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Eye Patching and Visual Evoked Potential Acuity in Children Four Months to Eight Years Old

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ABSTRACT

The monocular visual acuities of six children aged 4 months to 8 years were measured using visual evoked potentials (VEP's) before and during patching therapy. A seventh child had both Snellen and VEP monocular acuities determined before patching. In a cooperative child, it was estimated that VEP acuity was within 0.25 octaves (one line on an eye chart) of Snellen acuity. In the four children less than 3 years of age, patching resulted in a 1.8-octave decrease in acuity of the patched eye and a 2.0-octave improvement in the unpatched eye. After cessation of patching therapy, acuity of the previously patched eye improved 2.0 octaves and that of the abnormal eye declined 1.75 octaves. In the two children older than 4 years, patching resulted in a 1.25-octave acuity decrease in the patched eye. Cessation of patching resulted in a 1.25-octave improvement in acuity of the patched eye. No permanent deleterious effects of patching on acuity were observed.

Key Words: visual acuity, amblyopia, patching, visual evoked potentials

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Certain abnormal visual experience impairs the function of the visual system in some species of young mammals. The most frequently studied animal model of abnormal visual experience is unilateral deprivation of pattern stimulation by unilateral eyelid suture in the cat[1, 2] and monkey.[3, 4]

In their initial reports, Hubel and Wiesel[1, 2] suggested that unilateral eyelid suture might be analogous to patching, which is a common therapeutic procedure in ophthalmic practice. Because unilateral eyelid suture provided deprivation which had deleterious and irreversible effects on the responses of cortical cells,[1, 2] the size of lateral geniculate cells,[5] and the visual behavior of the animal,[6] they warned that patching might impair the visual function of the patched eye in young patients. Some clinicians have provisionally accepted the analogy of unilateral eyelid suture to patching and its attendant concern (e.g., von Noorden[4, 7]). Others have questioned the validity of the analogy, arguing that patching is a deprivation of light resulting from total occlusion, whereas eyelid suture is a deprivation of form resulting from diffusion of light through the closed lids. The clinically observed effects of form deprivation are said to be more severe than are the effects of total light deprivation.[8] It is generally assumed that patching as practiced clinically has no permanent, deleterious effects on the patched, normal eye, but has potentially beneficial effects on the unpatched, abnormal eye.[9, 10]

Retrospective studies of the consequences of abnormal visual experience in infants and children on later visual functions indicate impaired visual function resulting from the abnormal experience. Strabismus can lead to loss of some binocular functions,[11, 12] meridional deprivation may lead to meridional amblyopia,[13] and unilateral patching sometimes leads to amblyopia of the occluded eye.[14-18]

The deprivation of form vision in young animals by unilateral eyelid suture is most representative of the effects in humans of early form deprivation due to unilateral opacities such as cataracts, ptosis, corneal leucoma, or vitreous hemorrhage. Such natural deprivation has a very poor prognosis unless very early corrective measures are taken.[19] The presumed maximum sensitive period is shown by Awaya et al.[16] as well as by Vaegan and Taylor[18] to continue until about 8 to 10 years. Patching was found generally to be more effective on patients less than 4 or 5 years old.

The effects of early unilateral patching are not clear. Awaya et al.[14, 15] noted that eyes patched for as little as 1 week in children less than 1 year of age may be subsequently found to have developed a deep, intractable amblyopia. Their later evidence does not seem to be in harmony with this view.[16] Furthermore, Hartwig et al.[17] indicated that 7 to 9 days of patching had no lasting effect on infants who were 4, 5, and 8 months of age.

Thomas et al.[20] measured the acuity of two esotropic infants less than 1 year of age. They found that patching resulted in reduced acuity of the patched eye and improved acuity of the unpatched eye. In the one infant they were able to test after patching was stopped, the acuities returned to approximately their prior levels. Thomas et al.[20] interpreted their results as supporting the early views of Awaya et al.,[14, 15] despite the transiency of Thomas's observed changes. Removal of the patch sometimes resulted in an increase in the acuity of the previously patched eye to a level beyond either the prior acuity of that eye or the normal acuity for infants of that age.[21, 22]

Because patching is such a widely used therapeutic procedure, it seems important to determine what effects it has on visual function with regard to the age of the child and the degree and duration of the occlusion. The presence of irreversible, detrimental effects would limit the utility of the treatment.

Visual evoked potentials (VEP's) were chosen to measure acuity because they have several advantages over behavioral procedures. First, the VEP represents a neural response so that neither a verbal nor a motor response to the stimulus is required. Consequently, poor motor coordination or abnormal eye movements need not affect the determined acuity. Second, there are no age limitations; the same stimulation procedures may be used and the same response measured on patients of any age. Third, the only requirements are that the patient be looking at the stimulus pattern and be relatively quiet during the averaging. A rare disadvantage of VEP acuity (but not applicable to this study) is that in certain uncommon neurological diseases, there may be dissociation of subjective and VEP-estimated acuity.[23]

METHODS

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

The experimenter observed the eye position of patients directly. 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.

Visual acuity was determined from its maximum by linear extrapolation of VEP amplitude to the baseline voltage or to the noise level of the control, which was obtained by presenting the smallest pattern slide out of focus.[24, 25] Amplitude was measured from a negative peak near 100 msec to its preceding positive peak. Pattern size was the log minutes of arc determined by measuring the diagonal of the dark checks. Use of the diagonal provides the angular subtense of the largest separation (or lowest spatial frequency) in the pattern. When possible, two averages of each pattern were performed and their average was used in the extrapolation. If one average appeared anomalous (e.g., the child was more or less attentive), it might be excluded.

RESULTS

Effects of Patching

Data were obtained from six patients. JT had a dense congenital polar cataract in the left eye correction was fitted for the left eye and the visual acuities were determined. They were 6/30 (20/100) and 6/60 (20/200) in the right and left eyes, respectively. A regimen of patching 6 hr daily was prescribed for the right eye. At 4 months and 1 week, after 4 days of patching therapy, the acuities were 6/27 (20/90) and 6/12 (20/40) for the right and left eyes, respectively. Patching therapy was continued but implementation was intermittent due to contact lens difficulties. At 5 months and 3 weeks, the acuity of the left eye was assessed as 6/18 (20/60). One week before testing at age 6.5 months, the contact lens for the left eye was lost and patching of the right eye was discontinued. After refitting of the contact lens, acuity was assessed as 6/12 (20/40) and 6/27 (20/90) in the right and left eyes, respectively.

CB was 5 months of age at the time of the first VEP acuity measurement (Fig. 2). A congenital, unilateral/dense cataract in the right eye had been removed by one of us (CSH) at 3 days of age. A final, soft contact lens correction was fitted at age 2.5 months. At 5 months, the infant showed 30^{Δ} of right esotropia with no maintained fixation observable in the corrected aphakic right eye but with a VEP acuity of 6/21 (20/70). The left eye could not be measured at that time. Left eye patching for 6 days weekly was begun. At 6 months and 3 weeks, CB continued to show 30^{Δ} of alternating esotropia but now preferred to fix with the right eye. VEP acuities were 6/18 (20/60) in the right and 6/60 (20/200) in the left eye. Subsequently, the parents were unable to return to the clinic for 3 months, during which time they stopped patching. Because of difficulties with the contact lens, they reportedly used it only once a week for 8 to 12 hr. CB returned at 9.75 months of age. VEP acuity was 6/80 (20/300) in the right eye and 6/7.5 (20/25) in the left eye. The contact lens was refitted and the parents were instructed to resume the patching regimen and return in 1 week. Due to contact lens difficulties, the parents did not comply. On returning at 10 months, there were no changes in the patient clinically, and the VEP yielded an acuity in the right eye of 6/75 (20/250). Upon returning 3 weeks later after once again using a correcting contact lens on the aphakic right eye and patching the left, acuities were reversed for the two eyes once again, the right now being 6/24 (20/80) and the left 6/18 (20/60). On two subsequent visits at 3-week intervals, the acuities remained relatively unchanged.

SH was age 15 months at the time of first VEP acuity measurement (Fig. 3). At approximately 3 months of age, she had suffered bilateral retinal hemorrhages. The hemorrhage in the left eye cleared spontaneously, but that in the right eye was observed to have erupted into

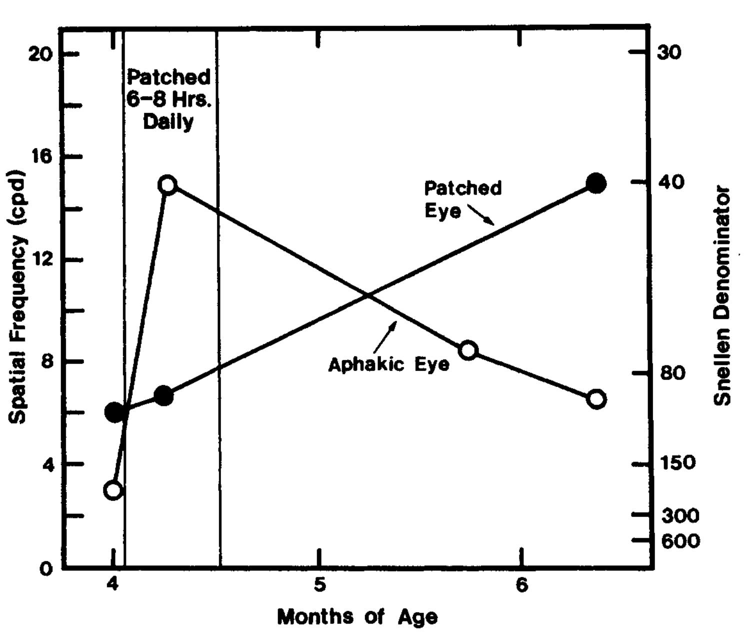

FIG. 1. Patient JT. VEP acuity as a function of age and treatment. JT had a dense polar cataract in the left eye which was extracted at 6 weeks of age. At age 4 months, a final correction was obtained and acuity was assessed. After 4 days of patching therapy, the acuities were assessed. The acuities of both eyes were again assessed at age 6.5 months. Patching had been intermittent for 1.5 months before testing and the contact lens was lost three days before patching. Contact lens replacement was made before the test.

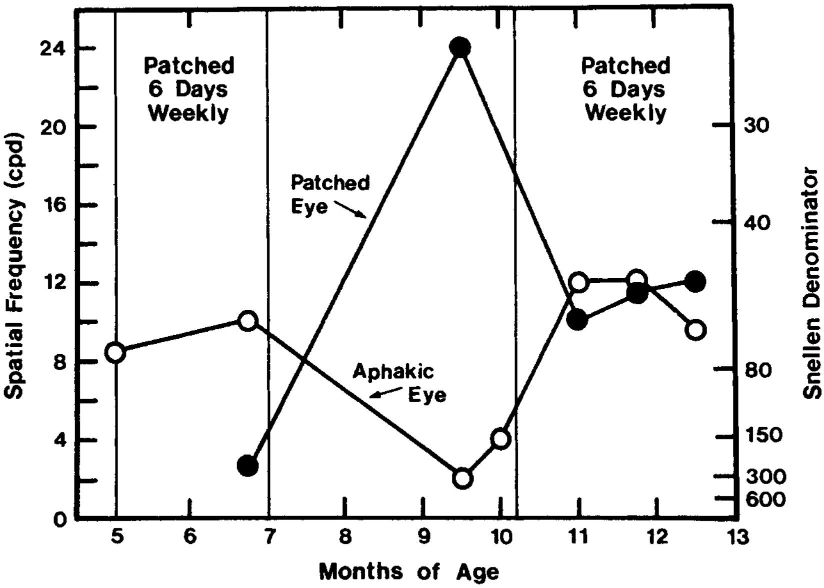

FIG. 2. Patient CB. VEP acuity as a function of age and treatment. CB had a 30^{Δ} right esotropia after cataract removal from the right eye at 3 days of age and contact lens aphakic correction at age 2.5 months. Left eye patching was begun at 5 months with a regimen of 6 consecutive days of patching weekly. After unprescribed discontinuation at 7 months, patching was reinstated at 10 months. Variations in acuity at age 11 months and after may be within the error of measurement.

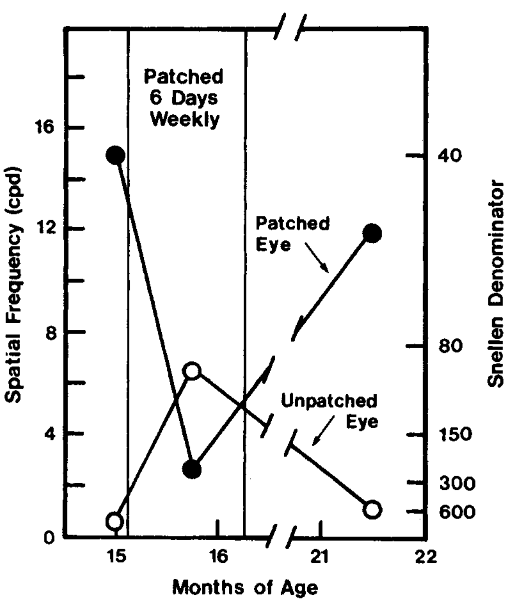

FIG. 3. Patient SH. Acuity as a function of age and treatment. SH had a vitrectomy of the right eye at age 15 months. 10^{Δ} right esotropia was noted before and after surgery. Initial VEP estimates were made the day after surgery following overnight patching of the left eye. A regimen of left eye patching 6 consecutive days weekly was begun. Patching was discontinued by the parents at some point between 16 and 21 months.

the vitreous at 11 months. A 10^{Δ} right esotropia was noted at 15 months, and a vitrectomy was performed to clear the media. After the operation, ophthalmoscopy of the fundus became possible, and a residual scarring of the macular internal limiting membrane was observed. VEP latencies were normal, and the amplitudes gave acuities of 6/210 (20/700) in the right eye and 6/12 (20/40) in the left. A regimen of patching the left eye for 6 consecutive days per week was begun and followed for 3 weeks. At 15 months and 3 weeks, SH's acuity was 6/27 (20/90) in the right eye and 6/60 (20/200) in the left. Then patching was reversed, and the right eye was covered for 5 consecutive days per week to prevent the possibility of occlusion or patching amblyopia. The parents were unable to return with her until SH was 21.5 months. During the intervening time, patching had been discontinued. Right eye acuity was 6/180 (20/600) and left eye acuity was 6/15 (20/50). The right esotropia had become 30^{Δ}.

CR, aged 32 months (Fig. 4), had a dense cataract in the right eye of unknown origin and had developed a slight esotropia. Acuity in the left eye was 6/18 (20/60); when the left eye was patched to attempt to estimate the acuity of the right eye, CR began to cry and refused to cooperate. One of us (CSH) extracted the cataract from the right eye at about age 33 months. After receiving a soft contact lens correction, CR was

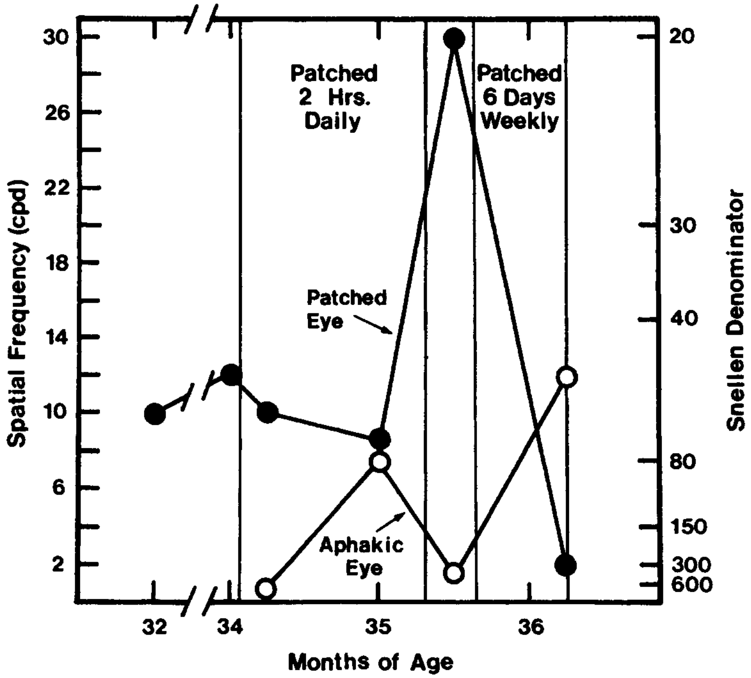

FIG. 4. Patient CR. Acuity as a function of age and treatment. CR had a dense polar cataract in the right eye and had developed a slight right esotropia. At age 32 months, the acuity of the left eye was estimated. The cataract was extracted at age 33 months. At age 34 months, an aphakic contact lens correction was fitted and left eye acuity was estimated. A regimen of left eye patching 2 hr daily was begun. The contact lens was lost and patching stopped for 1 week before testing at age 35.5 months. A patching regimen of 6 days weekly was instituted.

again tested at age 34 months. Acuity in the left eye was estimated as 6/15 (20/50); no estimate for the right eye could be obtained. A regimen of left eye patching 2 hr per day was begun. CR returned in 1 week having been patched for 5 days and her acuity was 6/255 (20/850) in the right eye and 6/18 (20/60) in the left. The regimen of patching the left eye was continued for another 3 weeks. At age 35 months, CR's acuity was 6/21 (20/70) in the left and 6/24 (20/80) in the right eye. A patching regimen of 6 days per week was prescribed. After 1 week of this regimen, the contact lens was lost and it was not replaced for 1 week. At 35.5 months, the acuities in the right and left eyes were 6/225 (20/750) and 6/6 (20/20), respectively. The patching regimen was restarted. At 36.5 months, acuities were 6/15 (20/50) and 6/60 (20/200) for the right and left eyes, respectively.

DG was 50 months old at the time we first measured him (Fig. 5). The left eye had a congenital polar cataract and 40$^{\Delta}$ left esotropia. VEP acuity was 6/21 (20/70) in the left cataractous eye and 6/6 (20/20) in the right eye. A regimen of patching the right eye 12 hr per day was begun. At 51 months, acuity was 6/21 (20/70) in the left eye and 6/15 (20/50) in the right, patched eye. The patching regimen was continued for another 2.5 months. At age 52.5 months, DG's acuity was 6/18 (20/60) in the left eye and 6/12 (20/40) in the right. One month later at 53.5 months, the acuity of the left eye was 6/24 (20/80) and the acuity of the right was 6/12 (20/40). The minor fluctuations in acuity during patching are not significant. Patching was discontinued at 53.5 months and extraction of the cataract was performed at age 55 months, 1 week. The acuity of the previously patched right eye was tested before DG left the hospital. Despite 3 months of patching, acuity had returned to 6/6 (20/20).

TE was 8 years and 3.5 months old when we first measured her VEP acuities (Fig. 6). After corrective surgery for a right esotropia of 30 to 40$^{\Delta}$, TE still possessed an esotropia of 20$^{\Delta}$ at distance and 30$^{\Delta}$ at near. She was diagnosed as suffering from nystagmus blocking (compensation) syndrome, characterized in this patient by a variable esotropia, abduction nystagmus, and head turn. Left eye patching for 6 days per week was begun to see whether it would improve the vision. VEP acuity was 6/13.5 (20/45) in the right eye and 6/7.5 (20/25) in the left. After the 6 days of patching, TE's acuity was about the

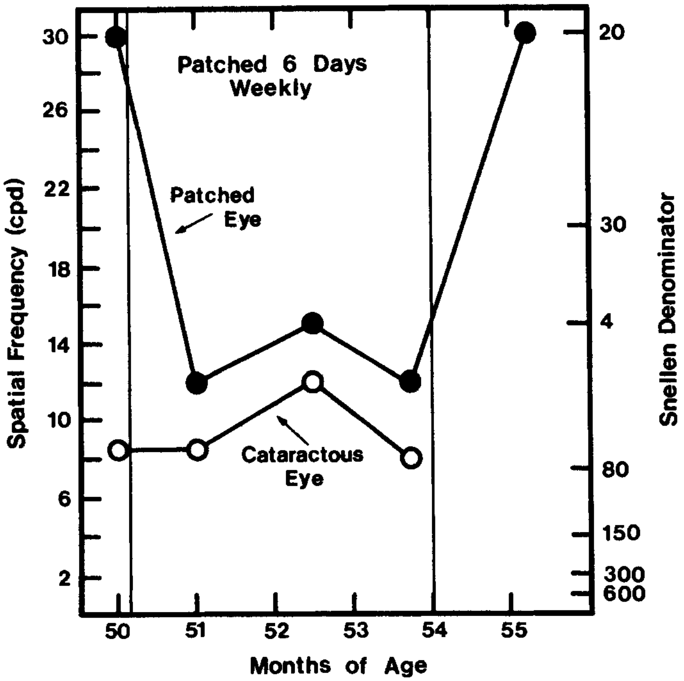

FIG. 5. Patient DG. Acuity as a function of age and treatment. DG had a 40$^{\Delta}$ left esotropia and a congenital, polar cataract in the left eye. A regimen of right eye patching for 12 hr daily was begun at age 50 months. Variations of acuity during patching probably reflect measurement error. Because of lack of success, patching was discontinued at age 54 months and the cataract was extracted at age 55 months. Before leaving the hospital, the acuity of the right eye was estimated.

same in the right eye and 6/18 (20/60) in the left.

Relationship between VEP and Snellen Acuities

Of particular interest is the relationship between acuity determined using standard eye charts (Snellen acuity) and acuity determined using VEP's. We had the opportunity to test one cooperative patient on repeated visits using both types of measures.

PU, a non-English-speaking 4-year-old, had a subcapsular cataract in the right eye and a cortical cataract in the left eye (Fig. 7). Her Snellen acuities obtained with the aid of an interpreter at near were 6/12 (20/40) and 6/9 (20/30) for the right and left eyes, respectively. PU's eyes were straight, both at near and far. At age 59 months, PU returned. The cataracts were more dense and Snellen acuities were 6/24 (20/80) in each eye; VEP acuities were 6/21 (20/70) and 6/27 (20/90) for the right and left eyes. CSH extracted the cataract from the right eye at age 60 months. At age 61 months, PU was fitted with a soft contact lens aphakic correction. Her right and left eye VEP acuities were 6/18 (20/60) and 6/24 (20/80), respectively; Snellen acuity in the right eye was 6/21 (20/70). VEP acuity and Snellen acuity are within 0.25 octaves (or one line on an eye chart) of one another.[a]

[a] An octave is a doubling (or halving) of a frequency. For example, 15 cycles per degree (cpd) 6/12 (20/40) is one octave above 7.5 cpd 6/24 (20/80) and one octave below 30 cpd 6/6 (20/20). Thus, an increase of 1 octave represents a 100% increase, whereas a decrease of 1 octave represents a 50% decrease. Mathematically, an octave is a binary exponential function. It is defined as the base 2 logarithm of the ratio of two frequencies (or 3.322 times the base 10 logarithm of the ratio of two frequencies). To determine the percent change represented by a fractional octave, (1) give the octave a sign appropriate to the direction of change, (2) determine the ratio of the two spatial frequencies by obtaining the base 2 antilog of the octave, (3) subtract 1 from the ratio, and (4) multiply by 100. Thus, a 1.75 octave decrease represents a ratio of 0.297 and a 70% decline, whereas a 1.75 octave increase represents a ratio of 3.36 and a 236% increase. Octaves may be calculated on a less formal algebraic basis, as we have done. Thus, 1.75 octaves equals 1 octave plus 0.75 of a second octave. The ratio represented is 3.5 (or 0.375), and the percent change is 250% (or −63%).

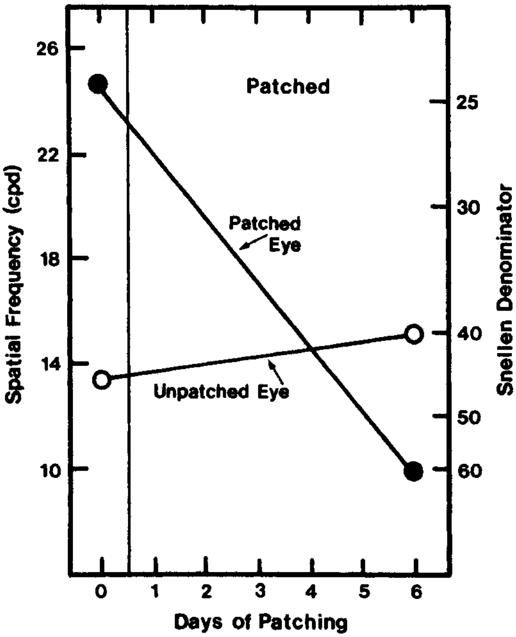

FIG. 6. Patient TE. Acuity pre- and postpatching. TE demonstrated a residual right esotropia of 20 to 30$^{\Delta}$ after surgery. Variable esotropia, abduction nystagmus, and head turn were noted leading to a diagnosis of nystagmus blocking (compensation) syndrome. Left eye patching was instituted for 6 days to see whether vision would improve. The slight improvement in acuity of the right eye was within the 0.25 cycle/degree error of measurement; therefore, patching was terminated.

DISCUSSION

The results are summarized in Table 1. All of our patients had deprivations of long duration, months to years. In all but the oldest child (TE), the initial deprivation was due to unilateral diffusion of the retinal image (cataract or cloudy vitreous). Patching lasted days to months; however, in keeping with current clinical practice, it was not continuous. Subsequent periods of deprivation in the younger children were attributable to large refractive errors due to uncorrected aphakia.

In the four patients less than 3 years of age, the acuity of the formerly deprived eye improved dramatically with patching (2.0 octaves on the average) and rapidly returned to an impaired level with the removal of the patch (1.75 octaves on the average). The removal of the patch was associated with a state of deprivation, e.g., loss of a contact lens, and poor optical imagery to the abnormal eye, esotropia, or both. In the two older patients, no clear improvement of vision in the abnormal eye was observed. No opportunity existed for observations after patch removal.

In general, patching the normal eye resulted in reduced visual acuity of that eye and removal of the patch resulted in a quick return to normal acuity levels. In children less than 3 years old the decline in acuity of the normal eye with patching was 1.8 octaves on the average and the increase with patch removal was 2.1 octaves. In children older than 4 years, the decline in acuity with patching and the improvement with patch

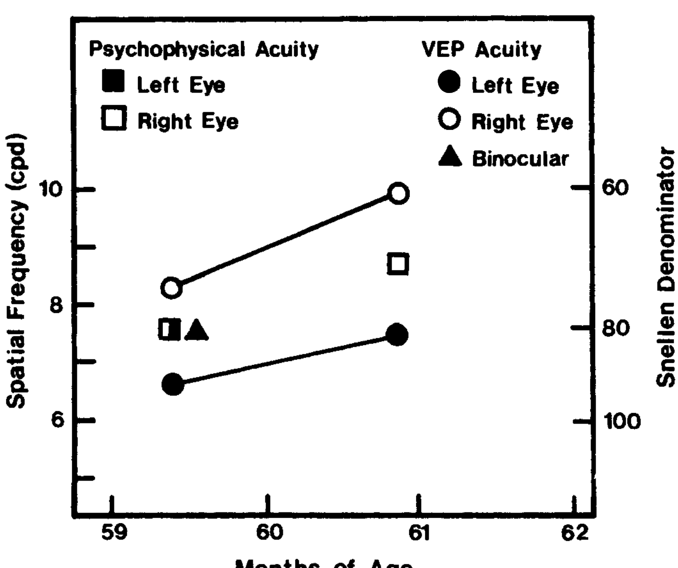

FIG. 7. Patient PU. Comparison of Snellen and VEP acuities. PU had bilateral cataracts. Snellen and VEP acuities were determined at age 59 months for both eyes. The right eye cataract was extracted at age 60 months and acuities were again estimated at age 61 months.

TABLE 1. Summary of conditions and results.[a]

Patient	Type of Deprivation	Age during Deprivation (months)	Age during Patching (months)	Patching-Induced Acuity Changes		Patch Removal (Renewed Deprivation) Acuity Changes	
				Normal Eye	Abnormal Eye	Normal Eye	Abnormal Eye
JT	Monocular	0.00–4.11	4.11–4.25	No change	Improved (2.25)		
		5.00–6.50				Improved (1)	Impaired (1)
CB	Monocular	0.00–2.50	5.00–6.75	—	Improved slightly (0.25)		
		6.75–10.00				Improved (3)	Impaired (1)
			10.00–12.50	Impaired (1)	Improved (1.25)		
SH	Binocular then monocular	3.00–15.00	15.00–15.75	Impaired (2)	Improved (3)		
		15.75–21.50				Improved (2.5)	Impaired (2.5)
CR	Monocular	?–34.00	34.00–35.00	Impaired (0.75)	Improved (3.5)		
		35.25–35.50				Improved (1.75)	Impaired (2.5)
			35.50–36.25	Impaired (3.5)	Improved (2.5)		
DG	Monocular	0.00–50.00	50.00–53.50	Impaired (1.25)	No change		
		53.50–55.25				Improved (1.25)	—
TE	Esotropia	?–79.50	79.50–79.75	Impaired (1.25)	No change		

[a] We distinguish between patching and deprivation. Deprivation is the effect of cataract, hemorrhage, or large refractive error such as in uncorrected aphakia. Patching is a prescribed occlusion of the eye. Ages are expressed in months. Patching change (the numbers in parentheses) are octaves of change rounded off to the nearest 0.25 octave. An indication of no change indicates that any changes in acuity were less than 0.25 octaves. Missing data are indicated by a dash (—).

removal were both 1.25 octaves. Therefore, the magnitude of change appears greater in children less than 3 years old.

The most amazing aspect of our results is the marked plasticity that is observed, at least through the first 3 years of life. Some differences may be attributable to age, the type of deprivation (i.e., cataract, cloudy optical media, uncorrected aphakia, or strabismus), or to individual variables. Determination of the relative importance of these potential causes must await a larger sample size.

Patching for 3 to 15 weeks as performed here resulted in an impairment of visual acuity of the patched eye which was quickly reversible when the patch was removed and normal visual stimulation began. While consistent with most clinical observations that patching does not permanently impair visual function of the normal eye,[9, 10, 17, 18] these observations are not supportive (1) of observations of permanent acuity loss resulting from patching of brief duration in children less than two years of age,[14, 15] (2) of the proposed distinction between occlusion and diffusion,[8] and (3) of current animal models of amblyopia.[1–3, 5, 6]

The data indicate the reliability and validity of VEP acuity. Undoubtedly, cooperation can influence any estimate of acuity. Not surprisingly, VEP acuity seems more reliable and, therefore, more valid in cooperative subjects. Prior results with cooperative adults[25–29] and our results with PU indicate a very close agreement between VEP acuity and clinical measures of acuity. In the case of PU, VEP and Snellen acuities were within 0.25 octaves or within one line difference on an eye chart. Between sessions, the VEP acuity remained stable, again within

0.25 octaves. In other patients, notably DG and CB, where conditions were constant and, therefore, one might expect stable VEP acuities, the maximum difference between sessions was 0.5 octaves (about two lines on an eye chart). Certainly the variation in VEP acuity between sessions (0.25 to 0.5 octaves) is less than the variation which is observed between testing methods (1.0 to 2.0 octaves) by a factor of 2 to 8.

In addition to estimating the reliability and validity of a measure, it is important in clinical practice to know the ease with which the measure may be obtained. In ophthalmic practice, the most difficult populations are (1) children under 3 or 4 years of age, and (2) the handicapped, whether the handicap be neurological, mental, or physical.[30-33] Table 2 indicates the number of visits to our clinic during a 9-month period by patients of different ages. Also indicated are the number of visits on which complete tests were performed. The least testable groups were those referrals under 3 years (25% of referrals untestable), handicapped (13% of referrals untestable), and normal children between 3 and 10 years of age (8% of referrals untestable). Untestability among children, especially those less than 6 months of age, was usually due to tiredness following a period of waiting and the ophthalmic examination. These children were usually testable on return visits when they were tested before their ophthalmic examination. In brief, VEP's can be used to measure the acuity of the most difficult clinical populations and do so with a rate of testability which is of the same order of magnitude as that of standard acuity measures with preschool (3 to 6 years old) aged children.[30-33]

Animal Models

The early reports of unilateral eyelid suturing indicated a relatively permanent alteration of anatomy, physiology, and behavior.[1-3, 5, 6] The mechanism of these effects was presumed to involve a competition in the visual cortex between inputs from the two eyes.[1, 2] More recent investigations, although they do not alter the picture presented above for binocular functions, indicate that recovery of monocular visual acuity in cats is virtually complete with reverse suturing and slightly less without.[34, 35] The final acuity in the formerly sutured eye appears to be a complex interaction of the age at suturing, duration of deprivation, and type of visual experience before, during, and after deprivation for both eyes.[34-36]

Other Human Data

A number of investigators have reported that pattern VEP's are useful in distinguishing functional amblyopia from normal vision,[37-42] and from organic amblyopia,[43] and that abnormalities in the pattern VEP may be better indicators of the success of patching therapy than clinically determined acuity.[44-48] The conclusions are based on the VEP elicited by a small number of patterns. Ours are the first results of which we are aware in which VEP acuity was determined in a clinical population both to detect the presence of amblyopia and to monitor its treatment.

The acuity of normal infants may be determined using visual preference,[49-51] the VEP,[24, 25, 52, 53] or conditioned responses.[54-57] The application of these methods to clinical populations is still new. Despite possible differences in the absolute values of the acuities obtained using the different methods, the relative changes with patching are similar. Reports based on visual preference techniques indicated that infants in their 1st year were very plastic and that occasionally a paradoxical enhancement of acuity occurred in the patched eye after cessation of patching.[20-22] An earlier report of our data indicated that the plasticity extended at least to the 2nd year.[58] The present data indicate that the plasticity appears to remain at least until 3 years of age (CR). There is also further support of the plasticity during the 1st year (JT). In the four infants less than 1 year old who have been examined, there is no clear indication of permanent, deleterious effects of patching. Whether this is due to insufficient sample size, a difference in the anomalies, or other cause is unknown. However, our results are consistent with the view that the response of visual acuity to deprivation is highly plastic, at least through the 3rd year of life.[7, 16, 18]

TABLE 2. Testability as a function of age.[a]

Age	Less than 3 yr	3–10 yr (Handicapped)	3–10 yr (Normal)	More than 10 yr
Total	72	23	60	15
Untestable	18 (25%)	3 (13%)	5 (8%)	0 (0%)

[a] The number of referrals are indicated by age. The percentage of untestable referrals is presented in parentheses.

CONCLUSIONS

We have shown the utility of VEP acuity assessment for both the detection of amblyopia and the assessment of patching therapy. We believe that the VEP method of acuity determination has the advantages (1) of being applicable at all age levels, and (2) of requiring no motor response (which can confound results in some patients).

We have found no clear indication that patching therapy in young children causes irreversible acuity loss in the patched, normal eye. In our small sample, the monocular acuity of children less than 3 years of age appeared to be very plastic. Neither patching therapy of several weeks duration nor deprivation of several months duration appears to result in loss of this plasticity. A reduction in plasticity with age was indicated by the fact that the acuity of the patched eye was less affected by patching in children over 4 years than in children less than 3 years of age.

Our sample size was too small and restricted to determine answers to several important questions relating to the origin, course, and recovery from amblyopia and effects of patching. Particularly, we have not determined the time course of the effects of patching and patch removal, we have not clearly separated possible mechanisms of origin of amblyopia to determine their relative importance, nor did we determine the time course of the human sensitive period for acuity. We are continuing to collect cases in order to attempt to answer these questions.

Finally, we should note that, although animal models have greatly aided our understanding of principles of neural organization in vision, as a guide to patching therapy, they seem to be inadequate. Attention has been centered on the most severe deprivation conditions, eyelid suture, and extreme esotropia. Studies of recovery in animal esotropia are virtually nonexistent and reverse eyelid suture is the frequently used method to study recovery in unilateral eyelid suture. In human patients, many conditions, i.e., small cataracts or small angle strabismus, result in much less form deprivation than in the animal experiments; similarly, patching is less complete in the human than is reverse suturing in the animal. Animal experiments designed to answer clinically relevant questions, in conjunction with more information gained on human infants and young children, may yield a model more predictive for clinical application than current ones.

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