Eye Contact and Face Scanning in Early Infancy

Abstract. *Visual fixations of 3- to 5-week-old, 7-week-old, and 9- to 11-week-old infants were recorded as they scanned an adult's face which was stationary, moving, or talking. A dramatic increase in face fixations occurred between 5 and 7 weeks for all conditions. Talking produced an intensification of scanning in the eye area in the two older groups.*

The infant's response to the human face has been studied widely. Because the face is a recurrent and interesting stimulus for the infant, it has frequently been used in studies of the early development of memory and perceptual organization (*1*). In addition, the universal development of infant smiling to familiar faces and fear of strange faces has stimulated many studies of emotional and social development (*2*). Eye contact has come under special study as one of the earliest social behaviors and as an important factor in the attachment of mother to infant (*3*).

Two problems with prior research limit understanding of the infant's response to faces. With few exceptions (*4*), face photographs, drawings, or masks have been used, and the generalizability of findings to real faces is unknown. Additionally, the procedures have generally not permitted precise specification of where on the face the infant looks. Studies of infants' looking at faces have typically used third-person observation of the adult-infant dyad (*5*). This approach may be valid for determining when the baby looks at the face but not for determining when he looks at the eyes or at any other facial feature. Even members of adult dyads frequently make errors when judging whether their eyes are being fixated (*6*).

In the present study, we measured infants' fixations on real faces each half second and were thus able to reconstruct their scanning patterns. We were interested in the early development of face scanning and eye contact as well as the effects of familiarity and movement. We also explored how talking affects scanning, both to determine whether there is early intercoordination between the auditory and visual systems and to test the popular interpretation of eye attraction. By this interpretation, eyes are attractive because they provide color, contrast, and movement. If these physical characteristics are exclusively responsible for the attractiveness of the eyes, then similar changes associated with talking—whiteness of teeth, contrast of lips and teeth, and lip and chin movement—should attract fixations to the mouth area.

Twenty-four infants equally divided across three age groups—3 to 5, 7, and 9 to 11 weeks—participated in the study. Data from 23 other infants (eight, eight, and seven from each of the three groups) were not used because the infants cried or fell asleep.

The infant lay prone under a 25.4-cm-high by 50.8-cm-wide dichroic mirror (mirror Y, see Fig. 1) tilted at a 45° angle to reflect the image of the adult's face which was above the infant's head. From the position of either the adult or the infant the other face appeared upright and directly in the line of sight about 40.6 cm away (*7*). Behind mirror Y were two television cameras mounted horizontally. The lower camera recorded the adult's face through mirror Y (*8*), and the upper infrared camera (*9*) recorded the image of the infant's right eye through mirror Y by reflection from front surface mirror X. Two tungsten bulbs (40 watt), located 25.4 cm to either side of the infant's head, provided visible illumination. The infant's eye was further illuminated by six Bausch & Lomb Nicholas lamps mounted behind mirror Y 40.6 cm from the infant's eye. The beams of these lights passed through specific points at the plane of the virtual image of the adult's face and converged on the infant's eye. Infrared Polaroid filters (3 HN7) and heat filters (Corning 7-69) in front of the lamps transmitted invisible bands of light (900 nm to 1100 nm) which were well within normal heat-radiation levels (total of 0.17 mcal sec^{-1} cm^{-2}). The infrared TV camera recorded the image of the eye with the reflections of these infrared lights. Since the positions of these lights in the infant's visual field were known, his fixation point could later be determined by measuring the distance of one of the lights from the center of his pupil.

Every infant was presented both the mother's and a stranger's face under three conditions—still, moving, and talking. In the still condition, the adult maintained one position in the center of the infant's visual field while fixating the baby's eyes in the mirror and remaining expressionless. The moving condition was identical except that the adult moved slowly from side to side; the range and speed of movement were not precisely controlled, but the adult tried to stay within a range that would maintain the infant's gaze, generally about 10 cm to either side of center. The talking condition was identical to the moving condition with the addition that the adult continuously talked to the infant. For half of the subjects in each age group the stranger was a male, and for the other half, a female. All possible presentation orders of conditions and faces were used within each age group, except that the three conditions were all presented for one face before the other face appeared, and the condition sequence for a particular baby was constant for both faces. Each condition lasted 45 seconds. During the experiment the outputs of the two TV cameras were alternately switched by a mixer to an Ampex videotape recorder in the following manner: 1/2 second infant's eye, 1/30 second adult's face.

The infant's fixations on the adult's face were determined by first recording alternate eye and face frames on a videodisc from the videotape playback. The Cartesian coordinate positions of hairline, eyes, nose, mouth, chin, and ears on the adult's face were then measured on ten face frames with the aid of electronic circuitry (*10*). Similarly, the position of the adult's eyes were measured on each face frame, and the positions of the center of the infant's pupil and of the closest infrared reflection were recorded on the following eye frame. Computer programs compensated for variable position, tilt, and distance of the face, and calculated the point of the infant's fixations on it. Then, for each condition the facial features were plotted

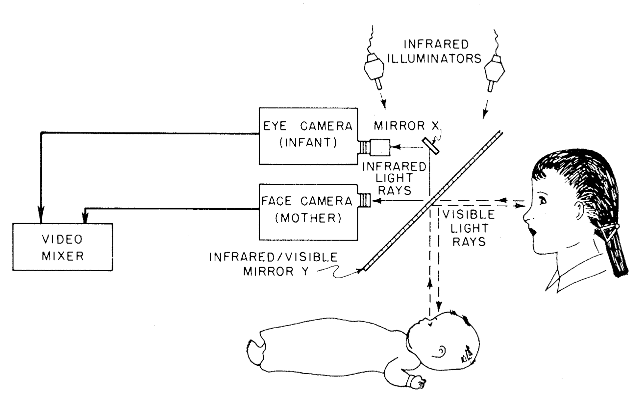

Fig. 1. Schematic drawing of the apparatus used to record scanning of the face by infants. See text and (*8*) for further details.

Table 1. Distribution of face fixations in specific regions.* Data were included only for conditions in which at least 25 percent of all fixations were on the face (13 for 3- to 5-week-olds; all 48 for the two older groups).

Age groups (weeks)	Percentage of face fixations			
	Eyes	Nose	Mouth	Edges
3 to 5	29.8	7.9	4.9	57.4
7	54.8	7.2	4.2	33.8
9 to 11	48.9	12.7	5.7	32.7

*Regions refer to the following zones in Fig. 2: eyes, 3C, 3D, 3E; nose, 4D; mouth, 5D; edges, all other face and head zones.

by a Calcomp plotter with the sequence of the infant's fixations superimposed.

The data were analyzed for the effects of age, stimuli, conditions, and order on the tendency to fixate the face, on the allocation of face fixations to particular regions, and on the way the face was scanned. None of these analyses revealed an effect of mother versus stranger or of order of presentation; therefore, stimuli and order were disregarded for further analyses. Whereas 3- to 5-week-olds fixated the face only 22.1 percent of the time, 7-week-olds and 9- to 11-week-olds fixated 87.5 and 89.9 percent of the time, respectively. The three conditions reliably affected the percentages of face fixations only for the oldest group ($P < .02$ by the Friedman two-way analysis of variance of ranks) with the still, moving, and talking conditions eliciting an average 86.7, 87.7, and 95.4 percent, respectively.

The distribution of face fixations in various regions was calculated by first summing fixations in zones (see Fig. 2) and then combining zones into regions. Table 1 shows the percentage of face fixations in the eye, nose, mouth, and edge (hairline, chin, cheeks, and ears) regions for the three age groups. It can be seen that 7-week-olds and 9- to 11-week-olds distributed their fixations similarly, with the eye region attracting, by far, the most fixations. Although 3- to 5-week-olds fixated about the same amount as the older groups in the nose and mouth area, they spent much less time in the eye area and much more time in the edge regions. In fact, the figure in Table 1 for eye-region fixation is somewhat of an overestimate for this group because the 29.8 percent shown is based only on face fixations. (The percentages of all fixations which fell in the eye area for 3- to 5-, 7-, and 9- to 11-week-olds were 5.8, 48.2, and 43.5, respectively.) Further analyses examined the effect of condition on fixation distribution as shown in Table 2; since the 3- to 5-week-olds had so few face fixations for some conditions, their data were excluded from these analyses. Talking had an effect which was opposite to that predicted by the accepted interpretation of eye attraction. The percentage of face fixations in the eye area was larger for the talk condition than for either of the other two conditions; this unexpected reversal bordered on statistical significance ($P < .10$) and was bolstered by close similarity in the percentage of mouth fixations across conditions (Table 2).

The final set of analyses examined how the conditions affected the way the older two groups scanned the face. Face fixations were more confined under the talk than under the movement or still conditions, as reflected by a significant difference in fixation variance along the horizontal axis (Table 2). Since most of the fixations were in the eye area, this finding suggests that talking produced a tighter, more intense scanning of the eyes, an impression confirmed by inspection of the graphic displays of scanning patterns.

These findings relate to several issues in early perceptual and social development. The finding of edge attraction for 3- to 5-week-olds supports earlier findings of contour attraction in newborns (*11*). Clearly, the ethological claim that faces are seen as such at birth is not supported by our data. One interpretation of the dramatic shift in face looking (away from edges and toward the eyes) between 3 to 5 and 7 weeks of age is that the face has changed its status from a mere collection of elements to a meaningful entity or perceptual configuration, or both. If so, then the accompanying finding of increased attractiveness of the eyes may reflect "forces" that are known to operate in visual configurations; specifically, if the face were seen as an entity, the central location of the eyes as well as their symmetry would make them compelling components (*12*). The alternative popular interpretation that the eyes are attractive for infants only because of such physical attributes as movement, color, and contrast was not supported by the finding that, if anything, the increase in lip movement and lip-tooth contrast associated with talking produced more eye fixations. Although the increased attractiveness of curvature around 2 months of age might play a role in eye appeal, there is no obvious reason why talking should enhance that appeal; perhaps, in fact, the attractiveness of curved forms depends on the emergence of eye attractiveness. It is possible that the eyes became attractive to 7-week-olds partly because they had acquired signal value in social interaction. Whatever the interpretation for the emergence of eye and face looking in 7-week-olds, it is highly likely that this activity carries special social meaning for the infant's caretakers and plays an important role in the development of the social bond (*3*).

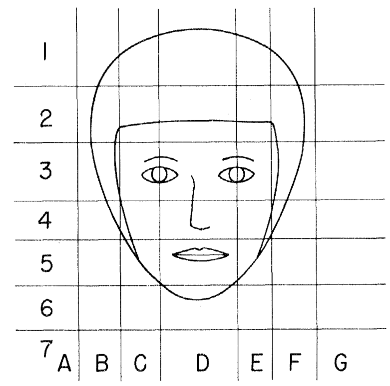

Fig. 2. Scheme of zones for stimulus face. Zones were individually determined for each adult.

Table 2. Effect of conditions on eye and mouth fixations and on the variance of fixations on the face.

Condition	Percentage of face fixations on eyes*	Percentage of face fixations on mouth†	Variance of face fixations along horizontal axis‡ (cm)
Still	50.8	6.0	5.18
Move	49.1	4.2	7.01
Talk	54.1	5.3	4.34

*$P < .10$ by Friedman analysis of variance by ranks test. †$P > .25$ by Friedman test. ‡$P < .01$ by Friedman test.

The effect of talking on visual scanning supports other findings from our laboratories of auditory effects on scanning both with newborn and older infants (*13*), and suggests that visual perceptual activity is not determined by visual stimuli alone. Perhaps the intensification of scanning in the eye area produced by talking signals the mother that the infant is focusing attention on her, which, in turn, encourages her to continue talking. Further research is needed to determine if these findings are unique to voices.

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5. Maurer and Salapatek [see (*4*)] made judgments of infant fixations on real adult faces. Since they did not measure fixations or the regions of the adult faces, their determination of regional fixations must be regarded as estimates. They reported as we do here an increase in face and eye looking to a still face between 4 and 8 weeks of age. Donnee [see (*13*)] measured fixations of infants as they scanned a face photograph.
6. C. E. Lord and M. M. Haith, *Percept. Psychophys.* **16**, 413 (1974).
7. The cooing and smiling of the older infants to the faces indicated that they found the situation to be relatively natural and realistic.
8. Mirror Y (Libby-Owens-Ford No. 956-1) transmitted most of the infrared light and reflected most of the visible light. Enough visible light was transmitted for video recording of the adult's face with a standard vidicon tube.
9. This camera was a Shibaden HV-14 fitted with a Tivicon 1602 infrared silicon diode tube and an *f*/2.0, 100-mm lens.
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Magnification in Striate Cortex and Retinal Ganglion Cell Layer of Owl Monkey: A Quantitative Comparison

Abstract. *Magnification, the relative size of the neural representation of a portion of the visual field, decreases more rapidly with increasing visual field eccentricity in striate cortex than in the retinal ganglion cell layer of the owl monkey (*Aotus trivirgatus*); the proportion of the cells in striate cortex devoted to central vision is much larger than the comparable proportion of retinal ganglion cells. Magnification in striate cortex is a power function of magnification in the retinal ganglion cell layer. A formula for convergence (ganglion cells to cortical neurons) follows from this relationship.*

Sensory surfaces project to mammalian neocortex in orderly topographic fashion. Sensory surfaces associated with behavioral specializations receive expanded representation, for example, the human and monkey hand, and the snout of the pig and coatimundi (*1*). Differential cortical representation may merely reflect differential innervation of the sensory surface or may be the consequence of an additional cortical adaptation.

In the mouse somatosensory system, cortical representation of the different whiskers may be described in terms of "peripheral scaling," that is, the number of cortical neurons per whisker is directly proportional to the peripheral innervation density (*2*). In the visual system, peripheral scaling describes the representation of the visual field (or retinal surface) in striate cortex of the cat (*3*) but not the rabbit (*4*). In primates, the central portion of the visual field receives a greatly expanded representation in striate cortex (*5–7*). Investigators disagree, however, as to whether this is solely because of increased ganglion cell density near the center of the retina (*8*) or whether the cortex provides additional "magnification" (*9*). The present study demonstrates that in the owl monkey, *Aotus trivirgatus*, the representation of the center of the visual field is expanded much more than might be expected from the distribution of retinal ganglion cells. This strongly suggests that, in primates, striate cortex is even more specialized than the retina for central vision.

We defined magnification in a given portion of a neural structure as the proportion of the structure devoted to the representation of a particular visual field zone divided by the proportion of the visual field represented (*7, 10*):

$$M(\phi_1,\phi_2) = \frac{N(\phi_1,\phi_2) \div N_{\text{tot}}}{A(\phi_1,\phi_2) \div A_{\text{tot}}} \qquad (1)$$

where $M(\phi_1,\phi_2)$ is the magnification for the representation of the zone between two isoeccentricity contours of radii ϕ_1 and ϕ_2 with the center of gaze at the origin; $N(\phi_1,\phi_2)$ is the number of cells within the representation of that zone in a given structure; N_{tot} is the number of cells in the structure; and $A(\phi_1,\phi_2)$ and A_{tot} are the area of the zone and the total area of the visual field, respectively. For structures where cell density is invariant with respect to eccentricity, volume measurements yield equivalent values for magnification, and where the thickness of the structure also does not change as a function of eccentricity, magnification may be calculated on the basis of surface area.

We calculated magnification in striate cortex of the owl monkey using a three-dimensional model of the brain constructed on the basis of serial sections and receptive field data from a previous electrophysiological mapping study (*11*). These results were compared to calculations of magnification for the ganglion cell layer of the owl monkey retina (*12*) based upon ganglion cell counts along both horizontal and vertical meridians made from whole mounts by Webb and Kaas (*8*). The owl monkey is an excellent subject for studying quantitative relations between representations of the visual field in different structures because: (i) the ganglion cell layer is thin enough to permit cell counts from whole mounted retinas; (ii) ganglion cells are not displaced about a fovea as they are in most other higher primates; (iii) the ratio of rods to cones does not change as a function of eccentricity (*13*), implying equivalent (normalized) magnification functions for scotopic and photopic vision; (iv) the topographic representations of the visual field have been determined for more structures of the owl monkey visual system than for any other primate (*14, 15*); and (v) its relatively smooth brain makes it possible to map the cortical visual areas more accurately in the owl monkey than in other species with more convoluted neocortices.

The expanded representation of the center of the visual field in owl monkey striate cortex cannot be attributed solely to peripheral scaling (*16*). While magnification decreases monotonically as a function of eccentricity in both retina and striate cortex, the decrease is considerably more gradual in the retina, and cortical magnification for the central 10 degrees greatly exceeds retinal magnification (Fig. 1); that is, the proportion of the cells in striate cortex devoted to central vision is much larger than the comparable proportion of retinal ganglion cells. Functionally, this suggests that, in primates, striate cortex is even more specialized than the retina for processing information concerning the center of the visual field. Anatomically, this means that the ratio of retinal ganglion cells to neurons in striate cortex increases with eccentricity. More specifically, the relation between magnification for corre-