



Contents lists available at ScienceDirect

Cognitive Development



Learning words from pictures: 15- and 17-month-old infants appreciate the referential and symbolic links among words, pictures, and objects[☆]



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ARTICLE INFO

Keywords:

Infants
Word learning
Symbolic development
Conceptual development
Developmental theories
Representation
Learning from pictures

ABSTRACT

This experiment was designed to clarify the referential status of infants' newly learned words. We introduced 15- and 17-month-olds to a novel noun, presented in conjunction with pictures of two whisks that differed in color (one purple, one orange). We asked whether infants would extend this newly learned noun to other members of the same kind (other whisks), one differing only in color (a picture of a silver whisk) and another differing in both color and representational medium (a real three-dimensional silver whisk). Fifteen- and 17-month-olds' interpretation of the novel noun was not tethered tightly to the perceptual features with which the word had previously been paired. Instead, their interpretation was sufficiently abstract to include a new member of the same object category, although it differed in color and representational medium (a real silver whisk). Thus, by 15 months, infants appreciate the referential status of words and extend their meaning flexibly from pictures to objects.

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[☆] This research is supported in part by a grant from the National Science Foundation.

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1. Introduction

As developmental psychologists, we strongly endorse reading books with infants not only for its benefits to the infant–caregiver bond, but also for the advantages book reading confers on infant language development – word learning in particular. Although research reveals that infants can map novel words to two-dimensional representations (presented in picture books or on screens), remarkably little is known about whether and how they link those words to the real, three-dimensional objects they may later encounter. This is an important question, because despite the consensus that infants are successful at word learning, the representational status of their early words remains a topic of spirited debate (Booth & Waxman, 2003, 2006; Ganea, Allen, Butler, Carey, & DeLoache, 2009; Gelman & Waxman, 2009; Graham, Booth, & Waxman, 2012; Plunkett, 1997; Sloutsky, 2009; Sloutsky, Lo, & Fisher, 2001; Smith, Jones, Yoshida, & Colunga, 2003; Smith & Samuelson, 2006; Waxman & Gelman, 2009). This debate engages a classic tension, ubiquitous throughout the psychological and developmental sciences, surrounding the fundamental content of human knowledge (in this case, the content of infants' word meanings) and the kinds of processes that underlie its acquisition.

The present experiment was designed to shed new light on the referential status of novel words that infants learn within the context of a picture book (e.g., “whisk,” applied exclusively to pictures). We ask whether, at 15–17 months, infants' interpretation of a newly learned word is sufficiently abstract to permit them to extend it to new exemplars from the same object category (e.g., other whisks) that differ in color and representational medium (real, three-dimensional whisks).

1.1. *Words as abstract and referential entities*

We begin with a brief overview of the two alternative frameworks for word learning. Within an associationist framework, early word meanings are built exclusively on sensory and perceptual contents bound together by association (Rakison & Lupyan, 2008; Sloutsky, 2009; Sloutsky et al., 2001; Smith et al., 2003; Smith & Samuelson, 2006). Proponents of this view argue that the nature of word meaning undergoes a developmental shift: Initially, word meanings incorporate perceptual content alone; only later do infants incorporate conceptual content into word meaning as well. Associationist accounts differ considerably in the age at which they locate this developmental shift – in some as early as age 2 (Samuelson & Smith, 1999) and in others as late as 8–11 (Sloutsky et al., 2001, p. 1707) – but all share the assumption that for infants and young children words are “. . . features of objects that contribute to their overall similarity, rather than symbols denoting category membership” (Sloutsky, Kloss, & Fisher, 2007, p. 180). Put differently, early in development, a word is nothing more than a feature of the perceptual and sensory experience(s) with which it has co-occurred, just as a black beret is a feature of the experience we associate with Jean Piaget.

We have argued for a different view, one based on fundamentally different assumptions about words, concepts, and development (see Waxman & Gelman, 2009 for extended discussion). On this view, early word meaning incorporates conceptual as well as sensory and perceptual content from the start, and in the process of establishing the meaning of a word, infants interpret this content within the context of their expectations about words, concepts, and reference (Baillargeon, 2008; Baldwin, 1995; Booth, Waxman, & Huang, 2005; Carey, 2009; Gelman & Waxman, 2009; Gelman & Williams, 1998; Putnam, 1973; Spelke, 2000; Xu, Cote, & Baker, 2005). In essence, development is characterized by continuities rather than developmental shifts. Considerable evidence is consistent with this continuity view. From infancy, words (and the concepts to which they refer) are more than collections of sensory and/or perceptual features, bound together by purely associative processes. By roughly their first birthdays, infants extend novel nouns in a principled fashion, extending them specifically to object categories and not to other similarity-based groupings (Booth et al., 2005; Waxman, 1999), and using them to support inferences about new objects (Graham et al., 2012; Graham, Kilbreath, & Welder, 2004; Keates & Graham, 2008; Xu et al., 2005). Results like these indicate that infants appreciate that a word is a symbol whose referential scope extends beyond the particular object with which it has been paired.

The distinction between the two frameworks was illuminated in an experimental paradigm introduced by Preissler and Carey (2004). An experimenter introduced 18- and 24-month-olds to

| Study | Training | | Test | |
|---|---|---|---|--|
| <i>Ganea et al., (2009) Study 2</i> |  |  |  |  |
| <i>Current Study</i> |  |  |  |  |

Fig. 1. Target pictures and objects presented by Ganea et al. (2009) and in the present experiment. Pictures are represented with black frames; three-dimensional objects are represented with no frames.

a picture of a novel entity (a whisk) and named it (“a whisk”). She then presented infants with (a) another picture of a whisk and (b) an actual, three-dimensional whisk, asking, “Can you show me a whisk?” Preissler and Carey reasoned that infants should select the picture because it is perceptually more similar to the picture with which the word “whisk” had been previously introduced. In contrast, on a referential account, infants should select the real three-dimensional object as readily as the picture, because both are instantiations of the same concept.

Infants not only selected the real object, but favored it over the picture, revealing that 24-month-olds understood something both subtle and profound: Words refer to concepts and are not tethered tightly to the perceptual impressions with which they have been previously paired. In contrast, when children with Autistic Spectrum Disorder (ASD) participated in the very same paradigm, they almost exclusively selected the picture and not the three-dimensional object (Preissler, 2008). This response pattern, conforming to the associative account, is consistent with evidence that word learning is impaired in children with ASD and that when such children do acquire words, meanings tend to center around sensory and perceptual associations (Baldwin, 1995; Baron-Cohen, Baldwin, & Crowson, 1997; Frith & Happé, 1994; Preissler, 2008).

Ganea and colleagues (2009) built upon these findings to explore the developmental roots of the referential status of words in younger, typically developing infants. They taught infants younger than 24 months a novel word for a picture of a novel object, and asked whether infants would extend that word to real three-dimensional objects. At issue was whether these younger infants could appreciate the referential status of newly learned words (revealing developmental continuity) or would respond in an associative fashion (revealing a developmental shift from an initially associative to a later referential pattern). To address this question, they modified the original paradigm in several ways to accommodate infants as young as 15 and 18 months. For example, they introduced the novel noun in conjunction with realistic colored photographs (rather than line-drawings) within the context of a naturalistic book-reading session. Second, they introduced a training phase to support the younger infants’ abilities to respond systematically to the kinds of test questions that would follow. This training phase also permitted the researchers to identify infants unable to establish the word-picture pairing during the book-reading session. After completing this training, infants responded to a series of test questions, patterned after those of Preissler and Carey (2004).

This experiment revealed intriguing developmental effects. At 24 months, although many infants selected both the real object and the picture (replicating Preissler & Carey, 2004), they did not favor the object over the picture (in contrast to Preissler & Carey, 2004). At 18 and 15 months, infants divided their responses evenly among the three possible response patterns: roughly one third chose both the real object and the picture, one third chose the object alone, and one third chose the picture alone.

Ganea et al. (2009) conducted a second experiment with infants of this age, this time changing the color of the real object (but not the picture) presented at test (Fig. 1). The goal was to increase the perceptual distance between the pictures with which the novel noun was paired during book-reading (two pictures of a white whisk) and the real object presented at test (a blue three-dimensional whisk). The logic was straightforward. If infants’ interpretation of a newly learned word rests primarily on its

associative link to the exemplars with which it was previously paired, then increasing the perceptual distance between these named exemplars and the test object should have a strong effect: Infants should rarely (if ever) select the three-dimensional test object. But if infants appreciate that words refer to concepts, they should readily accept the test object as a referent of the newly learned word, because despite its difference in color, it is nonetheless a member of the same previously named object category.

Once again, there were intriguing developmental effects. Most 15-month-olds were unable to master the task and their data could not be analyzed further. Although 18-month-olds fared better, they tended to select the test picture alone, and not the real three-dimensional test object. At 24 months, performance was equivocal: Infants favored neither the picture nor the object and rarely selected both.

What is the best interpretation of this pattern of results? When infants hear a novel word applied to a picture of an object, are they unable to extend it to real three-dimensional exemplars of the same object category? We suspect that, on the contrary, infants can indeed extend a word from a picture book to real three-dimensional objects, but that something in this paradigm inadvertently led infants to interpret the novel word narrowly (see Fig. 1).

We know that infants are sensitive to the range of objects to which a novel word is applied (Waxman, 1990). We suspect that when the experimenter repeatedly paired the novel noun with pictures of a *white* whisk, infants may have adopted a narrow interpretation: in the absence of evidence to the contrary, they may have expected “whisk” to apply to white whisks in particular. After all, many nouns refer to object categories whose members tend to be uniform in color (e.g., “lemon,” “raven”). Notice, too, that in the test phase, infants could maintain this narrow interpretation by selecting the (white) picture, rather than extending the word to the (blue) three-dimensional object. Of course, infants’ apparently adopting a narrow interpretation of a novel noun in these circumstances does not constitute evidence that they failed to grasp its referential status. Rather, Ganea et al.’s infants may simply have opted for a restricted range of extension, in the absence of any information to the contrary.

1.2. The present study

Our goal was to delve more deeply into infants’ representational capacities for newly learned words. Using Ganea et al.’s (2009) paradigm, we introduced three design modifications. First, and most important from a theoretical perspective, we introduced the novel noun in conjunction with pictures of two whisks that differed in color (one purple, one orange). At test, we asked whether infants would extend the noun to an exemplar of the same category that differed in color (a picture of a silver whisk; a real three-dimensional silver whisk). If infants’ interpretation of a novel noun is influenced by the variability of exemplars to which it has been applied, infants in the present experiment should adopt a broader interpretation – one that includes exemplars that vary in color. The key question is whether they will extend the novel noun to exemplars that differ not only in color but also in representational medium (from pictures to objects).

Our second modification was designed to minimize any a priori preferences for selecting objects over pictures at test. Ganea et al. (2009) found that infants, especially at 15 months, exhibited a strong “object bias” (a tendency to handle the three-dimensional objects rather than pictures, independent of the experimenter’s request). The authors pointed out that if an infant reveals this a priori bias, it is impossible to interpret their performance at test. To reduce such a bias, before the experiment proper began, we permitted infants to play with the test pictures and objects until their interest waned.

Third, we introduced the training phase *before* children looked through the picture book with the experimenter. This modification permitted us to identify and replace any infant having a persistent ‘object bias’ (a bias to select objects over pictures), and it permitted infants to move smoothly from training to test without an intervening period that might disrupt learning of the new word (Horst & Samuelson, 2008).

With these modifications in place, the predictions of the two theoretical accounts can be distinguished. If infants’ interpretation of a novel word’s meaning is guided only by its association with the perceptual features of the objects with which it has co-occurred, infants should be more likely to extend “whisk” at test to the picture of a silver whisk (than to the real silver whisk) because the picture

shares more perceptual features with the exemplars with which the word had been introduced. But if infants appreciate the referential status of the novel word, they should extend “whisk” at test to both the picture and to the real object, because although these differ from the picture–book exemplars in color (the picture of silver whisk) and in representational medium (the three-dimensional silver whisk), they are both members of the same object kind to which “whisk” refers.

2. Method

2.1. Participants

Twenty-four English-acquiring primarily Caucasian infants were recruited, via mailings, from middle-class families in the US Midwest. Twelve participants were 15 months old (nine females; mean age 15–21, range 14–16 to 16–15) with average productive vocabulary score of 41 on MacArthur Communicative Development Inventory (MCDI). Twelve participants were 17 months old (six females; mean age 17–10, range 16–16 to 18–15) with average productive vocabulary score of 39 (MCDI). Additional infants (12 15-month-olds and 11 17-month-olds) were excluded for failure to respond correctly on one or more training questions (16) for fussiness (6), or for parental interference (1). Excluded infants did not differ from those included in the final sample by age or by the MCDI measure.²

2.2. Materials

Objects were eight familiar toys (dog, keys, baby-bottle, cup, car, phone, ball, and apple) and two novel objects (silver whisk, silver garlic press). The pictures were high-quality color photographic images printed on cardstock and laminated (13 cm × 10 cm). They depicted the eight familiar objects and six novel objects (one orange, one purple, and one silver whisk; one green, one pink, and one silver garlic press).

For the book-reading phase, we created a book containing 10 two-picture displays in which two pictures were presented side-by-side on facing pages. Pictures of each of the familiar and novel objects were included in the book, with two exceptions: the picture of the silver whisk and the silver garlic press were reserved for the test phase. We constructed the book as follows: On the first eight displays, a picture of one novel and one familiar object appeared, counterbalanced for side. The picture of each of the four novel objects (orange whisk, purple whisk, green garlic press, pink garlic press) appeared twice, once on each side. On the final two displays, only novel objects were depicted (i.e., orange whisk paired with pink garlic-press, green garlic-press paired with purple whisk). In total, then, each of the four novel pictures (orange whisk, purple whisk, green garlic press, pink garlic press) appeared three times in the book, yielding six depictions of whisks (three orange and three purple) and six depictions of garlic presses (three green and three pink).

2.3. Procedure

Infants and caregivers were welcomed into a laboratory playroom. While the infant played, the caregiver signed a consent form and completed the MacArthur Communicative Development Inventory (Fenson et al., 1993). They were then escorted into an adjoining test room where infants sat at a small table on their caregiver’s lap, across from the experimenter. Caregivers were instructed not to talk to or influence infants’ attention in any way. The procedure included four phases: familiarization, training, book-reading, and test.

² This rate is roughly comparable to the attrition rate reported in previous work. In Ganea et al.’s (2009) Study 2, which closely resembles the procedure we have adopted here, five of 20 15-month-olds were excluded for fussiness or failure to complete the procedure. Of the remaining 15, eight were excluded from analysis because they demonstrated an “object bias.” Thus, in Ganea et al.’s study, 65% of 15-month-olds (13 of 20) were excluded from analysis. In our study, 50% of 15-month-olds were excluded from analysis, 12 due to fussiness, parental interference, or failure to respond correctly on one or more training trials.

2.3.1. Familiarization phase

First, the experimenter presented infants with the two real objects that would be presented later at test (silver whisk, silver garlic-press) along with two familiar objects (selected randomly from those that would be used later in training). Infants played with these freely until their interest waned (roughly 3 min). Our goal was to minimize the possibility that infants might favor objects over pictures at test simply because they had not yet had an opportunity to handle the novel test objects.

2.3.2. Training phase

This³ phase was designed to: (1) clarify that infants could offer either pictures or objects when the experimenter asked for them by name, (2) support infants' selection of pictures on trials in which an object and picture were pitted against each other (in *picture-object training*, the experimenter consistently requested the picture), and (3) identify infants unable to select a familiar picture when asked for it by name. Infants who failed to respond correctly on all training questions were replaced. Thus, we are confident that all infants included in the experiment understood the task and were able to select either pictures or objects as referents of familiar nouns.

Single-object training. To begin, the experimenter placed a single familiar object (e.g., toy dog) in front of the infant, touched the object, and named it ("This is a dog"). She then placed her hand on the table and pointed at her open palm, saying, "Can you give me the dog?" If the infant selected the object, the experimenter provided positive reinforcement (e.g., "Yay, that is a dog!"). On this, and on all subsequent training and test trials, if the infant failed to make a selection, the experimenter repeated the question twice, paraphrasing slightly (e.g., "Can you show me/give me the dog?") before moving on.

Object-object training. The experimenter presented two familiar objects (e.g., apple, car), saying, "Look! Here is an [apple] and here is a [car]." With her palm outstretched, she asked, "Can you give me the [apple]?"

Picture-picture training. This was identical to the object-object training (above), except that pictures of familiar objects (rather than the objects themselves) were presented.

Picture-object training. This was identical to the prior training (above), except that a familiar object was pitted against a familiar picture (counterbalanced for side). The experimenter introduced the picture (e.g., "Here is a ball") and the object (e.g., "Here is a cup"), counterbalanced for order. She then requested the picture (e.g., "Can you give me the ball?"). This permitted us to assess whether an infant could select the named familiar item, even if it meant selecting a picture rather than an object.

Picture-object (novel) training. This was identical to the prior training, except that an unfamiliar object (one not presented in familiarization) was pitted against a familiar picture. The experimenter introduced both items, saying, "Here is a [car]" while pointing to the picture, and "Look at this," pointing to the novel object. She then requested the picture, saying, "Can you give me the [car]?" This permitted us to assess whether an infant could select the named item, even if it meant selecting a familiar picture, rather than a novel (and presumably attractive) three-dimensional toy object.

2.3.3. Book-reading phase

The experimenter read through the picture book with the infant. Whenever a picture of a familiar object appeared, the experimenter pointed to it and named it twice ("Look, this is a cup. Do you see the cup?"). When a picture of the novel target kind (whisk) appeared, she did the same, saying, "Look, this is a whisk. Do you see the whisk?" When a picture of the novel distractor kind (garlic press) appeared, she pointed and drew attention to it, but provided no name ("Ooh, look at this! Wow, do you see that?"). Because the book included six pictures of whisks (three orange, three purple) and because

³ Ganea et al. (2009) also provided a training phase, but it differed from our own in several ways. First, it followed (rather than preceded) the book-reading phase. Second, during training, infants were shown pictures of two *familiar* objects (ball, cup) and asked, "Show me the ball/cup." Third, children were presented with pictures of the novel objects (target, distractor) and asked to indicate the target ("Show me the whisk"). Immediately after this training phase, infants participated in an object familiarization phase during which the experimenter presented the novel target and distractor objects (different in color from the ones presented in testing), in succession for a few seconds each, saying, "Look at this," and then allowed infants to handle the objects.

with each appearance the experimenter named it twice, there was a total of 12 naming episodes in which the novel noun was paired with a picture of a whisk.

2.3.4. Test phase

In this phase, the experimenter presented infants with three test questions, each involving a pair of items. All of the test items were silver in color and none had appeared earlier in either the picture book or training phases. The test questions, inspired by previous designs (Ganea et al., 2009; Preissler & Carey, 2004), were presented in counterbalanced order.

Target Picture vs. Target Object test. The experimenter presented a real silver whisk and a picture of a silver whisk, saying, “There is a whisk here. Can you show me (or give me) a whisk?” Both the picture and object were members of the same novel object category that had been named during the book-reading phase, but both differed in color from the pictures in which the novel noun had been introduced. We noted which choices infants made, as well as the order in which they made them.

We asked whether infants would extend the novel word to a new member of a target kind that differed in color from ones depicted during book reading (e.g., to a silver whisk), and whether they would extend it to a picture, an object, or both. If infants are unable to generalize the novel word to either the new color or the new medium, they should offer no choice on this test question or should select randomly between the two silver choices. But if, as we predict, infants appreciate that the novel noun refers to the object kind, they should extend “whisk” to other exemplars of that kind, including a picture of a whisk that differs in color (here, silver) and a real three-dimensional silver whisk.

Note that on this trial (where both object and picture are members of the named object category), if infants appreciate the referential status of novel nouns, both choices may be seen as referents of “whisk.” But recall that in the training phase, infants responded to questions in which only *one* choice (either the picture or the object) was correct. Therefore, to ensure that infants understood that, on this trial, they could select both picture and object if they wished, we adopted the following strategy: If an infant selected only the picture or only the object in response to this question, the experimenter said, “There is another whisk here. Can you show me another whisk?” Because most infants spontaneously selected both the object and the picture, most did not receive this prompt. Even among the few who did receive it, not a single infant changed their answer in response.

Target Object vs. Distractor Object. The experimenter presented two objects (silver whisk, silver garlic press) and said, “Can you show me the whisk?” We asked whether infants would extend “whisk” selectively to another member of the named target kind and not to an object of a different kind.

Distractor Object vs. Target Picture. The experimenter presented a real silver garlic press and a picture of a silver whisk, asking, “Can you show me the whisk?” We asked whether infants’ interpretation of “whisk” was sufficiently robust to permit them to select the picture, even if this required ignoring a real three-dimensional object.

2.4. Coding

Infants’ behavior was coded from their videotaped sessions, following established criteria (Ganea et al., 2009; Preissler & Carey, 2004). We first identified all intentional responses. To be credited as intentional, infants had to indicate their choice(s) explicitly, either by giving it to the experimenter, pointing to it, or picking it up while making eye contact with the experimenter. Responses were coded as unintentional if an infant simply touched, played with, or explored an item but did not clearly indicate it to the experimenter. If an infant failed to make an intentional response, the experimenter presented the items again and repeated the question before moving on to the next set of items. For example, if on the picture–object test, an infant pointed to the picture while making eye contact with the experimenter and then picked up the object only to play with it, this was coded as a “picture alone” response. If the infant indicated the object to the experimenter and then subsequently played with the picture, this was coded as an “object alone” response. If the infant pointed to both the picture and object while making eye contact with the experimenter, or gave both to the experimenter, this was coded as a “both” response, and we identified the order in which infants made their selections

Table 1

For each test question, the number of infants at each age choosing both test alternatives, only one of the two test alternatives, or making no choice.

| Test question | Age | |
|---|----------------------------|----------------------------|
| | 15 months (<i>n</i> = 12) | 17 months (<i>n</i> = 12) |
| Target object vs. target picture | | |
| Both | 7 | 11 |
| Selection order: | | |
| Object and picture simultaneously | 3 | 4 |
| Object first | 4 | 6 |
| Picture first | 0 | 1 |
| Object only | 2 | 1 |
| Picture only | 2 | 0 |
| No choice | 1 | 0 |
| Target object vs. distractor object | | |
| Both | 0 | 0 |
| Target object only | 9 | 10 |
| Distractor object only | 0 | 0 |
| No choice | 3 | 2 |
| Target picture vs. distractor object | | |
| Both | 0 | 0 |
| Target picture only | 7 | 8 |
| Distractor object only | 3 | 3 |
| No choice | 2 | 1 |

(simultaneously, object first, or picture first). A second rater, blind to the hypotheses, coded all test trials. Inter-rater reliability was 90%; disagreements were resolved by a third rater.

3. Results

Infants at both 15 and 17 months understood their task: 91% of their responses were intentional and unambiguous. Moreover, infants' interpretation of the novel word was not bound to the particular perceptual features of the instances with which it had been introduced. Instead, infants at both ages spontaneously extended "whisk" to the real three-dimensional silver whisk, even though it differed both in color and representational status from the pictures with which this novel noun had been previously paired. Infants' responses to each of the three test questions are displayed in Table 1.

We consider first infants' responses on the target picture vs. target object test. Although "whisk" had been introduced exclusively in conjunction with pictures, infants did not favor the picture of a whisk over a real object. On the contrary, infants overwhelmingly extended "whisk" to the real silver whisk, indicating that their representation of the novel word was abstract enough to extend to new members of the same object kind, despite a change in color and in representational medium (from two-dimensional to three-dimensional).

Twenty-one of the 24 infants (88%) chose the real object, either selecting alone or in conjunction with the picture (binomial test, $p = .0001$); this pattern did not differ as a function of infants' age (Fisher's exact test, $p = .22$). There was a reliable difference between infants' likelihood of choosing both the picture and object, choosing the picture alone, choosing the object alone, or not making a choice, $\chi^2(3, 24) = 32.333$, $p < .0001$. Infants' predominant response was to select both the object and picture; this tendency exceeded chance levels (binomial test, $p = .008$) and did not differ as a function of age (Fisher's exact test, $p = .16$). Moreover, among infants selecting both alternatives, some made their selections simultaneously and others made them sequentially. In the latter group, infants were significantly more likely to select the object first, (binomial test, $p < .05$); this pattern was evident at both 15 months (all four infants making sequential selections chose the object first) and 17 months (six of seven infants making sequential selections chose the object first), Fisher's exact test, $p = .10$. This tendency to select the object first is not consistent with the predictions of the associationist account. On that view, infants should favor the picture over the object.

We considered whether infants' tendency to select the object on this critical test trial might have been influenced by their participation in other test trials. To address this possibility, we focused on infants who received the target picture vs. target object first, before they had an opportunity to see the target object on any other test trial. The pattern was clear: Every infant in this group either chose the object alone or together with the picture. This rules out the possibility that infants' tendency to select the object might somehow have been influenced by its presence in other test trials.

Infants' responses on the remaining test questions demonstrate that infants extended "whisk" systematically to other members of the same object kind, despite changes in color (the picture of silver whisk) and representational medium (the three-dimensional silver whisk). In response to these questions, not a single infant selected both alternatives. Instead, infants systematically singled out the target, whether it was a picture or an object. On the target object vs. distractor object test, infants overwhelmingly selected the target object (silver whisk), but not the distractor object (silver garlic press), binomial test,

$p = .003$; this robust pattern did not differ as a function of infants' age, Fisher's exact test, $p = 1.0$. Thus, when infants extended "whisk" from pictures to objects, they did so selectively, systematically identifying a new three-dimensional object from the same object category (silver whisk), but not a distractor object (silver garlic press). On the target picture vs. distractor object test, infants did not favor a three-dimensional object over a picture. On the contrary, infants favored the picture of the whisk over the real garlic press by a factor of greater than 2:1, binomial test, $p = .04$; this preference did not differ as a function of age, Fisher's exact test, $p = 1.0$. Thus, infants' overwhelming selection of the real silver whisk in the target picture vs. target object test should not be attributed to an a priori bias favoring objects over pictures.

Finally, we tabulated each infant's responses across the three test questions to learn whether individuals extended "whisk" in a principled fashion, flexibly and correctly extending it to either the picture or to the real object and systematically rejecting the non-whisk distractors. The probability of guessing correctly on all three trials is .125; if infants were guessing on each question, only three of the 24 infants should guess correctly on all three. Instead, we found that 17 of the 24 infants responded correctly on all three test questions, eight at 15 months and nine at 17 months (both p 's < .001, binomial tests). These results indicate that interpretation of the novel noun, paired exclusively with pictures during training, was broad enough to include other members of the same object category, despite a change in both color and representational modality.

4. Discussion

The goal of the present study was to clarify the representational status of infants' newly learned words. We asked whether infants could extend a novel word, applied exclusively to pictures of a novel object, to real three-dimensional members of the same object category. We introduced 15- and 17-month-old infants to a novel noun, applying it to two distinct pictures representing a particular object kind, and asked whether infants would extend this newly learned noun to other members of the same kind (other whisks), one which differed in color only (a picture of a silver whisk) and another which differed in both color and representational modality (a real three-dimensional silver whisk). If a word is nothing more than a feature of the perceptual and sensory experience(s) with which it has co-occurred, infants should be more likely to extend the novel word to the picture of the whisk than to the real three-dimensional object, because the picture is perceptually closer to the items with which the word had previously been paired. But if infants interpret a novel noun as referring to an object category, they should extend the word to both the real three-dimensional silver whisk and the picture, because both are representations of the same object category.

The results were straightforward: 15- and 17-month-old infants' responses reflected neither (a) a strict reliance on perceptual similarity (which would have led them to favor the picture over the object in the target picture vs. target object test) nor (b) an overarching preference for objects over pictures (which would have led them to favor the real garlic-press over the picture of the whisk in the target picture vs. distractor object test). Instead, infants interpreted "whisk" as referring to an object concept, extending it in a principled and flexible way to other whisks. Infants' interpretation of "whisk" was not tethered tightly to the particular perceptual features with which the word had previously been paired. It was sufficiently abstract to include new (and as yet unnamed) members of the same object category, although they differed in color and in representational medium.

Notably, many infants were excluded from analyses, as in prior reports with 15- and 19-month-olds using this paradigm (Ganea et al., 2009).² Like Ganea et al. (2009), we have pointed out the advantages of including infants who successfully complete the training and reveal no a priori "object bias" (a tendency to select an object over a picture, independent of the experimenter's request). Nonetheless, future work should assess the generalizability of these results to a broader sample of 15- and 17-month-olds.

These results also shed light on infants' sensitivity to variability in learning. When infants and young children are exposed to variability in stimuli, they acquire more abstract representations during grammatical rule learning (von Koss Torkildsen, Dailey, Aguilar, Gómez, & Plante, 2013), object categorization and word learning (Waxman, 1990; Waxman & Klibanoff, 2000; Xu & Tenenbaum, 2007), and category-based induction (Rhodes, Gelman, & Brickman, 2010). Our findings provide additional evidence that infants benefit from variability in input. In Ganea et al. (2009, Study 2), when the novel noun was applied to a picture of a whisk that did not vary (four pictures of a white whisk), infants adopted a conservative interpretation, rarely (if ever) extending the noun to a three-dimensional object of a different color. Our results suggest that this conservative pattern reflects infants' sensitivity to the range of exemplars with which novel words are introduced, rather than an inability to appreciate their abstract referential status. We provided variability during learning, introducing the novel noun

to two different pictures of a whisk (one purple, one orange). Under these conditions, infants at both ages spontaneously and systematically extended the novel noun to a new color (a picture of a silver whisk) and to a new medium (a real three-dimensional silver whisk). At 17 months, 11 of 12 infants extended the noun to include the three-dimensional silver whisk; at 15 months, 10 of 12 infants did so. We suspect that varying the stimuli enabled infants to extend the novel label broadly to the category “whisk” rather than adopting a more conservative interpretation. We propose that infants’ spontaneous extension of the novel noun – across colors and across representational media – reflects not only their appreciation of a link between words and object categories, but also their sensitivity to the input conditions.

However, because we introduced other procedural modifications that may have improved infants’ performance (e.g., providing a training phase early in the procedure; providing infants with an opportunity to play with the test objects before the experimental protocol⁴), future research should examine which modification(s), individually or collectively, led to infants’ successful extension of the novel noun. Indeed, there may be a developmental change in how readily infants interpret a naming event – in a picture book or in the world at large – as referring to a kind. Our findings suggest that infants are capable of extending labels from pictorial representations to more abstract kinds that the pictures represent.

5. Conclusion

Our results demonstrate that for infants as young as 15 months, words refer to categories of objects, their meaning extending beyond the particular items with which they were introduced. Armed with this early appreciation that nouns refer to object categories, infants attend carefully to the range of application for a novel noun and integrate this understanding with their concepts of individuals and kinds to discover the meaning of a word. Our findings also provide good news about reading picture books to infants and toddlers: Infants glean information from two-dimensional representations and apply that information systematically to real three-dimensional objects when they encounter them.

Acknowledgements

This research was supported by NSF BCS-0950376 to SRW. We are grateful to Ilana Clift for assistance with coding and to the children and caregivers who participated.

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⁴ A potential concern is that permitting infants to play with the unfamiliar objects in the familiarization phase, before introducing the novel words in the picture–book reading phase, may have led infants to connect the novel noun to the unfamiliar object they had seen before. Note however, that for this to be true, infants must already possess the representational capacity that we are testing. That is, if infants do connect the novel noun (applied to a picture) to a real object that they saw earlier but in the absence of any name, then infants (a) appreciate that the picture and object are members of the same object category, and (b) appreciate that a novel noun applied to the picture alone would also apply to other members of that category, even if they differ in color and representational format.

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