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Specifying the role of function in infant categorization

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ABSTRACT

Research demonstrates that object functions facilitate artifact categorization in infancy. To explicate the nature and magnitude of this effect, 16-month-olds participated in three studies. In Experiment 1, categorization was facilitated more by object functions than by distinctive motions, suggesting that the motion properties of function cannot fully explain its influence. In Experiment 2, infants failed to categorize when each category exemplar performed a different function, thus revealing the importance of shared functionality in facilitating categorization. In Experiment 3, infants were tested after each new exemplar was introduced. When object functions were provided during training, infants were more likely to appropriately extend the novel categories on the very first trial. This suggests that function reduces the need for exposure to multiple exemplars in forming categories. Together, these findings confirm the conceptual nature of the facilitative effect of function on early categorization.

A wealth of evidence demonstrates that object function exerts a powerful organizing force on early categorization (Booth & Waxman, 2002; Greco, Hayne, & Rovee-Collier, 1990; Horst, Oakes, & Madole, 2005; Kemler Nelson, Frankenfield, Morris, & Blair, 2000; Nelson & Ware, 2002; Träuble & Pauen, 2007). Not only do object functions directly influence decisions that infants and toddlers make regarding category membership, they also facilitate the formation of new categories, exemplars of which can later be identified on the basis of less transient object properties (like shape or color). For example, Booth and Waxman (2002) demonstrated that 14- and 18-month-old infants extend novel artifact categories on the basis of perceptual similarity more readily when provided with information about object function than when exposed to other perceptual object properties alone.

Infants in Booth and Waxman (2002) first observed an experimenter manipulate four examples of a novel artifact category. For some infants, the experimenter demonstrated how each object functioned on a uniquely designed apparatus while directing the infant to 'look what I can do with this one.' For other infants, the experimenter simply picked up each object while directing the infant to 'look at this one.' The experimenter then held up a contrast object drawn from a perceptually different category and highlighted that it did not belong with those preceding. After re-presenting one of the original category members as a reminder, the experimenter placed two novel test objects in front of the infant: one drawn from the trained category and one from a novel category. The experimenter then held up a target object (drawn from the original set of trained category exemplars) and twice asked the child to 'find another one of these' from among the test objects. Importantly, because the functions of the test objects were never demonstrated, category extension necessarily relied on static object properties equally available in both conditions. Infants who previously were familiarized to object functions were more likely than those who were not to select the novel test object drawn from the same category as the target. Based on this finding, Booth and Waxman (2002) concluded that object functions promote the formation of categories in infancy and that they likely do

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so by virtue of the conceptually rich connections that they embody among goals, actions, outcomes, and object properties. This latter conclusion, however, was necessarily tentative, requiring validation through further empirical investigation.

We have since gained further insight into the mechanisms by which object function facilitates early categorization. For example, we now know that function can direct attention both generally to broad similarities among objects, as well as specifically to functionally relevant features (Booth, 2006; Kemler Nelson, 1999; Träuble & Pauen, 2007). Using the same design as Booth and Waxman (2002), Booth (2006) familiarized infants to objects with properties that were either loosely or tightly tied to their functions (e.g., disks that could slide down a slide vs. T-shaped objects that were uniquely designed to slide down 2 parallel bars into a bell). At test, infants were asked to choose between a completely novel object and an object that bore either global perceptual or functional similarity to the target object. The globally similar test object shared all properties with the target category exemplar except that a key functionally relevant property was disabled (e.g., a disk was made too large to fit down the slide). The functionally similar test object shared the key functionally relevant feature (e.g., an asymmetric angular shape with the correct dimensions to fit down the slide previously used with the disks) with the target category exemplar, but differed in all other respects. When infants had been familiarized with objects loosely tied to their functions, they extended to the globally similar, but not the functionally similar test object. This finding was taken as evidence that function facilitates categorization via a 'global attention-enhancing mechanism.' However, when infants had been familiarized with objects tightly tied to their functions, they extended to the functionally similar, but not the globally similar test object. This was taken as evidence for the operation of a 'specific attention-enhancing mechanism,' whereby infants' attention was drawn to functionally-relevant object features. This specific attention-enhancing mechanism implies that infants are at least sometimes able to capitalize on meaningful causal (i.e., conceptual) relationships between object properties and functional goals/outcomes in the process of forming new categories.

Despite these advances, questions remain regarding the *conceptual* nature of functions' facilitative effect on early categorization. For example, although function might be the only type of information that can specifically direct attention to functionally-relevant features, other information might be equally effective at facilitating artifact categorization through something akin to the less specialized 'general attention-enhancing' mechanism described by Booth (2006). Indeed, both names (Booth & Waxman, 2002; Waxman & Markow, 1995) and causal properties (Booth, 2008) have already been shown to facilitate categorization in this manner. Functions, names and causal properties, however, are all arguably rich conceptual cues to categories. What of other perceptually salient possibilities? For example, Rakison (2003) and Rakison and Poulin-Dubois (2002) has convincingly argued that object motion plays a dominant role in guiding attention during infancy, and specifically, in organizing early categories. Impressively, work by Greco et al. (1990) demonstrates that infants will extend categories on the basis of motion as early as 3 months of age. Yet it remains unclear whether the ubiquitous attentional draw of motion (Dannemiller, 2001; Slater, Morison, Town, & Rose, 1985) is enough to support the formation of new categories in infancy, exemplars of which can be identified not only on the basis of object motion itself, but also on the basis of associated static features. If it proves to be, then the dynamic (i.e., motion) properties of object functions might be wholly responsible for their 'general attention-enhancing' effect on categorization, leaving no need to invoke their conceptual properties as part of the explanation.

A second question relevant to the conceptual nature of function's facilitative effect on early categorization, perhaps surprisingly, is illuminated by a close examination of the methodological details of earlier work. Oakes and her colleagues (Oakes, Plumert, Lansink, & Merryman, 1996; Oakes & Spalding, 1997) have repeatedly demonstrated how the specific procedures utilized in categorization tasks can influence infants' performance and have highlighted how these principled variations can reveal clues to the cognitive mechanisms at play. The original procedure developed by Booth and Waxman (2002) to test the influence of function on novel artifact categorization was relatively complex, involving three distinct phases. As described above, in the familiarization phase, infants saw four exemplars of a novel category presented in pairs. During the contrast phase, infants saw an out-of-category object that was identified by the experimenter as distinct from the familiarization objects. During the test phase, infants were twice asked to extend the category to one of two novel objects; one drawn from the now familiar category, the other drawn from a different novel category. By modifying this procedure, it might be possible to isolate the contribution of specific cognitive processes.

For example, the original procedure offered ample opportunity for both perceptual comparison and contrast within and across categories during familiarization. Both of these processes have been highlighted as important in the formation of categories, as well as other key cognitive operations (e.g., Eimas, Quinn, & Cowan, 1994; Greco et al., 1990; Kovack-Lesh & Oakes, 2007; Kurtz, Miao, & Gentner, 2001; Oakes, Kovack-Lesh, & Horst, 2009; Oakes & Ribar, 2005; Waxman & Klibanoff, 2000). However, in her foundational work, Nelson (1974) argued that the functional relations inherent in individual objects are sufficient for forming the foundation for new concepts. Although 'categorization' technically requires that more than one entity be treated as equivalent in some respect, it is possible that skeletal expectations for the existence of important kinds can emerge after exposure to a single exemplar. In a sense, a single exemplar might act as a 'kind placeholder,' priming the child to anticipate encounters with additional exemplars that will fully specify category extension. Indeed, infants are able to infer the functional (and other hidden properties) of novel objects on the basis of experience with just one other categorically related exemplar (e.g., Baldwin, Markman, & Melartin, 1993; Graham, Williams, & Huber, 1999). And by the time they reach preschool, children seem to link these inferences to notions of kind, as evidenced by their naming patterns (Kemler Nelson, 1999; Kemler Nelson et al., 2000). Perhaps then, the comparison and contrast inherent in the Booth and Waxman (2002) task was not critical to the facilitative effect of function on categorization revealed therein. Could function instead have enhanced categorical responses to perceptual commonalities among objects by acting as a 'kind placeholder'?

The questions outlined thus far are important because they address both the specificity of the effect of function on early categorization, as well its underlying mechanisms. Most importantly for the current goals, they are relevant to establishing the degree to which function's facilitative effect on early categorization can rightfully be conceived of as conceptual in nature, extending beyond global attention enhancement and the greater efficiency and completeness of perceptual comparison that this heightened attention might engender. We proceeded by conducting three experiments. In Experiment 1, we compared categorization when object functions were demonstrated to categorization when exaggerated object motions were demonstrated. This manipulation was intended to test the importance of functions, as opposed to motion information more generally speaking, in infant categorization. In Experiment 2, we ran an additional 'inconsistent function' condition in which each familiarization object performed a unique function despite maintaining common category membership. This manipulation was intended to provide the strongest possible test of whether function facilitates categorization by virtue of its attention-getting properties alone (all of which were maintained here). In Experiment 3, we introduced familiarization objects (with or without demonstrating their function) one at a time and tested for categorization after each one. This manipulation permitted evaluation of the importance of comparison across similarly functioning objects (none of which was available at the time of first testing), as well as the importance of explicit contrastive information (none of which was provided at any time in the new procedure).

1. Experiment 1

In our first experiment we asked whether exaggerated object motions are as effective as fully specified object functions in facilitating categorization in infants. It is well documented that motion is highly salient to infants (Dannemiller, 2001; Slater et al., 1985). Moreover, early sensitivities to motion have figured prominently in theory and research on early categorization and conceptual development (Greco et al., 1990; Mandler, 1992; Poulin-Dubois, 1999; Rakison & Lupyan, 2008). Accordingly, the 'general attention enhancing effect' of function on categorization demonstrated by Booth (2006), and Booth and Waxman (2002) might be interpreted as hinging on the distinctive motions presented therein rather than on the provision of functions per se.

It should be noted that Booth and Waxman (2002) did include a control condition in their original study that was meant to address this possibility. Infants in this 'motion only' condition observed the familiarization objects undergo the same trajectories of motion observed in the function condition, but in the absence of the functions themselves. These infants failed to categorize at test. However, it was impossible to precisely reproduce the function-specific motion trajectories in this condition because the objects were never released to interact independently with the function apparatuses (as they were in the function condition). Thus, the motions provided in the function condition might have been more distinctive and salient than those presented in the motion only condition.

A more direct test of the influence of object motion on infants' categorization of Booth and Waxman's (2002) artifacts is therefore required. In implementing such a test, we replicated the original procedure, but contrasted the function condition with an exaggerated motion condition in which category exemplars all performed the same highly distinctive and salient motions. If object function facilitates categorization by virtue of its salient dynamic properties, then infants should perform similarly across conditions. Indeed, infants in the exaggerated motion condition might even outperform those in the function condition because the motions are so clearly and deliberately articulated therein. Alternatively, if object function facilitates categorization for some other reason, perhaps by virtue of its conceptual or causally rich structure, then infants in the function condition might outperform those in the exaggerated motion condition.

1.1. Method

1.1.1. Participants

Because both 14- and 18-month-olds benefited from demonstrations of object function in Booth and Waxman, we recruited subjects within this developmental window. Thirty-two infants participated in total. Six females and 10 males, averaging 16.3 mo (range = 14.3–18.8) in age, participated in the function condition. Seven females and nine males, averaging 16.5 mo (range = 14.4–18.7), participated in the exaggerated motion condition. An additional 16 infants were excluded due to failure to make clear choices on 50% or more of the test trials ($n = 10$), experimenter errors ($n = 5$), or equipment failure ($n = 1$). All infants were recruited either through mailings to homes in the northern Chicago area or advertisements in flyers and local media. The participants consisted of 71% Non-Hispanic Caucasian, 10% African American, 6% Hispanic, and 13% Asian infants.

1.1.2. Materials

Thirty-two objects, all easily grasped and manipulated by infants, served as stimuli. These objects were organized into 4 sets, each containing 5 different objects from a single category and 3 additional objects drawn from different categories. All stimuli were three-dimensional objects, created with colorful FIMO clay. Novel stimuli were created to ensure that the objects were completely unfamiliar to the infants, thus minimizing any potential influences of prior knowledge of their category membership, their functions, or their names. Although the individual objects in each category varied somewhat in shape, size, color, and patterning, their similarities in overall shape (Category A: blob-like; Category B: pot-like; Category C: peg-like; Category D: disk-like), color range (Category A: blues and greens; Category B: yellows and oranges; Category C: browns

Fig. 1. Familiarization, one (out of two) contrast, and test objects comprising the four sets of stimuli used in Experiment 1.

and grays; Category D: pinks and purples), and parts or pattern elements (Category A: loops and crosshatching; Category B: lip bulges and base holes; Category C: rings and velcro bases; Category D: spirals and squiggles) allowed adults to easily sort them appropriately. Previous research also established that objects within each category were readily distinguishable by infants (Booth, 2008). See Fig. 1 for a full illustration.

In addition to the stimuli, an apparatus was constructed on which the functions (i.e., the intended use) of the objects could be demonstrated. The apparatuses remained in a stationary position out of the infants' reach at all times in both conditions. The apparatuses (see Fig. 2) and functions they supported consisted of (1) a hook on which objects from Category A could be hung and swung into chimes, (2) a clear plastic container filled with couscous, which could be scooped and sifted through objects from Category B, (3) a velcro-topped platform mounted on a spring to which objects from Category C could be stuck and jiggled, (4) and a slide down which objects from Category D could be smoothly slid. Although these might not seem like very compelling functions from an adult perspective, they embody the types of simple goals (scooping, sliding, swinging) that are of great interest to infants and toddlers. This is evident in both the empirical literature (e.g., Horst et al., 2005; Madole, Oakes, & Cohen, 1993) and in the composition of toys developed for this age group.

The object motions demonstrated in the exaggerated motion condition included (1) a vertical u-shaped trajectory, (2) a circular path on the table, (3) a rocket-launching motion and (4) a rotational shaking back and forth. These were selected because they are both distinctive and attention grabbing, as well as comparable to those shown to be salient to 18-month-olds by Rakison and Poulin-Dubois (2002). Although no clear goal or object utility was embedded in these object motions, it was necessary that a human agent demonstrate them by directly manipulating the objects in order to parallel this feature of the function condition. Thus, we recognized the possibility that infants might construe the distinctive object motions as impoverished object functions (e.g., objects from Category A are used by people to trace a circular motion on tables). In the absence of any feasible way of assessing the construals of our infant participants, we proceeded, knowing that this possibility might mitigate predicted difference between our experimental conditions.

1.1.3. Procedure

The procedure replicated that of Booth and Waxman (2002). After being randomly assigned to one of two conditions (function vs. exaggerated motion), infants completed a familiarization, contrast, and test phase with each of the four sets of stimuli.

Familiarization phase. Infants in both conditions were first familiarized with two pairs of objects, all of which were drawn from the same category. The experimenter introduced the first pair, attracting the infant's attention by exclaim-

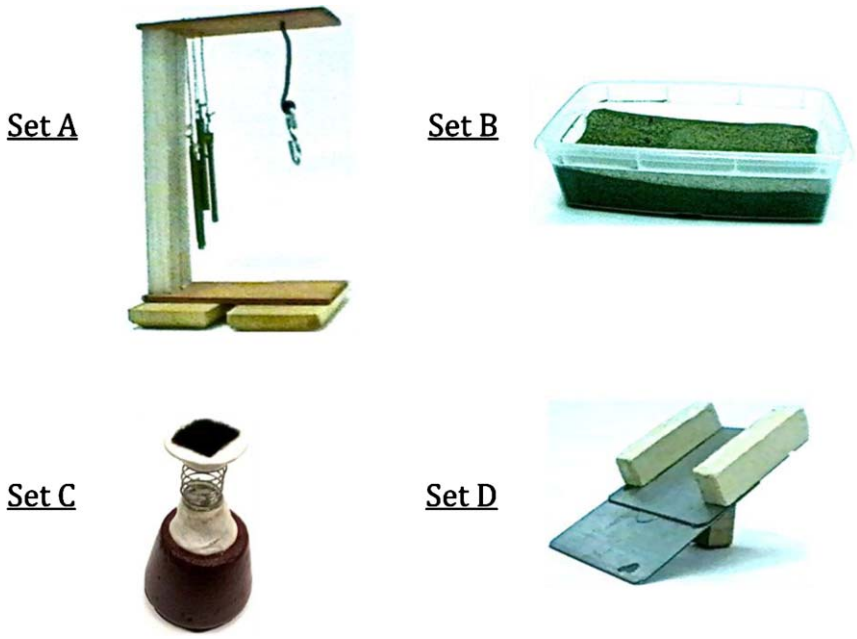

Fig. 2. The apparatuses used to demonstrate the functions of objects in Experiment 1.

ing, "Look at these!" The experimenter then demonstrated the function or motion for each object individually, saying, "Look [child's name] I can do this with this one." In order to maintain infants' attention in the task, the first pair of objects was then given to the infant for 10 s. Although the infants were allowed to play freely with the objects, they never had access to the apparatuses and therefore could not explore the object function. After retrieving the objects, the experimenter then said, "Remember. . ." and repeated her previous comments and demonstrations on them. She then followed the same procedure for the second pair of familiarization objects. The entire familiarization phase lasted approximately 30 s.

Contrast phase. Next, the experimenter held up an object from a contrasting category. She shook her head solemnly, saying "Uh oh! I can't do that with this one" while she disappointingly dropped the object onto the table. The experimenter then introduced a target object that was drawn from the category exemplars introduced in the original familiarization set. She happily exclaimed, "Yay, I can do that with this one" and re-demonstrated the function or motion of the target object.

Test phase. At this point, the experimenter simultaneously presented the infant with the familiar category test object (e.g., a previously unseen member of the familiarization category) and the novel category test object (e.g., a previously unseen member of a different category). Infants played freely with these objects for 15 s, after which the objects were retrieved and placed out of the infant's reach on the table. The Experimenter then re-presented the target object, drawing attention to it by pointing and saying, "Remember, I can do this with this one," as she demonstrated its function or motion. While pointing to the target object, she then asked the infant "Can you find me another one of these?" She quickly pushed the test objects into the infant's reach, approximately 12 in apart, and queried, "Can you give me another one of these?" as she pointed to the target object and then to her hand. Recall that because the functions or motions of the test objects were not demonstrated, this task requires the infants to infer category membership from other static perceptual features of the objects that were correlated with the functions or motions presented to them during familiarization.

The contrast and test phases were repeated once before proceeding with familiarization to the next set of stimuli. On this second round, a new contrast object was presented. Although the same target and test objects were presented on both the first and second test, the left-right placement of the test objects was counterbalanced across the two trials.

1.1.4. Coding

Coders scored all of the infant responses from videos with the sound turned off and with only the infant visible on screen, such that coders remained blind to condition assignment. A secondary coder scored 12 videos (6 from each condition). Coders agreed on an average of 99.2% of choice test trials. Coders also recorded looking times to the familiarization objects, as well as to each of the test objects during the free play periods immediately preceding forced choice testing. Average percent agreement was 96% (Cohen's Kappa = .93) for the familiarization measure and 93% (Cohen's Kappa = .90) for the test object free play measure.

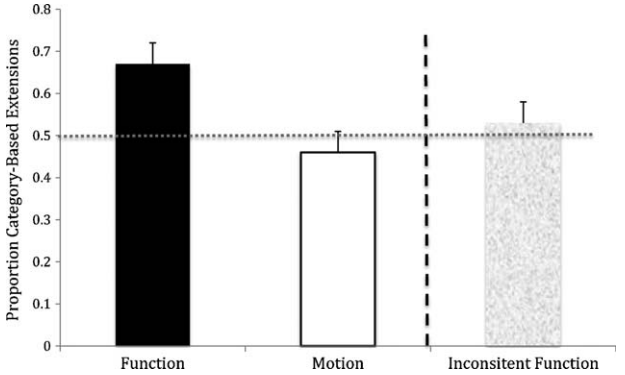

Fig. 3. Proportion of trials on which infants selected the category-match at test in each condition of Experiment 1 (on the left) and Experiment 2 (on the right).

1.2. Results

For each infant, we calculated the proportion of trials (out of a maximum of eight) on which they selected the familiar category test object. No main effect of gender, or its interaction with condition was evident, so this factor was not included in subsequent analyses. As summarized in Fig. 3, infants in the function condition ($M = .68$, $se = .06$) were, on average, more likely to categorize than were those in the exaggerated motion condition ($M = .46$, $se = .06$), $t(30) = 2.67$, $p < .02$. Moreover, performance in the function condition rose significantly above that which would be expected by chance (50%), $t(15) = 3.25$, $p < .01$, while performance in the exaggerated motion condition did not, $t(15) = .64$, *ns*. This pattern of results is also reflected in the number of infants performing above vs. below chance (i.e., 50%) in each condition. Twelve performed above chance in the function condition, while only 5 did so in the exaggerated motion condition, Fisher's exact test $p < .01$.

In order to determine whether these effects were due to differences in engagement during familiarization, we compared looking times during the training demonstrations across conditions. No differences were evident, $t(30) = .82$, *ns*. We also checked to see whether choices were driven by preferences (built up through perceptual experience over familiarization) rather than an explicit response to the category extension task. To this end, we examined patterns of attention during the brief free play period with the test objects that immediately preceded choice testing. Infants spent equal proportions of time attending to the familiar- and novel-category test objects in both the function ($M_{fam} = .25$, $M_{nov} = .20$, $t(16) = .62$, *ns*) and the exaggerated motion ($M_{fam} = .18$, $M_{nov} = .17$, $t(16) = .15$, *ns*) condition.

1.3. Discussion

In sum, infants who observed object functions were more likely than those who observed exaggerated object motions to categorize. Indeed, only infants who observed object functions showed any evidence of having detected the categories presented during familiarization. These results might be somewhat surprising in light of other evidence documenting infants' sensitivity to correlations between the dynamic and static properties of objects (Madole et al., 1993; Rakison & Poulin-Dubois, 2002). However, Rakison (2004) has shown that infants' ability to utilize these correlations in extending novel categories does not emerge until 22 months of age. Moreover, that body of work differs from the current investigation in a number of important respects, including characteristics of the stimuli (two-dimensional cartoons engaged in self-generated motion vs. three-dimensional artifacts manipulated by live experimenters) and procedure (habituation and novelty preference vs. familiarization and dual-choice extension). Perhaps most importantly, infants in the Rakison studies were presented with stimuli at test that either preserved or violated previously established correlations between visual object properties and motion, while infants in the current work were provided with no dynamic information at all at test. Rather, infants in the current experiment responded only on the basis of the static perceptual features that had correlated with motion during familiarization. This task is considerably harder and asks an acutely different question (i.e., whether motions can draw attention to other static object properties that can subsequently be used as the basis for extension in the absence of transient motion cues).

In any case, the current results help to rule out the possibility that functions facilitate early categorization merely because of their perceptually salient dynamic properties. As such, they are consistent with Booth and Waxman's (2002) previous report that infants perform poorly at category extension when exemplars move along the trajectories embedded in object functions. Taken together, these results buttress the alternative possibility that function facilitates categorization because of the conceptually rich causal links it embodies between object properties, goals, and outcomes.

Still, one might argue that this conclusion is premature. After all, the functions demonstrated in Booth and Waxman (2002) and the current study are clearly perceptually distinct from the corresponding exaggerated motions. For example, although familiarization objects were presented along with the function apparatuses in all conditions, function demonstrations involved contact with those apparatuses, while motion demonstrations did not. The function demonstrations

also involved both agent-produced and unimpeded physical forces (e.g., gravity, momentum) while the exaggerated motion demonstrations only included the former. Perhaps these unique perceptual qualities made the function demonstrations more salient, heightening attention in the task, and in turn improving the likelihood of detecting similarities among familiarization objects that could support categorization.

2. Experiment 2

One way of addressing this possibility is to present infants with familiarization objects that each perform a unique function, rather than all performing the same function (as in the original function condition). By doing so, we can offer the same potentially attention-grabbing benefits of functional demonstrations without allowing function to serve as a consistent cue to shared category membership. A similar manipulation was conducted by Waxman and Braun (2005) in the context of disambiguating whether naming facilitates early categorization simply because it enhances attention during the task or because names act more conceptually as 'invitations to form categories.' The results supported the latter explanation: Twelve-month-olds successfully categorized when each exemplar within a set was labeled with the same name, but not when each was labeled with a distinct name. Here, we ask which explanation best characterizes the facilitative effect of function on early categorization.

2.1. Method

2.1.1. Participants

Sixteen 14–18-month-olds participated. Seven females and nine males, averaging 16.2 mo (range = 14.0–18.9) in age, participated. An additional two infants were excluded due to failure to make clear choices on 50% or more of the test trials. Recruitment proceeded as in Experiment 1 resulting in a sample that consisted of 78% Non-Hispanic Caucasian, 11% Asian and 11% African American infants.

2.1.2. Materials and procedure

The same materials and procedure were used as in Experiment 1 with the one exception that each familiarization object performed a unique function (i.e., its function differed not only from those of objects drawn from contrasting categories, but also from other exemplars drawn from its own category).

2.2. Results

For each infant, we calculated the proportion of trials on which they selected the familiar-category test object. As summarized in Fig. 3, infants failed to categorize above the level expected by chance ($M = .53$, $se = .05$), $t(15) = .78$, *ns*. Indeed, only 7 infants extended to the category match on more than 50% of the test trials. Performance was also significantly below that observed in the function condition of Experiment 1, $t(30) = 2.06$, $p < .05$, Fisher's exact test $p < .05$.

The proportion of time infants attended during the familiarization demonstrations was near ceiling, $M = .99$, $se = .004$, and did not differ from that observed in the function condition of Experiment 1, $t(29) = .66$, *ns*. Infants spent equal proportions of time attending to the familiar- and novel-category test objects during free play ($M_{fam} = .13$, $M_{nov} = .15$, $t(14) = .47$, *ns*).

2.3. Discussion

These results reveal the importance of shared function in facilitating early categorization. While infants readily formed categories when the familiarization exemplars all performed the same function (Experiment 1), infants failed to do so when familiarization exemplars each performed a unique function (Experiment 1a; also see Horst et al., 2005 for similar evidence from younger infants). This failure maintained despite the presentation of highly dynamic interactions between the familiarization objects and unique apparatuses on every trial, as well as near ceiling attention to the functional demonstrations during familiarization. Function therefore does not appear to facilitate categorization simply by heightening attention to the task in a general way. Instead, the conceptual relevance of object functions may underlie this phenomenon.

3. Experiment 3

In this experiment we approach the issue of conceptual relevance from a different angle. Specifically, we asked whether function facilitates categorization solely through its influence on basic processes of perceptual comparison and contrast or whether it can also exert an influence as a 'kind placeholder.' Booth and Waxman (2002) focused heavily on the former possibility in their original work, particularly stressing the importance of comparison among multiple exemplars. They reasoned that, when multiple objects share the same function, infants might search for other (more consistently observable) commonalities among them that can be utilized as the basis for subsequent categorization. Thus, function facilitates categorization by highlighting a restricted set of objects for perceptual comparison.

This explanation was consistent with numerous studies demonstrating the contribution of perceptual comparison and contrast to the formation of categories (e.g., for an excellent review see Oakes et al., 2009, and more specifically, Eimas et

al., 1994; Greco et al., 1990; Hayne, Rovee-Collier, & Perris, 1987; Kovack-Lesh & Oakes, 2007; Oakes et al., 2009; Oakes & Ribar, 2005). Moreover, it was bolstered by the poor categorization performance of infants in their own 'hint alone' control condition (Booth & Waxman, 2002). In this condition, infants observed the function of the first (out of 4), familiarization objects, but the remaining objects were presented without any demonstration of function. Lack of categorization in this condition suggests that demonstrating the function of a single exemplar (i.e., providing a 'hint alone') is not enough to facilitate categorization. There is some possibility, however, that infants were confused by the behavior of the experimenter in this condition. Specifically, after the experimenter demonstrated the function of one object, the infant might have anticipated that she would do so for all subsequent objects. When she did not, the infant might have become frustrated by their thwarted expectation for more demonstrations of interesting events or they might have inferred that subsequent objects were not capable of performing any function. These alternative explanations for the null result in the 'hint alone' condition, while purely speculatory, seem reasonable to entertain given that infants and toddlers demonstrate intricate sensitivities to social and pragmatic cues to human intentions (e.g., Baldwin, 2005; Tomasello & Carpenter, 2007; Woodward, 2009).

Moreover, there exists strong theoretical reason to predict that exposure to a single functioning exemplar could provide the anchor for a new concept, thereby facilitating categorization of newly encountered exemplars (Nelson, 1974). Although direct empirical support for this idea is limited, evidence does suggest that infants readily make inductive generalizations regarding object function after experience with only one object (e.g., Baldwin et al., 1993; Barnat, Klein, & Meltzoff, 1996; Brown, 1990; Graham et al., 1999), and preschoolers link these inferences to kinds (Booth, 2009; Kemler Nelson, 1999; Kemler Nelson et al., 2000). It seems likely, then, that the function of individual objects could support categorization in infants. It may do so by acting as a 'kind placeholder,' signaling to the infant that an important category exists, additional exemplars of which are likely to be encountered in the future. As a result, subsequent assimilation of new category exemplars may be facilitated.

In order to disambiguate this possibility from one in which perceptual comparison and contrast across exemplars is fundamental to the facilitative effect of function on early categorization, we familiarized infants to only one exemplar at a time and tested for categorization after each such instance. No exemplars from alternative categories were presented at any time, thus eliminating any basis for contrastive processing across categories. If infants require neither exposure to multiple exemplars nor contrastive information, then they should successfully extend the category to a novel exemplar after a single familiarization trial. If they require exposure to multiple exemplars, but not contrastive information, they should categorize only after two or more familiarization trials. If they require multiple exemplars and contrastive information, infants should fail to categorize over the course of the study (i.e., they should perform similarly to infants who are provided with no information at all about object functions).

3.1. Method

3.1.1. Participants

Thirty-two 16-month-olds (nine males in each of two conditions; $M = 16.1$; range = 15.6–16.9) participated. An additional four infants were excluded due to failure to make clear choices ($n = 2$), parental interference ($n = 1$), or developmental delay ($n = 1$). All infants were recruited through mailings to homes in the northern Chicago area. Participants consisted of 45% Non-Hispanic Caucasian, 15% African American, 30% Hispanic, and 10% Asian infants.

3.1.2. Materials

Most of the stimuli were drawn from the first three sets described for Experiment 1 (see Fig. 1). These were supplemented with additional objects such that each set was expanded to contain eight exemplars from a single category (six training and two test objects) and two from different categories (two test objects). See Fig. 4 for an illustration of the two test pairs designed for each set. In addition, two different toy boats, two different toy saws, a toy bunch of grapes, and a small plastic plate were used during task training.

3.1.3. Procedure

After random assignment to a function or no function condition, infants completed a task-training phase designed to introduce them to the testing procedure. They then completed training and test trials until criterion was reached with each of the three sets of stimuli, beginning with set 1 and subsequently moving on to set 2, then set 3.

Task training. Infants were allowed to play freely with toy models of two familiar items (a boat and a bunch of grapes) for 10 s. The experimenter then introduced a second boat and, while pointing to it, asked the infant if they could "find another one of these." The experimenter then placed her boat in a clear plexiglass box while saying "I am going to put mine in here, can you put yours in here too?" As she turned the box towards the infant, she repeated, "Can you find another one of these?" Infants were given lots of encouragement as well as corrective feedback. The procedure was repeated until infants responded correctly or became visibly impatient. The same procedure was then repeated with a second set of familiar stimuli (two saws and a plate). The task training phase was included to minimize the possibility that lack of familiarity with the task requirements would mask infants' ability to demonstrate systematic category extension on the first experimental test trial.

Familiarization. Infants in both conditions were trained on the same novel objects in precisely the same order. On each familiarization trial, the experimenter began by holding up a new familiarization object while enthusiastically exclaiming, "[Child's name], look at this!" In the function condition, the experimenter demonstrated the function of the object. In the

Fig. 4. Both test pairs utilized to test categorization of each of the three stimulus sets used in Experiment 3.

no function condition, she rotated the object in her hand to maintain the infant's attention. The experimenter then placed the first familiarization object on the table directly in front, and within easy reach, of the infant. The infant was permitted to play freely with the object until they either appeared disinterested or a maximum of 20 s elapsed.

Testing. Test trials were similar to task-training trials except that the test objects were novel and no corrective feedback was provided. Infants chose between a familiar category test object (a novel exemplar drawn from the familiarization category) and a novel category test object (drawn from a different unfamiliar category). If the infant chose the novel category object (i.e., failed to categorize) on the first test trial, the experimenter moved to the next familiarization trial with a new object (because it would be impossible for the infant to reach criterion on that round of testing). If the infant chose the familiar category object (i.e., successfully extended) on the first test trial, the experimenter immediately repeated the test phase with a new familiar and novel category test object arranged in reversed left-right positioning relative to the immediately preceding test trial. If the infant chose the novel category object (i.e., failed to categorize) on this second test trial, the experimenter moved on to the next familiarization trial with a new object (because criterion was not reached in that testing round). If the infant chose the familiar category object (i.e., successfully extended) on this second trial, they were credited with having reached criterion and the experimenter began familiarizing the infant to the next category (unless all 3 categories were already completed, at which point the experiment was over). Thus, in order to be credited as having 'categorized,' infants had to respond correctly on two consecutive trials, each with a different pair of test objects. Only consistently neutral feedback (e.g., 'Ok, thanks') was provided to ensure that responses were based on what was learned during familiarization, rather than reinforcement provided on previous test trials.

3.1.4. Coding

The primary experimenter was required to make on-line judgments regarding infant's choices in order to determine whether to proceed with another familiarization or test trial. Her decisions were checked retrospectively by coders who viewed silent videotapes of the infants alone (so that they could remain blind to condition assignment). Coders agreed on 99.7% of choice test trials. Because, in the few ($n = 4$) cases of disagreement, the primary experimenter's decisions favored the alternative hypothesis (i.e., heightened performance in the no function condition), we conservatively chose to use her codes throughout. Coders also recorded looking times to the objects presented on each training trial. Average percent agreement was 93.4% (Cohen's Kappa = .93) for this measure based on 10 double-coded participants.

3.2. Results

As summarized in Table 1, a significantly greater proportion of infants reached criterion on their first opportunity to do so in the function condition than in the no function condition on each of the first two sets, Fisher's exact test $ps < .05$. This comparison approached significance for the third set as well, $p = .09$. Based on the binomial formula, the probability of observing this pattern of success in the function condition by chance alone was remote, $p < .01$, for each set. The probabilities of the patterns observed in the no function condition were substantially more likely, $.17 < p < .23$. By the second opportunity to reach criterion, however, Fisher's exact tests revealed the total number of successful infants to be statistically equivalent across conditions on all sets, $ps > .10$.

In order to determine whether these effects were due to differences in amount of engagement during familiarization, we compared looking times of those infants who reached criterion in the first trial to those who did not. No differences in

Table 1
The number of infants reaching criterion after 1, 2, 3 or more training trials for each stimulus set in each condition.

Set and condition	Number of training trials				
	1	2	3	>4	Excluded
Set 1					
Function	12	2	1	1	
No function	5	5	1	4	1
Set 2					
Function	9	2	1	4	
No function	3	4	1	7	1
Set 3					
Function	9	0	1	4	2
No function	4	3	2	4	2

looking were detected for the first ($M = .64$, $se = .06$ vs. $M = .62$, $se = .04$), second ($M = .61$, $se = .03$ vs. $M = .62$, $se = .04$), or third ($M = .66$, $se = .04$ vs. $M = .59$, $se = .03$) set, *t*s ranged from .44 to 1.14, all *p*s *ns*.

3.3. Discussion

In sum, infants were more likely to extend categories after exposure to a single exemplar if that single exemplar was shown performing a distinctive function than when it was not. This effect emerged despite the fact that infants who categorized on the first test trial and those who did not attended equally to the familiarization objects. These results suggest that while perceptual comparison across like functioning and contrasting exemplars is no doubt critical in supporting some aspects of early categorization (e.g., evaluating potential exemplars for extension), function can also begin to facilitate categorization before these processes come into play, perhaps by acting as a 'kind placeholder' of sorts. These results are consistent with studies revealing principled inductive inference of object function in infants after exposure to only one functioning target object (e.g., Baldwin et al., 1993; Brown, 1990; Graham et al., 1999). The current results further add to this literature by explicitly demonstrating that these inferences are linked to categorization in infants. Heretofore, this connection has only been demonstrated in older children (Booth, 2009; Kemler Nelson, 1999; Kemler Nelson et al., 2000).

4. General discussion

The current research was designed to address lingering questions regarding the impact of object function on categorization in infancy. Specifically, we were interested in whether function does more than heighten attention and enhance perceptual comparison and contrast among objects. We approached the question of whether conceptual processes might also contribute in two ways. First, in Experiment 1, we attempted to clarify the specificity with which object function, as opposed to other perceptually salient object properties, facilitates categorization. To do so, we compared the categorization performance of infants who observed the function of familiarization objects to that of infants who observed the same objects moving in distinctive ways (Experiment 1). We followed up on this investigation with a strong test of whether the perceptual salience of object functions, in and of itself, is enough to support categorization (Experiment 2). We did so by assessing categorization after infants observed familiarization objects from a single category each performing a distinct function (rather than a shared function, as in Experiment 1). Second, in Experiment 3, we asked whether perceptual comparison and/or contrast are critical to the facilitative effect of function on early categorization. Here, we presented infants with one exemplar at a time and tested for category-based extension after each such exposure. Perceptual comparison was only possible after the first trial, and contrastive information was never provided (as it was in previous work by Booth & Waxman, 2002). The results establish that (1) object functions facilitate categorization while exaggerated distinctive motions do not (2) shared, but not contrasting functions facilitate categorization and (3) the benefit of object function is realized after exposure to a single exemplar (without opportunities for comparison and contrast across exemplars).

Each of these findings contributes to the overall conclusion that function facilitates categorization in infancy, not only by affecting attention and subsequent perceptual processing in an unprincipled way, but by bringing to bear its conceptual relevance for organizing kinds. The first finding discounts the possibility that function facilitates categorization merely because it provides additional salient information that correlates with category membership. Distinctive dynamic information that was perfectly correlated with category membership failed to facilitate performance. As noted in the discussion of Experiment 1, this might seem surprising in light of ample evidence that infants are highly sensitive to motion, and that they encode relationships between dynamic and static object properties well before two years of age (e.g., Dannemiller, 2001; Greco et al., 1990; Madole et al., 1993; Rakison & Poulin-Dubois, 2002). However, attending to object motions, and correlations with them, is a far cry from using this information as the cornerstone for organizing new categories. Indeed, Rakison (2004) found that infants were not able to capitalize on correlations between form and motion in a categorization context until they were 22 months of age (also see Horst et al., 2005). And even that demonstration does not parallel the difficulty of the current task. Rakison and Poulin-Dubois (2002) and Rakison (2004) tested infants on their extension to new exemplars

that shared or differed from familiarization stimuli in their motion characteristics. In contrast, we tested infants on their extension to new exemplars in the absence of any demonstration of the dynamic characteristics of those new exemplars. We therefore suspect that motion does figure prominently in infants' categorization, but that it does not typically serve as a 'kind placeholder' for artifacts in the same way that object function can. This is not to say that object motions can never play this role. Indeed, when agent-produced object motions are tightly limited by physical constraints, some evidence suggests that they can prime subsequent categorization (Booth, 2001). Whether the self-generated motions of novel animals are more conceptually salient for infants, and therefore potentially more effective at anchoring new categories in that domain, also remains to be seen.

The second finding reported here reinforces the conclusion that the salient perceptual properties of object functions do not fully drive their facilitative effect on early categorization. If they did, we should have observed successful categorization when each object within a category functioned in a distinct way. We suspect that we did not because the distinct functions signaled contrasting kinds for infants, thereby potentially highlighting perceptual differences, rather than commonalities (Wilcox & Chapa, 2004). Our findings from Experiment 3 are consistent with this possibility. Recall that, in that study, infants who observed the function of a single familiarization object were more likely to systematically extend the category to two additional novel exemplars than were infants who observed no functions. Thus, although function might well promote comparison among objects, exposure to two or more like-functioning exemplars is not necessary to reveal its facilitative effect on categorization. Rather, these findings suggest that when infants discover that a novel individual object functions in a distinctive way, they take this as evidence that a new kind of thing exists and expect to encounter additional exemplars of this kind in the future. Although the precise impact of this realization is yet to be specified, we suggest that it may enhance encoding of the novel object's other kind-relevant perceptual properties as well as prime infants to look for and attend to additional exemplars of its same kind, thereby facilitating efficient assimilation when those new exemplars are encountered.

These results are consistent with a number of other studies suggesting that object functions are intimately tied to categories and can support kind-based classification on the basis of a single learning trial (e.g., Baldwin et al., 1993; Barnat et al., 1996; Graham, Kilbreath, & Welder, 2004; Kemler Nelson et al., 2000; Ware, 2007). However, the current results seem to contrast with earlier evidence documenting the failure of 14–15-month-old infants to categorize after exposure to the function of a single exemplar (see the 'hint alone' condition of Booth & Waxman, 2002). There are a number of potential explanations for these disparate results. First, infants in the current investigation were slightly older. Recent evidence demonstrated that developmental differences among 14-month-old infants are related to their sophistication in utilizing functional information about object compressibility for categorization in a sequential touching task (Ellis & Oakes, 2006). Second, infants in the current investigation had the benefit of a familiarization phase in which they were able to learn about the testing procedure with familiar objects. Combined, these two factors may have made the task easier, thereby increasing the overall likelihood of success. Indeed, infants in both the function and no function conditions reached the learning criterion more readily than expected. Another possibility is that infants in the hint alone condition of Booth and Waxman (2002) underperformed because they became confused by pragmatic inconsistencies inherent in the procedure. Specifically, infants in that study were introduced to four novel category exemplars, only the first of which was shown functioning on a specially designed apparatus. If infants did indeed establish a 'kind placeholder' after exposure to a single functioning exemplar, they might well have expected the experimenter to demonstrate the function of subsequent exemplars on the same continuously available apparatus. When this did not occur, infants may have become confused or distracted, or might have even more detrimentally reasoned that the other familiarization objects were not members of the same category (because, had they been, the experimenter would have demonstrated their shared function). Further research will be necessary to disambiguate these possibilities.

Additional research will also usefully consider the time frames of learning, both developmentally and within the context of an individual's experience with functioning and non-functioning category exemplars. It is clear that important changes occur in both categorization and sensitivities to functionally relevant information over the course of the first two years of life (e.g., Madole et al., 1993; Perone & Oakes, 2006). Are the ideas presented here relevant to interpreting categorization performance at different developmental moments? For example, might the notion of function as a 'kind placeholder' provide an alternative explanation for why 10-month-olds appear to form summary representations of function-based categories more readily than they do for appearance-based categories, as has been shown by Horst et al. (2005)? One step towards answering questions like these will be to establish the age range over which the effects reported here are evident.

It will also be important to establish the time course over which exposure to a single functioning exemplar can facilitate categorization. The current investigation establishes that new category exemplars can be successfully assimilated by infants (on the basis of superficial visual-tactile properties alone) within minutes after exposure to a single functioning exemplar. However, in the course of natural experience, infants are likely to encounter new potential category members only after substantially longer delays. Therefore delineating the 'time window' during which infants are primed to detect new category members is critical to establishing the importance of this effect (Merriman, Rovee-Collier, & Wilk, 1997; Rovee-Collier, Greco-Vigorito, & Hayne, 1993). Likewise, consideration of context sensitivity will be essential to establishing ecological validity as investigations proceed (Shields & Rovee-Collier, 1992).

In the meantime, it is worth considering what precisely is so special about function that allows it to contribute to early categorization in such a powerful way. Several studies now help narrow down the field of possibilities. It is not the dynamic path through which objects pass as they perform their functions (Booth & Waxman, 2002). Indeed, the current results suggest that even highly distinctive and salient motion trajectories don't facilitate categorization (Experiment 1). Even functions

themselves, in all their perceptually rich glory, fail to facilitate categorization when each category exemplar functions in a distinct way (Experiment 2). This suggests that it is not the attention-grabbing qualities of function alone that account for its effect. Neither is it simply correlations between objects and attractive outcomes (also see Booth, 2008). Because statistical regularities relating object properties to each other cannot be computed on the basis of a single exemplar, the results from Experiment 3 are also consistent with the notion that early conceptual development relies on more than simple associative mechanisms broadly speaking (e.g., Booth & Waxman, 2008; Gelman & Diesendruck, 1999; Gopnik et al., 2004; Markson, Diesendruck, & Bloom, 2008).

Importantly, these conclusions should not be taken to suggest that attention and associative mechanisms play no role in early categorization and conceptual development. Ample evidence suggests that they do, and the current results are not inconsistent with this reality. Our results simply, but importantly, demonstrate that influences on infants' gross level of attention fail to account for the facilitative effect of function on categorization. Instead, we argue here and elsewhere (Booth, 2006) that function likely facilitates categorization by directing attention in more nuanced ways. For example, function might enhance encoding of other related object properties (e.g., shape) and might prime subsequent attention to similar objects. Eye-tracking and other physiological measures may be particularly useful in specifying these mechanisms in future work.

In conclusion, we speculate that the key quality that sets function apart in its ability to facilitate categorization, and to do so after experience with only a single exemplar, actually corresponds to something that object functions, names, and causal properties all share in common. Each of these cues have been shown to both facilitate categorization in infancy (Booth, 2006, 2008; Booth & Waxman, 2002) and to support kind-based extensions after a single learning trial in older children (e.g., Behrend, Scofield, & Kleinknecht, 2001; Booth, Waxman, & Huang, 2005; Waxman & Booth, 2000). All are salient even in infancy, and are tightly tied to concepts throughout development (Booth & Waxman, 2008; Booth et al., 2005; Gopnik & Schulz, 2007; Kemler Nelson et al., 2000; Sobel & Kirkham, 2007). The current studies join others (e.g., Booth, 2006; Waxman & Braun, 2005) in diminishing the importance of their perceptual salience in supporting early categorization. We therefore suggest that the common thread of greater importance relates more critically to their conceptual relevance.

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