Development of Pattern ERG and Pattern VEP Spatial Resolution in Kittens With Unilateral Esotropia

Zheng-Qin Yin,* Chao-Yi Li,* Xing Pei,* Vaegan,* and Qian-Xun Fang†

Purpose. To follow the development of strabismic amblyopia longitudinally by comparing mean amplitudes and the visual spatial resolving ability of retinal and cortical pattern responses at various stages of postnatal development in unilateral iatrogenic convergent strabismic kittens.

Methods. Surgery to produce iatrogenic convergent strabismus was performed on 20 kittens at 3 weeks of age; three kittens were used for controls. The monocular transient pattern electroretinogram (PERG) and pattern visual evoked potential (PVEP) were recorded simultaneously on the 23 kittens throughout development.

Results. The PVEPs of the strabismic eyes were very reduced at 4 to 5 postnatal weeks (P < 0.01). The reduction increased at 6 to 16 weeks but was even worse at 17 to 30 weeks. The PERG of the squinting eye showed only a slight reduction in the first 4 to 5 weeks of age (P > 0.05), the decrease of responses was significant (P < 0.01) at 6 to 16 weeks and 17 to 30 weeks. At 4 to 8 weeks of age, the PVEP evoked through the unoperated eye in kittens consisted mainly of two positive components of similar amplitude. During development, the slow component decreased in comparison to the fast one, and its peak shifted forward until it merged into the fast (P100) component.

Conclusions. Esotropic amblyopia did affect the PERG and the PVEP in the amblyopic eye, but the effect on the PERG was less severe, had slower onset, and did not continue as long as for the PVEP. Invest Ophthalmol Vis Sci. 1994; 35:626-634.

The neuronal basis of strabismic amblyopia has been widely investigated in various animal models in an attempt to understand the mechanism of the amblyopia observed clinically in humans with strabismus. Hubel and Wiesel1 produced a strabismus through early surgical section of one of the extraocular muscles or a deprivation amblyopia by occlusion of one eye. They established that cortical single cells were subsequently more likely to be activated by stimulation of the appropriate receptive field area of the unoperated eye than the strabismic eye. They argued that the effect of strabismus was similar to that of form deprivation and was related to the existence of binocular inputs to the same cortical cells, which could not occur before the cortex. Other investigators confirmed this effect in different animal models.2-9 Ikeda and Tremain10 were the first to report a similar effect in the retina. They found that sustained X-cells in the area centralis of the squinting eye of cats with esotropia without alternating fixation showed significant reductions both of spatial resolution and contrast sensitivity, compared with cells in the area centralis of the normal eye. Ikeda and Tremain10 and Jacobson and Ikeda11 have argued that the retinal X-cells, like the binocular cells in the cortex, require well-focused and normal visual input for development. Additional evidence for an effect of strabismus on retinal ganglion cell properties has been provided by Chino and colleagues.12 However, Cleland et al13 found that the maximum spatial resolution of ganglion cells in the amblyopic eye of strabismic cats was normal and, in a separate study, that atropine-induced blur also had no effect.14 They argued that the difference between their surgical method (single muscle section) and that used by Ikeda (total excision of two muscles) was responsible for the difference.

More recently, pattern visual evoked potentials (PVEPs) and pattern electroretinograms (PERGs) have been used as measures of visual function to inves-
tigate strabismic amblyopia because these responses have been reported to correlate well with loss of visual spatial resolution at cortical and retinal sites, respectively. The amplitudes of PVEPs, recorded from area 17 while stimulating the squinting eye with phase alternating square wave gratings, were found to be lower than those obtained by stimulating the normal eye. Similarly, it was reported that the PERG recorded from the strabismic amblyopic eye was smaller than that from the normal eye. However, some clinical reports have found the PERG to be normal in amblyopic eyes. The steady-state PERG is thought to originate predominantly from retinal ganglion cells. These results suggest that, although the retinal effect is less certain, both retinal and visual cortical dysfunction might be involved in strabismic amblyopia.

In this study, we used kittens with unilateral, iatrogenic, convergent strabismus induced by myectomy and compared the visual spatial resolving ability of retina and cortex at various stages of postnatal development using simultaneous monocular PERG and PVEP recordings. Both the normal and the squinting eyes of each animal were studied during each recording session, and the same animals were studied at several ages.

MATERIALS AND METHODS
Animal Preparation
Twenty-three kittens (Table 1) were reared normally for 3 weeks after birth, at which time surgery was performed on 20 kittens to produce iatrogenic convergent strabismus. In contrast to earlier studies, we used procedures more similar to standard clinical practice to induce strabismus. The lateral rectus muscle was separated from the insertion to globe, and the distal portion was removed (myectomy). The attachment of the superior oblique muscle to the globe was weakened by cutting the tendon (tenotomy). All surgery was carried out under pentobarbitone sodium (30 mg/kg) anesthesia. Topical antibiotics were administered. The degree of esotropia was checked while the kittens were alert on at least the third and seventh postoperative day and then each week when no recording was done. The range was always between 5° and 10°. Eye movements appeared normal after 4 weeks of age, but some disturbance in motility could be detected in one kitten (number 8) until 8 weeks of age. Three kittens were used for controls. No operated eye ever became straight and in cover testing, alternating fixation was not observed. The first recording session was at least 7 days after surgery to allow the kittens to recover completely. Eleven kittens died after the first recording as a consequence of a colony epidemic.

On the day of recording, a kitten was anesthetized with ketamine hydrochloride (20 mg/kg), intubated with an endotracheal cannula, mounted in a stereotaxic apparatus, and paralyzed intravenously with gallamine triethiodide (flaxedil, 20 mg/kg) and artificially resired.

During the experiment, continuous intravenous infusion of gallamine triethiodide (8 mg/kg · hr), ethyl

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<th>Control 2</th>
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<td>Recording Age (wk)</td>
<td>5, 7</td>
<td>4, 6, 8, 10, 12, 14, 17</td>
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<tr>
<td>Degree of strabismus</td>
<td>0°</td>
<td>15° convergence 8° rotation</td>
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<td>Kitten No.</td>
<td>Control 2</td>
<td>Control 3</td>
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<tr>
<td>Recording Age (wk)</td>
<td>4, 6, 8, 10, 12, 14, 17</td>
<td>15° convergence 8° rotation</td>
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<td>4, 6, 8, 10, 12, 14, 17</td>
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<td>Degree of strabismus</td>
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carbamate (Urethane, 200 mg/kg·hr), and glucose (120 mg/kg·hr) in Ringer's solution was maintained (infusion speed 1.5 to 2 ml/hr). The EEG and ECG were continuously monitored as a parameter of the depth of anesthesia, and additional anesthetic was given when necessary. Rectal temperature was maintained at 37.5°C and end tidal CO² at around 4%. Phenylephrine hydrochloride (10%, Neosynephrine, Winthrop) was used to retract the nictitating membranes and atropine (1%) to dilate the pupils. The optic disk and retinal blood vessels were projected onto a tangent screen by a modified ophthalmoscope and plotted to determine the central area as well as to estimate the strabismic angle under paralysis. The procedure was carried out at least twice at the beginning of the experiment and repeated on the next recording. If the strabismic angle was larger than 25°, a thread was sutured onto the lateral corneal limbus and the esotropic eye was drawn laterally to maintain a clear visual axis. The stimulus pattern was moved so that it was always centered on the projection of the area centralis of the eye being stimulated. The corneas were protected with optically neutral contact lenses, and the refraction of the eyes (including contact lenses) was corrected by additional lenses to focus the eye on the screen, 32 cm in front of the eyes. A DTL electrode was used for recording the PERG. The PVEP was recorded with a stainless steel screw electrode implanted in the skull over the striate cortex at P4–L2. The reference electrodes were subdermal wires at the outer canthus for PERG and at the frontal for PVEP. The stereotaxic apparatus was grounded. When one eye was tested, the untested eye was occluded. Artificial pupils (4 mm in diameter) were employed during the experiments. All contact points were anesthetized with xylocaine jelly (2%) or subdermal xylocaine injections. Head restraint was minimal. The ears were filled with cotton wool soaked in xylocaine before the ear bars were lightly pressed against them. The preparation and recording session normally lasted 10 to 12 hours. Any fluid in the endotracheal tube was regularly cleared by suction. Toward the end of the recording period, the infusion solution was replaced by a normal one without either flaxedil or urethane. Ketamine hydrochloride (20 mg/kg) was given at intervals. One to three hours later, the kittens began to breathe freely. When this became reliable, the endotracheal tube was withdrawn and dismounted. After recording, the kittens were treated with gentamicin (4 mg/kg). The next recording was after a pause of at least 7 days. All procedures adhered to the principles of the ARVO resolution on the use of animals in research.

**Stimulation and Recording**

The visual stimuli for PERG and PVEP tests were vertical rectangular gratings subtending 18° × 18° of visual angle positioned 32 cm in front of the eyes and generated by an image synthesizer (Picasso, Innisfree, Huntingdon, Cambridgeshire, UK) on an oscilloscope (608 monitor, Tektronix, Beaverton, OR). The gratings phase-reversed in a square wave mode at 1 Hz (500 ms for each 180 degree phase). Mean luminance of the gratings was kept constant at 25 cd/m², and the contrast (L_max - L_min/L_max + L_min) was 0.57. The spatial frequency of the gratings varied from 0.1 to 10 c/deg (0.2 c/deg for a step). When the focal ERG was examined by diffuse light flashes (FERG), the same CRT screen was used to display a homogeneous light flash (1:1 light-to-dark ratio, 1 Hz), and the surround was illuminated by a 100-watt light bulb. One recording was made from each eye in the absence of any stimulus to determine independently the base noise level for each test session. The electrical responses recorded from the cornea and the striate cortex were amplified (10,000 for PVEP; 50,000 for PERG) and filtered (0.1 to 100 Hz for PVEP; 0.1 to 30 Hz for PERG). The signals were fed to the A/D port of a computer, digitized at a rate of 1024 samples per second, and then averaged (N = 450). The Fourier analyses of each mean response was calculated. Because even harmonics dominate both PERG and PVEP responses, the amplitudes of the first 12 even Fourier components were added. The root mean squares of the sums were plotted to construct the spatial frequency tuning (SFT) curves.

**RESULTS**

**Differences Between PERGs and FERGs in Strabismus**

Figure 1 shows typical PERGs and FERGs recorded from the normal and the strabismic eye of a kitten at different ages. PERGs were obtained with 0.2 c/deg square wave gratings reversed in phase at 1 Hz. Two equal responses were obtained in a cycle, each to a 180°-phase reversal. The FERG showed a positive deflection to the onset of light and a negative deflection when the stimulus went off. The results show that both the PERG and the FERG of the normal eye (Fig. 1, left column) increased in amplitude with age; the PERG of the squinting eye (Fig. 1, upper right) was considerably smaller than that of the normal eye (Fig. 1, upper left) at each stage of development, and there is little difference between the FERGs of the squinting and normal eyes, either in amplitude or shape. In Figure 2, average amplitudes of the FERGs recorded from the normal (blank bars) and the strabismic eye (hatched bars) of the 23 kittens were compared at different age groups. Although in general the response amplitude increased with age, little difference was shown between the strabismic and the normal responses (t-test,
PERG and PVEP in Strabismic Kittens

$P > 0.05$). Thus, the focal ERG did increase with development but was unaffected by esotropia.

**PERG and PVEP Spatial Frequency Tuning Changes Due to Development and Strabismus**

Figure 1 shows that, in contrast to the FERG, the PERG amplitude at an intermediate spatial frequency, was affected by both esotropia and development. Because amblyopia is predominantly a high spatial frequency resolution deficit, we concentrated in our sub-

sequent analyses on changes in the PERG and PVEP as a function for spatial frequency. The individual and population SFT curves were similar. To eliminate variance due to amplitude, we normalized to the largest PERG or PVEP from each animal on each occasion. Usually, but not invariably, the response to the lowest spatial frequency in the unoperated eye was the largest response. All PERGs or PVEPs obtained from an animal were converted to fractions of this measure.

Average normalized SFT curves for all 23 kittens, grouped into three postnatal age ranges, are shown in Figure 3. PERG and PVEP SFT curves for the squinting eye were reduced in amplitude as early as 4 weeks of age, that is, 1 week after the operation. The reduction of the strabismic eye relative to the normal eye was greatest at the low frequency side. PERG amplitude change at low spatial frequency reached about 25% in both the 6 to 16 and 17 to 30 week groups, but PVEP amplitude loss was greater than 50%. For both tests, the relative degree of amplitude loss in the squinting eye was greater, and amplitude ratios increased at high spatial frequencies. The PERG of the strabismic eye showed an insignificant reduction, mainly at the low frequency side, compared to the normal eye in the first 4 to 5 weeks (F-ratio, $P > 0.05$). The PERG decrease became significant ($P < 0.01$) across all spatial frequencies between 6 and 16 weeks. The significant reduction persisted ($P < 0.01$) but became slightly less because some normal animals in this small sample had poorer than expected high spatial frequency responses at 17 to 30 weeks (Fig. 4). The PVEPs of strabismic eyes were significantly reduced across all spatial frequencies at 4 to 5 weeks (F-ratio, $P < 0.01$). The reduction increased between 6 and 16 weeks ($P < 0.01$) and became somewhat greater in the high-frequency range (1 to 4 c/deg) at 17 to 30 weeks ($P < 0.01$).
PERG and PVEP amplitudes were normalized by taking the maximal response in each animal as unity.

We used PERG and PVEP amplitudes to estimate objectively the visual acuity for retina and cortex, respectively. We extrapolated the high spatial frequency range of the SFT curves to the baseline. A straight line was fitted by linear regression to responses in each SFT curve at spatial frequencies between the highest spatial frequency where the response was below the independently measured noise and the first maxima at a lower spatial frequency. These high spatial frequency cutoffs are plotted against age in Figure 4 for those nine squinting kittens in which PERG and PVEP recordings were made at two or more different ages. The resolution limit increased with age by 0.014 c/deg per day in normal kittens (r = 0.87) for PERG and by 0.012 c/deg per day for the PVEP (r = 0.82). In normal eyes, both the PVEP and the PERG had an initial mean spatial resolution of about 1.5 c/deg and a maximum (adult value) of about 3.75 c/deg. Strabismic reduction of spatial resolution was already present on the first test at age 30 days, 7 days after the operation, and was less marked for the PERG than for the PVEP.

In squinting eyes, the high cutoff spatial frequencies also increased with age but with lower slope. PERG resolution limit increased much more slowly with age in squinting eyes than it did in normals (0.0085 c/deg per day, r = 0.72), and the cutoff reached about 2.5 c/deg at around 200 days. The PVEP resolution limit in squinting eyes increased even less with age (0.0012 c/deg per day, r = 0.27). The initial value was about 0.65 c/deg and final adult value about 1 c/deg, much lower than that of the corresponding PERG.

**Peak Time and Wave Shape Changes of Normal PVEPs of Kittens During Development**

Figure 5 shows the PVEP evoked through the normal and the squinting eye in one kitten at different stages (4, 10, and 20 weeks of age). The kitten, stimuli, and test occasion were the same as in Figure 1. When the stimulus pattern was presented to the normal eye (Fig. 5, left column), the PVEP increased in amplitude with age.
PERG and PVEP in Strabismic Kittens

PVEP

NORMAL SQUINT

4 Week 10 Week

10µV 20 Week

500MS

FIGURE 5. PVEPs recorded from the normal eye (left) and the squinting eye (right) of the kitten whose PERGs and FERGs are shown in Figure 1. The stimuli used and the age of recording are the same as in Figure 1.

age so that the response became about twice as large at 20 weeks as it was at 4 weeks. In comparison to the normal control at each corresponding ages, the PVEPs evoked through the strabismic eye (Fig. 5, right column) were noticeably reduced but did increase somewhat with age. In the squinting eye, responses were smaller and noisier. In general, the implicit time of the second peak appeared to decrease rapidly with increasing age as it did in normal eyes (Fig. 6). This was not studied systematically because the peaks could not be reliably detected in the squinting eye after 10 weeks.

Figure 6 shows the PVEP evoked through the unoperated eye of a kitten during the period between 4 and 17 weeks after birth. At the initial stages (4 to 8 weeks of age), the PVEP consisted of two positive peaks of similar amplitude followed by a third small positivity (Fig. 6A). During development, the slow positive component (second one) decreased in comparison to the fast positive component (first one), and its peak time decreased. It merged gradually into the fast positive component with increasing age (see the 17-week recording). In parallel, a slow negative potential developed in front of the third positive wavelet at about 10 weeks and became conspicuous after 14 weeks. These variations appeared similar in those 10 animals in which PVEP recordings were made from normal eyes at four or more different ages (Table 1).

To investigate quantitatively the variations of different components, the peak implicit times of the first two components to stimulus gratings of different spatial frequencies for the kitten were measured and plotted against age (Figs. 6B, 6C). Figure 6B shows the variations of peak implicit times for the fast component at four representative spatial frequencies, which all shortened progressively with increasing ages. Figure 6C shows the peak implicit time of the slow components for the same four spatial frequencies and the average of these regressions. The slope of the average regression line for the slow component (9 ms/wk) is six times steeper than that for the fast component (1.5 ms/wk), indicating that the age-dependent shortening of peak implicit time occurred much more rapidly in the slow component. At early stages of postnatal development, high spatial frequencies showed much longer peak times than lower spatial frequencies. This difference between peak times of PVEPs to high and low spatial frequency stimuli was progressively reduced during development. The peak implicit times stabi-
lized at adult values and were no longer dependent on spatial frequency after about 14 weeks. This final fast component peak implicit time was about 70 ms, and the slow component time was about 120 ms.

DISCUSSION

Electrophysiologic studies of retinal deficits induced by strabismus have been performed. Reports of retinal change\textsuperscript{10-12} and PERG reductions\textsuperscript{19-24} have not always been confirmed.\textsuperscript{13,25,26} The importance of the present experiments is that esotropic strabismus, induced by a typical clinical surgical method, significantly reduced the PERG in both amplitude and spatial resolution. The FERGs from two eyes, from the same retinal regions as those that produced the PERGs, were similar in amplitude. This result is in agreement with earlier clinical works\textsuperscript{9,20,22,24} and supports results from studies with more extensive surgery by Ikeda.\textsuperscript{10,11}

Amblyopia is characterized by reduction of foveal visual acuity without any observable retinal pathological correlate. Amblyopia has previously been demonstrated behaviorally in kittens raised with unilateral convergent strabismus. If one views the PVEP as an equivalent measure of visual acuity, the amblyopia should be manifest at the high frequency end of the spatial frequency response functions. We have used the PVEP to demonstrate amblyopia in kittens using this criteria. We have, in a separate publication, shown there was no histological difference between the amblyopic and normal eyes, at the light microscopic level using cresyl violet stain, in eight of animals.\textsuperscript{32} Freeman et al.,\textsuperscript{17} reported amplitude reductions in the esotropic eye but the high frequency cutoff values of the PVEP for deviated and nondeviated eye were nearly identical. We used nearly the same stimuli as Freeman's work\textsuperscript{17} and recorded PVEP from the primary visual area cortical representation of the central visual field. We found the PVEP showed reductions in both amplitude (Fig. 3) and spatial resolution (Fig. 4) in the squinting eye at one week after the operation. Cortical deficits appeared rapidly after deviation surgery and did not reverse during development. The speed and magnitude of change is consistent with other descriptions of cortical plasticity during the critical period. The spatial frequency cutoff values that we measured for the nondeviated eye are within the same range as that determined by Berkley and Watkins,\textsuperscript{33} and considerable reductions of responses were seen from the deviated eyes across a broad range of spatial frequencies with a particularly greater defect at the high frequency end. This led to a reduction of high frequency cutoff of 1.5 to 2.5 octaves in the deviated eye relative to the nondeviated and, consequently, a significant reduction of visual acuity of the strabismic eyes. The present result is consistent with many clinical studies in humans. An apparent discrepancy with a study by Freeman and colleagues in cat\textsuperscript{17} may be partly attributed to differences in stimulus luminance. We used 25 cd/m\textsuperscript{2} because intensities higher than 30 cd/m\textsuperscript{2} are known to cause response saturation in some single units in the cat visual cortex,\textsuperscript{34} whereas they used 300 cd/m\textsuperscript{2}. There are other difference in procedure and sample size. Their anesthetic was halothane but we used ketamine–urethane. They had 17 cats (4 convergent, 4 divergent, 5 monocular deprivation, and 4 normal), and we had 23 cats and all were convergent except for 3 normals. The influence of these various factors is still to be determined.

We found the PVEP waveform changed regularly with age from two peaks to one. The slow component of PVEP changed more rapidly than the fast component as the kittens matured. The peak implicit time of the second positive peak gradually came closer to the first one until they merged. Anatomically, the cat visual system is immature at birth. Until 4 to 5 weeks of age, it is difficult to classify ganglion cells as X or Y type in the retina.\textsuperscript{35} Hamasaki and Sutija\textsuperscript{26} found in the kitten that most of the cells they could classify at 3 weeks were Y-cells. The proportion of X-cells approached adult levels around 12 weeks. This suggests that the PVEP waveform reflects visual development. One possible model of the origin of these waves is that the fast component may represent the Y-system, the second component of PVEP may represent the X-cell system, and the small late component seen in the oldest cats may be the W-system.

The PVEP result shows that our kittens were amblyopic, and the comparisons between PVEP and PERG measures show that there was a retinal effect but that the cortical effect was greater. Ikeda and colleagues\textsuperscript{10-11} suggested that blur was the amblyogenic factor, even in strabismus, and Chino et al\textsuperscript{12} confirmed this. They showed spatial resolution and center–surround organization of X-type ganglion cells was reduced. This was not confirmed in subsequent studies in cats reared with chronic atropinization\textsuperscript{14} or strabismus.\textsuperscript{13} There is no simple explanation for the differences between the single unit studies. Our control FERG studies and direct observations show that the PERG loss cannot be attributed to optical differences. Kittens’ pupils were dilated. Pupillary apertures were measured and equal. Artificial pupils (4 mm) were used. Refractive correction for both eyes was determined by streak retinoscopy. Media were clear. The stimulus was centered on the optic axis (determined by reverse ophthalmoscopy). Recordings were monocular. Thus, the stimuli were comparable between eyes.

It has been suggested that the visual changes that take place after surgically induced strabismus may be artifacts of the surgery itself. Cleland et al\textsuperscript{15} argued that the removal of two muscles, conjunctiva, and
other extraocular structures according to Ikeda’s method\textsuperscript{19} "would have caused a severe and long-lasting impairment of the ocular motility of the deviating eye, which by itself may have effects in the developing visual system." Extensive scarring and other interruptions to normal retinal physiology also might have occurred. Their own surgery involved cutting just the tendon of the lateral rectus. They found no subsequent effect at the retinal single unit level. It appears that such surgery does not introduce the retinal functional damage. In their surgery, the tendon and body of the lateral rectus were not shortened and could have spontaneously reattached. They showed that their kittens were behaviorally amblyopic and said the strabismus was manifest, but they did not indicate what squint angles were achieved nor how consistent they were. It is possible that their kittens’ eyes might have had better retinal correspondence and, hence, less constant blur than ours. We used surgical procedures similar to those used in humans, myectomy of the lateral rectus muscle and, tenotomy of superior oblique in our kittens. The eye movements became normal and we think spontaneous reattachment occurred, but the squint angle was constant and nonalternating. There was cyclorotation and a vertical deviation as well. It is unlikely that the surgery caused the PERG and PVEP loss because PERG differences between the eyes were minimal in those animals recorded at the shortest times after surgery. Therefore, the retinal and cortical changes are direct physiological correlates of strabismic amblyopia.

The PERG is known to be generated at a different site from the FERG\textsuperscript{27} and to involve the ganglion cells.\textsuperscript{28} Even at low spatial frequency, the PERG may be more sensitive to the functional change in the retina caused by strabismus than the FERG. PERG changes were neither as substantial nor as rapid as PVEP changes at corresponding ages. This differential response of deterioration shows that the well-known cortical change\textsuperscript{17,18} occurs on top of a smaller but significant retinal loss. Similar PERG losses have been described in most studies of patients with anisotropic amblyopia, but studies of patients with strabismic amblyopia are less clear. Normal PERGs have been found in both strabismic and anisotropic amblyopic eyes by Hess\textsuperscript{29} and Gottlob and Welge-Lüssen.\textsuperscript{26} Arden\textsuperscript{38} has shown that the results of Hess’ study\textsuperscript{29} demonstrated a significant PERG change in all seven patients in the group with anisotropic amblyopia if a more comprehensive statistical test was used. Of the 33 tests conducted on seven patients, the response of the ambylopic eye was smaller in 31. The binomial probability of this occurring by chance is low. Even in the group with strabismic amblyopic, the response of the ambylopic eye was smaller in 19 tests and larger in 14 (seven patients). Similarly, Gottlob and Welge-Lüssen\textsuperscript{26} recorded from 14 patients and found no significant reduction on average if they controlled for the angle of strabismic deviation. However, the best response of the amblyopic eye was reduced relative to the normal eye in nine patients, larger in four, and equal in one. Arden and Wooding\textsuperscript{22} found PERGs reduced in 27 of 28 children with amblyopia in whom reliable data could be obtained from a total sample of 62 children. Thus, in all studies including the current study, the PERG is more likely to be reduced in the strabismic eye. The mechanism by which this occurs is still to be determined.

**Key Words**

strabismus, amblyopia, kitten, pattern electroretinogram, pattern visually evoked potential

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**References**


