Diagnostic and Therapeutic Considerations In An Amblyopic Child: A Case Report

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Abstract

Degraded retinal imagery and concomitant abnormal binocular interaction, as a result of significant unilateral uncorrected refractive error, can result in unilateral functional amblyopia in young humans.[1-7]

The "plastic or critical period of vision" could be considered as the physiologic epoch in which visual deprivation can impede complete development of normal vision or in which visual stimulation can "reverse" the effects of previous stimulus deprivation. This plastic period has been defined in some mammals[8,9] *but is still approximated in humans.*[8,10,11] *The prevention of normal visual acuity development with maturation is referred to as amblyopia of arrest; a condition that is non-treatable by definition.*[3] *Amblyopia of extinction represents a reduction in acuity from that previously developed and consequently acuity is recoverable.*[3] *The clinical differentiation of amblyopia of arrest from amblyopia of extinction would be greatly simplified if the critical plastic period in humans was more clearly defined.*

Optometrists must assess many factors in addition to age when evaluating the prognosis for amblyopia therapy.[11] *This case study helps illustrate the importance of early detection and subsequent correction of unequal refractive errors as well as the aniseikonic, binocular and electrophysiologic consequences of the condition and its treatment.*

History

Three year old AR and her fraternal twin were brought by their parents to Primary Care Services at the University of Waterloo, School of Optometry for their first oculo-visual assessment in June of 1984.

The 26 year old mother reported that throughout her pregnancy she suffered no illnesses, took only occasional aspirin, but smoked approximately three cigarettes a day. The instrument birth of the twins was without complications. AR weighed 5 lbs. 14 oz. at birth. Her general mental and physical development had been unremarkable. No visual problems were obvious to the parents.

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Diagnostic Findings

An oculo-visual assessment of AR's twin sister revealed normal monocular and binocular acuities, gross binocularity, unremarkable ocular health as well as insignificant and equal hyperopia in each eye.

An initial assessment of AR uncovered a gross acuity reduction in the right eye only. A significant amount of myopia was revealed in the right eye by retinoscopy and ophthalmoscopy (approximately −13 DS). The left eye was slightly hyperopic (+0.75DS).

An internal referral to Electrodiagnostic Services was arranged to determine the functional integrity of the macular-cortical pathways and the prognosis for amblyopia therapy. At that assessment the reduction in acuity and the presence of significant anisometropia were confirmed. Fixation was centred by ophthalmoscopic visualization.

Unpatterned flicker Visually Evoked Responses (VERs) were recorded with a bipolar surface electrode configuration placed along the occipital mid-sagittal plane. The active electrode rested approximately 2 cm above the inion with the reference electrode 4 cm higher. The right earlobe was grounded. VERs were recorded to white flashes (Grass stimulator X16 intensity) presented in a ganzfield at 10, 30 and 50 Hz. Thirty 200 ms epochs

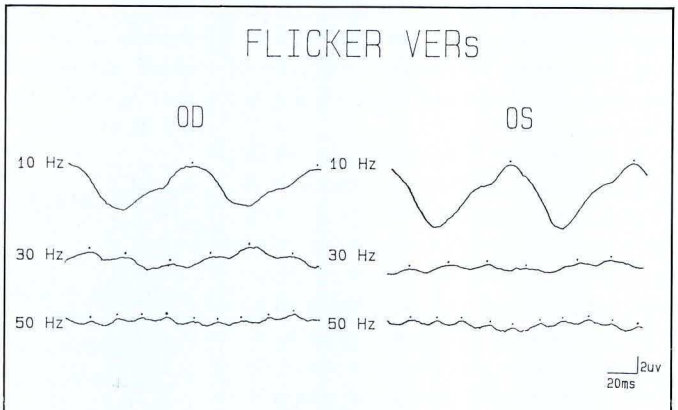

Figure 1
June 1984. Unpatterned VERs for the right and left eye for 10, 30, and 50 Hz flash presentations. No interocular difference was apparent (Bandpass 1-30 Hz, Sensitivity 50μv for all VERs).

constituted a trial. The responses were fed into a Nicolet C.A. 1000 and stored for later analysis.

The unpatterned VERs were of normal amplitude and waveform up to at least 50 Hz flash stimulation (Fig. 1). There were no inter-ocular differences. These findings indicated normal gross functional integrity of the macular-cortical temporal frequency channels.

Patterned VERs were recorded with the same electrode configuration as described for the unpatterned VERs. Steady state patterned VERs were recorded with a T.V. monitor generated 6° checkerboard field that contained black and white checks reversed at 7.5 Hz (space averaged luminance 100 cd/m^2). Thirty 500 ms epochs constituted a trial.

Steady state VERs to 14' arc checks were of normal waveform and amplitude for the unaided left eye. The response was virtually extinguished with the unaided right eye (Fig. 2). The correction of 75% of the myopia (−10 DS) in the right eye produced a recognizable but significantly attenuated response relative to the left eye. With the −10.0 DS lens before the right eye, steady state VERs were recorded to graded check sizes (14', 28', 56' and 112' of arc). The largest amplitude and best waveform was obtained with 56' checks (Fig. 3). This suggested a physiologic acuity potential of at least 6/24 (20/80) with the partial correction. The under correction of the 13 D of myopia by three diopters put the farpoint at approximately 0.33m. With the viewing distance of the checkerboard pattern being 1m, the potential acuity was predicted to be better than the achieved 6/24 acuity if the refractive error were fully corrected. Patient fatigue, however, prevented further assessment.

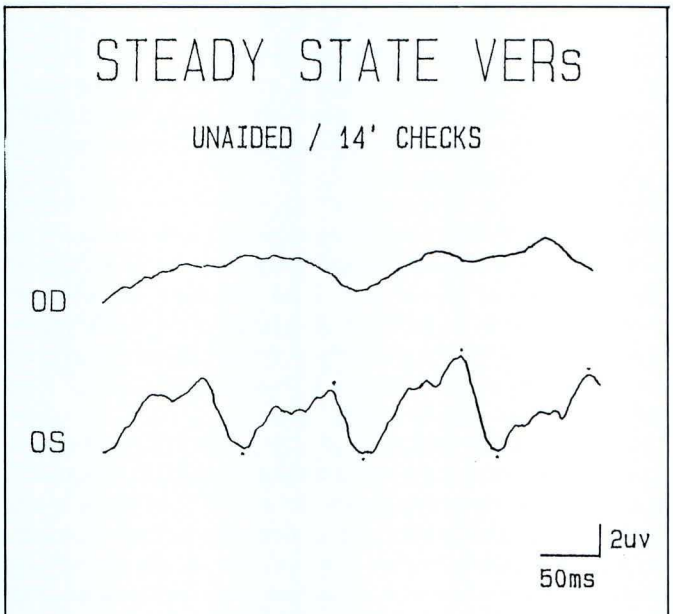

Figure 2
June 1984. Patterned steady state VERs for the unaided right and left eyes, using the 14' arc check size checkerboard.

An external referral was made to confirm the presence of healthy ocular tissues. The ophthalmological assessment supported our findings and revealed no indications of obvious myopic retinal degeneration in the right eye.

In view of the large inter-ocular difference in refractive error, the apparent appreciation of reasonable form vision in the right eye, and the young age of the patient, an internal referral to Contact Lens Services was made. After the successful fit of a contact lens on the right eye, the Electrodiagnostic and Binocular Vision Services would co-ordinate an amblyopia therapy programme.

Treatment

A) Contact Lens Therapy

A decision was made to fit AR's right eye with a soft contact lens using the predicted parameters: 7.8 mm base curve radius (BCR); 12.5 mm diameter; −11.25 D power. These parameters were based on keratometric readings of 45.75 @ 065 and 47.25 @ 175, a spectacle prescription of −13.25 DS and a visible iris diameter (VID) of 11.00 mm.

Since only the B&L lens was available with the desired predicted parameters, a predicted custom lens was calculated. A diameter 1.5 mm to 2.0 mm larger than the VID was chosen so that the lens would not be too large to be inserted by the mother onto her daughter's eye and yet would supply good corneal coverage. Initially the lens was also fitted 0.5 mm flatter than the flattest K reading of the eye to ensure good movement as well as tear and debris exchange. The power was chosen to fully correct the refractive error when vertexed back to the eye. Table 1 indicates the different trial lenses assessed.[12]

TABLE 1
Trial lenses assessed

Manufacturer	Lens	B C R (mm)	Diameter (mm)	Power (D)
ALL Vision	Snowlfex50™	7.8	12.50	−11.25
		7.63	12.8	−13.00
B&L	HO3™	N/A	13.5	−11.00
Cooper	Permalens™	7.7	13.5	−13.50
CCCL	C-Flex70™	7.63	13.0	−13.50
Trans Canada	N & N M79™	7.8	12.5	−11.25
Trans Canada	TC75™*	7.8	12.5	−11.25

*Provided Best Fit

The best tolerated and best fitting initial lens for this patient was the TC-75™ from Trans Canada Optics. Modifications were made to the fitting of the lens after the initial assessment, since all lenses sat at an inferior position and had 2 mm of lag with blinking. Therefore the final lens was made larger in diameter and steeper in base curve. The lens was then better centered and lagged approximately 0.5 mm to 1 mm with the blink. The final lens had the parameters: 7.63 mm BCR; 13.0 mm diameter; and −11.25 D power. A peroxide system was prescribed for daily cleaning and disinfection and a premixed protein cleaning regimen for weekly use.

After three weeks of wear of the contact lens, AR returned to Contact Lens Services for re-evaluation. The lens was comfortable and there were no problems of irritation with the solutions. The patient gradually increased her wearing time to 10 hours/day.

On subsequent check-ups there were no signs of edema or lens intolerance. The over-refraction was found to be +1.00 over the right contact lens. The patient was hyperopic in the left eye (+1.00 −0.25 × 090).

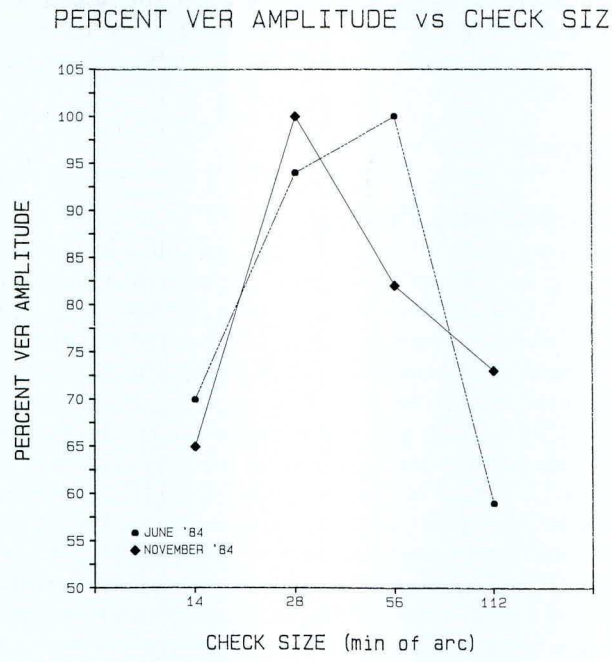

Figure 3

Figure of VER amplitude as a function of check size; plotted as a percentage of the check size producing the largest VER amplitude.

June 1984. The largest amplitude and best waveform was obtained for the 56' arc check size, predicting at least 6/24 acuity.

November 1984. The largest amplitude and best waveform was obtained for the 28' arc check size, predicting at least 6/12 acuity.

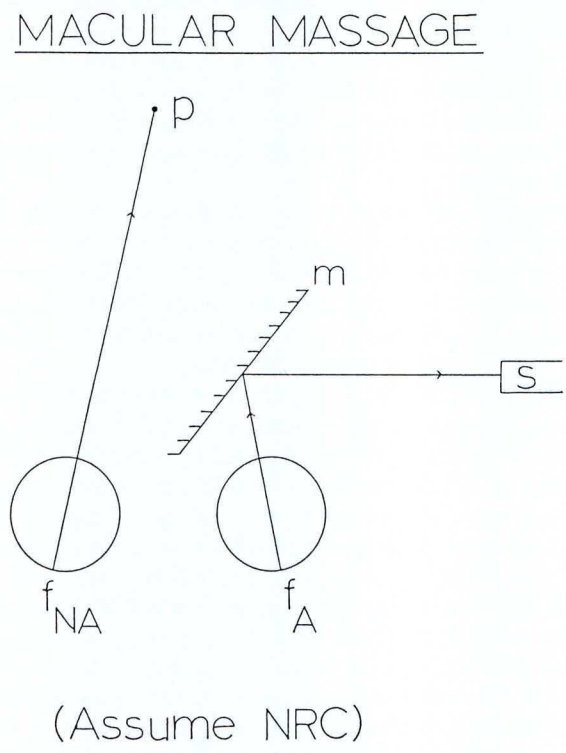

Figure 4A

Schematic for the Macular Massage exercise.
p = fixation point; m = hand held mirror;
s = penlight source; f_{NA} = non-amblyopic left eye fovea;
f_A = amblyopic right eye fovea.
A "game" in which the patient attempts to superimpose the image of the penlight on an indicated fixated target. Performed for about 5 minutes at least 2-3 times per day.

B) Amblyopia Therapy

After the successful fitting of a contact lens on the right eye AR returned to Electrodiagnostic Services in November of 1984 for re-evaluation of the eye's potential physiologic acuity. Figure 3 shows the steady state VERs recorded to 14', 28', 56' and 112' arc checks. The largest amplitude and best waveform was achieved with the 28' arc checks, predicting at least 6/12 (20/40) acuity with the refractive error corrected. This finding, coupled with the apparent cortical differentiation of stimulus size presented to the right eye, suggested a favorable prognosis for amblyopia therapy. The amplitude of the amblyopic right eye VERs was approximately 56% of the amplitude of the non-amblyopic left eye using 28' checks. The subjective acuity using Ffook's symbols was 6/36 (20/120) with the right eye and 6/6 (20/20) with the left eye. Fixation was centred by visualization and 200" of stereopsis was indicated by the Stereofly test.

An amblyopia therapy programme was initiated. Macular massage and the Modified Brock Posture Board were performed daily by the child under the guidance of her mother. Figure 4A and B shows a sketch of the basic design of the Macular Massage and Modified Brock Posture Board exercises that were employed. By January 1985 the subjective acuity had improved enough that macular massage was replaced by daily direct patching. Initially the left eye was occluded with an opaque patch 30 minutes a day. The visual deprivation period was gradually increased to three hours per day. The approach of gradually increasing the patching period was taken to minimize psychological trauma, thereby maximizing patient compliance. The mother was to encourage her child to pursue visually demanding tasks such as colouring, reading, watching T.V. or quiet nearpoint games while patching. As a result of the family's rigorous schedule, the patching and Brock Posture Board programme was not carried out as routinely as had been prescribed. The contact lens was worn everyday.

Steady state VERs performed in May 1985, to 14' checks, confirmed the persisting inter-ocular difference in spatial frequency sensitivity. The right eye amplitude was 35% of the left eye amplitude. The greater inter-ocular difference in amplitude than was found six months earlier was a function of the smaller stimulus check size presented. What was also of interest was the degraded binocular amplitude and waveform. It has been suggested in vision literature that smaller binocular VERs, relative to the constituent monocular VERs, are an objective indicator of binocular dysfunction.[13] AR's relatively attenuated binocular VERs were not a surprise in view of the significant anisometropia and presumed aniseikonia. Over the summer months of 1985 the amblyopia therapy program was suspended due to patient and parent disinterest. The progression in subjective acuity from June 1984 through October 1985 is indicated in Figure 5. As AR's acuity in her right eye improved, our concern over the consequences of aniseikonia increased. Our patient did not verbalize any of the typical symptoms of aniseikonia but her activities were demanding higher levels of binocularity; for

instance playing catch and riding a bike. Consequently, the patient was referred to Aniseikonic Services in June 1985.

C) Aniseikonia Therapy

Aniseikonia was measured using the Multi-meridional Space Eikonometer[14] designed by Arnulf Remole (Fig. 6). The Space Eikonometer consists of one fixed and ten adjustable steel drill rods. The central rod is marked with a red dot for fixation. The other rods are individually brought towards the patient from a position beyond the fixation rod until the patient indicates that the moveable rod is in the apparent frontal parallel plane (AFPP) determined by the fixation rod. The rods can be rotated so as to test for a tilt of the AFPP along with 45°, 135° and 180° meridians.

The absence or correction of aniseikonia results in the AFPP being parallel to the face plane (i.e. a 0° tilt) in all meridians. Aniseikonia manifests itself as a tilt of the AFPP proportional to the magnitude of the size difference. In classic aniseikonia, the tilt of the AFPP is such that the rods closest to the face place are ipsilateral to the eye with largest ocular image.[14] The average size and direction of the AFPP tilt is measured using a protractor indicator placed above the rods.

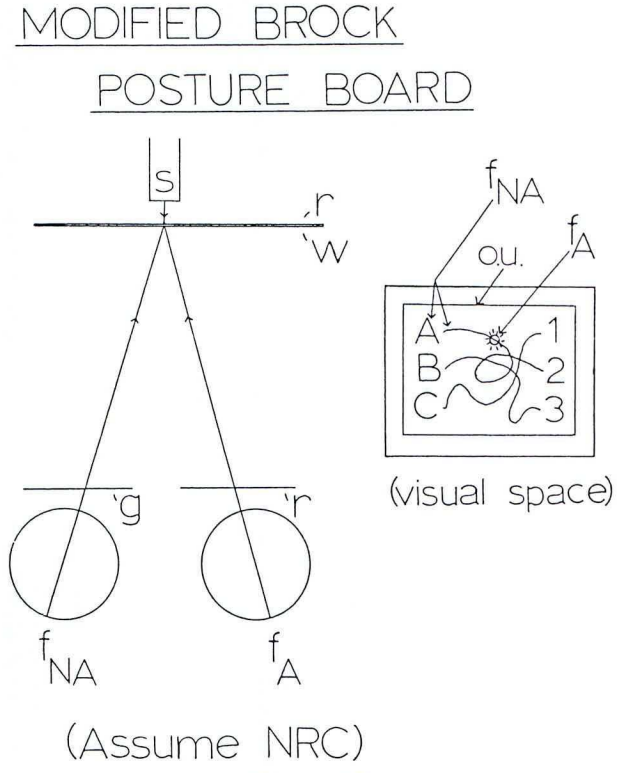

Figure 4B

Schematic for the Modified Brock Posture Board exercise.

s = penlight source; r = red filter; g = green filter

w = white paper, f_{NA} an f_A as in Figure 4A.

The patient attempts to trace a design drawn in *red* pencil on the white paper (seen by the left eye only) with the penlight (seen by the right eye only). Different designs can be drawn on different white sheets of paper to provide variety. A fixation hold, seen by both eyes, is created with a black pencil border around the white paper.

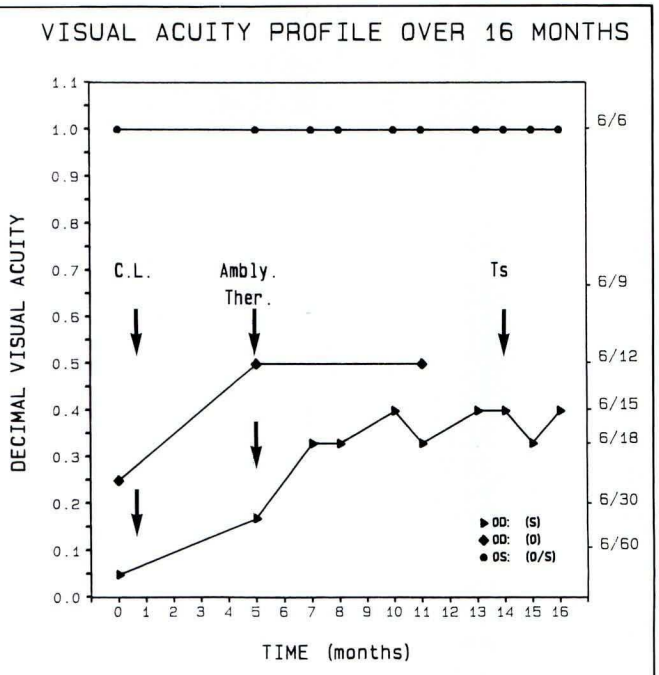

Figure 5

Subjective (S) and Objective (O) visual acuities recorded over a 16 month period from June 1984 through October 1985. The major improvement in subjective acuity occurred in the first seven months and could be attributed to the provision of the contact lens and the initial phases of the amblyopia therapy programme.

(C.L. = the time when the contact lens was first worn on the right eye; Ambly. Ther. = the time when the amblyopia therapy programme was initiated; Ts = the time when the spectacle-contact lens telescope was first worn).

Using the working distance and the patient's interpupillary distance, Ogle developed a mathematical approximation relating the angle of horizontal tilt to the magnitude of aniseikonia.[14,15] The approximation states that a 1% magnification difference corresponds to a tilt of the rods of 3°. An average 12° tilt of AR's AFPP suggested a 4.0% magnification difference. This approximation provided a good prediction since a 4.6% magnifying size lens over AR's right eye virtually eliminated the tilt of the AFPP.

Remole[16] and Enoch[17] described how to incorporate a Galilean telescope to correct aniseikonia in the unilateral aphake. The same principles may be applied to correct an unilateral myope. Before the myopic eye, the telescope is formed by a spectacle-contact lens combination. A plus power spectacle lens forms the "eyepiece" of the telescope and thereby magnifies the ocular image. A contact lens, that is overminused to negate the plus power of the spectacle lens, forms the "objective" of the telescope. The intent of the telescope is to enlarge the image of the more myopic eye so that it equals the image of the less myopic eye.

The calculation of the desired reversed telescopic system for AR was as follows:

1) "Eye piece" Spectacle Lens (F'_Vspec)

$$F'_V\text{spec} = \frac{\Delta\,\text{Mrq}}{\text{t(Mrq)}}$$

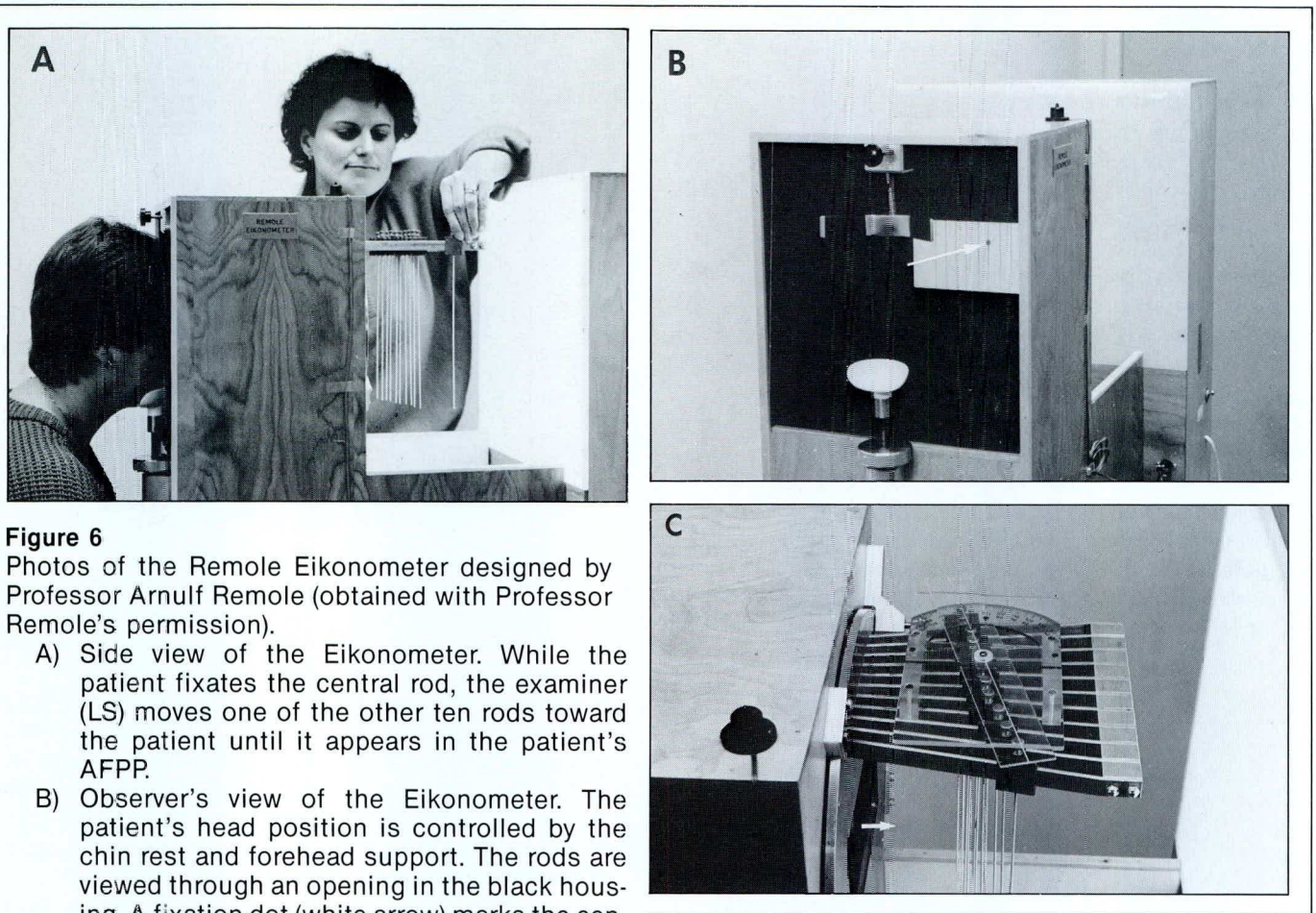

Figure 6
Photos of the Remole Eikonometer designed by Professor Arnulf Remole (obtained with Professor Remole's permission).

A) Side view of the Eikonometer. While the patient fixates the central rod, the examiner (LS) moves one of the other ten rods toward the patient until it appears in the patient's AFPP.

B) Observer's view of the Eikonometer. The patient's head position is controlled by the chin rest and forehead support. The rods are viewed through an opening in the black housing. A fixation dot (white arrow) marks the central rod.

C) Top view of the modified protractor used to measure the tilt of a patient's AFPP. The patient views the rods through the opening (white arrow) in the black housing. This photo illustrates the type of AFPP tilt that AR demonstrated prior to her aniseikonic correction (i.e. the rods on the patient's left side were set closer to the patient than the rods on the right side).

where Mrq = magnification required; t = vertex distance (m)

$$F'_V \text{spec} = \frac{0.046}{.012(1.046)} = +3.66\text{D}$$

$$F'_V \text{spec} \doteq +3.50\text{D}$$

2) "Objective" Contact Lens (F'_{Vcl}) increment

$$F'_{Vcl} = \frac{-F'_V \text{spec}}{1\text{-}tF_V \text{spec}}$$

$$F'_{Vcl} = \frac{-3.50}{1\text{-}0.012(3.50)} = -3.65\text{D}$$

$$F'_{Vcl} \doteq -3.50\text{D}$$

The consistent over-refraction of +1.00D, with the stabilized original contact lens, required consideration in the lens design. The final spectacle-contact lens correction that was provided to compensate for the unilateral myopia and to correct the induced aniseikonia was:

1) Contact Lens Rx:
OD Permalens™: 7.7 mm BCR/13.5 mm diameter
/−13.50 D power
OS none

2) Spectacle Rx:
OD +3.25 DS PD = 50 mm
OS +1.00 −0.25 × 090

A change to Permalens™ was made since when the replacement of the TC-75™ lens was needed the high power was no longer available. The visual acuity subsequent to amblyopia training and spectacle-contact lens therapy was: OD 6/15; OS 6/6

Discussion

Diagnostic Considerations

During a routine oculo-visual assessment, a significant impairment in form perception was uncovered in a healthy three year old fraternal twin's right eye. The diagnosis of anisometropic functional amblyopia affecting the right eye was made after considering the results of a combination of routine and special oculo-visual test procedures.

The diagnosis of a functional amblyopia was contingent upon there being no detectable ocular pathology. The absence of such pathology was supported by both optometric and ophthalmologic assessments of the ocular structures. In addition, objective tests of macular-cortical function were obtained with the VER.

Unpatterned VERs were recorded to ensure that the temporal frequency channels of the visual system were functionally intact and free of detectable pathology. Most vision literature would agree that unpatterned VERs are normal in functional amblyopia.[18-20]

Both waveform and amplitude of patterned VERs are affected by functional amblyopia.[18,21] AR demonstrated the typical reduction in patterned VER amplitude with her amblyopic eye. The cortical differentiation of stimulus size was an encouraging prognostic sign for amblyopia therapy. The significant inter-ocular differences in VER amplitude using small check sizes emphasized the significant disruption of form vision in the amblyopic eye. After the initial VER assessment, periodically recorded patterned VERs provided a useful index by which to objectively monitor neural effects of the therapy programme. The electrophysiologically determined corrected acuity of 6/12 provided a realistic prediction for therapy. After less than one year of a combined contact lens/amblyopia therapy programme, psychophysically determined acuity in the amblyopic eye had reached 6/15.

The diagnosis of anisometropic functional amblyopia was established by the presence of a large uncorrected inter-ocular difference in refractive error in the absence of strabismus, eccentric fixation or pathology.

Therapeutic Considerations

Optometric therapy for this functional amblyope was carried out in three phases: 1) fitting the highly myopic right eye with a suitable contact lens, 2) initiating an amblyopia therapy programme involving a combination of Macular Massage, Modified Brock Posture Board and opaque patching, and 3) correcting aniseikonia with a spectacle-contact lens combination telescope. The first two phases were directed towards maximizing acuity in the amblyopic eye. The final phase was designed to improve binocularity.

The use of a contact lens rather than a spectacle lens was the therapy of choice for two main reasons. Firstly, the contact lens was superior cosmetically. Secondly, the significant interocular difference in image size for this patient was smaller with a contact lens than with a spectacle lens. An important consideration was that the parents were willing to adopt proper care and hygiene in the management of the contact lens. Patient compliance was quite good after the initial contact lens fitting.

Several factors and diagnostic test results were considered to determine the design and prognosis of the amblyopia therapy programme. These included: 1) the patient's age, motivation and health, 2) the type of functional amblyopia, monocular fixation and sensory integration, and 3) the degree of impairment as assessed by both acuity and non-acuity features.

The importance of patient age in determining the prognosis for amblyopia has evolved over the past fifty years. In 1939, McMullen[22] recommended patching and spectacle therapy only for anisometropic amblyopes younger than 10 years of age. Bishop,[10] in 1957, suggested that treatment would be markedly less successful in amblyopes over the age of 11 years; although amblyopes up to 15 years of age might occasionally benefit from amblyopic therapy. Sen[23] supported the treatment of older amblyopic children in a 1982 study of 102 patients. Although the prognosis for improvement of acuity was better in the 6 to 12 year old age group than the 13 to 20 year old age group, 50% of the 46 patients in the latter group showed improved post-treatment acuity. Forty nine percent of the patients showed a concomitant improvement in stereopsis. By all age standards in the vision literature, three year old AR was a desirable candidate for therapy. The fact that AR did not achieve post-treatment acuity better than 6/15 in the amblyopic eye would suggest that factors in addition to age must also be considered.

When dealing with very young patients, parental motivation is as important if not more important than patient motivation. In this case, parental motivation was initially very high. Their motivation did decline as the child reached her acuity plateau.

Oculo-visual assessment revealed a healthy oculo-visual system, free of detectable pathology. ARs general health was excellent. Both of these factors suggested a good prognosis for therapy. Other encouraging prognostic indicators included the presence of centred monocular fixation and gross stereopsis (200").

The type of functional amblyopia may affect the prognosis for therapy. Excluding small angle strabismics, detection and subsequent therapy of strabismic patients often occurs early in life due to their cosmetic presentation (the onset of strabismus also plays a role in the determination of amblyopia of arrest or extinction).[23] In contrast, non-strabismic anisometropic patients are often diagnosed and treated later in life and therefore, may be at a disadvantage with respect to prognosis.[23] AR's parents were predictably surprised at the diagnosis because there had been no indications of visual problems evident in AR's behavior. One must also consider that the degree of amblyopia cannot be directly correlated with the degree of anisometropia. One of the reasons for this is that the magnitude of the anisometropia at the diagnosis may have been different than that which initially existed.[7] The type of unilateral ametropia also affects the prognosis. Unlike an uncorrected significantly hyperopic eye, AR's uncorrected myopic right eye would have had the benefit of some stimulation at near working distances, thereby improving the prognosis for therapy.

When possible, both acuity and non-acuity features should be used to identify amblyopic eyes and determine the therapeutic prognosis.[24-26] Non-acuity amblyopic features include: greater contour interaction, spatial distortion and uncertainty, as well as abnormal pursuit and saccadic tracking.[24,25] Differences in spatial-temporal contrast sensitivities across the visual field also differ between amblyopic and non-amblyopic eyes and even between different forms of amblyopic eyes.[26] Considering the young age of our patient, the easiest and most powerful diagnostic non-acuity tool was the investigation of contour interaction. The effect of contour interaction can be clinically demonstrated by comparing interaction Snellen and interaction-free tumbling E acuities. A functional amblyope will usually perform inferiorly when the acuity test includes interaction. An encouraging prognostic sign for amblyopia therapy is an improvement in acuity demonstrated when contour interaction is eliminated. For AR, her initial corrected interaction-free acuity (IFA) was 6/30.

Within two months of wearing the right contact lens daily and performing amblyopic exercises, the IFA was 6/21. Six months later, after continuing amblyopic exercises intermittently, the IFA plateaued at 6/15. Interaction acuities using conventional Snellen optotypes were always unsuccessful despite the child being lettered. This might have been an indication of the significant effect of contour interaction, spatial distortion and uncertainty. In part, the reduction in acuity demonstrated with the Snellen chart may have been the result of the higher level of patient co-operation required; specifically the need for vocalization of the target identity. The IFA was obtainable without vocalization because the child used hand symbols to represent what she saw. Shyness was

not considered to be a major factor since the child became quite familiar and comfortable with the clinicians over the numerous visits.

The amblyopia therapy programme was designed keeping the patient's age and level of amblyopia in mind. Exercises were chosen that minimized demands on patient effort and attention span yet maximized the development of visual function. Patching was initiated only after acuity had improved using a combination of the Macular Massage and Modified Brock Posture Board exercises. This strategy was adopted to reduce any potential hazards created by AR relying solely on a highly amblyopic eye for mobility and subsequently maximize patient compliance during patching. Compliance was also enhanced by one of the parents handmaking a patch that was more cosmetically acceptable yet still met our therapeutic specifications. During periods of patching, visually stimulating activities were encouraged such as: colouring, tracing and drawing. As is frequently the case, patient and parent motivation was directly related to the degree of perceived visual improvement.

The aniseikonic therapy was initiated out of a concern for binocular function. The provision of spectacle-contact lens combination telescope before the right eye and a spectacle lens before the left eye provided an optical correction that minimized interocular differences in the stimulus to accommodation and ocular image size.

Unfortunately, AR was discharged from the School of Optometry prior to electrophysiologically studying the efficacy of the aniseikonic correction. AR's care was transferred to an optometrist in private practice whose location and hours were more convenient for the family. One year after discharge from the School, AR was still wearing her contact lens and spectacles. Her acuities were unchanged and there were behavioral indications of improved binocularity.

This case helps emphasize the importance of both the early detection of significant anisometropia and the subsequent tailoring of a therapy programme appropriate for the particular patient. The use of the VER both as an objective diagnostic tool as well as an objective prognostic tool is illustrated. This report also demonstrates the relative ease of fitting a contact lens of high prescription, provided a local custom lab is available to manufacture the appropriate lens. Finally, the need for multi-phased therapy in some patients to attend to both monocular as well as binocular functional integrity is addressed by the employment of aniseikonic therapy subsequent to refractive and amblyopic therapy.

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