Binocular Testing

Binocular Anomalies of the Binocular Patient

Classical optometry became very concerned with the way in which spectacle lenses affected the binocular status of patients. After all, when a patient accommodates his eyes converge so lens power affects binocularity and the effect of prism in lenses is obvious. And binocular function problems can be associated with a variety of asthenopic symptoms. The human binocular system came to be viewed as a fragile entity at war with itself and the environment, prey to a variety of serious problems. But how should the optometrist diagnose and treat these problems?

Classical optometry concerned itself mainly with two quantities: the phoria, a measure of the relative position of the two eyes when dissociated; and the vergence, a measure of the degree to which the eyes could be separated prismatically without blur or diplopia. Clearly the smaller the phorias and the larger the vergences, the better off the patient was, but that kind of simple-minded analysis wasn't enough. An extremely complex analysis scheme was developed by the Optometric Extension Program (OEP) involving twenty one distinct tests, most concerned with binocularity. These tests were integrated into an analysis scheme based on deviations of the test results from certain expected values. Graphical analysis provided an alternative scheme in which analysis was based on a graphical representation of the clinical data.

A more recent addition to the diagnostic armamentarium has been fixation disparity. Fixation is a measure of the degree of misalignment of the eyes when they are looking at the same thing.

Note that the discussion below concerns patients who have more or less **normal** binocular systems. In particular they don't suffer from ambloypia, a diminished acuity in an otherwise healthy eye, or tropia, a permanent deviation of one eye as when the patient is cross-eyed or wall-eyed.

Phorias

The phoria may be assessed by alternating cover test or behind the phoroptor using one of several methods based on the Risley variable prism.

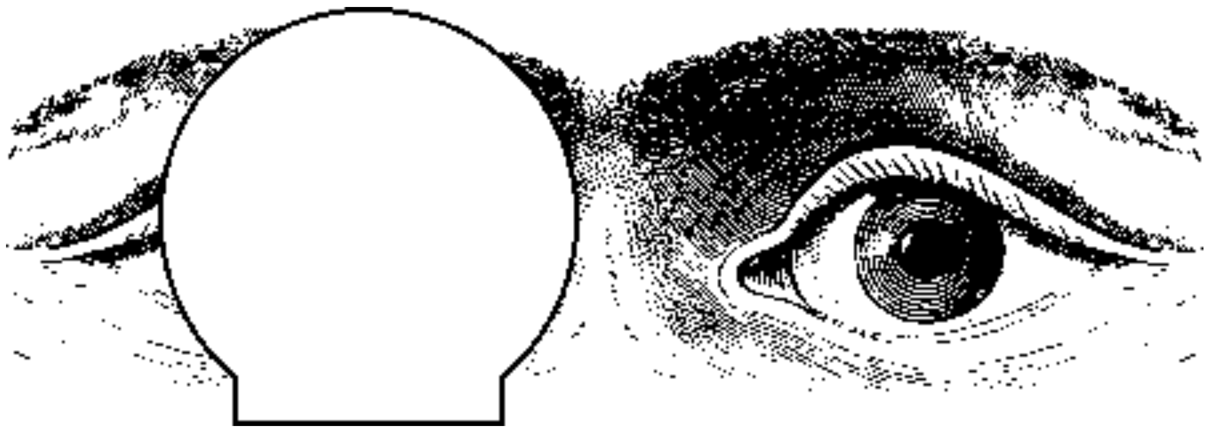
Cover Test

In the alternating cover test the two eyes are alternately covered with an occluder or "cover paddle" while the patient looks at a target which he can see clearly. The test is done while the patient fixates a distant target and again when he fixates a near target. When the occluder covers an eye, it is dissociated from its fellow and moves to its phoria position. When the occluder is removed, the eye resumes fixation.

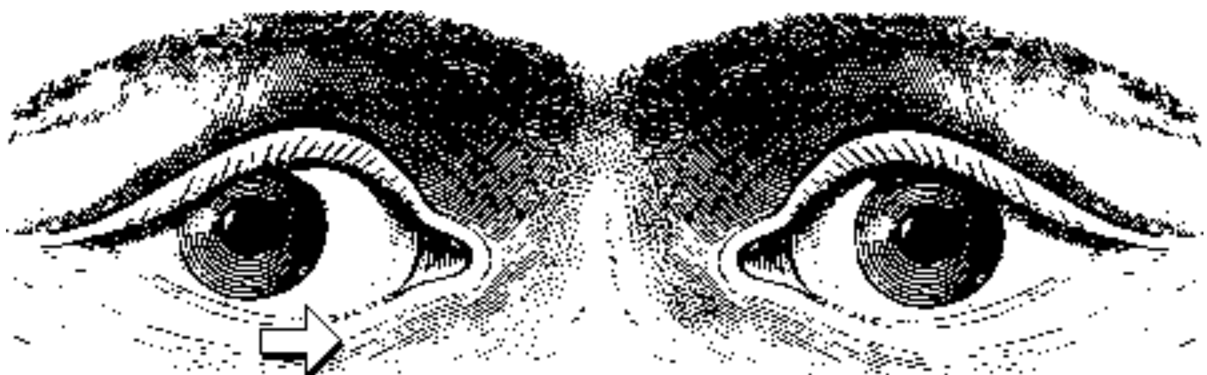
The examiner looks for the direction and amount of movement the eye when the cover paddle is removed. If the patient is exophoric, his eyes diverge in the phoria position and the eye will move medially when uncovered. If the patient is esophoric, his eyes converge in the phoria position and the eye will move laterally when uncovered. An eye may also be hyperphoric (deviated upward) or hypophric (deviated downward) with corresponding motions down and up, respectively, of the uncovered eye.

With practice, doctors can learn to approximately quantify the amount of motion in prism diopters so that it corresponds to the result obtained with Risley prisms. The motion of the patient's eyes may also be neutralized with hand-held prisms.

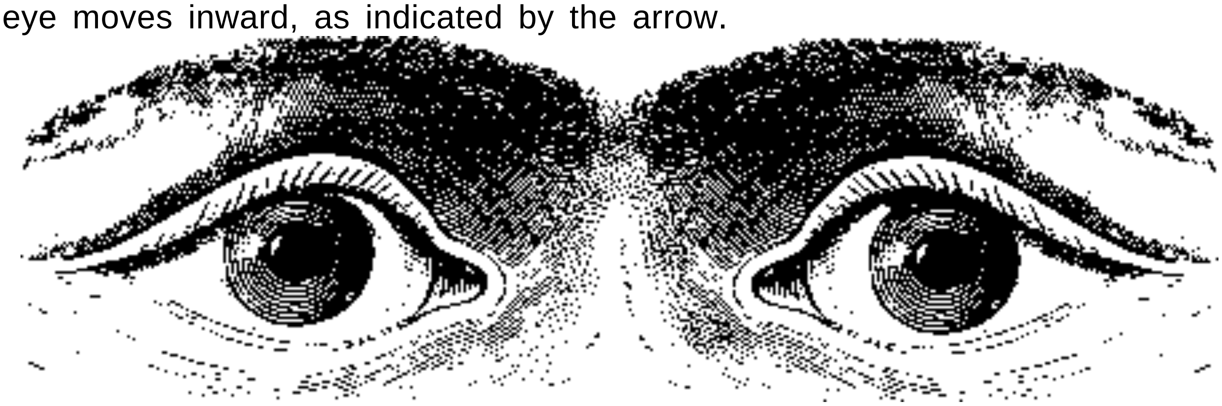
The figure below shows the unilateral cover test applied to an exophore. If the patient were esophoric, the eye movement would be in the opposite direction.



The first step in the cover test is to cover the right eye with a cover paddle.



In the unilateral cover test, the paddle is removed while the doctor watches the motion of the uncovered eye. This patient is exophoric so eye moves inward, as indicated by the arrow.



After an instant, the eyes of the patient with a phoria will take a straight-ahead fixation position.

Phoria Testing

To test phorias, first dissociate the eyes with prisms. For example place a 6 p.d. BD prism before the right eye and 6p.d. BO prism before the left. Various targets can be used. At distance a single letter or vertical row of letters works fine. The patient sees something like the left hand side of the figure below. Now adjust the lateral prism of the left eye until the two targets are aligned vertically. Tell the patient to, "say **now** when the two letters pass, one above the other, like buttons on a shirt." The patient should respond when the letters are in the configuration at the right of the figure below. The magnitude of the phoria is the power of the prism when the images are aligned. If the prism is base in (BI) the patient is exophoric and if the prism is base out (BO) the patient is esophoric.

E E	E E
view of patient with dissociating prism	view of patient when prisms neutralize lateral phoria

The vertical phoria is neutralized by varying the base up-base down while instructing the patient to "say **now** when the two letters pass, one beside the other, like headlights on a car." (See illustration below).

E E	E E
view of patient with dissociating prism	view of patient when prisms neutralize vertical phoria

The test is repeated at near using some appropriate target held 40cm from the patient with the near point rod to get the near phoria. At near it is important to encourage the patient to, "keep the target as clear as possible," so that he will accommodate.

Vergences

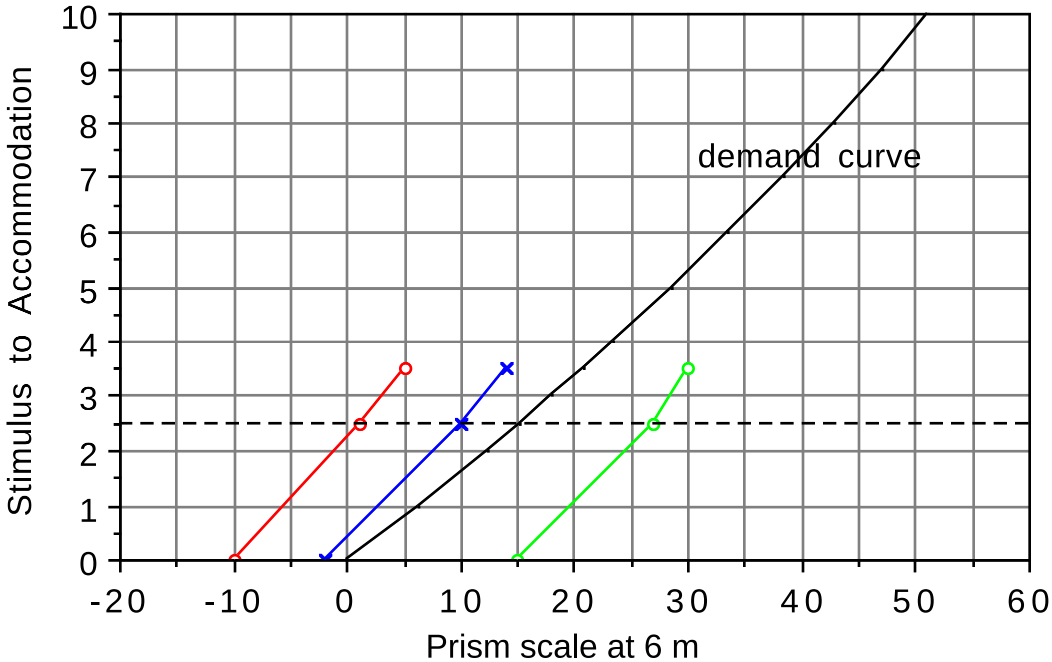
To test lateral vergences or ductions, place the Risley prisms in the lateral prism positions over both eyes but with zero power dialed in. With the patient looking at an acuity chart or single line of letters near his acuity limit, slowly dial in BI prism over **both** eyes. Try to keep the amount of prism about equal. (Prism is dialed in over both eyes rather than just one so as to minimize monocular prismatic blur.) Instruct the patient to tell you when the letters blur and/or double. When doubled, reverse the direction in which the prisms are dialed and ask the patient when the letters are seen singly again. The combined powers of the two prisms correspond to the blur, break, and recovery.

The same procedure can be used with vertical vergences, except it is not necessary to split the prism between the two eyes since vertical vergence powers are small.

Analysis of Phoria and Duction Data

Lateral Phorias and Ductions

Classical or graphical analysis of phorometric data plots lateral phoria and duction data on a graph like that below.



The important quantities in the analysis are phorias and base in and base out to blur findings. These are plotted as a function of accommodataion and the *prism scale at 6 m*, actually a measure in prism diopters of the **total** convergence of the two eyes. Clinical measurement of convergence actually measures it with respect to the demand line shown in the graph. The demand line gives the locus of combinations of accommodation and convergence along which the patient will be perfectly converged for a fixation target. Let's start by finding the equation of the demand line.

The convergence required of the eyes to see a target at a particular distance may be reckoned from the diagram below. The total convergence is 2θ. From the diagram, θ is given by

$$\theta(\text{rad})=\{[PD(\text{mm})/2]/10\}/\{b(\text{cm})+r(\text{cm})\}.$$

where b is the distance from the spectacle plane to the object of regard, r is the distance from the spectacle plane to the center of rotation of the eye, and PD is just the interpupillary distance. Taking r=2.7cm the convergence becomes

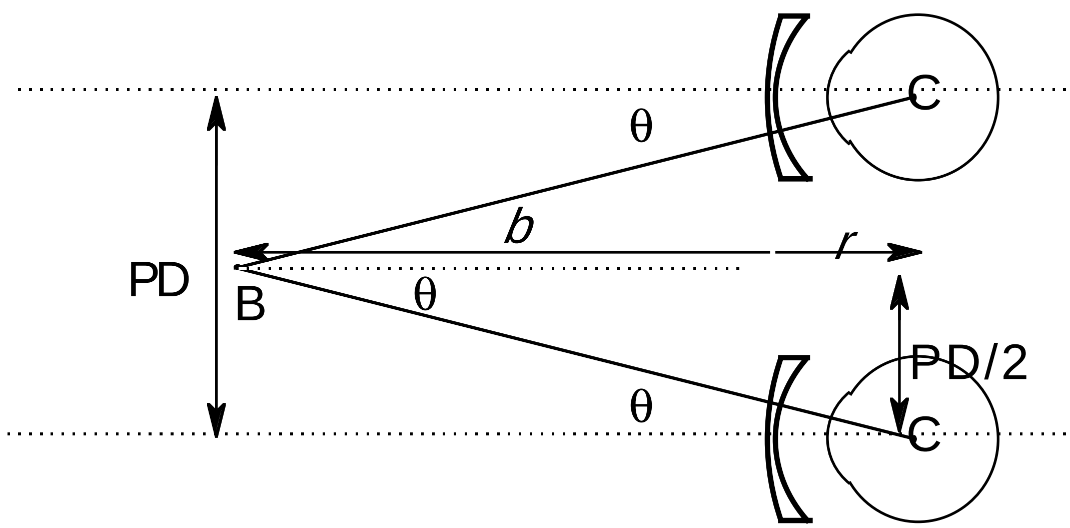
$$\text{convergence(p.d.)}=2\theta(\text{p.d.})=200\theta(\text{rad})=200\{[PD(\text{mm})/2]/10\}/\{b(\text{cm})+2.7\text{cm}\}$$

or finally

$$\text{convergence(p.d.)}=10PD(\text{mm})/[b(\text{cm})+2.7\text{cm}].$$

Suppose, for example, that a patient of 65mm PD looked at a target at 40cm. The convergence required would be

$$\text{convergence for 40 cm}=(10)(65\text{mm})/(40\text{cm}+2.7\text{cm})=15.2\text{p.d.}$$



In the graph above, data has been plotted for a patient with the following findings:

at 6 M

phoria	2 exo
BI to blur	10 p.d.
BO to blur	15 p.d.

at 40 cm

phoria	5 exo
BI to blur	14 p.d.
BO to blur	9 p.d.

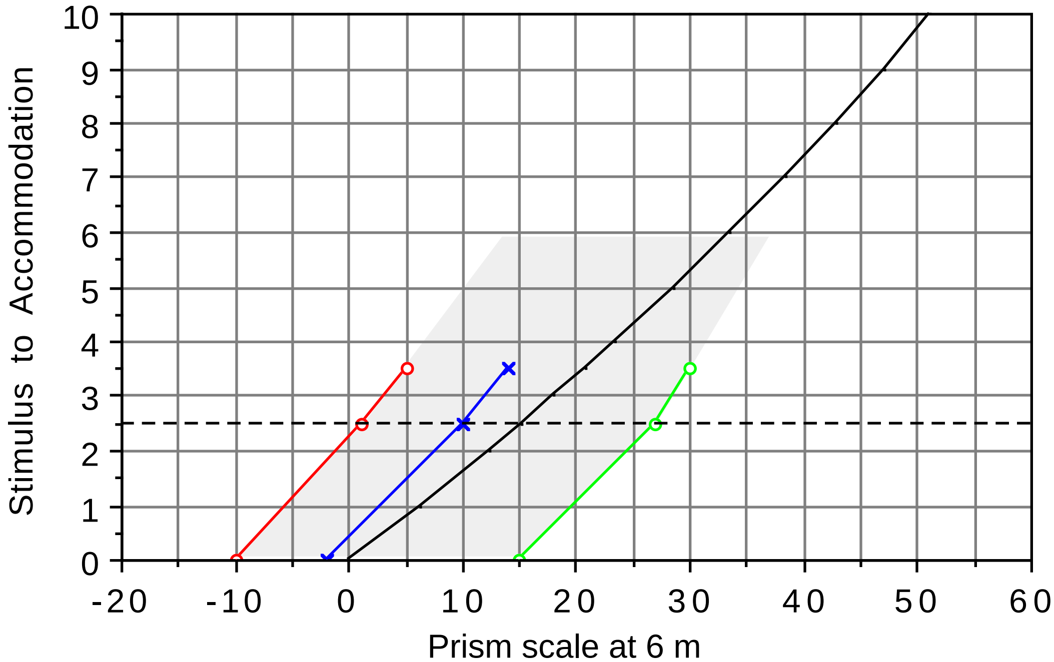
at 40 cm through an additional -1.00D lens

phoria	1 exo
BI to blur	10 p.d.
BO to blur	15 p.d.

amplitude of accommodation, 6.00D

Note that the 40cm findings are reckoned from the demand line and the 40cm findings with -1.00D lens are reckoned from the demand line at 2.50D but displaced upward 1.00D. By convention, phorias are indicated by crosses and vergences by open circles.

So what can we tell from all this? First of all we can see at a glance the patient's zone of clear single binocular vision, those combinations of accommodation and convergence in which he can see well. The zone is bounded left and right by the vergence findings and at the top by the amplitude of accommodation. The zone for this patient is shaded in the diagram below.



Theoretically the zone of clear single binocular vision should be a parallelogram with its left and right hand sides parallel to the phoria line. In practice there are slight deviations as in the graph.

The slope of the phoria line is the ACA ratio, the ratio of accommodative convergence to accommodation. From the phoria line of the patient of the graph this is 12p.d./2.5D=4.8. If the patient had been orthophoric (had zero phoria) at distance and near the ACA ratio would have been 15/2.5=6. Like this patient, most patients fall a bit below the ideal ratio of 6 , hence underconverge. A few patients have high ACA ratios, as high as 9 or more. These suffer from overconvergence.

Generally speaking, the closer the patient's phoria line falls to the demand curve, the better centered the phoria line is between the BI and BO to blur curves, and the further apart the BI and BO to blur curves are, the more apt the patient is to have comfortable binocular vision. And what if he doesn't? There are really three options.

The first is to apply prism. If, for example, the patient is exophoric and has low ACA, apply BI prism. If he overconverges, apply BO prism. But how much prism? A couple of rules of thumb are in common use. The best known is Sheard's criterion which takes into account the magnitude of the phoria and the *opposing* duction. If the patient is exophoric, that means the criterion uses the phoria magnitude and the magnitude of the base out to blur finding. The actual magnitude is given by the equation

$$\text{prism}=[2(\text{phoria})-\text{opposing vergence}]/3.$$

The criterion is most commonly applied at near. For the patient in the graph, at 40cm the phoria is 5 exo and BO duction is 9p.d. so Sheard's criterion gives (2x5-9)/3=1/3 p.d. BI. Since that is such a small prism, the patient effectively satisfies Sheard's criterion.

Percival's criterion states that the demand line should be between 1/3 and 2/3 of the way between the lateral boundaries of the zone. The prism required to achieve this is given by

$$\text{prism}=G/3-2L/3$$

where G is the greater of the two vergence findings at a given distance and L is the lesser of the findings. In our example, the patient's BI duction at 40cm is 14p.d. and the BO is 9p.d. so Percival's criterion requires prism power of 14/3-2x9/3=1.33BI. Percival's criterion is relatively little used.

A second approach to binocular problems is prescription of bifocals, at least in cases of high ACA. The amount of add necessary to move the patient to the demand line can be calculated from the near phoria and ACA ratio. Suppose, for example, the patient has ACA 8 and 12 p.d. of esophoria at near. An add of 12/8=+1.50 should straighten the eyes completely at near.

The third approach is visual training. The most common exercises are convergence exercises like pencil push-ups ("watch the pencil while you move it toward your nose") and jump ductions ("look at the pencil and then look beyond it to a distant object"), but there is actually a bewildering number of techniques.

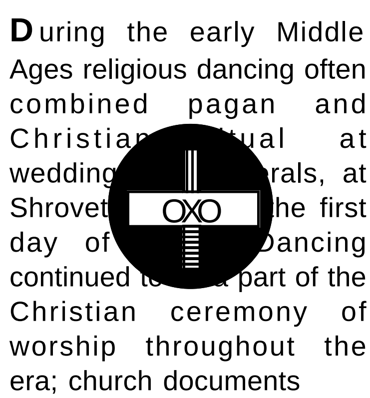
The OEP analysis was, at least initially, an offshoot of graphical analysis. Eventually it acquired a scheme and vocabulary all its own.

Vertical Phorias and Ductions

Vertical misalignment of the eyes is especially devastating. Even a couple of diopters of phoria can dissociate the eyes and cause serious binocular problems. The usual therapeutic approach is to prescribe prism of magnitude equal to half the phoria. The vergences serve mainly to confirm the phoria since the phoria position should be centered between the vergences. If significant vertical phoria is discovered, it is wise to confirm it with the patient looking through the phoroptor's pinholes just to be sure his eyes are centered in the lens cells. It is prudent to check the effects of vertical prism with trial lenses before prescribing them.

Fixation Disparity

Fixation disparity measures the <u>retinal slip</u> of two eyes when they are associated, not when they are dissociated as in phoria measurements. The patient wearing polaroid anaglyph glasses looks at a target with two aligned and oppositely polarized targets superimposed on detailed material designed to stimulate accommodation and provide a peripheral fusion lock. The Mallett unit, the first practical means of testing fixation disparity, has a target somewhat like that below:



The patient reports whether the two vertical lines (which he is seeing monocularly) are aligned with each other and the X. If they are not, the doctor places prism over the deviating eye(s) until alignment is achieved. Mallett recommends prescribing exactly that prism.

Elsewhere on the same unit is a measurement of vertical fixation disparity rather similar to that above bot with the central circular target rotated 90° so the lines are horizontal. Neutralization and prescription are achieved just as with the horizontal fixation disparity. It may be argued that vertical fixation disparity is much more useful than vertical phorias since the eyes are directed at the same target during the measurement thus elimating the possibility of tonic muscle effects when the eyes are separated.

In recent years, a number of devices and charts have been marketed to measure fixation disparity at near and far. The basic principle is the same as that of the Mallett box, but the examiner must be aware that results may not be the same with the different instruments.

