THE DEVELOPMENTAL ASPECT OF CHILD VISION

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THE development of vision in infancy and childhood is very complex, for the simple reason that it took countless ages of evolution to bring human vision to its present advanced state. Visual perception ranks with speech as a distinctive human trait and it passes through comparable growth stages. Moreover, vision is not a separate, isolated function; it is profoundly integrated with the total action system of the child—his posture, his manual skills and motor sets, intelligence, and even personality make-up. Indeed, vision is so intimately identified with the whole child that we cannot understand its economy or its hygiene without investigating the whole child.

Under a program of cooperative research at the Yale Clinic of Child Development, we have made periodic studies of the normal visual functions in their relation to the total action system of the child at a score of advancing age levels from early infancy to the tenth year.* In general, about fifty children were investigated at each age. The data were gathered through clinical examinations of behavior patterns; naturalistic observations of spontaneous behavior at home, school, and guidance nursery; graded tests of visual skills; optometric measurements; and retinoscopic determinations of the brightness, the motion, the direction, speed, and color of the retinal reflex in the natural reactive eye. All the findings were analyzed and compared from age to age and from child to child to define growth trends.

THE EMBRYOLOGY OF VISUAL BEHAVIOR

Studies of viable premature infants yielded data concerning the fetal stages of visual development. This development is very precocious. Vision has a motor basis. The eyes of the fetus move beneath their fused lids as early as the twelfth week after conception. For over six months prior to birth the eyes, although in darkness, move with increasing coordination to meet the demands that will be made upon them when subjected to light. Two months before birth the retina assumes an adult arrangement. Four lunar months before birth the fovea forms and establishes itself definitively at the final adult distance from the optic nerve head. This remarkable fact certifies to the profound importance of vision in the organization of human behavior. The eye itself will more than double its weight before birth. The brain will increase three and one-half times from birth to maturity, and the body twenty-one times. Nevertheless, the distance between fovea and nerve head remains an absolute, a fixed pivotal area in all the ensuing morphogenesis of the action system.

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A healthy fetal-infant, born about eight weeks prematurely, exhibits two behavior patterns highly significant in the development of vision. He assumes a tonic-neck-reflex posture with the head averted to one side, the arm at that side extended, the opposite arm flexed at the shoulder, simulating a fencing attitude. His early ocular fixations will be channelized in the direction of this attitude. He does not give true regard to a dangling four-inch ring slowly moved across the field of vision, but the eyes move saccadically in momentary after-pursuit.

The visual competence of the full-term newborn infant exceeds that of the premature, indicating that intrinsic maturation is more basic than experience in the patterning of visual behavior. Incipient fixation of a near, approaching object is observable in the first day of life; sustained fixation of a near object occurs in the first week; fixation of more distant objects occurs at the end of the first month. When the neonate fixates an object of interest, his sporadic bodily activities tend to subside. The fixational response clearly involves the entire action system to some degree. The scope and complexity of his vision are delimited by the postural attitudes of eyes, head, body, limbs. With increasing maturity the visual system assumes more autonomy, but it never operates altogether independently of the total action system.

The eyes, however, take the lead in the conquest and manipulation of space. The baby takes hold of the physical world ocularly long before he grasps it manually. He can pick up a pellet (7 mm. in diameter) with his eyes full twenty weeks before he picks it up with his fingers.

Although an infant stares vaguely into faraway space, his structured visual world begins in the near vicinity of his eyes. For him the space-world is not a fixed, static absolute. It is a plastic domain which he manipulates in terms of the nascent powers of his growing action system. The supine infant, the runabout infant, the sedentary school child, each has his own space-world with a distinctive set of planes of regard. Biological space is a function of the organism. The space-world of the myope differs from that of the hyperope. Every child organizes his space-world in obedience to laws of development, general for the species and unique for himself.

FUNCTIONAL COMPLEX OF THE VISUAL SYSTEM

This organizational process operates in three basic functional fields: skeletal, visceral, and cortical. These fields are correlated with the three primary embryological divisions and with the conventional fixation-focus-fusion triad. The *skeletal* component of this functional complex seeks and holds a visual image (optical stimulus); the *visceral* component discriminates and defines the image; the *cortical* unifies and interprets it.

The three functional fields develop conjointly but by no means uniformly. The ratio between skeletal, visceral, and cortical manifestations varies with advancing stages of maturity. In the course of individual development, gradients of performance are built up concurrently but unevenly in the three basic functional fields. Four factors enter into these gradients: (1) *coordination*, which refers to the teaming of the eyes and right versus left dominances; (2)

reach, which refers to the distance and precedence of the planes of regard; (3) *scope,* which concerns the important relationships between central and peripheral vision; (4) *drift,* which denotes the growth trends signified by the break and recovery span of ocular ductions, the preferred zones of regard, and accommodation and dominant directionalities.

All these variables and gradients are subject to the organizing processes of growth. Accordingly, each age of infancy and childhood affords a distinctive constellation of visual behavior patterns. With so many components and variants entering into the functional complex of the visual system, it is natural that no two children should see exactly alike. The possible constellations of visual components, normal, atypical, and abnormal, are beyond enumeration. The individual variations, however, are governed by a general ground plan of ontogenetic development. This ground plan is manifested in five distinguishable areas: eye-hand coordination, postural orientation, fixation, projection, and retinal response. Our studies, although preliminary, have demonstrated that it is possible to formulate developmental gradients in each of these areas.

The adequacy of child vision cannot be appraised by a simple refractive criterion of acuity. All vision is mediated by an intricate functional complex. The task is to interpret vision in terms of over-all achievement and to analyze that achievement in terms of the developmental status of the organism.

The retinoscope has revealed an intimate relationship between the functional complex of the visual system and the maturity of the total action system. The retinoscope projects a beam of light upon the reflecting surface of the retina. The examiner takes note of the returning light and finds that it varies significantly in relation to identifiable moments of the visual act. A comparison of the retinal reflex patterns at near and far shows that the infant is more fully organized for vision in the near point areas than at distance. An increase of brightness in the reflex occurs characteristically at the moment when the infant identifies a target. At that moment the eye and the brain appropriate the object of interest. Coincidentally, the reflex registers an *against* motion which, by streak retinoscope, indicates a *minus* refractive value but not necessarily a fixed myopic deviation. For this minus may increase or decrease with the stress of the task and at certain moments of adjustment may give way to a *with* motion which suggests a shift in the hyperopic or *plus* direction. Such variations seem paradoxical, but if one thinks of the reaching eye as essentially a teleceptive prehensory organ, these patterns of response are understandable. The visual system gropes and grasps and manipulates. The infant manipulates toys, the preschool child models clay, the school child copes with the symbolic targets of a printed page; but the retinocortical manifestations for all three types of manipulation are comparable.

The retinoscopic and associated findings indicate that the visual mechanism of the growing child is in a labile condition, dynamically and developmentally. Superimposed upon a basic delimiting refractive state is a margin of adaptability which is manifested in the brightness, motion, direction, color, and velocity of the retinal reflex. Such a relationship between consolidated and plastic structure would seem to be a necessary condition of growth.

DEVELOPMENTAL MANIFESTATIONS

We need broadened methods of observation of the young eye in action and also of the underlying growth factors. The concept of development adds a new dimension to all problems of visual care, to diagnosis, supervision, prevention, education, training, and re-education. This concept applies with equal force to the normal and to the visually disadvantaged child. With failure to recognize developmental mechanisms, the culture tends to make excessive visual demands on the young child in the form of premature reading and writing tasks.

Both ophthalmology and optometry stem historically from the study of the mature adult eye. Many of the prevailing principles and procedures naturally reflect this adult orientation. It is increasingly evident that such an orientation introduces certain errors and shortcomings. We are confronted with the sobering realization that the child is never a miniature adult, even in his visual equipment. He is qualitatively a different organism and he is always changing qualitatively at a more rapid rate than the adult. This is peculiarly true of his visual system.

It should not be necessary to wait until belated adolescent and adult years to determine the efficiency of his visual functions. With increased knowledge the developmental status of these functions can be appraised and supervised throughout the period of infancy and childhood. In this sense the developmental aspect of child vision has implications for preventive and supervisory pediatrics.

Even on the basis of present information, it is possible to distinguish visual behavior traits which are characteristic of certain maturity levels. We may illustrate this by considering various deviations of visual behavior which appear at three different age periods, namely: infancy, the preschool years, and the school years.

INFANCY

Infants reveal their visual individualities in ocular and other postural attitudes and demeanors. Virtually all infants repeatedly assume, in one form or another, the tonic-neck-reflex posture and the symmetro-tonic-reflex posture during the first half-year of life. These postures, both quiescent and active, constitute a morphogenetic matrix for the basic patterning of the coordinations, dominances, and functional correlations of eyes and hands, singly and in pairs.

Excessive hand regard, if not due to retarded development, may signify a myopic trend. Excess manifests itself in the intensity and duration of episodes and in a marked continuation beyond the age of 12 weeks. One of our myopic subjects, now 6 years old, held the hand regard attitude so persistently and steadily in infancy that he acquired the nickname "Statue of Liberty." Delayed hand regard is a symptom of retardation, but it may also be associated with normal intelligence and atypical spatial manipulation.

Another deviation consists in a poorly defined postural orientation, a neutral tendency to assume somewhat indifferently either a right or a left tonic-neck-reflex. Ordinarily, there is a defined preference for right or left which must have correlations with ocular and manual dominance, and with the organization

of the functional asymmetry of the total action system. Little is known about the nature of these correlations, but we may be sure that they have predictive import for later visual patterns. The whole subject needs extensive investigation, because it has significance for preventive hygiene.

Complicating clinical factors, however, must not be overlooked. Minimal cerebral injuries are more common than is ordinarily supposed, and they account for certain persisting as well as temporary visual deficits. In some instances there are associated personality deviations occasioned by the visual defect or traceable to a damage of the cortical mechanisms concerned with emotional organization.

Strabismus is a common symptom of minimal injury. It frequently undergoes spontaneous resolution. It may also be combined with oculomotor incoordination and atypical eye-hand patterns in which arms and fingers assume eccentric postures. This leads to bizarre patterns of exploitive behavior. The infant, for example, may poke and twiddle a cube in a restricted, perseverating manner. Atypical motor patterns may persist for three years or more. These mild neurological difficulties may set up an extremely complicated interaction of developmental potentialities and dynamic forces. The mild motor disabilities may be associated with speech defects, with imperfect manual dominance, and with delayed integration. Such syndromes lie at the basis of certain school entrance problems and cases of reading disability. Vision is involved, but the total behavior equipment of the child demands searching individual study. For these reasons, eye specialists and educators must reckon with the clinical category of minimal cerebral injury, and must be alert to its developmental manifestations. The early symptoms of minimal cerebral injury are often overlooked. They do not yield to the ordinary methods of clinical neurology, but they can be elicited by a systematic developmental examination of infant behavior patterns.

PRESCHOOL YEARS

Visual difficulties come to somewhat franker expression in the preschool years. The child begins to leave the confines of the home and is thereby brought into more frequent comparison with his peers. If he has serious ineptitudes, he reveals them in his play activities, in postural demeanors, in his adjustments to a nursery school group, in his use of cup and spoon, of crayon and paints, and in his response to picture books. He may show a moderate amount of staring (or perhaps too little). He may show forms of caution, fear, and withdrawal which may denote visual, rather than purely emotional, factors. Indeed, even his atypical personal-social relations with his companions may have a visual basis in faulty space manipulation.

On the basis of everyday patterns, a discerning teacher may detect evidences, more or less predictive, of potential reading disabilities—specific weaknesses in drawing and in form perception; ill-defined handedness; reduced acuity; atypical directionalities in movement patterns, and so on. When the norms of visual behavior are more widely known by parents and teachers, it will be possible to use naturalistic observations of spontaneous behavior for the benefit of children who need early guidance in solving their visual problems. Such observations should both precede and supplement formal visual skill tests. They become

doubly important, under professional guidance, for appraising the responses of the child to lens assistance and to special visual training procedures. Naturalistic observation of the spontaneous child is at times more valuable than technical observation, because it brings into view the total child and his unitary action system.

In considering the visual economy of a young child, one does not think only in terms of refraction and fusion. One considers the over-all organization of his visual equipment, and asks whether he has the ability to meet the normal visual tasks demanded by the culture. A developmental approach to his problem puts us in a better position to give him the developmental support which will benefit him more than a full refractive correction would. Indeed, in some instances, a full correction given too early and insisted upon too long may create a crutch which, in turn, becomes an impediment. The growing visual equipment then organizes about the full-strength lens, whereas a more natural and advantageous organization could have taken place with the aid of lenses of lesser strength, carefully timed to put the organism on its own best resources. The same principle applies to training procedures and to the planning of eye-care regimes. Wise timing in small, well-spaced sessions, with interested motivation, is more efficacious than an overstrenuous practice-makes-perfect program. In all programs of visual care it is important to appraise the kind and degree of acceptance manifested by the child.

The causative factors underlying strabismus are so diversified that generalized discussion is almost impossible. There are two major types of strabismus, one predominantly visceral, the other predominantly skeletal. Symptoms and premonitions are prone to occur during transitional stages of readjustment in equilibrium—for example, at 21 to 24 months. At these stages, the organism is more loosely organized in order to give play to counterpoised opposites. The looseness or morphogenetic flux characterizes the action system as a whole and more or less evenly paired body members and paired functions, such as flexors versus extensors, abduction versus adduction, and so on. Accordingly, a liability to strabismus may declare itself in frank eye discoordination or, more indirectly, in faulty motor demeanors and awkwardness. A clumsy hand, a foot drag, or a postural slump on the "weak side" may come into evidence in a 2½-year-old child as a precursor of a manifest strabismus a year or two later. Such a presquinter, if accurately identified, on developmental premises would be approached orthopedically first, and orthoptically later, with due consideration as to whether the condition is primarily skeletal or visceral in character.

SCHOOL YEARS

The culture is not too aware of the school beginner's difficulties and potentialities. Rightly construed, many of his difficulties are actually symptoms of potentialities—new abilities in the making. Lacking finesse, it deals with him en masse, and tends to use rigid and undiscriminating procedures. If he is unfortunate enough to enter a strictly regimented school, his teacher frowns upon him even if he drops a pencil. Now, he is very likely to drop a pencil, because his patterns of visual behavior are not adequate to all the demands which are made upon his seeing and interpreting equipment.

All too soon, he encounters difficulties which are due to the discrepancy of the culture and his own immature visual and manual structures. He may have trouble in adapting to the blackboard, and in making adjustments from far to near and near to far. The culture, as embodied by the schoolroom, may make unreasonable demands upon sustained attention at a stage of development when he is geared to brief and multiple adjustments that require a shifting, flexible activity program. If he began to identify letters and numerals at the age of 2½ years, he is not likely to experience undue difficulty in responding to reading instruction, whatever method may be used. However, many children are in a phase of development, or they present individual maturity traits which make it difficult or impossible for them to profit from the prevailing method of instruction. A sizeable fraction of these children in a year or two are classified as poor readers, nonreaders, and slow readers. Broadly speaking, the difficulties of these academically disadvantaged children are due to a rather clumsy disparity between the educational environment of the school and the organisms which are in attendance.

All children, after the age of 5 years, undergo fundamental and more or less striking reorganizations in their visual equipment. They acquire new abilities, but not always in balanced or well-timed relationships. Often new trends become observable by the age of 5½ years. Appraisal at 6 years may show a developmental direction in the nature of the interaction of the visceral and skeletal functions. At 7 years, there may be frank evidence of such directional trends. Typically the visceral-skeletal linkage is relatively tight at the age of 7 years. By 8 years, this tightness gives way to a looser and more facile interplay. By 9 years, the looseness is being superseded, in turn, by a more robust consolidation of the visceral-skeletal components.

It is difficult, with our present meager knowledge, and on the basis of a single visual appraisal at 5 years, to predict the probable course of development in the years from 5 to 10: but systematic examination and supervision of the visual functions in the preschool years will serve to identify children who present potential difficulties in book learning and other school tasks.

This possibility, however, should not blind us to the fact that the culture is making unreasonable demands upon many young children. The demands overburden the limited powers of spatial manipulation and, in many instances, rearrangement and amelioration of the cultural demands would be a more basic solution than a therapeutic approach to the visual handicap. In a flexible educational system, both lines of approach may be conjointly utilized; the one directed toward the environment, the other toward the organism.

The pediatrician, therefore, may well have an interest in the developmental aspect of child vision. He is in a position to recognize behavior patterns which are symptomatic of visual difficulties and which may be serious enough to require specific guidance or referral to a specialist.

Child care involves eye care, and eye care involves child care. Developmental optics in theory and in application is concerned with the development and organization of visual functions in their dynamic relation to the total action system.