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Attention to Multiple Cues During Spontaneous Object Labeling

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It is well established that 2-year-olds attribute a novel label to an object's global shape rather than local features (i.e., parts). Although recent studies have found that younger infants also attend to global rather than local features when given a label, the test stimuli in these experiments confounded parts and shape by varying both or neither. With infants (16- and 24-month-olds) and adults, this experiment disentangled shape and parts with appropriate test objects. Results showed a clear development of a strategy incorporating multiple cues. Across three age groups, there was an increase in generalizing labels to objects matching the exemplar's local and global features (parts, base, and shape), and a decrease to objects matching in only one local feature. We discuss these results in terms of a learned flexibility in using multiple cues to predict lexical categories.

It is well established that young children exhibit a shape bias during spontaneous lexical categorization. When shown an object and told its name, 2-year-olds, like adults, extend the same label to other objects with the same

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overall shape rather than those with the same color or texture (e.g., Landau, Smith, & Jones, 1988, 1992; Smith, Jones, & Landau, 1996). More recent work by Smith and colleagues (Gershkoff-Stowe & Smith, 2004; Samuelson, 2002; Samuelson & Smith, 1999; Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002) showed that an increase in the use of shape as the basis of label generalization from 16 to 24 months parallels the acquisition of count nouns in an infant's lexicon. In other words, attention to shape emerges as a function of word-learning experience.

As yet, the basis for label generalization by younger infants remains unresolved. Research from lexical and nonlexical categorization tasks suggests that younger infants may exhibit a part bias. Specifically, Rakison and colleagues (Rakison, 2007; Rakison & Butterworth, 1998a, 1998b; Rakison & Cohen, 1999) showed that 12- to 22-month-old infants use salient parts as the basis for categorization. Rakison and Butterworth (1998a) found that when 14-month-olds were presented with hybrid stimuli (e.g., animals with wheels), they tended to categorize them with other objects that possessed the same parts (e.g., vehicles with wheels) rather than with objects from the same category (e.g., animals with legs). In contrast, 22-month-olds in the same task attended to multiple cues, one of which was object parts. This developmental trend suggests that the part bias exhibited by 14 months decreases with experience as attention to multiple attributes increases. Furthermore, Rakison and Lupyan (2008) found that when 18-month-old infants were habituated to moving objects with moving parts in the presence of a label (e.g., "neem"), they associated the label with the parts rather than the body or motion of the object.

In contrast to these findings, other studies show that by 12 months of age infants more readily associate novel labels with whole objects, and their attribution of labels on the basis of object parts is secondary (e.g., Hollich, Golinkoff, & Hirsh-Pasek, 2007; Kobayashi, 1998; Markman & Wachtel, 1988). Infants and children associate labels with parts only if their attention is drawn to the part by the experimenter (Kobayashi, 1998), if a label is already known for the whole object (e.g., dorsal fin of a fish; Markman & Wachtel, 1988), or if multiple linguistic cues are provided to differentiate the part from the whole object (Saylor & Sabbagh, 2004). These findings imply that children do not readily use parts when initially assigning labels to objects. If infants have such difficulty labeling object parts, then it follows that they would not use parts as the basis for extending a label to a novel object.

There are nonetheless a number of reasons why infants may generalize on the basis of object parts during lexical categorization. Parts are often confounded with global shape: Objects with the same shape tend to have the same parts (Tversky, 1989), and if parts are sufficiently large they can determine a significant portion of an object's shape. Unfortunately, many previous word-learning experiments with the forced-choice test procedure failed to take this into account; that is, they confounded overall shape with parts. For example, in recent work by Hollich et al. (2007) that examined infants' whole object and part biases during labeling, 12- and 19-month-olds were asked to choose between an identical object to the exemplar (with both the salient part and nonsalient base) and just the part or base of that object. With only these options, infants chose the test stimuli that were identical to the exemplar. Thus, it is possible that what is interpreted as a whole-object bias in lexical categorization could instead be a part bias (i.e., attending to the part and base separately) or a shape bias (i.e., attending to the overall shape of the combined part and base). Moreover, the test objects in studies that examined infants' shape bias tend to vary only in shape, color, or texture (e.g., Samuelson & Smith, 2005; although see Samuelson & Horst, 2007). The test trials did not include, for example, objects with the same parts but different global shape or objects with the same global shape but different parts.

The aim of the current experiment was to determine whether infants exhibit a part bias when they are given the appropriate options during the test phase of a lexical categorization task. One way to assess this question is to provide infants with four alternatives that vary in parts, part location, base, and global shape to the target exemplar and then examine lexical generalization to these objects. In the present experiment, we investigated the developmental trajectory of attention to parts and shape in early word-learning infants (16-month-olds), in post vocabulary-spurt children (24-month-olds), as well as in adults. In this study, participants first were shown an object that was labeled by an experimenter, and then they were given four test choices that were designed to disentangle parts and shape. One of the test objects had the same parts as the exemplar in different locations (changing its global shape). Another object had the same parts as the exemplar, but on a different base. A third object had the same base but different parts to maintain a similar global shape. The fourth object had the same base but no parts (changing its global shape). Each participant was tested with four different sets of objects. Given young infants' attention to parts and older infants' attention to multiple cues (e.g., Rakison & Butterworth, 1998a; Rakison & Lupyan, 2008), we predicted that the 16-month-olds would generalize labels to objects based on parts, while 24-month-olds and adults would exhibit both part and shape biases.

METHOD

Participants

Adults

Forty-four undergraduate students (*M* age = 19.61 years, range = 18–22 years) participated in separate group sessions of three to six participants each. These participants were recruited via an online psychology experiment website. Participants were given academic credit for participating in the study.

Infants

Fourteen 16-month-olds (*M* age = 15 months, 30 days; range = 15 months 16 days to 16 months 16 days) and sixteen 24-month-olds (*M* age = 16 months, 2 days (range = 23 months 19 days to 24 months 16 days) participated in this experiment. An additional 25 participants were excluded from the final analysis (fifteen 16-month-olds and ten 24-month-olds) because of (a) fussiness (i.e., failing to respond in two or more test trials, $N = 16$), (b) experimenter error while training seven different experimenters ($N = 7$), and equipment failure ($N = 2$).

Stimuli

Four sets of objects with varying shapes, parts, color, and texture were used in this experiment (Figure 1). Each set consisted of an exemplar and four test objects, which varied from the target exemplar by having (a) different part locations, (b) same parts/different base, (c) same base/different parts, and (d) no parts. The sets consisted of felt-covered wooden pieces (set 1), painted foam clay (set 2), painted Styrofoam shapes (set 3), and sponges wrapped with fuzzy material (set 4). The heights of the stimuli ranged from 7.5 to 12 in. Each object was given a label (i.e., dax, zup, rif, or wug), and object-label assignments were counterbalanced among all infants.

Design and procedure

Adults

The experimenter introduced the exemplar to the participants while saying, “This is a ___. Take a look at the ___.” and allowed each participant to touch it. This object was then hidden, the four test objects were introduced, and participants explored each of them. The four objects were then placed

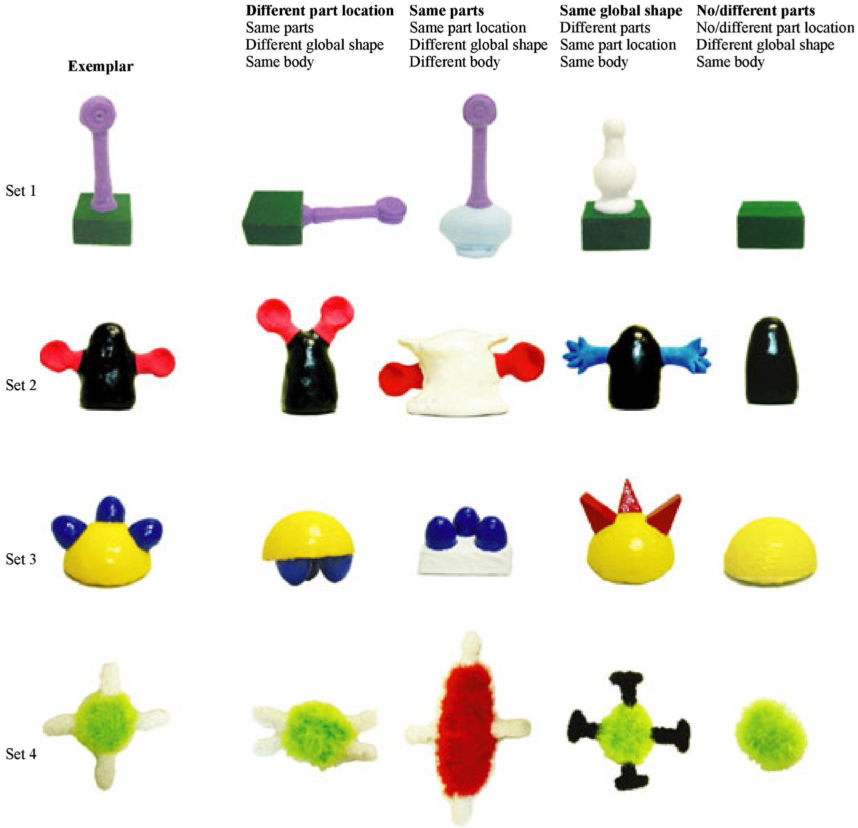

Figure 1 The sets of experimental stimuli used with infants and adults. The object categories are: Part location change, Same parts, Part change, and No parts.

in front of the participants in a random order, and the experimenter asked the participants to list in rank order the objects that they thought were also a ___ (e.g., a dax). Participants were told that they did not have to rank all four objects if they thought that any did not match the target exemplar. The experimenter repeated this procedure with each object set.

Infants

Each infant sat on the parent's lap in a small, quiet room at a table diagonally to the right of the experimenter. Parents were asked to refrain from commenting or guiding their infant's behavior. To acclimatize the infants to the experimental setting, they participated in two simple warm-up tasks in which they were encouraged to imitate an action performed by the experimenter (e.g., putting a block in a cup).

During the main procedure, the experimenter brought out the exemplar and placed it in front of the infant. The experimenter introduced a label (i.e., dax, zup, rif, or wug) six times using carrier phrases, such as "Look at the ___", and "Do you see the ___?" The experimenter allowed the infant to explore the exemplar for 30 sec. Then, the experimenter hid the exemplar under the table and brought out the four test objects from the same set and placed them in front of the infant, who was allowed to play with them for approximately 1 min. The experimenter encouraged the infant to touch each object by saying, "Look at these! What can you do with all of these toys?" while drawing a circle in the air over the four objects with her index finger.

After 1 min, at the start of the test phase, the experimenter brought out the exemplar again and asked, "Look, this is a ___. Do you remember the ___? Do you see another ___? Can you give me another ___?" The experimenter waited up to 30 sec for the infant to hand over one of the four objects on the table. When given any object, the experimenter encouraged the infant by saying, "Good job!" and placed that object away from the infant. Prompts continued until responses were not made within 30 sec or all four objects had been handed to the experimenter.[1] This procedure was repeated with each set of objects. The presentation order of the four object sets and labels was counterbalanced with a Latin square across the infants in each age group, and the placement of the test objects on the table was determined randomly.

All experimental sessions were video-taped for initial and reliability coding. The order in which the infants handed the experimenter the objects was recorded. Infants were coded as handing over an object if they lifted and held it to the front diagonal right (in front of the experimenter) while making eye contact with the experimenter. Seven judges initially coded the videotapes and later cross-coded 20% of the infants' actions for reliability. Interrater reliability was 100%.

RESULTS AND DISCUSSION

Following Samuelson and Smith (2005), we considered infants' and adults' mean number of first choices in the final analysis. To calculate the mean

[1]Infants were asked to choose more than one object per set so that there did not seem to be only one correct answer. The multiple prompts were also intended to encourage participants to explore the whole set of objects. On average, infants (both age groups) chose 14 out of 16 objects over an experimental session (16-month-olds: $M = 14.07$, $SE = .62$; 24-month-olds: $M = 14.13$, $SE = .73$).

number of choices for a particular object type, we totaled the number of times that object type was given to the experimenter and divided that number by four. A 4 (Object type) × 3 (Age) repeated-measures analysis of variance (ANOVA) revealed a main effect of object type, $F(3, 213) = 25.86$, $p = .001$, partial $\eta^2 = .27$, and an interaction of object type and age, $F(6, 213) = 5.94$, $p = .001$, partial $\eta^2 = .14$. Bonferroni-corrected pairwise comparisons to investigate the main effect revealed that infants and adults chose objects with part location changes more than objects with same parts/different base ($p < .001$), different parts/same base ($p = .058$), and no parts ($p < .001$). Participants also chose objects with different parts but same base more than objects with the same parts ($p < .01$) and no parts ($p < .001$). Objects with only the same parts but different base or no parts were chosen with equal frequency ($p = .41$).

Critically for our hypotheses, infants' and adults' object choices revealed a clear developmental trend. Adults chose objects with part location changes more than both infant groups ($p = .02$). The 16- and 24-month-olds chose these objects with equal frequency ($p = 1.00$). Adults chose objects with only the same parts but different base less often than both infant groups ($p \leq .02$). The 24-month-olds chose these objects less often than the 16-month-olds, though this difference was not significant ($p = .13$). All groups chose objects with different parts and same base with equal frequency (16-month-olds compared to 24-month-olds: $p = .55$, 24-month-olds compared to adults: $p = 1.00$). Choices for objects without parts decreased with age (16-month-olds compared to 24-month-olds: $p < .01$, 24-month-olds compared to adults: $p = .03$), where no adults matched these objects to the exemplar (Figure 2).

We also conducted within-group analyses (by age). Sixteen-month-olds did not seem to choose any object type significantly more than the others, $F(3, 39) = 1.49$, $p = .23$, partial $\eta^2 = .10$. Twenty-four-month-olds displayed clear choices, $F(3, 45) = 5.60$, $p = .002$, partial $\eta^2 = .27$, choosing objects without parts less often than objects with the same parts in different locations ($p = .02$) and objects with different parts but the same base ($p = .01$). Adults displayed even clearer choices, $F(3, 129) = 62.59$, $p < .001$, partial $\eta^2 = .59$, choosing objects with the same parts in different locations most often ($p < .01$), objects with different parts but similar global shape with less frequency ($p < .01$), and the other two equally least often ($p = .62$).

A 4 (Object set) × 4 (Object type) ANOVA revealed interactions between different object sets for infants and adults, 16-month-olds: $F(9, 99) = 3.38$, $p = .001$, partial $\eta^2 = .24$, 24-month-olds: $F(9, 117) = 2.36$, $p = .02$, partial $\eta^2 = .15$, adults: $F(9, 333) = 38.60$, $p < .001$, partial $\eta^2 = .51$. These

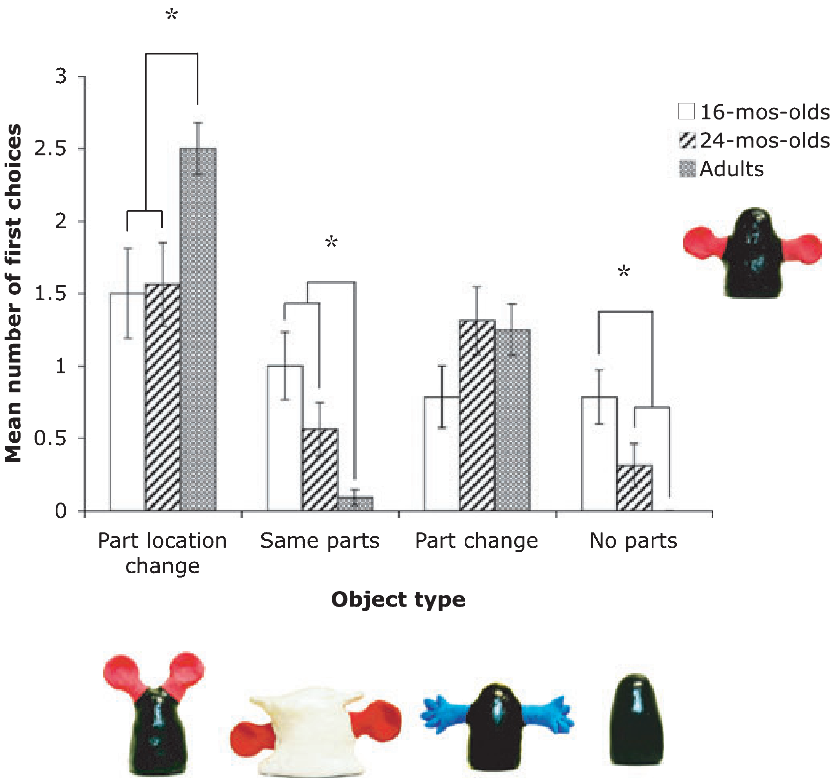

Figure 2 Mean number of first choices made by 16- and 24-month-old infants and adults. Error bars represent standard error. $*p \leq .03$.

interactions indicate that different object sets mediated infants' and adults' attention to parts, base, and shape.

DISCUSSION

The current experiment investigated the developmental trajectory of generalizing novel labels based on the perceptual similarity of objects. Specifically, participants were asked to match exemplars to test objects that differed in shape and parts. Overall, the three age groups (16- and 24-month-olds, and adults) generalized labels most often to objects that matched the exemplar's parts and base, less often to those that matched in global shape, and least often to objects that just matched in parts or base. Importantly, we found a developmental trend, whereby each older age group used more cues to generalize unfamiliar labels to novel objects. Across three age groups, there was an increase in generalizing labels to objects matching the exemplar's parts *and* base and a decrease to objects matching only in parts or base. Our findings suggest that with increased experience, word learners use multiple cues and develop the ability to integrate those cues. At 16 months, the infants chose all test objects with equal frequency, suggesting that their criteria for category inclusion involved either parts or base (i.e., one cue—local feature). At 24 months, infants seemed to rely equally on parts and shape (i.e., two cues—local and global features). Adults relied on parts and shape (i.e., two cues), and displayed clear choices for objects that were most similar (cue-use hierarchy). It is possible that the same choices could be made without lexical decisions, and follow-up studies should address whether labels mediate perceptual similarity judgments in this paradigm (see Plunkett, Hu, & Cohen, 2008). Moreover, our findings showed that the stimulus set can mediate object labeling behavior.

This developmental trend of using multiple cues as a function of word-learning experience supports similar trends found in other lexical and nonlexical categorization tasks (Pereira & Smith, 2009; Rakison & Butterworth, 1998a; Sheya & Smith, 2006; Smith, 2003; Son, Smith, & Goldstone, 2008). Pereira and Smith (2009) found that infants with the least amount of word-learning experience generalized labels to objects with matching surface details despite shape differences compared to the exemplar; infants with more word-learning experience generalized labels based on both local features and shape. It seems that younger infants constrain the definition of perceptual 'sameness' based on local features (surface details in Pereira & Smith, 2009, and parts or base in the current study), and that word-learning experience allows infants to consider multiple cues.

One unresolved issue with this study is its high infant attrition rate. The abnormally high exclusion rate in this study may have been due to the difficulty of our procedure for the infants, causing many to become fussy or nonresponsive during the experimental session. In our study, infants were presented with four test objects, as well as an exemplar. Perhaps infants would have responded better with fewer test options (e.g., three test items, Samuelson & Smith, 2005). Recently, Horst, Scott, and Pollard (2010) showed that even 30-month-olds had difficulty remembering a labeled object among only three distracters. Given that our experimental manipulation requires four test options, follow-up studies could increase the number of test trials so that each trial contains fewer items. However, longer experimental sessions may also exclude many infants. Perhaps infants could be motivated to continue a longer experimental session with play breaks between test trials. Due to our high attrition rate in the current study for both infant age groups, perhaps our findings cannot be generalized to all infants at these ages. Future work should investigate possible factors that contributed to the infants' attrition, and whether infants who do not finish the task show different behavioral patterns compared to infants who can complete the task.

The current experiment, in conjunction with previous work on early word learning, suggests that infants first rely on objects' local attributes and then eventually integrate prior knowledge to be more accurate when determining an object's label (Imai, Gentner, & Uchida, 1994; Samuelson & Horst, 2007; Yoshida & Smith, 2003). Future studies should identify the exact mechanisms driving the development of multiple cue use. Some have suggested that statistical learning underlie toddlers' incredible word-learning abilities (e.g., Plunkett et al., 2008; Samuelson, 2002; Smith & Yu, 2008). Infant word learners may internalize the co-occurrence of particular object features and labels to learn what usually predicts that labeled object category (Samuelson & Horst, 2007; Smith & Samuelson, 2006). If this is the case, then infants could use this information to predict categories when only given one exemplar (Smith et al., 2002; Xu & Tenenbaum, 2007; Yoshida & Smith, 2003).

Besides information from the labeled objects, some other cues may also support word-learning abilities (e.g., social attention cues: Houston-Price, Plunkett, & Duffy, 2006; Pruden, Hirsh-Pasek, Golinkoff, & Hennon, 2006; linguistic cues: Waxman & Gelman, 2009). As asserted by the emergentist coalition model (Hollich, Hirsh-Pasek, & Golinkoff, 2000), future studies on object labeling should include test stimuli that account for multiple attentional and cognitive strategies, as well as mapping a cue-use hierarchy. In doing so, such investigations would elucidate how infants learn to use multiple cues in ambiguous situations, in other words, how infants *learn to learn* from their environment.

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REFERENCES

Gershkoff-Stowe, L., & Smith, L. B. (2004). Shape and the first hundred nouns. *Child Development*, *75*, 1098–1114.

Hollich, G., Golinkoff, R. M., & Hirsh-Pasek, K. (2007). Young children associate novel words with complex objects rather than salient parts. *Developmental Psychology*, *43*, 1051–1061.

Hollich, G., Hirsh-Pasek, K., & Golinkoff, R. M. (2000). Breaking the language barrier: An emergentist coalition model for the origins of word learning. *Monographs of the Society for Research in Child Development*, *65* (3, Serial No. 262), 17–29.

Horst, J. S., Scott, E. J., & Pollard, J. A. (2010). The role of competition in word learning via referent selection. *Developmental Science*, *13*, 706–713.

Houston-Price, C., Plunkett, K., & Duffy, H. (2006). The use of social and salience cues in early word learning. *Journal of Experimental Child Psychology*, *95*, 27–55.

Imai, M., Gentner, D., & Uchida, N. (1994). Children's theories of word meaning: The role of shape similarity in early acquisition. *Cognitive Development*, *9*, 45–75.

Kobayashi, H. (1998). How 2-year-old children learn novel part names of unfamiliar objects. *Cognition*, *68*, B41–B51.

Landau, B., Smith, L. B., & Jones, S. (1988). The importance of shape in early lexical learning. *Cognitive Development*, *3*, 299–321.

Landau, B., Smith, L. B., & Jones, S. (1992). Syntactic context and the shape bias in children's and adults' lexical learning. *Journal of Memory and Language*, *31*, 807–825.

Markman, E., & Wachtel, G. (1988). Children's use of mutual exclusivity to constrain the meaning of words. *Cognitive Psychology*, *20*, 121–157.

Pereira, A., & Smith, L. B. (2009). Developmental changes in visual object recognition between 18 and 24 months of age. *Developmental Science*, *12*, 67–80.

Plunkett, K., Hu, J.-F., & Cohen, L. B. (2008). Labels can override perceptual categories in early infancy. *Cognition*, *106*, 665–681.

Pruden, S. M., Hirsh-Pasek, K., Golinkoff, R. M., & Hennon, E. A. (2006). The birth of words: Ten-month-olds learn words through perceptual salience. *Child Development*, *77*, 266–280.

Rakison, D. H. (2007). Inductive categorization: A methodology to examine the contents of concepts in infancy. *Cognition, Brain, Behavior*, *4*, 773–790.

Rakison, D. H., & Butterworth, G. (1998a). Infants' use of object parts in early categorization. *Developmental Psychology*, *34*, 49–62.

Rakison, D. H., & Butterworth, G. (1998b). Infants' attention to object structure in early categorization. *Developmental Psychology*, *34*, 1310–1325.

Rakison, D. H., & Cohen, L. (1999). Infants' use of functional parts in a basic-like categorization. *Developmental Science*, *2*, 423–431.

Rakison, D. H., & Lupyan, G. (2008). The development of modeling or the modeling of development? *Brain and Behavioral Sciences*, *31*, 726–726.

Samuelson, L. K. (2002). Statistical regularities in vocabulary guide language acquisition in connectionist models and 15–20 month olds. *Developmental Psychology*, *38*, 1016–1037.

Samuelson, L. K., & Horst, J. S. (2007). Dynamic noun generalization: Moment-to-moment interactions shape children's naming biases. *Infancy*, *11*, 97–110.

Samuelson, L. K., & Smith, L. (1999). Early noun vocabularies: Do ontology, category structure and syntax correspond? *Cognition*, *73*, 1–33.

Samuelson, L. K., & Smith, L. (2005). They call it like they see it: Spontaneous naming and attention to shape. *Developmental Science*, *8*, 182–198.

Saylor, M., & Sabbagh, M. A. (2004). Different kinds of information affect word learning in the preschool years: The case of part-term learning. *Child Development*, *75*, 395–408.

Sheya, A., & Smith, L. B. (2006). Perceptual features and the development of conceptual knowledge. *Journal of Cognition and Development*, *7*, 455–476.
Smith, L. B. (2003). Learning to recognize objects. *Psychological Science*, *14*, 244–250.
Smith, L. B., Jones, S., & Landau, B. (1996). Naming in young children: A dumb attentional mechanism? *Cognition*, *60*, 143–171.
Smith, L. B., Jones, S., Landau, B., Gershkoff-Stowe, L., & Samuelson, L. (2002). Object name learning provides on-the-job training for attention. *Psychological Science*, *13*, 13–19.
Smith, L. B., & Samuelson, L. K. (2006). An attentional learning account of the shape bias: Reply to Cimpian and Markman (2005) and Booth, Waxman, and Huang (2005). *Developmental Psychology*, *42*, 1339–1343.
Smith, L. B., & Yu, C. (2008). Infants rapidly learn word-referent mappings via cross-situational statistics. *Cognition*, *106*, 1558–1568.
Son, J., Smith, L. B., & Goldstone, R. (2008). Simplicity and generalization: Short-cutting abstraction in children's object categorizations. *Cognition*, *108*, 626–638.
Tversky, B. (1989). Parts, partonomies, and taxonomies. *Developmental Psychology*, *25*, 983–995.
Waxman, S. R., & Gelman, S. A. (2009). Early word-learning entails reference, not merely associations. *Trends in Cognitive Sciences*, *13*, 258–263.
Xu, F., & Tenenbaum, J.B. (2007). Sensitivity to sampling in Bayesian word learning. *Developmental Science*, *10*, 288–297.
Yoshida, H., & Smith, L. B. (2003). Known and novel noun extensions: Attention at two levels of abstraction. *Child Development*, *74*, 564–577.