

Perceptual Cues That Permit Categorical Differentiation of Animal Species by Infants

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Eight experiments were performed to determine the perceptual cues used by 3- and 4-month-old infants to categorically distinguish between perceptually similar natural animal species. These experiments provided evidence that information from the facial and head region, specifically, the internal features of the face and the external contour of the head, give the infant a necessary and sufficient basis to form a categorical representation for cats that excludes dogs. The results are discussed in terms of Johnson and Morton's (1991) theory of facial recognition and more general accounts of the information underlying categorical representations. © 1996 Academic Press, Inc.

A number of studies over the past 20 years have shown that young children and even infants form categorical representations for at least some of their experiences (e.g., Cohen & Younger, 1983; Mandler & Bauer, 1988; Markman, 1989; Mervis, 1987; Quinn & Eimas, 1986). The categorization abilities of infants in the domain of vision have been revealed largely through the use of a *familiarization-novelty preference procedure* which relies on the preference that infants have for novel stimuli (Fantz, 1964). In a typical study, infants are shown a number of instances from one category and then given

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a preference test that pairs a novel member of the familiar category with an exemplar from a novel category. A preference for the exemplar from the novel category that cannot be attributed to an a priori preference or a failure to discriminate among the familiar category instances is taken as evidence that the infant has formed a categorical representation of the familiar category. By categorical representation, we mean nothing more than that during familiarization the infant has formed a representation, undoubtedly perceptually based and most likely involving either an abstract prototype or multiple exemplars, which allows the familiarity attached to the previously encountered category instances to generalize to novel instances of the familiar category. With this procedure, infants under 1 year of age have been shown to form categorical representations of geometric forms (Bomba & Siqueland, 1983; Quinn, 1987; Younger & Gotlieb, 1988), colors (Bornstein, Kessen, & Weiskopf, 1976), women's faces (Cohen & Strauss, 1979), animals (Roberts & Cuff, 1989), and spatial relations such as above vs below and left vs right (Behl-Chadha & Eimas, 1995; Quinn, 1994).

In a series of experiments we have sought to determine the young infant's ability to categorically represent a number of species of animals and even begin to group these animals into a more general, superordinate-like representation (Behl-Chadha, 1994; Behl-Chadha, Eimas, & Quinn, 1994; Eimas & Quinn, 1995; Eimas, Quinn, & Cowan, 1994; Quinn, Eimas, & Rosenkrantz, 1993). For example, 3- to 4-month-old infants were shown to form a categorical representation for domestic cats that includes novel domestic cats, but that excludes instances of birds, horses, tigers, dogs, and even female lions. They can also form a categorical representation for horses that excludes cats, giraffes, and zebras. Moreover, a recent study has shown that infants of the same age can compile a more global categorical representation that includes many of these animals, but excludes instances of furniture, birds, and fish (Behl-Chadha, 1994). Taken together, these findings indicate that young infants are able to categorically represent information about animal species on at least two levels—a *basic* level (e.g., cat, horse) and a more inclusive *superordinate-like* level (e.g., mammal).

Of current interest are the cues infants use to differentiate the basic level categories of animals. Given the age of the infants, the cues are clearly perceptual, rather than conceptual in nature (cf. Mandler, 1992). Infants as young as 3 months of age are not likely to have any understanding that cats have biological insides, nor are they likely to understand that animals grow, reproduce, and die (cf. Carey, 1985; Murphy & Medin, 1985). But exactly what are the perceptual cues that infants use to form perceptually based categories? At the basic level, some of the differentiations are undoubtedly based on relatively simple salient attributes or their absence. For example, birds can be distinguished from cats on the basis of the number of legs, the presence of a beak (instead of a nose), and feathers rather than fur. In addition, giraffes and zebras can be excluded from the categorical representation for

horses because of distinctive body markings. And at the more global superordinate level, animals can be distinguished from furniture because of the presence of faces, tails, and fur.

Nevertheless, how young infants distinguish between categories such as cats, dogs, and female lions that have no clear perceptually based, category-defining attributes and that are of roughly comparable size and possess fur, four legs, a tail, a body torso perpendicularly aligned with the leg base, and a configuration of facial features, remains unclear. The conventional wisdom has been that subtle differences in overall shape or in one or more of the attributes or their correlated appearance provides the basis for differentiation (e.g., Marr, 1982; Murphy, 1991; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). In support of these explanations, there is evidence indicating that infants can group stimuli into different categories on the basis of overall shape or correlated attribute information (e.g., Bomba & Siqueland, 1983; Younger, 1985; Younger & Cohen, 1986). Another possibility, motivated by Johnson and Morton's (1991) theory of facial recognition, is that information from the facial region is the basis for this fine level of category differentiation. Johnson and Morton argue that infants possess a neural mechanism termed CONSPEC that is subcortical in origin, functional at birth, and that alerts infants to the presence of faces in the peripheral visual field (Johnson, Dziurawiec, Ellis, & Morton, 1991). Over the next 2 months, a second mechanism termed CONLERN develops that is cortical in origin and that enables infants to learn about the specific faces to which they attend (Johnson, Dziurawiec, Bartrip, & Morton, 1992). Johnson and Morton propose that CONSPEC and CONLERN allow infants to attend to and recognize members of their own species and also specific persons such as the primary caregiver. It is also possible that the two mechanisms facilitate the formation of categorical representations by allowing infants as young as 2 months to distinguish between entities that have faces (e.g., animals) and those that do not (e.g., furniture), as well as to differentiate categories marked by distinctive configurations of facial features (e.g., cats vs dogs). The present experiments were undertaken to investigate whether body or facial information or both may provide sufficient, perhaps even necessary, information for infants' early categorical representations of species of animals with no obvious category-defining attributes.

EXPERIMENT 1

In Experiment 1, we compared infants' use of information in the face and body alone to form a categorical representation for cats that excludes dogs. Three- and 4-month-old infants were randomly assigned to one of three experimental groups: Whole Animal, Face Only, and Body Only. In the Whole Animal Group, infants were familiarized with pictures of intact domestic cats and tested with a novel cat paired with a novel dog. The Face Only Group was presented and tested with the same cats and dogs as the Whole Animal Group, but now only their faces were visible; the body information had been

occluded. The third group, the Body Only Group, was familiarized and tested with the same animals, but, in this case, the face information had been occluded and only the body information was available. A reasonable expectation, based on the results of Quinn et al. (1993) and the arguments of Johnson and Morton (1991) is that infants in the Whole Animal Group and Face Only Group would show a preference for the novel category. Moreover, on the basis of infants' previously documented abilities to categorize form information (e.g., Bomba & Siqueland, 1983) and sensitivity to correlated attributes (Younger & Cohen, 1986), one might predict that infants in the Body Only Group would also show a preference for the novel category.

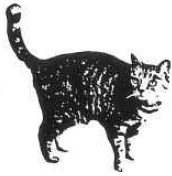
Method

Subjects. The subjects used in each of the eight experiments were completely independent groups. In Experiment 1, the subjects were 72 infants, 46 3-month-old and 26 4-month-old infants (mean age = 3 months, 14 days, $SD = 15$ days). There were 34 females and 38 males. Seventeen additional infants were tested, but 16 did not complete the procedure because of fussiness and 1 was excluded from the data analysis because of the failure to compare the stimuli during the preference test. When excluding infants for failure to compare the test trial stimuli, we are excluding those infants who, with their first look, lock onto the familiar (or novel) category stimulus on the first test trial and then again lock onto the same stimulus shown on the opposite side with their first look on the second test trial. This gives rise to individual novel category preference scores of either 0 or 100%. Such infants are excluded from the data analysis because the paired-comparison procedure requires at least some comparison of the two test stimuli. Preliminary analyses were performed on looking times during familiarization trials and on novelty or spontaneous preferences during test trials as a function of age in all experiments where possible (exceptions were Experiments 4 and 7 where there was only a single 4-month-old participant). However, there were no instances in which the 3- and 4-month-old infants differed.

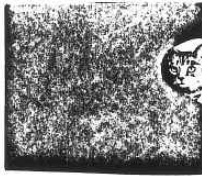
Stimuli. The stimuli were 36 colored photographs of cats and dogs (18 exemplars per category). The pictures were cut from *Simon and Schuster's Guide to Cats* (Siegal, 1983) and *Simon and Schuster's Guide to Dogs* (Schuler, 1980). Each stimulus contained a single animal that had been cut away from its background, centered, and mounted onto a white 17.7×17.7 -cm posterboard for presentation to the infants. Rectangular pieces of gray construction paper occluded body and face information in the Face Only and Body Only conditions, respectively. Examples of the stimuli (black and white versions) presented to each experimental group are shown in Fig. 1.

Apparatus. Each infant was tested with a portable visual preference apparatus adapted from the one used by Fagan (1970). The apparatus is essentially an enclosed viewing box with a hinged gray display stage that contains two compartments to hold the stimuli. The stage is illuminated by a 60-Hz fluo-

Whole Animal Condition



Face Only Condition



Body Only Condition

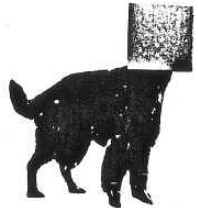
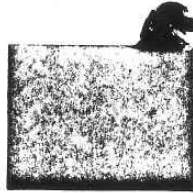
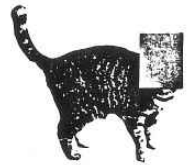


FIG. 1. Examples of the stimuli (black and white versions) used in Experiment 1.

rescent lamp shielded from the infant's view. The center-to-center distance between the compartments is 30.5 cm. A 0.625-cm peephole located midway between the stimulus compartments permitted observation and recording of the infant's visual fixations.

Procedure. The infants were tested individually and brought to the laboratory by a parent and seated in a reclining position on the parent's lap. An experimenter moved the apparatus over the infant, keeping the infant's head centered with respect to the middle of the display stage. As soon as the infant was properly aligned and apparently at ease, the familiarization trials were begun. At the start of a trial, the experimenter loaded the appropriate stimuli from a nearby table into the compartments of the display stage, elicited the infant's attention (by talking or making noises if the infant was looking down) and closed the stage, thereby exposing the stimuli to the infant. The center of the display stage was approximately 30 cm above the infant while the stimuli were being viewed. During a trial, the experimenter observed the infant through the peephole, recording the infant's fixations to the left and right stimuli by means of a 605 XE Accusplit stopwatch held in each hand. The criterion for fixation was observing corneal reflection of the stimulus over the infant's pupil. Interobserver reliability of the corneal reflection procedure is high (see for example, Cohen & Strauss, 1979; Haaf, Brewster, de Saint Victor, & Smith, 1989), with estimates in our laboratory ranging from 0.88 to 0.93 (Bomba, 1984; Eimas & Miller, 1992; Quinn, 1994). With the exception of Experiments 3 and 6, two experimenters were used to record fixations, one during familiarization trials and another during test trials. Both

experimenters were trained research assistants who were naive to the hypotheses under investigation. The experimenter measuring fixations during test trials was unaware of the stimulus information that the infant had been shown during familiarization. Experiments 3 and 6 involved measuring spontaneous (i.e., a priori) perceptual preferences and required only a single experimenter to measure fixations. While it is possible that the presence of the experimenter(s) in between trials could bias the infant to the faces of the animals, we believe this not to be the case for two reasons. First, not only is the experimenter's face visible to the infant in between trials but so also is much of the upper half of the clothed body of the experimenter, a region inclusive of the stomach, chest, arms and hands. As such, one could just as easily make the argument that the infant's attention should be biased in the direction of body shape and/or parts. Second, we have recently replicated the results of Quinn et al. (1993) and the findings obtained in the Whole Animal condition of Experiment 1 with a new computer-driven, stimulus presentation and data recording system, which removes the presence of the experimenter in between trials. We therefore have no reason to suspect that infants would perform differently in the absence of the experimenter in between trials.

The experiment was performed in two replications of 36 infants each. Within each replication, 12 infants were randomly assigned to each of three experimental groups: Face Only—familiarized with cat faces (body parts occluded) and tested with a novel cat face vs a dog face; Body Only—familiarized with cat bodies (faces occluded) and tested with a novel cat body vs a dog body; Whole Animal—familiarized with cats and tested with a novel cat vs a dog. During familiarization, each infant was presented with 1 of 12 randomly selected sets of 12 cat faces or cat bodies or whole cats. The sets of cats were the same across groups, differing only with regard to what parts of the animals were presented. In each group, two infants received the same set of 12 animals. Two different cats, or faces, or bodies were shown on each of six 15-s trials, one in the left panel and one in the right panel.

The test trials consisted of two, 10-s trials, which paired a novel cat with a novel dog. There were 12 randomly selected sets of test-trial stimuli, which again were used in all three groups. They differed as before only with respect to the parts that were displayed—whole animal, face only or body only. The stimuli were assigned to two infants in each group. The left–right positioning of the two stimuli was counterbalanced across infants on the first trial and reversed on the second trial.

Results and Discussion

Familiarization trials. Individual looking times were summed over both stimuli on each trial and then averaged across the first three and last three trials. The mean looking times are shown in the left half of Table 1. An analysis of variance, Experimental Group (Whole Animal vs Face Only vs Body Only) \times Replication (One vs Two) \times Trial Block (First three vs Second

TABLE 1

Mean Fixation Times (Seconds) during the Familiarization Trials and Mean Novel-Category Preference Scores (Percentages) during the Preference Test Trials in Experiment 1

Familiarization category	Fixation time						
	Trials 1-3		Trials 4-6		Novelty preference		
	Mean	(SD)	Mean	(SD)	Mean	(SD)	t^a
Whole animal	10.74	(2.52)	9.24	(2.90)	63.58	(19.11)	3.48*
Face only	9.29	(2.92)	8.88	(2.85)	67.06	(25.60)	3.26*
Body only	8.46	(3.49)	8.25	(3.94)	48.14	(19.82)	-0.46

^a t for mean versus chance.

* $p < .005$, one-tailed test.

three), performed on the individual scores revealed a significant effect of Trial Block $F(1,66) = 4.27$, $p < .05$. No other effects were reliable, $p > .05$, in each instance. The quite small, but significant, decrement in looking time observed in all three experimental groups indicates that infants reliably habituated to the stimuli—something that does not always occur when complex and presumably interesting stimuli are used during familiarization (Eimas & Quinn, 1994; Quinn et al., 1993).

Preference 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 for the three experimental groups are shown in the right half of Table 1. A two-way analysis of variance, Experimental Group \times Replication, performed on the individual percentages yielded only a significant effect of Experimental Group, $F(2,66) = 5.06$, $p < .01$. No other effects were reliable, $p > .05$, in both cases. A post-hoc Tukey test indicated that both the Whole Animal and Face Only means were significantly higher than the Body Only mean, $HSD = 15.22$, $p < .05$, and did not differ from each other. As is shown in Table 1, the difference between the groups is consistent with comparisons of the mean preference scores with the chance value of 50%. These t tests vs chance showed the Whole Animal and Face Only group preferences to be significantly higher than chance, but not that of the Body Only group.

The mean preference of the Whole Animal group provides a replication of our earlier finding that 3- and 4-month-old infants can form categorical representations for perceptually similar natural categories—in this case, a categorical representation for cats that excludes dogs (Quinn et al., 1993). Moreover, the combined results of the Face Only and Body Only groups indicate that facial information provides the infant with a sufficient and apparently necessary basis to form this categorical representation. The mean novel-

category preference of the Face Only group was actually higher, but not reliably so, than that observed for the Whole Animal group, thereby hinting at the possibility that the rest of the body may have acted as a distractor from the face region.

It is noteworthy and perhaps surprising that the infants did not use body information to form a categorical representation for cats, given their abilities to categorize basic form information (e.g., Bomba & Siqueland, 1983) and given that adults can classify on the basis of body shape as informal testing has indicated. Three adults, naive to the hypotheses under investigation, were presented with the Body Only versions of the 36 cat and dog stimuli (shown in a random order) and asked to identify each stimulus as a cat or dog. All three subjects performed without error.

One unexpected aspect of the results of Experiment 1 was the high variability observed among the novel-category preferences of the infants in the Face Only Group. One explanation for this result is that the face comprises such a small portion of each stimulus that some infants may have failed to consistently detect it in a sufficient number of the familiar exemplars to form a categorical representation of cats differentiated enough to exclude dogs. We provide an indirect test of this hypothesis in Experiment 4.

EXPERIMENT 2

Categorization generally refers to the equivalent response to *discriminably different* entities (e.g., Smith & Medin, 1981). Experiment 2 was conducted to determine if 3- and 4-month-old infants could discriminate among the cat stimuli used in Experiment 1. Each infant was familiarized with either the Whole Animal, Face Only or Body Only version of a single cat and then tested with the familiar cat paired with a novel cat.

Method

Subjects. The subjects were 72 infants, 41 3-month-olds and 31 4-month-olds (mean age = 3 months, 15 days, $SD = 15$ days). Thirty-two of the infants were females and 40 were males. An additional 6 subjects were tested, but 4 failed to complete the procedure because of fussiness and 2 were not included in the data analysis because of position preference ($n = 1$) or failure to compare the test stimuli ($n = 1$).

Stimuli and apparatus. The pictures of cats and dogs and apparatus were those used in Experiment 1.

Procedure. The experiment was performed in two replications of 36 infants each. Twelve infants were randomly assigned to each of the three experimental groups: Whole Animal, Face Only, and Body Only. As in Experiment 1, infants in the Whole Animal group were tested with the whole animal versions of the cat stimuli. Those in the Face Only group were tested with the cat faces alone (body parts were occluded), whereas those in the Body Only group were tested with the cat bodies alone (faces were occluded). Each

TABLE 2

Mean Fixation Times (Seconds) during the Familiarization Trials and Mean Novelty Preference Scores (Percentages) during the Preference Test Trials in Experiment 2

Familiarization category	Fixation time						
	Trials 1-3		Trials 4-6		Novelty preference		
	Mean	(SD)	Mean	(SD)	Mean	(SD)	t^a
Whole animal	9.76	(3.76)	8.59	(3.99)	58.05	(21.36)	1.85*
Face only	9.06	(3.89)	7.93	(4.22)	64.92	(18.07)	4.05**
Body only	7.47	(3.25)	7.19	(3.75)	69.67	(19.42)	4.96**

^a t for mean versus chance.

* $p < .05$, one-tailed test.

** $p < .0005$, one-tailed test.

infant received six 15-s familiarization trials during which a single cat or part of a cat was presented in both compartments of the display stage. Immediately after familiarization, each infant received two 10-s test trials, pairing the familiar cat with a novel cat. The left-right positioning of the novel stimulus was counterbalanced across infants on the first trial and reversed on the second trial. There were 12 randomly chosen familiar cat-novel cat pairings, each used twice in each of the three experimental groups. In this way, the within-category discriminations were based on the same cats and thus identical in the three groups of infants.

Results and Discussion

Familiarization trials. The mean looking times for the first three and last three trials of familiarization are shown in the left half of Table 2. All three groups show a decline in looking time that was found to be reliable by a three factor analysis of variance, Experimental Group \times Replication \times Trial Block, performed on the looking times, $F(1,66) = 5.96$, $p < .02$. The infants had habituated to the familiar stimulus in each of the three presentation conditions. No other effects were significant, $p > .05$, in each instance.

Preference test trials. The mean preference scores for the novel stimulus are shown in the right half of Table 2. A two factor analysis of variance, Experimental Group \times Replication, performed on the individual novelty preference scores, yielded no significant effects, $p > .05$, in each case. As Table 2 shows, the preference score for each experimental group was reliably greater than the chance value of 50%. The above-chance performance of the Whole Animal group replicates an earlier finding (Quinn et al., 1993) and indicates that infants are capable of discriminating among individual instances of cats. The reliable performance of the Face Only group provides additional evidence that 3- and 4-month-old infants are able to differentiate between individual

cat faces. Moreover, the discriminative abilities of infants in these groups argue against the interpretation that infants in Experiment 1 may have preferred the novel category instance simply because they failed to differentiate among members of the familiar category. Notably, discrimination performance of the Body Only group was above chance, indicating that infants can discriminate between one cat body and another. Such a finding is consistent with previously documented abilities of young infants to attend to and process basic form information (e.g., Milewski, 1979). The combined findings from the Body Only group in Experiments 1 and 2 indicate that while infants can represent the basic form information from cat bodies, they did not use this information to form a categorical representation for cats that excludes dogs. The results thus imply that infants are selectively attending to and representing the face region even though they may be capable of using other features to differentiate between the two categories.

EXPERIMENT 3

In a previous study, we uncovered evidence for spontaneous perceptual preferences for instances of one category over exemplars of another during a series of paired preference trials (Eimas & Quinn, 1994). For example, 3- and 4-month-old infants were found to prefer cats over horses and tigers over cats. Some of these category preferences may be rooted in the preference for a conspicuous perceptual property possessed by members of one category and not by exemplars of the contrast category, for example, the striping of the tigers. The basis for other instances of category preference is not as apparent. For example, it is difficult to specify a particular perceptual property that would explain why cats are preferred to horses. Subtle and undoubtedly complex shape and/or part cues may be the likely basis for this second type of category preference.

Irrespective of the explanation that eventually comes to be accepted for their existence, spontaneous category preferences are important to investigate because they may play a role in facilitating the acquisition of categorical representations (Eimas & Quinn, 1994). In Experiment 3, we explored the possibility of a role for spontaneous preferences for dogs over cats, dog faces over cat faces and dog bodies over cat bodies, by presenting infants with different, randomly selected pairs of pictures from the two categories across a series of eight 15-s trials.

Method

Subjects. Seventy-two infants, 46 3-month-olds and 26 4-month-olds (mean age = 3 months, 14 days, $SD = 17$ days), served as subjects. Forty of the infants were males, and 32 were females. Seven additional infants were tested, but did not complete the procedure because of fussiness ($n = 6$) and sibling interference ($n = 1$).

TABLE 3
 Mean Spontaneous Perceptual Preference Scores (Percent) for the Dog Stimuli
 in the Three Conditions of Experiment 3

	Familiarization category		
	Whole animal	Face only	Body only
Novelty score	52.28	55.17	53.91
<i>SD</i>	9.68	11.73	12.91
<i>t</i> (vs chance)	1.15	2.16*	1.48

* $p < .05$, two-tailed test.

Stimuli and apparatus. The stimuli and apparatus were those used in Experiments 1 and 2.

Procedure. The experiment was performed in two replications of 36 infants each. Within each replication, 12 infants were randomly assigned to each of the three experimental groups: Whole Animal, Face Only and Body Only. On each of eight 15-s trials, infants received a cat paired with a dog. The left-right positioning of the two categories was counterbalanced across infants on the first test trial and reversed on each successive trial. Different pairs of pictures were randomly chosen for each trial. There were 12 different sets of the eight pairs of stimuli, each randomly assigned to two infants in each of the three experimental groups. Thus, the stimuli were again based on the same animals for each group.

Results and Discussion

Category preference scores were calculated for dogs, dog faces, and dog bodies when exemplars of these categories were paired with cats, cat faces, and cat bodies, respectively. A category preference score was determined for each infant by dividing the summed looking time to the dog stimuli (i.e., dogs, dog faces, or dog bodies) over all eight trials by the summed looking time to both categories over all eight trials. This score was then converted to a percentage and averaged across infants to yield a mean category preference score for each of the three experimental groups. The three scores are shown in Table 3. A two-factor analysis of variance, Experimental Group (Whole Animal vs Face Only vs Body Only) \times Replication (One vs Two), performed on the category preference scores, revealed no significant effects, $p > .05$, in each case. However, as can be seen in the table, *t* tests vs the chance preference of 50% revealed a significant preference for dog faces over cat faces, but no reliable preferences for dogs or dog bodies in the other two experimental groups.

Given the spontaneous preference for dog faces over cat faces, it is necessary to reevaluate the preference for dog faces over cat faces in the Face

Only group of Experiment 1. A comparison of the mean novel-category preference for the dog faces in Experiment 1 ($M = 67.06$) with the spontaneous preference for the dog faces in the current experiment ($M = 55.17$) revealed a significant difference, $t(46) = 2.07, p < .05$, two-tailed. This result confirms that the novel-category preference for the dog faces in Experiment 1 was based at least in part on infants' categorical representation of the cat faces, although it was perhaps facilitated by a spontaneous or a priori preference for dog faces.

Our conclusion of a novel-category preference for dogs in the Whole Animal group of Experiment 1 was similarly strengthened on the basis of the results of Experiment 3. The novel-category preference for dogs in Experiment 1 ($M = 63.58$) was found to be reliably higher than the spontaneous preference for dogs in Experiment 3 ($M = 52.28$), $t(46) = 2.58, p < .02$, two-tailed. This finding indicates that there is a strong novel-category preference for dogs after familiarization with cats. The other major conclusion of Experiment 1 that was reinforced by the results of Experiment 3 was that there was no novel-category preference for dog bodies after familiarization with cat bodies. No significant difference was found between the novel-category preference for dog bodies in Experiment 1 ($M = 48.14$) and the spontaneous preference for dog bodies in Experiment 3 ($M = 53.91$), $t(46) = -1.20, p > .10$, two-tailed.

Taken together, the results of Experiments 1–3 replicate our earlier finding that infants can form a categorical representation for cats that excludes dogs (Quinn et al., 1993). The current experiments also provide evidence that after familiarization with discriminably different instances of cat faces, infants prefer to look at dog faces rather than at novel cat faces. Neither of these responses can be attributed solely to preexisting, spontaneous preferences for dogs or dog faces or to a failure to discriminate among the instances of the cats or faces of cats. The pattern of results across experiments supports the idea that information from the facial region provides infants with a necessary and sufficient basis for distinguishing and categorizing cats and dogs.

EXPERIMENT 4

In Experiment 4, we sought further evidence for the proposal that infants can utilize facial information to categorically differentiate between cats and dogs. Three- and 4-month-old infants were familiarized with cat faces and then tested with a novel cat face paired with a novel dog face. The stimuli were photographic enlargements of the faces used in Experiment 1. The faces were detached from the rest of the animal body and were presented in isolation on the stimulus card. In effect, Experiment 4 provided a test of the generality of the Face Only findings of Experiment 1 as well as a test of one explanation as to why the novel-category preferences of the infants in that group displayed such a high amount of variability. We reasoned that by making the facial information larger and presumably more salient, the variation in novel-cate-

gory preference responses would be reduced. In addition, given positive results, larger faces will allow us to parcel the facial information more easily and thereby begin a fine-grain search for the information underlying the representation for cats.

Method

Subjects. Twelve infants, 11 3-month-olds and 1 4-month-old (mean age = 3 months, 8 days, $SD = 9$ days), served as subjects. There were 4 females and 8 males. Five additional infants were tested, but 3 did not complete the procedure because of fussing and 2 were excluded from the data analysis because of a position preference ($n = 1$) or a failure to compare the two test stimuli ($n = 1$).

Apparatus and stimuli. The stimuli were color enlargements of the facial regions of the stimuli used in Experiment 1. They were approximately the same size as the whole animal stimuli. The apparatus was the same one used in earlier experiments.

Procedure. Each infant was familiarized with 12 cat faces, randomly selected and different for each infant, presented during six 15-s trials (two cat faces per trial). Each infant was then presented with a novel cat face paired with a novel dog face during two 10-s preference test trials. The test pairs were randomly selected and different for each infant. The left–right positioning of the novel and familiar category instances was counterbalanced across infants on the first test trial and reversed on the second test trial.

Results and Discussion

Infants did not display a reliable decrement in looking time from the first to the last three trials of familiarization (first three trials = 11.17 s, $SD = 3.34$; last three trials = 10.50 s, $SD = 2.77$; $t(11) = 0.75$, $p > .05$, one-tailed). This lack of habituation probably reflects the young infants' well-documented interest in facelike stimuli (Fantz, 1961; Johnson & Morton, 1991) and should not imply lack of processing as is evidenced in the novel-category preference data (cf. Eimas & Quinn, 1994; Quinn et al., 1993).

The mean novel-category preference for the dog face on the two test trials was 63.40 ($SD = 14.23$), a value reliably higher than chance, $t(11) = 3.26$, $p < .005$, one-tailed, as in Experiment 1. Moreover, the lower standard deviation of this group suggests that the variability of the infants in the Face Only condition of Experiment 1 was likely a consequence of the face information comprising such a small portion of the entire stimulus.

EXPERIMENT 5

To conclude that the novel-category preference in Experiment 4 was a categorical response and not simply due to a failure to discriminate among the exemplars of enlarged cat faces, Experiment 5 tested the ability of 3- and 4-month-old infants to discriminate between individual exemplars of

enlarged cat faces. Infants were familiarized with a single exemplar of an enlarged cat face and tested with the familiar cat face paired with a novel enlarged cat face.

Method

Subjects. Twelve infants, 10 3-month-olds and 2 4-month-olds (mean age = 3 months, 9 days, $SD = 12$ days), served as subjects. There were 8 males and 4 females. One additional infant was tested but did not complete the procedure because of fussiness.

Stimuli and apparatus. The stimuli and apparatus were the same as those used in Experiment 4.

Procedure. Each infant was presented with a single exemplar of an enlarged cat face during six 15-s familiarization trials. On each trial, two identical copies of the exemplar were presented, one in each of the compartments of the display stage. Each infant was then presented with the familiar exemplar paired with a novel enlarged cat face during two 10-s test trials. The left-right positioning of the familiar and novel exemplars was counterbalanced across infants on the first test trial and reversed on the second test trial. The familiar and novel exemplars were randomly selected and different for each infant.

Results and Discussion

The decrease in looking time from the first three to the last three familiarization trials was not significant (first three trials = 9.63 s, $SD = 4.07$; last three trials = 9.05 s, $SD = 4.32$; $t(11) = 0.74$, $p > .10$, one-tailed), providing further evidence of infants' sustained interest in faces even when the stimulus is a single face viewed over 6 familiarization trials. More importantly, the lack of habituation does not indicate a failure to process the face as the preference data indicate.

The mean preference for the novel stimulus obtained on the test trials ($M = 66.26$, $SD = 18.37$) was significantly greater than that expected by chance, $t(11) = 3.06$, $p < .01$, one-tailed. This result indicates that the enlarged cat faces used in Experiment 4 were discriminably different for infants and that the mean novel-category preference obtained in the experiment cannot be explained in terms of a failure to discriminate.

EXPERIMENT 6

One additional control necessary to interpret the novel-category preference obtained in Experiment 4 is to demonstrate that the preference cannot be explained in terms of an a priori preference for enlarged dog faces over cat faces. Experiment 6 therefore compared infants' spontaneous looking times to exemplars of the enlarged dog and cat faces.

Method

Subjects. Twelve infants, 10 3-month-olds and 2 4-month-olds (mean age = 3 months, 6 days, $SD = 14$ days), served as subjects. There were 6 males and 6 females.

Stimuli and apparatus. The stimuli and apparatus were the same as those used in Experiments 4 and 5.

Procedure. Eight pairs of enlarged cat and dog faces were randomly selected for each infant. A different pair was displayed during each of eight 15-s trials. The left-right positioning of the stimuli from the two categories was counterbalanced across infants on the first trial and reversed on each successive trial such that stimuli from each category appeared equally often in the left and right compartments of the display panel.

Results and Discussion

The mean spontaneous preference for enlarged dog faces was 51.05% ($SD = 10.39$), a value not significantly different from 50%, the value expected by chance, $t(11) = 0.35$, $p > .10$, two-tailed. Further comparison revealed that the novel-category preference for enlarged dog faces obtained in Experiment 4 was significantly greater than the spontaneous preference, $t(22) = 2.43$, $p < .05$, two-tailed. The combined results of Experiments 4–6 are consistent with those of Experiments 1–3 and indicate that 3- and 4-month-old infants can form a categorical representation for cat faces that excludes dog faces and that cannot be attributed to an a priori preference for dog faces or to a failure to discriminate among individual exemplars of cats or cat faces. It is noteworthy that there was a spontaneous preference for the faces of dogs presented in Experiment 3 but no spontaneous preference for the enlarged dog faces in Experiment 6. One possible explanation is that the enlarged faces of both categories attracted and maintained infants' attention more nearly equally because of their size and complexity.

EXPERIMENT 7

In Experiment 7, we sought further evidence to strengthen our contention that facial information provides the infant with a sufficient basis for categorically differentiating between cats and dogs. We tested whether infants familiarized with the smaller faces (e.g., the Face Only stimuli of Experiments 1–3) would generalize their responses to novel Whole cats and thus prefer Whole dogs in a test trial comparison between the two.

Method

Subjects. Twelve subjects, 11 3-month-olds and 1 4-month-old (mean age = 3 months, 7 days, $SD = 9$ days), served as subjects. There were 7 females and 5 males.

Stimuli and apparatus. The stimuli and apparatus were the same as those used in Experiments 1–3.

Procedure. Each infant was presented with 12 cat Face Only stimuli (bodies occluded) during six 15-s familiarization trials. Each infant was then tested with a novel Whole Animal cat and a novel Whole Animal dog during two 10-s test trials. The left-right positioning of the stimuli from the two categories was counterbalanced across infants on the first trial and reversed on the second trial. The familiarization and test stimuli were randomly selected and different for each infant.

Results and Discussion

Looking times did not decline reliably from the first to the second half of familiarization (first three trials = 10.17 s, $SD = 3.35$; last three trials = 9.50 s, $SD = 3.50$; $t(11) = 0.69$, $p > .10$, one-tailed). The mean novel-category preference for the Whole Animal dog stimuli was 66.50 ($SD = 18.36$), a result reliably above chance, $t(11) = 3.11$, $p < .005$, one-tailed. It is also reliably greater than the spontaneous preference for whole dogs obtained in Experiment 3, $t(34) = 3.06$, $p < .01$, two-tailed. This finding indicates that after experiencing a number of cat faces infants will generalize presumably to the facial information in the novel entire cat and prefer whole dogs. The result provides further evidence that information contained in the face provides the infant with a sufficient basis for categorically differentiating cats and dogs.

EXPERIMENT 8

The first seven experiments support the hypothesis that cues from the facial region provide a source of information that allows young infants to form a categorical representation for cats that excludes dogs. Experiment 8 was undertaken to determine what region of the face underlies this differentiation—the internal features of the face or the external contour of the head and neck. One group of infants, the Face Occluded Group, was familiarized with the enlarged cat faces used in Experiments 4–6, but with the internal features occluded so that only the external contour information could provide the basis for a categorical representation. These infants were then tested with a novel enlarged cat face paired with an enlarged dog face, both of which had the internal features occluded. A second group of infants, the Face Exposed group, was familiarized with enlarged cat faces, but in this case with the external contour occluded, so that the internal facial features could be the only basis for categorization. The Face Exposed group was then tested with a novel enlarged cat face and an enlarged dog face, both with the external contour occluded.

Method

Subjects. Twenty four infants, 15 3-month-olds and 9 4-month-olds (mean age = 3 months, 16 days, $SD = 16$ days), served as subjects. There were 11

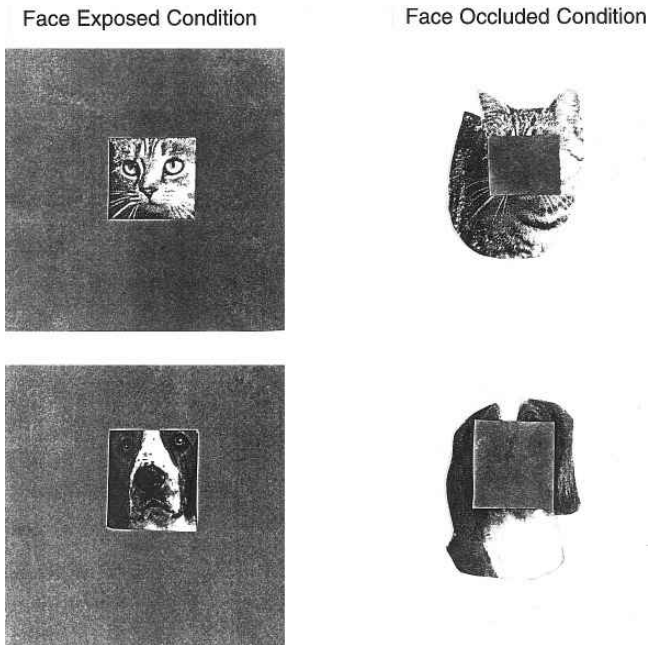


FIG. 2. Examples of the stimuli (black and white versions) used in Experiment 2.

males and 13 females. One additional infant was tested but not included in the data analysis because of a failure to compare the test stimuli.

Stimuli and apparatus. The stimuli and apparatus were the same as those used in Experiments 4–6. For each stimulus presented to the Face Occluded group, a piece of gray construction paper was cut to occlude the internal facial features, leaving only the external contour. During presentation, the construction paper cut-out was superimposed over the internal features region (i.e., eyes, nose, mouth), thereby preserving its external contour. For each stimulus presented to the Face Exposed group, a piece of gray construction paper was cut into a rectangular frame. During presentation, the frame was superimposed over the outer border of the stimulus, thereby occluding the external contour, while preserving the internal facial features (i.e., eyes, mouth, nose). Examples of the stimuli (black and white versions) presented to the Face Exposed and Face Occluded groups are shown in Fig. 2.

Procedure. Twelve infants were randomly assigned to each of two groups, defined by the information available to the infants, Face Occluded or Face Exposed. Over the course of six 15-s familiarization trials, each infant was presented with 12 pictures of face-occluded or face-exposed cat faces. Two different faces were shown on each trial. Familiarization was followed by two 10-s test trials in which a novel cat face was paired with a dog face. Face-

TABLE 4
 Mean Fixation Times (Seconds) during the Familiarization Trials and Mean Novel-Category Preference Scores (Percentages) during the Preference Test Trials in Experiment 8

Familiarization category	Fixation time						
	Trials 1-3		Trials 4-6		Novelty preference		
	Mean	(SD)	Mean	(SD)	Mean	(SD)	t^a
Face occluded	9.70	(2.91)	8.31	(3.44)	60.21	(17.62)	2.01*
Face exposed	8.90	(2.88)	8.55	(2.96)	55.55	(13.02)	1.48

^a t for mean versus chance.

* $p < .05$, one-tailed test.

occluded test pairs were presented to the Face Occluded group and face-exposed test pairs were shown to the Face Exposed group. The left-right positioning of the familiar and novel category instances was counterbalanced across infants on the first test trial and reversed on the second test trial. There were 12 sets of familiar and novel-category preference test stimuli, each used once in both groups.

Results and Discussion

Familiarization trials. Mean looking times for the first and last three trials of familiarization are shown in the left half of Table 4. A two-factor analysis of variance, Experimental Group (Face Occluded vs Face Exposed) \times Trial Block (First vs. Second), performed on the individual looking time scores, revealed no significant effects, $p > .05$, in each instance.

Preference test trials. The mean novel-category preference scores for the two experimental groups are shown in the right half of Table 4. The two means were not significantly different from each other, $t(22) = 0.74$, $p > .10$, two-tailed. Nevertheless, the Face Occluded group mean was found to be reliably above chance, whereas the Face Exposed group mean was shown to be only marginally different from chance ($p < .10$, one-tailed). Because of the lack of a difference between the two means and the borderline nature of the significance of the Face Exposed group mean, we tested an additional group of 12 subjects with the Face Exposed stimuli (mean age = 3 months, 12 days, $SD = 17$ days). They yielded a mean novel-category preference of 64.03% ($SD = 13.55$), a value that was reliably above chance, $t(11) = 3.59$, $p < .005$, one-tailed, but not reliably different from the mean obtained with the original 12 subjects, $p > .10$, two-tailed. An analysis of the scores of all 24 infants revealed a significant mean novel-category preference of 59.79%, $SD = 13.70$, $t(23) = 3.50$, $p < .005$, one-tailed. It would thus appear that infants can use both the external contour of the head region and the internal facial features to form a categorical representation of cat faces that excludes

dog faces. That infants were able to form the categorical representation by using either the internal or external features of the face and head is consistent with data showing that young infants visually scan both the internal and external features of schematic faces (Maurer, 1983) and evidence that adults' recognition of unfamiliar human faces can occur on the basis of either internal or external features (Ellis, Shepherd, & Davies, 1979). That young children appear to rely on external features to recognize familiar human faces, whereas older children and adults use internal features is an issue that is beyond the scope of the present paper and currently under investigation by others (Campbell, Walker, & Baron-Cohen, 1995).

GENERAL DISCUSSION

The present studies were undertaken to investigate the information infants use to form categorical representations for perceptually quite similar animal categories chosen from the same superordinate category. The results of these experiments indicate that cues from the facial and head region provide the critical source of information that allows young infants to categorically differentiate cats and dogs and presumably a number of other animal species that bear a close resemblance with one another.

We make no strong claim on the basis of these findings that faces are somehow "special." It may simply be that facial information is the foundation for the categorical differentiation because the face has more information in it, attracts more attention during familiarization than other parts of the animal, and attracts more attention during the test phase in which the infant uses the representation obtained during familiarization to separate the two categories. However, we would also note that the findings are consistent with arguments and evidence that infants' attention to the information contained in faces may be a powerful mechanism that functions to add organization and coherence to early visual experiences (Johnson & Morton, 1991). Earlier we discussed the model of Johnson and Morton and their colleagues which proposes that newborns are attracted to the presence of faces in general and by 2 months of age, infants can engage in detailed learning about faces. According to Johnson and Morton, initial orientation to and subsequent processing of faces allow young infants to attend to and recognize members of their own species and also specific persons such as the primary caregiver. The data from the current studies suggest that infants' attention to faces also aids the formation of categorical representations by allowing infants to differentiate categories marked by distinctive facial and head information.

It is of interest to us that the theory of Johnson & Morton can be extended to make predictions about the course of category formation in even younger infants. The infants in the present study were 3 and 4 months old, ages during which both the CONSPEC and CONLERN mechanisms are assumed to be functional. In contrast, during the first month of life, only the CONSPEC mechanism is presumed to be operational. Given that the CONSPEC mecha-

nism can detect only the *presence* of the face (specifically, the internal features—eyes, nose and mouth) and not the detailed aspects of these features, one would not expect newborns or 1-month-old infants to be able to differentiate dogs from cats. However, one would predict that infants 1 month of age would be capable of making more global categorical distinctions between entities that have faces (e.g., animals) and those that do not (e.g., furniture). Moreover, because CONSPEC is not postulated to be able to discriminate within the category of faces, the categories formed during the first month would actually be the products of categorical perception (Harnad, 1987) rather than categorization. Shortly thereafter, from about two months on, when CONSPEC and CONLERN both become available, one should begin to observe the onset of categorization of different animal species on the basis of the particulars of the configural arrangement of the internal features and other features such as the contour of the head. Thus, over the first few months of life, there may be a shift in the type of categories that emerge (e.g., global vs basic-level) and the mechanism of their formation (e.g., categorical perception vs categorization). Interestingly, the predicted development from more global to more specific perceptually based categories corresponds with the reported developmental course of what are presumed to be conceptual categories occurring later in infancy (Mandler & McDonough, 1993).

It now becomes of interest to learn what specific aspects of the facial and head region permit differentiation. With respect to the internal features, we do not know whether the categories are specified by the dimensions of one particular feature (e.g., the nose) or by the configuration of several features (eyes, nose, mouth). Similarly, we are unable to say whether it is the “gestalt” of the outer contour or some specific region of the external border of the head that distinguishes the categories. Additional experimentation will be needed to test these possibilities.

On a more general level, the results of the experiments are relevant to the debate over the information contained in categorical representations. Various accounts have maintained that basic level categories are differentiated from one another on the basis of overall shape (Marr, 1982), particular parts (Murphy, 1991) or a set of correlated attributes (Rosch et al., 1976). Indeed when adults are asked to identify what the properties of basic-level categories are, they will mention a number of attributes besides the face and the head (e.g., Malt & Smith, 1984). However, the data collected in our experiments indicate that the information distinguishing between categories does not consist of perceptual attributes from various regions of the bodies of the category exemplars (e.g., leg length, shape of body torso, appearance of tail). Rather, it seems to be information from a very specific region (namely, the head) that defines the category. It could be that young infants generate early animal categories by “anchoring” their representations to a very small number of salient perceptual properties. It will be of interest to learn if other categories begin in this way and if so, whether this may represent one way in which

the early categories of young infants may be differentiated from the more mature categories of older infants and children, the latter presumably being structured by more elaborate sets of attributes.

The present data also have implications for a recent question that has been raised about the nature of concepts, namely, whether enduring conceptual structures actually exist (Jones & Smith, 1993). We have thus far emphasized the role that facial information may play in the formation of categorical representations at the basic level. It is also possible that facial information may play a role in categorical partitions at other levels of abstraction: animate–inanimate, animal–nonanimal, human–nonhuman, and familiar human–strange human. In other words, selective attention to faces may be viewed as a mechanism for innately guided, domain-specific knowledge acquisition (Carey & Spelke, 1994; Hirschfield & Gelman, 1994). If further empirical study does indicate that facial information provides a basis for each of these categorical distinctions later in development, then such evidence can also be viewed as supporting a stability view of conceptual structure (e.g., Smith & Medin, 1981). However, it is possible that the importance of facial information as a category specifying cue may vary as function of context (i.e., the contrast category). For example, when cats are distinguished from birds, furniture or vehicles, overall shape or the particular pattern of correlated attributes may replace facial information as the most relied upon cue(s) for categorical differentiation. It is also possible that if the animal stimuli were presented in motion, then species-specific biological movement could come to be relied on to a greater extent than facial information as a cue for categorical differentiation (cf. Pinto, 1994). Thus, the properties which allow for categorical differentiation may shift from one situation to another. An outcome of this nature would bolster recent arguments that there is no stable conceptual structure; rather, conceptual representations are computed as needed depending on situational variables such as the nature of the classification task, the goals of the cognizer, and the stimulus context (Barsalou, 1993; Jones & Smith, 1993). We would add to this position that the acquisition of knowledge in general may increase the likelihood that concepts will become less stable with development. The more one knows, the more contexts are potentially available and thus the more likely that concepts could be defined by context or contrasts. Clearly, additional research which attempts to identify the attributes that provide the basis for a category (e.g., cats) that is contrasted with a range of contrasting categories (e.g., birds, furniture) under different experimental conditions and at different ages represents a promising empirical approach toward providing data relevant to this issue regarding conceptual structure.

REFERENCES

- Barsalou, L. W. (1993). Challenging assumptions about concepts. *Cognitive Development*, *8*, 169–180.
- Behl-Chadha, G. (1994). *Perceptually driven superordinate-like categorical representations in early infancy*. Unpublished doctoral dissertation, Brown University.

- Behl-Chadha, G., & Eimas, P. D. (1995). Infant categorization of left-right spatial relations. *British Journal of Developmental Psychology*, **13**, 69–79.
- Behl-Chadha, G., Eimas, P. D., & Quinn, P. C. (1995, March). *Perceptually driven superordinate categorization by young infants*. Paper presented at the meeting of the Society for Research in Child Development, Indianapolis, IN.
- Bomba, P. C. (1984). The development of orientation categories between 2 and 4 months of age. *Journal of Experimental Child Psychology*, **37**, 609–636.
- Bomba, P. C., & Siqueland, E. R. (1983). The nature and structure of infant form categories. *Journal of Experimental Child Psychology*, **35**, 294–328.
- Bornstein, M. H., Kessen, W., & Weiskopf, S. (1976). Color vision and hue categorization in young infants. *Journal of Experimental Psychology: Human Perception and Performance*, **2**, 115–129.
- Campbell, R., Walker, J., & Baron-Cohen, S. (1995). The development of differential use of inner and outer face features in familiar face identification. *Journal of Experimental Child Psychology*, **59**, 196–210.
- Carey, S. (1985). *Conceptual change in childhood*. Cambridge, MA: MIT Press.
- Carey, S., & Spelke, E. (1994). Domain-specific knowledge and conceptual change. In L. A. Hirschfield & S. A. Gelman (Eds.), *Mapping the mind: Domain specificity in cognition and culture* (pp. 169–200). Cambridge, England: Cambridge Univ. Press.
- Cohen, L. B., & Strauss, M. S. (1979). Concept acquisition in the human infant. *Child Development*, **50**, 419–424.
- Cohen, L. B., & Younger, B. A. (1983). Perceptual categorization in the infant. In E. K. Scholnik (Ed.), *New trends in conceptual representation: Challenges to Piaget's theory?* (pp. 197–220). Hillsdale, NJ: Erlbaum.
- Eimas, P. D., & Miller, J. L. (1992). Organization in the perception of speech by young infants. *Psychological Science*, **3**, 340–345.
- Eimas, P. D., & Quinn, P. C. (1994). Studies on the formation of perceptually based basic-level categories in young infants. *Child Development*, **65**, 903–917.
- Eimas, P. D., Quinn, P. C., & Cowan, P. (1994). Development of exclusivity in perceptually based categories of young infants. *Journal of Experimental Child Psychology*, **58**, 418–431.
- Ellis, H. D., Shepherd, J. W., & Davies, G. M. (1979). Identification of familiar and unfamiliar faces from internal and external features: Some implications for theories of face recognition. *Perception*, **8**, 431–439.
- Fagan, J. F. (1970). Memory in the infant. *Journal of Experimental Child Psychology*, **9**, 217–226.
- Fantz, R. L. (1961). The origin of form perception. *Scientific American*, **204**, 66–72.
- Fantz, R. L. (1964). Visual experience in infants: Decreased attention to familiar patterns relative to novel ones. *Science*, **164**, 668–670.
- Haaf, R. A., Brewster, M., de Saint Victor, C. M., & Smith, P. H. (1989). Observer accuracy and observer agreement in measurement of visual fixation with fixed-trial procedures. *Infant Behavior and Development*, **12**, 211–220.
- Harnad, S. (1987). *Categorical perception: The groundwork of cognition*. New York: Cambridge Univ. Press.
- Hirschfield, L. A., & Gelman, S. A. (1994). Toward a topography of mind: An introduction to domain specificity. In L. A. Hirschfield & S. A. Gelman (Eds.), *Mapping the mind: Domain specificity in cognition and culture* (pp. 3–35). Cambridge, England: Cambridge Univ. Press.
- Johnson, M. H., Dziurawiec, S., Bartrip, J., & Morton, J. (1992). The effects of movement of internal features on infants' preference for face-like stimuli. *Infant Behavior and Development*, **15**, 129–136.
- Johnson, M. H., Dziurawiec, S., Ellis, H., & Morton, J. (1991). Newborns' preferential tracking of face-like stimuli and its subsequent decline. *Cognition*, **40**, 1–19.

- Johnson, M. H., & Morton, J. (1991). *Biology and cognitive development*. Cambridge, MA: Blackwell.
- Jones, S. S., & Smith, L. B. (1993). The place of perception in children's concepts. *Cognitive Development*, **8**, 113–139.
- Malt, B. C., & Smith, E. E. (1984). Correlated properties in natural categories. *Journal of Verbal Learning and Verbal Behavior*, **23**, 250–269.
- Mandler, J. M. (1992). How to build a baby: II. Conceptual primitives. *Psychological Review*, **99**, 587–604.
- Mandler, J. M., & Bauer, P. J. (1988). The cradle of categorization: Is the basic level basic? *Cognitive Development*, **3**, 247–264.
- Mandler, J. M., & McDonough, L. (1993). Concept formation in infancy. *Cognitive Development*, **8**, 291–318.
- Markman, E. M. (1989). *Categorization and naming in children*. Cambridge, MA: MIT Press.
- Marr, D. (1982). *Vision*. San Francisco: W. H. Freeman and Company.
- Maurer, D. (1983). The scanning of compound figures by young infants. *Journal of Experimental Child Psychology*, **35**, 437–488.
- Mervis, C. B. (1987). Child-basic object categories and early development. In U. Neisser (Ed.), *Concepts and conceptual development* (pp. 201–233). Cambridge: Cambridge Univ. Press.
- Milewski, A. E. (1979). Visual discrimination and detection of configurational invariance in 3-month-old infants. *Developmental Psychology*, **15**, 357–363.
- Murphy, G. L. (1991). Parts in object concepts: Experiments with artificial categories. *Memory and Cognition*, **19**, 423–438.
- Murphy, G. L., & Medin, D. L. (1985). The role of theories in conceptual coherence. *Psychological Review*, **92**, 289–316.
- Pinto, J. (1994, June). *Human infants' sensitivity to biological motions in point-light cats*. Paper presented at the meeting of the International Society for Infant Studies, Paris, France.
- Quinn, P. C. (1987). The categorical representation of visual pattern information by young infants. *Cognition*, **27**, 145–179.
- Quinn, P. C. (1994). The categorization of above and below spatial relations by young infants. *Child Development*, **65**, 58–69.
- Quinn, P. C., & Eimas, P. D. (1986). On categorization in early infancy. *Merrill-Palmer Quarterly*, **32**, 331–363.
- Quinn, P. C., Eimas, P. D., & Rosenkrantz, S. L. (1993). Evidence for representations of perceptually similar natural categories by 3-month-old and 4-month-old infants. *Perception*, **22**, 463–475.
- Roberts, K., & Cuff, M. D. (1989). Categorization studies of 9- to 15-month-old infants: Evidence for superordinate categorization. *Infant Behavior and Development*, **12**, 265–288.
- Rosch, E., Mervis, C. B., Gray, W. D., Johnson, D. M., & Boyes-Braem, P. (1976). Basic objects in natural categories. *Cognitive Psychology*, **8**, 382–439.
- Schuler, E. M. (Ed.) (1980). *Simon and Schuster's guide to dogs*. New York: Simon and Schuster.
- Siegal, M. (Ed.) (1983). *Simon and Schuster's guide to cats*. New York: Simon and Schuster.
- Younger, B. A. (1985). The segregation of items into categories by ten-month-old infants. *Child Development*, **56**, 1574–1583.
- Younger, B. A., & Cohen, L. B. (1986). Developmental change in infants' perception of correlations among attributes. *Child Development*, **57**, 803–815.
- Younger, B. A., & Gottlieb, S. (1988). Development of categorization skills: Changes in the nature or structure of infant form categories? *Developmental Psychology*, **24**, 611–619.