

# Effect of Natural Deprivation and Unilateral Eye Patching on Visual Acuity of Infants and Children

## Evoked Potential Measurements

J. Vernon Odom, PhD; Creig S. Hoyt, MD; Elwin Marg, PhD

● **Evoked potential measurements of visual acuity were made on four children aged from 5 months to 8 years. They were deprived of normal visual stimulation by various disorders: unilateral aphakia from a congenital cataract, vitreous hemorrhage, polar cataract, and esotropia. In the two younger children, aged 5 and 15 months, respectively, the visual acuity improved when the eye had good optical imagery and declined with poor or no imagery. Reversal of the imagery to the contralateral eyes again brought large changes in opposite directions. In the two older children, aged 4 and 8 years, respectively, there were marked decreases in acuity in the patched eye, but little or no change in the unpatched eye. It is not known whether these differences are due to age or to the original kind of visual disorder, such as deprivation, occlusion, or strabismus, or are merely individual differences. It is clear, however, that some children exhibit large changes in acuity in response to visual deprivation or patching, or to its removal, in a readily reversible manner. Also, we have demonstrated that visually evoked potential acuities may be obtained from pediatric, clinical patients without regard to age, which may be useful in management of the conditions.**

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An abnormal visual experience, such as that caused by unilateral eye patching, impairs the function of the young visual system. The most frequently studied animal model of abnormal visual experience is the unilateral deprivation of pattern by eyelid suture in the kitten<sup>1,2</sup> and monkey.<sup>3,4</sup>

Wiesel and Hubel<sup>1,2</sup> suggest that monocular deprivation by unilateral eyelid suture might be analogous to patching, a common and sometimes essential therapeutic procedure in ophthalmic clinical practice, and that patching in children might have irreversible and harmful effects on subsequent visual acuity. Many clinicians have provisionally adopted this analogy and its attendant concern (for example, see von Noorden<sup>5</sup>). Others have made distinctions between light (occlusion) and form (diffusion) deprivation in monocular deprivation where the neural disruption is severe when only form is reduced or eliminated (for example, see Jampolsky<sup>6</sup>).

The best evidence for a loss of visual acuity or amblyopia elicited by visual deprivation in infants and children

has come from retrospective studies of the consequences of abnormal visual experience on later visual functions (for binocular functions, Banks et al<sup>7</sup> and Hohmann and Creutzfeldt<sup>8</sup>; for meridional deprivation, Mitchell et al<sup>9</sup>; for unilateral patching, Awaya et al<sup>9,10</sup> and Hartwig et al<sup>11</sup>). Awaya et al noted that eyes patched for as little as one week in children aged less than 1 year were subsequently found to experience the development of a deep and intractable amblyopia. Conversely, Hartwig et al indicated that seven to nine days of patching had no lasting effect on infants who were aged 4, 5, and 8 months.

Thomas et al,<sup>12</sup> who used the fixation-preference method to determine visual acuity, found that patching affected the acuity of two infants aged less than 1 year. Although the effect was transient, they interpreted their results as supportive of the findings of Awaya et al,<sup>9,10</sup> who concluded from their retrospective study that permanent amblyopia occurs with only one week of patching at that age.

Because patching is so widely used, its effects, especially lasting ones, on visual function should be determined with regard to age of the child and the degree and duration of the occlusion. The data presented herein were obtained in an attempt to determine the effects of patching on visual acuity in infants and young children. Visually evoked potential (VEP) acui-

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From the School of Optometry, University of California, Berkeley (Drs Odom and Marg), and the Department of Ophthalmology, University of California School of Medicine, San Francisco (Dr Hoyt).

Reprint requests to School of Optometry, University of California, Berkeley, CA 94720 (Dr Marg).

ty was chosen since it can be used with infants or with people of any age. In contrast with this, the fixation-preference method of determining visual acuity is generally limited to infants aged less than 1 year.

### METHODS

Visually evoked potentials were elicited with a pattern onset-offset presentation. Two carousel projectors were focused on a retroilluminated screen subtending  $20^\circ$  at 1.14 m. One projector had a neutral density (ND) filter of 50% transmittance (Wratten Filter 96, 0.3 ND) and provided a diffuse, nonpatterned field for 710 ms. The second projected a checkerboard for 40 ms to provide the onset-offset pattern of the same average luminance as the diffuse field did without the pattern. Presentation of the pattern initiated averaging for 64 iterations. The active electrode was at the occiput (OZ) referenced to the right mastoid area, with the left mastoid area serving as ground. Signals were amplified by two preamplifiers (Grass P-15) in cascade, with the high- and low-frequency half-amplitude cutoff at 30 and 1 Hz, respectively. Total preamplification was typically  $10^5$ . Electroencephalograms were monitored on a cathode-ray oscilloscope and the VEP was averaged with a special purpose digital computer (Nicolet 527).

Eye position of patients was monitored directly by the experimenter. If patients turned their eyes away from the screen, became fussy, cried, or fell asleep, averaging was stopped and resumed only when the patient was looking in the direction of the screen.

Refractions were obtained by retinoscopy, and, if desirable, patients were fitted with contact lenses to correct the refractive error.

Visual acuity was reckoned by extrapolating VEP amplitude as a function of the basic fundamental spatial frequency of the checkerboards to the baseline voltage or to the noise level of the control, which was obtained by presenting the smallest pattern slide out of focus.<sup>13,14</sup> This method is no more or no less accurate than psychophysical acuity determined with, for example, a Snellen chart. One may not have high confidence that there is a real difference between Snellen or VEP 20/20 and 20/25 in many patients but good confidence in the reality of the difference between 20/20 and 20/40. One readily has complete confidence in the large changes, such as between 20/200 and 20/25 or even 20/300 and 20/60.

### REPORT OF CASES

**CASE 1.**—A female infant was aged 5 months at the time of the first VEP acuity measurement (Fig 1). A congenital, unilateral dense cataract in the right eye had been removed by one of us (C.S.H.) when she was 3 days old. A final, soft contact lens was fitted when she was 2.5 months old. At 5 months, the infant showed  $30\Delta$  of right esotropia with no maintained fixation observable in the corrected aphakic right

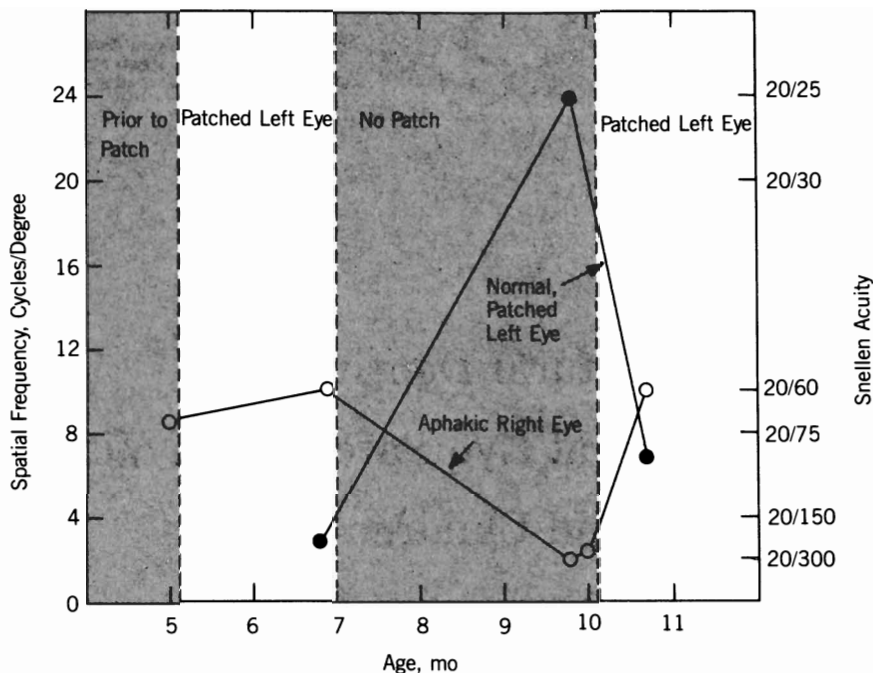
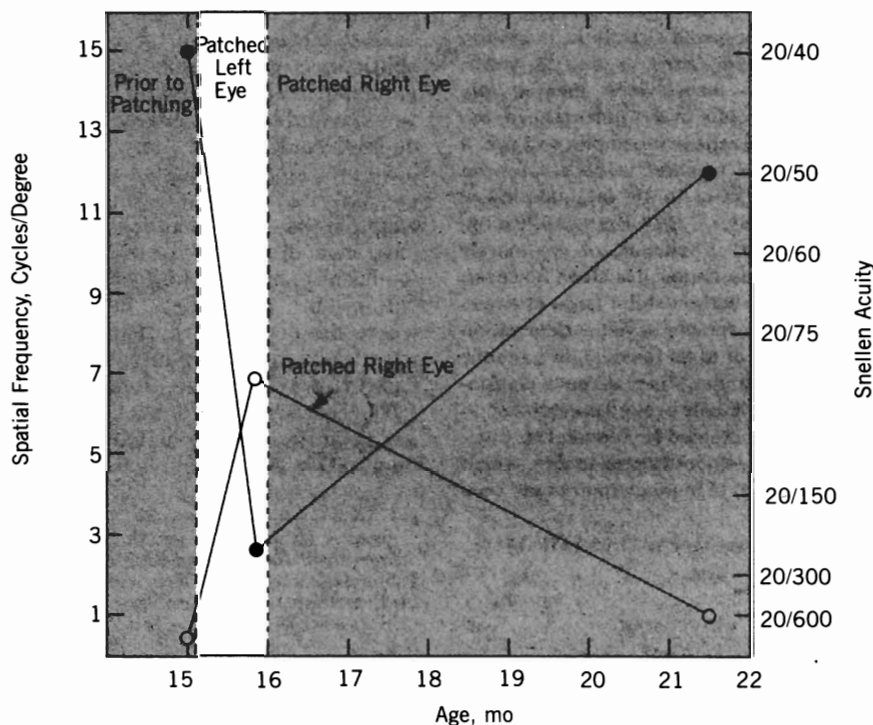


Fig 1.—Visually evoked potential acuity expressed in spatial frequency on left ordinate and Snellen notation on right as function of age (case 1). Patient 1 had a  $30\Delta$  right esotropia following removal of cataract from right eye at 3 days of age and contact lens aphakic correction at 2½ months. Patching of the left eye was begun at 5 months, with a regimen of six consecutive days of patching weekly. Following discontinuation at 7 months, patching was reinstated at 10 months.

Fig 2.—Patient 2. Visually evoked potential acuity as in Fig 1. Patient 2 had vitrectomy of right eye at 15 months of age with approximately  $10\Delta$  of right esotropia following surgery. Patching of the left eye at 15 months was accomplished with a regimen of six consecutive days of patching weekly and reverse patching at 16 months of age with five consecutive days of patching weekly.



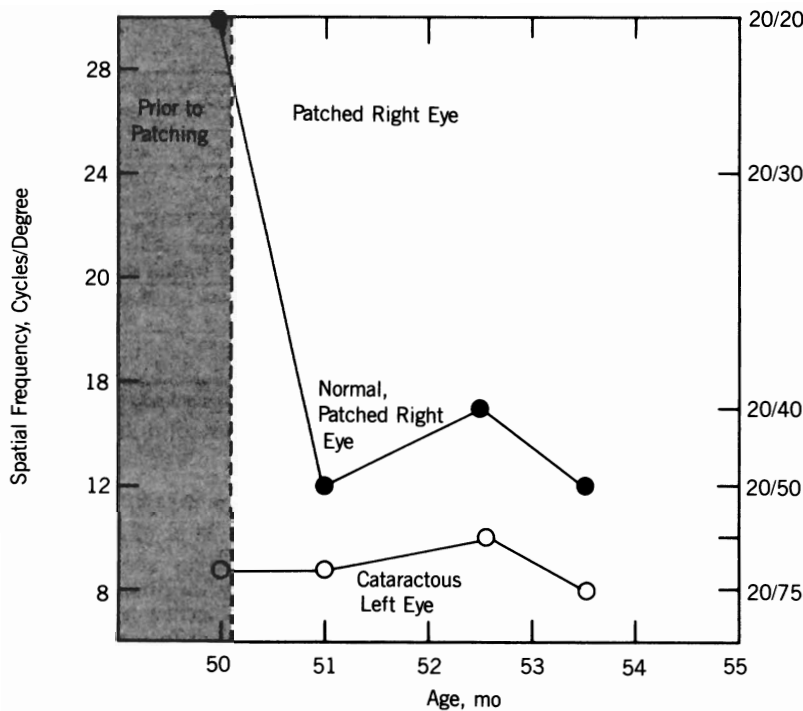


Fig 3.—Visually evoked potential acuity for patient who had 40- $\Delta$  left esotropia resulting from reduced vision in left eye caused by polar cataract (patient 3). Patching regimen of 12 hr/day, 7 days/wk was begun on right eye. Changes between 51 and 52½ months of age are too small to be sure they are real.

eye but with a VEP acuity of 20/70. The left eye could not be measured at that time. Patching of the left eye for six days per week was begun. At the age of 6 months and 3 weeks, patient 1 continued to show 30  $\Delta$  of alternating esotropia but now preferred to fix with the right eye. The VEP acuities were 20/60 in the right eye and 20/200 in the left eye. The parents were unable to return to the clinic for three months, during which time they stopped patching. Because of difficulties with the contact lens, they now used it only once a week for eight to 12 hours. Patient 1 was returned at the age of 9½ months. The VEP acuity was 20/25 in the left eye and 20/300 in the right. The contact lens was refitted, and the parents were instructed to resume the patching regimen and return in one week. Because of difficulties with the contact lens, the parents did not comply. At the age of 10 months, the patient showed no changes clinically, and the VEP yielded an acuity in the right eye of 20/250. Three weeks later, after a correcting contact lens had been used on the aphakic right eye and the left eye had been patched, acuities were reversed for the two eyes once again, the right now being 20/80 and the left being 20/60. In both eyes the rise in acuity was about +7 cycles per degree per month ( $c^\circ/\text{mo}$ ). The fall was about  $-3 c^\circ/\text{mo}$  in the right and  $-16 c^\circ/\text{mo}$  in the left. These rates assume a linear function that is not likely and so must be viewed as a rough measure. However, the parallel rising slopes for the two eyes during both the three- and one-month periods help justify the linear approximation.

**CASE 2.**—A 15-month-old girl (Fig 2) suffered bilateral retinal hemorrhages when she was aged 3 months. The hemorrhage in the left eye cleared spontaneously, but that in the right eye was observed to have erupted into the vitreous at 11 months. When she was aged 15 months, a 10- $\Delta$  right esotropia was noted and a vitrectomy was performed to clear the media. Following the operation, ophthalmoscopy of the fundus became possible, and a residual scarring of the macular, internal limiting membrane was observed. The VEP latencies were normal, and the amplitudes gave acuities of 20/700 in the right eye and 20/40 in the left. A regimen of patching the left eye for six consecutive days per week was followed for three weeks. At the age of 15 months and 3 weeks, patient 2's acuity was 20/90 in the right eye and 20/200 in the left. Patching then was reversed, and the right eye was covered for five consecutive days per week to prevent the possibility of occlusion or patching amblyopia. The parents were unable to return with her until she was aged 21½ months. During the intervening time, patching had been discontinued. Acuity was 20/600 OD and 20/50 OS. The right esotropia had become 30  $\Delta$ . The change of acuity after the initial patching of three weeks was an increase of about +9  $c^\circ/\text{mo}$  in the right eye and a left eye decrease of about  $-16 c^\circ/\text{mo}$ .

**CASE 3.**—A 50-month-old boy had a congenital polar cataract in the left eye and 40- $\Delta$  left esotropia. The VEP acuity was 20/70 in the left cataractous eye and 20/20 in the right eye (Fig 3). A regimen of patching the right eye 12 hr/day was begun. At 51 months, acuity was 20/70 in

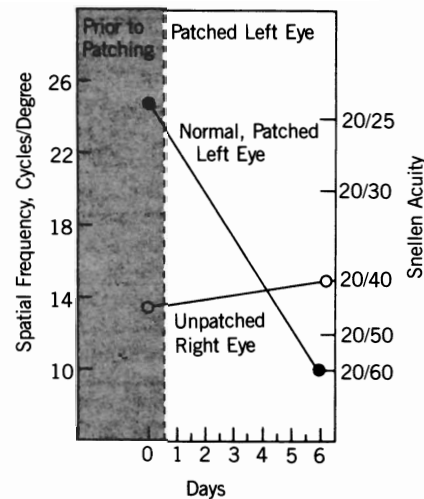


Fig 4.—Visually evoked potential acuity for patient who demonstrated a residual of 20  $\Delta$  at distance and 30  $\Delta$  at near (patient 4). Left eye was patched for six days when patient was aged 8 years, 3½ months.

the left eye and 20/50 in the right, patched eye. The patching regimen was continued for another 1½ months. At 52½ months, patient 3's acuity was 20/60 in the left eye and 20/40 in the right. One month later, at 53½ months, the acuity of each eye appeared to decrease slightly; however, this change, amounting to about one line on a visual acuity chart, may not be any more important than the previous slight increase at 52½ months. Nevertheless, the acuity remains at the same level within the limits of confidence for acuity measurement, VEP or psychophysical. The initial acuity decrease of the right, patched eye was about  $-18 c^\circ/\text{mo}$ . The acuity in the right eye seemed to remain the same, again within reasonable error in acuity measurement.

**CASE 4.**—This patient was 8 years 3½ months old when we first measured her VEP acuities (Fig 4). Following corrective surgery for a right esotropia (30 to 40  $\Delta$ ), she still had a right esotropia of 20  $\Delta$  at distance and 30  $\Delta$  at near. A diagnosis of a nystagmus blocking (compensation) syndrome, characterized by a variable esotropia, abduction nystagmus, and head turning, was made. The left eye was patched for six days/wk to see whether the procedure would improve vision. The VEP acuity was 20/45 in the right eye and 20/25 in the left. Following the six days of patching, patient 4's acuity was about the same in the right eye and 20/60 in the left. The change in the left was  $-75 c^\circ/\text{mo}$ . The high value probably can be ascribed to measuring the initial decrease, which no doubt is steeper than that measured during the several-month period.

#### COMMENT

Since the original deprivation studies of Wiesel and Hubel,<sup>1,2</sup> mon-

Conditions and Results*							
Patient	Type of Deprivation	Age During Deprivation, mo	Age at Patching (Reverse Deprivation), mo	Duration of Patching	Age at Later Deprivation, mo	Patching-Induced Acuity Changes	
						Normal Eye	Abnormal Eye
1	Monocular	0-2½	5-6%	2 mo	10	Large recovery	Decrease and recovery
2	Binocular then monocular	3-15	15-15%	3 wk	15%-21½	Large decrease and recovery	Large increase and decrease
3	Slight mon-ocular	0-50	50-53½	3½ mo	...	Small decrease	No clear change
4	Esotropia	7-79½	79½-79%	6 days	...	Small decrease	No clear change

\*For clarity, we make a distinction between the words "patching" and "deprivation." The latter is reserved for that effect such as cataract, hemorrhage, or large refractive error caused by uncorrected aphakia. Patching is a prescribed occlusion of the eye.

ocular occlusion for a short period, especially during the height of the kitten's sensitive period, has been believed to cause a lasting and largely irreversible neurophysiological deficit, although subsequently a slight behavioral recovery may occur (Dews and Wiesel<sup>13</sup>). The process was explained as a competitive interaction between the two eyes, deprivation of one eye tilting the advantage of neurophysiological connections to the other eye. Most retrospective studies on children have been based on this assumption that unilateral deprivation resulting from naturally occurring anomalies of vision or from prescribed unilateral patching may cause an irreversible amblyopia. Animal studies indicated that the longer the duration of deprivation is, especially during an early age at the height of the sensitive period, the deeper and more intractable is the amblyopia.

Kittens recently have been shown to exhibit considerable recovery of the deprived eye (but not of binocular function) both behaviorally and neurophysiologically.<sup>16,17</sup> Despite prolonged monocular lid suturing during the most sensitive part of the sensitive period, the eye shows extensive recovery (almost to a normal level) without any patching at all. These data were obtained on a day-to-day basis by measuring the visual acuity of the recovering eye. The studies differ in approach from our studies on infants and children in that the decrease in acuity of the normal eye in response to patching was not monitored. However, our data do not yet show recoveries after removal of deprivation without cross patching.

The human data alone, as summarized in the Table, will be considered before a comparison with possible animal models. All of our patients had lengthy deprivations of months to

years. Patching lasted days to months, although it was not done continuously, in keeping with the accepted current clinical practice. In each patient, patching the normal eye caused a precipitous decrease in acuity and removal of the patch brought a quick recovery.

In the two younger children, aged 5 and 15 months, respectively, the formerly deprived eye demonstrated clear and rapid increases in acuity that seemed to be caused by the cessation of deprivation and/or the contralateral patching. In the two older children, aged 4 and 8 years, respectively, there was no clear improvement in acuity in the originally deprived eye. There seems to be less plasticity in the older children.

These differences could be ascribed to several possible causes: age, individual differences, and the original kind of deprivation, such as opaque optical media, uncorrected aphakia, or strabismus. A larger sample of patients will be required to distinguish among these possibilities. Undoubtedly, age must play an important role at some levels.

However, clear individual differences of response to lid suturing have been observed in monkeys.<sup>18</sup>

One must remember that the original deprivation and subsequent patching were not complete for several reasons. Patches were not in place continuously. Deprivation by polar cataract or a large refractive error, as in the case of uncorrected aphakia, does not prevent illumination of the retina. Nevertheless, if future patients show the same pattern, we can conclude that patching for about three to 7.5 weeks as performed herein causes changes that quickly are reversible when the patch is removed.

None of our patients had binocular vision and would not be expected to

demonstrate any kind of binocularity.<sup>6,7</sup>

The concept of a distinction between a complete occlusion to light as well as form, and diffusion, a loss of form alone<sup>8</sup> is not supported by our data. The latter is theorized to be more damaging, inducing a deep amblyopia, whereas the former is believed merely to suspend development because of a lack of competitive effect. All of our patients initially had form deprivation but not light deprivation. Patching was opaque and in effect most of the time, yet rapid changes in acuity occurred with both kinds of stimulus alteration.

#### Kitten Data

The new data on kittens<sup>16,17</sup> seem to be in harmony with our findings. If these data are scaled up by a factor of 5, based on a normal acuity of 6 c/° in cats and 30 c/° in people, the long-term improvement rate is 10 to 20 c/°/mo, and the initial rate can be many times that, which seems to agree with our findings. As was mentioned earlier, these new data do not include any acuities of the eye being deprived during deprivation or patching, so the comparison with our children must be confined to recoveries. Our data do not yet include any curves without patching after the removal of the occluding deprivation. Patching was instituted in what has been generally believed to be the best therapeutic interest of the patients, but the notion of best may be incorrect. If almost complete recovery can be effected without patching, as in the kitten, and if binocular vision can be maintained, then more binocular function may be saved by not patching at all. More acuity data from kittens along the lines of acuity-deprivation data obtained here from infants is necessary to determine if the animal

model of deprivation is useful clinically.

In the younger patients, who demonstrate a high degree of visual acuity plasticity, the removal of the patch seems to allow the eyes to revert toward or to their original acuities. In older patients there seems to be less plasticity. Although the patched eye declines somewhat in acuity, the acuity of the unpatched eye changes little if at all in response to patching or to the cessation of patching. It may be a slower process in older children, but it will require a larger sample to be sure the individual differences or the kind of deprivations are not important.

#### Other Infants

Our results from the young infants agree with the preferential-looking data from two infants, aged just less than 1 year old, in the report of Thomas et al<sup>12</sup> (their method cannot be used with older children). However, neither their results nor ours, nor indeed those of Hartwig et al<sup>11</sup> support the conclusions of Awaya et al<sup>9,10</sup> that a week's patching causes irreparable damage at this age. The plasticity of the visual system of infants of this age seems to work both ways, ie, rapid depression on deprivation or patching and a

bouncing recovery on a return to normal stimulation. It is conceivable that patching caused amblyopia in the infants described by Awaya et al because of some added factor, such as the stress of being surgical patients during that time, or because of some individual differences.

#### Psychophysical Acuity

The data presented herein were collected on regular patients in a pediatric clinic. They point to the practicability and importance of assessing the objective visual acuity in children in the management of pediatric visual problems. A number of reports have indicated the feasibility of testing normal infant acuities with the use of visual preference<sup>19-21</sup> and the visual evoked potential.<sup>13,14,22,23</sup> The utility of all these methods is emerging, and they are being further developed. It is noteworthy that in our clinical center, the routine use of VEP measurements has proved essential in the successful management of monocular congenital cataracts in children (unpublished data, Beller et al, 1981).

For example, until now it has not been possible to use a psychophysical method to test the visual acuity of children around the age of 1 to 2 or

more years. Two new operant conditioning methods have been devised to overcome this hiatus. Mayer and Dobson<sup>24</sup> have reported an operant preferential-looking method wherein the child is reinforced by a "dancing bear." The method is least effective at about 1 year of age. Naegele et al<sup>25</sup> devised a method using "Cheerio" rewards, called "reward contingent acuity." It requires extensive training of the child but can extend the testing into the upper age barrier of the preferential-looking method. The required training makes the procedure less suitable for clinic patients than other methods.

These psychophysical methods give lower absolute acuity values than does the VEP method; however, this factor is of no consequence in deprivation measurements since only the relative acuities are of interest. A psychophysical method can sometimes be faster, but the same VEP method which requires no motor response can be used on people of any age without any training whatsoever.

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