The Categorization of above and below Spatial Relations by Young Infants
Author(s): Paul C. Quinn
Source: *Child Development*, Vol. 65, No. 1 (Feb., 1994), pp. 58-69
Published by: Blackwell Publishing on behalf of the Society for Research in Child Development
Stable URL: http://www.jstor.org/stable/1131365
Accessed: 07/01/2010 12:46

The Categorization of Above and Below Spatial Relations by Young Infants

Paul C. Quinn
Washington and Jefferson College

Quinn, Paul C. *The Categorization of Above and Below Spatial Relations by Young Infants.* Child Development, 1994, **65**, 58–69. 3 experiments using the familiarization-novelty preference procedure were conducted to investigate whether 3-month-old infants could form categorical representations of the spatial relations above and below. In Experiment 1, one group of infants familiarized with exemplars depicting a dot in different positions above a horizontal bar displayed a subsequent visual preference for a novel category exemplar (dot below bar) that was paired with a familiar category exemplar (dot in novel position above bar). A second group of infants presented with exemplars in which the dot appeared in variable locations below the bar also responded preferentially to a novel category exemplar (dot above bar) when it was paired with a familiar category exemplar (dot in new position below bar). These preferences did not result from the salience of vertical up-down changes in dot position or the encoding of dot positions relative to an *internal* horizontal midline (Experiment 3) or from an inability to discriminate the members of each category (Experiment 2), but rather would seem to be a consequence of the ability to represent categorically the spatial relations above and below. The data provide evidence for early categorical organization in human spatial memory.

In the past 20 years researchers have shown that human infants have the capacity to form categorical representations of their experiences (see Eimas & Miller, 1990). This early ability to categorize occurs in different domains, including speech (e.g., Eimas, Miller, & Jusczyk, 1987) and vision (e.g., Quinn & Eimas, 1986; Reznick, 1989). Within the domain of vision, there is evidence that categorization occurs for different levels of stimulus information. For example, 3- and 4-month-old infants have been shown to categorize local attributes of stimuli such as orientation (Bomba, 1984; Quinn & Bomba, 1986) and hue (Bornstein, 1983; Bornstein, Kessen & Weiskopf, 1976). Infants under 1 year of age have also been shown to form categorical representations for more global visual patterns including angles (Slater, Mattock, Brown, & Bremner, 1991), forms (Bomba & Siqueland, 1983; Colombo, McCollam, Coldren, Mitchell, & Rash, 1990; Quinn, 1987; Younger & Gotlieb, 1988), black-and-white schematic faces and animals (Roberts, 1988; Sherman, 1985; Strauss, 1979; Younger, 1990), and photographic exemplars of women's faces and animals (Cohen & Strauss, 1979; Quinn, Eimas, & Rosenkrantz, 1993).

The early formation of categorical representations for objects and their attributes would appear to reflect the operation of biologically given processes of categorization that are driven by the large number of exemplars and categories encountered in the first few months of life (Bomba & Siqueland, 1983; Eimas & Miller, 1990; Quinn, 1987). The information-processing consequences of object categorization are adaptive and include organized storage, efficient retrieval, and the capability of responding equivalently to an indefinitely large number of exemplars from multiple categories.

Although the evidence and advantages of infants' parsing the environment into physical object categories are reasonably clear, less has been written about infants' abilities to parse physical space into categories defined by the positional arrangement of these objects (see Jackendoff & Landau, 1991, for similar observations regarding object and spatial categories in adulthood). The question is whether, in addition to categoriz-

Portions of this study were presented at the Society for Research in Child Development meeting, Seattle, WA, April 1991. I thank Peter Eimas, Gregory Murphy, and three anonymous reviewers for their critical comments. I also thank Phillipe Schyns for assistance in preparing the figures and Barbara Rea for help in all phases of manuscript preparation. Correspondence and reprint requests should be sent to Paul C. Quinn, Department of Psychology, Washington and Jefferson College, Washington, PA 15301.

[*Child Development*, 1994, **65**, 58–69. 0009-3920/94/6501-0009$01.00]

ing objects, infants also make categorical distinctions between their possible spatial relations such as above versus below, left versus right, and inside versus outside. Investigations of spatial memory in both adults (e.g., Hirtle & Jonides, 1985; McNamara, Hardy & Hirtle, 1989) and children (e.g., Kosslyn, Pick, & Fariello, 1974; Newcombe & Liben, 1982) have suggested that objects or buildings are organized into categorical-like clusters or regions with internal boundaries determined by physical landmarks or barriers. It seems reasonable to conjecture that categorical organization in spatial memory may exist even earlier in development, given that infants encounter objects in numerous locations and in various arrangements. The ability to form spatial relations categories would help the infant to experience objects in coherent spatial layouts rather than as spatially unrelated entities residing in disconnected locations. Early spatial relations categories may also yield functional units (e.g., primitives) necessary for the construction of more complex representations of larger-scale spaces.

Given the potential importance and utility of categorical representations of spatial relations, the present study attempted to increase our understanding of whether such representations are available in early infancy. Previous work has suggested that even newborns are sensitive to the positional arrangement of objects in a visual scene (Antell & Caron, 1985). Neonates who are familiarized with an invariant spatial arrangement of two shapes (e.g., square above cross) will dishabituate to a rearrangement of the shapes (cross above square). The three experiments reported here seek to build on these findings by employing the familiarization-novelty preference procedure to investigate whether 3-month-old infants categorize the above and below spatial relations between a dot and a horizontal reference bar.

Experiment 1

Experiment 1 was a categorization task, and Figures 1 and 2 display its design. To investigate possible acquisition of the concept "dot above bar," one group of infants was familiarized with four exemplars, each depicting a single dot in a different position above a horizontal bar. Figure 1 displays the locations of the dot as it appeared in the familiar exemplars. Half of the infants were presented with the dot appearing in each of the four corner positions of an imaginary square located in the left half of the area above the bar (shown in panel *a* of Fig. 1). After familiarization, test trials were administered in which a novel exemplar from the familiar category (e.g., dot in new position above bar) was paired with a novel category exemplar (e.g., dot below bar). It should be noted that the dot in both test exemplars was moved the same distance from the average position of the dot during familiarization (i.e., the center of the imaginary square). In the case of the familiar category exemplar, the dot was simply moved to the right of the square's center; in the novel category exemplar, the dot was moved the same distance down (from the square's center) and consequently below the bar. If infants can categor-

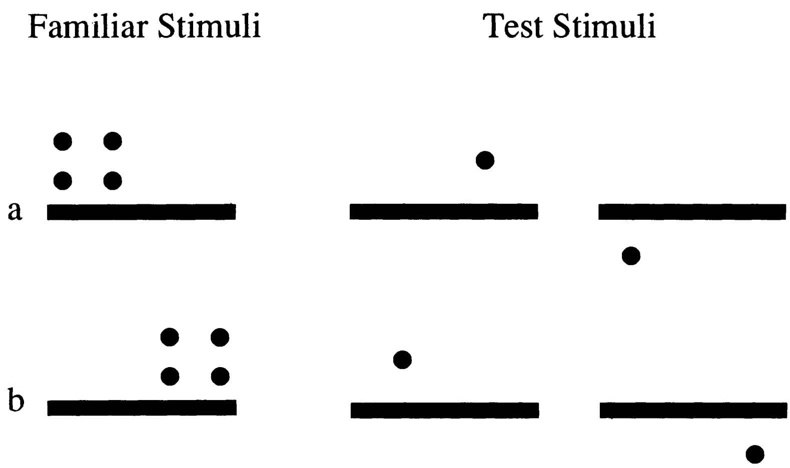

FIG. 1.—Panels *a* and *b* each display familiarization stimuli (a composite of the four exemplars) and test stimuli used to test formation of the concept "dot above bar" in Experiment 1.

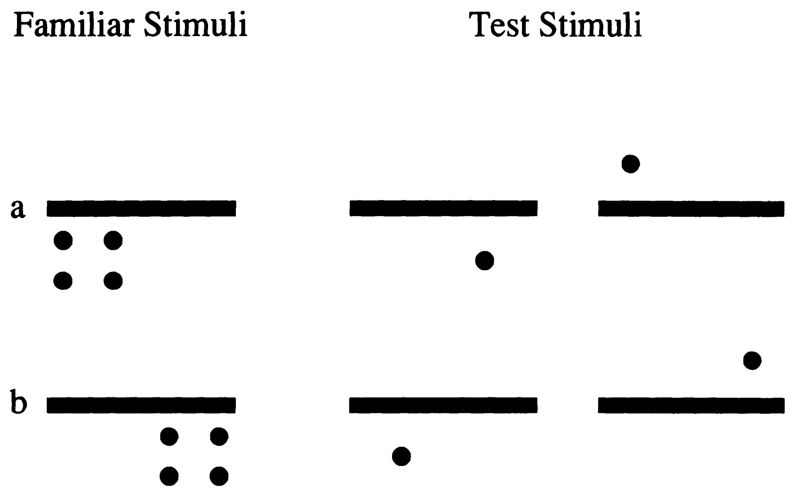

FIG. 2.—Panels *a* and *b* each display familiarization stimuli (a composite of the four exemplars) and test stimuli used to test formation of the concept "dot below bar" in Experiment 1.

ically represent the spatial relation "dot above bar," then they should show a visual preference for the novel category exemplar depicting the dot below the bar. If, on the other hand, infants are only processing information about the dot or the bar, or if they are processing the dot and the bar independently of one another (see Cohen & Younger, 1984), then a differential preference would not be expected. The other half of the infants tested for acquisition of the concept "dot above bar" were familiarized with exemplars in which the dot appeared in the four corner positions of an imaginary square located in the right half of the area above the bar (shown in panel *b* of Fig. 1). Test trials followed in which a familiar category exemplar (dot moved to the left of the square's center) was paired with a novel category exemplar (dot moved the same distance below the square's center). Figure 2 shows comparable experimental sequences designed to investigate formation of the concept "dot below bar" with a second group of infants.

Method

Subjects.—The subjects were 48 3-month-old infants recruited by letter and phone from a local hospital. There were 24 males and 24 females. Thirteen additional infants failed to complete the procedure because of fussing or crying ($n = 9$), orientation or position preferences toward one or the other side that entailed 95% or more of the looking time to that side ($n = 3$), or experimenter error ($n = 1$). The subjects in all the experiments were predominantly Caucasian and from middle-class backgrounds.

Stimuli.—Each stimulus was created by appropriately arranging a black dot and horizontal bar onto a 17.7 × 17.7-cm white poster-board card (see Figs. 1 and 2). The width and length of the bar were 1.25 and 14 cm, respectively. The dot was 1.6 cm in diameter and appeared in different positions above and below the bar. Each infant was familiarized with the dot appearing in each of the four corners of an imaginary square located in one of the four quadrants of the stimulus card (quadrants = Above Bar, Right of Vertical Midline; Above, Left; Below, Right; Below, Left). The center-to-center distance between the dots closest to the bar and the bar itself was 2.3 cm. The center-to-center distance between each adjacent familiar dot location was 4.6 cm. The dot location of the novel exemplar of the familiar category was 6.9 cm to the right or left of the average of the familiar dot locations (e.g., center of the imaginary square). The dot location of the novel category exemplar was 6.9 cm above or below the square's center.

Apparatus.—Each infant was tested with a portable visual preference apparatus, adapted from that used by Fagan (1970). The apparatus is essentially an enclosed viewing chamber with a hinged display stage which is positioned approximately 30 cm above the infant. The stimuli were presented on white cards that could be attached to the stage and easily removed to change the presentation when the stage was opened. When the stage was closed, the infants could see only the gray surround of the viewing chamber and the two stimulus cards which, when presented to the infants, were 30 cm apart from center to center. A 0.625-cm peephole located midway between the two stimuli permitted observation and recording of the infant's visual fixations. The display stage was evenly illuminated by a 60-Hz fluorescent lamp.

Procedure.—The infants were tested individually. Each infant was placed in a reclining position on the mother's lap, with his or her head resting against the mother's midsection. An experimenter wheeled the preference apparatus over the infant, taking care to keep the infant's head centered with respect to the midline 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 stimulus cards into the compartments of the display stage, elicited the attention of the infant, and then closed the stage, exposing the stimuli to the infant. During the familiarization and test trials, the experimenter observed the infant through the peephole, recording the infant's fixations to the left and right stimuli by means of a Cronus 4 electronic stopwatch held in each hand. The criterion for fixation was observing corneal reflection of the stimulus over the infant's pupil. This corneal reflection recording procedure is quite reliable; the mean interobserver reliability estimate obtained using this procedure in the author's laboratory is .92, a value in line with those obtained in other laboratories (e.g., Bomba, 1984). Between trials, the experimenter lowered the panel, changed the stimuli or their left-right positions (if required), elicited the attention of the infant, and then closed the stage to begin another trial. In order to prevent experimenter bias, two different experimenters were used to record the infant's fixations. The first recorded fixations during the familiarization trials, and the second recorded fixations during the test trials without being aware of the stimuli that were used during the familiarization period.

Twenty-four infants were randomly assigned to each of two groups, defined by the familiar category, Dot Above Bar or Dot Below Bar. All infants in the Dot Above Bar group were administered four 15-sec familiarization trials. On each trial, these infants were presented with two identical copies of a pattern in which a dot appeared above the bar. For half of the infants in the Dot Above Bar group, the dot appeared in one of four corners of an imaginary square located in the top left quadrant of the stimulus card (Fig. 1*a*). The order of presentation of the four dot positions was randomized for each infant. Immediately after the familiarization trials, two 10-sec test trials were administered in which a novel stimulus from the familiar Dot Above Bar category was paired with a stimulus from the novel Dot Below Bar category. In the familiar category stimulus, the dot appeared in a location to the right of the center of the imaginary square. In the novel category stimulus, the dot was moved the same distance, but to a location below the square's center. It is important to note that the two test stimuli were in one sense equally novel in that the dot was moved an equivalent distance away from the average position of the dots during familiarization. The left-right positions of the familiar and novel category stimuli were counterbalanced across infants on the first test trial and reversed on the second test trial. For the other half of the infants in the Dot Above Bar group, the familiarization trials had the dot appearing in the four corner positions of an imaginary square located in the top right quadrant of the stimulus card (Fig. 1*b*). These infants were tested with a familiar category exemplar in which the dot appeared to the left of the square's center and a novel category exemplar in which the dot was located the same distance below the square's center.

Infants in the Dot Below Bar group were tested in the same manner as those in the Dot Above Bar group. For half of them, the familiarization trials consisted of four stimulus presentations in which the dot appeared in each of the four corners of an imaginary square located in the bottom left quadrant of the stimulus card (Fig. 2*a*). During test trials, a dot placed to the right of the square's center (familiar category stimulus) was paired with a dot located the same distance above the square's center (novel category stimulus). The other half of the infants in the Dot Below Bar group were familiarized with the dot appearing in each of the four corners of an imaginary square located in the bottom right quadrant of the stimulus card (Fig. 2*b*). The test trials paired a dot shifted to the left of the square's center (familiar category stimulus) with a dot located the same distance above the square's center (novel category stimulus).

An initial preference study was conducted to evaluate the possibility of a priori preferences among the Dot Above Bar versus Dot Below Bar test stimuli. Sixteen 3-month-old infants (9 males and 7 females) received two 10-sec trials during which a Dot Above Bar stimulus was paired with a Dot Below Bar stimulus. Test stimuli (shown in Figs. 1 and 2) were one of two types and can be described with reference to the horizontal bar that divided the stimulus card into top and bottom halves. The two test pairs were: (1) dot in bottom right quadrant of stimulus card versus dot in top left quadrant and (2) dot in bottom left quadrant versus dot in top right quadrant. Each infant was randomly assigned to one of the two test pairs with the result that eight infants viewed each pair. The left-right positioning of the stimuli was counterbalanced across infants on the first test trial and reversed on the second.

A preference for the Dot Above Bar stimulus was determined for each infant by dividing the time that this stimulus was observed by the total looking time to both stimuli. The score was then converted into a percentage by multiplying by 100. The mean preference scores for the dot appearing in the top left and right quadrants were 52.35 (SD = 16.97) and 48.67 (SD = 17.19), respectively. Neither of the mean scores differed reliably from chance or from each other. The combined mean of 50.51 (SD = 16.58) also did not differ significantly from chance. These results suggest that the infants did not have an a priori preference for the locations of the dots displayed on the test trials, and that any differential dishabituation found in the main experiment cannot easily be attributed to an a priori preference (see Colombo, O'Brien, Mitchell, & Horowitz, 1986).

Results and Discussion

Familiarization phase.—Individual looking times were summed over both stimuli on each trial. Mean looking times for each of the familiarization trials are shown in Table 1. An analysis of variance, trials (1–4) × vertical position of dot (above bar vs. below bar) × horizontal position of dot (left square vs. right square), was performed on the looking time scores of the infants to determine whether looking times during familiarization were influenced by these stimulus variables. Results of the analysis revealed that the effect of trials was not significant, $F(3, 132) = 2.04, p = .11$, nor were the interactions of trials with the other factors, $F(3, 132) < 1, p > .25$, in all cases. In addition, there were no effects of vertical or horizontal dot position or their interaction, $F(1, 44) < 2.90, p > .05$, in each case.

That the infants did not show a reliable decline in looking time across familiarization trials is perhaps not surprising given that on each trial a different exemplar from the familiar category was presented. Several other studies in which infants have been presented with multiple exemplars from a common category have also failed to find evidence for habituation (Mandler, Fivush, & Reznick, 1987; Quinn et al., 1993; Ross, 1980). The data actually suggest that trial-to-trial changes in dot location were effective in maintaining the infant's attention.

Preference test phase.—To analyze test trial data, each infant's looking time to the novel category stimulus was divided by the looking time to both test stimuli and then converted to a percentage score. The mean novel category preference scores for the two experimental groups can be seen in Table 2. A two-way analysis of variance, vertical position of familiar dot (above bar vs. below bar) × horizontal position of familiar dot (left square vs. right square), performed on the individual percentages, yielded no significant effects, $F(1, 44) < 1, p > .25$, in all cases. As Table 2 shows, the preference scores for both experimental groups differed reliably from the chance value of 50%. In addition, 17 of 24 infants in each group had

TABLE 1

MEAN FIXATION TIMES (Sec) AND STANDARD DEVIATIONS DURING THE FAMILIARIZATION TRIALS IN EXPERIMENT 1

Familiar Category	Trials 1	2	3	4
Dot above bar:				
Mean	6.16	5.12	5.00	5.08
SD	3.08	3.55	3.24	3.29
Dot below bar:				
Mean	7.00	5.95	6.55	5.28
SD	3.46	3.58	4.20	3.21

TABLE 2

MEAN NOVEL-CATEGORY PREFERENCE SCORES (%) FOR EXPERIMENT 1

	FAMILIARIZATION CATEGORY		
	Dot Above Bar	Dot Below Bar	COMBINED
Novelty score	58.12	61.82	59.97
SD	16.70	19.18	17.89
N	24	24	48
t(vs. chance)	2.38*	3.02**	3.86***

* $p < .025$, one-tailed.
** $p < .005$, one-tailed.
*** $p < .0005$, one-tailed.

preference scores greater than 50% ($p < .025$, in both cases). The above-chance performance for the Dot Above Bar group suggests that these infants were able to form a categorical representation of the above relation on the basis of their experience with the familiar exemplars, each of which contained a dot in a different position above a reference bar. This categorical representation then allowed the infants to generalize habituation to an exemplar in which the dot was placed in a novel location, but still above the bar, while preferentially responding to the novel category exemplar in which the dot appeared below the bar. The comparable preference test result for the Dot Below Bar group has similar implications, namely, that these infants were able to compute the categorical description of below for a group of exemplars, each depicting a dot in a different position beneath the reference bar. This categorical representation of the below relation was then used as a basis for generalization to an exemplar in which the dot had moved to a new location below the bar, and a basis for preferential responding to an exemplar in which the dot appeared in the novel relation above the bar. In summary, the preference test performance of the infants in Experiment 1 suggests that they can categorically represent the spatial relations above and below.

There are, of course, several alternative explanations for the results of the preference test that should be considered before it can be concluded that infants categorically represented above and below relations. First, one needs to consider the issue of within-category discriminability of the category members. The traditional criterion for concluding that infant categorization has taken place is observing generalization to novel instances of a familiar category despite the ability to discriminate these new instances from the familiar instances of the category. In other words, it is possible that generalization to the new instance of the familiar category in the preference test phase of Experiment 1 occurred simply because of an inability to distinguish between it and the familiar exemplars of the category. If infants were unable to discriminate within the Dot Above Bar and Dot Below Bar categories, then the test trials involved a comparison between a familiar and novel stimulus, and the results reflect simply a preference for novelty and not for a novel category. Experiment 2 was designed to test this possibility.

A second alternative explanation for the preference test results of Experiment 1 is that infants may have been encoding the positions of the dot independently of the bar, and that vertical (up-down) changes in dot position are more salient than horizontal (left-right) changes. In order to rule out this explanation, it is necessary to show that infants perform differently (i.e., that they show no preferences among the test stimuli) if Experiment 1 were to be repeated with stimuli that do not contain a horizontal bar. A no-preference result in such a control experiment would also obviate one other related explanation of Experiment 1, namely, that infants were encoding the dot positions relative to an *internal* horizontal midline. If infants look equally at the test stimuli in the absence of a bar, and look reliably longer at the novel category exemplar when the bar is present, then the force of these alternative explanations is considerably weakened. Experiment 3 repeated the categorization test procedures of Experiment 1 using dot stimuli without the horizontal bar.

Experiment 2

Experiment 2 was conducted to determine if 3-month-old infants could discriminate within the Dot Above Bar and Dot Below Bar categories. Specifically, each infant was familiarized with a single member of the Dot Above Bar or Dot Below Bar categories and then presented with two test trials in which the familiar stimulus was paired with a novel stimulus from the familiar category.

Method

Subjects.—The subjects were 32 3-month-old infants. There were 13 females and 19 males. Fourteen additional infants were tested but not included in the data analysis because of fussiness ($n = 10$), orientation preference ($n = 3$), and experimenter error ($n = 1$).

Stimuli and apparatus.—The stimuli and apparatus were the same as those used in Experiment 1.

Procedure.—The within-category discrimination tests followed from the categorization tests of Experiment 1. In Experiment 1, each infant was familiarized with four exemplars, each containing a dot located in one of four corners of an imaginary square located in one of the four quadrants on the stimulus card. The novel instance of the familiar category shown during test trials contained a dot shifted to the right or left of the dots shown during familiarization. In Experiment 2, each infant was tested for discrimination between one of the familiar category exemplars, randomly chosen (from among the four corner positions of a given quadrant) and different for each infant, and the novel exemplar from the familiar category. Familiarization consisted of four 15-sec trials, during which the familiar stimulus was shown in each compartment of the testing panel. Which stimulus served as familiar (i.e., the familiar category exemplar vs. the novel exemplar from the familiar category) was counterbalanced across infants. Immediately after familiarization, the familiar stimulus was paired with the novel stimulus for two 10-sec test trials. The left-right positioning of the novel stimulus was counterbalanced across infants on the first trial and reversed on Trial 2. Half of the 32 subjects were tested with Dot Above Bar exemplars. For half of these subjects, the familiar category exemplar contained a dot located to right ($n = 8$) or left ($n = 8$) of the vertical midline. The remaining half of the subjects were tested with Dot Below Bar exemplars. For half of this group, the familiar category exemplar also contained a dot located to the right ($n = 8$) or left ($n = 8$) of center.

Results and Discussion

Familiarization phase.—As in Experiment 1, individual looking times were summed over both stimuli on each trial. Mean looking times for each of the familiarization trials are shown in Table 3. An analysis of variance, familiar stimulus (dot above bar vs. dot below bar) × familiarization trials (1–4), revealed a significant trials effect, $F(3, 90) = 2.91$, $p < .05$. With less information to observe during familiarization, infants showed a reliable decrement in looking time, providing evidence of habituation. No other effects were reliable, $p > .05$, in each instance.

Preference test phase.—The mean preference scores for the novel stimulus are shown in Table 4. A t test showed that the two mean scores were not reliably different from each other, $t(30) = 0.94$, $p > .20$, two-tailed. In addition, t tests comparing the mean scores to 50% revealed discrimination performance to be marginally above chance for the Dot Above Bar category and reliably so for the Dot Below Bar category and the combined categories. The marginal performance for the Dot Above Bar category exemplars was due to two rather discrepant low individual scores. Thirteen of the remaining 14 infants in the cell had individual preferences above the 50% chance level. These results indicate that infants were able to discriminate exemplars from the two categories used in Experiment 1.[1]

Experiment 3

Experiment 3 examined whether the preferences for the test stimuli found in Experiment 1 would be observed with stimuli

[1] It should be acknowledged that the results of Experiment 2 do not provide direct evidence that infants discriminated the exemplars when they were presented in the familiarization phase of Experiment 1 (see Sherman, 1985). This is because infants in Experiment 1 have less familiarization time with each exemplar and consequently less time to process and represent a given dot position. Indirect evidence for discrimination is provided, however, by the presence versus absence of habituation across experiments. Habituation was not observed with trial-to-trial changes in dot position (Experiment 1), whereas habituation did occur when dot position was constant across trials (Experiment 2). This combination of results suggests that infants were sensitive to changes in dot position as they occurred during familiarization. If infants in Experiment 1 were not discriminating trial-to-trial changes in dot location, then they should have behaved like the infants in Experiment 2 and habituated to the dot. The finding that infants in Experiment 3 did not habituate to dot location changes is also consistent with this argument.

TABLE 3

MEAN FIXATION TIMES (Sec) AND STANDARD DEVIATIONS DURING THE FAMILIARIZATION TRIALS IN EXPERIMENT 2

FAMILIAR STIMULUS	TRIALS 1	2	3	4
Dot above bar:				
Mean	6.72	5.13	4.18	3.83
SD	4.28	3.08	3.13	3.32
Dot below bar:				
Mean	6.04	6.25	6.48	5.16
SD	3.84	4.10	4.33	4.10

that did not contain a horizontal bar. A group of 3-month-olds was administered the same procedures used in Experiment 1, but with stimuli that contained only the dot and not the bar.

Method

Subjects.—The subjects were 24 3-month-old infants drawn from the same population described in Experiment 1. There were 12 males and 12 females. Eight additional infants were tested. Two failed to complete the procedure because of fussiness, whereas the other six were excluded from the data analysis because of position preference.

Stimuli and apparatus.—The stimuli were the same as those used in Experiment 1 with the exception that the horizontal bar was removed from each, leaving only the dot. The apparatus was the same one used in Experiment 1.

Procedure.—The procedure was the same as that used in Experiment 1. Twelve infants were randomly assigned to each of two experimental groups, Dot Above Midline or Dot Below Midline. Half of the infants in each group ($n = 6$) were presented with the dot on the left, the other half on the right. Each infant received four 15-sec familiarization trials during which a dot appeared in each of the four corners of any imaginary square located in one of the four quadrants on the stimulus card. The order of presentation of the four corner locations was randomized for each infant. Two copies of the dot in the same location were shown on each trial. Familiarization was followed by two 10-sec test trials, during each of which a novel instance of the familiar category (dot shifted to the right or left) was presented with a novel category exemplar (dot shifted above or below midline). The left-right positions of the familiar and novel category stimuli were counterbalanced across infants on the first test trial and reversed on the second test trial.

Results and Discussion

Familiarization phase.—Data analyses paralleled those of Experiment 1. Individual looking times were summed over both stimuli on each trial. Mean looking times are shown in Table 5. An analysis of variance, trials (1–4) × vertical position of dot (above midline vs. below midline) × horizontal position of dot (left vs. right), performed on the individual looking times, revealed no main effects or interactions, $p > .10$, in all instances. As was true in Experiment 1, infants did not show a decline in looking time across

TABLE 4

MEAN NOVELTY PREFERENCE SCORES (%) FOR THE WITHIN-CATEGORY DISCRIMINATIONS OF EXPERIMENT 2

	CATEGORY: Dot Above Bar	Dot Below Bar	COMBINED
Novelty score	58.03	64.42	61.23
SD	20.94	17.41	19.22
N	16	16	32
t(vs. chance)	1.53*	3.31**	3.31**

* $p < .10$, one-tailed.
** $p < .005$, one-tailed.

TABLE 5

MEAN FIXATION TIMES (Sec) AND STANDARD DEVIATIONS DURING THE FAMILIARIZATION TRIALS OF EXPERIMENT 3

FAMILIAR STIMULI	TRIALS 1	2	3	4
Dot above midline:				
Mean	4.72	4.50	4.96	4.33
SD	2.57	3.74	3.71	2.59
Dot below midline:				
Mean	5.12	4.50	4.61	5.82
SD	4.02	3.13	3.16	4.09

the trials, providing further evidence of sensitivity to trial-to-trial changes in dot location.

Preference test phase.—Each infant's looking time to the novel category stimulus (dot moved above or below midline) was divided by the looking time to both stimuli and converted to a percentage score. The mean preference scores for the two groups are shown in Table 6. A two-factor analysis of variance, vertical position of familiar dot (above midline vs. below midline) × horizontal position of familiar dot (left vs. right), performed on the individual preferences, revealed no reliable effects, $F(1, 20) < 1.5$, $p > .20$, in each case. As Table 6 shows, neither of the group preference scores, nor the combined score, differed from the chance value of 50%. When the combined score is compared with the overall mean preference obtained in Experiment 1 ($M = 59.97$), the difference is significant, $t(70) = 2.32$, $p < .05$, two-tailed.

The overall pattern of results from Experiment 3 indicates that while infants were sensitive to dot position changes during familiarization, they did not form a categorical representation of the dot positions relative to an internally generated midline. In the test phase, the novel category exemplar (created by above or below movement of the dot relative to the midline of the stimulus card) did not capture the infant's attention more than the familiar category exemplar (created by the left or right movement of the dot relative to the midline). These results suggest further that above-below movement is not more salient than left-right movement. Moreover, the findings provide evidence that infants in Experiment 1 formed a categorical representation of the dot's above versus below relation to the horizontal bar.

General Discussion

Investigations of infant categorization have established that infants under 1 year of age are able to form categorical representations for a variety of stimuli (e.g., objects, attributes) that have spatial locations (e.g., Eimas & Miller, 1990). The experiments reported here extend these findings by suggesting that young infants can also form categorical representations of physical space that are defined by the positional relations of objects in the environment. Experiment 1 showed that 3-month-old infants who are familiarized with a series of exemplars, each depicting a dot in a different position above a horizontal reference bar, displayed a novelty preference for an exemplar in which the dot appeared below the bar. Similarly, infants familiarized with the dot appearing in

TABLE 6

MEAN NOVEL-CATEGORY PREFERENCE SCORES (%) FOR EXPERIMENT 3

	FAMILIARIZATION STIMULI: Dot Above Midline	Dot Below Midline	COMBINED
Novelty score	49.90	48.06	48.98
SD	19.91	22.69	20.90
N	12	12	24
t(vs. chance)	−.02	−.29	−.24

multiple locations below the bar showed a preference for a stimulus in which the dot was positioned above the bar. Experiment 2 showed that the preferences of Experiment 1 were not a result of failing to discriminate among category members, and Experiment 3 showed that the preferences were not obtained when the bar was removed from the stimuli. The combined results of Experiments 2 and 3 suggest that the preference behavior observed in Experiment 1 was in fact a consequence of the infant's ability to form categorical representations of the spatial relations above and below and to respond to novel object arrangements on the basis of these representations. Continuing investigations should make it possible to determine whether infants can form even more abstract spatial concepts that exist despite variation in objects (e.g., dot, star, and cross above or below bar) and bar locations.

Thus far in the article we have discussed spatial information processing as if it were a single unitary process. However, several groups of investigators have recently suggested that there may be two distinct systems involved: one processes abstract categorical spatial relations that exist between objects in a visual scene (e.g., above and below), whereas the other processes coordinate locations of objects and metric distances between them (Huttenlocher, Hedges, & Duncan, 1991; Kosslyn, 1987; McNamara, Halpin, & Hardy, 1992). Evidence for separate processing systems in adults has been obtained with the neuropsychological technique of selectively presenting visual information to either the left or right hemisphere. This procedure has revealed a reaction time advantage for the left hemisphere in tasks requiring a categorical spatial judgment such as whether a dot is above or below a line. In contrast, a right hemisphere superiority is in evidence when the task demands a precise judgment of metric distance such as whether a dot is less than or greater than 2 cm from a line (Hellige & Michimata, 1989; Kosslyn et al., 1989). These findings provide evidence that the categorical representation of spatial information is localized in the left hemisphere, whereas coordinate location and metric distance information are represented in the right hemisphere. Koenig, Reiss, and Kosslyn (1990) have most recently obtained developmental data indicating that the hemispheric dissociation is present by 5 years of age. While the findings reported here do not bear directly on or provide evidence of dissociation, they are consistent with the idea that young infants might represent both categorical and metric spatial information. Evidence was obtained for the processing of categorical spatial information in Experiment 1 and dot position information in Experiment 2. Processing of dot position changes was also evidenced during the familiarization trials of Experiments 1 and 3.

It is interesting to consider the present findings in light of theory and data on the processing of spatial relations by adults and children which suggest that above is processed more efficiently than below (e.g., E. Clark, 1973; H. Clark, 1973; Clark & Chase, 1972; Friedenberg & Olson, 1977). For example, in sentence-picture comparison experiments conducted with adults by Clark and Chase, subjects are required to comprehend a linguistic description of a spatial relation and match it to a pictorial representation. Interestingly, subjects who are shown two objects, A and B, with A being above B, take a longer time to verify the statement "B is below A" compared with the statement "A is above B." Friedenberg and Olson traced the roots of this processing asymmetry to the preschool years and found that children between 2.5 and 5 years of age make more placement errors following instructions to place "object A below object B" compared with instructions to place "object B above object A." H. Clark (1973) has argued that this processing advantage for the above relation is a consequence of how our perceptual apparatus interacts with the environmental landscape. As we move through the physical environment in a canonical, upright orientation, our representation of space is structured by the natural horizontal reference plane of ground level. Given that most objects in natural scenes fall above this reference plane, we come to be especially well skilled in processing the above relation.

The present findings that infants categorize above and below equally well raises the question of when during development the processing advantage for above occurs. Perhaps a processing advantage for above is present throughout development, but the current experiments were not sensitive or demanding enough to provide evidence for it. Alternatively, the processing advantage might arise only with maturation or experience or both. It follows from H. Clark's (1973) reasoning that the processing advantage for above would appear with the onset of crawling and walking, a time period when the infant's reliance on the ground and floors as spatial reference planes may conceivably increase (see Bertenthal & Campos, 1990, for evidence and arguments that a number of cognitive changes occur with the onset of locomotion). Additional experimentation with older infants will be needed to test this reorganization hypothesis (see Werker & Tees, 1984).

It is finally interesting to consider what role these early nonlinguistic concepts play in the acquisition of word meanings. A small number of infant categorization studies have examined the formation of categories that may later come to be associated with lexical items. Roberts and his colleagues (Colombo, O'Brien, Mitchell, Roberts, & Horowitz, 1987; Roberts, 1988; Roberts & Horowitz, 1986), for example, have found that 6- and 9-month-old infants can form a categorical representation for bird and have argued that the existence of such an early concept (and others like it) is suggestive of a facilitative role for nonlinguistic categorical representations in the word learning process. It is likewise tempting to speculate that infants in the present study were forming spatial concepts onto which the English words above and below could eventually be mapped. While such a simple story is appealing and has support in traditional theories of word mapping (e.g., H. Clark, 1973), Slobin (1985) has argued that the initial sensory concepts of space are extensively reorganized by language, and Bowerman and her colleagues have recently argued that language-specific learning has a substantial influence on the way children as young as 17 months of age conceptualize space (Bowerman, 1989; Choi & Bowerman, 1991). Regardless of which of these or other accounts of the acquisition of spatial terms come to be accepted, the results of the present study provide useful data for theory development by enabling the beginnings of a description of some very early (if not initial) representations of space.

References

Antell, S. E. G., & Caron, A. J. (1985). Neonatal perception of spatial relationships. *Infant Behavior and Development*, **8**, 15–23.

Bertenthal, B. I., & Campos, J. J. (1990). A systems approach to the organizing effects of self-produced locomotion during infancy. In C. Rovee-Collier & L. P. Lipsitt (Eds.), *Advances in infancy research* (Vol. **6**, pp. 1–60). Norwood, NJ: Ablex.

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. (1983). Psychological studies of color perception in human infants. In L. P. Lipsitt (Ed.), *Advances in infancy research* (Vol. **1**, pp. 1–40). Norwood, NJ: Ablex.

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.

Bowerman, M. (1989). Learning a semantic system: What role do cognitive predispositions play? In M. L. Rice & R. L. Schiefelbusch (Eds.), *The teachability of language* (pp. 133–169). Baltimore: P. H. Brookes.

Choi, S., & Bowerman, M. (1991). Learning to express motion events in English and Korean: The influence of language-specific lexicalization patterns. *Cognition*, **41**, 83–121.

Clark, E. V. (1973). What's in a word? On the child's acquisition of semantics in his first language. In T. E. Moore (Ed.), *Cognitive development and the acquisition of language* (pp. 65–110). New York: Academic Press.

Clark, H. H. (1973). Space, time, semantics and the child. In T. E. Moore (Ed.), *Cognitive development and the acquisition of language* (pp. 27–63). New York: Academic Press.

Clark, H. H., & Chase, W. G. (1972). On the process of comparing sentences against pictures. *Cognitive Psychology*, **3**, 472–517.

Cohen, L. B., & Strauss, M. S. (1979). Concept acquisition in the human infant. *Child Development*, **50**, 419–424.

Cohen, L. B., & Younger, B. A. (1984). Infant perception of angular relations. *Infant Behavior and Development*, **7**, 37–47.

Colombo, J., McCollam, K., Coldren, J. T., Mitchell, D. W., & Rash, S. J. (1990). Form categorization in 10-month-olds. *Journal of Experimental Child Psychology*, **49**, 173–188.

Colombo, J., O'Brien, M., Mitchell, D. W., & Horowitz, F. D. (1986). Stimulus salience and relational processing. *Infant Behavior and Development*, **9**, 377–380.

Colombo, J., O'Brien, M., Mitchell, D. W., Roberts, K., & Horowitz, F. D. (1987). A lower boundary for category formation in preverbal infants. *Journal of Child Language*, **14**, 383–385.

Eimas, P. D., & Miller, J. L. (1990). Infant categories and categorization. In G. M. Edelman, M. Cowan, & E. Gall (Eds.), *Signal and sense: Local and global order in perceptual maps* (pp. 433–449). New York: Wiley-Liss.

Eimas, P. D., Miller, J. L., & Jusczyk, P. W. (1987). On infant speech perception and the acquisition of language. In S. Harnad (Ed.), *Categor-*

ical perception (pp. 161–195). New York: Cambridge University Press.

Fagan, J. F. (1970). Memory in the infant. *Journal of Experimental Child Psychology*, **9**, 217–226.

Friedenberg, L., & Olson, G. M. (1977). Children's comprehension of simple descriptions of vertical arrays. *Child Development*, **48**, 265–269.

Hellige, J. B., & Michimata, C. (1989). Categorization versus distance: Hemispheric differences for processing spatial information. *Memory and Cognition*, **17**, 770–776.

Hirtle, S. C., & Jonides, J. (1985). Evidence of hierarchies in cognitive maps. *Memory and Cognition*, **13**, 208–217.

Huttenlocher, J., Hedges, L. V., & Duncan, S. (1991). Categories and particulars: Prototype effects in estimating spatial location. *Psychological Review*, **94**, 148–175.

Jackendoff, R., & Landau, B. (1991). Spatial language and spatial cognition. In D. J. Napoli & J. A. Kegl (Eds.), *Bridges between psychology and linguistics: A Swarthmore festschrift for Lila Gleitman* (pp. 145–169). Hillsdale, NJ: Erlbaum.

Koenig, O., Reiss, L. P., & Kosslyn, S. M. (1990). The development of spatial relation representations: Evidence from studies of cerebral lateralization. *Journal of Experimental Child Psychology*, **50**, 119–130.

Kosslyn, S. M. (1987). Seeing and imagining in the cerebral hemispheres: A computational approach. *Psychological Review*, **94**, 148–175.

Kosslyn, S. M., Koenig, O., Barrett, A., Cave, C. B., Tang, J., & Gabrieli, D. E. (1989). Evidence for two types of spatial representations: Hemispheric specialization for categorical and coordinate relations. *Journal of Experimental Psychology: Human Perception and Performance*, **15**, 723–735.

Kosslyn, S. M., Pick, H. L., & Fariello, G. R. (1974). Cognitive maps in children and men. *Child Development*, **45**, 707–716.

Mandler, J. M., Fivush, R., & Reznick, J. S. (1987). The development of contextual categories. *Cognitive Development*, **4**, 339–354.

McNamara, T. P., Halpin, J. A., & Hardy, J. K. (1992). Spatial and temporal contributions to the structure of spatial memory. *Journal of Experimental Psychology: Learning, Memory and Cognition*, **18**, 555–564.

McNamara, T. P., Hardy, J. K., & Hirtle, S. C. (1989). Subjective hierarchies in spatial memory. *Journal of Experimental Psychology: Learning, Memory and Cognition*, **15**, 211–227.

Newcombe, N., & Liben, L. S. (1982). Barrier effects in the cognitive maps of children and adults. *Journal of Experimental Child Psychology*, **34**, 46–58.

Quinn, P. C. (1987). The categorical representation of visual pattern information by young infants. *Cognition*, **27**, 147–179.

Quinn, P. C., & Bomba, P. C. (1986). Evidence for a general category of oblique orientations in four-month-old infants. *Journal of Experimental Child Psychology*, **42**, 345–354.

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.

Reznick, J. S. (1989). Research on infant categorization. *Seminars in Perinatology*, **13**, 458–466.

Roberts, K. (1988). Retrieval of a basic-level category in prelinguistic infants. *Developmental Psychology*, **24**, 21–27.

Roberts, K., & Horowitz, F. D. (1986). Basic level categorization in seven- and nine-month-old infants. *Journal of Child Language*, **13**, 191–208.

Ross, G. S. (1980). Categorization in 1–2-year-olds. *Developmental Psychology*, **16**, 391–396.

Sherman. T. (1985). Categorization skills in infants. *Child Development*, **53**, 183–188.

Slater, A., Mattock, A., Brown, E., & Bremner, J. G. (1991). Form perception at birth: Cohen and Younger (1984) revisited. *Journal of Experimental Child Psychology*, **51**, 395–406.

Slobin, D. I. (1985). Cross-linguistic evidence for the language making capacity. In D. I. Slobin (Ed.), *The crosslinguistic study of language acquisition: Vol. 2. Theoretical issues* (pp. 1157–1256). Hillsdale, NJ: Erlbaum.

Strauss, M. S. (1979). Abstraction of prototypical information in adults and 10-month-old infants. *Journal of Experimental Psychology: Human Learning and Memory*, **5**, 618–632.

Werker, J. F., & Tees, R. C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. *Infant Behavior and Development*, **7**, 49–63.

Younger, B. (1990). Infant categorization: Memory for category-level and specific item information. *Journal of Experimental Child Psychology*, **50**, 131–155.

Younger, B. A., & Gotlieb, S. (1988). Development of categorization skills: Changes in the nature or structure of infant form categories? *Developmental Psychology*, **24**, 611–619.