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Evidence for representations of perceptually similar natural categories by 3-month-old and 4-month-old infants

Paul C Quinn
Department of Psychology, Washington and Jefferson College, Washington, PA 15301, USA
Peter D Eimas
Brown University, Providence, RI 02912, USA
Stacey L Rosenkrantz
Stanford University, Stanford, CA 94305, USA
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Abstract. The paired-preference procedure was used in a series of experiments to explore the abilities of infants aged 3 and 4 months to categorize photographic exemplars from natural (adult-defined) basic-level categories. The question of whether the categorical representations that were evidenced excluded members of a related, perceptually similar category was also investigated. Experiments 1-3 revealed that infants could form categorical representations for dogs and cats that excluded birds. Experiment 4 showed that the representation for cats also excluded dogs, but that the representation for dogs did not exclude cats. However, a supplementary experiment showed that the representation for dogs did exclude cats when the variability of the dog exemplars was reduced to match that of the cat exemplars. The results are discussed in terms of abilities necessary for the formation of more complex categorical representations.

1 Introduction

A number of investigators concerned with understanding the mechanisms of higher mental functions have in recent years turned their efforts toward defining the very early perceptual and cognitive abilities of the human organism (eg Mehler and Fox 1985). Studying the beginnings of cognition in early infancy presents a formidable set of challenges. Yet, a (perhaps implicit) belief shared by many investigators is that fundamental perceptual and cognitive capacities may be more accessible in the young infant than in the adult. The expression of these capacities in very young infants is not obscured by layers of acquired knowledge and idiosyncratic processing strategies in the way that such expression often is in the study of perception and cognition in adults.

An area of considerable concern has been the development of categorical representations in early infancy. The ability to form categorical representations of environmental experiences is a basic process, one that, in our view, must be in place before any organism can engage in other intellectual endeavors. An organism without such abilities would be continually confronted with an ever-changing array of seemingly unrelated objects and events.

The categorization abilities of young infants have been revealed largely through modifications in the standard habituation paradigm that until the mid-1970s had been used to study the infant's ability to perform simple sensory and perceptual discriminations. In the study of categorization the infant is shown a number of different exemplars from the same category and is then given a preference test that pairs an exemplar from a novel category with a novel exemplar from the familiar category. A preference for the exemplar from the novel category is taken as evidence for the infant possessing a representation of the familiar category. With this paradigm, infants between 3 and 7 months of age have been shown to form categorical representations

of female faces, colors, geometric forms, schematic line drawings of animals, and oblique lines [for a review of this work, see Quinn and Eimas (1986a)].

Given evidence that infants are able to form categorical representations of their experiences, investigators began to explore the internal structure of these representations. In adulthood, there is evidence, beginning with the work of Rosch (Mervis and Rosch 1981; Rosch 1975; Rosch and Mervis 1975), that prototype structures describe the internal representations of natural categories. Evidence of this nature has been obtained for children where it has been shown that typical exemplars of a category are better recognized than atypical instances (Lesky 1974) and that categorical representations are more readily learned when they are based on typical exemplars than when they are based on atypical exemplars (Mervis and Pani 1980). Tests for prototype structures in young infants first familiarize the infants with a number of exemplars from the same category and then present a preference test in which one of these exemplars is paired with the previously unseen prototype of the category. If infants compute and remember a summary prototype representation of the familiar exemplars, then the familiar exemplar should paradoxically be preferred over the unfamiliar prototype. Such a preference has been observed in infants as young as 3 months of age (Bomba and Siqueland 1983; Quinn 1987; Younger and Gotlieb 1988), thereby providing strong evidence that categorical representations with prototypic structure characterize the results of infants' early interactions with the environment.[1]

The research on categorization discussed thus far has made important contributions to our understanding of one of the earliest and most important forms of human cognition. Nevertheless, it is important to recognize that the categorical representations of young infants are undoubtedly different in kind from those of adults and most likely even those of young children (cf Carey 1985; Murphy and Medin 1985). The representations of infants are perceptually based, whereas those of adults, and some representations of children, are conceptual in nature (eg Mandler et al 1991). Young infants use surface features as the basis for categorization and presumably know little about dogs, for example, other than these characteristics. The conceptual representations of more mature individuals, being to a large extent defined and organized by higher levels of knowledge, permit inferences about function and properties not given by perceptual information, as well as descriptions of why all dogs constitute a particular kind of thing as well as a kind of animal. Of course, the recognition of exemplars belonging to conceptual representations must necessarily be determined at least in part by their perceptual properties.

It is the belief of ourselves, among others, that the earliest perceptually based categorical representations must constrain to some extent the development of knowledge-based conceptual representations. Thus, an understanding of mature concepts and their development seemingly must begin with an understanding of young infants' perceptual categories. Nevertheless, researchers have devoted relatively little attention to the problem of how the initial categories formed by infants develop into mature conceptual representations that include superordinate categories as well as networks of categorical representations organized by higher levels of knowledge (eg naive theories of biology) (Carey 1985; Murphy and Medin 1985). To come to possess even the beginnings of such complex representations, individuals must be capable of computing representations for members of (adult-defined) basic-level categories that exclude exemplars from related categories belonging to the same superordinate category. The development of this ability was the focus of the present studies.

[1] Recent work has shown that it is possible to capture what have been taken as effects of categorical representations with prototypic structures by means of representations that are based on the representation of individual exemplars (eg Nosofsky 1991).

In a few studies infants' categorization has been examined with the issue of category relatedness in mind. Quinn (1987) asked whether infants 3 and 4 months old are capable of forming separate representations for related categories at the same time. In a single sequence of familiarization trials, infants were presented with both square-like and triangle-like dot patterns. Quinn found that infants formed separate prototypic structures to represent each category. Further support for the idea that infants can form a basic-level representation that excludes instances of similar basic-level categories is provided by Cohen and Caputo (1978). Using the paired-preference procedure, Cohen and Caputo reported that 12-month-old infants could form a category for dogs that excluded an antelope. With the same procedure, Colombo et al (1987) found that 6-month-old infants who were familiarized with black-and-white line drawings of different birds showed a preference for a novel horse over a novel bird, evidence of a representation for birds that excluded horses [see also Roberts (1988) for comparable findings with 9-month-old infants].

Although the work of Quinn (1987) among others suggests infants aged 3 and 4 months can form separate categorical representations for two related categories, it can be argued that the dot-pattern geometric stimuli of Quinn and the black-on-white schematic drawings of animals used by others lacked ecological realism. It is therefore not clear how well the categorization routines of infants will function at only 3 and 4 months of age for naturally contrasting, more complex exemplars. Also motivating our work was the belief that our paired-comparison procedure might provide a more sensitive measure of categorical representations (cf Mitchell 1987; Quinn and Eimas 1986b) than a habituation-dishabituation procedure that presents test stimuli in isolation on each trial (Roberts 1988), or that relies on the manipulation of objects to evidence internal structures (Mandler and Bauer 1988; Mandler et al 1991). Using the paired-comparison procedure, we sought to begin to map the lower age boundary on the ability to form categorical representations from complex exemplars of natural categories. In addition, we attempted to determine if these representations come to exclude perceptually similar exemplars from a contrasting basic-level category from the same superordinate category.

In all of the experiments infants 3 and 4 months old served as subjects. The stimuli were photographic pictures of animals—dogs, cats, and birds—that closely resembled their real world counterparts in a large number of critical attributes. Experiments 1 through 3 were designed to examine whether infants were capable of forming a category 'cats' and a category 'dogs' on the basis of experiencing pictures of exemplars from these categories, each of which excluded examples of birds. The object of experiment 4 was to explore factors affecting the infants' abilities to form representations for the perceptually similar categories of dogs and cats that excluded exemplars of cats in the first instance and exemplars of dogs in the second instance. The paired-preference procedure was used to assess categorization in all experiments. Before proceeding with the description of our experiments two notes of caution should be made explicit. First, in that we have used photographs rather than live animals (for obvious reasons) or small 3-D models of the animals (because of the difficulty of obtaining models that would adequately represent the diversity of the pictures), it is reasonable to question whether we are in fact investigating the formation of categorical representations to natural (ie real-world) categories. We know of no reason why our findings with pictures would not be replicated with 3-D objects, live or otherwise. Indeed, evidence exists for older infants, aged between 12 and 14 months, that categorical representations for dogs can be performed from photographic exemplars (Cohen and Caputo 1978; Reznick and Kagan 1983) as well as from toy models (Dow et al 1992; Mandler and Bauer 1988). In addition, Mervis (1987) and Roberts and Cuff (1989) have shown that infants in the same age range can comprehend labels

for animals that are applied to pictorial representations or live models. The second note concerns the level of representation. Although the materials with which we are working are exemplars of basic-level categories in adults, this may not be true for infants. Mandler and her colleagues (Mandler and Bauer 1988; Mandler et al 1991) and Mervis (1985, 1987) have presented evidence consistent with the idea that representations of adult basic-level categories may be more global (ie 'child basic') in infants. To demonstrate that a perceptually based categorical representation in young infants is truly a basic-level category would require showing that this representation excludes all possible contrasting basic-level categories from the superordinate category 'animal'—an obviously impossible task. What can be shown is whether a categorical representation of exemplars of cats, for example, can be formed, and if so whether it is sufficiently differentiated to exclude perceptually similar exemplars of dogs. Positive findings from infants 3 and 4 months old would indicate that the process of development toward higher-level concepts is under way at a quite early age.

2 Experiment 1

In this experiment, infants were familiarized with exemplars of cats or of dogs. After familiarization, test trials were administered in which a new exemplar from the familiar category was paired with a picture of a bird—a novel exemplar from a category not previously experienced. Test trials consisting of a novel cat paired with a novel dog were not used, inasmuch as we wished to establish first that each of these kinds of animal could be represented by some categorical description. On obtaining evidence for this capacity, we then undertook further experiments to determine whether the representations of dogs and of cats excluded exemplars of the other, perceptually similar category.

2.1 *Method*

2.1.1 *Subjects.* The subjects were thirty-two infants, eighteen of whom were 3 months old and fourteen 4 months old. There were sixteen males and sixteen females. An additional sixteen infants failed to complete the study because of fussing or crying (n = 12), orientation (position) preferences toward one or the other side that entailed 95% or more of the looking time to that side (n = 2), and experimenter error (n = 2). All infants were recruited from the Women and Infants Hospital of Rhode Island within a few days of birth.

2.1.2 *Stimuli and apparatus.* The stimuli consisted of eighteen colored photographs from each of the three categories. The pictures were cut from *Simon and Schuster's Guide to Dogs* (Schuler 1980), *Simon and Schuster's Guide to Cats* (Siegal 1983) and the Audubon Society Pocket Guides: *Familiar Birds of North America. Eastern Region* (Whitman 1988). The pictures selected were chosen to represent a variety of shapes, colors, and orientations of each type of animal. Each picture contained a single animal that was either sitting or standing in the case of dogs and cats or, in the case of birds, perched on a small branch that was visible in some instances. The background was in all cases quite simple: grass, a solid-colored backdrop, or a lightly colored sky. Given the large number of exemplars and the considerable variation in shape, color, orientation, and background, it is unlikely that the infants were responding to any single salient feature. The pictures were cut to be as close to 9.6 cm × 8.3 cm as possible without cropping the picture of the animal itself, and mounted on 17.7 cm × 17.7 cm posterboards. The size of the animal in each picture was nearly the same, and thus not a reflection of their actual sizes. This was done to eliminate size as a basis for categorization and thereby to require that more subtle, but as yet unknown, sensory information provide the basis for categorization.

Infants were tested by means of a portable visual-preference apparatus, adapted from the system described by Fagan (1970). The essential feature of the apparatus was a hinged gray display panel that contained two compartments that would hold the 17.7 cm × 17.7 cm stimulus cards. The center-to-center distance between the two compartments was 30.5 cm. During a trial, the distance between the infant's eye and the center of the display panel was approximately 30.5 cm. Midway between the stimulus compartments was a 0.625 cm diameter peephole through which an experimenter could see the infant's visual fixations to the stimuli, which were illuminated by a fluorescent lamp shielded from the infant's view.

2.1.3 *Procedure*. The general procedural details common to all experiments were as follows. Prior to participation in one of the visual categorization studies, each infant was tested in an experiment concerned with the perception of speech, which lasted no longer than 20 min. After an interval of several minutes, the infant was placed in a reclining position on the parent's lap. The apparatus was then wheeled into position over the infant, with the infant's head kept centered with respect to the midline of the display panel. At this point, with the display panel open, the only object in the infant's view was the experimenter's face. The experimenter then loaded the stimuli into the two compartments, elicited the infant's attention, and closed the display panel, thereby exposing the stimuli to the infant. During the familiarization and the test trials, the experimenter observed the infant through the peephole, recording the infant's fixation to the left and right stimuli by means of a Cronus 4 electronic stopwatch held in each hand. Interobserver reliability of this procedure ranges from 0.88 to 0.93 (Bomba 1984). Between trials, the experimenter lowered the panel, changed the stimuli, elicited the infant's attention, and then closed the panel. In order to prevent experimenter bias, two different experimenters were used to record the infant's fixations. The first recorded fixations during the familiarization trials, and the second recorded fixations during the test trials without being aware of the stimulus (stimuli) that was (were) used during the familiarization period.

In experiment 1 each infant was assigned twelve randomly selected pictures of cats or dogs. On each of the six 15 s familiarization trials, two of the twelve stimuli, again randomly selected, were presented. Sixteen infants were randomly assigned to each group, defined by the familiar category 'cats' or 'dogs'. Immediately after the familiarization period, two 10 s test trials were administered in which a novel exemplar of the familiar category was paired with a novel member of the novel category—birds. The test stimuli were again randomly selected and different for each infant. On the first test trial, the left–right positioning of the exemplar from the novel category was counterbalanced over all infants and reversed on the second test trial.

2.2 *Results and discussion*

2.2.1 *Familiarization trials*. Individual looking times were first summed over both stimuli on each trial and then averaged across the block of first three trials and the block of last three trials. The mean looking times are shown in table 1. Somewhat surprisingly, there is little evidence of a trials effect, that is to say, little evidence for

Table 1. Mean fixation times (in seconds) and standard deviations (shown in parentheses) during the familiarization trials of experiment 1.

Familiarization category	Trials	
	1, 2, 3	4, 5, 6
Dog	9.88 (3.28)	9.45 (3.03)
Cat	9.27 (2.87)	8.63 (2.28)

the habituation of looking that typically occurs in experiments of this general nature (eg Bomba and Siqueland 1983; Quinn 1987). This was confirmed by an analysis of variance, Familiar Category (Cats versus Dogs) by Blocks of Trials (First versus Last), performed on the individual scores, which revealed a nonsignificant Blocks of Trials effect ($F_{1,30} = 2.33$, $p > 0.10$). The Familiar Category and its interaction with Blocks of Trials were also not significant ($F_{1,30} < 1.0$, $p > 0.10$, in both cases). The failure to find an effect of familiarization was, we believe, due to the nature of the stimuli; each was complex in design and often in color and each was different from the other eleven stimuli [see Mandler et al (1987) and Ross (1980) for comparable data with infants aged 12 and 24 months]. That this lack of an habituation effect was a result of the nature of the stimuli and not some artifact, such as the general attractiveness of the apparatus, is supported by previous findings of familiarization effects with the same apparatus when familiarization involved a single stimulus [Quinn and Eimas (1986b); see also experiment 3 in this paper]. What is interesting is that despite the infant's continued attention to the individual stimuli across the familiarization trials, processing and encoding had occurred, as the preference data indicated.

2.2.2 *Test trials.* Each infant's looking time to the stimulus from the novel category was divided by the total looking time to both test stimuli and converted to a percentage score. The mean preference scores, shown in table 2, did not differ from each other ($t_{30} = 0.30$, $p > 0.10$), but each score differed reliably from chance (ie 50%).

The preference for novel exemplars from a novel category is consistent with the view that during the familiarization period the numerous instances of dogs, for example, came to be represented by a single categorical description. As a consequence, new exemplars from the familiar category were also considered familiar and responded to less frequently than novel exemplars from a novel category.

What we do not know from these results, however, is how exclusive these categorical representations are, a concern we investigate in experiment 4 after consideration of two obvious alternative explanations for the observed preferences. First, infants may simply have preferred the pictures of birds to those of dogs and cats. Second, it is possible that infants were unable to discriminate among members of a category. If this were the case, then the test-trial stimuli actually involved a comparison of the preference for a familiar as opposed to a novel exemplar, and the obtained results reflected simply a preference for novelty and not for a novel category. Experiments 2 and 3 were designed to test these possible explanations. In experiment 2, we tested whether there was a preference to observe birds compared with dogs or cats, and in experiment 3 we tested whether individual exemplars from the categories of cats and dogs were discriminable.

Table 2. Experiment 1. Mean preference scores (percent) for the novel category, standard deviations (shown in parentheses), and statistical significance: Student's t (versus chance) and p (one-tailed test).

Familiarization category	N	Score	t	p
Dog	16	61.65 (19.93)	2.34	<0.025
Cat	16	63.63 (17.92)	3.04	<0.005
Combined	32	62.64 (18.67)	3.83	<0.0005

3 Experiment 2

3.1 *Method*

3.1.1 *Subjects.* The subjects were thirty-six infants aged 3 and 4 months drawn from the same population as that described in experiment 1. Sixteen infants were 3 months old and twenty 4 months old; nineteen of the infants were females and seventeen were males. Eight additional infants were tested but did not complete the session because of fussing or crying ($n = 5$) or an orientation preference ($n = 3$).

3.1.2 *Stimuli and apparatus.* The stimuli and apparatus were the same as those used in experiment 1.

3.1.3 *Procedure.* All infants received eight 15 s trials during which a picture of a bird was paired with a picture of a dog or a cat. Half of the infants were shown pictures of birds and dogs and the remaining infants viewed pictures of cats and birds. Different pairs of pictures were randomly chosen for each infant, and they remained constant for all eight trials. The left–right positioning of the pictures of the birds were counterbalanced across subjects on the first test trial and reversed on each successive trial.

3.2 *Results and discussion*

A preference score for birds was determined for each infant for each trial by dividing the time that the bird was observed by the total looking time devoted to both animals. The score was then converted into a percentage and averaged over the first two trials and the entire eight trials. The mean scores and their standard deviations are shown in table 3. The preference scores differed only slightly and nonsignificantly from chance, and did not differ reliably from each other ($F_{1,34} < 1.0$, $p > 0.10$, in both cases). The preferences observed in experiment 1 are thus unlikely to have been a consequence of a preference for birds.

Table 3. Experiment 2. Mean preference scores (percent) for birds, standard deviations (shown in parentheses), and Student's t (versus chance).

Category paired with bird	N	Trials 1–2		Trials 1–8	
		score	t	score	t
Dog	18	48.63 (16.06)	−0.36	49.70 (11.00)	−0.12
Cat	18	52.78 (19.91)	0.59	52.20 (17.06)	0.55

4 Experiment 3

Experiment 3 was designed to test whether the members of each category could be discriminated by infants aged 3 and 4 months. Each infant was familiarized with a single cat or dog and then given two test trials in which the familiar stimulus was paired with a novel stimulus from the same category.

4.1 *Method*

4.1.1 *Subjects.* The subjects were thirty-two infants; seventeen were 3 months old and fifteen 4 months old. Nineteen were females and thirteen were males. They were again from the greater Providence, RI, area. Seven infants failed to complete the experiment because of fussing or crying ($n = 4$), orientation preference ($n = 2$), or experimenter error ($n = 1$). The infants were actually tested in two replications, one with twelve infants and the other with four infants per familiar category. Because there was neither a reliable effect of replications nor any reliable interactions with replications and any other experimental variable, the data from the two replications have been collapsed.

4.1.2 *Stimuli and apparatus*. The stimuli and apparatus were the same as those used in the earlier experiments. A duplicate set of stimuli was constructed to allow the same stimulus to be shown in both compartments during the familiarization trials.

4.1.3 *Procedure*. Each infant received six 15 s familiarization trials, during which a single animal, randomly selected and different for each infant, was shown in both compartments of the testing panel. Immediately after familiarization, each infant received two 10 s test trials, during which the familiar stimulus was paired with a novel exemplar, randomly selected from the same category. The left–right positioning of the novel stimulus was counterbalanced across infants on the first trial and reversed on the second trial. One half of the infants received pictures from one category, and the remaining infants from the other category.

4.2 *Results and discussion*

4.2.1 *Familiarization trials*. The mean looking times, averaged across blocks of three trials, are shown in table 4. The apparent decline in looking times across trials was confirmed by a two-way ANOVA, Familiar Category (Cats versus Dogs) by Blocks of Trials (First versus Last) performed on the individual looking times, the effect of Blocks of Trials being highly significant ($F_{1,30} = 14.83$, $p < 0.001$). With less information to observe during the familiarization period, the infants did lose interest in (ie habituate to) the stimulus as may be inferred from a decline in looking times. There were no other reliable effects ($F_{2,22} < 1.0$, $p > 0.10$, in each case).

Table 4. Mean fixation times (in seconds) and standard deviations (shown in parentheses) during the familiarization trials of experiment 3.

Familiarization category	Trials	
	1, 2, 3	4, 5, 6
Dog	9.86 (3.56)	8.54 (3.82)
Cat	8.09 (3.08)	6.43 (3.87)

4.2.2 *Test trials*. The mean preference scores for the novel stimulus are shown in table 5. A t test showed that the two mean scores were not significantly different from each other ($t_{30} = 0.89$, $p > 0.10$), but that each differed reliably from chance as did the combined mean. The findings of experiment 3 indicate that infants are able to discriminate exemplars from the two familiar categories used in experiment 1. The results of experiment 1 are thus not likely a consequence of a failure to discriminate among category members, but are rather, given also the data of experiment 2, a consequence of categorization.

Table 5. Experiment 3. Mean preference scores (percent) for the novel category, standard deviations (shown in parentheses), and statistical significance: Student's t (versus chance) and p (one-tailed test).

Familiarization category	N	Score	t	p
Dog	16	58.32 (17.83)	1.87	<0.05
Cat	16	64.12 (18.79)	3.00	<0.005
Combined	32	61.23 (18.26)	3.48	<0.005

5 Experiment 4

In experiment 4, we explored the ability of infants to differentiate categorical representations of dogs from specific instances of cats and categorical representations of cats from specific instances of dogs. Members of these categories are marked by a large number of surface characteristics with identical or similar values, for example, the coloring, the presence of fur, the number of legs, body shape, the presence of tails (in the typical cases), the number of eyes and ears, and their shapes. As noted above, the ability to differentiate a category from exemplars of a different but perceptually similar category from the same superordinate category, and the ability to differentiate categories from the same superordinate category, are necessary prerequisites for the development of higher-order superordinate representations. Specifying when and how infants acquire these capacities is, we believe, necessary for a full description of the development of complex categorical representations. Experiment 4 was undertaken to add to our understanding of these abilities.

5.1 *Method*

5.1.1 *Subjects.* Twenty-four infants, eleven 3 months old and thirteen 4 months old, served as subjects. Half of the infants were males and half females, and all were recruited from the population described previously. Ten additional infants failed to complete the experiment because of fussing or crying ($n = 1$), orientation preference ($n = 8$), or experimenter error ($n = 1$).

5.1.2 *Stimuli and apparatus.* The pictures of dogs and of cats and the apparatus were those used in experiment 1.

5.1.3 *Procedure.* Each infant received six 15 s familiarization trials, during each of which two different pictures of either dogs or cats were presented. The twelve pictures used during familiarization were randomly selected for each infant. Half of the infants were familiarized with pictures of dogs and half with pictures of cats. The two 10 s test trials that immediately followed the familiarization phase paired a novel picture of a cat with a novel picture of a dog. There were twelve such pairs, randomly selected, and each pair, which was seen on both test trials, was assigned to one infant who had seen dogs and one infant who had seen cats during the familiarization period. The test-trial stimuli were thus identical for both groups of infants. The left–right positioning of the novel animal from the novel category was counterbalanced across infants on test trial 1 and changed on test trial 2.

5.2 *Results and discussion*

5.2.1 *Familiarization trials.* The mean fixation times for blocks of three trials are shown in table 6. While there was a small decline in looking times across blocks of trials (0.85 s), it was not statistically reliable ($F_{1,22} = 2.58$, $p > 0.10$). Once more, we presume that the complexity and variety of the stimuli were sufficient to maintain the infants' near maximal attention across the familiarization period. Neither the effect of Groups (Cats versus Dogs) nor the interaction of Groups and Blocks of Trials was significant ($F_{1,22} < 1.0$, $p > 0.10$, in each case).

Table 6. Mean fixation times (in seconds) and standard deviations (shown in parentheses) during the familiarization trials of experiment 4.

Familiarization category	Trials	
	1, 2, 3	4, 5, 6
Dog	10.30 (1.92)	9.60 (2.15)
Cat	9.99 (3.36)	9.00 (3.43)

5.2.2 *Test trials*. The mean preference scores for the novel member of the novel category are shown in table 7. The mean preference score for infants familiarized with cats was significantly greater than chance ($p < 0.01$). Although it was nearly 15% greater than the corresponding score for infants familiarized with dogs (which did not differ from chance), the difference between the two scores failed to attain statistical significance ($t_{22} = 1.68$, $p < 0.12$). The reason for this was the exceptionally high variability in the scores of infants familiarized with dogs. The fact that a novelty preference was shown for one category of animals, albeit only when infants were familiarized with cats, supports the idea that young infants are able to differentiate a categorical representation from exemplars of a highly similar category.

One explanation of the asymmetry in the preference scores is that there existed an overall preference for dogs over cats, which would also accommodate the highly significant preference for the novel dogs in the case of infants familiarized with cats and the near chance performance of infants familiarized with dogs. In the former situation, the picture of the novel dog would be preferred both because it is novel and because it is a dog, whereas in the latter condition, the preference for the novel cat is in competition with the general preference for dogs.

We assessed the existence of a preference for pictures of dogs over pictures of cats as in experiment 2. We presented each of eighteen infants a different picture of a cat and a dog for eight trials. The mean preference score was 49.73% (SD = 13.95%) for all trials and 49.10% (SD = 25.50%) for the first two trials, neither of which differed from chance ($t_{17} < 1.00$, $p > 0.10$). Thus, a preference for dogs is an unlikely explanation of the results of experiment 4.

Another explanation of this difference lies in a possible asymmetry in the structure of the two categories. As noted earlier, categories have an internal structure [Rosch and Mervis (1975); and see Smith and Medin (1981), for an extensive review]: there are prototypical exemplars, which observers believe best exemplify the category, and there are less-typical members that vary in their similarity to prototypic exemplars. Basic-level categories belonging to the same superordinate structure may differ in the extent to which exemplars vary in their resemblance to prototypic members. Interestingly, there is evidence that categories marked by greater variation among their exemplars are more difficult to acquire by adults (Homa and Vosburgh 1976; Rosch and Mervis 1975) and children (Mervis and Pani 1980). Casual inspection of our dog and cat pictures (and of dogs and cats in the natural world) suggested that the former were more variable than the latter. Thus the categorical representation for dogs may have differed in strength from the representation for cats, a difference that was only evident when a fine distinction was required, as was the case in experiment 4 but not in experiment 1. In support of these ideas, we found that individual typicality ratings of the dog pictures and the cat pictures provided by mothers who visited our laboratories were reliably more variable for the dogs than for the cats ($t_{12} = 2.12$, $p < 0.05$). Using these measures of typicality, we found that the different pictures of dogs that were viewed by each infant in experiment 4 varied more in typicality than

Table 7. Experiment 4. Mean preference scores (percent) for the novel category, standard deviations (shown in parentheses), and statistical significance: Student's t (versus chance) and p (one-tailed test).

Familiarization category	N	Score	t	p
Dog	12	50.17 (28.07)	0.02	ns
Cat	12	65.10 (13.22)	3.96	<0.005

the corresponding pictures of cats ($t_{22} = 16.20$, $p < 0.001$). We also found that the correlation coefficient between the measure of variability of the familiar pictures seen by each infant and the infant's novelty preference score was -0.33 ($p < 0.05$), a finding in keeping with the idea that the strength (ie exclusiveness) of a categorical representation, as measured by the preference for the novel category, is inversely related to the variability of the familiar stimuli.

Finally, we tested two groups of twelve infants, each of which received a different set of twelve exemplars of dogs during familiarization that matched the variability in typicality scores of the cat exemplars presented in experiment 4. The test trial stimuli consisted of the remaining six dogs and six randomly selected cats that were randomly paired and assigned to infants. There was now a reliable novelty preference for cats in each group of infants (63.4% and 65.1%, $t_{11} > 3.85$, $p < 0.01$). The variability of the internal structure of categories would seem to play a role in the formation of categorical representations in young infants as it does in children and adults [see also Dow et al (1992) for evidence from older infants consistent with this view]. Even more important is that the latter finding clearly indicates that infants can form a representation for dogs that excludes cats.

6 General discussion

The categorization abilities of infants aged 3 and 4 months was explored by investigating the acquisition of basic-level categories that share the same superordinate representation. Two major questions were addressed:

(i) Are infants able to form categorical representations based on experiencing pictures of perceptually complex exemplars of natural kinds (dogs and cats)?

(ii) Are young infants able to form a categorical representation of a natural kind that excludes members of a closely related, perceptually similar category?

The data from experiments 1 to 4 indicated that the answer to both questions is "yes". Moreover, these categorical representations were not the consequence of initial stimulus preferences nor of a failure to discriminate among category exemplars. These results fit well with similar findings of Cohen and Caputo (1978), Colombo et al (1987), and Roberts (1988) with older infants and extend the lower age boundary to 3 months for the formation of quite narrowly defined basic-level categories — an impressive accomplishment in light of the complexity of the various exemplars.

The categorical representations for dogs were shown to be strongly influenced by the variability of the dogs, more specifically the variability as defined by the adult typicality ratings. Indeed, when the variability exceeded some limit, the categorical representation for dogs was poorly differentiated, which suggests that categorical representations that are tightly structured around prototypic members develop earlier than representations for more variable, less tightly structured categories.

Whereas our findings are most directly related to the question of the age at which basic-level categories can be formed, it is also interesting to consider our results in relation to contemporary models of superordinate category development. The experiments reported in this paper, along with many of those previously cited which have made use of habituation–dishabituation or paired-preference procedures, have been driven (at least in part) by the traditional view that superordinate category development occurs when the initially individuated basic-level categorical representations are grouped together under a more inclusive superordinate structure (cf Rosch et al 1976). Nelson (1977) represents this perspective when she describes the development of superordinate representation as including "the process of combining two or more concepts into a superordinate category *without sacrificing the identity of the original concepts*" (page 127).

As noted in the introduction, an alternative account of the development of categorical representations has recently been proposed on the basis of data collected with different techniques. On the basis of data obtained from a sequential touching procedure, for example, Mandler and her colleagues have argued that the infant starts out by making global distinctions between conceptual representations—"kinds of things"—and only later derives basic-level conceptual representations through a process of differentiation (Mandler and Bauer 1988; Mandler et al 1991). More specifically, the results from the sequential touching procedure suggested that infants 18 months old distinguish animals from vehicles and only later (between 24 and 30 months) develop basic-level contrasts between cats and horses or between trucks and cars. Using word comprehension and production indices, Mervis (1985, 1987) has argued that the earliest representations are "child basic" which can be both more inclusive and more exclusive than adult basic representations. With regard to more inclusive representations, the initial, presumably perceptually based representation for cat, for example, may include instances of lions and panthers. During development, according to this view, there is both differentiation to form the adult basic level of representation and also the grouping of these representations to yield superordinate structures. Our results are consistent with the idea that at least some of the earliest perceptual categories are basic in the adult sense of exclusiveness or perhaps nearly so. It remains for future work to determine the extent of the level of differentiation (exclusiveness) for other basic-level categories of animals as well as the generality of this differentiation in other adult basic-level categories, be they natural or artifactual. Studies which measure infant categorization by applying different indices of categorization may be especially helpful in constructing a unified model of conceptual development that will address the exclusivity of both perceptual and conceptual representations and the transition from perceptually based categorizations to knowledge based concepts.

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