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Comparison and Function in Children's Object Categorization

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Abstract

Although young children often rely on salient perceptual cues, such as shape, when categorizing novel objects, children shift towards deeper relational reasoning when they compare category members or attend to functional properties. In this study, we investigated the independent and combined effects of comparison and function in children's categorization of novel objects. Across two experiments, we found that comparing two perceptually similar category members led children to discover non-obvious relational features that supported their categorization of novel objects. Together, these findings underscore the difficulty in categorizing novel objects but demonstrate that comparison may aid in this process by rendering less obvious relational structures more salient, thus inducing a shift towards a categorical rather than perceptual response.

Keywords: Comparison; function; object categorization; conceptual development

Introduction

The ability to rapidly form categories is a fundamental attribute of human cognition that involves remarkable flexibility and requires surprisingly few examples. Take, for example, a Dalmatian. We readily categorize a Dalmatian as a *dog*, along with German Shepherds, Chihuahuas, and Poodles despite their obvious differences in size, shape, and color. However, with just as much ease, we exclude cows from the category *dog* even though cows and Dalmatians have similar black spots and are both considered *animals*. This apparent dissociation between perceptual similarity and category membership raises a series of important questions about conceptual development: How do children form object categories and, critically, how do they learn to revise these categories to incorporate new information and accommodate novel instances?

Two predominant accounts of category formation have been proposed, each with empirical evidence to support it. The first approach suggests that young children rely heavily on salient perceptual features, such as shape, as a basis for categorizing (Baldwin, 1989; Landau, Smith, & Jones, 1988), but adapt the perceptual bases for their categorization based on information about how perceptual features correspond to and support object functions. Given that an object's form is often correlated with its function and goal-based actions (Kelemen, Seston, & Saint Georges, 2012; McCarrell & Callanan, 1995; Ware & Booth, 2010), the shape of an object (e.g., in the case of a ball) or a salient part of an object (e.g., wings in the case of a bird) may serve as a sound basis for categorizing. In contrast, the second approach claims that children form categories by identifying the abstract, relational properties, such as structural and functional relations, that bind the categories. This process can be facilitated by comparing two or more category instances, thereby realizing that these relations among features and their associated functions are shared amongst category instances (e.g., Gentner & Namy, 1999; Namy & Gentner, 2002). For example, children may base their classification of a kiwi as a fruit on the fact that it, like other fruit, is edible, sweet, and grows on trees.

Function Information

Children independently utilize both *form* (e.g., Landau et al., 1988) and *function* information (e.g., Kemler Nelson, 1999; Kemler Nelson, Russell, Duke, & Jones, 2000) as a basis for object categorization. These factors, however, are interrelated, enabling children to base their categories on the most functionally relevant perceptual features. For example, McCarrell and Callanan (1995) showed that young children not only recognize the functional affordances of particular perceptual features but also use these perceptual properties to make category-based inferences (e.g., generalizing the property "sees well at night" to animals with large eyes). Even for novel objects that perform novel functions, children are adept at identifying key perceptual features that are functionally relevant (Kemler Nelson, 1999; Kemler Nelson et al., 2000). For example, after learning that a basket attached to a handle dispensed balls into an out-of-reach chute, children who had the opportunity to physically explore the novel objects reliably identified other objects that could perform a similar function and generalized the category label to those functionally similar objects, rejecting those in which the handle was too short or the basket had a hole.

In some cases, rather than relying exclusively on *observed* functional affordances as a basis for categorization judgments, children may infer the creator's *intended* function, basing their categorization on the features that are most relevant to the intended function (e.g., Diesendruck, Markson, & Bloom, 2003; Kelemen et al., 2012; Ware & Booth, 2010). As a result, children will include a broken artifact in the object category even though this object no longer serves its intended function (e.g., a cracked cup that can no longer hold liquids is still a cup).

Comparison

Comparison, the process of identifying structural and relational commonalities (and differences) among two or more entities, is a powerful learning mechanism through which common relational structures that support deep reasoning are highlighted (Gentner, 2010; Gentner & Markman, 1997). In the case of object categorization, surface level similarities serve as an impetus to align two or more stimuli, leading to the identification of subtle relational commonalities that are most relevant for category membership, such as those that relate to object function. These relational commonalities are then projected to other entities, thus supporting inferences about category membership and facilitating category learning.

The role of comparison in category learning is evident even in young children's object categorization. Three- and four-year-olds who are given opportunities to compare perceptually similar category members reliably generalize categories based on conceptually relevant features other than overall shape. Gentner and Namy (1999; Namy & Gentner, 2002), for example, demonstrated that comparing two similarly shaped, familiar objects (e.g., a bicycle and a tricycle) led four-year-olds to inhibit attention to shape as a basis for categorization and instead extend category membership to objects sharing relational properties such as function or role (e.g., a skateboard). However, when children were presented only one object (e.g., a bicycle), they selected matches based predominantly on shape (e.g., a pair of reading glasses). Not only does comparison highlight category relevant properties in familiar objects, but comparison also facilitates the discovery of non-obvious perceptual commonalities among novel objects (Graham, Namy, Gentner, & Meagher, 2010) and of key perceptual parts (e.g., wings) that are necessary for performing functions (e.g., flying), (Gentner, Lowenstein, & Hung, 2007). Together, these studies provide converging support that comparison highlights non-obvious, functionally relevant structural properties that are shared across category members.

The Current Investigation

Existing evidence suggests clear roles for form-function relations and comparison-based structural alignment in children's categorization. Although both approaches foster object categorization, the emphases are subtly different. Categorization accounts based on form-function relations would imply that children would focus on those perceptual features that support object function. Comparison-based accounts highlight common relations among features (including those that would support functions). However both accounts would imply that children move beyond salient properties such as shape to focus on more category-relevant features as a basis for categorization.

The current investigation addresses the independent and combined contributions of these two factors to children's ability to categorize novel objects as instances of familiar object categories. When encountering static novel objects, children must rely on perceptual information to draw inferences about functional affordances and category membership, particularly because children lack specific conceptual knowledge about or experience with these novel objects. Therefore, the question of interest is whether children can use comparison of familiar category exemplars and/or information about the function of the object category to inhibit attention to shape as a basis for categorization and instead hone in on those (often subtle) perceptual features that reliably signal category membership.

Experiment 1

Experiment 1 explores the unique and combined roles of comparison and function information in the categorization of novel objects into familiar categories. Three-year-olds viewed either one (No Compare) or two (Compare) pictures of familiar objects from a target category (e.g., a penny and a dime from the coin category) and either were (Function) or were not (No Function) given functional information about the object(s) to highlight particular form-function relations (e.g., "You put it in a piggy bank"). Children were then asked to select a category match from among two novel objects: a similarly shaped object that belonged to a different target category (e.g., a compass) and a dissimilarly shaped object that belonged to the same target category (e.g., a triangular coin). If either comparison or functional information highlights functionally relevant perceptual properties of familiar objects, then children who viewed two objects and/or were given functional information should extend category membership to novel category members despite the overall greater perceptual similarity of the shape-similar foil. Of particular interest are the relative contributions of comparison and functional information, independently and jointly, in facilitating insight into category-relevant perceptual features of object categories.

Method

Participants Eighty-seven 3-year-olds (M = 3;7, range = 3;0–4;2, 44 girls) from the greater Atlanta area participated. Eleven additional children were tested but were excluded from the analysis for showing a side preference on at least nine out of ten trials (n = 7) or for incorrectly identifying items that were intended to be familiar on at least half of the ten trials in a post-experiment naming task (n = 4).

Materials Forty photographs of real objects were organized into 10 sets of four. Each set included two exemplars and two choice alternatives (see Figure 1). The exemplars, which belonged to the same target category, shared similar perceptual features and were selected to be *familiar* items to preschoolers (e.g., a penny and a dime from the coin category). The choice alternatives, in contrast, varied in their overall perceptual similarities to the exemplars and were selected to be *unfamiliar* to young children. One of the choice alternatives, the shape match, physically resembled the exemplars but fell outside the target category (e.g., a compass), whereas the other choice alternative, the taxonomic match, differed in shape from the exemplars but was within the target category (e.g., a triangular coin). Similarities and dissimilarities in shape between the choice alternatives and the exemplars were confirmed through adult ratings, whereas general familiarity with the objects was verified from pilot data with 3-year-olds.

For each set, a functional description of a unique yet familiar property of the target category was used to highlight functional affordances. For example, "You put it in a piggy bank," provided child-appropriate key functional information to describe the general category of coins. To ensure that the functional descriptions selected to characterize each target category were ones that children reliably associated with the categories, 19 3-year-olds (M = 3;8, range 3;1–4;0, 6 girls) who did not participate in the experiment proper completed a validation task, reliably matching the functional descriptions to the correct exemplars with 99% accuracy.

Procedure The procedure consisted of a *categorization task* followed by a *naming task*.

In the *categorization task*, children were randomly assigned to either the compare or no compare condition and, within each of these conditions, were also randomly assigned to either the function or no function condition. This combination yielded a total of four conditions: (1) compare-function, (2) compare-no function, (3) no compare- function, and (4) no compare-no function.

For children assigned to the *no compare-no function* condition, the experimenter began each trial by presenting a single exemplar (e.g., a penny) and exclaiming, "Look at this one! Do you see this one?" The experimenter then placed the two choice alternatives—the shape and taxonomic match—directly below the exemplar, as shown in Figure 1A, and asked the child, "Which one of these is the same kind of thing as this one?" After the child selected either the shape or taxonomic match, the experimenter removed the pictures and administered the next trial until all 10 trials were complete. Which exemplar was presented in each set was counterbalanced across children, and the left-right placement of the shape and taxonomic matches was randomized across trials.

The procedure for the *no compare-function* condition was identical to that in the no compare-no function condition with the exception that the experimenter also provided a functional description with the exemplar. For example, as illustrated in Figure 1B, the experimenter said, "Look at this one! Do you see this one? You put it in a piggy bank." following the presentation of the penny.

In the *compare-no function* condition, the experimenter presented the child with both exemplars (e.g., a penny and a dime) to elicit comparisons. As in the no compare conditions, the trial began with the experimenter laying down the first exemplar and saying, "Look at this one! Do you see this one?" The experimenter then placed the second exemplar directly beneath the first, drawing attention to the picture by exclaiming, "And now look at this one!" She then pointed back and forth between the two exemplars to prompt comparisons, saying, "Do you see how these are the same kind of thing?" Next, the experimenter placed the two choice alternatives below the exemplars, as depicted in Figure 1C, and asked the child, "Which one of these is the same kind of thing as these?" After the child selected one of the choice alternatives, the procedure was repeated until the child completed all 10 trials. Order of presentation of the two exemplars was counterbalanced across children, and the left-right placement of the choice alternatives was randomized across trials.

The *compare-function* condition was identical to the compare-no function condition except that children heard a functional description as each exemplar was presented. That is, for example, the experimenter said, "You put it in a piggy bank," after presenting the penny and then repeated the functional description for the dime, as shown in Figure 1D.

After completing the 10 trials, all children completed a *naming task* in which the experimenter re-presented the stimulus cards one at a time and asked the child to label the objects in English. If the child failed to provide a label or indicated that s/he did not know the name, the experimenter encouraged the child to provide a functional description by asking, "What do you think we do with it?" In the event that the child failed to respond even after the prompt, the experimenter reassured the child that it was fine to say "I don't know," and continued to the next picture until the child had attempted to name every object.

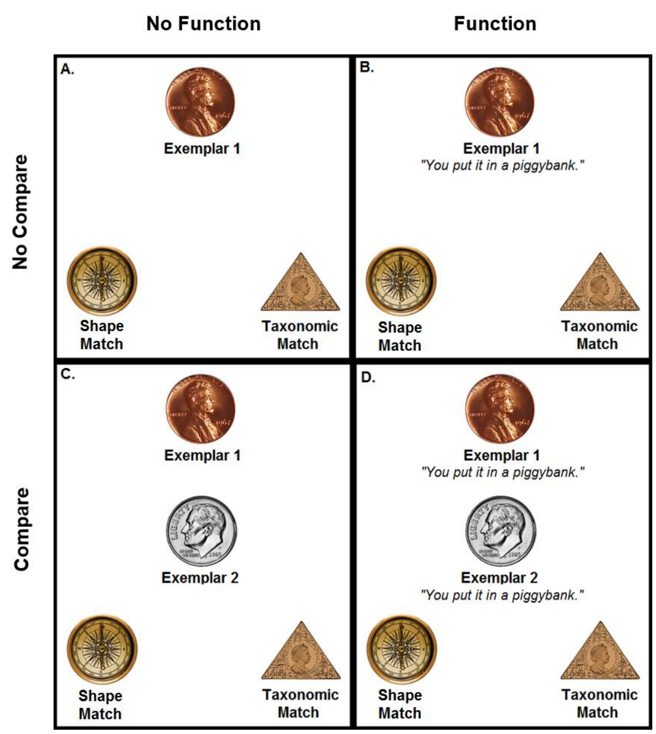

Figure 1: Sample stimulus set in *no compare–no function* (1A), *no compare–function* (1B), *compare–no function* (1C), and *compare–function* (1D) conditions.

Coding For each trial of the categorization task, responses were coded based on whether the child selected the shape or taxonomic match.

Post-experiment naming responses were transcribed from video recordings and all were scored as correct or incorrect by two independent raters. Inter-rater reliability between the two raters was 99%, and a third independent rater resolved all discrepancies. Correct responses were defined as any response demonstrating the child's knowledge of the object's identity or function. These included responding with correct labels at a subordinate, basic, or superordinate category level (e.g., "Liberty Coin", "penny", and "money" respectively, to label the penny) or by responding with the name of different basic level objects within the same superordinate category (e.g., "nickel" for the penny). Functional descriptions were also accepted as correct if the child provided enough information to sufficiently differentiate the target category from other potential categories (e.g., "You buy things with it" but not "You take it places" when describing the penny). Only trials in which the child correctly identified the familiar exemplars were included for analysis (M = 8.37 trials, median = 9). To ensure that children had an appropriate baseline knowledge of categories and objects more generally, children who incorrectly identified the exemplars on at least half of the trials were excluded (n= 4).

Results & Discussion

Figure 2 shows the mean proportion of taxonomic responses for each condition. To test whether comparison and functional information highlights key perceptual features that afford function, thereby increasing taxonomic responding, we performed a logistic regression analysis with comparison and function as predictors of taxonomic responses. The resulting model was statistically significant, $\chi^2(3) = 8.96$, $p = .03$, suggesting that when accounting for both comparison and function the model reliably predicted the likelihood that children selected the taxonomic match. Closer inspection revealed an effect of comparison, $\chi^2(1) = 7.25$, $p < .01$, with those in the compare conditions ($M = .43$, $SD = .22$) selecting the taxonomic match significantly more often than those in the no compare conditions ($M = .31$, $SD = .20$). Specifically, comparison increased children's odds of selecting the taxonomic match by 38%, $\beta = .48$, $SE = .22$, $p = .03$. The results, however, yielded no main effect of function, $\chi^2(1) = 1.24$, $p = .27$, nor was there an interaction between comparison and function, $\chi^2(1) = .14$, $p = .71$.

To examine whether children systematically employed a shape or taxonomic categorization response pattern, we compared children's performance in each condition to chance responding (i.e., .50). The analyses demonstrated that children in the no compare conditions selected the taxonomic match significantly less often than expected by chance in both the function, $t(18) = -2.66$, $p = .016$, and no function groups, $t(24) = -4.09$, $p < .001$. Those in the compare–no function condition also selected the taxonomic match significantly less often than predicted by chance, $t(20) = -2.14$, $p = .045$. In contrast, those in the compare–function condition did not reliably differ from chance, $t(21) = -.33$, $p = .74$. In other words, when children were given either comparison or functional information, they, like those who received neither comparison nor function, reliably selected the shape match over the taxonomic one. However, when children were given functional information alongside the presentation of both exemplars, children failed to show a reliable preference for the shape match. These findings indicate that children relied predominantly on shape as a basis for categorizing unless given an opportunity to compare *and* functional descriptions. Surprisingly, highlighting functional information apparently neither increased categorization based on subtle relational properties nor decreased attention to functionally irrelevant salient perceptual features. This experiment suggests that comparison but not functional information facilitates inclusion of novel instances into familiar object categories, although the phenomenon may best be characterized as shifting children away from shape matching.

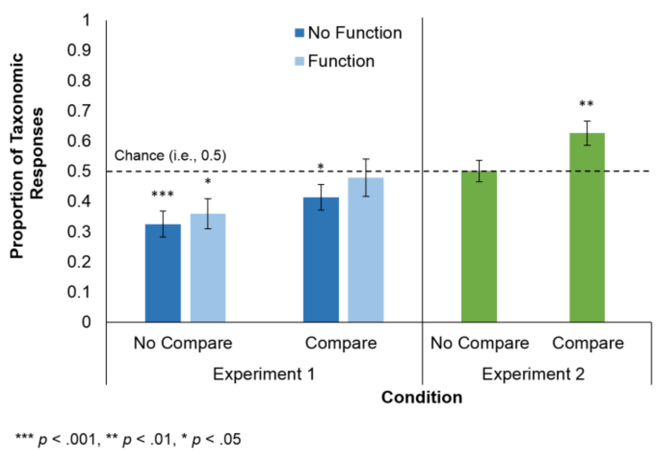

Figure 2: Mean proportion of taxonomic responses in Experiments 1 and 2.

Experiment 2

Although children who compared and were given functional information were the only ones who did not reliably select the shape match, the results from Experiment 1 indicate that comparison, but not function information, influenced children's correct extension of category membership to a novel category instance. This outcome is surprising given children's apparent ability to use functionally relevant perceptual features as a basis for categorization. One possibility is that performance on the category extension task may underestimate children's reliance on functional information as a basis for reasoning about object categories, perhaps due to information processing demands or ambiguity about the relevance of the functional information to the category extension task. Experiment 2 addresses this possibility by explicitly instructing children to extend functional properties to novel objects, while once again manipulating opportunities to compare. We reasoned that if comparison emphasizes and thus encourages children to attend to functionally relevant perceptual features, then children should select the taxonomic match more often in the compare than the no compare condition. However, if children are adept at judging function generalization to novel objects in this more direct task, then children may select the taxonomic match reliably in both the compare and no compare conditions. Finally, if children are unable to generalize a function to a novel object in the face of a surface-level shape match, then they may reliably select the shape match in both conditions.

Method

Participants Forty-nine 3-year-olds (*M* = 3;6, range = 3;0–4;2, 24 girls) from the same population as Experiment 1 participated. An additional 6 children participated but were excluded for showing a side preference on at least nine out of ten trials (*n* = 5) or for failing to complete the post-experiment naming task (*n* = 1).

Materials The stimulus sets and functional descriptions were identical to those used in Experiment 1.

Procedure As in Experiment 1, children completed a *categorization task* followed immediately by a *naming task*.

In the *categorization task*, children were randomly assigned to one of two conditions: (1) compare or (2) no compare. The procedure was identical to that used in Experiment 1 with two exceptions. First, every child received functional descriptions with the presentation of each exemplar. Second, each child was asked to extend the functional property to one of the choice alternatives rather than select a category match.

The experimenter began each trial by presenting either one or two exemplars for the no compare or compare conditions, respectively each accompanied by a functional description as in Experiment 1 (e.g., "You put it in a piggy bank.") The experimenter then laid out the shape and taxonomic matches, randomizing the left-right placement across trials, and asked, "Which one of these do you put in a piggy bank like these?" The presentation order of the exemplars as well as the order of the trials were counterbalanced across children.

After the child completed all 10 trials, the experimenter administered the *naming task* by re-presenting the stimulus cards and asking each child to label the objects in English, as in Experiment 1.

Coding The coding procedures were identical to those described in Experiment 1. Inter-rater reliability between two independent raters was 98%, with a third independent rater resolving discrepancies. Only trials in which the exemplars were correctly identified were included in the analysis (*M* = 8.80 trials, median = 9).

Results & Discussion

The mean proportion of taxonomic responses is illustrated in Figure 2. To explore the effect of comparison on children's responses, we performed a logistic regression analysis with comparison as the predictor. Consistent with the previous experiment, the model yielded an effect of comparison, $\chi^2(1) = 6.36$, $p = .01$, with children in the compare condition (*M* = .63, *SD* = .18) selecting the taxonomic match reliably more often than those in the no compare condition (*M* = .50, *SD* = .18). An odds ratio further revealed that the odds of selecting the taxonomic match was 39% greater in the compare condition than in the no compare condition, $\beta = .50$, $SE = .20$, $p = .01$.

As in Experiment 1, we also examined the probability that children's responses significantly differed from chance responding (i.e., .50) to explore whether children reliably exhibited a shape or taxonomic response pattern. Results indicated that children in the compare condition selected the taxonomic match more often than expected by chance, $t(21) = 3.20$, $p < .01$. Children in the no compare condition, in contrast, did not differ from chance responding, $t(26) = .01$, $p = .99$.

Consistent with Experiment 1, the results from this experiment revealed a significant difference in children's responses as a result of whether they had the opportunity to compare two exemplars. When shown two exemplars, children reliably selected the category match, a response that is consistent with previous studies examining the role of comparison in object categorization (Gentner & Namy, 1999; Graham et al., 2010; Namy & Gentner, 2002). In contrast, when children were shown either exemplar alone, they failed to show a preference for either the shape or taxonomic match. These data suggest that comparison highlights subtle functional properties. Nevertheless, unlike in Experiment 1, even children in the no compare condition avoided the lure of reliable shape-based responding, suggesting that children may more readily attend to functionally relevant perceptual properties in a function generalization than a category extension task.

General Discussion

In two experiments, we found that comparing similarly shaped objects from the same familiar category highlights non-obvious functional properties that are relevant for category membership. In Experiment 1, children categorized unfamiliar objects into familiar categories based predominantly on shape. However, when children were prompted to compare, their shape driven responses were attenuated such that children who compared highly similar category members were more likely to distribute their responses between the shape match and the taxonomic match, presumably based on other, subtler relational commonalities between objects. This finding underscores the alignment process elicited by comparison – despite the highly salient shape similarity between the two exemplars, children who viewed both objects were *less* likely to base their categorization on shape. Experiment 2 replicated this comparison effect, showing that those who compared two familiar objects were more likely to privilege the taxonomic match based on non-obvious relational features when asked to extend functional properties to novel objects.

Taken together, these findings suggest that comparing two objects enables children to inhibit attention to salient perceptual features and allows them to identify subtler commonalities that are more likely to be related to functional and relational commonalities among category members. In the current task, comparison not only *highlighted* relevant category information between familiar objects, it also *generated* new relational knowledge about unfamiliar items, thus enabling children to incorporate novel instances into familiar categories despite their limited experience with the stimulus items. For example, children who compare a penny and a dime may shift attention from round shape to category-relevant, yet subtle, relational features (e.g., the metal material, the engraved portrait, or the flatness of the object) that are better indicators of category membership and, critically, functional affordances (e.g., putting it in a piggy bank).

Although this study suggests that comparison reduces children's reliance on salient perceptual features by drawing attention to subtle relational features, this forced-choice task cannot directly inform which perceptual properties children utilize as a basis for categorization or why. To better understand how children's attention is being allocated to various perceptual features and how that relates to their understanding of the functional and relational properties of the objects, we plan to utilize eye-tracking measures in future research and systematically manipulate the information about structural relations and form-function correspondences to which children are exposed during category learning. Another important direction for future research is how children's perceptual analysis of object categories varies depending on whether the objects are artifacts, which are created for intended functions, or natural kinds, which arguably are less function-based. Recent work on children's teleological reasoning demonstrates that young children often assign functional properties to natural kinds (e.g., Kelemen, 1999; Kelemen et al., 2012), thus raising questions about children's categorization of natural kinds and how it may differ from artifact categorization.

The current study provides compelling evidence for the role of both comparison and function in children's ability to modulate their attention to perceptual features of novel objects that are most relevant for category membership. Although children likely employ a variety of strategies when learning about unfamiliar objects, the process of comparison serves as a powerful tool through which they may discover non-obvious properties that inform category membership.

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References

Baldwin, D. A. (1989). Priorities in children's expectations about object label reference: Form over color. *Child Development*, *60*, 1291-1306

Christie, S., & Gentner, D. (2010). Where hypotheses come from: Learning new relations by structural alignment. *Journal of Cognition and Development, 11*, 356-373.

Diesendruck, G., Markson, L., & Bloom, P. (2003). Children's reliance on creator's intent in extending names for artifacts. *Psychological Science, 14*, 164-168.

Gentner, D. (2010). Bootstrapping the mind: Analogical processes and symbol systems. *Cognitive Science,* 34, 752-775.

Gentner, D., Loewenstein, J., & Hung, B. (2007). Comparison facilitates children's learning of names for parts. *Journal of Cognition and Development, 8,* 285-307.

Gentner, D., & Markman, A. B. (1997). Structure mapping in analogy and similarity. *American Psychologist, 52*, 45-56.

Gentner, D., & Namy, L. L. (1999). Comparison in the development of categories. *Cognitive Development, 14*, 487-513.

Graham, S. A., Namy, L. L., Gentner, D., & Meagher, K. (2010). The role of comparison in preschoolers' novel object categorization. *Journal of Experimental Child Psychology*, *107*, 280-290.

Kelemen, D. (1999). The scope of teleological thinking in preschool children. *Cognition*, *70*, 241-272.

Kelemen, D., Seston, R., & Saint Georges, L. (2012). The designing mind: Children's reasoning about intended functions and artifact structure. *Journal of Cognition and Development, 13*, 439-453.

Kemler Nelson, D. G. (1999). Attention to functional properties in toddlers' naming and problem-solving. *Cognitive Development, 14*, 77-100.

Kemler Nelson, D. G., Russell, R., Duke, N., & Jones, K. (2000). Two-year-olds will name artifacts by their functions. *Child Development, 71*, 1271-1288.

Landau, B., Smith, L. B., & Jones, S. S. (1988). The importance of shape in early lexical learning. *Child Development, 62*, 449-516.

McCarrell, N. S., & Callanan, M. A. (1995). Form-function correspondences in children's inference. *Child Development*, *66*, 532-546.

Namy, L. L., & Gentner, D. (2002). Making a silk purse out of two sow's ears: Young children's use of comparison in category learning. *Journal of Experimental Psychology, 131*, 5-15.

Ware, E. A., & Booth, A. E. (2010). Form follows function: Learning about function helps children learn about shape. *Cognitive Development, 25*, 124-137.