her claims by showing that there are considerable differences in children's inductive inferences as a function of experience with

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4 Most category based induction studies rely on so called blank features to avoid influence of prior knowledge. These blank features are usually made up names that only sometimes bear resemblance to existing biological features.

nature. Second, due to exceeding complexity, Carey's double premise task could underrepresent children's understanding of living things (Inagaki & Hatano, 2002).

Vitalism assumes that children's biological understanding is founded on a construal of life force, which integrates growth, taking nutrients, being active and lively into a coherent biological framework (Inagaki & Hatano, 2002, p. 42). This framework supports a representation of a category that includes animals and plants. One of the tests of this account relies on a forced analogy paradigm (Inagaki & Hatano, 1996), in which a known biological feature is taught on two animals, and children are asked whether two plants and two artifacts have it as well. Children tend to attribute animal features to plants but not to artifacts. Moreover, this tendency is strengthened by vitalistic context. These results suggest that children have, at least implicit, representation of living things. However, Inagaki and Hatano's (1996) results do not show that children's representation of living things has inductive potential, as they probed familiar biological properties rather than novel ones.

Teleology. Opfer and Siegler (2004) argue that the extension of *living things* is directly constrained by the knowledge of prevalence of goal directed movement. The role of movement in the representation of living things is attested in adult research (Goldberg & Thompson-Schill 2009; Kerbe, 2016). Goldberg & Thompson-Schill (2009) show that even biology experts tend to process animates as 'better' living things than plants. In Opfer and Siegler's (2004) study, children who were taught that plants move toward goals inferred that plants are alive, while children who were taught that plants grow and need water did not make this inference. Opfer and Siegler demonstrated that preschoolers explicitly represent inclusive living things if they know that plants engage in teleological motion. However, their data provided no insight into the inductive potential of *living things*.

Essentialism. According to the essentialist proposal, children have implicit expectation that some categories are internally coherent by virtue of a shared essence (Gelman, 2003). Essentialism is restricted to natural kinds (Gelman, 2003) or biological kinds (Barrett, 2001; Medin & Atran, 2004). By this account, children expect all living organisms to share key biological features. They show understanding of natural causality in plants and animals (Gelman, & Kremer, 1991), believe that origin determines features of offspring in animals and plants (Gelman & Wellman,1991), expect that both animals and plants, but not artifacts grow (Inagaki & Hatano, 1996), regenerate (Backscheider, Schatz, & Gelman, 1993), maintain identity despite external transformations (Keil, 1989), and can die (Nguyen & Gelman, 2002). Moreover, children rely on individual categories of both plants and animals in induction (Coley, 2012; Gelman & Coley, 1990; Gelman & Markman, 1986; Gelman & O'Reilly, 1988; Ross et al., 2003; Tarlowski, 2006). All these data suggest a rich implicit understanding of the commonalities between animals and plants. Moreover, Leddon, Waxman, and Medin (2008) argued that classical categorization studies may have underestimated children's ability to group animals with plants. In their study, 6-year-olds who grouped objects as "living things" were more likely to include plants than those who grouped them as "alive." Leddon, Waxman, and Medin (2008) explain this result by arguing that "alive" has misleading connotations with "animate".

The essentialist framework suggests a rich representation of living things at an early age, but it does not demonstrate its inductive potential. Essences are readily attributed to kinds at a basic level, which means that children expect all squirrels to share a feature and all oaks to share a feature (Gelman, 2003). Whether they expect novel features to be shared by all living things remains to be established.

Why is the inductive potential of living things so elusive?

As can be seen from this review, despite the rich variety of research on preschooler's understanding of living things there is no evidence that children rely on *living things* in forming new beliefs. This is not surprising. Although kinds support inductive inferences (Gelman, 2003), inductive strength is greatest at the basic level of hierarchy, and decreases with growing category scope (Coley, Medin, & Atran, 1997). Living things is a very general grouping with more observable differences than commonalities. When the task is open-ended, neither children nor adults generalize a novel feature as broadly as to all living things. Rather, they tend to restrict projections within a kingdom (Carey, 1985). However, the fact that an open ended task restricts inductive projections to low level categories does not imply that higher level categories lack inductive potential. One way to demonstrate this potential is to present the projection in the context of an alternative in a forced choice task. For example, in Gelman and Markman (1986) children projected to a target from a category match or from a similarity match. This task demonstrated the strength of within-category projections *relative to* similarity-based projections. Although this approach proved very fruitful in the study of category-based induction and categorization (e.g. Coley, 2012; Gelman & Markman, 1986), it has never been used to test the inductive potential of *living things*.

Variability in biological knowledge

The acquisition of biological concepts is influenced by direct experiences with nature, language, and cultural models (Anggoro, Waxman, & Medin, 2008; Coley, 2012; Hatano et al., 1993; Inagaki, 1990; Medin et al., 2010; Prokop, Prokop, & Tunnicliffe, 2008; Ross et al., 2003; Tarlowski, 2006). The patterns of inductive inference within animates are related to living environment (urban vs rural), culture (western vs. indigenous) (Medin et al., 2010; Ross et al., 2003; Tarlowski, 2006), and specific experiences with raising animals (Inagaki, 1990; Geerdts, Van de Walle, & LoBue, 2015). Raising animals is related to concrete biological knowledge (Prokop, Prokop, & Tunnicliffe, 2008). The amount of activities in nature correlates with the ability to rely on ecological relationships in induction (Coley, 2012). There is also some data showing variability in the development of representation of living things. The inclusion of plants within *living things* has been shown to vary depending on language and culture (Anggoro, Waxman, & Medin, 2008; Hatano et al., 1993; Taverna et al., 2014).

While the body of research showing variability in biological knowledge is constantly growing, there are still many gaps to be filled. For example, most rural vs. urban or cross cultural comparisons (Medin et al., 2010; Ross et al., 2003; Tarlowski, 2006) do not control for potential confounds such as SES, cognitive development, parenting styles, access to educational and cultural resources, or everyday practices. Moreover, very few studies actually compare direct experiences with nature across rural and urban populations (i.e. Coley, 2012; Majcher & Suska-Wróbel, 2005; Zhang, Goodale, & Chen, 2014, see Longbottom & Slaughter, 2016 for a review).

Another shortcoming of comparative research on naïve biology is the failure to take individual differences into account. As Sutherland and Cimpian (2017) point out, Fisher, Godwin, and Matlen's (2015) recent paper was the first to show the role of general cognitive development measures (general intelligence, working memory, and inhibition) in the development of categorization and inductive inference. More refined theories of the development of biological categorization and reasoning will require new insights into the role of intelligence, memory, and language development.

The present research

The review of extant literature shows that while there is a large body of research on the development of *living things*, very little is known about *living things* inductive potential. This paucity may stem from the difficulty to study the inductive potential of superordinate groupings and it may be overcome by the use of the triad induction methodology. While there is a growing understanding of the role of cross cultural, linguistic, and experiential differences in the development of naïve biology, the representation of living things has not been studied across rural and urban children. Moreover, rural vs. urban comparisons of biological knowledge do not account for possible confound variables, and overlook the role of general measures of cognitive development. The present study aimed to address these limitations of past research. I tested preschool children's reliance on *living things* in inductive inference with the use of a novel inductive inference paradigm employing triad induction. I also probed rural and urban children while controlling for possible confounds with the use of a triangulation strategy. Additionally, I obtained a measure of children's linguistic development.

The forced choice triad induction task (Gelman & Markman, 1986) is a promising method to study the inductive potential of *living things*. It allows to test the inductive strength of one grouping against another grouping. In the present study I applied this method in a computerized serial forced choice induction task in which children project an internal property of humans to either inanimate living kinds (plants or fungi) or artifacts. In this task, children's tendency to project human property to another living kind rather than to an artifact provides a measure of inductive potential of *living things* relative to the associative connection between humans and artifacts.

Children's reliance on *living things* in induction should be studied in both urban and rural context, but urban vs. rural comparison may overlook important confounds, such as disparities in SES (Miller & Votruba-Drzal, 2013). Medin and Atran (2004) argue that it is close to impossible to isolate a set of variables that neatly separate two compared groups. To deal with this problem, they suggest carefully selecting a third group that matches each comparison group in a set of distinctive ways. For example, Ross et al. (2003) probed inductive inferences in urban majority culture children, rural majority culture children, and rural Native American children, the first two sharing a cultural background while the second and the third sharing a living environment. In the present study I focused on the accessibility of nearby nature, operationalized as living environment (urban vs. rural), but I also include SES, operationalized as economic status of the *gmina* in which the children were being raised (*gmina*, English commune, is the smallest territorial division of local government in Poland). I therefore compared inductive inference within living kinds in urban high SES, rural high SES, and rural low SES children. SES is likely a key confound in rural vs. urban comparisons because the urban population enjoys much higher SES than rural population (Czapiński & Panek, 2015), and SES plays an important role in cognitive development (Bradley & Corwyn, 2002).

The potential contribution of SES to the development of naïve biology is most likely mediated by some general dimension of cognitive development, such as the size of the child's vocabulary. There is a strong relationship between SES and children's vocabulary size (e.g. Fernald, Marchman, & Weisleder, 2013), and vocabulary size is linked to the richness of conceptual distinctions that the child employs in reasoning and communication. Newly acquired words facilitate categorization and inference (Neuman, Newman, & Dwyer, 2011), while conceptual information helps children acquire new words (Booth, 2009).

Considering these links between SES, vocabulary, and conceptual development, as well as links between experience and biological reasoning (Ross et al., 2003 and Tarlowski, 2006), it can be expected that children from high SES populations will have a higher level of receptive vocabulary, and that the ability to rely on *living things* in induction will be higher in children from rural environments and those with a rich vocabulary.

Method

Participants

Sixty five children participated in the study. Twenty one (11 girls) came from inner city Warsaw, 23 (13 girls) from Izabelin, Warsaw's suburb enclosed by Kampinoski National Park, while 21 (13 girls) came from Wiskitki, a village East of Warsaw. The mean age was 5.9 (SD = 5.2 months) with a range between 5.0 and 6.4, with Izabelin mean of 5.11 (SD = 3.4 months), Warsaw mean of 5.8 (SD = 5.3 months), and Wiskitki mean of 5.8 (SD = 6.4 months). I conducted a comparison of age across groups. ANOVA's homogeneity assumption was violated, Levene's $F(2,62) = 8.14$, $p < 0.01$, which was due to relatively low variance in Izabelin. Welsch's ANOVA revealed an age effect approaching significance, $F(2,37) = 3.03$ $p = 0.06$. This unfortunate effect occurred accidentally, because only a subset of parents in selected preschools agreed to have their children included in the study.

Children were recruited from three preschools, one per each of the tested locations. Parents received a written description of the study and completed consent forms and provided information about their education. Children were verbally asked whether they wanted to participate in the study. The study was conducted in late spring (May-June of 2014 and 2015). Spring months were chosen because it is the time of the year when plants and the biological processes they undergo are most salient.

Warsaw is a capital city of Poland with a population of over 1.7 million inhabitants. A preschool in a heavily urbanized affluent inner city (Śródmieście) was chosen for the study. Izabelin is an affluent suburb with a population of about 2500 inhabitants located just 18 km north of Warsaw's centre, surrounded by the densely wooded Kapminoski National Park. Wiskitki is a village of about 1500 inhabitants over 50 km west of Warsaw, surrounded by arable lands, bordering the vast woodlands of Bolimowski Park Krajobrazowy.

The communes differed in a global statistical SES indicator of commune per capita tax income. In a ranking including 2479 Polish communes, Warsaw and Izabelin ranked 41 and 42 with tax income just below 3000 PLN, while Wiskitki ranked 1213 with tax income just above 1100 PLN (with the average value of 1435 PLN for the whole country, samorzad.pap.pl).

Parental education varied across the three comparison groups. In Wiskitki, 3 children had both parents with higher education, 6 had one of the parents with higher education, 6 had at least one parent with high school education, and 6 children's parents did not provide the information about their education. In Warsaw, 10 children had both parents with higher education, 4 had one of the parents with higher education , and 7 had at least one parent with high school education. In Izabelin, 11 children had both parents with higher education, 8 had one of the parents with higher education, 2 had at least one parent with high school education and 2 children's parents did not provide the information. In order to test for statistical differences I collapsed the high school only and no data categories; the analysis yielded a significant relationship between place and parental education, $\chi^2(4) = 10.23$, $p < 0.05$, Cramer's $V = .28$. The relationship was mainly driven by Wiskitki sample, which had fewer children's both parents with higher education and more children's parents without higher education. These differences in parental education were consistent with global economic indicators of commune SES.

Materials

Children completed a computerized serial forced choice induction paradigm which included an introductory task and the main task. The main task tested children's reliance on *living things* in induction. In this task, they saw a sequence of pairs of objects (presented on photographs), and decided which of the objects in a pair contained a target feature, e.g. blicks inside. The sequence consisted of 12 training and 12 test pairs (trials). Each training pair was made up of a person and water (waves, icicles, clouds etc.) and included feedback indicating that a person had the target feature. Each test pair was made up of an inanimate living kind (a plant or a fungus) and an artifact, and was not followed by feedback. The inanimate living kinds set consisted of two angiosperm trees, two shrubs (one angiosperm, one gymnosperm), two herbs in blossom, one cactus in blossom, 3 angiosperm saplings, and two mushrooms. I expected that neither the plants nor mushroom would be readily identified by the children at the species or genus level, though I did not confirm that empirically. The artifact set consisted of two TV sets, a cell phone, a car, traffic lights, an electric drill, two watches, washing machine, a digital camera, a kite, and a laptop.

Prior to the main task probing reliance on living things children completed an introductory warm up task, which included 7 training and 7 test pairs. Both test and training pairs were made up of a shoe and a piece of furniture. The purpose of this task was to familiarize children with the procedure.

The order of feedback/no feedback trials, the position of objects in a pair (left – right), and the order of objects were each determined randomly and independently of one another. The order of presentation of feedback and no-feedback trials was pseudorandom. The first trial was always a training trial, and the second was always a test trial. After that, one test trial was coupled with one training trial but the order in which they appeared was random. Thanks to this design, training and test trials were evenly distributed across the task but their order of appearance was partially unpredictable (after two trials of the same kind, the next trial was always of a different kind). The side at which the objects appeared was randomly determined for each trial. The stimuli were presented in one randomly generated order, which means that the pairing of objects and their position in the sequence were fixed.

The study was administered on a 9.7 inch tablet. The objects were presented as naturalistic pictures, 5,7 by 5.7 cm. See Table 1 for a list of object categories in the main task and the introductory task.

Table 1. Object kinds presented during the experimental procedure

Type of task	Objects with the feature	Objects with no feature
Introductory task		
7 training (feedback) trials	Shoes	Furniture
7 test (no feedback) trials	Shoes	Furniture
Experimental (main) task		
12 training (feedback) trials	Humans	Water
12 test (no feedback) trials	Plants	Artifacts

Children also completed the Polish Picture Vocabulary Test - Comprehension (Obrazkowy Test Słownikowy - Rozumienie) OTSR (Haman & Fronczyk, 2012; see Muzyka-Furtak & Haman, 2015 for a brief description of the test in English). OTSR is a diagnostic tool providing normalized measure of Polish-speaking children's receptive vocabulary. The test probes single words that include nouns, verbs, and adjectives. The tool has norms for children between the ages of 2.0 and 6.11. The test includes 88 cards, each containing four pictures. The experimenter asks the child to point to a picture that corresponds to the probed word, for example "Where is the horse?", "Who runs?" There is only one correct response. The remaining three are distractors, phonetically, semantically, or thematically related to the probed word. The items are organized in increasing order of difficulty.

Procedure

All the tests were performed individually in a quiet room at the children's preschools.

Warm up. Prior to the induction task, great care was taken to ensure that the child had a clear understanding that the target feature is an internal property that cannot be observed with the naked eye. The child was told that the game is about finding what various things have inside. The child was then asked about what is inside a wallet, fridge, and a person. Then the experimenter drew the child's attention to the fact that it is impossible to see what is inside a person by simply looking. The experimenter then introduced a detector, a machine that people use to learn about insides of things they cannot open. The child was shown a toy metal detector and given an opportunity to look for a metal plaque hidden in one of two envelopes. After learning how to operate the metal detector, the child was introduced to the concept of particles – tiny, invisible bits that can be found in all objects. At that point the experimental procedure on a tablet began.

Induction task. The experimenter introduced the tablet, entered the child's name into the program, and showed the child the first screen containing pictures of particles. The child was told that these particles are in fact so tiny that one cannot see them and that she would look for them in different objects with the use of a detector. The child was asked to pick one of the particles by touching it. On the touch, the program played a recording introducing the particle's name –blick, or dax. The child was then prompted to touch on a vertical line that appeared in the middle of the screen. The line appeared before every trail. Its position ensured that the child's hand was exactly in-between the two objects when they appeared on the screen. When the first pair appeared on the screen the experimenter said "We have two things here. One of them has [blicks] inside, but we don't know which one, because [blicks] can't be seen. Guess what has [blicks] inside. Touch with your finger to check which one has [blicks] inside." For subsequent pairs the experimenter prompted the child by saying "And now, what has [blicks] inside? Touch with your finger." or did not say anything if the child completed the trials without hesitation.

On training trials, after the child touched on one of the objects, a detector appeared on top of each side of the screen. The detectors looked like complex oscilloscopes with translucent screen parts. The detectors moved down simultaneously scanning the two objects. One of the detectors stopped and remained on top of its corresponding object indicating by sound and light that this object has the target feature, while the other passed over its object and disappeared. When a detector 'discovered' the feature, it stopped in such a position that the object with the feature was clearly visible in the translucent screen part of the device. When the child selected a correct object, she heard "Yes! This one has [blicks] inside!"; when the child chose an incorrect object, the audio message was "No! the other one has [blicks] inside!" The objects and the detector signaling the particle remained visible until the next trial. On test trials both objects disappeared immediately after the child touched one of them, and there was no audio message. The experimenter said "Now the detector did not show us what has [blicks] inside." Children moved to the next trial by touching the vertical line that appeared on the screen after they had made the selection.

During the introductory task the experimenter told the child that the detector would only sometimes help them find the particles. On feedback trials the experimenter reinforced the feedback from the program by praising the child, and on the test trials the experimenter provided verbal feedback saying "This time the detector did not show us but it is this one/the other one, that has [bicks] inside." Experimenter feedback on test trials in the introductory task was provided for pragmatic reasons. In this way the child did not think that the lack of feedback from the program signified an incorrect response. In the main task the experimenter never provided feedback on test trials, only saying "This time the detector didn't help us. We will find out at the end." See Figure 1 for a schematic depiction of an example training and test trial in the main task.

At the end of each task a set of circles appeared on the screen. The number of circles equaled the number of correct responses in both training and test trials. The child heard an audio recording "Look how many you have found!"

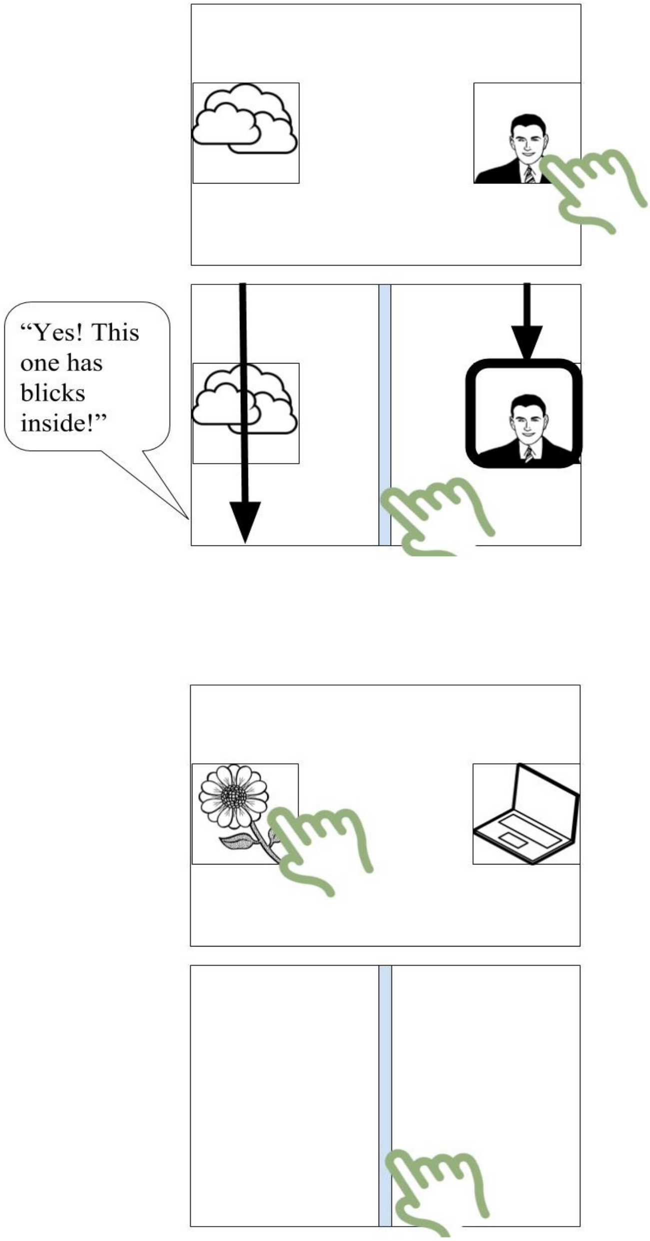

Figure 1. Schematic presentation of one training trial and one test trial in the induction paradigm. In the training trial, the child sees a person and clouds and points to a person as the object possessing the target feature. The detectors scan the objects (movement path indicated by the arrows). One of the detectors (here presented as a black rounded rectangle) stops over the person. There is beeping sound, flashing diodes, and a message "Yes! This one has blicks inside!" (the location of the thought bubble in the picture does not indicate the sound source, as it was always reproduced from the tablet speaker). The child then touches the vertical line to initiate the test trial, which contains a plant and an artifact. The child points to a plant, both objects disappear, a vertical line appears signaling a subsequent trial. In the actual task the images were photographs of real objects with natural backgrounds.

Children completed the Picture Vocabulary test one or two days after they completed the induction task. The task was administered according to the standardized procedure described in the handbook (Haman & Fronczyk, 2012). The experimenter told the child that they would look at pictures in a booklet, and that they would be asked to point to the one picture that fits the question. The experimenter flipped pages of the booklet, each containing four drawings and asked the child to point to one of the drawings with appropriate prompts, e.g. “Where is the horse? Who is sitting? What is tall?” After the child pointed to one of the four drawings, the experimenter recorded the response and moved to the next item. The children started the test from age appropriate start item and ended the test when they committed 4 consecutive errors or reached the end of the item list. The number of correctly indicated pictures constitutes the raw score, which was used in the analyses.

Results

In the main task probing children’s reliance on *living things* in induction, children performed 12 training and 12 test trials. During training trials children overwhelmingly chose humans over water as possessing the key feature (10.5 selections out of 12, $SD = 1.37$). This value did not differ across comparison groups, $F(2,62) = 1.48$, $p > .1$. Only 5 children (7.7%) did not choose a human on 9 or more trials out of 12. This result allows to confidently assume that the responses in test trials were based on the premise that humans possess the target feature.

Selections in test trials constituted a measure of children’s reliance on *living things* in induction. Based on training trial feedback indicating that humans have the feature, children chose between an inanimate living thing and an artifact. Their responses are represented as the number of living thing choices out of 12. Gender was not included in the analyses as it did not differentiate children’s living thing choices.

Children selected 5.69 living things overall ($SD = 3.8$), which was not significantly different from chance ($t < 1$). If children’s responses were in fact due to chance, their distribution would be close to normal, that is, they would be most likely to select about a half of the objects from each category. The observed distribution suggests that a large proportion of responses were not due to chance (see Figure 2). The observed distribution diverges from that expected by chance in that it underrepresents results around the mean and over represents extreme responses on both sides. This suggests that a large proportion of children made systematic responses that either favored living things or artifacts.

I identified three patterns of responses: *consistent living thing* - selecting at least nine living things out of 12, *consistent artifact* - selecting 3 living things at most out of 12, and inconsistent, or *mixed* - selecting between 4 and 8 living things out of 12. Based on binomial probability calculation each of consistent patterns has a probability of 0.07. The probability of the mixed pattern is 0.86. Twenty one children displayed a consistent artifact pattern, 18 displayed a consistent living thing pattern, and 26 displayed a mixed pattern. Hierarchical binomial probability calculation showed that the frequency of each of the consistent patterns was highly improbable, if the responses were to be due to chance, both *ps* < 0.001.

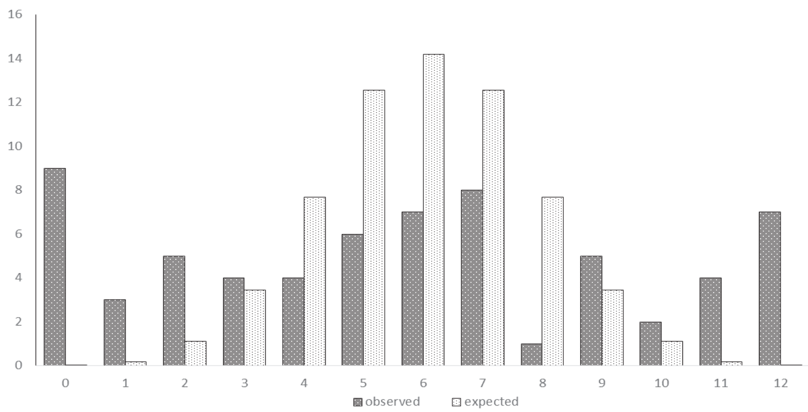

Figure 2. Histogram with frequencies representing the number of plant choices in 12 trials, set against frequencies expected by chance by binomial probability calculation. *N*=65.

After establishing that at least some children consistently projected an internal feature from humans to living things rather than artifacts, the key question was whether the reliance on living thing pattern was related to children's living environment and SES. In order to respond to this question I first cross tabulated the number of children adhering to the three patterns in the three comparison groups. The frequencies of the three patterns, as well as the expected frequencies in the three comparison groups are presented in Table 2.

Table 2. Frequencies of response patterns in three locations (expected frequencies in parentheses)

	Artifact	**Mixed**	**Plant**	**Overall**
Warsaw	7 (6.8)	13 (8.4)	1 (5.8)	21
Izabelin	8 (7.4)	4 (9.2)	11 (6.4)	23
Wiskitki	6 (6.8)	9 (8.4)	6 (5.8)	21
Overall	21	26	18	65

Chi square analysis on frequency data showed a significant relationship between the location and pattern, $\chi^2(4) = 13.00$, $p < 0.05$, Cramer's $V = .32$. This relationship was driven by the frequency differences of mixed and living things pattern between Warsaw and Izabelin, $\chi^2(1) = 13.08$, $p < 0.001$, Cramer's $V = .67$. As can be seen in Table 2, the odds of using living things over mixed pattern (the number of living things responses divided by the number of mixed responses) was much greater in Izabelin than in Warsaw (the odds ratio = 35.7). The responses of Wiskitki children fell between those from Izabelin and Warsaw, and did not differ from expected values. Moreover, the frequency of artifacts pattern was relatively constant across the three groups and also did not differ from expected values.

In order to better understand the observed differences, I compared receptive vocabulary (OTSR) scores across the three locations (see Table 3, for descriptive statistics).The analysis showed a significant difference between locations, $F(2,62) = 11.54$, $p < .001$. Post hoc analyses revealed that the Wiskitki sample had lower receptive vocabulary scores than both Izabelin and Warsaw samples. Because there is a well-established relationship between SES and vocabulary size (Bradley & Corwyn, 2002), it can be assumed that the initial economic characterization of Wiskitki as low SES and both Warsaw and Izabelin as high SES communes was accurate in respect to cognitive outcomes of SES.

Table 3. Measures of receptive vocabulary size in three samples

Location	**Mean**	***SD***	***N***
Warsaw	73.48	7.29	21
Izabelin	70.74	8.58	23
Wiskitki	61.57	9.29	21
Overall	68.66	9.72	65

Because finding predictors of the reliance on the living thing pattern was among the central goals of this study, I collapsed across the artifact and mixed pattern and performed a logistic regression analysis with reliance on the living thing pattern as a binary outcome variable (yes vs. no) and age, receptive vocabulary, nature (Wiskitki and Izabelin high; Warsaw low), and SES (Izabelin and Warsaw high; Wiskitki low) as predictor variables.

The analysis yielded a significant model fit $\chi^2(4) = 20.31$, $p < 0.001$. The coefficients, standard errors, p values and odds ratios with confidence intervals for the four predictor variables are shown in Table 4.

Table 4. The parameters of four variables in logistic regression predicting the reliance on the plant pattern

				95% CI for Odds Ratio		
Variable	**Coefficient**	**SE**	**p**	**Lower bound**	**O.R.**	**Upper bound**
Nature	3.64	1.20	0.002	3.66	38.06	396.19
SES	- 0.09	0.81	0.913	0.19	0.92	4.47
Age	- 0.73	0.86	0.395	0.09	0.48	2.58
Vocabulary	0.14	0.06	0.014	1.03	1.15	1.29
Intercept	- 9.3468	5.1436	0.069			

Note: SE - Standard error; OR –odds ratio; CI – confidence interval

As can be seen from Table 4, nature and receptive vocabulary size significantly predicted the reliance on living thing pattern in induction, while SES and age did not. This means that the reliance on living thing pattern was most likely to appear among rural children and those children who had high level of receptive vocabulary.

Discussion

In this study I used a novel serial forced choice inductive inference task to test whether 5-year-old children rely on *living thing* in induction. In the task, children extended an internal property from humans to either inanimate living things (plants and fungi) or artifacts. Consistent selection of living things served as an indication that a child had at least an implicit understanding of internal commonalities within the realm of biological beings. Three groups of children were probed, representing varying degrees of SES and access to nearby nature. The size of children's receptive vocabulary was also measured. The study did not yield evidence for kindergarteners' universal reliance on *living thing* in induction. However, there was a sizable minority of children who systematically extended an internal feature from humans to living things rather than artifacts, and the occurrence of this pattern of reasoning was predicted by children's access to nearby nature and their vocabulary size. This finding suggests that some form of mature understanding of living things can be attained at the age of 5, provided the children have access to rich biodiversity in their neighborhood and that they attained a high level of linguistic ability.

The findings are the first demonstration that access to nearby nature is related to the understanding of commonalities between living things, and the first study to demonstrate the relationship between a representation of living things and a measure of general cognitive development (in this case language development). Studies looking at the role of living environment focused on inductions constrained within a kingdom (Ross et al., 2003; Tarlowski, 2006) and tested whether children's reasoning is anthropocentric (Ross et al., 2003), or whether they rely on ecological relationships in reasoning (Coley, 2012). Studies specifically focused on the development of the living thing concept explored broad cultural and linguistic differences (Anggoro, Waxman, & Medin, 2008; Hatano et al., 1993).

Before it can be concluded that 5-year-olds can develop an implicit understanding of living things provided they have high level of linguistic ability and access to rich nearby nature, several questions need to be addressed.

First of all, the study relied on a novel design and it is necessary to discuss how the results obtained in this design can be interpreted. Typical triad induction studies pitting one kind of relationship against another (e.g. similarity vs. taxonomy in Gelman & Markman 1986, taxonomy vs. ecology in Coley, 2012) rely on a series of trials that are independent of each other, that is, each one probes a distinct set of categories and a distinct property. It is important to point this out because in such a design, what the child chose in one trial does not affect their choices in subsequent trials. The design used here is different. Because I tested a single categorical distinction (living vs. nonliving) it was impossible to create a series of unrelated problems, each with a different set of categories and features. Instead, I relied on a task in which children searched for a single internal property in a series of paired objects. This means that children could settle on a specific category and consistently respond by selecting its members. That is why, instead of analyzing the proportion of within-category responses, I divided the responses into two kinds of consistent patterns (living thing and artifact) and an inconsistent, or mixed pattern. It could be, though, that the reliance on a consistent pattern does not reflect child's commitment to one category as a correct response. Consistent patterns are very improbable, $p = .07$, provided that responses are random and independent. However, responses could be mutually dependent and still random, or accidental. That means the child could make an accidental decision to rely on a living thing or an artifact on the first test trial and then continue with this same decision for the rest of the trials. Although this interpretation of a consistent pattern of responses cannot be ruled out completely, it is quite unlikely. First of all, despite the fact that test trial items always represented the same two categories, they were very diverse, and ranged from pot plants and seedlings to trees and even mushrooms, from cars to cameras and traffic lights. Test trials were interspersed with training trials, which introduced additional variability of items. With such a diverse set of objects it is hard to imagine that children formed a response bias entirely based on an accidental first choices. Moreover, even more convincing evidence that children's consistent patterns were not accidental comes from the differences in living thing pattern frequency related to language development and exposure to nature. If children's responses were accidental, they would not be systematically related to factors relevant to the development of biological reasoning.

If consistent living thing pattern is not accidental, it remains to conjecture what its cognitive underpinnings are. So far, there is little past evidence showing 5-year-old children's ability to extend a human property to plants or fungi. Probably the closest is the study by Inagaki and Hatano (1996), who used a forced analogy task to show that children attribute a *known* biological feature from two animals to two plants and not to two artifacts. Inagaki and Hatano argued that this pattern of responses is due to children's vitalistic construal of plants and animals. By this account, children represent plants and animals as sharing key biological properties, which center around a concept of vital force, a force that all living things need to obtain from food, water (and sun) to grow, reproduce and stay healthy and lively. It is possible that analogous theoretical understanding underlies the living thing pattern responses in the present study. In such case, linguistically advanced children who have access to rich natural surroundings would notice biological commonalities between all living things, and integrate them into the core of their naïve biology. They would, then, naturally extend new features from humans to living things rather than to artifacts.

However, the rich interpretation of Inagaki and Hatano's (1996) findings can be challenged. Animals and plants are highly related thematically, and there is little reason to extend a feature from animals to artifacts, which means children did not need to rely on theoretical biological knowledge to resist such extension. Moreover, children were extending known biological features such as feeding, growing, reproducing, dying, or breathing. It is possible that they simply relied on their prior knowledge of those features. As Opfer and Siegler (2004) show, children's knowledge that plants display these biological features does not guarantee that they consider plants alive, neither does it guarantee that children would extend new features across the animal-plant categorical boundary. Therefore, before accepting Inagaki and Hatano's (1996, 2002) theory-rich interpretation of children's living things responses, other, leaner interpretations must also be considered.

It cannot be ruled out that children's selections of plants and fungi in the present study were purely associative – children selected objects based on their associations with humans rather than based on expected internal commonalities with humans. In rich natural settings plants are a dominant feature and humans tend to perform many activities associated with plants and fungi (e.g. mushroom picking). Some rural children may be more likely to associate humans with plants and fungi than to associate humans with artifacts. This interpretation fits well with the rural advantage in frequency of the living things pattern, but it cannot be reconciled with the fact that this pattern is also predicted by linguistic ability. Purely associative connections driven by mere exposure should not be related to the richness of children's linguistic development.

Finally, there is one more lean interpretation of the living things pattern. Children who rely on the living things pattern may have a prohibitive ontological commitment instead of a positive one. That is, they may be clear that humans are fundamentally different from artifacts without being aware of any commonalities between humans and plants or fungi. Their selections of living things would thus result from their stark rejections of artifacts. Given the distribution of responses across comparison groups this interpretation seems to be unlikely. It begs the question how the dominating presence of inanimate living things in rural children's immediate surroundings could strengthen their conviction that humans and artifacts are fundamentally different without building their conviction that humans and inanimate living things are fundamentally similar.

Another issue that needs to be addressed refers to the evidence showing the link between the role of *living things* in induction and the size of receptive vocabulary. This is the first demonstration that a specific aspect of biological understanding is linked to a very general measure of cognitive development. On the one hand, this finding seems intuitively plausible given that the size of vocabulary is related to the richness of the child's conceptual organization (Neuman, Newman, & Dwyer, 2011). The children with rich vocabulary can make sophisticated conceptual distinctions, and they are more flexible and efficient in forming and organizing new knowledge. This ability can make it easier to spot commonalities between humans and inanimate living kinds in biologically rich rural landscape. However, there is one piece of data that undermines this straightforward interpretation. Izabelin's overall OTSR mean was significantly higher than Wiskitki's mean, so Wiskitki living thing responders' OTSR values were higher than Wiskitki non-living thing responders', but equal to Izabelin non-living thing responders'. It cannot, therefore, be argued that a specific absolute level of vocabulary size along with access to nearby nature are necessary conditions for the reliance on *living thing* in induction to emerge. Rather, it is likely that the reliance on *living things* is directly related to a distinct cognitive feature which correlates with vocabulary. This feature could be some form of nature intelligence, or ontological awareness. It should be the object of future research to specify what this feature is.

Future directions

This analysis suggests that rich theoretical interpretation of children's reliance on consistent living thing pattern in induction is likely to be accurate, given the relationship between this pattern and the living environment and language. However, it is still necessary to run more studies testing the links between the reliance on *living thing* in induction and other aspects of mature representation of living things, namely explicit understanding that plants and fungi are alive, and knowledge of biological properties common to all living things. Only after this data is completed will we be able to make confident claims regarding the nature of children's projections from humans to living things in the present study.

Moreover, it is unclear what exactly are the experiences with nature that help contribute to a more mature representation of living things. The present study only relies on group comparisons so it only gives a very general measure of access to nearby nature. It is evident that children from Izabelin and Wiskitki have easier access to rich biodiversity, but I do not provide data that they actually use it to experience nature. It is important to rely on existing work, such as Majcher and Suska-Wróbel (2005) or Coley (2012) to develop a valid, reliable, and manageable scale of nature experiences to accompany future studies in the development of naïve biology.

In conclusion, the present study provides the first evidence that some kindergarteners rely on *living things* in induction. As the next step, the research should tie this reliance to other aspects of the representation of living things (i.e. categorization, knowledge of features), as well as to more refined measures of general cognitive development and direct experiences with nature. Within the field of science education there is a rich body of qualitative research on children's representation of plants and animals. Research tools from this field should enrich purely quantitative data. It would be beneficial to obtain open ended measures of biological knowledge such as justifications (e.g. Brulé et al., 2014), drawings (Bartoszeck et al., 2015; Rybska, Tunnicliffe, & Sajkowska, in press) and responses in interviews (Venville, 2004) to accompany data on inductive inferences.

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