Visual acuity screening of preterm infants

Velma Dobson, D. Luisa Mayer, and Clifton P. Lee

Visual acuity was screened in 36 healthy infants born 4 or more weeks prior to term. Preterm infants tested at 8 and 12 weeks of postnatal *age showed significantly poorer performances than those shown by 8- and 12-week-old full-term infants. However, no differences in performance were found when the scores of preterm infants tested at 4, 8, and 12 weeks of* postterm *age (i.e., 4, 8, and 12 weeks from due date) were compared with scores of 4-, 8-, and 12-week-old full-term infants. The results suggest that visual acuity is more closely correlated with age from conception than with age from birth and that visual acuity screening in preterm infants should be carried out with acuity gratings appropriate for the infant's postterm age rather than with acuity gratings appropriate for the infant's postnatal age.*

Key words: visual acuity, infants, preterm, vision screening technique

Since infants born prior to term have a higher incidence of visual problems, e.g., myopia, poor visual acuity, strabismus, retrolental fibroplasia, and cataracts,[1] than do full-term infants, it is important that any procedure for screening visual acuity in infants have the capacity to assess this at-risk group. In previous studies, we have reported the development of a procedure for behavioral screening of visual acuity in young infants.[2–4] The procedure involves testing an infant with a single acuity grating, termed the *diagnostic stripe width,* to estimate whether the infant's visual acuity is within the normal range for his or her age. Appropriate diagnostic stripe widths for 4-, 8-, 12-, and 16-week-old infants were selected on the basis of the data of full-term infants tested at the four ages. The purpose of the present research was to estimate appropriate diagnostic stripe widths for infants born prior to term.

Since preterm infants are, by definition, born before completion of a full 40-week gestation period, the question arises as to whether the infant's visual status is more closely correlated with the infant's age from birth or with the infant's age from conception. Visual acuity in preterm infants has been examined in four previous studies.[5–8] In all four studies, preterm infants exhibited poorer acuity than would be expected in full-term infants of the same postnatal (PN) age. However, three of the four studies lacked sufficient data to answer the question of whether an infant's visual acuity could be predicted better by its PN age or by its age from conception. Kiff and Lepard[5] and Miranda[6] did not include control groups of full-term infants of the same PN age as the preterm infants, and since most of their infants were tested before they reached term, these investigators also were unable to include control groups of full-term infants who were the

From the Department of Psychology, University of Washington, Seattle.

This research was supported in part by NSF grant BNS76-01503 and NEI grant 5 RO1 EYO1695 (Davida Y. Teller) and by NIH Postdoctoral Research Fellowship F22 EYO1523 and NEI grant 1 RO1 EYO2581 (V. D.)

Submitted for publication Nov. 13, 1979.

Reprint requests: Dr. Velma Dobson, Department of Psychology, NI-25, University of Washington, Seattle, Wash. 98195.

0146-0404/80/121498+08$00.80/0

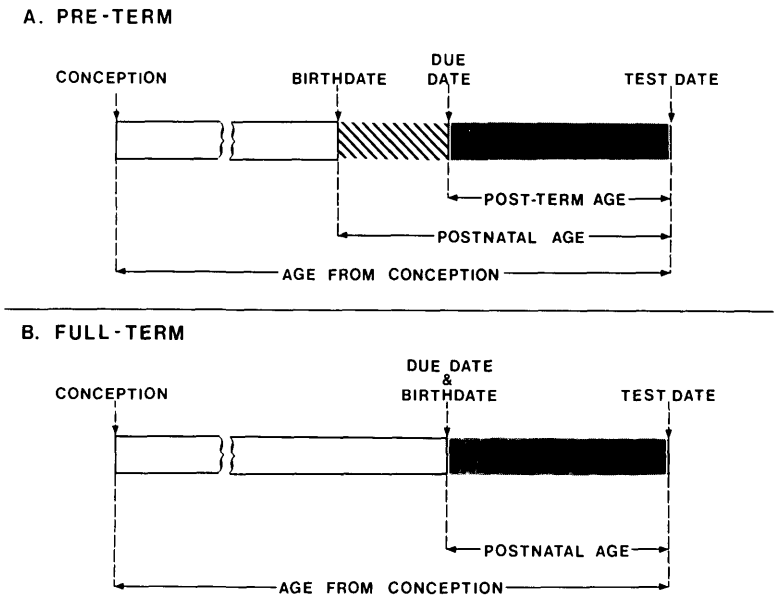

Fig. 1. A, Schematic diagram of the relation between PN age and PT age in a preterm infant. **B,** Diagram of PN age of a full-term infant conceived and tested on the same dates as the preterm infant illustrated in **A.** When the preterm and full-term infants are matched in age from conception, the PN age of the full-term infant is equal to the PT age but shorter than the PN age of the preterm infant.

same age from conception as the preterm subjects. Sokol[7] tested only one preterm infant, and therefore it is difficult to draw conclusions about the status of visual acuity in preterm infants on the basis of his data.

The fourth study, reported by Fantz et al.,[8] included results from full-term infants of the same PN age and the same age from conception as many of the preterm infants. These investigators measured visual preferences combined across three widths of black-and-white gratings rather than acuity per se. Their results suggest that acuity development is more closely related to the age from conception than to the PN age.* In summary, earlier studies of visual acuity in preterm infants suggest that acuity screening based on a preterm infant's PN age may not be the best indicator of whether or not the infant's acuity is within the normal range for a healthy preterm infant. Furthermore, the results of Fantz et al.,[8] who used a preference measure related to acuity, suggest that tests based on an infant's age from conception would be more appropriate for acuity screening than tests based on an infant's PN age.

In the present study, we pose the following empirical question. If one wishes to screen preterm infants for existing visual acuity deficits, would it be better to test the infants with diagnostic stripe widths selected on the basis of the infant's PN age or on the basis of the infant's age from conception? For convenience, we shall refer to age from due date as postterm (PT) age. A schematic diagram of the relation between PN and PT ages in a preterm infant and of their relation to PN age in a full-term infant of the same age from conception is shown in Fig. 1.

Materials and methods

Subjects. Preterm infants were solicited by letters to parents listed in the birth announcements section of the newspaper. All infants who weighed

*Similar results have often, but not always, been reported for the development of pattern preferences[9-12] and visual evoked potential latency.[13]

Invest. Ophthalmol. Vis. Sci.
December 1980

Table I. Characteristics of groups of preterm subjects

		Birth wt (gm)		*Gestational age at birth (wk)**		*PN age at test (wk)*		*PT age at test (wk)*	
Age group	*N*	*Mean*	*S.D.*	*Mean*	*S.D.*	*Mean*	*S.D.*	*Mean*	*S.D.*
4 weeks:									
PN	4	2166	160	35	1.2	4.1	0.5	−0.9	1.2
PT	9	2186	242	34	1.4	9.8	1.4	3.8	0.4
8 weeks:									
PN	15	2049	326	34	1.6	8.1	0.4	2.4	1.6
PT	16	2141	297	34	1.9	13.6	2.0	8.0	0.4
12 weeks:									
PN	13	1973	338	35	1.7	12.0	0.2	6.5	1.7
PT	10	2278	109	35	1.1	16.7	1.1	12.0	0.4

*Full-term = 40 weeks.

less than 2500 gm at birth and were born 4 or more weeks prior to term by the parent's report* and whose parents were willing to participate were included in the study. All infants were healthy at the time of testing and had no known ocular abnormalities or evidence of retrolental fibroplasia, by parent's report. Previous research indicates that better than 90% of these infants would be expected to show 20/20 acuity by 10 years of age.[1] Infants were scheduled for laboratory testing at the mutual convenience of the parents and experimenters at one or more of the following six ages—4, 8, or 12 weeks after their birth date and/or 4, 8, or 12 weeks after their due date.

A total of 36 infants were tested. Fifteen infants were tested at only one age, 13 were tested at two ages, six were tested at three ages, and two were tested at four ages, for a total of 67 data sets. Of the 21 infants tested at more than one age, only five were tested at one of the PN ages *and* at one of the PT ages: two infants at 4 weeks of PN and PT age, two at 8 weeks, and one at 12 weeks. The data of these five infants were not included in statistical analyses of differences between infants tested at PN vs. PT ages.

Overall, the average gestational age of the infants was 34.4 ± 1.5 (S.D.) weeks, and the average birth weight was 2096 ± 276 (S.D.) gm. Table I lists for the six age groups the number of infants tested, the mean and S.D. of the birth weights, PN ages and PT ages of each group, and the number of infants in each group who received oxygen or phototherapy as neonates. Student's t tests were conducted to compare test age, gestational age, and birth weight of 8- and 12-week PN and PT age groups; the 4-week-old groups were not compared because the sample of infants was too small. The only comparison that was significant was the birth weight comparison of the 12-week groups, with that of the infants tested at 12 weeks of PT age being more than that at 12 weeks of PN age ($t = 2.37$, $df = 19$, $p < 0.05$). Statistical analyses of the proportion of infants receiving oxygen or phototherapy in each group at each age were also carried out. Since proportions of the PT and PN age groups for whom treatment was not known did not differ at any age, comparison of the proportion of infants in each group who did or did not receive oxygen or phototherapy after birth was conducted with Fisher's Exact Test.[15] None of the comparisons was significant. In addition, there were no differences in the proportions of male and female infants in the PN and PT age groups (Fisher's Exact Test). Thus, with the exception of the birth weight difference at 12 weeks, there is no evidence that infants tested according to their PT age differed significantly from infants tested according to their PN age when compared for gestational age, test age, birth weight, sex, or presence or absence of oxygen or phototherapy shortly after birth.

Apparatus. The apparatus used has been described extensively elsewhere.[2, 16] Basically, it consisted of a gray screen with a luminance of about 1.2 log cd/m^2. The screen contained a centrally located peephole flanked by two stimulus holes centered to the left and right of the

*Thus infants in the present study were required to meet both the criterion for classification as preterm (<37 weeks gestation) and the criterion of low birth weight (<2500 gm) as defined by the World Health Organization.[14]

Oxygen			*Phototherapy*		
Yes	*No*	*Unknown*	*Yes*	*No*	*Unknown*
2	2	0	3	1	0
3	6	0	8	1	0
8	6	1	8	4	3
7	9	0	11	3	2
8	3	2	7	2	4
3	7	0	7	3	0

peephole. On each trial a black and white striped acuity grating was positioned behind one of the holes, and a piece of gray cardboard was placed behind the other.

Procedure. All infants were tested with the acuity screening procedure described in previous publications.[2-4] The procedure is based on the forced-choice preferential looking (FPL) technique.[16, 17] During testing, the infant was held in front of the gray screen by an adult, the *holder,* whose view of the screen was obscured by a cardboard shield. On each trial a striped acuity grating was positioned on the left or the right side of the screen. An *observer,* who was unaware of the left-right position of the stimulus, viewed the infant's face through the central peephole in the screen and was required to judge on each trial whether the grating was on the left or on the right. A third adult, the *experimenter,* set up the trials and gave the observer trial-by-trial feedback as to whether he or she had correctly judged the stimulus position.

As previously described, each infant received up to 40 trials: up to 20 trials with an acuity grating of large control stripes, each subtending 80 min of visual angle, intermixed with up to 20 trials of a finer acuity grating. Infants tested at 4 weeks of PN or PT age were tested with 40 min stripes; those tested at 8 weeks of PN or PT age, with 27 min stripes; and those tested at 12 weeks of PN or PT age, with 20 min stripes. These three-stripe widths were used because they were previously estimated to be the diagnostic stripes for 4-, 8-, and 12-week-old full-term infants.[2] Testing was continued until each infant either "passed" or "failed" on the finer stripe width. The infant received a passing score when the observer correctly judged the location of the finer stripes on 5/5, 9/10, 13/15, or 15/20 trials ($p = 0.05$, conditional binomial probabilities).* If the observer incorrectly judged the position of the finer stripes on six or more trials, a "fail" was recorded. An infant received a score of "incomplete" if testing had to be terminated before the observer's score met any of the five cutoff criteria.

Results

The actual scores (observer's percent correct) for each infant for both the diagnostic stripes and the large control stripes are shown in Fig. 2, along with data previously obtained from 4-, 8-, and 12-week-old full-term infants.[2]† Data from infants tested at 4 weeks of PN age are not included because all four infants in this group fell asleep before testing was completed.

For preterm infants tested at 4, 8, and 12 weeks of PT age, the distribution of scores obtained for the diagnostic stripes and the control stripes was similar to that of 4-, 8-, and 12-week-old full-term infants. Twenty-nine of the 31 preterm infants and all 30 full-

*These cutoff criteria are used in sequence. Each cutoff point in the sequence could occur only if the earlier cutoff criteria had not been met. For example, we stopped after 9/10 only if we had not already stopped after 5/5. To find the probability that an infant will pass the test when in fact he or she cannot see the stripes, we must sum the conditional probabilities of the four criteria for obtaining a passing score. This sum is 0.050.

An alternative approach that has been suggested to us would be to consult the tables of binomial probabilities and to terminate a run whenever the outcome of the run has a probability less than 0.05. Such a rule would terminate a run after 5/5, 7/8, 9/11, 10/13, 12/16, or 13/18 correct trials. The problem with this is that the probability of reporting that the infant can see the stripes when he or she actually cannot is 0.10 rather than 0.05. This occurs because the total probability of meeting these criteria if the observer is guessing is (1) the probability of 5/5 plus (2) the probability of 7/8, given that 5/5 did not occur, plus (3) the probability of 9/11, given that 5/5 and 7/8 did not occur, etc. The binomial tables do not show such conditional probabilities.

†The data of the full-term infants, previously reported as observer's percent correct based on 20 trials with the diagnostic stripes and 20 trials with the control stripes, have been rescored on the basis of the cutoff criteria of 5/5, 9/10, 13/15, 15/20, or 6 incorrect used in the present study (see procedure).

Invest. Ophthalmol. Vis. Sci.
December 1980

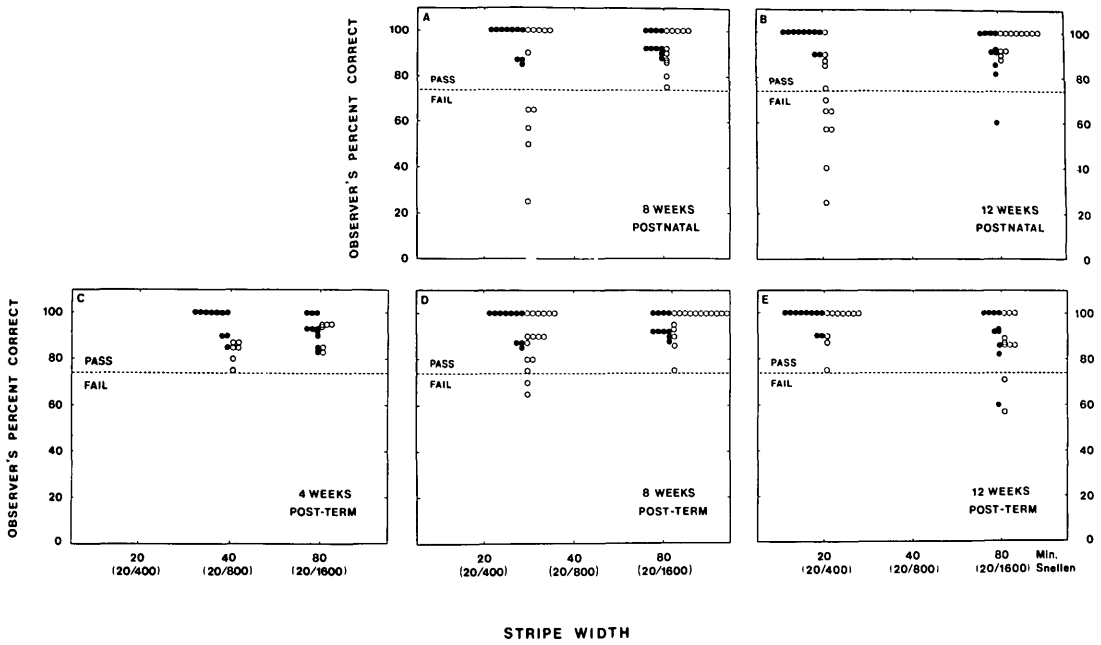

Fig. 2. Observer's percent correct on diagnostic and control stripes for preterm *(open symbols)* infants tested at various ages. Data from infants tested at 4 weeks of PN age are not shown because all four infants in this group failed to complete testing. *Filled symbols,* Data of full-term infants tested at 4, 8, or 12 weeks PN in a previous study.[2] Virtually all preterm infants tested according to PT age passed on the diagnostic stripes, whereas many of those tested according to PN age failed on these stripes.

term infants.[2]† Data from infants tested at 4 diagnostic stripes.* On the other hand, the groups tested at 8 and 12 weeks of PN age were each an average of 6 weeks younger in age from conception than were their 8- and 12-week PT-age counterparts, and this fact was reflected in their poorer performance; that is, 12 of the 23 infants who completed testing obtained a failing score. These results thus suggest that the group of preterm infants tested at 4, 8, or 12 weeks of PT age had visual acuity values similar to visual acuity values of 4-, 8-, and 12-week-old full-terms but that preterm infants tested at 8 or 12 weeks of PN age had lower acuities, in accord with their lower ages from conception.

Fig. 3 summarizes the percentage of infants from the three PN age groups *(A)* and the three PT age groups *(B)* who passed, failed, or did not complete the acuity screening procedure. Comparison of Fig. 3, *A* and *B,* indicates that preterm infants tested with diagnostic stripes appropriate for their PN age were more likely to fail or obtain an incomplete score and less likely to pass than were preterm infants tested with diagnostic stripes appropriate for their PT age.

Statistical analyses were conducted to compare proportions of preterm infants in the PT and PN age groups scoring pass, fail, or incomplete. Excluding infants who were tested at the same PT and PN age (two at 4 weeks, two at 8 weeks, and one at 12 weeks), significant differences were found for the 8-week and 12-week comparisons (for 8 weeks, $\chi^2 = 6.154$, df = 2, $p < 0.05$; for 12 weeks, $\chi^2 = 7.875$, df = 2, $p < 0.05$) but not for the 4-week comparison (perhaps because of the small number of subjects). Further-

*All four infants who showed poor scores on the large control stripes at 12 weeks obtained passing scores on the smaller diagnostic stripes, suggesting that the poor scores on the control stripes were not due to poor acuity. These results probably reflect older infants' relative lack of responsiveness to large pattern elements.[18]

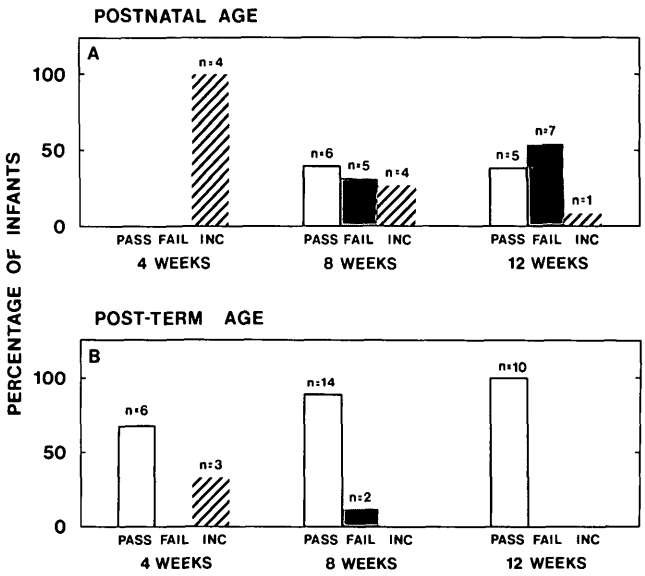

Fig. 3. Percentage of preterm infants who passed, failed, or did not complete testing with the acuity screening procedure. **A,** Results for infants tested at 4, 8, or 12 weeks of PN age. **B,** Results for infants tested at 4, 8, or 12 weeks of PT age. Preterm infants tested with diagnostic stripes appropriate for their PN age were more likely to fail or obtain an incomplete score and less likely to pass than were preterm infants tested with diagnostic stripes appropriate for their PT age.

more, significantly more preterm infants in the groups tested at 8 and 12 weeks of PN age failed or had an incomplete acuity test than did infants tested at 8 and 12 weeks of PT age (Fisher's Exact Test: for 8 weeks, $p < 0.05$; for 12 weeks, $p < 0.01$).

Discussion

Previously we defined a diagnostic stripe width as the smallest stripe width on which 95% of normal infants of a given age would perform significantly above chance in 20 trials or less with the FPL procedure.[2] The purpose of the present study was to select diagnostic stripe widths for infants born prior to term. Healthy preterm infants were tested with diagnostic stripe widths appropriate for full-term infants of the same PN age and/or with stripe widths appropriate for full-term infants of the same age from conception; that is, for this group we chose diagnostic stripes based on the infant's PT age. Of the infants tested at 4, 8, or 12 weeks of PN age, only 34% passed the acuity screening procedure, whereas 86% of infants tested at 4, 8, or 12 weeks of PT age obtained passing scores. Our data thus suggest that a preterm infant's visual development should be assessed on the basis of the PT age and not of the PN age.

In agreement with previous reports,[5–8] our data indicate that the visual acuity of healthy preterm infants as a group is poorer than the visual acuity of full-term infants of the same PN age. Our data further suggest that the visual acuity of healthy preterm infants is similar to, or perhaps slightly poorer than, that of full-term infants of the same age from conception. However, generalization from our results to preterm infants as a whole can be made only with caution. Our sample of preterm infants consisted of healthy infants with an average gestational age of 34.4 weeks and an average birth weight of approximately 2100 gm, whose parents were willing to bring them into the laboratory for testing. Thus our sample did not include very high-risk preterm infants who required long-term hospitalization or special treatment. Although it would be of interest to test very high-risk preterm infants, they are not the appropriate

group to use for establishing diagnostic stripe widths for preterm infants as a whole.

Data such as ours that show a correlation between a developmental trend and PT rather than PN age are often cited as support for the general hypothesis that the developmental trend is governed by maturational rather than environmental factors. We would resist the drawing of this conclusion for at least two reasons. First, the validity of this conclusion rests upon the assumption that preterm and full-term infants come from the same gene pools. This assumption is questionable because the time at which an infant is born doubtless depends partially upon genetic characteristics of the infant and mother. Second, during the last weeks of the normal gestational period, the preterm infant is exposed not only to visual stimulation but also to numerous other physiological factors that are totally different from the intrauterine environment experienced by the full-term infant toward the end of gestation. In conclusion, our results and similar acuity results of other researchers[8, 19] are consistent with the generalization that variations in the visual environment may exert no critical influence during the final weeks of the normally prenatal period. These results in no way contradict the profound effects of prenatal and postnatal physiological trauma (e.g., prenatal exposure to rubella virus or PN exposure to high levels of oxygen) or of abnormal visual environments (e.g., those caused by cataracts, ptosis, strabismus, or astigmatism). Neither do they contradict the importance of a normal visual environment to the maturation of vision during the early PN period.

In summary, the goal of the present experiment was to increase the utility of our visual acuity screening procedure by determining the appropriate diagnostic stripes to use with preterm infants. The results indicated that one should test preterm infants with diagnostic stripes appropriate for their PT age rather than their PN age. The results confirm previous data which suggest that the development of visual acuity in preterm infants is delayed in comparison with full-term infants of the same PN age and further suggest that acuity development in healthy preterm infants is similar to that of full-term infants of the same age from conception. Knowledge of the appropriate stripe widths to use for testing preterm infants is particularly important in the development of an acuity screening procedure, since preterm infants as a group are at risk for vision problems. Correlation of the results of early acuity screening with later assessment of visual status in these infants will be important for establishing the predictive value of the acuity screening procedure.

We thank Dr. Davida Y. Teller for her ideas, constructive criticism, and comments on the manuscript; Greg Stewart, Debby Salem, and Elyse Litvack for assistance in running subjects; Jill Burday Carson for drafting; Dr. Richard Rose for assistance with statistical considerations; and Marjorie Zachow for secretarial assistance.

REFERENCES

1. Fledelius H: Prematurity and the eye. Acta Ophthalmol Suppl **128**: 1976.
2. Dobson V, Teller DY, Lee CP, and Wade B: A behavioral method for efficient screening of visual acuity in young infants. I. Preliminary laboratory development. INVEST OPHTHALMOL VIS SCI **17**:1142, 1978.
3. Fulton AB, Manning KA, and Dobson V: A behavioral method for efficient screening of visual acuity in young infants. II. Clinical application. INVEST OPHTHALMOL VIS SCI **17**:1151, 1978.
4. Fulton AB, Manning KA, and Dobson V: Infant vision testing by a behavioral method. Ophthalmology **86**:431, 1979.
5. Kiff RD and Lepard C: Visual response of premature infants. Arch Ophthalmol **75**:631, 1966.
6. Miranda SB: Visual abilities and pattern preferences of premature and full-term neonates. J Exp Child Psychol **10**:189, 1970.
7. Sokol S: Patterned elicited ERGs and VECPs in amblyopia and infant vision. *In* Visual Psychophysics and Physiology, Armington JC, Krauskopf J, and Wooten BR, editors. New York, 1978, Academic Press, Inc., p. 453.
8. Fantz RL, Fagan JF, and Miranda SB: Early visual selectivity. *In* Infant Perception: From Sensation to Cognition. Vol. I, Basic Visual Processes, Cohen LB and Salapatek P, editors. New York, 1975, Academic Press, Inc., p. 249.
9. Jones-Molfese VJ: Individual differences in neonatal preferences for planometric and stereometric visual patterns. Child Dev **43**:1289, 1972.
10. Sigman M and Parmelee AH: Visual preferences of four-month-old premature and full-term infants. Child Dev **45**:959, 1974.

11. Fantz RL and Fagan JF: Visual attention to size and number of pattern details by term and preterm infants during the first six months. Child Dev **46**:3, 1975.
12. Sigman M: Early development of preterm and full-term infants: exploratory behavior in eight-month-olds. Child Dev **47**:606, 1976.
13. Sokol S and Jones K: Implicit time of pattern evoked potentials in infants: an index of maturation of spatial vision. Vision Res **19**:747, 1979.
14. World Health Organization, Scientific Group on Health Statistics: Methodology Related to Perinatal Events. WHO Document ICD/74, *4*, 1, Geneva, 1974.
15. Siegel S: Nonparametric Statistics for the Behavioral Sciences. New York, 1956, McGraw-Hill Book Co.
16. Teller DY, Morse R, Borton R, and Regal D: Visual acuity for vertical and diagonal gratings in human infants. Vision Res **14**:1433, 1974.
17. Teller DY: The forced-choice preferential looking procedure: a psychophysical technique for use with human infants. Infant Behav Devel **2**:135, 1979.
18. Karmel BZ and Maisel EB: A neuronal activity model for infant visual attention. *In* Infant Perception: From Sensation to Cognition. Vol. I, Basic Visual Processes, Cohen LB and Salapatek P, editors. New York, 1975, Academic Press, Inc., p. 77.
19. Lee CP and Boothe R: Visual acuity development in infant monkeys *(Macaca nemestrina)* having known gestational ages. (In preparation.)