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Form Categorization in 10-Month-Olds

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In five experiments, 10-month-olds were habituated to exemplars of a form category and tested for categorization in paired-comparison trials involving in-category versus out-of-category stimuli. Across these experiments, color was systematically manipulated during habituation and/or test trials. Infants categorized form when color was either held constant or varied during habituation, but failed to categorize form when exposed to color-constant stimuli during habituation and tested for categorization with novel-color form exemplars. Two subsequent experiments traced this failure to the narrow experience of exposure to color-constant exemplars during habituation. These results suggest that (a) infants' internal representation for a category will not include a stimulus dimension not varied in the exemplars from which the category was derived, but (b) if variation in that dimension is experienced, exemplars constructed of novel instances of that dimension will still be regarded as belonging to the category.

Over the past decade, interest has grown in the development of categorization skills during infancy (see reviews by Bornstein, 1984, 1985; Lewis & Strauss, 1985; Younger & Cohen, 1986), as the ability of infants to recognize similarity among a series of perceptually-related stimuli is thought to be quite relevant to major theories of perceptual development (e.g., Gibson, 1967), to the skills purported to underlie the acquisition of vocabulary and language (Roberts & Horowitz, 1986), and to the general nature of internal representations (Rosch, 1973). Indeed, the fact that infants have been shown to categorize stimuli without extensive training in both the visual (Colombo, O'Brien, Mitchell, Roberts, & Horowitz, 1987b; Roberts & Horowitz, 1986; Sherman, 1985) and au-

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ditory (e.g., Kuhl, 1985) modalities during the second half of the first year suggests the potential importance of this fundamental ability to the development of complex higher-order skills. Toward this end, some reports (e.g., Caron & Caron, 1981; Caron, Caron, & Glass, 1983) have suggested a direct empirical relationship between the ability to form stimulus classes or categories and later cognitive functioning.

Most current theories of both adult and infant categorization hold that some representation of the stimulus class is formed through the exposure of various examples ("exemplars") of the general class (Rosch, 1973, 1978). The physical properties of the various exemplars are then "averaged" into a prototypical representation of the stimulus class. Support for this type of processing early in life has emerged (Bomba, 1984; Bomba & Siqueland, 1983) from studies in which infants are habituated to a series of exemplars of a particular geometric form category (e.g., triangle) whose dimensions vary, and then tested for attention to either a "prototypical" stimulus (i.e., a form from the same class whose features represent the average of all the other previously exposed stimuli) or one of the previously-exposed examplars. Infants typically attend more to a stimulus less well-represented in memory (Fagan, 1971), and in support of prototype theory, following such habituation sequences they attend more to the previously exposed exemplar rather than the previously unseen "prototype," thus suggesting that the prototype has indeed been internally represented better than the various exemplars that form the prototype (Bomba & Siqueland, 1983). Very recently, Roberts (1988) has also demonstrated that prototypical examples of a stimulus category are retained longer than those examples that are less prototypical of that category.

The formation of such a prototypical representation or category, however, is based both on the ability of the infant to attend to those stimulus dimensions that constitute the prototype, as well as the ability of the infant to ignore those stimulus dimensions that are not relevant to the prototype. Although there has been much recent work on infants' ability to generalize across relevant dimensions, there has been little work on the nature of early abilities in the exclusion of particular stimulus features or dimensions from a categorical representation. For example, at this time it is unknown whether young infants will spontaneously generalize a particular stimulus dimension category across other dimensions with which they have had no experience. Furthermore, the degree to which the presence of another stimulus dimension (or dimensions) will interfere with the formation of a category during infancy is also unknown; a number of theories of stimulus dimension processing clearly predict that such should be the case under conditions in which "extraneous" dimensions are present (e.g., Trabasso & Bower, 1968).

The following report describes a programmatic series of five experi-

ments of categorization in 10-month-olds
bituation and paired-comparison test p
Mitchell, & Horowitz, 1987b). In these exp
were systematically varied across exposu
explore the structure of the infant's interna
stimulus-dimension class of form. These
infant's ability to categorize form; the stud
the manner in which the introduction of
(color) during exposure and test phases
the category, and the infant's categorizati

EXPERIMENT

Method

Subjects. Twenty-four full-term 10-mont
and telephone from the greater metropoli
sample, four infants were excluded from
siness (n = 3) or maternal interference w
leaving a final sample of 20, balanced a
graphic means for the sample are present

Apparatus. Infants were tested on a pare
inside a 2-m × 3-m booth. The booth wa
top with black fabric, with a front wall of
m × 0.7 m translucent screen was cente
used in all the experiments described in t

Stimuli. Eight stimuli were modelled aft
two major tree categories, oak and maple.
by tracing examples from a botany book on
cutting the tracings, and then mounting t
Of these eight forms, there were four "oa
Based on three adults' independent judgn
prototypical form was selected for each of

TABLE 1
DEMOGRAPHIC CHARACTERISTICS
FROM EXPERIMENT

Variable	
Gestational age (wks)	
Birthweight (g)	33
Mother's age (yrs)	
Father's age (yrs)	
Mother's education (yrs)	
Father's education (yrs)	
Number of siblings	

alities during the second half of the first
portance of this fundamental ability to the
er-order skills. Toward this end, some re-
1981; Caron, Caron, & Glass, 1983) have
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es a programmatic series of five experi-

ments of categorization in 10-month-olds using a multiple-exemplar habituation and paired-comparison test paradigm (Colombo, O'Brien, Mitchell, & Horowitz, 1987b). In these experiments, stimulus dimensions were systematically varied across exposure and test phases in order to explore the structure of the infant's internal representation of a particular stimulus-dimension class of form. These studies first demonstrate the infant's ability to categorize form; the studies that follow then investigate the manner in which the introduction of a second stimulus dimension (color) during exposure and test phases affect the infant's learning of the category, and the infant's categorization performance.

EXPERIMENT 1

Method

Subjects. Twenty-four full-term 10-month-olds were recruited by mail and telephone from the greater metropolitan Kansas City area. Of this sample, four infants were excluded from data analysis because of fussiness (n = 3) or maternal interference with infants' looking (n = 1), leaving a final sample of 20, balanced approximately for sex. Demographic means for the sample are presented in Table 1.

Apparatus. Infants were tested on a parent's lap while both were seated inside a 2-m × 3-m booth. The booth was darkened on three sides and top with black fabric, with a front wall of black plywood in which a 1.0 m × 0.7 m translucent screen was centered. This same apparatus was used in all the experiments described in this report.

Stimuli. Eight stimuli were modelled after leaf forms of subspecies of two major tree categories, oak and maple. The stimuli were constructed by tracing examples from a botany book onto colored construction paper, cutting the tracings, and then mounting them on a white background. Of these eight forms, there were four "oak" and four "maple" stimuli. Based on three adults' independent judgments, a most representative, prototypical form was selected for each of the two categories as a "test"

TABLE 1
DEMOGRAPHIC CHARACTERISTICS OF THE SAMPLE FROM EXPERIMENT 1

Variable	*M*	*SD*
Gestational age (wks)	40.2	1.20
Birthweight (g)	3378.0	472.0
Mother's age (yrs)	30.8	5.67
Father's age (yrs)	32.4	4.16
Mother's education (yrs)	15.4	1.74
Father's education (yrs)	16.1	1.83
Number of siblings	0.6	0.53

stimulus, while the remaining three stimuli were retained as "exemplars." Discrimination of each of the exemplars from the prototypical test stimulus within each of the categories has been demonstrated with 6- and 9-month-old infants in our laboratory (Colombo, Mitchell, Coldren, & McCollam, 1989b). The stimuli are presented in Fig. 1. For this first experiment, the color of the forms was held constant: light green on a white background. Stimulus slides were rear-projected (Kodak 650H Carousel) onto the translucent screen, with each slide subtending a visual angle of 19°.

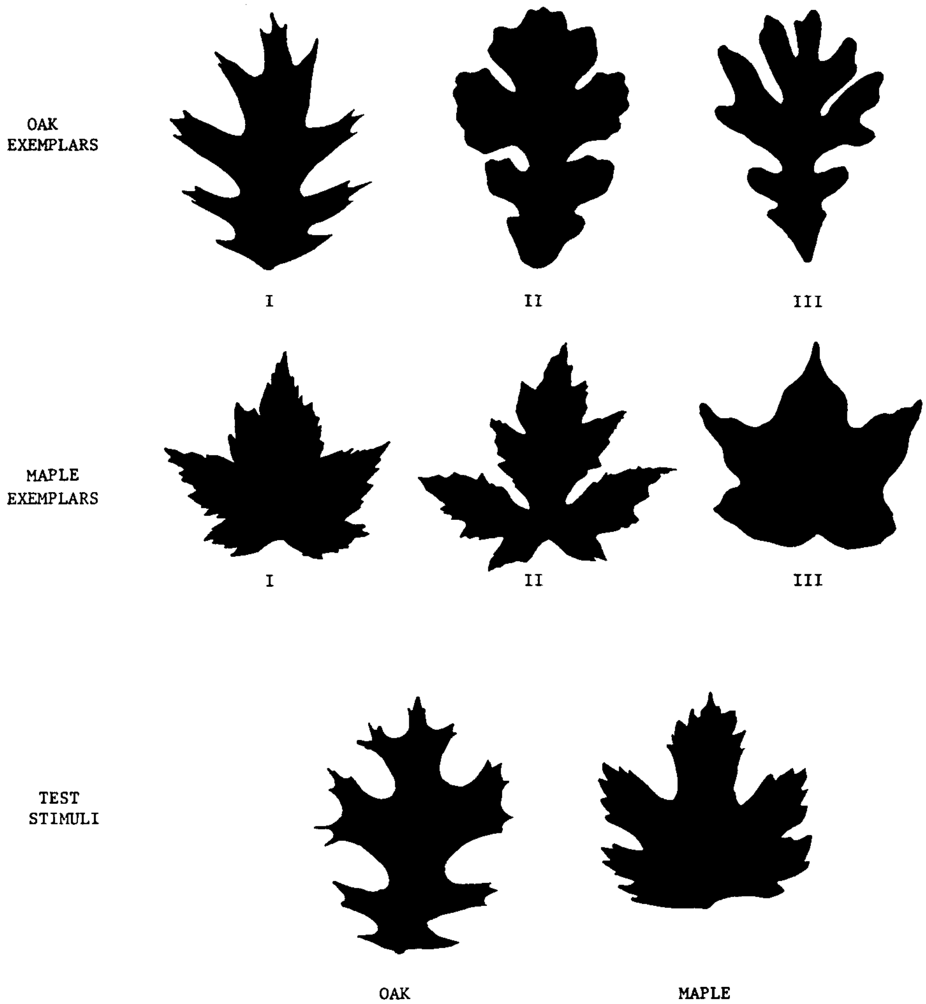

FIG. 1. Stimulus forms used in the habituation and test phases of the five experiments.

Procedure and design. The laboratory s
acquisition phase based on visual habit
followed immediately by a paired-compa
jects' category discrimination was assess

During the habituation phase, stimuli v
the screen. Half the infants were shown
were shown the "maple" category. The
form exemplars for each form category
a Latin-Square design. Fixations were co
infant to the stimulus lasted 1 s or more,
away from the stimulus for at least 1 s (C
2-s interstimulus interval followed the en
the presentation of the next slide. An obs
stimulus being presented recorded infan
corneal reflections through a 20 mm pee
of the screen.

Presentations of the exemplars contin
time to an entire block declined to a pred
half of the longest previous block (see
with the constraint that the infant be prese
(to ensure that each subject would see the
order). Observer reliability was assessed i
a second observer independently judged f
between the two observers' records rang

Immediately following the habituation
category was assessed during two paired-
infants accumulated a total of 10 s of
presentations of the test stimuli (see Fig.
edges of the screen. In this paired-comp
the test stimuli was identical to those pre
phase, and separated by a visual angle of
of the two stimuli was counterbalanced ac
were reversed for the second 10-s test tr
sitional looking bias.

The stimuli shown during the test phase
a novel in-category stimulus or a novel
example, the maple-test stimulus would b
for infants habituated to the oak exempl
would be the out-of-category stimulus for
exemplars. Since infants older than two
attend to a novel stimulus when paired w
"familiar") one (e.g., Fagan, 1971), if the
as a category, then they should show g
category stimulus than to the novel in-c

three stimuli were retained as "exem-
ı of the exemplars from the prototypical
e categories has been demonstrated with
our laboratory (Colombo, Mitchell, Col-
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the forms was held constant: light green
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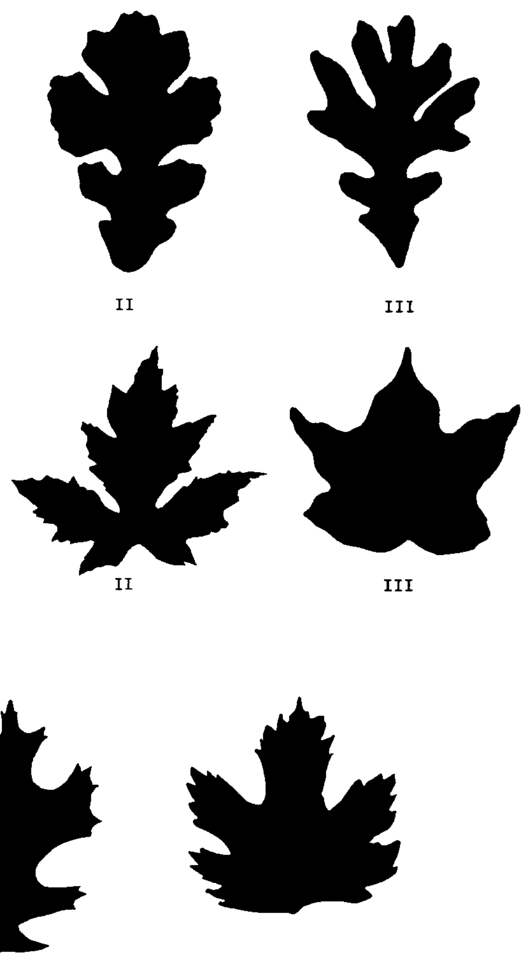

abituation and test phases of the five experiments.

Procedure and design. The laboratory session consisted of a category-acquisition phase based on visual habituation to multiple exemplars, followed immediately by a paired-comparison test phase in which subjects' category discrimination was assessed.

During the habituation phase, stimuli were projected in the center of the screen. Half the infants were shown the "oak" form category, half were shown the "maple" category. The presentation order of the three form exemplars for each form category was balanced across blocks in a Latin-Square design. Fixations were counted if the look made by the infant to the stimulus lasted 1 s or more, and were terminated by a look away from the stimulus for at least 1 s (Colombo & Horowitz, 1985). A 2-s interstimulus interval followed the end of each fixation, followed by the presentation of the next slide. An observer who was "blind" to the stimulus being presented recorded infants' fixation to the stimuli via corneal reflections through a 20 mm peephole situated on the left edge of the screen.

Presentations of the exemplars continued until the infant's looking time to an entire block declined to a predetermined criterion of less than half of the longest previous block (see Colombo et al., 1987a, 1987b) with the constraint that the infant be presented with three stimulus blocks (to ensure that each subject would see the full Latin-Square presentation order). Observer reliability was assessed in 25% of the sessions, in which a second observer independently judged fixation durations. Correlations between the two observers' records ranged from +.94 to +.99.

Immediately following the habituation sequence, acquisition of the category was assessed during two paired-comparison test trials in which infants accumulated a total of 10 s of fixation time to simultaneous presentations of the test stimuli (see Fig. 1) on the left and right outer edges of the screen. In this paired-comparison test phase, the size of the test stimuli was identical to those presented during the habituation-phase, and separated by a visual angle of 24°. The initial lateral position of the two stimuli was counterbalanced across subjects, and the positions were reversed for the second 10-s test trial to control for possible positional looking bias.

The stimuli shown during the test phase allowed infants to fixate either a novel in-category stimulus or a novel out-of-category stimulus. For example, the maple-test stimulus would be the out-of-category stimulus for infants habituated to the oak exemplars, and the oak-test stimulus would be the out-of-category stimulus for infants habituated to the maple exemplars. Since infants older than two months of age will selectively attend to a novel stimulus when paired with a previously exposed (i.e., "familiar") one (e.g., Fagan, 1971), if they were treating the leaf forms as a category, then they should show greater attention to the out-of-category stimulus than to the novel in-category stimulus (Colombo et al., 1987b), despite the fact that both stimuli are new to them. Therefore, to assess acquisition of the form category, we calculated infants' preferences for the novel out-of-category stimulus. Interobserver reliability for this preference was +.91.

Results and Discussion

Preliminary analyses indicated no differences in infants' habituation-phase visual behavior as a function of form category, and so results are collapsed across the two categories for presentation. Means for attentional variables from this experiment (and the experiments that follow) appear in Table 2.

The crucial test of this experiment was whether infants preferentially attended to the out-of-category exemplar during the paired-comparison test phase. Infants fixated this stimulus 58% of the time, collapsed across the two test trials; this percentage significantly exceeded chance (50%) responding, $t(19) = 4.34$, $p < .001$, indicating that infants indeed categorized the forms. The preference for the out-of-category exemplar was not significantly different between the two form conditions, $t(18) = 0.01$.

EXPERIMENT 2

Experiment 1 demonstrated that 10-month-olds could categorize these forms when all other stimulus dimensions were held constant. In Experiment 2, we sought to determine whether 10-month-olds could categorize form when another dimension (color) was varied during the habituation phase.

TABLE 2
MEANS (AND STANDARD DEVIATIONS) FOR ATTENTIONAL MEASURES FROM EXPERIMENTS 1–5

	Experiment				
	1	2	3	4	5
Attentional variable					
Number of fixations to criterion	13.8 (4.4)	12.9 (3.9)	17.0 (7.5)	18.6 (7.4)	19.0 (9.4)
Total fixation time to criterion (s)	81.7 (36.7)	87.3 (50.3)	87.8 (28.9)	113.1 (100.3)	114.6 (61.3)
Duration of peak fixation (s)	16.2 (8.5)	19.1 (11.1)	14.6 (4.3)	16.8 (9.4)	18.7 (9.6)
Total interlook interval (s)	48.7 (17.4)	42.1 (13.2)	58.3 (27.1)	66.3 (54.4)	74.8 (65.3)
Preference for novel form	0.58 (0.08)	0.57 (0.07)	0.43 (0.06)	0.59 (0.12)	0.57 (0.09)
Shifts during test trials	7.2 (1.7)	7.8 (1.8)	9.6 (1.9)	8.5 (1.9)	9.5 (3.4)

Method

Subjects. For this study, 23 full-term
cruited, of whom three were excluded f
fussiness. Demographic characteristics of
those infants in Experiment 1.

Apparatus and stimuli. Infants were test
and with the same equipment as in Exper
ulus color was held constant during Expe
stimuli employed in this second experim
The three habituation exemplars were pres
colors (red, blue, and brown; all projec
Because complete counterbalancing of sti
emplar would have required a habituation
(and therefore a procedural change from E
were partially balanced in a fixed order
3. Although the color of the stimuli was
color of the stimuli presented during the
was green, as in Experiment 1.

Procedure and design. The habituation
test (two 10-s paired-comparison trials) ph
tical to those described for Experiment 1
shown the oak-form category and half sh

Results and Discussion

Preliminary analyses indicated no differ
ior during habituation as a function of fo
collapsed across the categories for preser

Again, we sought to determine whether
to the out-of-category exemplar during the

TABLE 3
STIMULUS-COLOR COMBINA
PRESENTATION ORDER FOR E

Block no.	Trial no.	Sl
	1	
1	2	
	3	
	4	
2	5	
	6	
	7	
3	8	
	9	

ıt both stimuli are new to them. Therefore, ɔrm category, we calculated infants' pref- :ategory stimulus. Interobserver reliability

ted no differences in infants' habituation- ıction of form category, and so results are ·gories for presentation. Means for atten- eriment (and the experiments that follow)

eriment was whether infants preferentially y exemplar during the paired-comparison stimulus 58% of the time, collapsed across ıtage significantly exceeded chance (50%) .001, indicating that infants indeed cate- ence for the out-of-category exemplar was een the two form conditions, $t(18) = 0.01$.

⟨PERIMENT 2

that 10-month-olds could categorize these s dimensions were held constant. In Ex- rmine whether 10-month-olds could cate- ıension (color) was varied during the ha-

TABLE 2

ɔR ATTENTIONAL MEASURES FROM EXPERIMENTS 1–5

Experiment				
1	2	3	4	5
13.8	12.9	17.0	18.6	19.0
(4.4)	(3.9)	(7.5)	(7.4)	(9.4)
81.7	87.3	87.8	113.1	114.6
36.7)	(50.3)	(28.9)	(100.3)	(61.3)
16.2	19.1	14.6	16.8	18.7
(8.5)	(11.1)	(4.3)	(9.4)	(9.6)
48.7	42.1	58.3	66.3	74.8
17.4)	(13.2)	(27.1)	(54.4)	(65.3)
0.58	0.57	0.43	0.59	0.57
(0.08)	(0.07)	(0.06)	(0.12)	(0.09)
7.2	7.8	9.6	8.5	9.5
(1.7)	(1.8)	(1.9)	(1.9)	(3.4)

Method

Subjects. For this study, 23 full-term 10-month-old infants were recruited, of whom three were excluded from data analysis because of fussiness. Demographic characteristics of this sample did not vary from those infants in Experiment 1.

Apparatus and stimuli. Infants were tested in the same darkened booth and with the same equipment as in Experiment 1. However, while stimulus color was held constant during Experiment 1, the habituation-phase stimuli employed in this second experiment was systematically varied. The three habituation exemplars were presented in each of three different colors (red, blue, and brown; all projected on a white background). Because complete counterbalancing of stimulus category, color, and exemplar would have required a habituation phase lasting at least 27 trials (and therefore a procedural change from Experiment 1), color and stimuli were partially balanced in a fixed order of nine stimuli listed in Table 3. Although the color of the stimuli was varied during habituation, the color of the stimuli presented during the paired-comparison test phase was green, as in Experiment 1.

Procedure and design. The habituation (50% decrement criterion) and test (two 10-s paired-comparison trials) phases of the sessions were identical to those described for Experiment 1. Again, half the infants were shown the oak-form category and half shown the maple-form category.

Results and Discussion

Preliminary analyses indicated no differences in infants' visual behavior during habituation as a function of form category, and so data are collapsed across the categories for presentation (see Table 2).

Again, we sought to determine whether infants preferentially attended to the out-of-category exemplar during the paired-comparison test phase.

TABLE 3

STIMULUS-COLOR COMBINATIONS AND PRESENTATION ORDER FOR EXPERIMENT 2

Block no.	Trial no.	Shape	Color
	1	I	Blue
1	2	II	Red
	3	III	Brown
	4	II	Brown
2	5	III	Blue
	6	I	Red
	7	III	Red
3	8	I	Blue
	9	II	Brown

Infants fixated this stimulus 57% of the time, collapsed across the two test trials. This percentage significantly exceeded chance (50%) fixation, $t(19) = 5.24$, $p < .001$, indicating that these infants were able to categorize form even when an additional salient stimulus dimension (i.e., color) was varied during the category-acquisition phase. Again, infants' categorization performance did not significantly vary as a function of the form category, $t(18) = 0.84$.

EXPERIMENT 3

Experiment 1 showed that 10-month-old infants were able to categorize a particular type of form, and Experiment 2 showed this ability to be unaffected by variation in another dimension of the stimulus exemplars (color) irrelevant to infants' processing of form. However, in each of these previous experiments, the test trials were constructed such that no stimulus dimensions other than form was varied. Under such a procedure, categorization is examined only under conditions where all of the dimensions present during the test phase are dimensions to which infants have had previous exposure. In settings outside of the laboratory, infants (and adults) must learn categories in situations where many stimulus dimensions are varying, but must also learn to make responses based on those categories under conditions in which such other dimensions are varying. In terms of the present experiment, such a generalized response to the category would be tested by having infants learn a "form" category under conditions in which no other stimulus dimension is varied, and then test for categorical responding under conditions in which another stimulus dimension is introduced. If infants were capable of completely generalized responding, then they should still make the response to the form category, as in Experiments 1 and 2. If, however, the acquired category was limited to the specific examples that were presented during the acquisition (habituation) sequence, the introduction of the new stimulus dimension should prevent the categorization-based response. These predictions were tested in Experiment 3, where infants were habituated to a form sequence in which color was held constant, and then tested for categorization with a test phase in which a novel stimulus dimension was introduced.

Method

Subjects. Twelve 10-month-olds were recruited as previously described. No subject loss occurred in this study. The demographic characteristics of the sample were not different from those for previous experiments. The sample size for Experiment 3 is smaller than that for the other experiments reported here, but this cannot account for the failure to categorize, especially since the direction of the response is statistically significant in the opposite direction. The original design

planned for the study included 24 infants
ancing) in the study, but the trend agair
was so evident with only one infant per c
to double the sample size.

Procedure and design. Infants were ha
used in Experiment 1, in which the color
(green on white background). The same 5
in the previous two studies was employed
habituated to oak forms, half to maple fo
s paired-comparison test trials, the famil
presented in a novel color (red, blue, or b
across subjects), while the novel (out-of
in the green color used during familiariz
categorization of form, infants would ha
previously unexposed color.

Results and Discussion

Attentional data from this experiment a
did not demonstrate categorization for t
periment; their preference for the novel,
43%. In fact, this preference is significant
$p < .001$. This finding did not vary as
$t(6) = 0.29$), indicating that the presentat
with the infants' categorization-based re
direction of these results also suggests th
fact dominant over the form dimension.

The finding that variation on the color c
prevented infants from demonstrating for
questions regarding the nature of this d
plausibly be attributed to three possible so
any variation in color during paired-co
tracted infants from an attentional respon
Second, since the variation of color in t
involved presentation of a previously u
may be attributable simply to the presen
trials. Third, and most interesting from
interference may be linked to a deficiency
with the form exemplars. In Experiment 3
during habituation were not shown und
varied. If this third alternative was tru
responses under such test-phase variatio
exposing them to exemplars that varied in
of this report were conducted in order to

7% of the time, collapsed across the two
nificantly exceeded chance (50%) fixation,
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ategory-acquisition phase. Again, infants'
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(PERIMENT 3

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l here, but this cannot account for the
since the direction of the response is
pposite direction. The original design

planned for the study included 24 infants (two per cell with counterbalancing) in the study, but the trend against the categorization response was so evident with only one infant per cell that it seemed unnecessary to double the sample size.

Procedure and design. Infants were habituated to the same sequence used in Experiment 1, in which the color of all forms was held constant (green on white background). The same 50% decrement procedure used in the previous two studies was employed here, and half the infants were habituated to oak forms, half to maple forms. However, on the two 10-s paired-comparison test trials, the familiarized (in-category) form was presented in a novel color (red, blue, or brown; this was counterbalanced across subjects), while the novel (out-of-category) form was presented in the green color used during familiarization. In order to demonstrate categorization of form, infants would have to ignore the novelty of a previously unexposed color.

Results and Discussion

Attentional data from this experiment are presented in Table 2. Infants did not demonstrate categorization for the form dimension in this experiment; their preference for the novel, out-of-category form was only 43%. In fact, this preference is significantly *below* chance, $t(11) = 4.37$, $p < .001$. This finding did not vary as a function of form category, $t(6) = 0.29$), indicating that the presentation of a novel color interfered with the infants' categorization-based response to form. The reversed direction of these results also suggests that the color dimension was in fact dominant over the form dimension.

The finding that variation on the color dimension during the test phase prevented infants from demonstrating form categorization raised several questions regarding the nature of this deficit. This interference could plausibly be attributed to three possible sources. First, simply presenting *any variation* in color during paired-comparison trials may have distracted infants from an attentional response based on the form-category. Second, since the variation of color in the test trials of Experiment 3 involved presentation of a previously unseen color, such interference may be attributable simply to the presentation of a *novel* color on test trials. Third, and most interesting from a process point of view, such interference may be linked to a deficiency in infants' previous experience with the form exemplars. In Experiment 3, the form exemplars presented during habituation were not shown under conditions where color was varied. If this third alternative was true, then infants' categorization responses under such test-phase variation could be retained by simply exposing them to exemplars that varied in color. The final two eperiments of this report were conducted in order to test each of these hypotheses.

EXPERIMENT 4

In this fourth experiment, infants were habituated to form exemplars while color was varied (as in Experiment 2), and also while colors were varied on the test trial (as in Experiment 3). This experiment addressed whether any color-based variation on test trials would produce a deficit in the categorization response.

Method

Subjects. Twenty-six 10-month-old infants were recruited for this study. Two of these were excluded for fussiness, leaving a total of 24 infants in the final sample. The demographic characteristics of the sample were not different from those for previous experiments.

Procedure and design. Infants were habituated to form exemplars as in the previous experiments, using the 50% decrement procedure used in the previous experiments and the Latin-Square form order shown in Table 3. Following habituation, categorization was assessed in two 10-s paired-comparison choice trials as in the previous experiments.

While the previous block procedures were based on the use of three colors and three forms, this study used all four colors (red, blue, green, and brown) that were available and used in the previous experiments. However, complete between-subject counterbalancing for the two form types with all four colors under the three-exemplar habituation block procedure (eight possible combinations), combined with complete test-phase counterbalancing for both color and positional combinations (12 possible combinations), would have required at least 96 subjects. In order to streamline the design, we employed only two of the habituation color orders (all four colors appeared during these orders, but in one order, green appeared more than once, and in another, brown appeared more than once), and 12 of the test-phase orders (the use of colors were counterbalanced, but position was randomly determined). This design required a more reasonable sample size of 24 and yielded results that were in our estimation no less generalizable than a completely counterbalanced design.

Results and Discussion

Attentional data for this experiment are presented in Table 2. Under conditions in which color was varied during the habituation sequence in which infants were exposed to the form exemplars, color variation on the test trials did not interfere with infants' categorization of form, as their visual preference for the out-of-category exemplar was 59%, significantly higher than chance, $t(23) = 3.58$, $p < .01$. This did not vary as a function of category form, $t(12) = 0.34$.

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EXPERIMENT 5

In Experiment 4, we ruled out the possibility that variation in color during test trials per se precluded the demonstration of form categorization in 10-month-olds. By exposing infants to form exemplars that varied in color during the habituation sequence, infants clearly differentially attended to the out-of-category form on test trials, despite the fact that the two stimuli presented varied in color. However, it was still possible that the interference for form categorization demonstrated in Experiment 3 might not have been due to simply variation in color during test trials, but rather to the presentation of a *novel* color during the test trials. In this final experiment we habituated infants to form exemplars across which three colors varied (similar to Experiment 2). On the test trials, however, we presented the familiarized, in-category form in the novel color (as in Experiment 3) and the novel, out-of-category form in one of the colors shown during the habituation sequence. If infants failed to demonstrate form categorization in this study, it could be unequivocally attributed to the presence of a novel color during test trials. However, if infants did demonstrate form categorization in this study, it would indicate that he deficit incurred in Experiment 3 was attributable to a deficit in experience with form-color compounds, and would further suggest that the robustness of the categorization response was a direct function of the diversity of the exemplars exposed while infants learned the form category during the habituation sequence.

Method

Subjects. Twenty-six 10-month-old infants were recruited for this study. Two exclusions for fussiness left a final sample of 24. The demographic characteristics of the sample were not different from those for previous experiments.

Procedure and design. Infants were habituated to form exemplars using the 50% decrement criterion and tested for categorization with two 10-s choice trials, as in the previous experiments. The presentation of the three form exemplars was balanced across three different colors, with the fourth color used for the in-category stimulus during the test trials. On each of the test trials, the out-of-category stimulus was presented in one of the colors shown during the habituation sequence. The colors used during habituation, the color used for the test-trials in-category stimulus, and the colors used for the test-trial out-of-category stimulus were all counterbalanced between subjects. Assignment of stimulus position during test trials was random.

Results and Discussion

Attentional data from this final study are presented in Table 2. Infants' mean visual preference for the out-of-category stimulus collapsed across test trials was 57%. This significantly exceeded chance levels, $t(23) = 3.90$, $p < .001$, and did not vary as a function of the form category exposed during habituation, $t(12) = .02$. Therefore, when infants were habituated to form exemplars under conditions where color varied, the introduction of a completely novel color during the test phase did not interfere with infants' form categorization.

GENERAL DISCUSSION

These five experiments constitute a systematic investigation of infant visual categorization of one stimulus dimension (form) under conditions in which a second dimension (color) was varied across habituation (i.e., acquisition) and test phases.

In Experiment 1, infants were observed to categorize form when all other dimensions were held constant. In Experiment 2, color was varied during the habituation phase, but this did not interfere with form categorization. Only Experiment 3 demonstrated a failure by infants to categorize, as the test-phase presentation of a novel color following constant-color habituation presentations interfered with the categorization response. Experiments 4 and 5 tested two possibilities concerning the nature of infants' failure in Experiment 3: (1) was this interference due to the variation of color during the test trials, to a presentation of a *novel* color during the test trial per se, or (2) was this interference due to the limited exposure to exemplars during a habituation sequence in which color was not varied? The latter alternative was supported, as infants successfully categorized form when color was varied across the test trials (Experiment 4), and even when one of the colors varied across the test trials was a novel one (Experiment 5). To rule out the possibility that differences in infants' habituation sequences may have produced the differences observed across experiments (i.e., such differences in categorization response may have been attributed to systematic differences in habituation as a function of the stimulus dimensions varied during such exposure, or as a function of the degree of variability encountered on dimensions), we performed a one-way multivariate analysis of variance with a between-subject factor of Experiment 5 including the habituation variables of number of fixations to criterion, total duration of fixation to critrion, duration of peak fixation, and total interlook interval. This analysis did not yield a significant term (Multivariate $F(16, 282) = 1.11$, ns), indicating that such differences could not be invoked to account for these results. The finding that infants' habituation did not vary as a function of the number of dimensions present (as indicated by this nonsignificant multivariate analysis) in the stimulus categorization sequences is theoretically interesting, given the widespread belief that the length of the habituation sequence should vary directly as a function of the amount of information to be encoded from the stimuli presented (e.g.,

Jeffrey & Cohen, 1971; see also similar g
& Bower, 1968). Perhaps visual habituat
infants of this older age of the difficulty ir
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The results of these experiments are
indicate both limitations and capabilities ir
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TABLE 4
Summary of Results of the Five Form C

Experiment	Habituation phase[a]	T
1	Color constant	Color
2	Color varied (3)	Color
3	Color constant	Color
4	Color varied (4)	Color
5	Color varied (3)	Color

[a] Number in parentheses indicates number of colo
[b] Designation of novel in parentheses indicates t
was presented in a novel color.

ificantly exceeded chance levels, $t(23)$ =
vary as a function of the form category
(12) = .02. Therefore, when infants were
under conditions where color varied, the
novel color during the test phase did not
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RAL DISCUSSION

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Jeffrey & Cohen, 1971; see also similar general predictions in Trabasso & Bower, 1968). Perhaps visual habituation is not a sensitive index in infants of this older age of the difficulty incurred by the addition of such extra dimensions.

The results of these experiments are summarized in Table 4, and indicate both limitations and capabilities in 10-month-olds' categorization of form across color. Infants of this age will successfully generalize across an "irrelevant" stimulus dimension only if they experience exemplars of that category across which that irrelevant dimension is varied. Furthermore, however, if infants *do* experience such variation in that irrelevant stimulus dimension, the presentation of a novel (i.e., unexperienced) attribute on that irrelevant dimension on the exemplar will not preclude inclusion that exemplar in the category in question.

These points have several important theoretical implications for the development of categorization during early life. First, the suppression of the categorization response under conditions of limited variation in exemplar stimuli suggest that infants would not be likely to show spontaneous generalization or class inclusion across stimulus dimensions with which they have not had experience; thus, the formation of categories or stimulus classes based on single exposures reported for older subjects (see, e.g., Rosch & Lloyd, 1973) is unlikely to occur with preverbal infants such as these 10-month-olds. Perhaps such single-exemplar categorization may be attributed to verbal mediation (see Diamond, 1988) or the acquisition of superordinate categories. Second, these findings strongly support the Gibsonian (e.g., Gibson, 1967) position that the extraction of invariance from perceptual displays is a relatively basic psychological function early in life, but that such extraction is truly a perceptual-learning process that is largely dependent on previous exposure to stimulus dimensions from which invariance can be judged. Third, 10-month-olds' ability to ignore a novel attribute in an irrelevant dimension while responding categorically to another, "relevant" dimen-

TABLE 4
Summary of Results of the Five Form Categorization Experiments

Experiment	Habituation phase[a]	Test phase[b]	Categorization?
1	Color constant	Color constant	Yes
2	Color varied (3)	Color constant	Yes
3	Color constant	Color varied (novel)	No
4	Color varied (4)	Color varied	Yes
5	Color varied (3)	Color varied (novel)	Yes

[a] Number in parentheses indicates number of colors varied during habituation sequence.
[b] Designation of novel in parentheses indicates that the familiarized, in-category form was presented in a novel color.

sion (following experience with exemplars where both dimensions are varied) reflect at least a rudimentary capacity for dimensionalized stimulus processing (e.g., Trabasso & Bower, 1968).

A last point concerning these findings regards infants' alternate fixation ("shifts") between paired stimuli during the choice trials. Such shifts are generally taken as an index of the difficulty of the cognitive task at hand for infants, as even young infants shift more when paired stimuli are less discriminable (Colombo, Mitchell, & Horowitz, 1988; Ruff, 1975), and generally low rates of shifting early in infancy are correlated with good memory performance during the second year of life (Colombo, Mitchell, Dodd, Coldren, & Horowitz, 1989a). A one-way cross-experiment analysis of variance (5 levels: Experiment) on infants' shifts during test trials yielded a significant effect ($F(4, 95) = 3.90$, $p < .01$). We judged the order of difficulty of the three experiments from easiest to hardest as follows: Experiment 1 (in which form was the only dimension manipulated); Experiment 2 (in which form and color were manipulated during habituation, but color was not a factor during test trials); Experiment 4 (in which both color and form were manipulated during habituation and test trials were constructed so that neither color nor form had an advantage); Experiment 5 (in which color and form were manipulated during habituation but a novel color appeared during the test trials); and Experiment 3 (in which only form was manipulated during habituation, but both form and a novel color were manipulated during the test trials). If the experiments are ordered in terms of the difficulty of the categorization tasks involved, a distinctly linear trend ($F(1, 95) = 15.05$, $p < .001$) in the number of shifts emerges, with shifting occurring least in Experiment 1 (in which color was not involved as a stimulus factor whatsoever) and most in Experiments 4 and 5 (in which the out-of-category form competed for infants' attention with a previously unseen color). The means for the five experiments in the order listed here are 7.2, 7.5, 8.5, 9.5, and 9.6, and a Tukey HSD test probing the significant analysis of variance term indicated that the number of shifts during Experiment 1 were significantly less than the number of shifts occurring during either Experiment 4 or 5 ($p < .05$). Thus, these infants showed a higher degree of active comparison between stimuli under conditions where the categorization task was most difficult, and lesser amounts when the task was easier. This finding further suggests that the shift measure may be a sensitive index of the difficulty of perceptual-cognitive tasks for preverbal infants.

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Problems Brought About by "F
of Picture

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Caisse Régionale d'Assurance Maladie d'Ile de
Enfants, Boulogne,

The "reading" of a sequence of narrative pic
cognitive area. Sequences of pictures were pr
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