A Visual Habituation Test of the Development of Form Perception in Infants From 2 to 3 Months of Age

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ABSTRACT

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The purpose of this study was to develop a paradigm that would assess young infants' abilities to abstract configurational invariance from a changing visual display. Twenty infants were tested at both 8 and 12 weeks of age on a visual habituation task. Infants were shown 20 slides of two sizes of linear or triangular configurations of three white dots followed by two novel sizes of the familiar stimuli (generalization stimuli). Infants were then shown four slides of the other configuration; of which two were the same size as the familiar stimuli, and two were the same size as the generalization stimuli. Infants at both 8 and 12 weeks showed a significant response decrement ($p < .01$) from the first two to the last two familiar slides, and generalized this response to the generalization stimuli. Infants at 8 weeks fixated the first two configuration-change stimuli at similar levels to the generalization stimuli, but showed a significant response decrement to the second two configuration-change stimuli ($p < .05$). This indicated that the infants at 8 weeks had not abstracted configuration, and were not responding to size or contour density changes. At 12 weeks, the infants increased fixation from the

generalization stimuli to both the first two ($p < .05$) and second two ($p < .01$) configuration-change stimuli, thus showing evidence of form perception. The group results suggested that at 8 weeks, infants may have abstracted numerical invariance from the task, while at 12 weeks they abstracted configuration.

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A Visual Habituation Test of the Development of Form Perception in Infants From 2 to 3 Months of Age

Over the first few months of life, an infant's visual system matures rapidly. Visual acuity is estimated by behavioural and physiological measures to be 20/400 at birth, and improves to between 20/100 and 20/25 by 6 months of age (Dobson & Teller, 1978). Poor acuity in the newborn may be due to the immaturity of the fovea at this time. Abramov et al. (1982) found that at 8 days of age, the fovea of an infant has very thin nuclear layers, leaving little room for receptors between the external membrane and pigment epithelium. By 4 months of age, however, the fovea reaches near-adult development (Mann, 1964; cited in Abramov et al., 1982). The lateral geniculate nucleus (LGN), the major relay center between the retina and the visual cortex, also matures rapidly after birth. At birth, the cell bodies in the magnocellular and parvocellular layers of the LGN are smaller than in its mature form. The cells in the parvocellular layers grow very rapidly during the first 6 months, and reach adult size by the end of the first year. The large cells of the magnocellular layer grow rapidly during the first year to reach adult size by the end of the second (Hickey, 1977).

A number of changes also occur in the visual behaviour of infants over the first few months of life. Before the age of 2 months, infants can make discriminations based on intensity, contour, orientation, and shape of stimuli, and can discriminate moving from stationary objects. They can also localize stimuli in the periphery, track moving stimuli, and fixate stationary stimuli (Maurer & Lewis, 1979). Infants older than 2 months can make discriminations that younger infants do not, such as discriminating shapes and arrangement of features of stimuli inside identical frames. Older infants can also scan thoroughly, localize nasal stimuli, and track smoothly (Maurer & Lewis, 1979).

Two of the theories of neural maturation that attempt to account for these changes in visual behaviour are those of Bronson (1974) and Maurer and Lewis (1979). Bronson (1974) believes that the change in behaviour reflects a change from subcortical to cortical control of the visual system. He suggests that from birth to 2 months, visual responses are mediated by the secondary visual system (subcortical), which transmits information on the directional loci of salient stimuli located in the periphery. Around the ages of 2 to 3 months, the primary visual system (cortical) begins to control responses. This system is concerned with the analysis and encoding of complex patterns, and processes information received from the central area of the retina.

Although this theory fits the behaviours of pre- and post-2-month-olds reported by Maurer and Lewis (1979), there is some evidence that the visual cortex influences visual behaviour before 2 months. For example, researchers using infant visual evoked potentials to pattern stimuli have found evidence of an early positive component peak (with a latency of 100 to 250 msec from stimulus presentation) in infants as young as 4 to 6 weeks (Hoffman, 1978; Moskowitz & Sokol, 1983). This peak is said to be related to activity in the striate cortex (Atkinson, 1984). Thus the presence of the peak in the VEP records of these young infants suggests that the cortex influences visual responses.

Research comparing the discriminative abilities of young infants to that of decorticate animals also suggests that the cortex influences visual behaviour before 2 months of age. For example, Maurer and Martello (1980) showed that 5- to 6-week-old infants could discriminate patterns with different orientations of stripes (with regional intensity cues controlled). Loop and Sherman (1977), however, found that cats with occipito-temporal cortex ablations could not learn to discriminate horizontal from vertical stripes, even when given six times the number of training sessions as required preoperatively. Similarly, Milewski (1976) showed that 1-month-old infants could discriminate a circle from a triangle, while decorticate monkeys needed an average of 3700 trials to learn this discrimination (over ten times as many trials as needed preoperatively) (Schilder, Pasik, & Pasik, 1972). Thus the decorticate monkeys and cats needed extensive training to learn to make discriminations that young human infants learned very rapidly (Atkinson, 1984). The Maurer and Martello (1980) and Milewski (1976) studies thus suggest that the cortex may be involved in even the simple visual discriminations made by very young infants.

Maurer and Lewis (1979) account for this evidence of cortical involvement by proposing that two neural pathways are responsible for the visual behaviours shown at birth. Although some researchers believe that X- and Y-cells are not functionally segregated (Daniels, Pettigrew, & Norman, 1978; Hochstein, 1979), Maurer and Lewis (1979) suggest that the visual behaviours shown before 2 months of age are accounted for by a Y-pathway to the superior colliculus and pretectum, which mediates discriminations based on contour, intensity, movement, or flicker, and by an X-pathway to the cortex, which mediates fine acuity and the discrimination of orientation and shape. The more sophisticated visual behaviours exhibited after 2 months are attributed by Maurer and Lewis to the development of a Y-pathway to the cortex, which mediates smooth pursuit, mature sensitivity to flicker, and perhaps rudimentary form perception. Although Maurer and Lewis (1979) do not state what is meant by rudimentary form perception, Haber and Hershenson (1980) have defined it as seeing that a shape involves parts that must be seen in a particular relationship to one another. The present study was an attempt to develop a paradigm to test only one aspect of the Maurer and Lewis theory -- specifically the suggestion that form perception as defined above is possible soon after 2 months of age.

The study was not designed to test the function of the X- and Y-pathways, as a number of investigators have stated that their specific functions are uncertain (Atkinson, 1984;

Banks & Salapatek, 1983; Daniels et al., 1978; Hochstein, 1979). X-cells, or sustained cells, have been characterized as showing a sustained response to a stationary spot in the response field, showing linear spatial summation, and as having slow conduction times and small receptive fields. Y-cells, or transient cells, have been characterized as showing a transient response to stimulation of the response field, showing non-linear spatial summation, being sensitive to stimuli at low spatial frequencies, and having rapid conduction times and larger receptive fields (Hirsch & Leventhal, 1978; Lehmkuhle, Kratz, Mangel, & Sherman, 1980). Lehmkuhle et al. (1980) hypothesized that Y-cells are essential to the analysis of spatial patterns, since early lid suture in kittens which destroys Y-cells produced a profound loss of spatial pattern vision. They also suggested that X-cells add details to this spatial information. Other investigators, however, have found that the classifying characteristics of X- and Y-cells overlap. For example, Daniels et al. (1978) found that 9%-15% of X-cells in young kittens showed transient responses, and that 8%-16% of Y-cells showed sustained responses to stimulation of the response field. Hochstein (1979) reported that the dichotomy of X- and Y-cells is unclear in many tests that classify the cells, such as response dynamics, conduction times, and size of receptive field. Atkinson (1984) suggests an alternative hypothesis to account for the changes in visual behaviour that occur at 2 months of age in infants. Before 2 months, she suggests that most visual responses are determined by activity in subcortical pathways, and that a few responses are determined by some functional links between the eye and the cortex. The changes in visual behaviour that occur at 2 months of age are hypothesized to be due to maturation of cortical-subcortical pathways, when subcortical pathways become controlled by decisions taken in the cortex.

Study of the development of visual behaviour reflects neural maturation. Early studies of infant response to pattern showed that newborn fullterm infants can make many discriminations, such as discriminating patterned from unpatterned surfaces (Fantz & Nevis, 1967). Friedman (1972) found that some newborns can discriminate between patterns: infants who habituated (decreased looking time significantly) to either a 2 x 2 or 12 x 12 checkerboard increased attention to a novel size of checkerboard. Miranda (1970) reported that 4-day-old infants looked longer at patterns which were more discriminable because they were larger or had greater brightness contrast. Fantz and Miranda (1975) showed that 3-day-old infants looked longer at patterns with curved rather than straight outer contours. These studies show that newborns can make discriminations based on size, brightness, and curvature of outer contours.

By 1 month of age, the visual capabilities of the infant improve slightly. Milewski and Siqueland (1975) studied 1-month-old infants' abilities to discriminate changes in form and colour. Using a high amplitude nonnutritive sucking task, they discovered that infants showed increased sucking to a change in colour, form, or colour and form after being habituated to a familiar stimulus. In a further investigation of the ability to discriminate changes in form, Milewski (1976) found that 1-month-olds showed increased sucking to a change in external form after being habituated to a compound form of one shape inside another shape. There was no evidence of discrimination of changes in the internal form. Using similar stimuli, however, Bushnell (1979) showed that 1-month-olds could discriminate a change in the internal form if it flashed or moved. Similarly, Ganon and Swartz (1980) reported that a change in the internal form was discriminated if it was a "salient" stimulus for the infant, such as a checkerboard or a bull's-eye. Thus 1-month-olds readily respond to changes in external form, but do not attend to changes in the internal form of compound stimuli unless it is a salient target for them. By 3 and 4 months, however, infants typically respond to changes in nonsalient internal forms (Bushnell, 1979; Milewski, 1976).

Other studies have examined the responses of infants to stimuli varying in "complexity" (defined in the following studies as number of stimulus elements). Brennan, Ames, and Moore (1966) found that 3-week-olds fixated a 2 x 2 checkerboard significantly longer than a 24 x 24 checkerboard, and an 8 x 8 checkerboard. These findings suggest that young infants prefer a less complex stimulus. Haaf (1974) showed that 5-week-olds fixated face-like patterns made up of 13 elements significantly longer than more complex or less complex face-like stimuli. Similarly, Greenberg and O'Donnell (1972) reported that 6-week-olds fixated checkerboards, dots, and stripes of medium complexity significantly longer than when these stimuli were of low and high levels of complexity. Brennan et al. (1966) found similar results with 8-week-olds, who fixated 8 x 8 checkerboards longer than 2 x 2, or 24 x 24 checkerboards. These studies showed that 3-week-old infants are most interested by stimuli of low complexity, while infants between the ages of 1 and 2 months are most interested by stimuli of intermediate complexity.

The concept of complexity has been criticized because of the difficulty of defining the term. In addition, Haith (1980, p. 3) has pointed out that many factors that can control attention are often confounded with manipulations of complexity. The confounds he cited were size and number of stimulus elements, stimulus area, brightness of the stimulus, and amount of contour, which is defined as the sum of the lengths of all the light-dark contrast borders in a pattern (Maisel & Karmel, 1978, p. 132). Karmel (1969, 1974) has suggested that the contour density of a stimulus is the factor that best explains infant visual attention, where contour density is defined as the amount of contour in a given unit of a stimulus's area (Maisel & Karmel, 1978, p. 132). In reanalyzing Greenberg and O'Donnell's (1972) results, Karmel (1974) showed that contour density accounted for 48% of the variance of fixation times for 6-week-olds. Further, Karmel (1969) showed that Brennan et al.'s (1966) findings fit his developmental curve relating mean fixation time to amount of contour. These findings seem to indicate that contour density is an important factor in explaining young infants' visual fixations.

Maisel and Karmel (1978) investigated age differences in fixation time to stimuli of three levels of contour density. They found that 5- to 6-week-olds fixated low contour density stimuli the longest, and that 8- to 10-week-olds fixated intermediate contour density stimuli the longest. There were different results for different patterns, however, even though patterns had been equated in contour density: 5- to 6-week-olds looked longest at checkerboards at all three levels of contour density, while 8- to 10-week-olds looked longest at concentric circles at low levels of contour density, and at checkerboards at the other levels. Greenberg and O'Donnell (1972) also found pattern preferences in their study: the infants looked at dots and checkerboards longer than at stripes. Thus although contour density accounts for some differences in infants' visual fixations, patterns themselves also have differential effects.

These studies show that as infants mature from 3 weeks to 8 weeks, stimuli with greater contour density (or "complexity") are increasingly fixated. Other studies have found evidence of such a trend with older infants. For example, Haaf (1974) reported that 10-week-old infants fixated the most complex face-like stimuli the longest. Greenberg and O'Donnell (1972) found that 11-week-olds fixated highly complex patterns of dots, checks, and stripes more than 6-week-olds did. In analyzing these data, Karmel (1974) showed that contour density accounted for 82% of the variance of fixation time in the 11-week-olds. Karmel, Hoffman, and Fegy (1974) found that contour density was related to variations in the positive component peak of infants' visual evoked potentials, and that as age increased from 2 to 3 months, the maximum of the peak shifted to stimuli with greater contour densities (p. 39). Thus not only behavioural studies, but physiological studies show this shift of attention with increasing age to stimuli with increasing contour densities. Pipp and Haith (1984) have recently proposed a refinement of contour density called Contour Variability, Amount, and Location (CVAL). This metric provides a contour function weighted for the shape of the visual field, and the location and orientation of contour on the retina. Pipp and Haith found that CVAL was more accurate than contour length in describing infant fixations to stimuli of various orientations.

An alternative to the various contour metrics in accounting for infant pattern preferences over the first 3 months is linear systems analysis. This model assumes that perception of a pattern is based on the amplitude spectrum of the pattern and the sensitivity of the visual system to the spectrum (Gayl, Roberts, & Werner, 1983). The amplitude spectrum consists of the contrast of a pattern being broken down into sinusoidal components using Fourier analysis. With linear systems analysis, Banks and Salapatek (1983) showed that as infants mature to 3 months of age, they prefer visual stimuli of increasingly greater spatial frequencies (p. 498). Thus as infants mature from birth to 3 months, they show changing visual preferences for patterns with increasing contour density and spatial frequency.

A primitive kind of form perception has been suggested to appear at approximately 2 months of age. Infants showing this ability can discriminate one form from another when each form is made up of identical numbers of elements, differing only in arrangement. This is different from the ability to discriminate between two shapes, such as a circle and a triangle, which is present by at least 1 month (Milewski & Siqueland, 1975; Milewski, 1976). Fantz and Nevis (1967) showed infants four arrangements of 25 squares: a circular arrangement and three large square arrangements, with the 25 squares either upright, diagonal or in a random orientation. The arrangements were equated for length of contour, area (and thus contour density), size and number of elements, light reflectance, and contrast. They found that a group of infants tested between 1 and 2 months of age showed significant differences in attention to the different pattern arrangements, with older infants showing stronger preferences. This differential attention was not shown by infants younger than 1 month. Cohen, DeLoache, and Strauss (1979), however, have suggested that rotation of the elements might have produced the differential attention in the Fantz and Nevis study, rather than a difference between the forms as a whole.

Vurpillot, Ruel, and Castrec (1977) also investigated primitive form perception in $2^1/2$- and $4^1/2$-month-old infants. Subjects were habituated to an identical pair of large crosses made of nine small crosses, and then were tested for increased attention to a novel stimulus paired with the familiar stimulus. Infants were shown one of two types of novel stimuli. One novel stimulus tested whether infants attended to the elements of a stimulus, which would be evidenced by increased attention to a large cross made of nine small squares. The other novel stimulus tested whether infants attended to the whole configuration of a stimulus, which would be evidenced by increased attention to a large square made of nine small crosses. Size of the stimuli was also varied, with half of the infants being shown "large" stimuli and the other half being shown "small" stimuli. The small crosses and squares were half the size of those in the large stimuli. Vurpillot et al. found that both $2^1/2$- and $4^1/2$-month-olds showed increased attention to a change in configuration (large cross to square) only for small stimuli (35-63 mm), and showed increased attention to a change in elements only for large stimuli (66-124 mm). The authors stated that the results for the $2^1/2$-month-olds must be qualified, however, since these infants showed little or no habituation to the familiar stimuli, indicating that they had not completed processing the visual information. This study shows that for certain sized stimuli, infants as young as $2^1/2$ months may be able to discriminate a change in element arrangement that makes a different form. The results of this study, unfortunately, are contaminated by lower-order variables. Infants may have made the configuration discrimination on the basis of changes in factors such as figure size, figure position, or amount of contour, since they were habituated to only one type of stimulus.

Milewski's (1979) study of form perception in 3-month-olds attempted to control these lower-order variables. In a high amplitude nonnutritive sucking paradigm, infants were presented with numerous changes in lower-order variables throughout habituation. Infants were habituated to two lengths of either a triangular or linear configuration of three white dots, presented in two positions on the screen. This changing habituation display thus desensitized the infants to changes in size, contour density, and position, and encouraged them to abstract the configurational invariance of form. Following habituation, infants were shown one of two types of novel stimuli. One group was shown the familiar configuration with new vertical dimensions in two new positions on the screen. Another group was shown a new configuration of the same lengths in the same positions of the screen as the familiar stimuli. Milewski found that infants significantly increased sucking to, and hence discriminated, the configuration change, but did not respond to the size and position change. Thus the 3-month-olds appear to have abstracted the configurational invariance of the stimuli despite changes in size, contour density, and position. This study gives the best evidence to date of this more sophisticated type of form perception in infants as young as 3 months.

The purpose of the present study was to develop a paradigm based on Milewski's (1979) task that would be suitable for home assessments of the development of form perception between 2 and 3 months of age in fullterm and preterm infants. Although this study only investigated fullterm subjects at 2 and 3 months, certain aspects of the procedure were designed to accommodate a future preterm sample. Specifically, a visual habituation paradigm employing portable equipment was used so that testing could be conducted in the home to minimize subject loss. In addition, a modification of an infant-controlled trials procedure (Barrera & Maurer, 1981) was used to give infants as much time as they wished to view the stimulus on each trial. This is particularly important for the testing of preterm infants, because they need longer familiarization times than fullterm infants of the same postconceptional age to encode stimuli (Rose, 1980).

Stimuli in the present study were linear and triangular configurations of three white dots, as used by Milewski (1979). Infants were familiarized on two sizes of one configuration for 20 trials, and then shown three additional types of stimuli for test. The first type of test stimulus following the habituation trials examined whether the infant had abstracted configurational invariance. These generalization stimuli had the same configuration as the familiarization stimuli, but differed in size and contour density. Infants who showed the more mature response of abstracting configuration would continue to habituate (generalize their response) to the generalization stimuli.

Infants who have abstracted configuration should also dishabituate to changes in configuration. The last two types of test stimuli thus had a different configuration than the familiarization and generalization stimuli. One type of test stimulus was a test for discrimination of a configurational change in stimuli of the same vertical dimensions as the generalization stimuli. The other of these stimuli was a test for discrimination of a configurational change in stimuli of the same vertical dimensions as the familiarization stimuli. The difference in contour density between this second type of test stimuli and the familiarization stimuli was similar to the difference in contour density between the generalization and familiarization stimuli. The strongest evidence for form perception in the paradigm thus is generalization of habituation on the two generalization trials followed by dishabituation on the first two configuration-change trials regardless of which type of stimuli are presented.

Stimuli were projected onto two sections of the viewer screen to control for position cues in the discrimination of novel configuration. The upper left and upper right quadrants of the viewer were used, because pilot testing revealed that infants did not habituate if stimuli were presented diagonally (in the upper left and bottom right quadrants of the viewer). Only the upper half was used because evidence suggests that

1-month-old infants fixate well above the center of the visual field (van Giffen & Haith, 1984), and pilot testing revealed that 3-month-old infants looked significantly longer ($p < .01$) at stimuli on the top half of the viewer than on the bottom.

It was hypothesized that this test of form perception would detect age differences in the ability to abstract configurational invariance. Specifically, it was expected that, as a group, the infants at 12 weeks would abstract configurational invariance, as did the 12-week-olds in Milewski's (1979) study. Milewski's findings suggested that infants showing form perception would, following habituation to the familiarization stimuli, continue to demonstrate habituation to the generalization stimuli, and dishabituate to the first two configuration-change stimuli. The group of 8-week-olds, on the other hand, was not expected to show such evidence of form perception. These infants were expected to dishabituate to the generalization stimuli because they differed from the familiarization stimuli in size and contour density. Since form perception would not be expected to emerge in all infants at precisely the same age, some of the infants at 8 weeks were expected to show evidence of form perception. It was also expected that the proportion of infants demonstrating the ability to abstract configurational invariance would increase from 8 to 12 weeks of age.

Method

Subjects

Subjects were 20 fullterm infants born at 38 weeks, 5 days to 41 weeks, 3 days gestational age (M = 39.92 weeks). Gestational age was determined by asking mothers their infants' actual and expected dates of birth. Infants were tested at both 8 weeks (54-66 days, M = 60.2 days) and 12 weeks (84-98 days, M = 89.8 days) chronological age. Subjects were obtained by letter from published birth announcements in the Montreal area, and from local members of the La Leche League. Appendix A presents the letter sent to parents to solicit subjects, and the consent form signed by all parents. Infants had a mean birthweight of 3383.6 g (2807-3884 g), mean reported 1-minute Apgar scores of 8.67 (8-9), and 5-minute Apgar scores of 9.5 (9-10). Six of the infants were first-born, and the rest were born later in their families (second to fifth). Mothers of the infants had a mean age of 32.9 years (24-42 years), and a mean education of 16.1 years (11-22 years). The final sample consisted of 9 females and 11 males; 4 additional infants were tested, but not used, because of sleeping or excessive crying. The 20 subjects used in the final sample completed both the 8-week and 12-week testing sessions.

Apparatus

Stimuli were projected onto a 22.86 x 22.86 cm screen from a built-in projector (Kodak Audio Viewer model 200). The display was shown in either the upper left or upper right quadrant of the viewer. The center of each quadrant was separated by 11.43 cm horizontally and vertically. The viewer was located 30 cm from the infant's eyes, and sat on a table

66 cm from the ground. The height of the viewer was 35 cm.

A black wooden frame on top and to the sides of the viewer blocked the infant's view of the two observers. The frame was 29.5 cm wide on each side, and 29 cm high on top of the viewer. The observers watched the infant's eyes through 1-cm holes located in the side sections of the frame.

Two Radio Shack TRS-80 PC-2 pocket computers with attached printers were used to time the infants' fixations to 0.1 s. Fixation times were printed out at the end of the test session.

Stimuli

The warm-up stimuli were two Kodalith slides of 2 x 2 black and white checkerboards projected onto black space. Each checkerboard projected at a size of 9 x 9 cm (16.7° visual angle), and occupied only either the upper left or upper right quadrant of the viewer (see Figure 1).

The experimental stimuli were 26 Kodalith slides of three white dots (diameter 1.2 cm on the viewer, 2.29° visual angle) projected onto black space. The dots were presented in a vertical, linear arrangement, and in a triangular arrangement made by moving the center dot of the linear arrangement to the right. Four sizes of each configuration were shown. Line 3 and Triangle 3 extended beyond their quadrants by 1.5 cm vertically, and Line 4 and Triangle 4 extended beyond their quadrants by 2.5 cm vertically (see Figure 1). Table 1 presents the vertical size, horizontal size, and contour density of the experimental stimuli.

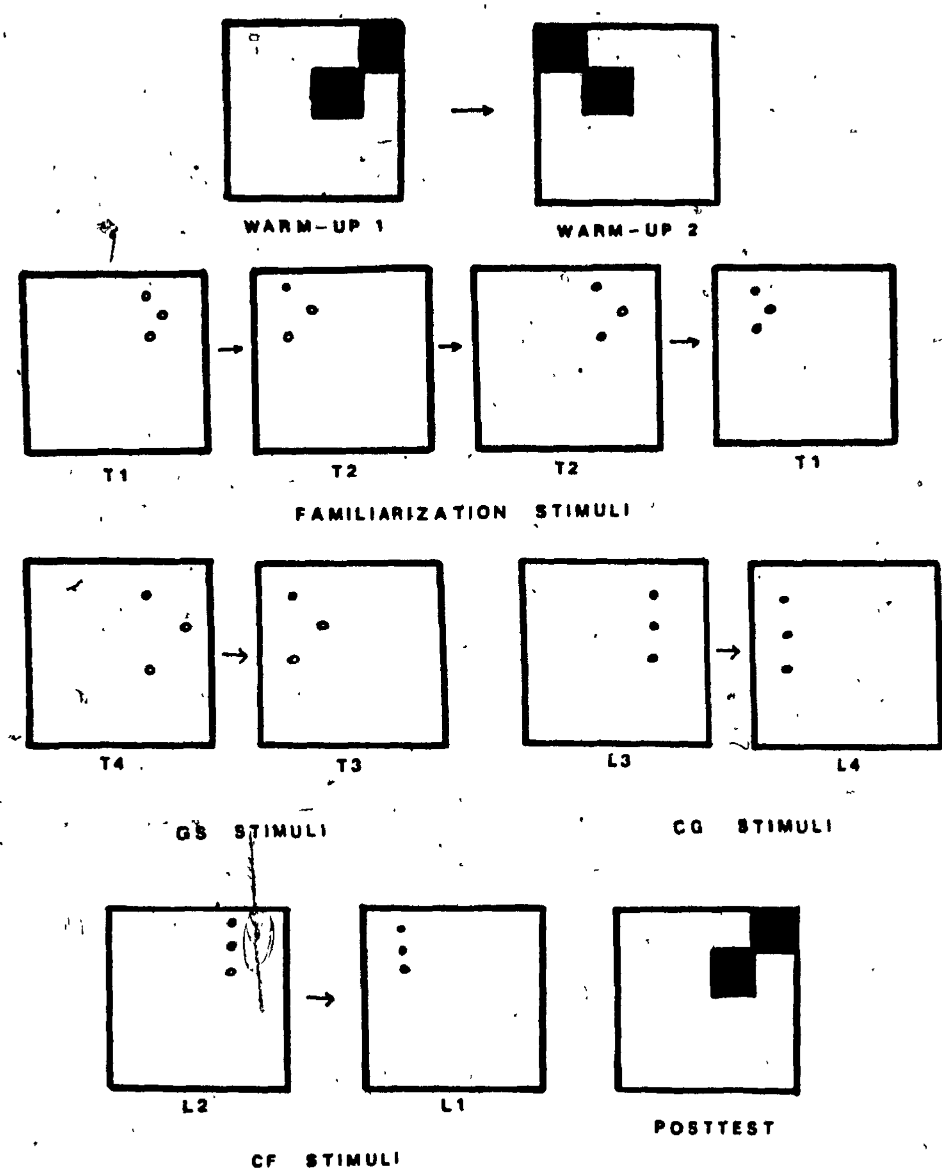

Figure 1. Sample set of stimuli (approximately one-tenth of projected size).

Table 1

Projected Size of Stimuli

Configuration	Size index	Vertical size (cm)	Horizontal size (cm)	Contour density* (cm/cm^2)
Linear	1	5.8	1.2	1.62
	2	7.4	1.2	1.27
	3	8.9	1.2	1.06
	4	10.2	1.2	0.92
Triangular	1	5.8	2.8	1.39
	2	7.4	4.0	0.76
	3	8.9	4.9	0.52
	4	10.2	6.3	0.35

*Contour density = $\frac{\text{Total amount of contour}}{\text{Area of the shape circumscribing the entire pattern}}$

These stimuli were originally intended to project at the same dimensions used by Milewski (1979), but all were changed slightly when they were photographed. Stimuli were projected at a visual angle ranging from 10.94° to 18.78° in the vertical plane, and 2.29° to 11.86° in the horizontal plane.

Procedure

All infants were tested in their homes in slightly darkened areas which were relatively free of distracting visual stimuli (windows, colourful pictures, etc.). Infants were seated in their mother's lap 30 cm away from the viewer. Mothers wore covered sunglasses so they could not see the slides and thus could not cue the infant when the nature of the stimulus changed.

Infants were tested in a quiet alert state, usually within 1 hour following a feeding. Once the infant and mother were comfortably seated, a white slide was shown to draw the infant's attention to the viewer. When the infant looked away from the viewer, the first warm-up slide was projected. Timing of fixation started when the observers judged that the infant was looking at the screen and continued to a maximum of 2 minutes until the infant looked away. The stimulus had to be reflected on the infant's pupils in order for the observers to decide that the infant was looking. The slide was not advanced to the next stimulus until both observers stopped timing (indicated by saying "No"). Two warm-up slides were shown, the first in the upper right and the second in the upper left quadrant of the viewer. Slides continued to be shown alternately in the upper right and left quadrants throughout the procedure.

Twenty familiarization trials immediately followed the two trials with the warm-up stimuli. Six males and four females were shown the two smaller triangles (T1 and T2), and five males and five females were shown the two larger lines (L3 and L4) (see Table 1). These stimuli were presented in an ABBA/BAAB order, where A represents one size of the stimulus, and B represents the other size. Each size of the familiarization stimuli appeared five times in the upper right and five times in the upper left quadrant. Immediately following the familiarization trials, all infants received two generalization stimuli (GS). These stimuli had the same configuration as the familiarization stimuli, but differed in size. If the infant was familiarized on T1 and T2, generalization stimuli were T3 and T4. If the infant was familiarized on L3 and L4, generalization stimuli were L1 and L2 (see Table 1).

The last four test trials were used to determine if infants were responding to form if generalization had occurred in the generalization trials. These stimuli had a different configuration than the familiarization and generalization stimuli. Two of the stimuli (CG) had a different configuration, but the same vertical size as the generalization stimuli. For infants familiarized on T1 and T2 and tested for generalization on T3 and T4, the CG stimuli were L3 and L4. For infants familiarized on L3 and L4 and tested for generalization on L1 and L2, the CG stimuli were T1 and T2. Stimuli on the other two test trials (CF) also had a different configuration, but were of the same vertical size as the familiarization stimuli. The difference in contour density between the CF stimuli and the familiarization stimuli was similar to the difference in contour density between the generalization and familiarization stimuli (see Table 2). For infants familiarized on T1 and T2, the CF stimuli were L1 and L2. For infants familiarized on L3 and L4, the CF stimuli were T3 and T4. The order of presentation of the two trials with the CG stimuli and the two trials with the CF stimuli was counterbalanced within each familiarization subgroup. Infants received one order of presentation of CF and CG stimuli at 8 weeks, and the other order at 12 weeks of age.

Immediately following the test trials, the first checkerboard warm-up stimulus was again shown in the upper right quadrant to determine if the infant had continued to attend to the task.

If the infant's attention was drawn away from the viewer at any time during the procedure (e.g. by looking at his/her feet or at the walls), one of the observers tried to reorient the infant by tapping on the frame, or on the front of the viewer.

If the infant cried or fussed in the middle of a trial, timing of fixation was stopped. When the infant settled, that particular trial was started again, and testing proceeded normally. Pacifiers were often used to calm the infants, but

Table 2

Contour Density Changes From Familiarization to Test Stimuli

Stimulus change	Contour density changes	Mean change
Familiarization to GS		
Triangles 1, 2 to Triangles 3, 4	.87, .41	.64
Lines 3, 4 to Lines 1, 2	-.56, -.35	-.46
Familiarization to CG		
Triangles 1, 2 to Lines 3, 4	.33, -.16	.09
Lines 3, 4 to Triangles 1, 2	-.33, .16	-.09
Familiarization to CF		
Triangles 1, 2 to Lines 1, 2	-.23, -.51	-.37
Lines 3, 4 to Triangles 3, 4	.54 .57	.56

were taken out once the infant settled. If crying persisted, the pacifier was left in the infant's mouth. If the infant interrupted more than three trials, testing was terminated.

Observer reliability was calculated for each subject at each age using both Pearson product moment correlation coefficients and percent agreement. The overall mean Pearson correlation coefficient for the two observers' recorded fixation times was r = .98 (range = .88 to .99). Mean reliability for the tests of infants at 8 weeks was r = .99, and for the tests at 12 weeks was r = .98. Percent agreement was defined as number of agreed-upon trials divided by total number of trials in a test session. The two observers were scored as being in agreement if their fixation times per trial were within 0.5 s of each other. The overall mean percent agreement was 65.4% (41%-85%). Mean percent agreement for the tests at 8 weeks was 60%, and for the tests at 12 weeks was 70.6%.

Results

The results are based on infants' fixation times to the slides presented. An infant's fixation time on each trial was an average of the recordings of the two observers. These data were then averaged into blocks of two trials, yielding ten blocks of familiarization, one block of generalization, and two blocks of configuration-change trials. All analyses were conducted on log transformed data because the distributions were positively skewed, and the variances were found to be heterogeneous (in every case the F_{max} statistic generated a p

value of less than .01). Table 3 presents the means and standard deviations of the log scores for the infants at 8 and 12 weeks. Scores included are: the first warm-up slide, the first and last familiarization trial blocks, the generalization and two configuration-change trial blocks, and the post-test slide. Appendix B presents the individual raw scores for all of the trial blocks. Although a number of analyses of variance were performed on the data, the alpha level was not adjusted to prevent false declaration of a non-significant difference in situations where no difference was the desired effect, such as generalization of habituation.

A preliminary analysis was conducted on response to the checkerboard stimuli to verify that the infant's attention was held throughout the task, and therefore that any habituation was not due to fatigue. A 2 x 2 repeated measures analysis of variance was conducted with Age (8- vs. 12-weeks) and Trial (first warm-up slide vs. posttest with the same slide) as within-subjects factors. The source table for this analysis is presented in Table 4. The analysis revealed a marginally significant main effect of Trial, $\underline{F}$ (1,19) = 7.20, $\underline{p} < .05$. This indicated that infants at both ages looked longer at the last slide ($\underline{M}$ = 0.96 log s) than at the first slide ($\underline{M}$ = 0.68 log s). Thus there was no evidence of fatigue or loss of interest in the task. The main effect of Age and the Age x Trial interaction were not significant.

The first major analysis examined whether infants habituated (decreased fixation time) from the first to the

Table 3

Mean Log Fixation Scores for the Pre and Posttest Trials, and Initial and Final Familiarization, Generalization, and Configuration-Change Trial Blocks

		Pre	F1	F10	GS	C1	C2	Post
8 weeks								
	M	.80	1.11	.97	1.00	1.08	.88	1.06
	SD	.57	.46	.34	.29	.26	.29	.42
12 weeks								
	M	.55	.87	.54	.55	.71	.75	.86
	SD	.51	.51	.30	.38	.44	.32	.30

Table 4

Analysis of Variance of Log Fixation Scores for First Pretest Trial and Posttest With Warm-up Stimulus

Source	SS	df	MS	F
Age (A)	1.071	1	1.071	4.23
Error	4.817	19	.254	
Trial: Pre vs. Post (T)	1.622	1	1.622	7.20*
Error	4.278	19	.225	
A x T	.010	1	.010	.07
Error	2.601	19	.137	

*$p < .05$

last familiarization trial block, and generalized their response to the generalization stimuli. It took the form of a 2 x 3 repeated measures analysis of variance with Age and Trial Block (first familiarization vs. last familiarization vs. generalization) as within-subjects factors. The source table for this analysis is presented in Table 5. The analysis of variance revealed a significant main effect of Age, $\underline{F}$ (1,19 = 33.93, $\underline{p} < .001$, and a marginally significant effect of Trial Block, $\underline{F}$ (2,38) = 4.52, $\underline{p} < .05$. Contrary to expectation, there was no significant Age x Trial Block interaction. The Age effect showed that the infants looked significantly longer at the stimuli at 8 weeks of age ($\underline{M}$ = 1.03 log s) than they did at 12 weeks ($\underline{M}$ = 0.65 log s). Comparisons were performed on the Trial Block effect using a Least Significant Differences test which follows a significant $\underline{F}$ (Keppel, 1973, p. 135). The LSD test was used because it gives a sensitive measure of non-significance in situations where non-significance is the desired effect (e.g. generalization). The first comparison showed that infants looked at the last familiarization trial block ($\underline{M}$ = 0.75 log s) for a significantly shorter time than at the first familiarization trial block ($\underline{M}$ = 0.99 log s), $\underline{p} < .01$. Thus the existence of habituation was confirmed. The next comparison indicated there was no difference in fixation time between the last familiarization trial block and the generalization trial block (M = 0.78 log s), $\underline{p} > .05$. This finding indicated the existence of generalization of habituation.

Table 5

Analysis of Variance of Log Fixation Scores for Initial Familiarization, Final Familiarization, and Generalization Trial Blocks

Source	SS	df	MS	F
Age (A)	4.293	1	4.293	33.93**
Error	2.404	19	.127	
Trial Block (T)	1.303	2	.652	4.52*
Error	5.477	38	.144	
A x T	.222	2	.111	.89
Error	4.709	38	.124	

*$p < .05$ **$p < .001$

A further analysis of the habituation data was conducted to verify that the habituation trend was similar at both ages. This was necessary because the prior analysis, although it showed no Age x Trial Block interaction, had only examined the first and last trial blocks of familiarization. A 2 x 10 repeated measures analysis of variance was conducted with Age and Familiarization Trial Block (1 through 10) as within-subjects factors. The source table for this analysis is presented in Table 6. The analysis revealed significant main effects of Age, $F(1,19) = 59.61$, $p < .001$, and Familiarization Trial Block, $F(9,171) = 6.08$, $p < .001$, but a nonsignificant Age x Familiarization Trial Block interaction. The Age effect again showed that the infants fixated the familiarization stimuli significantly longer at 8 weeks of age ($M = 1.04$ log s) than they did at 12 weeks ($M = 0.63$ log s). An orthogonal polynomial trend analysis indicated that the Trial Block effect was primarily attributable to a significant linear trend, $F(1,19) = 22.33$, $p < .001$, that reflected decreasing fixation times across trial blocks. The analysis also revealed the existence of a marginally significant eighth-order trend, $F(1,19) = 5.00$, $p < .05$. Figure 2 shows the habituation trend for infants at both 8 and 12 weeks.

The next stage of the analysis examined how infants responded to the test stimuli. The first of these analyses tested whether infants dishabituated from the generalization trial block to the first and second configuration-change trial blocks. This test took the form of a 2 x 3 repeated measures

Table 6

Analysis of Variance of Log Fixation Scores for Ten Familiarization Trial Blocks

Source	SS	df	MS	F
Age (A)	16.350	1	16.350	59.61*
Error	5.210	19	.274	
Familiarization Trial Block (T)	4.754	9	.528	6.08*
Error	14.864	171	.087	
A x T	.574	9	.064	.60
Error	18.239	171	.107	

*$p < .001$

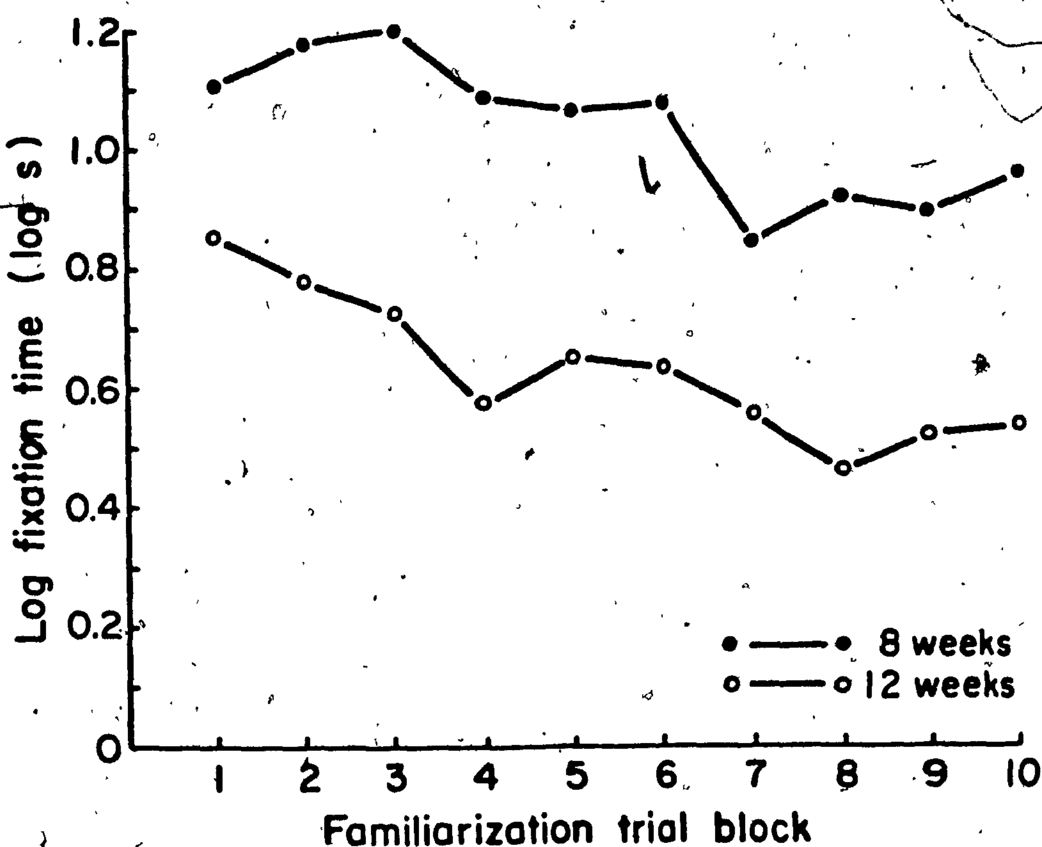

Figure 2. Habituation trend across familiarization trial blocks for infants at 8 and 12 weeks.

analysis of variance with Age and Trial Block (generalization vs. first configuration change (C1) vs. second configuration change (C2)) as within-subjects factors. The source table for this analysis is presented in Table 7. The analysis revealed a significant effect of Age, F (1,19) = 15.31, $p < .001$, which indicated that the infants fixated the test stimuli significantly longer at 8 weeks of age (M = 0.99 log s) than they did at 12 weeks (M = 0.67 log s). The main effect of Trial Block was not significant. The Age x Trial Block interaction was significant, however, F (2,38) = 7.3, $p < .01$, and is shown in Figure 3. The interaction was explored through the use of a Newman-Keuls post-hoc comparison. The Newman-Keuls test indicated that at 8 weeks, infants did not increase their fixation time from the generalization trial block to the first configuration-change trial block, but showed a marginally significant decrease in fixation time from generalization to the second configuration-change trial block, $p < .05$. At 8 weeks infants also showed a significant decrease in fixation time from the first to the second configuration-change trial block, $p < .01$. On the other hand, the Newman-Keuls test indicated that at 12 weeks the infants showed a marginally significant increase in fixation time from the generalization trial block to the first configuration-change trial block, $p < .05$, and a significant increase in fixation to the second configuration-change trial block, $p < .01$, but no difference in response between the first and second configuration-change trial blocks. Thus the hypothesis

Table 7

Analysis of Variance of Log Fixation Scores on Test Trials

Source	SS	df	MS	F
Age (A)	3.014	1	3.014	15.31**
Error	3.740	19	.197	
Trial Block: GS vs. C1 vs. C2 (T)	.304	2	.152	1.59
Error	3.641	38	.096	
A x T	.568	2	.284	7.53*
Error	1.433	38	.038	

*$p < .01$ **$p < .001$

5

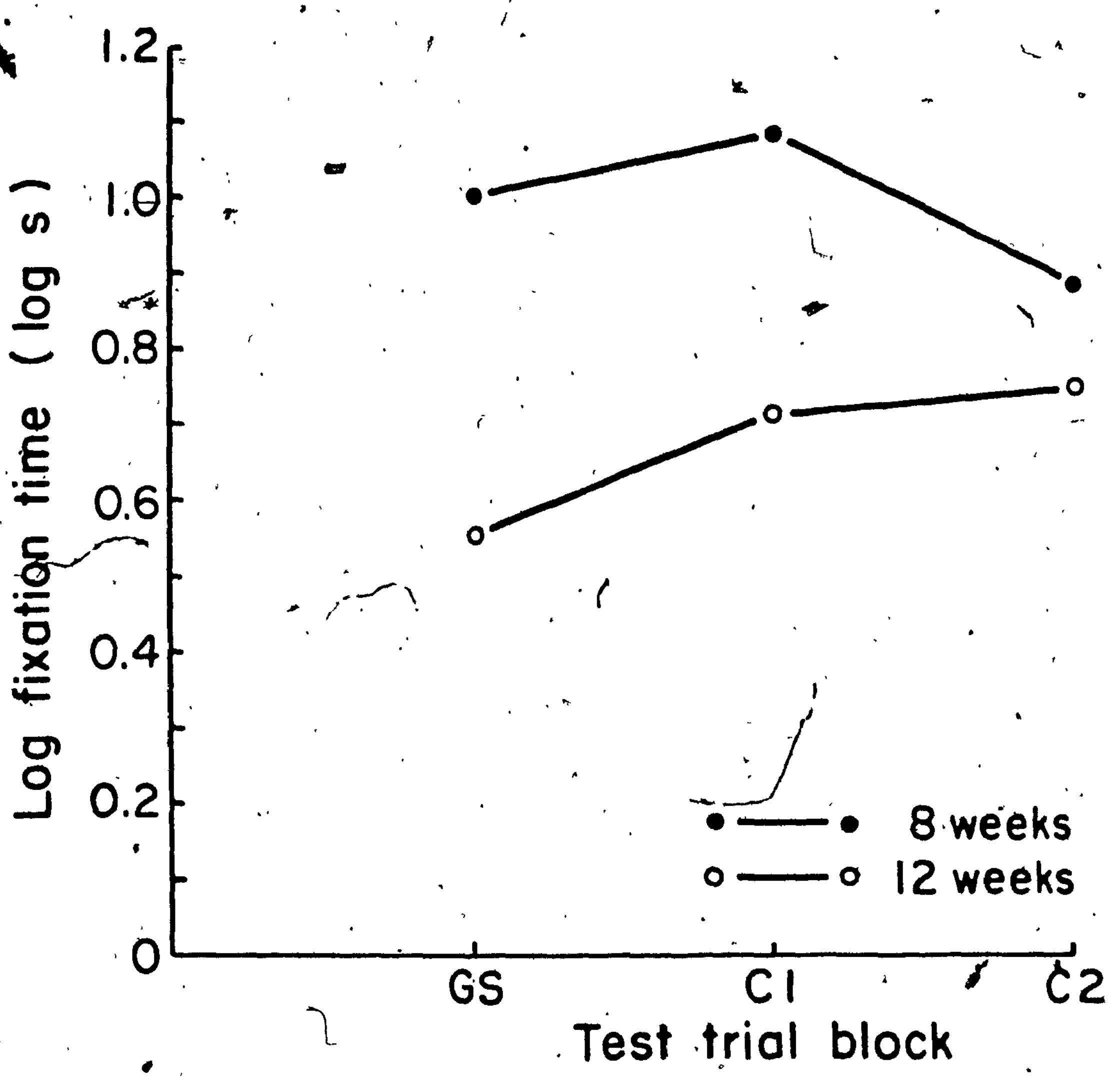

Figure 3. Age x Test Trial Block Interaction.

that evidence of form perception would be obtained for 12-week group data, but not for 8-week group data, was supported.

The second analysis of test stimuli examined whether infants responded differently to the two types of configuration-change stimuli: one the same vertical size as the familiarization stimuli (CF), and the other the same vertical size as the generalization stimuli (CG). Inspection of the data suggested differential fixation of the CF and CG stimuli. In order to examine dishabituation to the CF and CG stimuli from a baseline of fixation to the generalization stimuli, the log fixation score for the GS stimuli was subtracted from both the CF and CG log scores for each infant. Thus the data analyzed for CF and CG were change scores. The mean change scores and their standard deviations for infants at both ages are shown in Table 8. Data were analyzed separately for each age group because of the Age x Trial Block interaction obtained in the previous analysis.

The analysis of the change scores took the form of a 2 x 2 analysis of variance, with Trial Block (C1 vs. C2) as a within-subjects factor, and Stimulus Group (one group who saw the CF stimuli first and the CG stimuli second vs. another group who saw CG first and CF second) as a between-subjects factor. If the CF and CG stimuli were responded to differently, we would expect to find a significant Stimulus Group x Trial Block interaction.

The source table for the 8-week data is presented in Table 9. At 8 weeks, only the Trial Block main effect was

Table 8

Mean Change Scores From GS Log Fixation Time for CF and CG Stimuli

		CG		CF	
		C1	C2	C1	C2
8 weeks					
	M	.20	-.14	-.04	-.11
	SD	.39	.38	.31	.39
12 weeks					
	M	.20	.13	.12	.27
	SD	.37	.33	.44	.31

Table 9

Analysis of Variance of CF and CG Change Scores as a Function of Stimulus Group and Trial Block for 8-Week Data

Source	SS	df	MS	F
Stimulus Group: CF first vs. CG first (SG)	.202	1	.202	.95
Error	3.816	18	.212	
Trial Block: C1 vs. C2 (T)	.416	1	.416	6.91*
SG x T	.108	1	.108	1.80
Error	1.084	18	.060	

*$p < .05$

marginally significant, F (1,18) = 6.91, $p < .05$. It reflected the fact that the infants showed significantly greater dishabituation to the first configuration-change stimulus (M change score = 0.08 log s) than to the second (M change score = -0.13 log s). Neither the Stimulus Group effect, nor the Stimulus Group x Trial Block interaction was significant. The source table for the 12-week data is presented in Table 10. Analysis of the 12-week data revealed nonsignificant main effects of Stimulus Group and Trial Block as well as a nonsignificant Stimulus Group x Trial Block interaction. The lack of significant interactions indicates that the infants at 8 and 12 weeks did not respond differently to the CF and CG stimuli.

Since it was expected that more of the infants at 12 weeks would show evidence of form perception than at 8 weeks, and since group means do not always reflect individual performance, it was necessary to assess the responses of individual infants. The data of each infant were examined for evidence of habituation, generalization, and dishabituation to the first configuration-change stimulus. The performance criteria for evidence of form perception were: Habituation -- at least a 25% decrement in log fixation time from the first to the last familiarization trial block (see Appendix B for the percent decrement in habituation for individual infants); Generalization -- a fixation time to the generalization trial block which was shorter, or no more than 5% longer than to the last familiarization trial block; and

Table 10

Analysis of Variance of CF and CG Change Scores as a Function of Stimulus Group and Trial Block for 12-Week Data

Source	SS	df	MS	F
Stimulus Group: CF first vs. CG first (SG)	.128	1	.128	.65
Error	3.549	18	.197	
Trial Block: C1 vs. C2 (T)	.014	1	.014	.20
SG x T	.012	1	.012	.16
Error	1.285	18	.071	

dishabituation from the generalization to the first configuration-change trial blocks (any increase in fixation of more than 5%). Examination of the data revealed that 10 of the infants at 8 weeks habituated according to the criterion. Only 2 infants (both female) of these 10 generalized their response to the generalization stimuli and dishabituated to the first configuration-change stimulus (Dishabituation M = 142%, range = 128% - 156% increase in response), thus apparently showing evidence of form perception. The other 8 infants who habituated to the familiarization stimuli dishabituated to the generalization stimuli (Dishabituation M = 54%, range = 10% - 500%). At 12 weeks of age, 12 infants habituated according to the criterion. Five of these infants generalized their response to the generalization stimuli, and all 5 (4 female, 1 male) dishabituated to the first configuration-change trial block (Dishabituation M = 395.8%, range = 17% - 1250%), thus apparently showing evidence of form perception. A χ^2 test of association between gender and number of infants demonstrating form perception at 12 weeks was not significant, χ^2 (1, N=20) = 3.29, $p > .05$ (χ^2 = 3.84 required for significance at the .05 level when df = 1). The other 7 of the infants who habituated at 12 weeks dishabituated to the generalization stimuli (Dishabituation M = 105.43%, range - 16% - 433%). Thus 10% of the infants at 8 weeks, and 25% of the infants at 12 weeks showed the pattern of response suggesting form perception. There did not appear to be any difference in age between the infants who showed evidence of form perception at a given age and those who did not. At 8 weeks, the mean chronological age of the two infants showing evidence of form perception was 63 days, and their mean corrected age (age from expected date of birth) was 58 days. The 18 infants not showing evidence of form perception had a mean chronological age of 59.9 days, and a mean corrected age of 59.8 days. At 12 weeks, the 5 infants showing form perception had a mean chronological age of 90.4 days, and a mean corrected age of 89 days. The remaining 15 infants had a mean chronological age of 89.6 days, and a mean corrected age of 89.3 days.

Discussion

The results indicated that at both 8 and 12 weeks of age infants showed significantly less fixation of the stimuli on the final than on the initial familiarization trial block, thus showing evidence of habituation. At both ages, infants did not show a significant increase in fixation to the generalization stimuli, indicating that changes in vertical size of the stimuli were not salient to them. When the configuration of the stimuli changed on trial blocks C1 and C2, however, the infants only dishabituated at the age of 12 weeks. This pattern of response confirms the prediction that 12-week-olds, as a group, would abstract configuration from the task. At 8 weeks of age, the infants responded differently to the configuration-change stimuli. Eight-week-olds showed similar and significantly decreased fixation to trial blocks C1 and C2, respectively, relative to the generalization stimuli. This pattern of response seems to show that configuration is not salient to infants at 8 weeks, and confirms the prediction that 8-week-olds, as a group, would now show evidence of form perception. These results support the Maurer and Lewis (1979) suggestion that rudimentary form perception is possible soon after 2 months of age, and are consistent with their theory of neural maturation. The findings of the present study could also be accounted for by maturation of cortical-subcortical pathways after 2 months of age (Atkinson, 1984).

One methodological issue in the current study was that there were no controls for either random fluctuation from trial block to trial block, or for continued habituation on a hypothetical F11 trial block. A lagged control procedure in which half the infants at each age received two additional familiarization trials before receiving generalization and subsequent test trials might provide more sensitive bases of comparison for both the test of generalization and the tests for detection of a change in configuration. The only drawback to such a procedure is that because of the great inter-subject variability, it would necessitate increasing sample size. An alternative procedure might be a statistical control in which the habituation trend is projected for two additional trials to provide a basis of comparison for the generalization test trials.

A second methodological issue in the study was that there was no evidence from the group data of the infant's ability to discriminate between the familiarization and generalization stimuli, which differed in both vertical size and contour density (see Tables 1 and 2). There is evidence in the literature, however, that young infants can discriminate very small changes in vertical size and contour density. For example, 2-month-old infants have been shown to be able to discriminate between a grating of 2-3 cycles/degree and a homogeneous background (Bank & Salapatek, 1983). This means that they are able to discriminate changes as small as 0.5^{o} visual angle, and thus should easily be able to detect the 6^{o} change in visual angle between the vertical size of the familiarization and generalization stimuli. In addition, Karmel (1969) has shown that 11- to 14-week-old infants respond differentially to stimuli with differences in contour density similar to those between the familiarization and generalization stimuli in the present study. As well, Milewski (1979) found that 3-month-olds were capable of even smaller size and contour density discriminations than those used in the present study, although his subjects may also have been responding to changes in the position of the stimulus on the screen. Finally an examination of the individual responses of our subjects at 8 weeks, revealed that 8 of the 10 who habituated to the familiarization stimuli, dishabituated to the generalization stimuli, and thus apparently perceived the generalization stimuli as different.

The finding of the ability to abstract configurational invariance in the 12-week-old infants in the present study replicates Milewski's (1979) results. He also found that 3-month-olds could abstract configurational invariance from visual stimuli very similar to the stimuli of this study. Milewski used three groups of infants to demonstrate this effect: one shown a configuration-change stimulus in the test trials, another shown a stimulus of the same configuration but in a different size and position (similar to the generalization stimuli in the present study), and a third group shown no change in the test trials. On average, infants shown the configuration-change stimulus dishabituated their sucking response, while those shown the size- and position-change or no change generalized their response. Milewski concluded that these findings showed that 3-month-old infants could abstract configuration. Milewski's subjects, however, were not required to show the full response suggesting form perception, that is, both generalization to the same configuration, and dishabituation to a configuration change. This more stringent respose criterion ensures that the infant has abstracted configuration. For example, had the criterion for form perception in the present study been only dishabituation (a 5% or more increase in fixation) to a configuration-change stimulus, 3 more infants at 8 weeks, and 3 more at 12 weeks of age would have shown evidence of form perception. These infants, however, also dishabituated to the generalization stimuli, suggesting that they had not abstracted configuration. Thus a problem with Milewski's (1979) between-groups demonstration of form perception is that some of the infants may not have been responding to configuration alone.

Examination of individual data also supported predictions. Ten percent of the infants at 8 weeks showed the pattern of response suggesting form perception, while at 13 weeks, 25% of the sample did so. Thus the prediction that more infants at 12 weeks of age would show evidence of form perception than at 8 weeks was confirmed. The infants showing form perception were not older in terms of chronological or postconceptional age than those infants not showing form perception. There was a tendency for more females to show evidence of form perception than males. An examination of group data for 8 males and 8 females matched for stimuli seen suggested that males tended to show essentially an equivalent response across test trials, while females tended to generalize to the generalization stimuli, then dishabituate to the first configuration-change trial block, which is evidence of form perception. This tendency towards a gender difference in the form perception task is consistent with evidence that females are more neurologically mature than males of the same biological age. Tanner (1974) reported that at birth, females are 1 week to 10 days more mature than males, as measured by evoked potentials and conduction velocity of the peripheral nerves. Caron, Caron and Myers (1982) also found that 18-, 24-, and 30-week-old females were superior to males in their task of abstracting facial expression.

Although the task of the present study showed definite age differences in group response to the configuration-change stimuli, the age differences did not occur in all the areas that they were expected to. Specifically, the 8-week-olds were not expected to generalize their response to the generalization stimuli because they differed in size and contour density from the familiarization stimuli. Since the infants at 8 weeks did not dishabituate to either configuration-change trial block, their generalization response does not appear to reflect abstraction of configurational invariance. If the 8-week-olds were responding to changes in either size or contour density, they would have dishabituated to the generalization stimuli, and to the CG or CF stimuli, respectively (see Tables 1 and 2), which they did not. The significant decrease in fixation time that was shown to the second configuration-change trial block might suggest a loss of attention to the task. The increase in fixation shown by both age groups to the posttest slide (in comparison with the pretest slide), however, argues against this interpretation.

Thus the group of infants at 8 weeks appeared to habituate, generalize their response to the generalization stimuli, fixate the first configuration-change trial block at the same level, and then resume habituation to the second configuration-change trial block, despite changes in configuration, size, contour density, and position of the stimuli on the viewer. This type of response suggests that the infants at 8 weeks were habituating to the pattern merely as three white dots, and is consistent with the notion that they had not abstracted form.

A further novel stimulus could be added to the display to determine more exactly what the infants at 8 weeks had abstracted from the task. Such a stimulus could be a slide with a different number of dots. Strong dishabituation to this stimulus would confirm that 8-week-olds, in this task, abstract numerical invariance. Other authors have shown that infants are sensitive to numerical constancy. Antell and Keating (1983) found that neonates could discriminate between two- and three-dot stimuli, and Treiber and Wilcox (1984) found that 4-month-olds could discriminate between four- and five-dot stimuli.

The group data thus suggest that the visual habituation task is a good one for yielding information about the development of the ability to abstract configurational invariance. The group results show that the infants at 8 weeks did not abstract configuration from the stimuli, and suggest that they are responding to the stimuli's numerical invariance. These findings may mean either that configuration is not perceived by infants at 8 weeks, or that it is perceived but not salient to the infants. At 12 weeks of age, the group results suggest that the infants have abstracted configuration, because they habituate, generalize their response to the generalization stimuli, and dishabituate to the configuration-change stimuli.

The visual habituation task used in the present study also discriminates 8- from 12-week-olds in length of fixation. The infants at 8 weeks looked significantly longer at the experimental stimuli than they did at 12 weeks. Other authors investigating visual behaviour have also found similar age differences. For example, Bomba (1984) found that 2-month-old infants looked longer at stimuli of various orientations than 3- or 4-month-old infants. In an angular relations task, Cohen and Younger (1984) found that 6-week-old infants fixated stimuli significantly longer than 14-week-olds. McCarvill and Karmel (1976) found that 9-week-old infants fixated random and redundant checkerboard patterns longer than 13-week-olds. This longer looking time has been suggested to indicate that younger infants take longer to encode visual stimuli (Werner & Perlmutter, 1979, p. 23).

Another finding of the present study was the lack of correspondence between grouped and individual data. Although log scores were used to reduce variability, the variance of the scores was still high (see Table 3 for standard deviations). The high variance suggests that few infants reflect the group mean. For example, only 25% of the infants at 12 weeks showed the full response suggested by the group mean. This may be due to the fact that infants had to demonstrate three specific responses in order to show evidence of form perception. The low success rate is thus not unexpected due to these stringent criteria.

As well, 10 infants at 8 weeks, and 8 infants at 12 weeks did not habituate according to the criterion, although the analysis showed that both age groups habituated significantly. This lack of habituation on an individual level may be due to the complexity of the task. Infants were expected to habituate to stimuli that changed on a number of levels: in size, contour density, and position on the viewer. These factors also may have contributed to the fact that the slopes of the habituation curves were not steep. Other studies that habituated infants to multiple exemplars of a category did not present the stimuli in as varied locations as the present study. For example, in their study of neonatal perception of numerical invariance, Antell and Keating (1983) presented the dot stimuli centrally, and showed two lengths of lines. However, the stimuli in the present task cannot be shown in one location, because infants could then use the position of the dots as a cue to discriminate a configuration change. Perhaps the two locations of the stimuli could be moved closer to the center of the viewer instead of being centered in each quadrant. A more central location for the two stimuli would thus allow more infants to keep their attention to the task and might allow more infants to habituate. It was also noted that some of the infants at 12 weeks fixated the stimuli for short periods of time. Perhaps the stimuli could be presented in a bright colour such as yellow, instead of white, to capture the infants' attention, and thus encourage longer initial fixations. These modifications of the task should make the slopes of the habituation curves steeper, and would allow more infants to show habituation. If more infants habituate, the form perception task would be more sensitive because the responses to the generalization and configuration-change test trials would be more meaningful.

The results indicate that the visual habituation task used in the study is useful in discriminating between 2- and 3-month-old infants in the abstraction of configurational invariance. As predicted, infants at 3 months showed the pattern of response suggesting form perception, while they did not at 2 months. The stringent response criteria for evidence of form perception (habituation, generalization of response to generalization stimuli, and dishabituation to configuration-change stimuli) must remain in the task so that researchers can be certain that infants have abstracted configurational invariance. Stimuli should be presented in a bright colour and closer to the center of the viewer to encourage more infants to habituate. In addition, a novel slide of four dots should be added following the configuration-change stimuli to determine whether 8-week-olds, who continue to generalize their response through the test trials, have abstracted numerical invariance from the task. This form perception task should be used in a cross-sectional study of 2- and 3-month-olds to ensure that the age differences in response seen in the present study are not due to prior exposure to the stimuli or to the test experience itself. The cross-sectional study would also allow investigation of the proposed modifications of the task.

It is suspected that the evidence of form perception shown by the group of infants at 12 weeks was not due to practice effects or experience, but to maturational factors. Fantz and Fagan (1975) have shown that changes in infant visual response to pattern over the first 6 months of life occur as a function of biological, rather than experiential factors. The form perception task thus appears to be useful in showing a developmental change that reflects neural maturation from 2 to 3 months of age. The task could be used in an examination of the rate of neural maturation of preterm, as compared to fullterm, infants at these ages. The task would examine whether preterms tested at corrected ages (age from expected date of birth) would show the same responses to the stimuli as fullterm infants. Further, the results of each preterm could be examined to determine whether the proportion of infants showing form perception is equal to that of the fullterm sample. Another study conducted by our laboratory (Taylor & Potvin, 1985) showed that preterm infants with no medical complications differed from fullterm infants on a task reflecting functioning of a sub-cortical mechanism and development of cortical-sub-cortical connections at 2 months postconceptional age. The use of the present task with a preterm sample would provide additional information about the differences between preterm and fullterm infants in cortical functioning.

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Appendix A

Letter Sent to Parents to Solicit Subjects and Consent Form

Dear Parent,

I noticed in the birth announcements of The Gazette that you have recently had a baby. Congratulations! As a graduate student at Concordia University who is doing research with infants, I would like to know if you are interested in having your baby take part in a study we are conducting. The research investigates the development of form perception in 2- and 3-month-old infants, and will constitute my Master's thesis in Applied Psychology. This study is under the supervision of, and supported by a grant to Dr. Nancy Taylor, Associate Professor of Psychology.

The study will involve showing babies a series of slides of 3 white dots. The dots will be arranged to form small and large lines and triangles. The amount of time babies spend looking at each slide will be timed. The information obtained from the study will tell us the kinds of changes in form that young infants can discriminate.

The study will be conducted in your home, rather than in a lab, to ensure that each baby is comfortable, and to avoid extra work for you. The testing will take no longer than 45 minutes.

If you are interested in participating in the study, or have any questions, please call me (Nikki Pawliuk) as soon as possible:

484-7944 -- evenings
879-4146 -- Concordia University
(please leave a message)

Your help would be greatly appreciated.

Nikki Pawliuk

P.S. If this letter has reached the wrong address, please excuse the inconvenience.

Consent Form

The purpose of this research is to compare the responses of 2- and 3-month-old babies to changes in visual form. This experiment is the first stage of a larger project which will investigate the performance of preterm and full-term infants. It will constitute the Master's thesis of Nikki Pawliuk, a graduate student in Clinical Psychology at Concordia University. The research is under the supervision of, and supported by a grant to Dr. Nancy Taylor, Associate Professor of Psychology.

Infants will be shown a series of slides of 3 white dots, and the amount of time they spend looking at each slide will be timed. The dots will be arranged to form smaller and larger lines and triangles. The information obtained from the study will tell us the kinds of changes in form that infants at these ages can discriminate.

The research will be conducted in 2 visits to the infant's home: one at age 7-8 weeks and the other at age 12-13 weeks. At each visit, the infant will be seated in the mother's lap in front of a television-like screen. Two experimenters will stand behind the screen and, through small holes, watch the infant's eyes so they can time how long the infant looks at each slide. A total of 29 slides will be shown. Each slide will be shown for as long as the infant looks at it. Testing will be discontinued if the infant cries or fusses excessively (interrupting more than 3 slides). The length of the session should be approximately 45 minutes.

I, ____________________, have read the above description of the study of infant's responses to changes in visual form, and had the study explained to me. I am willing to participate in the study with my baby. I am aware that I am free to withdraw my child from the study at any time.

Date ________________ Mother's signature ____________________

Witness's signature ____________________

Mother's name ____________________ Telephone ____________

Mother's place of employment ____________________

Infant's name ____________________

Address ____________________

Would you like a summary of results for all subjects when the study is completed?

Yes ____ No ____

Appendix B

Individual Data

Table B-1

Fixation Times at 8 Weeks on Familiarization Trial Blocks (in s)

s	1	2	3	4	5	6	7	8	9	10
1	45.43	10.63	20.2	28.45	46.0	30.4	12.85	5.1	7.88	10.05
2	24.88	26.58	13.48	2.68	7.05	6.13	5.85	6.88	8.53	21.78
3	24.68	30.38	19.8	13.35	6.45	5.0	3.0	26.35	3.68	9.0
4	39.63	34.65	38.1	18.2	12.48	30.95	20.28	21.6	8.68	6.95
5	14.95	8.6	9.25	12.45	15.25	4.5	3.65	5.1	6.1	8.05
6	15.95	16.23	26.4	4.18	14.9	22.48	1.68	7.45	3.68	7.98
7	5.5	8.73	5.75	3.68	4.2	5.5	6.75	2.85	10.25	2.83
8	8.85	6.48	18.53	6.48	25.5	16.35	3.38	9.83	17.53	4.93
9	12.78	23.5	5.23	9.83	18.05	19.48	5.38	17.53	8.58	20.53
10	2.78	29.15	18.55	7.55	13.48	13.13	31.75	7.35	5.45	19.88
11	64.73	19.6	20.28	16.35	44.03	16.58	25.73	25.05	6.28	11.83
12	22.63	14.23	16.25	17.23	10.25	17.78	30.35	32.45	28.88	30.25
13	12.43	9.18	18.78	22.58	15.0	8.53	7.43	6.98	9.03	4.33
14	18.25	7.6	31.38	12.35	9.68	31.73	11.05	6.75	7.58	18.05
15	23.25	6.68	12.13	23.9	7.5	13.2	5.85	2.68	5.25	6.7
16	45.23	27.65	31.28	40.3	15.78	9.93	9.28	23.05	6.23	26.78
17	1.2	17.88	30.9	22.23	3.73	15.83	1.65	1.55	6.45	10.43
18	9.78	18.88	7.85	18.95	10.23	8.53	5.65	7.73	8.15	12.08
19	3.43	16.83	8.45	17.9	14.35	10.5	5.13	9.93	18.78	4.48
20	2.98	12.55	15.55	6.88	4.65	4.18	5.45	4.85	5.03	1.5
M	19.97	17.30	18.41	15.28	14.93	14.54	10.11	11.55	9.10	11.92
SD	17.08	8.79	9.33	9.41	11.58	8.85	9.34	9.21	6.06	8.20

Table B-2

Fixation Times at 12 Weeks on Familiarization Trial Blocks (in s)

s	1	2	3	4	5	6	7	8	9	10
1	27.05	16.2	1.55	2.43	1.83	1.65	1.75	5.58	5.38	1.98
2	2.78	9.83	13.23	14.55	21.55	1.85	11.93	10.9	13.48	2.6
3	1.58	10.33	10.53	4.88	2.6	9.25	6.7	1.43	5.58	2.0
4	9.93	4.68	6.63	3.18	6.23	3.28	3.35	3.03	2.78	3.58
5	7.28	16.78	15.35	9.33	3.85	3.95	2.7	4.9	7.68	8.05
6	19.55	3.05	5.98	3.05	1.88	2.23	2.0	2.28	1.5	5.15
7	5.48	2.65	3.0	0.9	1.6	1.48	1.25	2.2	0.93	3.15
8	1.38	0.65	0.7	1.03	1.28	3.98	2.2	2.4	6.4	24.58
9	7.3	72.55	7.85	2.25	4.95	10.78	2.98	2.45	2.68	4.38
10	29.8	19.0	33.15	6.73	30.08	11.83	11.2	6.23	3.8	3.18
11	8.13	13.85	7.75	7.75	11.95	4.83	12.0	1.08	3.68	6.48
12	3.18	1.73	10.05	5.7	5.83	5.28	1.88	2.53	0.73	3.2
13	31.15	5.55	10.03	4.88	2.78	12.85	3.65	3.48	4.25	3.0
14	23.25	7.98	5.98	12.78	3.18	4.58	2.55	1.98	2.9	1.38
15	9.1	2.95	6.85	0.88	1.83	6.95	9.75	11.33	8.98	5.13
16	33.88	12.85	7.28	13.43	24.83	28.85	2.28	2.0	4.13	3.05
17	1.15	1.15	1.65	2.08	2.08	1.25	1.45	1.03	0.93	1.08
18	1.48	2.25	13.3	2.48	2.85	2.1	1.9	1.25	1.13	2.08
19	22.0	9.1	0.95	2.05	20.45	10.93	17.6	10.28	4.05	5.55
20	2.23	4.7	1.03	5.0	2.63	1.13	3.05	2.35	8.73	2.45
M	12.38	10.89	8.14	5.27	7.71	6.45	5.11	3.94	4.49	4.61
SD	11.45	15.58	7.35	4.26	8.97	6.53	4.72	3.29	3.28	5.02

Table B-3

Fixation Times at 8 Weeks on Pre and Posttest Trials, and Initial and Final Familiarization, Generalization, and Configuration-Change Trial Blocks (in s)

S	Sex	Pre	F1	F10	GS	C1	C2	Post
1	F	4.7	45.43	10.05	12.8	15.05	8.25	3.6
2	M	3.45	24.88	21.78	6.28	13.43	10.73	41.95
3	F	5.25	24.68	9.0	3.58	25.95	3.95	29.3
4	M	1.3	39.63	6.95	8.43	11.8	23.15	20.9
5	M	2.4	14.95	8.05	10.3	19.1	3.95	20.6
6	F	0.45	15.95	7.98	2.95	11.85	2.48	12.4
7	M	3.7	5.5	2.83	6.53	3.08	3.83	3.8
8	F	8.0	8.85	4.93	14.23	11.9	5.9	22.6
9	M	32.95	12.78	20.53	10.78	19.9	6.78	8.4
10	F	2.0	2.78	19.88	9.8	22.8	6.7	16.4
11	M	72.5	64.73	11.83	23.18	30.1	22.08	48.75
12	F	15.6	22.63	30.25	5.0	6.93	17.8	33.3
13	M	83.95	12.43	4.33	14.45	12.1	7.4	13.3
14	M	37.3	18.25	18.05	15.53	8.33	11.38	21.7
15	M	2.75	23.25	6.7	46.63	9.5	8.43	6.5
16	M	9.2	45.23	26.78	18.1	23.53	5.1	3.75
17	M	5.3	1.2	10.43	15.9	8.03	4.3	3.15
18	F	4.3	9.78	12.08	5.48	14.73	20.7	15.95
19	F	4.15	3.43	4.48	6.45	6.3	10.23	1.6
20	F	5.55	2.98	1.5	12.13	5.03	3.18	7.7
M		15.24	19.97	11.92	12.43	13.97	9.32	16.78
SD		23.75	17.08	8.20	9.62	7.43	6.52	13.36

Table B-4

Fixation Times at 12 Weeks on Pre and Posttest Trials, and Initial and Final Familiarization, Generalization, and Configuration-Change Trial Blocks (in s)

S	Sex	Pre	F1	F10	GS	C1	C2	Post
1	F	2.7	27.05	1.98	1.13	1.98	3.98	23.35
2	M	0.9	2.78	2.6	8.78	6.75	6.38	2.1
3	F	0.7	1.58	2.0	1.8	7.48	9.53	12.85
4	M	12.35	9.93	3.58	1.05	1.88	0.98	3.75
5	M	3.15	7.28	8.05	2.78	4.8	3.63	5.3
6	F	12.1	19.55	5.15	3.15	21.6	4.63	23.55
7	M	2.1	5.48	3.15	3.83	3.53	6.93	9.8
8	F	0.9	1.38	24.58	4.55	33.13	7.05	9.15
9	M	111.25	7.3	4.38	5.58	19.55	11.18	6.6
10	F	1.9	29.8	3.18	3.18	5.33	8.13	3.0
11	M	3.3	8.13	6.48	11.38	8.25	6.68	4.4
12	F	2.2	3.18	3.2	7.05	9.65	8.55	5.1
13	M	12.4	31.15	3.08	15.0	12.05	25.0	12.0
14	M	5.6	23.25	1.38	1.68	3.15	4.53	3.85
15	M	1.7	9.1	5.13	6.75	2.65	5.98	10.25
16	M	6.25	33.88	3.05	5.23	16.5	7.83	14.25
17	M	1.5	1.15	1.08	1.45	0.8	1.23	3.85
18	F	2.0	1.48	2.08	1.15	2.13	2.68	12.6
19	F	3.5	22.0	5.55	1.15	1.18	9.68	3.8
20	F	5.2	2.23	2.45	13.78	2.6	5.33	8.75
M		9.59	12.38	4.61	5.02	8.25	7.00	8.92
SD		24.23	11.45	5.02	4.27	8.45	5.05	6.20

Table B-5

Percent Change in Log Fixation Scores From First to Last Familiarization Trial Block

S	Sex	8 Weeks	12 Weeks
1	F	-40	-79
2	M	- 4	- 7
3	F	-32	+50
4	M	-47	-45
5	M	-22	+ 6
6	F	-25	-45
7	M	-39	-32
8	F	-27	+893
9	M	+18	-26
10	F	+196	-66
11	M	-41	-11
12	F	+10	+ 2
13	M	-41	-67
14	M	+ 1	-90
15	M	-39	-26
16	M	-14	-69
17	M	+1175	-50
18	F	+9	+88
19	F	+20	-45
20	F	-62	+11