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The Influence of Co-Occurrence and Inheritance Information on Children's Inductive Generalization

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Abstract

Prior research suggests young children understand that labels serve as category markers and that they can utilize this information to perform category-based induction with both identical and semantically-similar labels (Gelman & Markman, 1986). Recent research suggests that children's ability to perform category-based induction is limited to a small subset of semantically-similar labels which co-occur in child-directed speech (Fisher, 2010; Fisher, Matlen, & Godwin, in press). However, most of the co-occurring labels used in prior research are not only semantically-similar but they also refer to baby-parent relationships (e.g., *puppy-dog*). Thus, children may be able to perform induction with these particular label-pairs, because they contain kinship information rather than because they co-occur. The present study aims to disentangle whether young children's induction performance is driven by kinship information or co-occurrence probability. Results indicate that 4-year-olds' (but not 5-year-olds, 7-year-olds, or adults) induction performance was influenced by co-occurrence probability; kinship information was found to be insufficient to promote young children's induction performance.

Keywords: Labels. Induction. Cognitive Development. Categories.

Introduction

It has been suggested that even young children understand that labels denote object categories, and that children rely on this information to make inductive inferences (Welder & Graham, 2001, Gelman 1988; Gelman & Coley, 1990; Gelman & Markman, 1986; Jaswal, 2004). The strongest evidence in support of this argument comes from a study demonstrating that preschool-age children make inferences based on semantically-similar labels (to be referred to as *synonyms* henceforth for brevity) (Gelman & Markman, 1986). In this experiment children were first presented with a triad of objects and provided with respective labels. For example, children could be presented with a rabbit (Target item), a squirrel (Test item), and another rabbit (Test item) that looked dissimilar from the target. Children were told

about the properties of the test items (e.g., that the rabbit ate grass and the squirrel ate bugs). Then children were asked to generalize one of these properties to the target item. Importantly, similarity in category membership was conveyed either by identical labels (e.g., rabbit-rabbit) or synonymous labels (e.g., bunny-rabbit). The results indicated that the rate of category-based inferences was above chance in both conditions (i.e., 67% with identical labels and 63% with synonymous labels).

However, more recent findings suggest children's ability to make inferences using synonyms is limited to a small set of words that not only share meaning but also co-occur in child-directed speech according to the CHILDES database (MacWhinney, 2000). In particular, Fisher, Matlen, and Godwin (in press) found that most 4-year-old children perform category-based inferences with synonyms that are likely to co-occur in child-directed speech (e.g., *bunny-rabbit*, *puppy-dog*); however, these same children are unlikely to make category-based inferences with synonyms that do not co-occur (e.g. *alligator-crocodile*, *rock-stone*). Importantly, children in this study exhibited near-ceiling accuracy in a task similar to the Peabody Picture Vocabulary Test (Dunn & Dunn, 1997) with both co-occurring and non-co-occurring synonyms (99% correct in both conditions).

One explanation for this finding is that children's inferences are based on co-occurrence probability rather than semantic similarity (Fisher, 2010; Fisher, Matlen, & Godwin, in press). Co-occurrence plays an important role in the formation of lexical associations (Brown & Berko, 1960; McKoon & Ratcliff, 1992) which may facilitate inductive generalization via priming. For example, when children are asked whether a "bunny" shares a property with a "rabbit" or a "squirrel", children's responses may be influenced by lexical priming (i.e., "bunny" priming "rabbit" but not "squirrel") rather than category-based reasoning.

In the English language we have only been able to identify a few semantically-similar labels that are not only familiar to preschool age children but also co-occur in child-directed speech. Incidentally, these words can be construed

as referring to baby-parent relationships (e.g., *puppy-dog*, *kitty-cat*, *bunny-rabbit*¹). Therefore, it is possible that children’s induction with these labels is driven by kinship information rather than label co-occurrence. In other words, it is possible that children engage in category-based induction when they are presented with semantically-similar labels, but do so only when these labels refer to kinship relationships.

There is evidence suggesting that children may be sensitive to kinship information and that children can utilize this information during the course of inductive generalization. For example, Opfer and Bulloch (2007) gave kindergarten and first grade children a label induction task. Participants were provided with kind information for two target items that consisted of perceptually-dissimilar parent-offspring pairs (e.g., “*This is a dax. It was born to these two daxes here. This is a fep it was born to these two feps here*”; p. 208). Children were then shown a test item that consisted of a novel parent-offspring pair; importantly, the perceptual similarity between the offspring and its parents was manipulated so that perceptual similarity was in conflict with kinship information. Children were asked to infer the name of the offspring (the offspring looked like a fep but its parents were daxes). This paradigm allowed Opfer and Bulloch to test whether children could capitalize on kinship information in order to make category-based generalizations. Opfer and Bulloch found that children were indeed sensitive to kind information conveyed through parent-offspring relationships and that children used this information to make category-based generalizations. Importantly, the same stimuli led to the opposite pattern of results when kinship information was removed (i.e., children generalized according to perceptual similarity when inheritance information was not available). These findings suggest that kinship information can aid inductive generalization.

The present study was designed to examine whether children’s performance in prior research (Fisher, 2010; Fisher et al., in press) was driven by the co-occurrence probability of semantically-similar labels or kinship information conveyed by these labels. Towards this goal, we presented participants with an induction task with semantically-similar labels pointing to kinship relations. Some of these labels were likely to co-occur in child-directed speech (e.g., *puppy-dog*) whereas other labels were unlikely to co-occur (e.g., *chick-hen*). Importantly, co-occurrence probability of labels was manipulated within participants, such that any observed differences can be

¹ Although *kitty* and *bunny* are not exclusive labels for baby animals, these labels are often used in the common vernacular to refer to the young of these species. For instance, the Meriam-Webster dictionary defines *bunny* as a “rabbit; especially young rabbit” and *kitty* as a “cat; especially kitten”. Furthermore, common usage of these words seems consistent with the dictionary definitions: a Google picture search using the term “bunny” yielded 74 images of animals of which 62% depicted young rabbits and the search term “kitty” yielded 79 images of animals of which 49% depicted kittens. Therefore, it is reasonable that children may interpret these words as referring to the young of the species.

attributed to the stimuli rather than to individual differences between participants.

Method

Participants

Participants were 20 four-year-old children ($M = 4.48$ years, $SD = 0.25$ years, 8 females, 12 males), 20 five-year-old children ($M = 5.28$ years, $SD = 0.21$ years, 13 females, 7 males), and 24 seven-year-olds ($M = 7.06$, $SD = 0.38$, 11 females, 13 males) recruited from local schools, and 20 undergraduate students from a local university who received partial course credit for participation.

Design

The experiment had a 2 (Co-occurrence probability: non-co-occurring vs. co-occurring labels) by 4 (Age: 4-year-olds vs. 5-year-olds vs. 7-year-olds vs. Adults) mixed design. Co-occurrence probability was a within subject factor: All participants performed induction with both co-occurring and non-co-occurring labels.

Materials

Verbal stimuli consisted of 8 label triads. Each triad consisted of a target, a category choice, and an unrelated lure. The properties that participants were asked to generalize during the induction task consisted of two-syllable blank predicates. The list of linguistic stimuli is provided in Table 1.

Table 1: List of Linguistic Stimuli

Target	Category Choice	Lure	Property
Bunny	Rabbit	Squirrel	Creighan
Kitty	Cat	Fox	Manchin
Puppy	Dog	Bear	Erwin
Caterpillar	Butterfly	Ladybug	Higa
Lion	Cub	Pig	Matlen
Lamb	Sheep	Cow	Koski
Chick	Hen	Mouse	Troxel
Tadpole	Frog	Fish	Omat

Visual stimuli consisted of sets of three identical doors: Children were told that the objects were hiding behind the doors. This procedure was used to encourage reliance on category information conveyed by labels, as this was the only source of information available to children (see Figure 1). This procedure has been successfully used in prior research and this work has also demonstrated that children have little difficulty with the memory demands of the task (see Fisher, et al., in press). An additional set of 8 pictures was utilized for the match task which assessed children’s knowledge of biological inheritance for the label-pairs used in this study. A detailed description of these tasks is provided in the procedure section.

Label Selection

Label selection was based on a separate calibration study ($N=16$) in which 4- and 5-year-old children ($M = 5.20$ years, $SD = 0.50$, 8 females, 8 males) participated in a picture

identification task similar to the Peabody Picture Vocabulary Test (Dunn & Dunn, 1997). The picture identification task served to assess children’s familiarity with the labels. Children were asked to select the animal labeled by the experimenter from four pictorial response options. Only word-pairs for which children exhibited high levels of accuracy were selected for the experiment ($M = 0.94$, $SD = 0.07$, range = 0.75 – 1.00 for the selected labels). The final list of stimuli consisted of three co-occurring semantically-similar word-pairs referring to kin relations (*bunny-rabbit*, *puppy-dog*, *kitty-cat*) and five non-co-occurring word-pairs referring to kin relations (*caterpillar-butterfly*, *chick-hen*, *tadpole-frog*, *lamb-sheep*, *lion-cub*). Co-occurrence probability was calculated using CHILDES, a corpus of child speech and child-directed speech (MacWhinney, 2000). Five databases in the corpus were analyzed: the Bates, Brown, Gleason, HSLLD, and Wells databases. Raw co-occurrence frequencies were normalized using the Jaccard index (Van Eck & Waltman, 2009): the number of raw co-occurrences was divided by the sum of each word occurring individually minus the number of times the two words co-occurred (for details see Fisher, 2010). Based on the analysis of the CHILDES corpus, the mean co-occurrence probability of labels in the co-occurring condition was 0.04 and in the non-co-occurring condition 0.00, independent-samples $t(6) = 3.16$, $p = 0.02$.

Procedure

All children were tested individually in a quiet room adjacent to their classroom. All adult participants were tested in a laboratory on campus. Visual stimuli were presented on a computer and instructions and labels were given verbally by hypothesis-blind experimenters.

Induction Task

Participants were told they would play a game in which objects were hiding behind doors. The experimenter told the participants what was hiding behind each door and then asked them a question. Participants were presented with an induction task which consisted of 8 triads. Each triad was comprised of a target, a category choice, and an unrelated lure; the target was the baby-animal², the category choice was the parent-animal, and the lure was an unrelated animal (e.g., *puppy-dog-bear*). Children were told the target had a novel-property and were asked to generalize the property to one of the test items (the category choice or the lure). Stimuli sets were presented in one of two random orders. Presentation order was counterbalanced across participants.

On every trial, the target object was always hidden behind the topmost door. The location of the response options were randomized across trials (e.g., to the right or left of the target). On every trial, the experimenter pointed to the topmost door first and told the participant what was hiding behind the door (e.g., “*There is a puppy hiding behind this door*”). Then, the experimenter disclosed what

was hiding behind the remaining two doors (e.g., “*There is a bear hiding behind this door. There is a dog hiding behind this door*”). The presentation order of the category choice-first or lure-first was randomized across trials. Subsequently, the experimenter asked the participant to infer which object (category choice or lure) shared the same property with the target object (e.g., “*This puppy has erwin inside, do you think that the dog behind this door or the bear behind this door has erwin inside?*”). A schematic description of the induction task is presented in Figure 1.

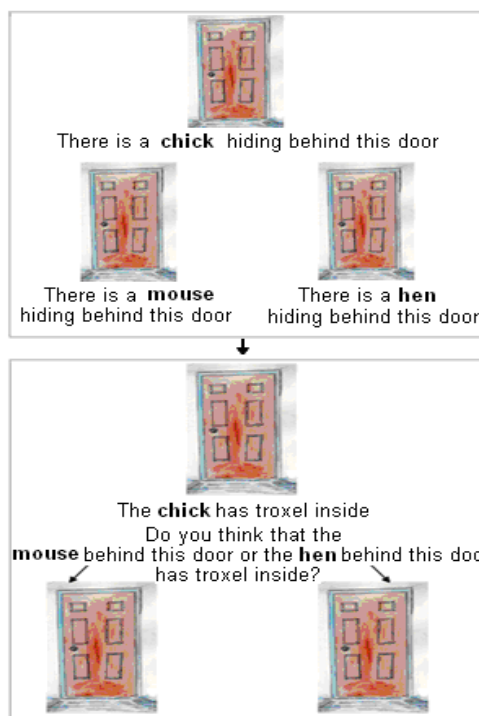


Figure 1: Schematic depiction of the induction task. All instructions were given verbally by the experimenter.

Match Task

Although, the picture identification task ensured that children were familiar with the labels used in the study, the picture identification task did not explicitly assess whether children were knowledgeable of the baby-parent relationships. Consequently, a match task was administered immediately after the experiment proper to ensure that participants had the pre-requisite knowledge of biological inheritance to be able to perform category-based induction. In the match task, participants were told that the baby animal was hiding behind a rock. The baby animal was never depicted to prevent children from selecting a response based on perceptual similarity rather than kinship. For each baby-animal, participants were asked to select the corresponding “mother” from two pictorial response options (i.e., the category and lure choice from the induction task). Figure 2 presents a schematic description of the match task.

² Except *lion-cub*, in which *lion* was the target and *cub* was the category choice.

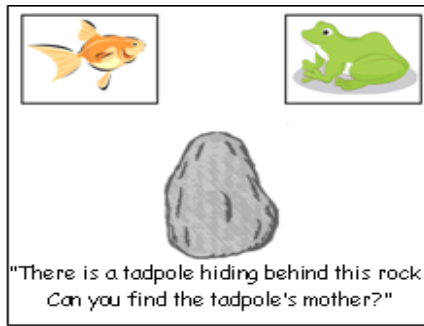


Figure 2: Schematic depiction of the match task.

Results

Induction Accuracy

Proportions of category-based responses were analyzed in a 2-way mixed ANOVA, with Age as the between-subject factor and Co-occurrence condition as a within-subject factor. This analysis revealed a significant effect of Age, $F(3, 80) = 5.28, p = 0.002, \eta^2 = 0.16$; a significant effect of Co-occurrence condition, $F(1, 80) = 13.95, p < 0.0001, \eta^2 = 0.15$; and a significant interaction between Age and Co-occurrence condition, $F(3,80) = 3.97, p = 0.011, \eta^2 = 0.13$. The significant interaction was further explored through planned comparisons.

Proportions of category-based responses were compared to chance level (0.5) using single-sample t-tests. For 5-year-olds, 7-year-olds, and adults induction performance was above chance regardless of co-occurrence probability: 5-year-olds averaged 80% and 70% of category-based responses in the co-occurring and non-co-occurring conditions respectively, all $t_s > 3.50$, all $p_s < 0.001$, 7-year-olds averaged 87% and 81% of category-based responses in the co-occurring and non-co-occurring conditions respectively, all $t_s > 7.25$, all $p_s < 0.0001$, whereas adults averaged 92% and 93% of category-based responses in the co-occurring and non-co-occurring conditions respectively, all $t_s > 8.75$, all $p_s < 0.0001$. In contrast, 4-year-olds' induction performance in the non-co-occurring condition (57.0%) was not significantly different from chance, single-sample $t(19) = 1.32, p = 0.10$. At the same time, the rate of category-based responses in 4-year-old-children in the co-occurring condition (82%) was above chance, single-sample $t(19) = 5.59, p < 0.0001$. These findings are displayed in Figure 3.

Induction performance as a function of condition (non-co-occurring labels vs. co-occurring labels) was analyzed using paired-sample t-tests. For adults there was no significant difference in the proportion of category-based responses in the co-occurring and non-co-occurring conditions (92% and 93%, respectively), paired-samples $t(19) = 0.53, p = 0.60$. Although 7-year-olds and 5-year-olds exhibited a higher mean induction score for co-occurring labels than for non-co-occurring labels (7-year-olds: 87% and 81% respectively; 5-year-olds: 80% and 70%, respectively), this difference was not statistically significant, all paired-samples $t_s > 1.36$, all $p_s < 0.19$. In contrast, among 4-year-old children the rate of category-

based responses was significantly higher in the co-occurring condition (82%) than in the non-co-occurring condition (57.0%), paired-samples $t(19) = 3.85, p < 0.001$.

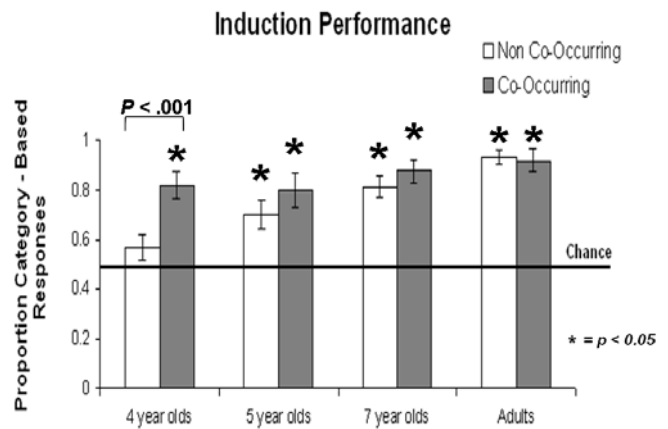


Figure 3: Proportion of category-based responses by age group and co-occurrence condition. Line indicates chance performance. Error-bars represent standard error of the mean.

Match Task Accuracy

Mean match task scores are displayed in Figure 4. All age-groups obtained mean scores that were significantly above chance (0.5) in both co-occurrence conditions, all single-sample $t_s > 4.75$, all $p_s < 0.0001$. Adults obtained statistically equivalent scores on the match task in the co-occurring condition and the non-co-occurring condition (100% and 96%, respectively), paired-sample $t(19) = 1.28, p = 0.21$. Similar to adults, 7- and 5-year-old children were equally accurate in both co-occurrence conditions (7-year-olds: 99% and 97%; 5-year-olds: 90% and 87%, for the co-occurring and non-co-occurring conditions respectively), all paired sample $t_s > 0.47$, all $p_s > 0.40$. However, 4-year-old children exhibited higher accuracy on the match task in the co-occurring condition (95%) than in the non-co-occurring condition (74%), $t(19) = 4.25, p < 0.0001$.

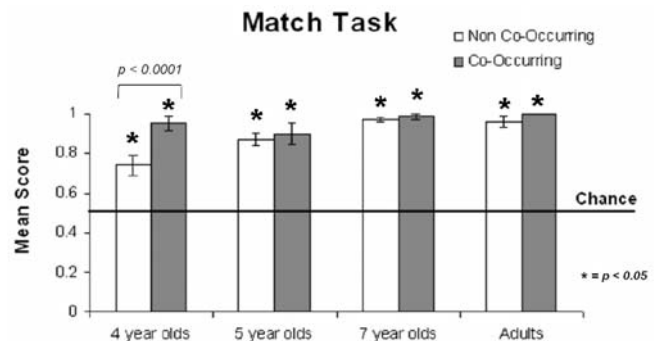


Figure 4: Match task mean scores by age group and co-occurrence condition. Line indicates chance performance. Error-bars represent standard error of the mean.

Could the difference in induction performance among 4-year-old children with co-occurring and non-co-occurring labels be explained by the difference in their ability to

identify kinship relations? We conducted several analyses to explore this possibility.

First, we re-analyzed the induction data. For every participant we removed the induction trials for label-pairs that children missed on the match task. For instance, if a child did not correctly identify that “frog” was “tadpole’s” mother, the induction data for this trial were removed from this child’s induction score. In other words, a child’s induction score was not penalized if the child did not know the kinship relation for a particular pair of labels. This procedure resulted in mean induction scores that were very close to those displayed in Figure 3: After correcting for knowledge of kinship relations, the rate of category-based induction was 81% in the co-occurring condition and 55.83% in the non-co-occurring condition. Results of all statistical analyses of induction performance remained unchanged after correcting for children’s knowledge of kinship relations.

Second, in the non-co-occurring condition we identified three label-pairs which elicited performance on the match task similar to that in the co-occurring condition in 4-year-old children. Specifically, 4-year-old children were highly accurate in identifying kinship relations with the following non-co-occurring labels: *chick-hen*, *lamb-sheep*, and *caterpillar-butterfly* (we will refer to this subset as “top 3” henceforth). Average rate of correct responses on the match task with these label-pairs was 90%, comparable to that in the co-occurring condition (95%), paired-sample $t(19) = 1.37, p = 0.19$. For this subset of labels, differences on the induction task can not be attributed to children’s superior knowledge of kinship relations with co-occurring labels. Yet, the difference in induction performance remained significant when we compared 4-year-olds responses with co-occurring labels (82%) to their responses on the “top 3” non-co-occurring labels (56.67%), paired-samples $t(19) = 3.30, p = 0.004$.

Finally, there was no significant correlation between 4-year-olds’ responses on the match task and their responses on the induction task in the non-co-occurring condition ($r = 0.36, p = 0.12$) as well as in the co-occurring condition ($r = -0.09, p = 0.70$).

Individual Response Patterns

To investigate individual patterns of responses, participants were classified as either category-based or non-category-based responders. To mitigate concerns about possible kinship knowledge effects for non-co-occurring labels, we limited this analysis to the “top 3” non-co-occurring condition trials – the trials on which 4-year-olds exhibited high accuracy in the match task. Thus, analysis of the individual patterns of responses involved three trials in each co-occurrence condition.

A category-based responder was defined as a participant who provided category-based responses on all three trials within each co-occurrence condition. Results of this analysis (displayed in Figure 5) mirrored group data. For adults, the majority of participants were classified as category-based responders regardless of the co-occurrence

condition: 85% (17 of 20) of adult participants were classified as category-based responders in the co-occurring condition and 90% (18 of 20) in the non-co-occurring condition. The association between condition and responder type was not significant, Fisher’s exact $p = 1.0$. Similarly, for 7-year-old children, 71% (17 of 24) of participants were classified as category-based responders in the co-occurring condition and 54% (13 of 24) in the non-co-occurring condition. The association between condition and responder type was not significant, Fisher’s exact $p = 0.37$. Among 5-year-old children, 65% (13 of 20) of participants were classified as category-based responders in the co-occurring condition and 45% (9 of 20) in the non-co-occurring condition. The association between condition and responder type was not significant, Fisher’s exact $p = 0.34$. In contrast to older participants, responses of 4-year-old children varied as a function of condition. The majority of 4-year-old children were classified as category-based responders in the co-occurring condition (60%, or 12 of 20), but only a small percentage of 4-year-olds were classified as category-based responders in the non-co-occurring condition (20%, or 4 of 20). The association between condition and responder type was significant, Fisher’s exact $p = 0.02$.

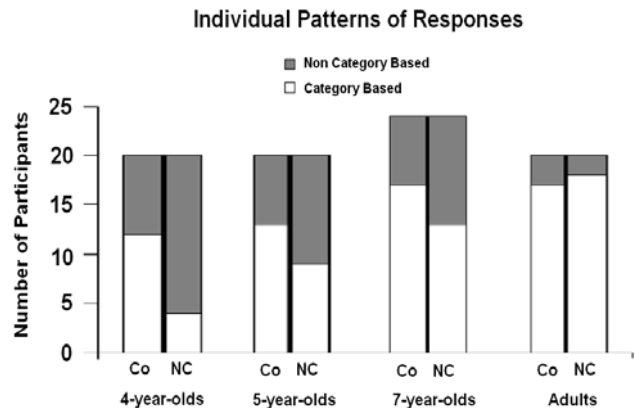


Figure 5: Number of participants classified as category-based responders and non-category-based responders by age and co-occurrence condition (Note: NC = non-co-occurring condition; Co = co-occurring condition).

When more liberal criterion in defining a category-based responder were utilized (i.e., a participant providing a category-based response on 2 out of 3 trials in each co-occurrence condition), the results remained largely unchanged: 90% (18 of 20) of adult participants were classified as category-based responders in the co-occurring condition and 100% (20 of 20) in the non-co-occurring condition, Fisher’s exact $p = 0.49$; 92% (22 of 24) of 7-year-olds were category-based responders in the co-occurring condition and 88% (21 of 24) in the non-co-occurring condition, Fisher’s exact $p = 1.00$; 80% (16 of 20) of 5-year-olds were category-based responders in the co-occurring condition and 65% (13 of 20) in the non-co-occurring condition, Fisher’s exact $p = 0.48$; 85% (17 of 20) of 4-year-old participants were category-based responders in the co-occurring condition and 55% (11 of 20) in the non-co-occurring condition, Fisher’s exact $p = 0.08$.

Discussion

The present study was designed to test whether young children base their inductive generalizations on kinship information or co-occurrence probability. Five-year-olds, 7-year-olds, and adults reliably based their inferences on kinship information with both non-co-occurring and co-occurring labels; in contrast, 4-year-olds' induction performance was influenced by co-occurrence probability of the label-pairs. Specifically, 4-year-olds performed significantly above chance in the co-occurring condition – when they could rely on both co-occurrence and kinship information – however, performance dropped to chance levels in the non-co-occurring condition when the only source of information for induction was kinship relations. These results suggest that 4-year-olds' induction performance found in earlier research (e.g. Fisher, 2010; Fisher et al., in press) was unlikely to stem from children's reliance on kinship knowledge.

A second contribution of this research is that it replicates and extends previous findings by Fisher et al. (in press). In that study – as in the present one – 4-year-old children were found to make category-based inductive inferences at above chance levels when synonymous labels were co-occurring but performed at chance when labels were non-co-occurring. Similar to the present study, the Fisher et al. study manipulated co-occurrence probability within participants. However, Fisher et al. blocked the presentation of co-occurring and non-co-occurring trials. In the present study co-occurring and non-co-occurring trials were intermixed, which is arguably the most stringent test of the co-occurrence hypothesis. Therefore, the present findings help to establish the robustness of this effect.

It is possible that some other factors associated with co-occurrence, such as label familiarity or frequency of occurrence, may account for children's adept performance with these labels. Fisher et al. (in press) examined these possibilities and did not find any evidence of correlations between these factors and children's inductive inferences.

In sum, the present study suggests that children's induction performance with co-occurring labels is unlikely to stem from children's knowledge of kinship relationships. Overall, children's knowledge of kinship relationships for items used in this study was good, but largely unrelated to their induction performance. Even when individual patterns of responses were analyzed using the most well known kinship label-pairs, preschoolers were more likely to be category-based responders with co-occurring labels. We interpret this as evidence that co-occurrence probability may play an important role in young children's induction performance. One possible pathway by which co-occurrence probability may facilitate young children's induction performance is lexical priming. Co-occurrence may result in strong lexical associations between word-pairs. Consequently, children may select the semantically-similar response option not because children are engaging in category-based reasoning but because lexical priming results in spreading activation from the target to the

synonymous word pair (e.g., *bunny* priming *rabbit* rather than *squirrel*). In conclusion, this study provides additional evidence that co-occurrence probability may influence young children's induction performance and demonstrates that the development of category-based induction follows a more protracted course than previously believed.

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