Children's Inductive Inference with Synonymous Labels

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Abstract

Prior research indicates that young children can generalize object properties on the basis of category information when it is conveyed by identical labels or semantically similar labels at the same level of taxonomy (i.e., synonyms) (Gelman & Markman, 1986). However, in previous research semantic similarity was confounded with co-occurrence probability. Therefore, it is possible that synonym-based induction observed in prior research stemmed from children relying on cues other than the semantic similarity of labels. The present study investigated synonym-based induction with labels that do and do not co-occur in child-directed speech. Results indicated that adults made inferences on the basis of the semantic similarity of labels regardless of co-occurrence probability. In contrast, 4-year-old children generalized based on synonymous labels at above chance levels only when synonyms co-occurred in child-directed speech.

Keywords: Labels. Synonyms. Word Learning. Induction. Cognitive Development. Categories.

Introduction

Labels are pervasive in thought. Within the first six years of life, a child may learn up to 14,000 labels (Markman, 1990). It has been suggested that labels convey an object's category, thereby facilitating knowledge generalization (Gelman & Markman, 1986). For example, if a sheepdog has a certain property, would a bulldog be likely to share the same property? Though this question has no definitive answer, one might surmise that, both the sheepdog and the bulldog are likely to possess the property because both are referred to as 'dogs.'

It is well documented that adults rely on category information conveyed by labels to generalize from the known to the unknown, however, it remains contested when children begin to do so. Some research has suggested that children can rely on category information conveyed by labels as early as 13 months of age (Welder & Graham, 2001). Numerous studies have indicated that toddlers and preschool-age children view labels as communicating objects' kind, and that identical labels elicit category-based induction in young children as well as adults (Gelman 1988; Gelman & Coley, 1990; Gelman & Markman, 1986; Jaswal, 2004).

This interpretation has recently been challenged on the grounds that children may treat labels as perceptual attributes of objects rather than as category markers (Sloutsky & Fisher, 2004). Under this view, when two objects share a label, children engage not in *category-based* induction, but instead in *label-based* induction. In other words, children may rely on shared labels in the course of induction not because they understand that labels refer to categories, but because auditory information (including category labels) has a higher attentional weight than visual information early in development (Robinson & Sloutsky, 2004; Sloutsky & Napolitano, 2003). Indeed, there is ample evidence that auditory modality dominates the visual modality in infancy (Lewkowicz, 1994; Robinson & Sloutsky, 2004, 2007) and that these effects extend into early childhood (Napolitano & Sloutsky, 2004). Furthermore, there is evidence that a similarity-based account of early induction (which considers labels to be features of objects contributing to the overall perceived similarity) can readily account for children's reliance on identical labels in the course of property induction as well as categorization tasks (Sloutsky & Fisher, 2004; Sloutsky, Lo, & Fisher, 2001).

Both label-based and category-based accounts predict that children should rely on identical labels during the course of induction. One way to tease apart these two perspectives, is to convey category membership via non-identical semantically similar labels: If it is the case that children perceive labels as windows into categories, then children's generalizations based on semantically similar labels should be similar to their generalizations based on identical labels. If however, children are willing to generalize based on identical labels but not on semantically similar labels, then induction early in development can be label-based without necessarily being category-based.

There are two ways to convey semantic similarity using non-identical labels: by using hierarchically-related labels (e.g., *poodle-dog*) or semantically-similar labels at the same level of taxonomic hierarchy (e.g., *puppy-dog*). For the purpose of brevity, semantically similar labels at the same level of taxonomic hierarchy will be henceforth referred to as *synonyms*. It has been shown that the ability to base

inferences on familiar labels organized into taxonomic hierarchies does not mature until 7- to 8-years of age (Gelman & O'Reilly, 1988; Johnson, Scott, & Mervis, 1997). This finding could suggest that preschoolers' induction with identical labels is unlikely to be category-based. However, it is possible that children's difficulty using hierarchically-related labels stems from the lack of understanding of class inclusion relations, rather than from the lack of understanding that labels denote categories. Indeed, children have been shown to master class inclusion relations by 7- to 8-years of age (Klahr & Wallace, 1972) – the same age at which children can use hierarchically-related labels in the course of induction. The argument presented above suggests that preschool-age children should be successful in performing induction with synonyms, because these labels denote objects of similar kind at the same level of taxonomic hierarchy. At present, however, few studies have examined this possibility.

In a now classic study, Gelman and Markman (1986, Experiment 2) presented 4- to 5-year-old children with triads of pictures consisting of a target item and two test items: one test item looked similar to the target and the other belonged to the same category as the target. Category information was communicated by either identical or synonymous labels. Children were asked to generalize a property from one of the test items to the target. For example, children could be told that a 'rabbit eats bugs' whereas a 'squirrel eats grass', and asked whether the target item (referred to as a 'rabbit" in the Identical Labels condition and as a 'bunny' in the Synonyms condition) 'eats bugs like the rabbit' or 'eats grass like the squirrel.' Gelman and Markman found that children generalized properties to categorically similar items at above chance level in both labeling conditions. Notably, children's performance with synonyms was no different than their performance with identical labels (63% and 67% of category-based responses, respectively).

Gelman and Markman's (1986) study provided support to the notion that children utilize category information conveyed by linguistic labels. However, it has recently been suggested (Fisher, in press) that some label pairs in the Synonyms condition consisted of labels that were not only semantically similar, but also likely to co-occur as compound nouns in child-directed speech (e.g., *bunny-rabbit, puppy-dog*) according to the CHILDES database (MacWhinney, 2000). Co-occurrence of words in natural language has been argued to give rise to strong lexical associations (Brown & Berko, 1960; McKoon & Ratcliff, 1992); therefore in Gelman and Markman's (1986) study it is possible that when children were told that a 'bunny' had a particular property and were asked whether this property would be true of a 'rabbit' or a 'squirrel', children's responses were based not on the understanding that bunnies and rabbits are the same kind of animal, but on the fact that the word 'bunny' primed the word 'rabbit', whereas the word 'squirrel' did not.

A recent study by Fisher (2010) provides preliminary evidence to support this possibility. In this study participants were presented with a label extension task, in which they were taught a familiar label for a novel target object (e.g. "on a different planet, this one is called a *rock*"), and then asked which of the three test objects would likely be referred by a synonymous label (e.g., "which one do you think is called a *stone* on a different planet?"). The three test objects varied in perceptual similarity to the target: one test object looked similar, one looked less similar, and one looked dissimilar. The Co-occurring Synonyms condition included labels that co-occurred in child-directed speech (e.g., *bunny-rabbit*, *puppy-dog*, *kitty-cat*), whereas the Non-co-occurring Synonyms condition included labels that never co-occurred in child-directed speech in the CHILDES database (e.g., *rock-stone, couch-sofa, child-kid;* MacWhinney, 2000). Fisher found that adults and six-year-old children inferred that objects referred to by synonymous labels were likely to look similar, exhibiting a high proportion of choices of similar test items in both labeling conditions. In contrast, 4 year-old children were more likely to choose similar test items in the Co-occurring Synonyms condition than in the Non-co-occurring Synonyms condition. Moreover, young children's performance in the Non-co-occurring condition did not exceed chance.

The present study was designed to directly examine the possibility that label co-occurrence may play a role in inductive generalization. Four-year-old children and adults participated in a triad induction task; on half of the trials participants were asked to make inferences based on non co-occurring synonyms and on the other half of the trials participants made inferences based on co-occurring synonyms. An Identical Label condition was also included as a control condition

Method

Participants

Participants were 33 4-year-old children (M = 4.52 years, SD = .40 years, 18 females, 15 males) recruited from local preschools and 30 undergraduate students from a local university who received partial course credit.

Design

The experiment had a 2 (Label condition: Synonymous vs. Identical Labels) by 2 (Co-occurrence condition: Non-co-occurring vs. Co-occurring Labels) by 2 (Age: Preschoolers vs. Adults) mixed design. Labeling condition was a between-subject factor: participants were randomly assigned either to the Synonymous or Identical Labels condition. Co-occurrence probability of labels was a within-subject factor: every participant performed induction both with co-occurring and non-co-occurring labels.

Materials

Language materials consisted of nine label triads, with each triad comprised of a target item, a semantically related test

item and an unrelated test item. Related test items could be conveyed either by identical or by semantically similar labels (in the Identical and Synonymous Labels conditions, respectively). Unrelated items consisted of labels that a separate group of adult participants judged to be unrelated to the target items (see details below). To-be-generalized properties consisted of two-syllable blank predicates. A full list of linguistic stimuli is provided in Table 1.

Visual stimuli consisted of three sets of doors, with each set including three identical doors. Participants were told that objects were hiding behind each of the doors. This procedure was used to provide participants with conditions that were maximally favorable to relying on semantic information conveyed by labels as there was no perceptual conflict that participants had to resolve to perform category-based induction. Since visual stimuli were identical, category information conveyed by labels was the only basis for induction. Additionally, a set of 27 pictures was used for a Picture Identification task that all children completed after the experiment proper. The goal of this task was to ensure that children were familiar with all of the labels used in this study, and that children were willing to use semantically similar labels to refer to the *same* object (see the Procedure section below for details).

Label Selection

Assignment of label pairs to the Co-occurring and Non-co-occurring conditions was similar to the procedure used in Fisher (2010). Five different databases in the CHILDES corpus were analyzed (i.e., Bates, Brown, Gleason, HSLLD, and Wells). Children's ages ranged from 1 ½ to 9 years, and, across all databases a total of 2,264,722 words were included. To obtain normalized co-occurrence scores, the number of raw co-occurrences was divided by the sum of instances of each word occurring individually minus the number of times the two words co-occurred. For example, the word "kitty" occurred in the analyzed databases 847 times, the word "cat" occurred 2,319 times, and these words co-occurred 131 times. Using the normalization procedure the probability of the words "kitty" and "cat" co-occurring was calculated as 131 ÷[847+2,319–131] = .04.

Four co-occurring synonyms were selected based on their above-zero co-occurrence probability and their likelihood of being known to young children. Because all four co-occurring label-pairs referred to natural kinds, only non-co-occurring synonyms referring to natural kind objects were selected for this study. We did not use some of the non-co-occurring label pairs used by Gelman and Markman (1986) (e.g., *cobra-snake* and *rose-flower*) because these labels were hierarchically related, and thus unlikely to generate category-based induction in 4-year-old children (Gelman & O'Reilly, 1988; Johnson, Scott, & Mervis, 1997).

Overall, the average co-occurrence probability of synonyms was .033 in the Co-occurring condition and .000 in the Non-co-occurring condition, independent-samples $t(6) = 2.26$, $p = .03$. Unrelated test items were also labels that referred to natural kind objects. Unrelated test items were matched in syllable length to the related items for all triads except one[1].

A separate calibration study was conducted with an independent group of 22 adults to establish semantic similarity of labels within each triad. Adults were asked to rate semantic similarity of the Target items to the Related and Unrelated test items (e.g., *rock-stone*, *rock-cloud*, and *stone-cloud*) on a scale of 1 – 7, with 7 indicating that the labels could be used interchangeably, and 1 indicating that the labels had no overlap in meaning. Results of this calibration confirmed that targets and related test items (i.e. synonyms) were more semantically similar ($M = 6.3$) than targets and unrelated test items ($M = 2.8$), $t(14) = 11.43$, $p < .001$. There were no differences found when the analysis was separated by co-occurrence condition, $F(1, 15) < 1$, *ns*.

Table 1: List of stimuli and co-occurrence probabilities of semantically similar labels.

Target Items	Related Test Items	Unrelated Test Items	Blank Predicates	Co-Occ Prob
Rock	Stone	Cloud	Higa	.000
Dolphin	Whale	Seal	Omat	.000
Alligator	Crocodile	Hippo	Matlen	.000
Toad	Frog	Bird	Koski	.000
Mouse	Rat	Duck	Lignin	.000
Puppy	Dog	Cow	Erwin	.010
Kitty	Cat	Pig	Manchin	.040
Bunny	Rabbit	Squirrel	Creighan	.070
Pony	Horse	Fox	Troxel	.01

Procedure

Children were tested individually at their daycares in a quiet room or hallway. Adults were tested individually in a laboratory on campus. Visual stimuli were presented on a computer and labels were provided verbally by experimenters.

Labels used in the Synonyms condition are displayed in Table 1. The same set of labels was used in the Identical condition with the exception that the Target items and Related Test items were referred by identical labels (e.g., *rock-rock* for half of the participants and *stone-stone* for the other half of the participants). Half of the participants participated in the Co-occurring condition first, and the other half participated in the Non-co-occurring condition first. Within each co-occurrence condition trials were presented in one of two random orders. The *rock-stone-cloud* triad always appeared first as served as an instructional trial for all participants; the data from this trial were not included in the analyses reported below.

Participants were told that they would be playing a game about objects that were hiding behind doors (see Figure 1). The experimenter told participants what object was hiding

[1] Due to 4-year-old parlance, hippo was included as a lure for alligator-crocodile, despite it not matching the number of syllables of the related test item.

behind each door. The Target objects were always hidden behind the topmost door, and the location of the Related and Unrelated Test objects (to the left or to the right of the Target) was randomized across trials. The experimenter first introduced the Target item (e.g., *There is a rock hiding behind this door*) and then introduced the Test items in random order (e.g., *There is a cloud hiding behind this door*. *There is a stone hiding behind this door*). Then participants were told about the property of the Target item (e.g., *The rock behind this door has higa inside*) and asked to generalize this property to one of the Test items (e.g., *Do you think that the cloud behind this door or the stone behind this door also has higa inside?*).

Additionally, participants were asked to remember where each object was hiding. The memory check was included to ensure that possible differences in induction performance could not be attributed to children's better memory for co-occurring than for non-co-occurring synonyms. After the induction response was recorded, a memory check was performed: the experimenter asked the participant if (s)he remembered what was hiding behind each door, pointing to the doors in random order.

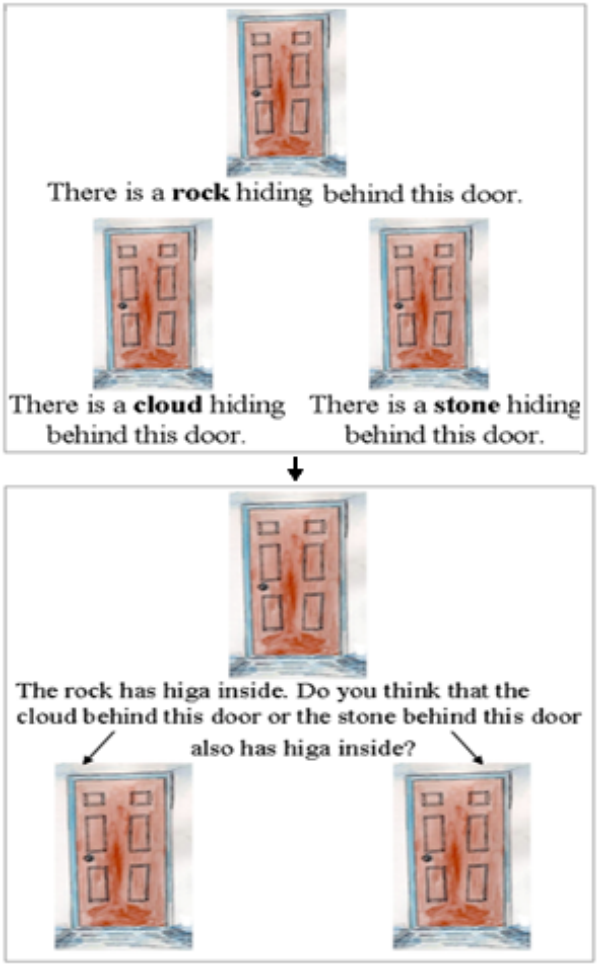

Figure 1: Schematic depiction of door task.

After the induction task children (but not adults) participated in a Picture Identification task similar to the Peabody Picture Vocabulary Test (Dunn & Dunn, 1997). The goal of this task was to confirm that children were familiar with each of the labels used in the induction task. In each trial children were presented with four different pictures, and asked to point to the target picture that was verbally indicated by the experimenter (e.g., "*can you find the rock?*"). Target items in the Picture Identification consisted of all Target, Related, and Unrelated labels that were included in the induction task. Importantly, knowledge of synonymous labels was always tested using *identical* pictures on separate trials (with location of the correct response counterbalanced across trials). There were 18 unique pictures of interest (for the two labels in eight experimental and one instructional trial in the induction task). Pictures testing knowledge of synonyms were presented twice and pictures testing knowledge of the unrelated items were presented once, resulting in a total of 27 trials in the picture identification task.

Results

Preliminary analyses revealed no effects of block order (all p's > .20). In the Picture Identification task, children's accuracy was .99 in each Label condition, indicating that 1) children were familiar with the words used in the experiment proper, and that 2) children could readily apply synonymous labels to the *same* objects.

Induction Accuracy

Proportions of category-based responses (i.e., choices of identical or synonymous labels) were analyzed in a 3-way mixed ANOVA, with Label condition and Age group as between-subject factors and Co-occurrence condition as a within-subject factor. The analysis revealed a significant effect of Age, $F(1, 58)=29.57$, $p<.001$; a significant interaction between Co-occurrence and Age $F(1, 59)=5.58$, $p<.05$; and a significant three-way interaction $F(1, 59)= 4.41$, $p<.05$. Follow-up analyses revealed no differences among conditions for adults (all p's >.63). Adults' category-based responding was above chance in all conditions (all p's < .001) (means in all conditions were ≥ .97, SD's ≤ .09).

Proportions of children's category-based responses are presented in Figure 2. For children there was a reliable difference in performance between the Non-Co-Occurring Synonyms and the Co-occurring Synonyms conditions, paired-sample $t(16) = 3.45$, $p <.005$ (M = .52 and .74, respectively). Within the Non-co-occurring condition, there was also a reliable difference between the Synonymous and Identical Label conditions, independent-sample $t(31) = 2.41$, $p <.05$ (M = .52 and .75, respectively). Furthermore, children's performance in the Non-co-occurring Synonyms condition did not exceed chance, one-sample $t(17) = .20$, *ns*., whereas performance in all other conditions was above chance (all one-sample t's > 2.54, p's <.05). There were no differences in children's performance with Identical Co-occurring and Identical Non-co-occurring labels, paired-samples $t(15) = .53$, *ns*, (M=.75 and .70, respectively).

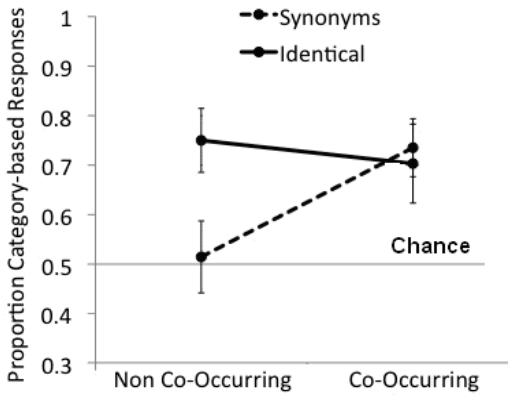

Figure 2. Proportion of category-based responses in children.

To investigate performance at an individual level, we classified participants into category-based and non-category-based responders. A category-based responder was defined as a participant who provided at least 3 of 4 category-based responses within each condition (see Figure 3). Individual response patterns mirrored the group data summarized above. In particular, all adult participants in all conditions were classified as category-based responders. In the Co-Occurring labels condition the majority of 4-year-olds were also classified as category-based responders: 11 out of 17 (65%) in the Identical labels condition and 10 out of 16 (63%) in the Synonyms condition (this association was not significant, Fisher's exact $p > .99$). Similarly, in the Non-Co-Occurring/Identical labels condition the majority of children were classified as category-based responders: 12 out of 16 (75%). However, in the Non-Co-Occurring/ Synonyms condition only 6 out of 17 children (35%) were classified as category-based responders. The association between condition and response type in the Non-Co-Occurring/Synonyms and Non-Co-Occurring/Identical labels condition was significant, Fisher's exact $p < .05$.

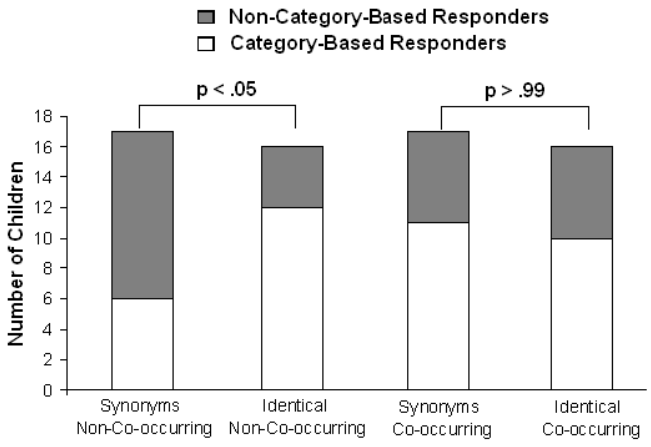

Figure 3. Number of children classified as category-based and non-category-based responders.

Memory Accuracy

Adults' overall memory scores were 99% in each label condition. Children's overall memory scores were 86% and 84% in the Synonymous and Identical Label conditions, respectively. Children's memory was well above chance level of 33% in both conditions, both one-sample p's $< .001$, indicating that children had little difficulty with the memory demands of the task. Most importantly, there was no difference in children's memory performance when separated by co-occurrence condition (86% and 85% correct in the Co-occurring and Non Co-occurring Synonyms conditions, respectively), paired-sample $t(32) < 1$, *ns*. A linear regression performed on children's memory scores and their induction performance revealed no significant relationship in the Synonyms condition, $r^2(134) = .055$, $p > .50$, or the Identical condition, $r^2(126) = .019$, $p > .95$.

Discussion

Contrary to the notion that the ability to perform synonym-based induction is well established by four years of age, the results of the present study suggest that this ability still undergoes development during the preschool years. In particular, 4-year-old children performed at chance in the triad induction task when semantically similar label-pairs did not co-occur in child-directed speech (e.g., *alligator-crocodile*). However, we observed a significant improvement in performance when children were presented with semantically similar labels that co-occurred in child-directed speech (e.g., *bunny-rabbit*) and with identical labels (e.g., *bunny-bunny* and *alligator-alligator*).

These findings are not easily explained by children's unfamiliarity with some of the words used in this research as our participants exhibited near ceiling accuracy on the picture identification task. Importantly, children readily applied different words with shared meaning (e.g., *alligator-crocodile*) to the *same* items in the picture identification task. Therefore, children clearly possessed the requisite knowledge to perform synonym-based induction. Yet, few 4-year-old children spontaneously relied on this knowledge in the induction task, unless the labels not only shared meaning but also co-occurred in child-directed speech.

Results reported in this paper suggest that poor understanding of class-inclusion relations is not the sole reason why preschool-age children fail to utilize taxonomic labels (e.g., *animal-cat*) in the course of induction tasks. The present findings add to the growing body of evidence suggesting that the understanding that labels refer to categories matures gradually between four and seven years of age (Fisher, 2010; Fisher & Sloutsky, 2005; Matlen & Fisher, 2008). In particular, consistent with the results reported in this paper, Matlen and Fisher (2008) found that only 15% of 4-year-old children spontaneously performed synonym-based induction with labels that did not co-occur in child-directed speech; this number increased to 51% of 5-year-olds. By 6 years of age the majority of children (86%) readily relied on synonymous labels to perform induction.

The present study is the first to demonstrate the effect of label co-occurrence on induction using a within-subject design. Therefore, this study provides direct evidence that results of earlier research on the development of synonym-based induction could stem from the fact that responses were averaged across items that were likely to result in above-chance performance (e.g., *bunny-rabbit, puppy-dog*) and items that were unlikely to result in above-chance performance (e.g., *rock-stone*, *cobra-snake*). It is conceivable that overall results aggregated over a bimodal distribution of responses could result in a mean proportion of synonym-based responses that exceeded chance level (i.e., 63%; Gelman & Markman, 1986; Experiment 2). Indeed, when children's responses in the Synonym condition of the present study were aggregated across both co-occurrence conditions, the average proportion of category-based responses was .63, above chance, paired-sample $t(16) = 2.17$, $p < .05$.

In sum, the results presented in this paper provide evidence that preschoolers' willingness to rely on semantically similar labels in the course of induction is influenced by co-occurrence probability of these labels in child-directed speech. This finding poses a challenge to the theoretical approach that assumes children's induction to be category-based from very early in development. At the same time, these results are consistent with the approach suggesting that the development of category-based induction follows a protracted developmental course.

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