Visual Acuity in Newborn Primate Infants.* (29004)

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Since pupillary, fixation, and other ocular pursuit reflexes can be elicited by light at birth or shortly after in human as well as subhuman primate infants, it is generally accepted that visual sensitivity to light is present at birth. However, the most prevalent view concerning visual acuity in newborn primates has been that they can discriminate only gross differences in light and darkness in their visual field. Based upon fragmentary experimental data, earlier anatomic, neurophysiologic, and ophthalmologic studies generally emphasized the structural and functional immaturity of image forming mechanisms, the retina, and visual pathways and centers in the brain at birth in man and lower primates. Behavioral studies dealing with early postnatal visual acuity in human infants have not been considered feasible since they presumably required the infant's cooperation and ability to follow test instructions. Similarly, animal studies with newborn infants have been impeded by the relatively slower development of manipulatory and motor responses which are essential for establishment of acuity thresholds by conventional discrimination training procedures. Since it is generally accepted that sensory maturation precedes motor development, considerable visual development may occur before human and other primate infants can be trained to make appropriate differential responses from which sensory acuity thresholds can be inferred.

High visual acuity plays a basic role in all visually guided behavior of the higher diurnal primates. Several investigators have attempted to study the onset and subsequent postnatal development of visual acuity in newborn human and subhuman primate infants by an optokinetic nystagmus acuity test (1,2,3). Previous findings have shown that adult as well as newborn primates respond to movement in their visual field by ocular pursuit responses characterized as optokinetic nystagmus. In the optokinetic test procedures, black-and-white stripes of equal width are used as test patterns. Such test striations of various sizes are mounted on large drums or cylinders and rotated in the visual field of the subject. These large moving test patterns represent a visually compelling stimulus which elicits an ocular pursuit reflex. If the black-and-white stripes are decreased in size until they cannot be resolved by the visual system of the subject, they appear uniformly illuminated and displacement or movement of the striations in the visual field fails to elicit optokinetic responses. Minimum separable visual acuity thresholds have been established by this procedure by the visual angle subtended by the smallest test patterns eliciting such optokinetic responses. Since appropriate oculo-motor, optical, and retinal mechanisms, as well as functional pathways in subcortical and cortical centers in the brain are essential for eliciting such coordinated visual pursuit responses in higher primates, objective visual acuity thresholds have been established by this optokinetic acuity test in newborn primates as well as in psychiatric patients where unreliable verbal reports or motivational factors may influence or preclude conventional Snellen acuity test results(4). Comparisons of the standard Snellen visual acuity measures with optokinetic acuity determinations on the same adult human subjects have indicated high reliability and validity for the optokinetic acuity test procedure(5). The broad objectives of this research were to study the postnatal development of visual acuity in relation to maturational changes in retinal electrophysiology and the morphologic development of the retina in newborn primates. The aims of the present report are to compare the early postnatal development of

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visual acuity as determined by an optokinetic acuity test in the neonatal Rhesus monkey, Baboon, Gibbon, Orangutan, and human infant.

Method. The subjects were 4 newborn Rhesus monkeys, 3 Baboons, 1 Gibbon, 1 Orangutan, and 46 human infants. The optokinetic apparatus for establishing minimum separable visual acuity thresholds consisted of 4 cylinders, 16 inches high and 22 inches in diameter. A test pattern consisting of vertical black-and-white striations of equal width printed on white non-gloss paper was fixed to the inner surface of each cylinder. The 4 test patterns consisted of 1/8, 1/16, 1/32, and 1/64 inch striations and at a distance of 12 inches represented 36, 18, 9, and 4.5 minutes of visual angle. The level of illumination was set at 100-foot-candles measured at the inner surface of the cylinder. The subhuman infants were placed on a vertical bar which was covered with a soft towel and located in a small chamber within the test cylinder. The characteristic grasping and clinging reflexes of these newborn primates to the vertical bar were utilized to obtain sustained and proper orientation of the body, head, and eyes toward the center of the test striations during the test sessions. The cylinder was rotated manually around the infant by the investigator. Subhuman primate infants were tested each day during the first 30 days after birth and then once weekly until they were 2 months old. Each test session consisted of 10 trials in each direction of drum rotation with each of the 4 test striations. Minimum separable acuity thresholds were established by observing prompt and properly directed rhythmic optokinetic responses in both directions of the rotation of the cylinder in 8 out of 10 trials with each test pattern. The human infants were tested 2 weeks after birth with a comparable optokinetic test procedure as well as a spontaneous visual fixation or preference test and more detailed descriptions of these test results have been published previously(6).

Results. Comparisons of early postnatal visual acuity development in human and subhuman primate infants are presented as free

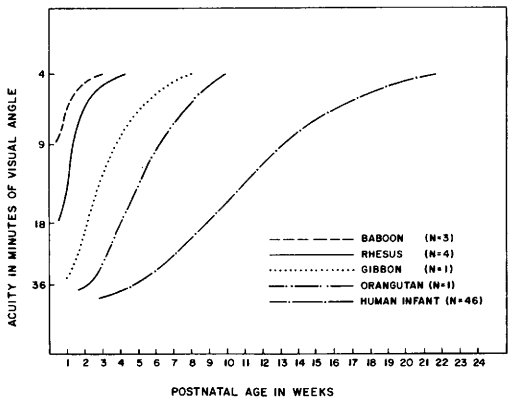

FIG. 1

hand curves shown in Fig. 1. It should be emphasized that these growth curves do not represent normative acuity data for successive age levels for the species included in these studies since some of the observations are based on only one anthropoid Gibbon and Orangutan infant.

As indicated in Fig. 1, acuity thresholds in the tested species ranged from 9 minutes of arc in the Baboon infants to 40 minutes in the human infants at birth or shortly after. Specifically, visual acuities observed in the 3 Baboon infants included 2 infants with 9, and 1 infant with 18 minutes of arc, at time of birth. Visual acuities in the 4 Rhesus monkey infants ranged from 18 minutes for 3 infants, to 36 minutes in a less mature infant on the first day after birth. The visual acuity of the Gibbon infant was 36 minutes at birth and also 36 minutes in the Orangutan infant first tested at 1 week after birth. Using a similar optokinetic test procedure, previous findings have established a visual acuity of 33.5 minutes of visual angle in 93 out of 100 newborn human infants ranging in age from 2 hours to 5 days(7). The visual acuities of the human infants first tested at 2 weeks after birth and included in the present investigation ranged from 20 to 40 minutes of visual angle. As shown in Fig. 1, visual resolution increased rapidly to 4 minutes in all of the Rhesus monkey and Baboon infants by the end of the first month. In the anthropoid Gibbon and Orangutan infants, visual resolution increased at a slower rate

to 4 minutes of arc by the end of the second month. Human infants did not attain the same level of visual acuity until approximately by the end of the sixth month after birth. From comparisons of the rates and sequences of early visual acuity development and other behavioral tests, it was apparent that visual functions developed much more rapidly in the Baboon and Rhesus monkey infant than in the anthropoid Gibbon, Orangutan, or human infant. Detailed ophthalmologic and behavioral examinations also revealed that these species differences in early postnatal visual acuity development were also characteristic for the early maturation of visual light reflexes, the near reflex, coordinated binocular versions, vergences, fixations, and the development of visually guided manipulatory grasping or reaching responses as well as general motor development. Behavioral studies reported by other investigators have also shown very rapid visual discrimination learning in neonatal Rhesus monkeys during the first month after birth, whereas comparable visually guided learning has not been reported in infant Apes until 3 to 4 years of age(8,9).

Discussion. It is generally accepted that minimum separable acuity norms of emmetropic adult human subjects are based on a resolution of 1 minute of arc usually designated as 20/20 in the Snellen notation. In view of the methodologic difficulties and lack of data regarding early postnatal dynamic growth changes in refraction, amplitude of accommodation, range of clear vision, binocular foveal fixation, and the maturation of visual pathways and centers in the brain, few experimental studies have attempted to obtain visual acuity thresholds during the early postnatal period. Clinical estimates of visual acuity levels for older human infants and early childhood have suggested that approximately 3 to 16% of the human infants may attain the adult visual acuity norm of 1 minute of arc or 20/20 in the Snellen notation by the age of 3 years, and at least 52% may reach adult acuities by the age of 7 years (10). However, no quantitative visual acuity norms are available for human infants prior to language development or their ability to follow test instructions(11).

Behavioral discrimination experiments with adult cebus monkeys, chimpanzees, and Rhesus monkeys have shown that these subhuman primates have minimum separable visual acuity thresholds comparable to those of adult human subjects(12). Visual acuities for the adult Gibbon, Orangutan, and Gorilla have not been reported. Utilizing behavioral discrimination procedures with 2 additional neonatal Rhesus monkeys in the present studies, adult minimum separable visual acuity thresholds of 1 minute of arc were established by the end of the second month after birth for both infants. The development of adult visual acuity levels during infancy has not been established for the Baboon or the anthropoid Gibbon, Orangutan, Chimpanzee, or Gorilla.

Although some isolated studies have been published on postnatal development of visual acuity, retinal electrophysiology, and maturation of the retina in newborn subprimate mammals, few multidisciplinary experiments have been reported dealing with specific interrelationships among morphologic, electrophysiologic, ophthalmologic, and behavioral sequences of visual development in primates during the early postnatal period.

Preliminary studies conducted in this laboratory involving histologic examinations of eyes obtained from several newborn Rhesus monkeys, Baboons, and one Gibbon infant have revealed advanced development of rods, cones, their inner and outer segments, adjacent pigment epithelium, as well as separation of the retinal layers, at the time of birth in these subhuman species. Ophthalmologic examinations and color photographs of the retina obtained shortly after birth and again at 2 months also revealed considerable differentiation of the retina, macula, fovea, pigment density and distribution, and rapid maturation of the light reflexes during this early period. Measurable electrophysiologic (ERG) potentials consisting of both the characteristic photopic and scotopic adult negative a-waves and positive b-waves were elicited at birth and shortly after in all sub-

human primate infants included in these studies. Growth of the light elicited potentials was rapid after birth. Visually evoked cortical responses obtained from cortical electrodes located in occipital areas and obtained after light and dark adaptation in response to various light stimuli were recordable on the day of birth, suggesting that the afferent visual pathways and centers were functional to a considerable degree in these newborn subhuman primates(13). By using higher light intensities in conjunction with dark adaptation, other investigators have also obtained both the negative a-wave followed by the positive b-wave immediately after birth in full term and even prematurely born human infants(14). Histologic examinations of the development of the retina, macula, fovea, as well as rods and cones in newborn human infants have revealed shorter and thicker light receptors than those of adult subjects, but otherwise already well advanced structural development of the retina at birth(15).

In summarizing the findings on the interrelationships among morphologic, electrophysiologic, and behavioral sequences of early postnatal visual development in newborn primates, it is noteworthy that visual acuity and other visual functions mature much more rapidly than is apparent from histologic, electrophysiologic, and ophthalmologic observations on the retina. Finally, contrary to most widely held popular as well as scientific views concerning the immaturity of the primate visual system at birth, the present multidisciplinary findings and other recent results obtained by other investigators indicate considerable structural and functional development of the primate retina and visual system at birth, as well as relatively rapid development of vision during the early postnatal period.

Summary. Minimum separable visual acuity thresholds were established by an optokinetic nystagmus acuity test in Rhesus monkey, Baboon, Gibbon, and human newborn infants. Acuity thresholds ranged from 9 minutes of arc in the Baboon to 40 minutes in the human infants at birth. Visual acuities increased rapidly to 4 minutes by the end of the first month in the Rhesus monkey and Baboon infants. The same level of visual resolution was attained by the Gibbon and Orangutan infants only by the end of the second month, and approximately at the end of the sixth month by the human infants.

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