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Experience-Based and On-Line Categorization of Objects in Early Infancy

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Abstract

What processes do infants employ in categorizing? Infants might categorize on line as they encounter category-related entities; alternatively, infants might depend on prior experience with entities in formulating categories. These alternatives were tested in forty-four 5-month-olds. Infants who were familiarized in the laboratory with a category of never-before-seen objects subsequently treated novel objects of the same category as familiar -- they categorized on line -- just as did infants who were exposed to objects from the same category at home for 2 months leading to their laboratory assessment of object categorization. Infants with home experience also recognized novel category objects as familiar from the outset -- that is, prior experience with category exemplars was brought to bear in laboratory tasks.

One of the central challenges of object identification and categorization is the ability to recognize and organize category-related objects independent of their orientation, where they appear in the visual field, and so forth. For object perception and cognition to proceed with any degree of organization, order, or coherence, both biological and environmental variation must be transcended. Categorization constitutes a critical and adaptive solution to the challenges posed by both biological instability and environmental diversity. Categories refer to shared representations of like, but (usually) discriminable, entities, and are in evidence when organisms treat (discriminably) different entities equivalently. Categorization allows generalization across experience, because categorization relates experienced entities to one another and to their mental representation. Categories mediate our interactions with the world in many ways (Bornstein, 1984; Harnad, 1987; Rakison & Oakes, 2003; Rosch, 1975; Smith & Medin, 1981; Smith, 1989). They structure and clarify perception and cognition; they facilitate the storage and retrieval of information; and they supply a principle of organization by which new information is banked efficiently in memory. An entity that is encountered for the first time could be treated as unique or, if categorization is brought to bear, in the same way as previously encountered entities that it resembles. Categorization is also used to generalize about newly encountered entities from the same category (Furrer & Younger, 2008; Gelman, 1988; Kalish & Gelman, 1992; Lin & Murphy, 2001; Proffitt, Coley, & Medin, 2000). Knowledge about a category affords expectations about novel entities *in toto* as well as about features of novel entities (Baldwin, Markman, & Melartin, 1993; Greco, Hayne, & Rovee-Collier, 1990; Mandler, 1998, 2000; Needham, Cantlon, & Ormsbee Holley, 2006). Categorization is thus a fundamental process by which the brain assigns meaning to sensory stimuli, and categorization is critical for rapidly and appropriately selecting behavioral responses (Freedman & Assad, 2006).

Little wonder, then, that the primate visual system has evolved such that single neurons respond selectively and quickly to complex object categories, like faces and hands (Bruce, Desimone, & Gross, 1981). The activity of even tiny populations of neurons (on the order of approximately 100 randomly selected cells) over very short time spans (as brief as 12.5 ms) process accurate and robust information about both an object's identity and its category, and that category information generalizes over a range of object orientations, locations, and scales, even for novel objects (Freedman, Riesenhuber, Poggio, & Miller, 2001; Hung, Kreiman, Poggio, & DiCarlo, 2005; Schwarzlose, Swisher, Dang, & Kanwisher, 2008). Notably, specific category-related brain activity has been observed in young human infants (Quinn, Westerlund, & Nelson, 2006).

Given the significance of categorization, surprisingly little is understood about the conditions required or the time course over which categorical representations are first formed in infancy. After all, infants are limited in the universe of objects to which they are exposed as well as in their cognitive capacities. Examining categorization processes in infancy can inform about factors that influence the nature and origins of categorization and the earliest accumulation of category-relevant knowledge (Furrer & Younger, 2008; Rakison & Oakes, 2003).

In a typical categorization study, infants are familiarized with discriminable exemplars of a category, and they are then tested with novel exemplars from the familiar category and from a contrasting different category (e.g., Arterberry & Bornstein, 2002; Behl-Chadha, 1996; Bornstein, Kessen, & Weiskopf, 1976; Quinn, Eimas, & Rosenkrantz, 1993). To show that they categorize, infants must include discriminably different novel exemplars of the category in the representation they have and simultaneously exclude contrasting novel exemplars from outside the category. Operationally, generalization of familiarization to a novel exemplar from the familiar category, coupled with heightened responsiveness to a novel exemplar from the novel category, are taken as evidence of category formation. For example, 5-month-olds who were habituated to varying facial expressions from one category (smiles) responded to a novel test image from the habituation category as if it were familiar, but responded differently to a novel (fearful) expression from a different category (Bornstein & Arterberry, 2003).

Routinely in infancy studies of object categorization, images or replicas of real-world objects are used, such as animals or vehicles or furniture, which are known and with which infants normally have experience. Visual-fixation studies have shown that infants as young as 3 to 4 months distinguish between categories such as animals and furniture, and even subcategories within animals and furniture such as cats, dogs, fish, and horses (Eimas & Quinn, 1994; Eimas, Quinn, & Cowan, 1994) or chairs, beds, sofas, and tables (Behl-Chadha, 1996). In these common cases, infants may categorize on the basis of their experience seeing exemplars in the course of the study or on the basis of experience they have in real life or from picture books, videos, television, and the like. Thus, it is unclear whether infants' categorization performance is based on preexisting familiarity with objects or categories, or, instead, if infants form categories during the (usually highly structured) experimental familiarization period. This circumstance leaves open key questions of whether and how infants actually construct categorical representations of objects they experience during fleeting encounters in routine daily life. Answers to these questions are important to fully understand human learning and how it develops.

Are object category representations in infants constructed before an experiment, or are they formed during the course of an experiment? If infants form category representations before being brought to the laboratory, it is probable that infants recognize experimental exemplars as representations of objects in the world with which they are already familiar and for which

they may have some existing category knowledge. On this view, the familiarization phase of the familiarization/novelty-test procedure presumably serves to prime the knowledge that infants have already acquired outside the laboratory. If infants initiate category construction during the course of familiarization, then the familiarization/novelty-test procedure is better understood in terms of category formation. Infants presumably construct a category representation as they see exemplars from the familiar category. However, from the extant literature it is difficult to completely rule out the possibility that prior experience or knowledge does not influence infant categorization. For most experiments designed to study categorization, it is possible that young infants recruit from their preexisting knowledge base in a way that, at least in part, determines their subsequent categorization behavior (Quinn, 2004).

In the present study, categorization was called *on line* when infants appeared to rely only on their immediate perceptions of the given experimental entities to form an object category within the familiarization period. Categorization was called *experienced based* when infants could refer to some already existing experience, knowledge, or representation that was activated by perceptions of given entities but included properties other than those corresponding to the physical attributes of the experienced material. The present study investigated whether infants younger than 6 months of age show on-line or experience-based categorization using an object-examination paradigm and objects that infants could never have seen before; so the study controlled experience and eliminated preexisting knowledge from explaining infant object categorization performance.

Infants might show on-line categorization, or infants might show experienced-based categorization. To take these two main options in reverse order, the second possibility holds that categorization in infants is experience based if infants refer to already existing knowledge representations that are being re-activated. By the middle to end of the first year (to take a common age-span at which object categorization studies are done), infants are already experience-rich and perceptually competent, and so could easily be expected to take full advantage of opportunities to categorically structure their interactions with objects. There are three ways that pre-existing experience could then affect categorization in the laboratory. One is that previous experience with the category is used during the familiarization phase of a categorization task and influences the acquisition or nature of the category representation. Another is that experience might be recruited during categorization judgments after the familiarization phase has ended. Familiarization might serve as a reminder that countervails forgetting by priming or reactivating an available but otherwise inaccessible category in memory (Tulving & Thomson, 1973), thereby facilitating access to that memory at the time of the subsequent test (Spear, 1973, 1978). In infants, reminders are effective in counteracting forgetting after retention intervals as long as 1 month (Fagen & Rovee-Collier, 1983; Rovee-Collier, Sullivan, Enright, Lucas, & Fagen, 1980; Sullivan, 1982). Last, of course, infants could use existing knowledge in both ways.

For example, asymmetries in young infants' categorization have been attributed to infants' relatively greater experience with one or another category (Quinn, 2002). Preliminary evidence for the role of previous experience in categorization was provided by Quinn, Yahr, Kuhn, Slater, and Pascalis (2002). Using a visual familiarization task, they found that 3- to 4-month-old infants with female primary caregivers formed an exclusive category of relatively unfamiliar male faces (i.e., a category that excluded female faces), but remembered individual exemplars from the more familiar category of female faces. Using an object-examining task, Pauen (2002) observed that 10- to 11-month-old infants responded to the distinction between furniture and animals both when between-category exemplars shared several perceptual properties and when they shared few. Pauen reasoned that on-line (perceptual) processes could not account for these results, and therefore infants' responding

must reflect accumulated knowledge. Likewise, it has been suggested that categorization of cats and dogs differs for infants who do or do not have pets in their home. Kovack-Lesh, Horst, and Oakes (2005) reported that infants whose parents rated them as being highly interested in dogs performed best on a pattern-learning task involving pets.

Thus, experience and experience-dependent preferences seem to play a role in categorization performance (Needham et al., 2006, discuss related findings), and pre-existing representations may help to explain categorization in young infants. More generally, these findings suggest that infants' experiences outside the laboratory can affect their categorical responding in the laboratory (Bar-Haim, Ziv, Lamy, & Hodes, 2006; Kelly et al., 2005, 2007).

However, other data cast some doubt on exclusively experience-based interpretations of infant categorization. If infant categorization of nonhuman animals in the laboratory is assisted by their real-world experiences with nonhuman animals occurring before arrival at the laboratory, Quinn (2004) argued, one might expect having home pets to facilitate infants' animal categorization performance. Two studies compared animal categorization by infants who had been exposed to pets at home and infants who had not, and neither revealed a facilitative effect of home pets on categorization performance. Data from 3- to 4-month-old infants tested in Quinn's (2004) Experiment 1, and 6- to 7-month-old infants tested in his Experiment 2, offered no evidence that categorization of cats or dogs as measured in the laboratory was influenced by the presence of a home pet. Similarly, whether or not infants had a pet dog at home was not a significant predictor of their category task performance, nor did it correlate with infants' reported interest in dogs, in Saffran, Pollak, Seibel, and Shkolnik (2007). "These null results thus fail to support the suggestion that infant categorization of nonhuman animals in the laboratory is assisted by real-world experience with nonhuman animals occurring prior to arrival at the laboratory" (Quinn, 2005, p. 113).

On the first possibility, then, infant categorization might not (solely) reflect their prior accumulated experience. Categorization might take place on line if infants rely on their immediate experiences with given stimuli to form categories. Even if infants possess some categorical knowledge, some infant categorization performance might still be best explained by spontaneous category learning (Mareschal, French, & Quinn, 2000; Mareschal & Quinn, 2001). For example, infants presented with the contrast between replica animals and people did not categorize in the first half of the task, but gave evidence that they did in the second half (Oakes, Plumert, Lansink, & Merryman, 1996). Infants in this study seemed to discover a categorical distinction as they actively explored the experimental objects. Younger and Fearing (2000) provided evidence for infant on-line category formation by showing that infants form categories at multiple levels that depend on similarities among the entities presented during the experiment. Presented with cat versus dog contrasts manipulated by changing featural (although not categorical) characteristics of the stimuli, infant responsiveness varied, suggesting that they formed categories during familiarization (and that category boundaries could be manipulated depending on the information presented during familiarization; see also French, Mermillod, Quinn, & Mareschal, 2001). The authors reasoned that, if infants were tapping into category representations that were fixed and established before their participation in this task, infant responsiveness would not differ with featural variation in the category information presented. Together, these findings suggest that categorization performance in infancy can be attributed to active on-line processing and within-task learning.

Finally, infant performance need not be one (on line) or the other (experience based), but both. Four-month-olds' previous experience with dogs, cats, or both and their on-line looking behavior during learning an adult-defined category of cat in a visual familiarization

task jointly determined whether or not infants categorized (Kovack-Lesh, Horst, & Oakes, 2008). Infants were divided by whether they had a pet at home and how much they shifted their gaze back and forth between stimuli during familiarization. Infants in a pet/high-switching group showed significantly greater novelty preference than did infants in a no-pet/high-switching group and infants in a pet/low-switching group. In this study, infants who had a pet at home and who engaged in relatively high levels of stimulus comparison demonstrated the highest level category functionality -- they remembered individual items and they recognized commonalities among items from within the same category. Infants in the other groups did not respond to either the category or to the individual items. One problem with this pattern of results, however, was that infants in the most advanced pet/high-switching group did not differ in novelty preference from infants in the least advanced no-pet/low-switching group.

The common use of real or familiar stimuli in these infancy studies restricts the analysis of performance contrasts and the important deductions that can be made from them. Even if young infants have not observed the exact stimuli in categorization experiments prior to their participation, they have been exposed to related stimuli that may be sufficient to build up representations that could influence learning within those tasks (Needham & Baillargeon, 1998, and Quinn & Eimas, 1998, discuss relations between real-world experience and within-task learning). It could also be that parents with pets treat their infants differently than do parents who do not have pets. In either case infants might differ in their attention and learning in general. Investigating infants' categorization abilities, some researchers have used novel stimulus materials such as meaningless dot patterns and unusual creatures (e.g., Bomba & Siqueland, 1983; Younger & Cohen, 1983). However, dot patterns are simplified stimuli and hardly ecologically representative of 3-D objects which have affordances for action and serve functional roles, and hybrid animal-part studies depict familiar parts and/or part-whole relations that enable (or specifically draw on) linkages to previous experience. Many factors influence the ease of representation of the input and facilitate categorization, and one obvious factor is familiarity; elements similar to those that have been encountered previously can be expected to be easier to represent, maintain in memory, and perhaps categorize (Saffran et al., 2007). Thus, materials that infants can readily represent, such as animals, vehicles, and furniture, might facilitate categorical task performance. Finally, one can expect natural variation in infants' experiences and, in consequence, infant performance in any natural experiment through unsystematic exposure to materials and images.

How then do infants categorize objects? To address this question, task performance is best examined independently of differing levels of stimulus experience and familiarity. Here, we investigated infant object categorization by directly examining infants' learning of entirely new object categories both with and without previous experience with object exemplars of those categories. Experience was controlled through the development and use of purpose-constructed never-before-seen objects and categories, and whether or not infants were shown the objects preceding their participation in a laboratory categorization task. If infants with no possible experience with such an object category and its exemplars form a categorical representation during a laboratory task, then previous, cumulative experience must not be requisite for object categorization, and infants can categorize "on the fly." If infants with no experience with the object category and its exemplars cannot form a categorical representation during a laboratory task, then previous, cumulative experience may be requisite for object categorization. If infants having such previous, cumulative experience with the object category and its exemplars form a categorical representation during a laboratory task, then that experience would appear to define a milestone of experience-dependent sufficiency for learning new categories and subsequently categorizing novel exemplars. Thus, along with its control of experience with the object stimuli, this study offers an experimental vantage point from which to examine infants' developing

categorization abilities. In this experiment, we contrasted laboratory object categorization in young preverbal infants given prior home experience with unique and entirely novel objects to laboratory object categorization in infants given no such experience.

Method

Infants

Nineteen normal and term infants (5 girls) were 3.15 months ($SD = 0.26$) when they began the Home Experience Condition; they were 5.38 months ($SD = 0.39$) at the laboratory assessment. (One additional infant was recruited, but the family moved during the home experience phase.) Twenty-five normal and term $M = 5.12$ -month ($SD = 0.42$) infants (13 girls) participated in the No Home Experience Condition. (An additional 3 infants were recruited, but their data were not included due to fussiness or experimenter error.) There were no differences in sociodemographic characteristics of infants or families in the two conditions.

Stimuli

Never-before-seen objects were constructed to comprise two novel categories (Figure 1 A and B) for infants. The objects were each made of 3 wooden pieces assembled in unique configurations. Individual parts were painted with a total of 8 different colors, 4 used for each category. Each category exemplar represented a unique combination of part configuration and color. Both within and between categories, the parts of each object were assembled in a similar way, but each varied with respect to the exact positioning of parts. Each category contained a total of 8 unique exemplars. Each object was painted with 3 colors (1 per part), and the colors did not overlap across categories. Thus, the two categories were similar in size, complexity, part configuration, and the distribution of color boundaries, but differed in the parts and colors of the objects. Curved vs. linear edge features were distributed over the entire object for each exemplar and category. The familiarization exemplars were depicted in numerous and varied orientations and viewpoints, so edge composition did not provide a single, location-invariant feature for discrimination between images.

Home Experience Procedure

At the 3-month laboratory visit, parents of infants in the Home Experience Condition received materials and training for conducting stimulus exposure sessions at home. They were provided with a booklet containing 20 photographs, four pictures each (differing in orientation) of five randomly selected exemplars from one category. The images were 10.2 cm $\times$ 15.2 cm and printed on standard size plain white paper which was then laminated. Parents were instructed to show their infants the pictures once per day on a daily basis until they returned to the laboratory for the experimental task. They were provided with a timer and were instructed to pace presentations so that the entire stimulus set was shown over the course of 2 min. Parents were telephoned on a weekly basis to evaluate compliance with the procedures. Mothers were accommodating in conducting the stimulus exposure sessions at home, reporting successful administration of 5.54 sessions per week on average ($SD = 1.04$) throughout the 2-month home-experience period. They reported no significant problems with administration. Missed sessions were distributed uniformly over participants, most typically resulting from competing household demands and minor illness.

Laboratory Object Examination

Object examination procedure—To test preference, discrimination, and categorization, an object-examination procedure was used following established conventions (Oakes &

Tellinghuisen, 1994; Ruff, 1986). Actual objects were presented directly to infants. The data of primary interest from object examination are the amounts of time infants spend in focused examination of objects while handling them. Oakes and Tellinghuisen (1994) have argued that focused examination provides a more sensitive index of information processing than traditional measures of looking time. Each session was videorecorded, and infants' examination of stimulus objects was coded from the videorecords. All coders were blind to the hypotheses of the study and condition assignment of the infants. Reliability of coding was established by calculating agreement between coders. All together, 35% of sessions were coded twice, with high agreement, $r = .91$.

Stimulus preference and discrimination—To assess baseline stimulus preference and within-category exemplar discrimination, an independent sample of 14 normal and term infants participated in a fixed-trials familiarization/novelty-preference task (M age = 5.23 months, $SD = 0.26$; 6 girls). (Two additional infants were tested, but their data were not included due to fussiness and inattention.) Infants participated in two different sessions, one involving each of the two different object categories. For each session, a single exemplar of one category was randomly selected and presented repeatedly over the course five 20-s familiarization trials. At the end of each trial, the experimenter retrieved the object from the infant, removed it from view, then re-presented it to begin the next trial. Two discrimination trials were then administered in the same fashion. In one trial the same object was presented again, and in the other trial a randomly selected novel member of the same category was presented. The order in which the discrimination trials were administered (novel exemplar first or second) was counterbalanced across infants. The order of sessions for the two categories was also counterbalanced.

To assess infants' baseline preference, infants' object examination was compared between categories within the first 20 s of exposure during the familiarization phase. Examination times did not differ between categories (A, $M = 2.88$ s, $SD = 4.37$ vs. B, $M = 3.66$ s, $SD = 4.80$), $t(13) = 0.70$, *ns*. Infants' discrimination of exemplars within categories was examined in an ANOVA utilizing category (A vs. B) and discrimination trial (familiar exemplar, $M = 2.05$ s, $SD = 1.65$, vs. novel exemplar, $M = 3.50$ s, $SD = 2.01$) as within-infants factors. Only the discrimination trial contrast was significant, $F(1,13) = 6.10$, $p = .028$, with infants examining the novel exemplars longer than the familiar ones. In brief, infants had no *a priori* preference for one category over the other and could discriminate among same-category exemplars.

Categorization—All infants participated in the same laboratory categorization task. The categorization procedure comprised a familiarization phase and a test phase. Five objects from one (or the other) category were randomly assigned for familiarization. Using a fixed-trials procedure (Ruff, 1986), each object was examined twice over the course of 10 familiarization trials in an order uniquely randomized for each infant. During familiarization, the experimenter presented one object at a time to the infant, using a count-down timer to mark an elapsed time of 20 s per trial. At the end of each trial, the experimenter retrieved the object from the infant and then presented the next object. Except for the one being presented, the remaining objects were hidden from the infant's view. Two test trials were then administered in the same fashion. In one test trial a novel previously unseen member of the familiar category was presented, and in the other test trial a randomly selected member of the novel category was presented. The order in which the test trials were administered (novel category first or second) was counterbalanced over infants.

In summary, infants in the Home Experience Condition and infants in the No Home Experience Condition came to the laboratory at 5 months. At that laboratory visit, infants were familiarized to 5 objects – for infants in the Home Experience Condition, they were the

same objects as those depicted in the picture booklet the infants saw at home -- and then tested with two previously unseen objects (one from each category). Half of each sample was familiarized to each category, after which every infant received both a familiar-category novel test trial and a novel-category novel test trial. Laboratory visits and data analysis were conducted in exactly the same manner for infants in the Home Experience and No Home Experience Conditions.

Results

Infants' laboratory object-examination categorization was analyzed in two mixed-model ANOVAs utilizing familiar category (A vs. B) as a between-infants factor and a series of planned trial contrasts as within-infant factors. Planned comparisons examined effects of (a) familiarization (mean of first 2 familiarization trials vs. mean of last 2 familiarization trials), (b) category generalization (mean of last 2 familiarization trials vs. the familiar-category novel-object test trial), and (c) category discrimination (mean of last 2 familiarization trials vs. the novel-category novel-object test trial). Preliminary analyses revealed no effects of test condition order or gender, so subsequent analyses excluded those factors.

Familiarization, Category Generalization, and Category Discrimination Following Prior Home Experience

The familiarization and category generalization contrasts were not significant, $F_s(1,18) = 0.009$ and 0.334 , *ns*, but the category discrimination contrast was significant, $F(1,18) = 14.05$, $p = .001$, partial $\eta^2 = .438$ (Figure 2A).

Familiarization, Category Generalization, and Category Discrimination without Prior Home Experience

The familiarization contrast was significant, $F(1,24) = 5.73$, $p = .025$, partial $\eta^2 = .193$; the category generalization contrast was not significant, $F(1,24) = 1.21$, *ns*; and the category discrimination contrast was significant, $F(1,24) = 7.92$, $p = .010$, partial $\eta^2 = .248$ (Figure 2B).

Familiarization Differences and Similarities between Experimental Conditions

To examine whether their home experience modified infants' familiarization (encoding) during the laboratory task, three additional analyses compared object examination times between the two groups. First, the means of the first two familiarization trials differed across conditions, $M = 2.69$ s ($SD = 2.09$) in the Home Experience condition vs. $M = 5.88$ s ($SD = 4.91$) in the No Home Experience condition, $F(1,42) = 7.01$, $p = .011$, partial $\eta^2 = .143$. Second, a main effect of condition emerged over the start through the end of familiarization, $F(1,42) = 5.02$, $p = .030$, partial $\eta^2 = .107$, with infants in the No Home Experience Condition examining objects longer ($M = 9.80$ s, $SD = 6.92$) than infants who had previous Home Experience ($M = 5.44$ s, $SD = 3.53$). Additionally, trial interacted marginally with condition, $F(1,42) = 3.59$, $p = .065$, partial $\eta^2 = .079$. As noted above, a significant decrement was observed in the No Home Experience condition but not in the Home Experience condition. Third, the average duration of object examination per individual look throughout familiarization was significantly longer in the No Home Experience condition ($M = 2.48$ s, $SD = 1.96$) than in the Home Experience condition ($M = 1.41$ s, $SD = 1.07$), $F(1,42) = 4.64$, $p = .037$, partial $\eta^2 = .099$.

To assess infants' general orientation to the task and its demands during familiarization, two additional analyses were conducted. First, the total duration of casual looking toward the stimuli -- that is, general visual regard not limited to focused examination -- was calculated across familiarization trials and compared between groups. Mean looking did not differ

between infants in the Home Experience ($M = 12.10$ s, $SD = 2.58$) and No Home Experience ($M = 10.54$ s, $SD = 4.64$) conditions, $t(42) = 1.32$, *ns*. Additionally, general interest in the stimulus objects was independently rated for each trial using a 5-point Likert-type scale from 1 = *no interest* to 5 = *extremely interested*. Fifteen percent of the sessions were rated by a second coder, and ratings correlated $r = .94$ between coders. Ratings did not differ between infants in the Home Experience ($M = 3.75$, $SD = 0.50$) and No Home Experience ($M = 3.76$, $SD = 0.88$) conditions, $t(42) = 1.32$, *ns*. Together, these findings indicate that infants' general engagement in the task did not differ between conditions and therefore cannot account for the differences observed in infants' processing of the stimulus objects during familiarization.

Discussion

At 3 months, infants were randomly assigned either to a Home Experience condition that consisted of their parents showing them images of exemplars of a novel, never-before-seen category of objects or to a No Home Experience condition. At 5 months, all the same infants participated in a laboratory categorization study with objects from those same categories. Infants in the Home Experience Condition did not decline in looking at objects over the course of laboratory familiarization; they generalized from the end of familiarization to presentation of a novel within-category object; and they examined a novel-category novel object longer than they examined objects at the end of familiarization. Infants in the No Home Experience Condition declined in looking over the course of familiarization to the objects; they generalized from the end of familiarization to the presentation of a novel within-category object; and they examined a novel-category novel object longer than they examined objects at the end of familiarization. These findings were not ascribable to infants' differential engagement with the stimuli or to differential preferences for or failure to discriminate among the stimuli.

Two Lessons Learned

This study of infant categorization of *ad hoc*, unfamiliar objects eventuated in 2 main sets of findings. First, 5-month infants with no prior experience with a completely novel category of never-before-seen objects categorized them on line at the time of an experimental session, just as infants would presumably do in encountering category-related objects in everyday life. Second, infants with prior experience also categorized the objects at the time of an experimental session, and home experience with completely novel objects in a novel object category also influenced infant behavior at the time of the later experimental laboratory session.

Infants familiarized to exemplars of a never-before-seen object category during an experimental session generalized examination time to a novel object exemplar from the same category, while discriminating one from a contrasting category. Because otherwise equivalent infants showed no baseline preference for exemplars of one category over the other, and demonstrated an ability to discriminate exemplars within both categories, the No Home Experience infants' performance clearly reveals their ability to categorize objects on line, that is as never-before-seen objects in a category are encountered. Because infants participating in the No Home Experience condition had never previously experienced exemplars of the novel stimulus categories, their representations could only have formed during the task itself. These findings affirm the position that young preverbal infants' responses during laboratory tasks incorporate and reflect experience during the task. The present work indicates that infants can formulate categorical representations of objects entirely within the confines of a few short minutes exposure. Infants appear to have learned an object category during familiarization. It may be that mere exposure on the task of comparing different exemplars of the same category over time leads to the extraction of a

category (Gentner & Medina, 1998). In adults, categorization experience with stimuli analogous to those used in testing attunes the individual and the brain to relevant dimensions of a stimulus (Baker, Behrmann, & Olson 2002; Goldstone, Steyvers, & Larimer, 1996; Jiang et al., 2007; Schyns, Goldstone, & Thibaut, 1998).

This is not to imply that prior experience plays no role in infant cognition. The second question of whether infants construct categorical representations over their encounters with objects as they arise in everyday life and later call on that information was examined in the complementary Home Experience condition. These infants were exposed to pictures of novel objects every day (for just a few s each) over the course of 2 months. When these infants participated in the same laboratory categorization task, they too demonstrated categorical representations during the test phase of the task, but no evidence of learning during the familiarization phase. On the convention that attention during familiarization reflects active encoding (Bornstein, 1985; Colombo, 1993), experience at home clearly exerted a direct effect: More encoding occurred when prior opportunity for encoding was absent. This finding underscores the conclusion that infants utilized stimulus representations they had constructed at home, bringing them to bear on their categorization performance in the laboratory. Because the category exemplars were novel and unique to this research program, infants must have constructed categorical representations of the stimulus objects over the course of their distributed home experience, brought this information with them to the laboratory, and then used this information during the laboratory task. The facts that infants in the Home Experience condition (a) treated stimuli at the beginning and end of the laboratory familiarization the same and (b) treated stimuli at the start of familiarization differently from infants in the No Home Experience Condition provide additional evidence that infants carried their knowledge of the category from previous home experience into the laboratory. (Checks verified that the two groups did not differ overall in engaging the stimuli.) This finding is consistent with the positions that infants can construct stable categorical representations of objects they experience and that those representations can guide the systematic generalization of familiarity and knowledge to novel entities. The different patterns of familiarization between groups for objects that were previously experienced versus those that were not indicate that prior representations (based on experience) exerted a more dramatic influence on property extensions than did in-task modeling.

Furthermore, young infants in the Home Experience Condition had to transfer knowledge from pictures to objects, and from looking to looking and handling. These differences are nontrivial and require intersensory and mental generalization. This deduction accords with previous research that revealed the abilities of infants in this age range to detect equivalences between objects and their photographs (e.g., DeLoache, Pierroutsakos, & Uttal, 2003). Real-life exposure to images of objects appears to influence infants' responses to categories of the same 3-dimensional objects in the laboratory.

Object Representation: Items or Prototypes?

On what basis do infants learn object categories? One approach to answering this question starts from the nature of infant representation in category development. Object categories may be represented by individual exemplars of the category or by a summary representation (perhaps a prototype or rule) of the category (e.g., Medin & Schaffer, 1978; Nosofsky, 1984). Item-based approaches tend to rely on (sometimes large) mnemonic stores of previous experience; prototype or rule-based approaches usually rely on simpler criteria and presumably do not require extensive memory. In adults, when the number of stimuli is small, categorization may be mediated by individual items, but when the number of stimuli exceeds some capacity, categorization is presumably handled by prototypes or rules rather than by individual exemplars (Ashby & Ell, 2001). It has been asserted that infants form

categories both as collections of individual items (e.g., Hayne, Rovee-Collier, & Perris, 1987; Quinn et al., 2002; Younger, 1993) and as organized around prototypes (e.g., Bomba & Siqueland, 1983; Bornstein, 1982; Younger, 1985). Which infants do appears to depend on their age, the task at hand, or other factors. Younger (1990) reported that 13-month infants use specific-item information in categorization, but younger babies do not. Quinn (2002) proposed that experience with exemplars from a particular category changes infants' categorization from forming a summary representation (prototype) of exemplars to remembering each individual exemplar as well as maintaining a summary representation. Horst, Oakes, and Madole (2005) also reported results that supported infants' learning individual exemplars and forming a summary representation. Perhaps after extensive experience with a limited number of items in a category, infants can both maintain a summary representation or prototype and remember individual items. In light of the constancy in infants' home experience in our study – seeing the same 5 objects each in a limited number of orientations every day – it is possible that infants stored and retained each exemplar individually and compiled a summary representation (prototype) of the category. If so, Home Experience infants' flat familiarization profile could reflect individual item recognition or common reference to a previously developed category (prototype) representation. It is impossible to discern from the present familiarization data which format infants used to encode their home experience and applied during laboratory familiarization.

That said, any related ambiguity with respect to infants' familiarization performance in no way undermines our interpretation of infants' test phase performance where both groups provided clear evidence for categorical representations. Because the Home Experience infants in the present study demonstrated categorization of familiar-category novel exemplars in the test, and there was no evidence for their learning during familiarization, we deduce that infants acquired a categorical representation prior to the laboratory task (i.e., over the course of home experience) and used it during the test. It is possible that infants in the Home Experience condition formulated specific memories of each individual image or stimulus object, and showed reduced examining during familiarization because they recognized individual stimuli instead of recognizing the category. On closer inspection, however, this interpretation is not consistent with the evidence available. First, infants in the laboratory task had to bridge their home experience with pictures into their responses to objects over significant differences in setting, context, and presentation mode. More critically, however, if infants simply recognized individual objects during familiarization, they would not have generalized examination time to either test stimulus. Because infants in a separate task discriminated among members of both categories, the familiar-category novel-object test stimulus would have been discriminated if infants relied on item recognition alone. As reported above, however, this is not what happened. Infants in the Home Experience condition, like their No Home Experience counterparts, generalized looking from familiarization to the familiar-category novel object.

Object Representation: Features or Configurations?

Another approach to the basis of infant object categorization turns on the question of what about objects and object categories constitute critical criteria. Infants in our study treated discriminably different same-category novel objects in the test equivalently to the objects in the familiarization set and discriminated different-category novel objects. Some investigators contend that infants younger than 1 year of age form categories based on knowledge about causal and functional similarities of objects (Gelman, Durgin, & Kaufman, 1995; Mandler, 2000, 2004; Mandler & McDonough, 1993; McDonough & Mandler, 1998; Van de Walle, 1999). The object stimuli used in the present study lack causal or functional relations as such, and so these bases of categorization are ruled out. Thus, novel objects were presumably categorized or discriminated by their similarity of appearance to familiar

ones. Such comparisons could refer to (a) similarity of critical features or (b) similarity of a configuration of features. In a sense, the answer to this question further specifies the nature of the infant's representation of the object category.

Perhaps infant object representations are holistic, based on an object category's overall configuration or appearance without selective attention to individual features, dimensions, or attributes. Using sequential touching, Rakison and Butterworth (1998) deduced that infants under 2 years attend, not to individual object parts per se, but to the structural configuration of the parts perceived as a whole, and Träuble and Pauen (2007) found that 1-year-olds categorized objects on the basis of their overall similarity and not their part similarity. Elsewhere, infants have been shown to rely on overall shape similarity as a basis of object categorization (Graham, Kilbreath, & Welder, 2004; Welder & Graham, 2001). Later, infant categorization could become more analytic, with selective attention paid to features, dimensions, or attributes (Shepp, 1978). There is evidence, too, however, that young infants discriminate and categorize on a so-called partonomic bias. Tversky and Hemenway (1984) contended that children first form categories based on partonomies rather than taxonomies (see also Mash, 2006; Rakison & Butterworth, 1998; Rakison & Cohen, 1999). This means that infant categorization refers to a focus on specific parts rather than the entire object (Booth & Waxman, 2002; Madole & Cohen, 1995; Mash, 2006). Parts are known to be highly relevant for object discrimination and categorization in adults as well as in children (Biederman, 1993; Hummel & Biederman, 1992; Madole & Cohen, 1995; Saiki & Hummel, 1996; Tversky & Hemenway, 1984; Younger, 1990). Younger and Cohen (1983, 1986) found that 10-month-olds recovered attention on the basis of correlations among stimulus features, whereas 4- and 7-month-olds recovered attention on the basis of individual stimulus features. Children graduated over age from processing features (parts of animal pictures) independently at 4 months to processing correlations among features (the animal as a whole) at 10 months. Well into their 2nd year of life, infants seem still to reference prominent perceptual features of objects. Infants between 1 and 2 years categorize unmodified cars from unmodified cows (Rakison, 2000). However, 14-month-olds fail to categorize cows from cars when object parts (legs and wheels) are removed, and 14- and 18-month-olds fail to categorize cows from cars when the same object parts are possessed by all exemplars.

The stimuli in the present task held configural relations constant between categories (i.e., part attachment positions and angles), while the shape and color of local parts differed. Thus, for infants to categorize our stimuli, they had to compare the objects on the basis of part features (shape, color, or both). Because the familiarization and test objects in this study had similar perceptual features, infants' choice of object following familiarization likely reflects a perceptual match of the test object to the familiarization exemplars (Rakison, 2005; Rakison & Hahn, 2004; Rakison & Poulin-Dubois, 2001). It is also possible of course that local part differences give rise to overall shape differences if separate parts enter equally into visual analysis and memory. Thus, the perceptual basis of object categorization -- features or configurations -- appears still an open question.

Future Directions and Conclusions

Infants in a home experience condition saw a variety of objects for approximately 100 min in total (or 20 min per object image) which was apparently sufficient to influence their later laboratory familiarization behavior. Future research might be directed at quantifying exposure times more precisely and determining relations between amount and kind of exposure (massed vs. distributed practice, for example) and the development and robustness of infants' resulting categorical representations. Questions about whether it is the amount, kind, or schedule of experience can be addressed in training studies similar to this one in which infants are assigned parametrically programmed protocols to determine the critical

experiences for formation and use of object category knowledge. Extensive experience with items from a particular category likely help infants form relatively strong and stable category representations. Further comparisons could be made between visual only, manual only, and visual-manual experiences to determine whether intersensory information confers category construction advantages over single sensory experience alone (Iachini, Borghi, & Senese, 2008). Additional research might be directed to uncover how infants come to regard novel objects as familiar, what information they store about objects, and how object categories arise even earlier in life. Is experience with particular objects or with categories of objects critical? Metacognitively, an effect of experience need not be specific to a particular categorical contrast or set of stimuli; experience outside the laboratory with one set of categories might influence infants' responding to a new category in the laboratory.

The categories we used here were *ad hoc* and unfamiliar, and babies' reactions to them reveal a basic category-abstraction mechanism in infancy that does not seem to require a deep understanding of any specific object domain. We note too that, just because the stimuli are simple and abstract, it does not automatically follow that these results are generalizable. Nonetheless, an impressive category extraction mechanism seems to be at work in the first half-year of life that gives infants the wherewithal and flexibility to learn new categories on the fly as well as retain and apply those categories they have previously experienced. These findings articulate with, and bring to a functional behavioral level, evidence showing that distinct neural signals correspond with category learning and representation in infants as young as 6 months.

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References

- Arterberry ME, Bornstein MH. Variability and its sources in infant categorization. *Infant Behavior and Development*. 2002; 25:515–528.
- Ashby FG, Ell SW. The neurobiology of human category learning. *Trends in Cognitive Sciences*. 2001; 5:204–210. [PubMed: 11323265]
- Baker CI, Behrmann M, Olson CR. Impact of learning on representation of parts and wholes in monkey inferotemporal cortex. *Nature Neuroscience*. 2002; 5:1210–1216.
- Baldwin DA, Markman EM, Melartin RL. Infants' ability to draw inferences about nonobvious object properties: Evidence from exploratory play. *Child Development*. 1993; 64:711–728. [PubMed: 8339691]
- Bar-Haim Y, Ziv T, Lamy D, Hodes RM. Nature and nurture in own-race face processing. *Psychological Science*. 2006; 17:159–163. [PubMed: 16466424]
- Behl-Chadha G. Basic-level and superordinate-like categorical representations in early infancy. *Cognition*. 1996; 60:105–141. [PubMed: 8811742]
- Biederman, I. Visual object recognition. In: Goldman, AI., editor. *Readings in philosophy and cognitive science*. Bradford Press; Cambridge, MA: 1993. p. 9-22.
- Bomba PC, Siqueland ER. The nature and structure of infant form categories. *Journal of Experimental Child Psychology*. 1983; 35:294–328.
- Booth A, Waxman S. Object names and object functions serve as cues to categories for infants. *Developmental Psychology*. 2002; 38:948–957. [PubMed: 12428706]
- Bornstein, MH. Perceptual anisotropies in infancy: Ontogenetic origins and implications of inequalities in spatial vision. In: Reese, HW.; Lipsitt, LP., editors. *Advances in child development and behavior*. Vol. 16. Academic Press; New York: 1982. p. 77-123.
- Bornstein, MH. A descriptive taxonomy of psychological categories used by infants. In: Sophian, C., editor. *Origins of cognitive skills*. Erlbaum; Hillsdale, NJ: 1984. p. 313-338.

- Bornstein, MH. Habituation of attention as a measure of visual information processing in human infants: summary, systematization, and synthesis. In: Gottlieb, G.; Krasnegor, NA., editors. *Measurement of audition and vision in the first year of postnatal life: A methodological overview*. Ablex Publishing; Westport, CT: 1985. p. 253-300.
- Bornstein MH, Arterberry ME. Recognition, discrimination and categorization of smiling by 5-month-old infants. *Developmental Science*. 2003; 6:585–599.
- Bornstein MH, Kessen W, Weiskopf S. Color vision and hue categorization in young human infants. *Journal of Experimental Psychology: Human Perception and Performance*. 1976; 2:115–129. [PubMed: 1262792]
- Bruce C, Desimone R, Gross CG. Visual properties of neurons in a polysensory area in superior temporal sulcus of the macaque. *Journal of Neurophysiology*. 1981; 46:369–384. [PubMed: 6267219]
- Colombo, J. *Infant cognition: Predicting later intellectual functioning*. Sage; Newbury Park, CA: 1993.
- DeLoache JS, Pierroutsakos SL, Uttal DH. The origins of pictorial competence. *Current Directions in Psychological Science*. 2003; 12:114–118.
- Eimas PD, Quinn PC. Studies on the formation of perceptually based basic-level categories in young infants. *Child Development*. 1994; 65:903–917. [PubMed: 8045176]
- Eimas PD, Quinn PC, Cowan P. Development of exclusivity in perceptually based categories of young infants. *Journal of Experimental Child Psychology*. 1994; 58:418–431. [PubMed: 7844501]
- Fagen JW, Rovee-Collier C. Memory retrieval: A time-locked process in infancy. *Science*. 1983; 222:1349–1351. [PubMed: 6658456]
- Freedman DJ, Assad JA. Experience-dependent representation of visual categories in parietal cortex. *Nature*. 2006; 443:85–88. [PubMed: 16936716]
- Freedman DJ, Riesenhuber M, Poggio T, Miller EK. Categorical representation of visual stimuli in the primate prefrontal cortex. *Science*. 2001; 291:312–316. [PubMed: 11209083]
- French, RM.; Mermillod, M.; Quinn, PC.; Mareschal, D. Reversing category exclusivities in infant perceptual categorization: Simulation and data. In: Moore, JD.; Stenning, K., editors. *Proceedings of the twenty-third annual conference of the Cognitive Science Society*; London: Erlbaum; 2001. p. 307-312.
- Furrer SD, Younger BA. The impact of specific prior experiences on infants' extension of animal properties. *Developmental Science*. 2008; 11:712–721. [PubMed: 18801127]
- Gelman SA. The development of induction within natural kind and artifact categories. *Cognitive Psychology*. 1988; 20:65–95. [PubMed: 3338268]
- Gelman, R.; Durgin, F.; Kaufman, L. Distinguishing between animates and inanimates: Not by motion alone. In: Sperber, D.; Premack, D.; Premack, AJ., editors. *Causal cognition – a multidisciplinary debate*. Clarendon Press; Oxford: 1995. p. 150-184.
- Gentner D, Medina J. Similarity and the development of rules. *Cognition*. 1998; 65:263–297. [PubMed: 9557385]
- Goldstone, RL.; Steyvers, M.; Larimer, K. Categorical perception of novel dimensions. In: Cottrell, GW., editor. *Proceedings of the 18th Annual Conference of the Cognitive Science Society*; Hillsdale, NJ: Erlbaum; 1996. p. 243-248.
- Graham SA, Kilbreath CS, Welder AN. Thirteen-month-olds rely on shared labels and shape similarity for inductive inferences. *Child Development*. 2004; 75:409–427. [PubMed: 15056196]
- Greco C, Hayne H, Rovee-Collier C. Roles of function, reminding, and variability in categorization by 3-month-old infants. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. 1990; 16:617–633.
- Harnad, S., editor. *Categorical perception: The groundwork of cognition*. Cambridge University Press; New York: 1987.
- Hayne H, Rovee-Collier C, Perris EE. Categorization and memory retrieval by three-month-olds. *Child Development*. 1987; 58:750–767. [PubMed: 3608647]
- Horst JS, Oakes LM, Madole KL. What does it look like and what can it do? Category structure influences how infant categorize. *Child Development*. 2005; 76:614–631. [PubMed: 15892782]

- Hummel JE, Biederman I. Dynamic binding in a neural network for shape recognition. *Psychological Reviews*. 1992; 99:480–517.
- Hung CP, Kreiman G, Poggio T, DiCarlo JJ. Fast readout of object identity from macaque inferior temporal cortex. *Science*. 2005; 310:863–866. [PubMed: 16272124]
- Iachini T, Borghi AM, Senese VP. Categorization and sensorimotor interaction with objects. *Brain and Cognition*. 2008; 67:31–43. [PubMed: 18082300]
- Jiang X, Bradley E, Rini RA, Zeffiro T, VanMeter J, Riesenhuber M. Categorization training results in shape- and category-selective human neural plasticity. *Neuron*. 2007; 53:891–903. [PubMed: 17359923]
- Kalish CW, Gelman SA. On wooden pillows: Multiple classification and children's category-based inductions. *Child Development*. 1992; 63:1536–1557. [PubMed: 1446568]
- Kelly DJ, Liu S, Ge L, Quinn PC, Slater AM, Lee K, et al. Cross-race preferences for same-race faces extend beyond the African versus Caucasian contrast in 3-month-old infants. *Infancy*. 2007; 11:87–95. [PubMed: 18974853]
- Kelly DJ, Quinn P, Slater AM, Lee K, Gibson A, Smith M, Ge L, Pascalis O. Three-month-olds, but not newborns, prefer own-race faces. *Developmental Science*. 2005; 8:31–36.
- Kovack-Lesh, K.; Horst, J.; Oakes, LM. Previous experience influences infants' category learning in the laboratory. Poster presented at the Biennial Meeting of the Cognitive Development Society; San Diego, CA. October. 2005
- Kovack-Lesh KA, Horst JS, Oakes LM. The cat is out of the bag: The joint influence of previous experience and looking behavior on infant categorization. *Infancy*. 2008; 13:285–307.
- Lin EL, Murphy GL. Thematic relations in adults' concepts. *Journal of Experimental Psychology: General*. 2001; 130:3–28. [PubMed: 11293459]
- Madole K, Cohen L. The role of object parts in infants' attention to form- function correlations. *Developmental Psychology*. 1995; 31:637–648.
- Mandler, JM. Representation. In: Damon, W.; Kuhn, D.; Siegler, RS., editors. *Handbook of child psychology: Vol. 2. Cognition, perception, and language*. 5th ed. John Wiley & Sons, Inc.; New York: 1998. p. 255-308.
- Mandler JM. Perceptual and conceptual processes in infancy. *Journal of Cognition and Development*. 2000; 1:3–36.
- Mandler, JM. *The foundations of the mind: Origins of conceptual thought*. Oxford University Press; New York: 2004.
- Mandler JM, McDonough L. Concept formation in infancy. *Cognitive Development*. 1993; 8:291–318.
- Mareschal D, French RM, Quinn P. A connectionist account of asymmetric category learning in infancy. *Developmental Psychology*. 2000; 36:635–645. [PubMed: 10976603]
- Mareschal D, Quinn PC. Categorization in infancy. *Trends in Cognitive Sciences*. 2001; 5:443–450. [PubMed: 11707383]
- Mash C. Multidimensional shape similarity in the development of visual object classification. *Journal of Experimental Child Psychology*. 2006; 95:128–152. [PubMed: 16793055]
- McDonough L, Mandler JM. Inductive generalization in 9- and 11-month-olds. *Developmental Science*. 1998; 1:227–232.
- Medin DL, Schaffer MM. Context theory of classification learning. *Psychological Review*. 1978; 85:207–238.
- Needham A, Baillargeon R. Effects of prior experience on 4.5-month-old infants' object segregation. *Infant Behavior and Development*. 1998; 21:1–24.
- Needham A, Cantlon JF, Holley S. M. Ormsbee. Infants' use of category knowledge and object attributes when segregating objects at 8.5 months of age. *Cognitive Psychology*. 2006; 53:345–360. [PubMed: 16899236]
- Nosofsky RM. Choice, similarity, and the context theory of classification. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. 1984; 10:104–114.
- Oakes LM, Plumert JM, Lansink JM, Merryman JD. Evidence for task-dependent categorization in infancy. *Infant Behavior and Development*. 1996; 19:425–440.

- Oakes LM, Tellinghuisen DJ. Examining in infancy: Does it reflect active processing? *Developmental Psychology*. 1994; 30:748–756.
- Pauen S. Evidence for knowledge-based category discrimination in infancy. *Child Development*. 2002; 73:1016–1033. [PubMed: 12146730]
- Proffitt JB, Coley JD, Medin DL. Expertise and category-based induction. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. 2000; 26:811–828.
- Quinn, PC. Beyond prototypes: Asymmetries in infant categorization and what they teach us about the mechanisms guiding early knowledge acquisition. In: Kail, RV.; Reese, HW., editors. *Advances in child development and behavior*. Vol. Vol. 29. Academic Press; San Diego, CA: 2002. p. 161-193.
- Quinn PC. Development of subordinate-level categorization in 3- to 7-month-old infants. *Child Development*. 2004; 75:886–889. [PubMed: 15144492]
- Quinn, PC. Young infants' categorization of humans versus nonhuman animals: Roles for knowledge access and perceptual process. In: Gershkoff-Stowe, L.; Rakison, DH., editors. *Building object categories in developmental time*. Erlbaum; Mahwah, NJ: 2005. p. 107-130.
- Quinn PC, Eimas PD. Evidence for a global categorical representation of humans by young infants. *Journal of Experimental Child Psychology*. 1998; 69:151–174. [PubMed: 9654437]
- Quinn PC, Eimas PD, Rosenkrantz SL. Evidence for representations of perceptually similar natural categories by 3-month-olds and 4-month-old infants. *Perception*. 1993; 22:463–475. [PubMed: 8378134]
- Quinn PC, Westerlund A, Nelson CA. Neural markers of categorization in 6-month-old infants. *Psychological Science*. 2006; 17:59–66. [PubMed: 16371145]
- Quinn PC, Yahr J, Kuhn A, Slater AM, Pascalis O. Representation of the gender of human faces by infants: A preference for female. *Perception*. 2002; 31:1109–1121. [PubMed: 12375875]
- Rakison DH. When a rose is just a rose: The illusion of taxonomies in infants' categorization. *Infancy*. 2000; 1:77–90.
- Rakison DH. Developing knowledge of motion properties in infancy. *Cognition*. 2005; 96:183–214. [PubMed: 15996558]
- Rakison DH, Butterworth G. Infants' use of object parts in early categorization. *Developmental Psychology*. 1998; 34:49–62. [PubMed: 9471004]
- Rakison D, Cohen L. Infants' use of functional parts in basic-like categorization. *Developmental Science*. 1999; 2:423–431.
- Rakison, DH.; Hahn, ER. The mechanisms of early categorization and induction: Smart or dumb infants?. In: Kail, R., editor. *Advances in child development and behavior*. Vol. Vol. 32. Academic Press; New York: 2004. p. 281-322.
- Rakison, DH.; Oakes, LM., editors. *Early category and concept development: Making sense of the blooming, buzzing confusion*. Oxford University Press; Oxford: 2003.
- Rakison DH, Poulin-Dubois D. The developmental origin of the animate-inanimate distinction. *Psychological Bulletin*. 2001; 127:209–228. [PubMed: 11316011]
- Rosch E. Cognitive representations of semantic categories. *Journal of Experimental Psychology: General*. 1975; 104:192–233.
- Rovee-Collier CK, Sullivan MW, Enright M, Lucas D, Fagen JW. Reactivation of infant memory. *Science*. 1980; 208:1159–1161. [PubMed: 7375924]
- Ruff HA. Components of attention during infants' manipulative exploration. *Child Development*. 1986; 57:105–114. [PubMed: 3948587]
- Saffran JR, Pollak SD, Seibel RL, Shkolnik A. Dog is a dog is a dog: Infant rule learning is not specific to language. *Cognition*. 2007; 105:669–680. [PubMed: 17188676]
- Saiki J, Hummel JE. Attribute conjunctions and the part configuration advantage in object category learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. 1996; 22:1002–1019.
- Schwarzlose RF, Swisher JD, Dang S, Kanwisher N. The distribution of category and location information across object-selective regions in human visual cortex. *Proceedings of the National Academy of Sciences*. 2008; 105:4447–4452.

- Schyns PG, Goldstone RL, Thibaut J. The development of features in object concepts. *Behavioral and Brain Sciences*. 1998; 21:1–17. [PubMed: 10097010]
- Shepp, BE. From perceived similarity to dimensional structure: A new hypothesis about perceptual development. In: Rosch, E.; Lloyd, BB., editors. *Cognition and categorization*. Erlbaum; Hillsdale, NJ: 1978. p. 135-167.
- Smith, EE.; Medin, DL. *Categories and concepts*. Harvard University Press; Cambridge, MA: 1981.
- Smith LB. A model of perceptual classification in children and adults. *Psychological Review*. 1989; 96:125–144. [PubMed: 2928416]
- Spear NE. Retrieval of memory in animals. *Psychological Review*. 1973; 80:163–194.
- Spear, NE. *The processing of memories: Forgetting and retention*. Erlbaum; Hillsdale, NJ: 1978.
- Sullivan MW. Reactivation: Priming forgotten memories in human infants. *Child Development*. 1982; 57:100–104.
- Träuble B, Pauen S. The role of functional information for infant categorization. *Cognition*. 2007; 105:362–379. [PubMed: 17129581]
- Tulving E, Thomson DM. Encoding specificity and retrieval processes in episodic memory. *Psychological Review*. 1973; 80:352–373.
- Tversky B, Hemenway K. Objects, parts, and categories. *Journal of Experimental Psychology: General*. 1984; 113:169–193. [PubMed: 6242749]
- Van de Walle, G. Conceptual categorization in infancy: Membership in colour vs. kind categories. Poster presented at the meeting of the Society for Research in Child Development; Albuquerque, NM. 1999.
- Welder AN, Graham SA. The influences of shape similarity and shared labels on infants' inductive inferences about nonobvious object properties. *Child Development*. 2001; 72:1653–1673. [PubMed: 11768138]
- Younger B,A. The segregation of items into categories by ten-month-old infants. *Child Development*. 1985; 56:1574–1583. [PubMed: 4075875]
- Younger B. Infant categorization: Memory for category-level and specific item information. *Journal of Experimental Child Psychology*. 1990; 50:131–155. [PubMed: 2398330]
- Younger BA. Understanding category members as “the same sort of thing”: Explicit categorization in ten-month infants. *Child Development*. 1993; 64:309–320. [PubMed: 8436037]
- Younger BA, Cohen LB. Infant perception of correlations among attributes. *Child Development*. 1983; 54:858–867. [PubMed: 6617307]
- Younger BA, Cohen LB. Developmental change in infants' perception of correlations among attributes. *Child Development*. 1986; 57:803–815. [PubMed: 3720405]
- Younger BA, Fearing DD. A global-to-basic trend in early categorization: Evidence from a dual-category habituation task. *Infancy*. 2000; 1:47–58.

Figure 1.
Examples of the two categories A and B.

Figure 2. Mean examination time (in $s \pm 1$ SEM) at the start of familiarization, at the end of familiarization, for the test of the familiar-category novel exemplar, and for the test of the novel-category novel exemplar. (A) Home Experience condition. (B) No Home Experience condition.