Fifteen-month-old infants attend to shape over other perceptual properties in an induction task

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\textbf{ABSTRACT}

This study examined whether infants privilege shape over other perceptual properties when making inferences about the shared properties of novel objects. Forty-six 15-month-olds were presented with novel target objects that possessed a nonobvious property, followed by test objects that varied in shape, color, or texture relative to the target. Infants generalized the nonobvious property to test objects that were highly similar in shape, but not to objects that shared the same color or texture. These results demonstrate that infants' attention to shape is not specific to lexical contexts and is present at the early stages of productive language development. The implications of these findings for debates about children's shape bias, in particular, and the nature of infants' categories more generally, are discussed.

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Forming categories enables infants to organize the vast diversity of objects that surround them. To categorize, infants must treat objects as similar in some way. This may involve attending to similarity in appearance of objects and/or to similarity in causal, functional, and structural properties. A classic debate focuses on whether infants' early categories represent their emerging conceptual understanding of kinds (Dewar & Xu, 2009; Gelman & Coley, 1990; Keates & Graham, 2008; Mandler, 2000; Pauen, 2002; Trauble & Pauen, 2007; Welder & Graham, 2006) or whether they are instantiations of contextual groupings based on perceptually salient dimensions of similarity (Quinn, 2000; Quinn & Eimas, 2000; Quinn & Johnson, 2000). It can be difficult to adjudicate between these positions because the methodologies used to address them often vary substantially (Mareschal & Quinn, 2001). For example, using generalized imitation paradigms, advocates of “conceptual” categorization...
have shown that infants generalize the properties of familiar objects respecting ontological boundaries (Mandler, 2004; Mandler & McDonough, 1996, 1998). In contrast, using visual preference and object examining methodologies, proponents of “perceptual” categorization have found that infants group objects into categories based on particular visual properties (Oakes, Coppage, & Dingle, 1997; Rakison & Butterworth, 1998). Thus, to assess these alternative accounts, it is important to investigate similar phenomena.

Integrally tied to the debate over the relative contribution of perceptual and conceptual information in young children's categorization is consideration of the role of shape in infants' and preschoolers’ categories. Infants and preschoolers preferentially attend to object shape in the presence of a novel count noun (Baldwin, 1992; Graham & Poulin-Dubois, 1999; Landau, Smith, & Jones, 1988). Echoing the debate just noted, a question that has arisen regarding this phenomenon is whether children's attention to shape results from the perceptual or conceptual salience of shape.

Consistent with the claim that shape is a perceptually salient feature, infants are more likely to use shape differences than color or pattern differences between objects to find object boundaries (Needham, 1999), to individuate objects (Wilcox, 1999), and to identify objects in occlusion events (Tremoulet, Leslie, & Hall, 2000; Xu, Carey, & Quint, 2004). Also consistent are process models of the shape bias in word learning (Colunga & Smith, 2008; Samuelson & Horst, 2008; Landau et al., 1988; Smith & Samuelson, 2006).

Others propose that children attend to shape information because it serves as an available cue to object kind (Bloom, 2000; Booth & Waxman, 2002; Gelman, 2003; Markson, Diesendruck, & Bloom, 2008). They use shape to extend count nouns because they appreciate that count nouns refer to object categories (Dewar & Xu, 2007, 2009; Keates & Graham, 2008) and because shape is a readily available and highly reliable cue to object categories (Burger & Prasada, 1997; Prasada, Ferenz, & Haskell, 2002).

In support of the “shape-as-cue” account, Diesendruck and Bloom (2003) asked 2- and 3-year-olds to extend a new word to a novel object, to find another object “that was the same kind of thing” as a target object, or to find an object that shared a particular category-defining property with a target object. Children chose a shape match over a color or texture match. That is, children exhibited a shape bias both when extending a novel label and when categorizing objects, suggesting that the shape bias arises in any task that requires children to categorize objects into conceptual kinds. Furthermore, Graham and Poulin-Dubois (1999) found that 18-month-olds' reliance on shape to extend novel words did not covary with vocabulary size or composition, suggesting that a same-shape strategy for word generalization does not increase in strength with vocabulary acquisition during late infancy. Again, this finding supports the shape-as-cue account by indicating a possible dissociation between word learning and the significance of shape similarity to children's object concepts. As an account of infants' object categories, however, a crucial piece of evidence still missing from the shape-as-cue proposal is whether infants manifest a shape bias in a task that requires them to categorize objects into kinds. The present study tests this prediction by investigating whether 14–15-month-old infants rely on shape, versus other perceptual properties, to guide their generalization of nonobvious properties in an inductive inference task.

Inductive inferences typically involve reasoning about the shared properties of objects based on some type of perceived similarity between these objects. For example, upon learning that dogs bark, a young child may predict that a newly encountered dog, but not a cat, will also bark. Examining young children's inductive inferences affords insight into the nature of their categories. The extent to which children generalize a property from one entity to another is indicative of their belief about whether these two entities belong to the same category or kind (Gelman & Markman, 1986). To examine inductive reasoning in infants and children, researchers rely on imitation paradigms in which an experimenter models a specific action on a target object, presents infants with test objects, and notes whether or not the child imitates the target action on these objects (Baldwin, Markman, & Melartin, 1993; Mandler & McDonough, 1996). The rationale is that if children regard the test objects to be members of the same category as the target, they will imitate the target actions on the test objects.

Research on infants' inductive reasoning abilities using imitation paradigms has demonstrated that inductive reasoning emerges relatively early in development. That is, infants as young as 9 to 12 months may develop expectations about nonobvious object properties after a short exposure to a novel object (Baldwin et al., 1993). Furthermore, infants form specific expectations about nonobvious properties
and will only generalize these properties to objects that are either highly perceptually similar (Baldwin et al., 1993) or that belong to the same category (Mandler & McDonough, 1996, 1998). For example, Mandler and McDonough demonstrated that 14-month-olds generalized “animal” properties (e.g., drinking) to other animals and “vehicle” properties (e.g., being keyed) to other vehicles. Similarly, Graham and colleagues have demonstrated that infants rely on both similarity in overall appearance and shared same count noun labels to guide inferences about whether two objects share nonobvious properties (Graham & Kilbreath, 2007; Graham et al., 2004; Keates & Graham, 2008; Welder & Graham, 2001).

Although these studies provide important insights regarding the development of inductive reasoning, they do not address specifically the role of shape similarity, versus other types of perceptual properties, in guiding infants’ generalization of nonobvious object properties. For example, Graham and colleagues’ studies typically present infants with objects that are highly similar (i.e., share both shape and texture similarity) versus dissimilar (share only similarity in texture). Thus, the unique contribution of shape versus other features cannot be assessed. In the present study, we presented children with test objects that varied in their similarity to the target on a single dimension—shape, texture, or color. This manipulation allowed us to assess which of these physical attributes infants treat as most reliably indicating category membership.

We presented infants with novel target objects that possessed visually nonobvious sound properties (e.g., rattled when shaken). These objects were designed to be construed as artifact-like objects with properties not immediately available upon visual inspection. The properties of the objects were structurally independent (i.e., were not afforded by a part of the object or the texture of the object), and they were intrinsic to the objects. The experimenter first demonstrated how a particular target action performed on the target object could invoke the properties and then presented infants with the test objects.

Infants were presented with object sets in three within-subjects conditions. In the baseline condition, neither the target nor the test objects possessed the nonobvious property. This condition was included to ensure that the nonobvious properties were not visually detectable or afforded by the structure of the object. In the predicted condition, the target and test objects all possessed the same nonobvious property. This condition was included to ensure that infants did not get frustrated or bored if all test objects did not possess the nonobvious property. Finally, in the condition of particular interest, the unpredicted condition, the target object possessed a nonobvious property, but the test objects did not. This condition allowed for assessment of expectations about shared properties. If infants viewed two objects as belonging to the same category and thus expected them to share nonobvious properties, they should persist in trying to elicit the property. If shape is a privileged physical property that is conceptually salient for infants, we predicted that infants in the unpredicted condition should perform more target actions on the same-shape test objects versus the same-color and same-texture objects. Infants in the baseline condition, however, should show no preference for the same-shape test objects because in that condition there is no demand to categorize objects into kinds.

1. Method

1.1. Participants

The final sample consisted of forty-six 15-month-old infants (mean age = 15.48 months; SD = .43; range = 14.36–16.00; 23 females). An additional seven infants were tested but were excluded due to excessive fussiness or parental interference (n = 3) or as statistical outliers (n = 4). Infants were recruited through advertisements in health clinics, at trade shows, and in local newspapers. Infants were from varied socioeconomic backgrounds, from homes in which English was the primary language spoken, and were predominantly Caucasian.

1.2. Materials

Three objects were used in a warm-up phase—a clicking clock, a clothesline pulley, and a pastry press. Objects used for these trials were selected to ensure that they bore no resemblance to the test
objects, and further, to ensure that the actions performed on them were different from the actions performed on the test objects.

We constructed three object sets for use in the main phase—a rattling set, a ringing set, and a squeaking set (Figs. 1–3). Each set consisted of a target object and three test objects—a same-shape object, a same-color object, and a same-texture object. The same-shape objects had the same shape as the target object but differed in color and texture. The same-color objects were the same color as the target object, but differed in shape and texture. The same-texture objects had the same texture as the target object, but differed in color and shape. All objects in each set differed somewhat in size.\(^1\)

Each set had two versions. In one version, each object possessed the nonobvious target property: in the second version it did not, i.e., the object was not capable of producing this property. The first (functional) version of the ringing set produced a ringing sound when tapped; the functional version of the squeaking set produced a squeaking sound when squeezed, and the functional version of the rattling set produced a rattling sound when shaken.

1.3. Design

For each infant, one of the three object sets was presented across all trials in the unpredicted condition, one across trials in the baseline condition, and one across trials in the predicted condition (Table 1). Assignment of object set to condition was counterbalanced across infants so that each set appeared an equal number of times in each condition.

The testing phase consisted of three blocks of three trials each, one in each condition, a total of nine trials per infant. The order of presentation of conditions within each block was randomized and then fixed for each infant within each of their three blocks. Each object set was presented once within each trial block. As such, one test object (e.g., the same-color object) from a given set was presented in the

\(^1\) The same-shaped object is most similar in size to the target object in the rattling and ringing sets. While these objects are similar in size, this fact does not significantly affect the results as analyses indicate no effect of object set. Thus, infants were no more likely to choose the same-shape object when it was more similar in size to the target.
Figure 2. Ringing set.

Figure 3. Squeaking set.
Table 1
An overview of the within-subjects conditions.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Target</th>
<th>Test objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>No property</td>
<td>No property</td>
</tr>
<tr>
<td>Predicted</td>
<td>Nonobvious property</td>
<td>Nonobvious property</td>
</tr>
<tr>
<td>Unpredicted</td>
<td>Nonobvious property</td>
<td>No property</td>
</tr>
</tbody>
</table>

Note. The specific object set assigned to each condition was counterbalanced across infants.

first block, another (e.g., the same-shape object) in the second block, and a third (e.g., the same-texture object) in the third block. Order of presentation of test objects (same-shape, same-color, same-texture) was randomized within blocks.

1.4. Procedure

Infants were tested in a quiet room in the laboratory, seated on their parent’s lap or in a booster seat, across a table from the experimenter. The experimenter instructed parents not to direct, prompt, or cue their infants in any way (with the exception of demonstrating the property on the target objects as instructed by the experimenter, as described below). Parents were further instructed to place objects on the table in front of their infant, if their infant dropped an object off the table during the session, or if he or she passed it to the parent.

Testing began with three warm-up trials. The goal of these trials was to help infants feel at ease in the testing situation and to demonstrate to infants that they were to imitate the experimenter’s actions. The action on the warm-up trials involved an action using a part of the objects. For the clicking clock, the experimenter turned a knob, for the pastry press, she used the handle to close the object, and for the clothesline pulley, she moved it along the table using the wheels. On each warm-up trial, the experimenter first demonstrated a target action on an object. She then handed the object to the parent who also demonstrated the same action on the object. The parent then presented the object to the infant so that the infant could imitate the demonstrated actions. Following the three warm-up trials, infants proceeded to the test phase, whether or not they imitated the target actions.

Infants were presented nine test trials, three per condition. The procedure across conditions was identical with one exception: The experimenter did not demonstrate a visually nonobvious property on the target objects in the baseline condition. At the beginning of each test trial, the experimenter first introduced the target object using general attentional phrases (e.g., “Look at this one. Look what this one can do.”). She then demonstrated the nonobvious property (in Unpredicted and Predicted conditions) a total of six times while using general phrases to draw the infant’s attention to the object. After introducing the target object, the experimenter handed the object to the parent, who demonstrated the property with the target object twice. Parents only demonstrated the properties with the target objects the first time a target object from each set was introduced. The experimenter, however, continued to demonstrate the properties with the target object on each trial. The parent passed the object to the infant, who was then given 10 seconds to explore it. After this period elapsed, the experimenter placed the target object on one side of the table such that it was still within the infant’s view but was out of reach. The experimenter then introduced one of the test objects using general attentional phrases (e.g., “Look at this one”) but did not demonstrate any actions on this object (in any expectation condition). Infants were permitted to explore the test object for 20 s. This same procedure was repeated for the next eight trials.

If an infant dropped an object off the table or the object was moved out of the infant’s reach, the experimenter (or parent) placed the object back in front of the infant. We did not compensate for any time lost during a trial due to these occurrences as they were seen as intentional acts of disinterest or frustration (Oakes, Madole, & Cohen, 1991).

Either before or after testing or at home, parents were asked to complete the MacArthur-Bates Communicative Development Inventory: Words and Gestures (Infant form) (MCDI; Fenson et al., 1991) to obtain measures of infants’ receptive and productive vocabulary. All MCDIs completed at home were mailed back within a one-week period, except for two that were not returned.
1.5. Coding and data screening

The frequency of target actions performed on the target and test objects was recorded from videotapes by a coder unaware of the hypotheses and unable to distinguish the expectation conditions from each other on the videotape. The coder was also unaware of the study design, that three different conditions were presented.

The target action for the rattling set was defined as a movement of the object with the wrist and/or whole arm in a back-and-forth or up-and-down motion. The target action for the squeaking set was defined as a squeezing of the fingers together on the object. The target action for the ringing set was defined as a patting or tapping of the object with the hand.

Approximately 21% of the data (10 participants) was coded by a second coder, who was also unaware of the hypotheses and design of the study. Intraclass correlations (ICCs) were used to establish level of agreement between coders as these statistics assess both the pattern of agreement and the level of agreement of raters and thus provide a more conservative measure of inter-rater reliability than a traditional Pearson correlation (Sattler, 1992). ICC coefficients for target and test object frequency ratings were significant, ICC(89) = .99, p < .001, and ICC (89) = .99, p < .001, respectively.

Data were screened to assess for outliers. Four infants with frequency of target action standard scores greater than 3.0 standard deviations above or below the mean in the unpredicted condition were eliminated from the analyses.

2. Results

Preliminary analysis indicated that performance of the target actions on the target objects did not vary significantly across unpredicted and predicted conditions. The focus of our analyses is on infants' actions on the test objects in the unpredicted and baseline conditions.\footnote{We did not include the data from the predicted condition in our analyses as it is impossible to interpret why infants continued to perform target actions on test objects in this condition. That is, those target actions performed as a result of an expectation about an object's nonobvious property cannot be differentiated from those performed as a result of the reinforcing nature of the sound property of the test objects themselves (Baldwin et al., 1993; Graham et al., 2004; Welder & Graham, 2001). We do present the relevant means for the predicted condition for each test object and expectation condition.} Mean frequencies of target actions performed on target and test objects in each condition are presented in Table 2.

2.1. Unpredicted and baseline condition analyses

The unpredicted condition was the key condition of interest as it allows us to assess infants' expectations about shared properties. In this condition, the target object possessed a nonobvious property that could be elicited by a target action but the test objects did not have this property. If infants view two objects as members of the same category and thus expect them to share nonobvious properties, they should persist in performing the target actions in order to invoke the property. A comparison of infants' performance in the unpredicted and baseline conditions allows us to assess whether the properties of the objects were nonobvious. That is, if infants attempted the target actions on the test objects in the unpredicted condition (in which they knew about the property of the target) but not the baseline condition (in which they were not shown the property), we can be confident that the test objects in themselves did not suggest the property through their appearances.

To examine whether infants' performance of target actions varied as a function of condition and test object type, we subjected these data to a 2- (condition: baseline vs. unpredicted) by 3- (test object type: same-shape, same-color, same-texture) repeated measures analysis of variance (ANOVA). This analysis yielded a significant main effect of condition, $F(1,45) = 13.58$, $\eta_p^2 = .23$, $p < .001$, such that infants in the unpredicted condition performed significantly more target actions on test objects ($M = 1.50$, $SD = 1.53$) than those in the baseline condition ($M = 0.52$, $SD = 0.85$). Thus, appearances of the objects did not suggest that the objects possessed the nonobvious properties. Instead, infants performed target actions on test objects only after they had been exposed to the properties of particular target objects in the unpredicted condition. The analysis also yielded a significant effect of test object type, $F(2, 90) = 6.36$, $p < .001$. 
Table 2
Frequency of target actions performed on each type of test object within each expectation condition.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Target</th>
<th>Test object type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Same-shape</td>
<td>Same-color</td>
</tr>
<tr>
<td>Unpredicted</td>
<td>4.58 (2.69)</td>
<td>2.41 (3.08)</td>
</tr>
<tr>
<td>Baseline</td>
<td>–</td>
<td>0.74 (1.50)</td>
</tr>
<tr>
<td>Predicted</td>
<td>4.27 (3.01)</td>
<td>5.35 (6.04)</td>
</tr>
</tbody>
</table>

Note. Standard deviations in parentheses.

\( \eta_p^2 = .12, \ p < .01 \). Follow-up t-tests on this main effect revealed that infants performed significantly more target actions on the same-shape test object than on the same-color or same-texture object \( (p < .01) \). The number of actions performed on the same-color and same-texture objects did not differ significantly \( (p > .80) \). Importantly for our hypothesis, these main effects were qualified by a significant condition by test object type interaction, \( F(2, 90) = 3.11, \eta_p^2 = .07, \ p < .05 \).

In order to understand the source of this interaction, we examined the influence of test object type on infants’ generalization of nonobvious properties within the baseline and unpredicted conditions separately. As the baseline condition was included as a control condition to ensure the appearances of the objects did not invite performance of the target actions, we did not expect that target actions would vary by test object type. Consistent with this prediction, the results of a repeated-measures ANOVA on the number of target actions in the baseline condition yielded no significant main effect of test object type \( (p > .30) \). Thus, infants did not differ in their performance of target actions on the same-shape, same-color, or same-texture test objects in the baseline condition.

In contrast to predictions for the baseline condition, we expected that test object type would influence infants’ performance of target actions in the unpredicted condition. That is, infants in the unpredicted condition should perform more target actions on the same-shape test objects than on the same-color or same-texture test objects. The results of a repeated measures ANOVA yielded a significant main effect of test object type, \( F(2, 90) = 6.37, \eta_p^2 = .12, \ p < .01 \). To examine this main effect, we carried out planned pair-wise comparisons of the frequency of target actions performed across the three test object types. Our alpha level remained at .05 for all pair-wise tests, as the comparisons were each separate planned t tests (Maxwell & Delaney, 1990). As expected, infants performed significantly more target actions on the same-shape objects than on the same-color objects, \( t(45) = 3.42, d = .60, p < .001 \), or the same-texture objects, \( t(45) = 2.31, d = .46, p < .03 \). Furthermore, infants did not differ significantly in their performance of target actions on the same-color and same-texture test objects, \( p > .37 \). Thus, infants were more likely to expect that objects that shared the same shape, but not those that shared color or texture, would have the same nonobvious properties.

To ensure that this result could not be attributed to the salience of the shape match over the color and texture match, we examined whether actions on the test objects differed as a function of type in the predicted condition as well. This ANOVA yielded no significant main effect of test object type \( (p > .16) \), consistent with the results from the baseline condition. Thus, it is only in the unexpected condition that infants performed more actions on the shape match than on the color and texture matches.

2.2. Object transfer data analyses

In the next set of analyses, we examined instances of object transfer within the unpredicted condition. Object transfer was considered the performance of a target action from one object set on a test object from another set. To examine whether infants restricted target actions to appropriate test objects, we compared the number of target actions to the number of transfer actions performed on the various test objects using a 2 (action type: target vs. transfer) \times 3 (test object type: same-shape, same-color, same-texture) repeated-measures ANOVA. This analysis yielded a significant main effect of action type, \( F(1, 90) = 7.08, \eta_p^2 = .14, p < .05 \), such that children performed more target actions \( (M = 1.50, SD = 1.53) \) than transfer actions \( (M = .68, SD = 1.06) \). This effect, however, was qualified by a significant action type by test object type interaction, \( F(2, 90) = 7.50, \eta_p^2 = .14, p < .001 \). We followed this analysis with planned t-tests comparing the number of target versus transfer actions for each test object type.
Table 3
Descriptive data for vocabulary measures.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productive vocabulary</td>
<td>27.95</td>
<td>22.79</td>
<td>1–88</td>
</tr>
<tr>
<td>Receptive vocabulary</td>
<td>164.88</td>
<td>83.68</td>
<td>27–321</td>
</tr>
<tr>
<td>Percentage of count nouns produced</td>
<td>36.65</td>
<td>17.21</td>
<td>0–67.05</td>
</tr>
<tr>
<td>Percentage of count nouns understood</td>
<td>50.38</td>
<td>7.33</td>
<td>29.55–70.30</td>
</tr>
</tbody>
</table>

As expected, infants performed significantly more target ($M = 2.41, SD = 3.08$) than transfer actions ($M = 0.30, SD = 0.79$) on the same shape objects, $t(45) = 4.29, d = .94, p < .001$. In contrast, there was no significant difference between target actions and transfer actions on the same-color (target actions: $M = 0.87, SD = 1.80$; transfer actions: $M = 0.98, SD = 2.71$) and same-texture test objects (target actions: $M = 1.22, SD = 1.94$; transfer actions: $M = 0.76, SD = 1.73$; $p s > .20$).

Finally, we examined whether transfer actions on the matches in the unexpected condition varied as function of test object type. This ANOVA yielded no significant main effect of test object type ($p > .24$), consistent with results of the analyses of target actions in the baseline and predicted conditions.

These results indicate that infants were more likely to perform target actions than transfer actions on the same-shape test objects, rather than simply trying any type of action previously seen. Furthermore, the lack of difference in the type of action (transfer vs. target) performed on the same-color and same-texture objects suggests that infants did not view these types of test objects as preferential candidates for having the particular property possessed by the target object. In other words, they did not view these objects as members of the same category as the target object. Finally, transfer actions on the test objects did not vary as a function of test object type, further ruling out the possibility that infants attended to shape as it was simply more salient in general. Instead, infants attended to shape in a judicious manner, i.e., only for generalizing nonobvious object properties.

2.3. Relations to vocabulary and age

In a final set of analyses, we assessed the influence of overall vocabulary size, percentage of count nouns in vocabulary, and age on infants’ performance of the target actions on the same-shape, same-color, and same-texture test objects within the unpredicted condition. One infant was excluded from these analyses as he was a significant outlier on productive vocabulary size. Two additional infants were excluded from count noun analyses as they were significant outliers on percentage of count nouns produced. Table 3 presents mean vocabulary scores. Pearson correlations revealed significant relations between performance of target actions on the same-shape test object and age, receptive vocabulary size, productive vocabulary size, and percentage of count nouns understood (Table 4). No other correlations were significant.

To further examine the relations between inductions to the same-shape object, age, and vocabulary measures, we conducted two multiple regression analyses with number of actions performed on the same-shape test object as the dependent variable. In the first regression, the independent variables were age, productive vocabulary, and receptive vocabulary. The predictor variables together significantly predicted the number of actions performed on the same-shape object, $F(3, 42) = 6.30, p < .001$, Adjusted $R^2 = .28$. When the semi-partial correlation coefficients were examined, age (semi-partial $r = .33$) and productive vocabulary size (semi-partial $r = .27$) significantly accounted for unique variance in the performance of target actions on the same-shape object, $p s < .05$. In the second regression, the independent variables were age, percentage of count nouns produced, and percentage of count nouns understood. Again, the predictor variables together significantly predicted the number of actions performed on the same-shape object, $F(3, 40) = 5.51, p < .001$, Adjusted $R^2 = .24$. When the semi-partial correlation coefficients were examined, only age (semi-partial $r = .37$) significantly accounted for unique variance in the performance of target actions on the same-shape object ($p < .05$). Together,

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Overall vocabulary scores and count noun measures could not be analyzed in the same multiple regression analyses as these variables were too highly correlated.
Table 4
Correlations between target actions on test objects (unpredicted condition) and age and vocabulary measures.

<table>
<thead>
<tr>
<th>Test object type</th>
<th>Same-shape</th>
<th>Same-color</th>
<th>Same-texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>.36*</td>
<td>.25</td>
<td>.09</td>
</tr>
<tr>
<td>Receptive vocabulary</td>
<td>.39*</td>
<td>.01</td>
<td>-.04</td>
</tr>
<tr>
<td>Productive vocabulary</td>
<td>.43*</td>
<td>-.04</td>
<td>.05</td>
</tr>
<tr>
<td>Percentage of count nouns produced</td>
<td>.23</td>
<td>-.09</td>
<td>-.02</td>
</tr>
<tr>
<td>Percentage of count nouns understood</td>
<td>.34*</td>
<td>.06</td>
<td>-.04</td>
</tr>
</tbody>
</table>

* p < .05.

these analyses indicate that infants’ age and productive vocabulary size were significantly related to the number of actions they performed on the same-shape test object.

3. Discussion

A longstanding debate in the infant categorization literature revolves around whether infants’ early categories stem primarily from conceptual understandings or perceptual processes (Madole & Oakes, 1999; Mandler, 2004; Mareschal & Quinn, 2001; Rakison & Oakes, 2003, for reviews). One phenomenon that reflects this debate is children’s attention to shape in categorization tasks (Diesendruck & Bloom, 2003; Graham et al., 2004; Samuelson & Smith, 2005). The goal of the present study was to shed light on this debate by evaluating whether infants privilege shape over other perceptual properties of objects when drawing novel nonobvious inferences about objects – a task that has been extensively used to assess infants’ and children’s kind concepts (Gelman & Coley, 1990; Gelman & Markman, 1986; Graham et al., 2004; Keates & Graham, 2008). Our findings clearly indicate that they do.

In the unpredicted condition, infants were more likely to generalize a nonobvious property to objects that were highly similar in shape to a target object than to objects that were similar in color or texture. Infants did not show this preference in the baseline or predicted conditions and did not show a preference for shape when performing transfer actions. In other words, shape-matches were not always selected more often than the other test object types, implying that the privileged status of shape in the unpredicted condition likely did not derive from the perceptual salience of the shape-matches. Previous findings have shown that infants generalize nonobvious properties based on general physical similarity in the absence of naming (Graham et al., 2004; Graham & Kilbreath, 2007). By disentangling shape from other perceptual properties – something previous studies have not done – our results document the primacy of shape information alone (versus other kinds of perceptual properties) in guiding inductive inferences at 15 months of age.

Our findings indicate that infants expect those objects that share the same shape will also share nonobvious properties, suggesting that they appreciate that shape similarity is a reliable cue to category membership. However, it could be that infants are simply generalizing properties from one object to another on the basis of shared shape similarity without any need to invoke notions of categories or kinds. We suggest that this explanation is unlikely for the following reasons. First, in our task, the finding that infants used the target action to evoke the hidden property on the test objects that they considered equivalent to the target (i.e., the shape matches) suggests that infants had indeed formed a mental representation of the target object. That is, they had formed some representation of the object possessing a hidden property that could be invoked with a particular action. (Note that even though the target objects remained in view when the test object was presented, the target action was not continuously available.)

Second, other research using the identical paradigm clearly indicates that infants make purposive generalizations based on kind-relevant cues (i.e., shape and/or shared labels). For example, a number of studies have demonstrated that when objects are labeled with identical count nouns, infants will generalize nonobvious properties to objects that differ significantly in shape (Graham et al., 2004; Graham & Kilbreath, 2007; Welder & Graham, 2001). Importantly, however, infants only rely on labels to guide their inferences if those labels are presented within a naming context that clearly marks
them as count nouns. For example, Keates and Graham (2008) demonstrated that when objects were named by an experimenter with a shared count noun, infants de-emphasized shape information and relied on shared object labels to generalize nonobvious properties. In contrast, when objects were described with labels that were presented referentially but in isolation (e.g., “Look here! Blick”) or marked as adjectives (e.g., “This is blickish”), infants relied on shared shape similarity to guide their inferences. Furthermore, infants only used count nouns to guide their inferences when those count nouns were presented by an experimenter with clear evidence of referential intent. That is, when count noun labels were presented by a recorded voice, infants relied on the only other kind-relevant cue available—shared shape similarity.

In summary, these studies show that infants of the same age as the ones tested in the present study, and using the same paradigm, do not infer that two objects with the same shape or same label inevitably have the same nonobvious properties. Rather, they generalize properties based on these cues only when these cues provide guidance about the object’s kind or category. Based on the results of these studies, we suggest that that infants’ performance on our task reflect some understanding of objects as belonging to the same kinds or categories.

When considered with other research on the shape bias in preschoolers and infants, the present findings add to our understanding of the circumstances under which young children attend to shape in categorization tasks. As described earlier, Diesendruck and Bloom (2003) found that by 2.5 years of age, children privilege shape when generalizing kindhood or category-relevant properties. In the present study, we show that infants generalize nonobvious properties preferentially across objects that are similar in shape, rather than objects that are similar on other physical dimensions. In turn, the results of studies conducted by Smith and her colleagues (Jones, Smith, & Landau, 1991; Landau et al., 1988), indicate that young children will not attend to shape in nonlexical tasks that assess thematic or similarity relations. Taken together, these findings indicate that from early in development, the status of shape is neither completely general nor unique to lexical tasks. Rather, it is limited to a variety of tasks involving categorization by kind. This conclusion is consistent with the general notion that infants’ categories, like those of preschoolers, may not be solely driven by considerations of perceptual salience within given stimuli configurations, but also by an emerging understanding of object kinds (Booth & Waxman, 2008; Dewar & Xu, 2009; Diesendruck & Bloom, 2003; Keates & Graham, 2008; Mandler, 2004; Markson et al., 2008; but see Colunga & Smith, 2008 and Samuelson & Horst, 2008 for differing interpretations of the shape bias).

More specifically, the present results add a crucial piece of evidence in support of the shape-as-cue account. Previous findings showed that within the first 18 months of life, infants expect labels to refer to objects that are distinct in shape (Dewar & Xu, 2007, 2009), that infants attend to functional and causal properties when categorizing objects (Booth, 2006, 2008; Booth & Waxman, 2002; Trauble & Pauen, 2007), that both shared count noun labels and overall physical similarity guide infants’ inferences regarding nonobvious object properties (Graham et al., 2004; Keates & Graham, 2008), and that infants can draw inferences based on global conceptual categories (Mandler and McDonough, 1998). These results support the notions advocated by the shape-as-cue account that even prior to substantial vocabulary acquisition, infants have a basic concept of object kind, which is associated with count nouns, physical similarity, and functional properties. By revealing a preferential bias to draw inferences based on the physical dimension of shape over other types of perceptual properties, the present findings provide a missing link for the shape-as-cue account of the shape bias. Namely, from a young age, infants indeed treat shape as a reliable cue to object kind (but see Colunga & Smith, 2008 and Samuelson & Horst, 2008, for differing interpretations of the role of shape in early categories).

Furthermore, our findings offer insight into the possible relations between vocabulary acquisition and attention to shape. We found significant positive correlations between children’s shape-based inferences and both age and vocabulary measures. Previous studies reported positive correlations between vocabulary measures and a shape bias in name extension tasks (Gershkoff-Stowe & Smith, 2004). These correlations can be interpreted as suggesting a causal relation from the learning of words – particularly shape-based count nouns – to the abstract learning of a shape bias. (See also Smith et al., 2002, for evidence that experience learning names tunes children into attending to shape.) The present findings of correlations between age and vocabulary size with attention to shape in a non-lexical task may be indicative of this type of relation (i.e., more words lead to more attention to
shape) or of a different type of relation altogether. It may be that as infants acquire more sophisticated understanding of object kinds, they become more attuned to the cues related to object kinds (e.g., both shape similarity and common labels). In other words, the correlations between age, vocabulary size and shape-based categorization may be explained by the fact that both derive from children's developing concepts of kinds. This explanation is consistent with results from longitudinal studies demonstrating that infants' categorization skills improve around the same time that their vocabulary shows significant growth (Gopnik & Melzoff, 1992; Poulin-Dubois, Graham, & Sippola, 1995). Clearly, our correlational findings do not provide clear adjudication between these two alternatives. Thus, our discussion of these causal relations remains speculative. Nonetheless, it seems to us that the direction of causality grounded on the argument that it is via language that infants learn about categories and nonobvious properties stipulates that these correlations should be evident only once children have achieved a substantial vocabulary size. In fact, this requirement seems all the more critical if language learning per se is to explain the correlations reported here, in which children's attention to shape was assessed in a non-linguistic task. Thus, the fact that these correlations were found in infants with relatively small vocabulary sizes seems to undermine this direction of causality.

In summary, our results indicate that attention to shape is present in a nonlexical task and prior to the acquisition of a substantial productive vocabulary. These findings support the proposal that from early on in development, shape is taken as a reliable physical cue to the category membership of objects.

References


