# The clinical calculation of fixation disparity

LEONARD J. PRESS, O.D.

*ABSTRACT—The application of the triangulation formula to the calculation of measured fixation disparity is presented. Comparison of results amongst the currently available clinical disparity targets is listed. It is demonstrated that any of the targets enable measurement of fixation disparity, but the clinical practicality of determining the four disparity variables varies widely.*

*KEY WORDS—fixation disparity, triangulation formula, fusion, binocular vision, vision therapy, orthoptics, oculomotor imbalance.*

## Introduction

Studies have recently been performed to determine the diagnostic effectiveness of fixation disparity variables according to discriminability of symptomatic patients with binocular oculomotor imbalance.[1–3] Whereas it had previously been presumed that the associated phoria was the most significant fixation disparity variable[4,5] (X-intercept or prism required to neutralize fixation disparity), these studies[1–3] have shown that it is the least significant measure.

The rank ordering of the diagnostic effectiveness of fixation disparity variables has been reported[6] as follows: 1) Curve type (1 – IV), 2) Slope of the fixation disparity curve, 3) Y-intercept (measured fixation disparity), 4) x-intercept (associated phoria). Clinically what is typically done is to determine the x-intercept by neutralizing the fixation disparity with prisms or spherical lenses.[7] Traditional clinical targets to measure this associated phoria value include the Mallett test,[5] Bernell slides,[8] Borish slide[9] and AO vectographic slide.[10] Although the associated phoria is readily determined clinically, it is the least discriminate fixation disparity parameter. According to the aforementioned rank order, it would be more useful to measure the manifest fixation disparity.

## Calculation of fixation disparity

The manifest fixation disparity value may be estimated with traditional test targets by utilization of the triangulation formula. This formula is useful in determining the subtense of visual angle at a known viewing distance, and may be applied to fixation disparity calculation as follows:

To measure fixation disparity (FD) one may calculate the tangent of the angle subtended by the target separation (ts) divided by the viewing distance (vd):

$$\tan \text{FD} = \frac{(\text{ts})}{(\text{vd})}$$

$$\text{FD degrees} = \text{arc tan} \frac{(\text{ts})}{(\text{vd})}$$

$$(\text{FD degrees})(60\ \text{min/degree}) = \text{FD minutes of arc}$$

The following example illustrates the application of this calculation to a widely used target, the Bernell Nearpoint Analysis Slide (No. 553 A):

(ts) = separation from center "0" to first reference marker "1"
= 4 mm

(vd) = viewing distance from patient to target
= 40 cm = 400 mm

$$\tan \text{FD} = \frac{(\text{ts})}{(\text{vd})}$$

$$\tan \text{FD} = 4/400 = .01$$

$$\text{FD} = \text{arc tan } .01$$

$$\text{FD} = 0.573 = 34 \text{ minutes of arc}$$

## Discussion

The clinical measure of the associated phoria is typically obtained by initially directing the patient's gaze to a central fixation spot. It is the awareness when fixing this spot, of a misalignment in upper and lower vernier lines,

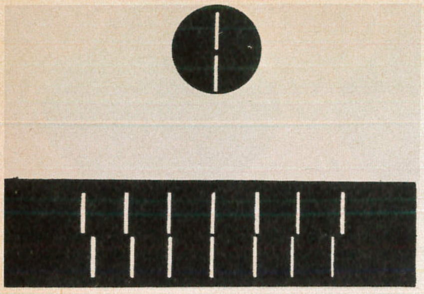


Figure 1: The Disparometer target (after Sheedy) used to measure fixation disparity. The top circle represents the aligned polarized vernier lines within a black fusion stimulus. The lower rectangle demonstrates the incrementally offset pairs, one of which the patient selects to indicate the actual disparity.

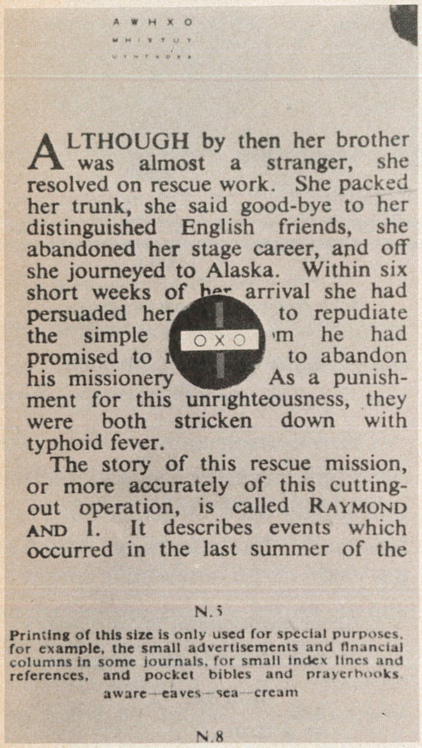



Figure 2: The nearpoint Mallett target with fusion stimulus embedded in a reading paragraph of detailed size.


Figure 3: The distance Mallett target with fusion stimulus not surrounded by detail.

**TABLE 1**
**A comparison of the measured fixation disparity to the first reference point of currently available clinical test targets.**

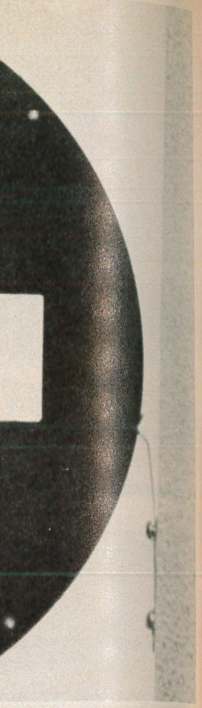
| Test Target | Reference Point | Distance | Separation | FD (mins. arc) |
|---|---|---|---|---|
| Disparometer | Offset lines | 40 cm | 0.2 mm | 2′ |
| Mallett | X to 0 | 40 cm | 2.5 mm | 22′ |
| Borish | X to 0 | 40 cm | 2.7 mm | 24′ |
| Bernell | 0 to 1 | 40 cm | 4.0 mm | 34′ |
| Mallett | X to 0 | 6 m | 25.0 mm | 14′ |
| A.O. Vecto | Dot to Circle | 6 m | 10.0 mm | 6′ |
| Bernell | 0 to Diamond | 6 m | 29.0 mm | 16′ |

which confirms the presence of a manifest fixation disparity. Whereas the associated phoria is measured by the amount of prism required to eliminate this misalignment, the manifest fixation disparity may be determined by measuring the actual amount of this misalignment.

Under most clinical conditions, the amount of fixation disparity manifest is less than 10 minutes of arc.[11] To measure disparity of less than 10 minutes of arc would require some means of demonstrating and measuring misalignment of less than 1 mm at a viewing distance of 40 cm. A comparison of measured fixation disparity to the first reference point of currently available test targets is listed in Table 1. Targets other than the Disparometer have no reference point in the region of 10 minutes of arc. The Disparometer facilitates this measurement in that it presents pairs of vernier lines offset in 2 minute of arc increments until the patient perceives alignment.

The triangulation formula utilizes the measure of vernier line misalignment (ts) and the measure of viewing distance (vd) to calculate the angular subtense at the eye (FD) represented by this misalignment. This formula $\left(\text{FD degrees} = \arctan \frac{(\text{ts})}{(\text{vd})}\right)$ assumes a steady slope of the fixation disparity curve for points between the fixation spot and the nearest fiduciary or reference point. The validity of this assumption diminishes as misalignment of the vernier lines increases.

A fixation disparity curve, the most effective diagnostic disparity variable, may be constructed by determining the fixation disparity response to incremental amounts of



...unded by detail.

...reference point of

| ...ration | FD (mins. arc) |
|---|---|
| ...2 mm | 2′ |
| ...5 mm | 22′ |
| ...7 mm | 24′ |
| ...0 mm | 34′ |
| ...0 mm | 14′ |
| ...0 mm | 6′ |
| ...0 mm | 16′ |

...g distance (vd) ... angular subtense ...) represented by ...nt. This formula ...rc tan $\left(\frac{(ts)}{(vd)}\right)$ as- ...lope of the fixation ...or points between ...t and the nearest ...erence point. The ...assumption dimin- ...nment of the ver- ...es.

...sparity curve, the ...iagnostic disparity ...constructed by de- ...ation disparity re- ...nental amounts of

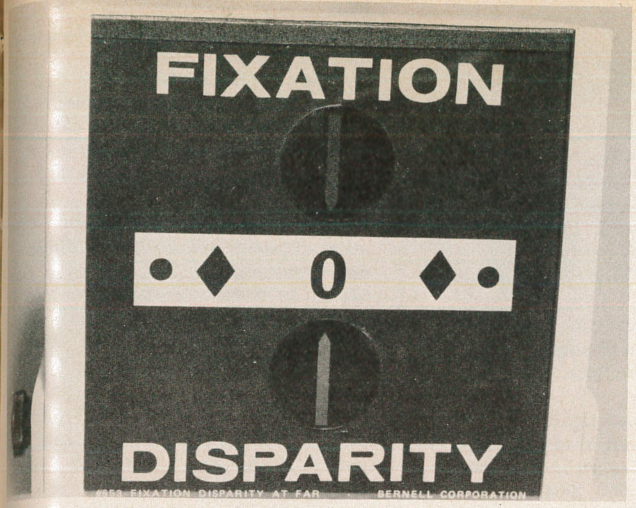



Figure 4: The distance Bernell target with fusion stimulus surrounded by detail (letters).

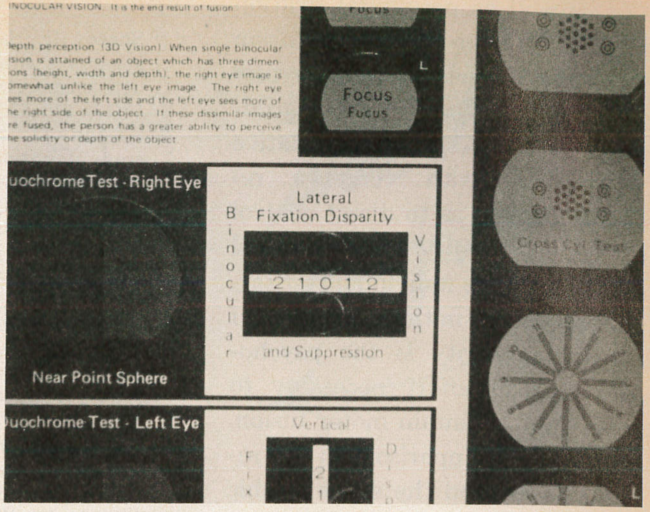



Figure 5: The near Bernell target with fusion stimulus surrounded by detail (letters).

prism. In recent studies[1-3] the slope of the fixation disparity curve, the second most effective variable, has been calculated by fitting the best line through the points at 3 prism diopters base-in, at zero demand, and at 3 prism diopters base-out.[6] Consequently the tediousness and imprecision of measuring fixation disparity by application of the triangulation formula as illustrated, is compounded in attempting to generate the type or slope of a fixation disparity curve with other than the Disparometer target. The repeatability of these measures is of particular concern when evaluating the results of vision therapy or prescriptive lens approach.

## Conclusion

Clinical nearpoint fixation disparity targets have been considered in this presentation only in the context of application of the triangulation formula. The key variable in this formula is the separation of the binocular vernier lines from a central reference point. Although it is this variable which determines the amount of manifest fixation disparity, the measured value is influenced by several interdependent variables. These variables include

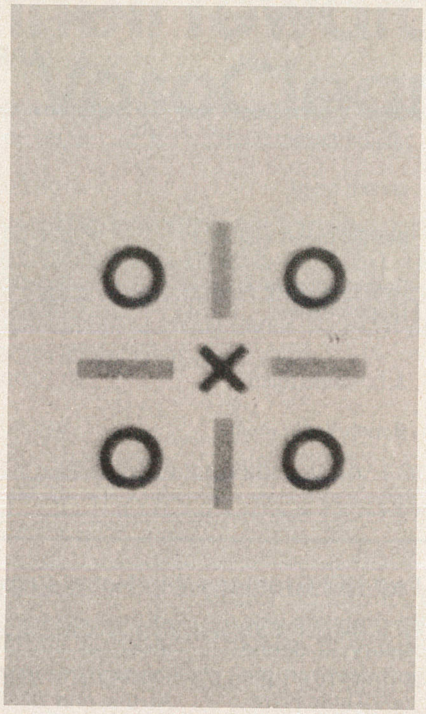


Figure 6: The Borish vectographic nearpoint target with fusion stimulus surrounded by detail (circles).

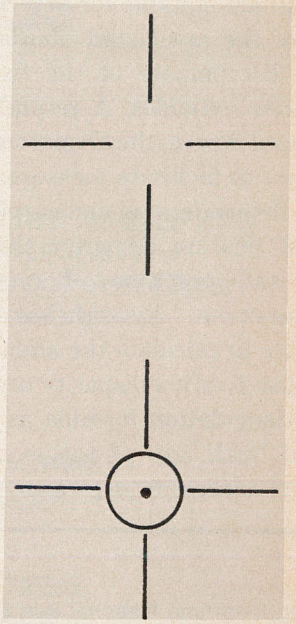


Figure 7: The A.O. vectographic distance slide. The upper target lacks a central fusion stimulus. The lower target incorporates a circular fusion lock, but neither target is surrounded by peripheral fusion detail.

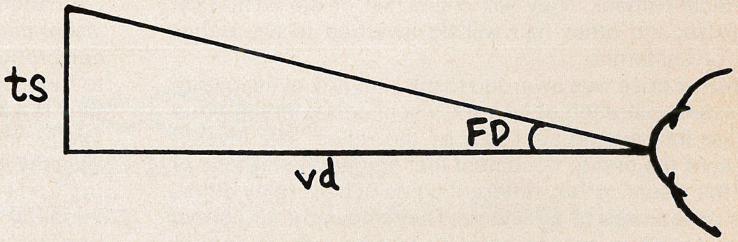



Figure 8: Graphic representation of the triangulation formula. "vd" is the viewing or testing distance from eye to target. "ts" is the distance from the central fixation point to the point where the vernier line or fiduciary is reported by the patient. "FD" is the angular subtense at the eye which this amount of fixation disparity represents.

the size, area and contrast of central as well as peripheral fixation areas and fusion locks, in addition to length and width of the vernier lines.[12] Furthermore these considerations relate to accommodative interactions with vergence response as well as to direct control of fusional stability.[13] An additional property of the individual test target to consider in the magnitude of fixation disparity is the psychophysiological effort necessary to obtain and maintain motor fusion. Inter-target comparisons in this regard are beyond the scope of this paper.

Inspection of currently available nearpoint disparity targets reveals that all are suitable for determination of the associated phoria, the least discriminate of the fixation disparity variables. A recently introduced device, the Disparometer, appears to facilitate measurement, slope determination and curve typing of fixation disparity through ease and precision of repeated measurement. Nevertheless it is possible to calculate the amount of manifest fixation disparity utilizing the triangulation formula as illustrated, with any of the available clinical nearpoint targets. **AOA**

### REFERENCES


1. Sheedy JE, Saladin JJ: Association of symptoms with measures of oculomotor deficiencies. *Am J Optom Physiol Opt,* 55(10): 670–676, 1978.
2. Saladin JJ, Sheedy JE: Population study of fixation disparity, heterophoria, and vergence. *Am J Optom Physiol Opt,* 55(11): 744–750, 1978.
3. Sheedy JE, Saladin JJ: Phoria, vergence, and fixation disparity in oculomotor problems. *Am J Optom Physiol Opt,* 54(7): 474–478, 1977.
4. Borish IM: Instructions for use of the Borish vectographic nearpoint card, Optometric Research Institute, Inc., Memphis, TN 38104.
5. Mallett RFJ: The investigation of heterophoria at near and a new fixation disparity technique—part 1. *The Optician,* 148(3844): 547–551, 1964.
6. Sheedy JE: Fixation disparity analysis of oculomotor imbalance. *Am J Optom Physiol Opt,* 57(9): 632–639, 1980
7. Grosvenor T: More about fixation disparity. *Optom Weekly,* 67(12): 42–42, 1976.
8. Rouse M, Peck B, Best T: Research in fixation disparity—part 1. *Optom Monthly,* 69(15): 96–98, 1978.
9. Borish IM: The Borish nearpoint chart. *J Am Optom Assoc,* 49(1): 41–44, 1978.
10. Grolman B: Binocular refraction—fixation disparity. *Optician,* 162(4195): 16–19, 1971.
11. Sheedy JE: Actual measurement of fixation disparity and its use in diagnosis and treatment. *J Am Optom Assoc,* 51(12): 1079–1084, 1980.
12. Carter DB: Fixation disparity with and without foveal contours. *Am J Optom Arch Am Acad Optom,* 41(12): 729–736, 1964.
13. Semmlow JL, Hung G: Accommodative and fusional components of fixation disparity. *Assoc Res Vis Ophth,* 18(10): 1082–1086, 1979.
14. Carter DB: Parameters of fixation disparity. *Am J Optom Physiol Opt,* 57(9): 610–617, 1980.


## APPENDIX

| Instrument | Approx. Cost | Source |
|---|---|---|
| Mallett (near) | $160.00 | Ocular Instruments Co.<br>P.O. Box 1787 |
| Mallett (dist) | $100.00 | Los Gatos, CA 95030<br>(or Bernell Corp.) |
| Bernell (near) incl. box | $26.00 | Bernell Corp.<br>422 E. Monroe |
| Bernell (dist) incl. box | $34.00 | South Bend, IN 46601 |
| Disparometer | $250.00 | Vision Analysis<br>P.O. Box 14390<br>Columbus, OH 43214 |
| A.O. Vecto (dist) | $120.00 | A.O. Corp.<br>Southbridge, MA |
| Borish Vecto (near) | $40.00 | Optometric Research Institute<br>11 N. Montgomery<br>Memphis, TN 38104<br>(or Bernell Corp.) |

## Two NEI Grantees Win Nobel Prize

Two long-time National Eye Institute (NEI) grantees who began their research in a basement laboratory at Johns Hopkins University more than 20 years ago have won the 1981 Nobel Prize in Physiology or Medicine. Their prize-winning research has completely changed our view of how the brain processes signals sent to it from the eye and helped to place studies of the visual system in the forefront of brain research.

The NEI grantees, Dr. David Hubel and Dr. Torsten Wiesel, are now professors of neurobiology at Harvard University Medical School. They will share half of the $180,000 Nobel Prize; the other half will be awarded to Dr. Roger Sperry, of California.

The Nobel prize was awarded to the Harvard investigators for their demonstration of how the visual cortex of the brain processes information sent to it by the retina. The investigators were the first to document that among the millions of cells in the visual cortex, different types of cells relay different bits or features of an image. They showed that certain cells are sensitive only to color or to size, others only to contrast, contour, movement, or spatial orientation.

These cells are organized into columns which represent increasingly complex stages in the visual process. Columns at the beginning of the process contain simpler cells than those at the later stages. Visual signals are transmitted through this hierarchy of cells in a carefully ordered manner. At the end of the process, the individual components are integrated into a single visual impression.

Hubel's and Wiesel's elucidation of this complex visual process demonstrated that seeing is much more than a simple point by point transfer of the visual image on the retina to an image projected onto the cortex of the brain, as was previously thought.

In addition to shedding light on how the brain processes visual information, Hubel and Wiesel also found that visual cells require normal visual stimulation in infancy if they are to function properly later in life. They were the first to show that if a newborn has an eye disorder which distorts the image received or obscures it at this critical stage of development of the visual cells, the ability of these cells to pick up, transmit, and analyze visual impressions may be forever impaired. Their findings already have influenced treatment of cataract, strabismus, and other blinding or vision-distorting conditions in children.

Drs. Hubel and Wiesel continue to pursue research on the visual system with support from the NEI.