The clinical testing of fixation disparity.

Selwyn Super[*]

INTRODUCTION

Since the time (1949-1967) that Ogle[1-4,] and his colleagues researched the entity they termed *fixation disparity* (FD), a number of clinical tests have become available based on this original work. The purpose of this paper is to discuss the design of these tests and to propose some major modifications that expand on the standard methods of testing of FD in order to make such testing more clinically relevant.

FIXATION DISPARITY.

FD, defined by Hofstetter et al. [5] is *a condition in which the images of a bifixated object do not stimulate exactly corresponding points, but which still fall within Panum's areas, the object thus being seen singly…*

The fact that single binocular vision can be maintained in Panum's fusional space[6], in the absence of perfect visual axis alignment suggests that this is of benefit to visual performance. Without this facility, we would see double, or have to compromise binocular vision by suppressing one of the double images.

Notwithstanding the benefits allowed within Panum's fusional space, the question remains as to what causes visual axes to be misaligned and whether this misalignment is, indeed, desirable.

When the visual axes are aligned to intersect at the point of regard, objects lying in front or behind the point of intersection in the plane of regard will fall on disparate points of the retinae. It is this disparity that contributes mainly to depth perception and three dimensional seeing –stereopsis[7].

FD occurs when the visual axes do not intersect at the point or in the plane of regard. This reduces the quality of binocular vision and stereopsis. It has been claimed, however, that FD is a purposeful error of alignment that helps to drive the binocular system to see singly[8], but this has not been proved conclusively.

CURRENT TESTING OF FIXATION DISPARITY

Almost all tests designed to detect FD provide for the simultaneous viewing of some form of a binocular fusion lock target, which is seen by both eyes, and two other monocular targets; one of which is seen only by the right eye, and the other which is seen only by the left eye. It is the misalignment of these uniocularly viewed targets in the presence of a binocularly fused field, that reveals the presence of fixation disparity[9].

Based on Ogle's work and to standardize test conditions, the most common tests (Disparometer[10], Wesson Card[11], Saladin[12] test) provide a central field fusion lock with an angular width of 1.5^0 At a distance of 16" this measures little more than $1cm^2$. The uniocular targets of these tests are housed within the fusion lock area and consist of nonius lines that lie in close proximity to each other. Vertical line targets are used for assessing horizontal FD, and horizontal line targets are used for assessing vertical FD.

The degree to which the monocular targets appear to be misaligned to the viewer provides a measure of the fixation disparity. Figure 1 illustrates the Ogle type test targets that are used in the Sheedy Disparometer and Wesson fixation disparity tests. In both of these tests, an additional small area of printed material adds somewhat to the central fusion lock. FD measured in this way usually measures no more than a few minutes of arc.[13]

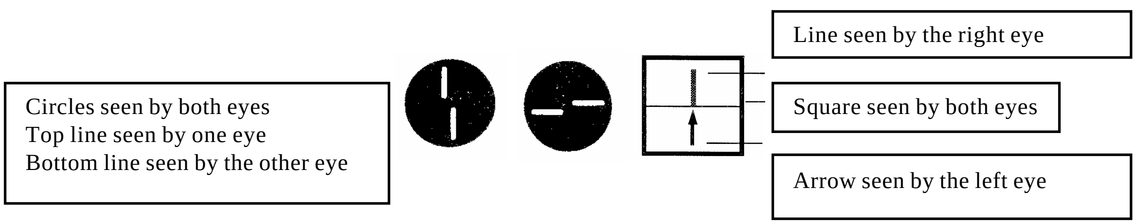


Figure 1, Left and Right
Disparometer (Left). The vertical nonius lines are for testing horizontal FD, and the horizontal nonius lines are for testing vertical FD. (Right) Wesson type card.

The artificially, and arbitrarily chosen small fusion lock that Ogle and his colleagues selected, and that has been incorporated in the Sheedy, Wesson and Saladin FD tests does not appear to reflect or measure accurately, the relationship of the visual axes of subjects using their binocular vision in normal space. It would seem, rather, that individuals with normal binocular vision use all binocularly seen objects in the widest possible space as locks to three dimensional fusion, and that those that cause problems in this respect are either seen as double, or with one of the images suppressed[14].

Limitations in Ogle type testing of fixation disparity.

The following are considered to be limitations in the clinical diagnostic value of Ogle based tests of FD:

i) The centrally placed fusion locks subtend an angle of 1.5^0 and provide little or no peripheral vision stimulation within the binocular field.

ii) The use of nonius lines in close proximity to each other are known to drift toward alignment.[15] This would cause inconsistent and erroneous measurements.

iii) Postural alignments of the head away from the vertical, when using polarized dissociating goggles, may result in binocular viewing of the nonius lines, and cause erroneous measurement

iv) The Ogle type forced vergence generated curves[16] that are held to be symptom related are time consuming, somewhat complicated, and are more appropriately implemented in the laboratory than in the consulting room;

v) Statically measured FD, performed only in the central position of gaze, does not take dynamic movement of the eyes into account, or evaluate degrees of fixation disparity in other positions of gaze;

vi.) FD tests that are used in conjunction with the phoropter: a) restrict the peripheral field of view, and b) when used with the attached near point testing bar affect proximal vergence and eliminate the haptic/kinesthetic information that would be gained from the actual holding of the test cards;

vii) The designated near point testing distance of 40 cm is arbitrarily conceived and does not take into account the comfortable or habitual near point working distance of the individual being tested. Unless this is accounted for, it will give rise to erroneous measurement.

viii) The small lines and the small degrees of fixation disparity measured in minutes of arc make measurement difficult and imprecise.

ix) One time testing , and taking only one measurement does not take prism adaptation into account and the variations in fixation disparity that may become apparent with repeated testing.

Incorporating principles of test design employed by Hess, Lancaster, and Brock to test fixation disparity.

Tests designed by Hess[17] and Lancaster[18] and by Brock[19] , (figures 2 and 3), appear ideal for detecting and measuring fixation disparity, although they were originally intended for different purposes.(- such as measuring oculomotor incomitancy, and/or the relationship of the two eyes related to head and body posture). These tests essentially provide for the binocular viewing of large peripheral fusion locks, in free space, and with the monocular viewing of different visual axis markers seen simultaneously by each eye. This allows for unrestricted vision of the periphery and binocular field, and at the same time, also provides for a measure of visual axis alignment. As such these tests may also be used usefully to detect and measure fixation disparity. Such type of testing usually elicits FDs that measure up to several degrees[13].

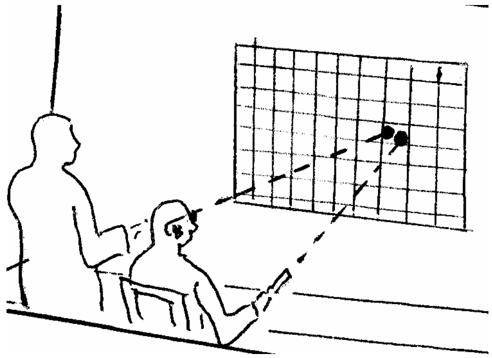


Figure 2.

Hess-Lancaster test using red/green anaglyph goggles and red and green projection lights.

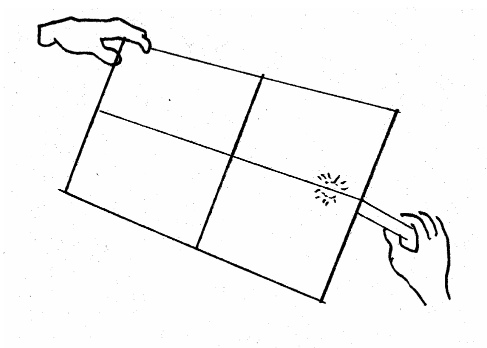


Figure 3

Brock Posture Board red cross drawn on a white translucent background
Red light shone from behind and used with red/green anaglyphs.

The Super Fixation Disparity test (Super FDT)

The Super FDT incorporates the principles of the Hess and Lancaster Screen tests and also those of the Brock Posture Board, and allows for the assessment and measurement of visual axis alignment in free space, at the patient's near point working distance and at far distances up to about 500 feet. Like other tests of fixation disparity, the Super FDT also requires the patient to wear anaglyph goggles. With this test the patient wears complementary color red/green anaglyph goggles and sees the whole visual field as red when looking only through the red filter, and green when looking only through the green filter, and as a mixture of the two when looking simultaneously through both the red and green filters. The white distance and near point test plates are also seen in this fashion.

Super FDT near point testing.

Two near point targets are provided with the Super FDT on opposite sides of a translucent white plate, illustrated in figure 4. The first consists of a series of equally spaced red circles radiating out from the center with increasing radii, while the second test has nine circles placed in the cardinal positions of gaze, so that the patient has three numbered circles above the horizontal, three at eye level and three below eye level, viewed horizontally, and three to the left of the midline, three in the midline and three to the right of the midline, viewed vertically. These red targets are seen as black targets by the fixating eye which views them through the green anaglyph filter, while the non fixating eye does not see any of the red targets, the color of which are absorbed by the red anaglyph filter. The subject is directed to place a red projected light from behind the test plate into the center of concentric ring target or at the center of the red cross, depending on which near test plate is used. The red projected light is seen by the eye with the red anaglyph filter in front of it, while the green anaglyph filter absorbs the red projected light and therefore does not allow that eye to see it.

Measurement of the fixation disparity at the patient's habitual and comfortable working distance is accomplished by measuring the disparity of the red projected light from the center of the red targets and by using this formula which takes the working distance into account:

Prism diopters of disparity = Disparity in cm. multiplied by the reciprocal of the working distance in cm.

e.g 2cm of uncrossed disparity at a working distance of 25 cm
2cm x 100/25 = 8 prism diopters of exo FD.

Super far point FD testing.

By using a laser projection pointer (red light) it is possible to test fixation disparity to distances of 500 or more feet. This is done by placing red targets on a white surface in the nine cardinal positions of gaze. (Figure 5). The patient wearing the red/green anaglyph goggles is directed to project the red laser beam, in turn, to the center of each of these red targets.

The same formula for measurement applies to far point testing as applies to near point testing. For example if a patient is being tested at 12 meters and displays a crossed fixation disparity of 40 cm., the fixation disparity at this distance would be 40 x the reciprocal of the working distance,

i.e. 40 x100/1200 = 3.33 Prism diopters of eso F.D.

It is important to note that the fixation disparity and the associated phoria are not one and the same[20] although their readings may sometimes be the same. The associated phoria is the amount of prism that is needed, under binocular conditions of viewing to restore a fixation disparity position of the eyes to the ortho position. An example of this might be a viewer who manifests 3 prism diopters of exo fixation disparity, but who requires 5 prism diopters of base in prism to attain an ortho position.

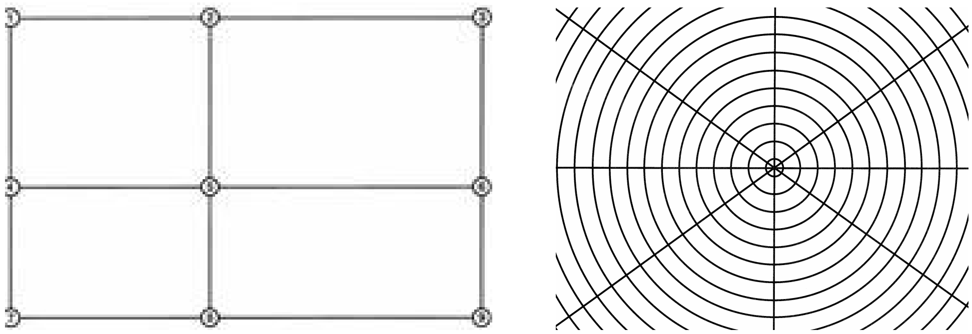
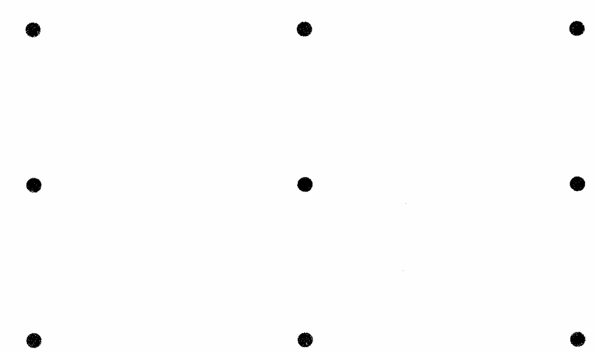


figure 4
Super Fixation Disparity near distance (within arms' length) testing targets (orangy/red on white translucent backgrounds).



Circular orangy/red targets placed in the nine cardinal positions of gaze.

figure 5
Super Fixation Disparity Test for distance (Beyond arms length and to 500 or more feet)

Advantages in incorporating Hess, Lancaster and Brock principles in clinical tests of fixation disparity.

The major advantages of the Super FD disparity tests based on the principles in the design of the Hess Lancaster Screen tests and Brock Posture Board test are:
i) they approach the demands of normal binocular vision;
ii) they are not conducted in the phoropter and allow for a wider field of view;
iii) They do not contain any central fusion locks and rely on peripheral fusion locks that are more reflective of how individuals normally use their visual systems;
iv) they do not rely on the central alignment of thin nonius lines which are not reflective of how binocular vision is broadly used;

v) they can be conducted beyond arms' length to distances that extend to 500 or more feet and chosen to assess an individual's specific far distance tasks such as are required in sports, and in driving;
vi) the near point Brock type tests allow for haptic/kinesthetic feedback with the patient holding the test instruments; this contributes to the centering in tasks such as reading, writing and other fine hand/eye coordination manipulation.
vii) repeated testing provides information about prism adaptation and its effects on FD;
viii) they provide for testing FD centrally and in all other fields of gaze, and for assessing comitancy and incomitancy;
ix) the use of minus and plus lens flippers and base/in and base out prism flippers makes it possible to assess accommodative and vergence effects on FD, and to detect unequal degrees of right and left eye accommodation and vergence effort, respectively.

The effort made by each of the components of the vergence system in maintaining binocular single vision is not readily apparent. In trying to determine the relative contributions of these components, it is important to remember that the principle of Hering's law of equal innervation[21] of each eye applies as much to the ocular muscles responsible for vergence as for version movements. The Super FD test[22] provides a combination of test probes that enable the practitioner to assess the relative contributions of tonic, accommodative, proximal and fusional vergence components both centrally and in different positions of gaze. The tests which are simple to conduct have the added advantage of providing immediate feedback both to the patient and the practitioner with respect to symptom related diagnosis and indications for treatment.

References:

1.Ogle, K.N., F. Mussey, and A. deH. Prangen. Fixation disparity and the fusional processes in binocular single vision, Am. J. Ophthal. 32,1069, 1949.
2.Ogle, K.N. Stereopsis and vertical disparity, Arch. Ophth., 53:495, 1955.
3.Ogle, K.N., and A. deH. Prangen, Further considerations of fixation disparity and the binocular fusional processes, Amer. J. Ophthal. 34.57, 1957.
4.Ogle, K.N., T.G. Martens and J.A. Dyer. Oculomotor imbalance in Binocular Vision and Fixation Disparity, Philadelphia, Lea and Febiger, 1967.
5.Hofstetter HW et al. Dictionary of visual science. 5th edition Boston, Butterworth Heinemann, p148.
6. Panum, PL. Physiologische untersuchungen uberdassehenmitzweiaugen, Kiel, 1858.
7. Howard,IP., Rogers,BJ. Binocular vision and stereopsis.Oxford, Oxford University Press, Chapter 7, 235-312, 1995.
8. Schor, CM. The relationship between fusional eye movements and fixation disparity. Vis.Res. 19,1359-67, 1979.
9.Steinman, SB., Steinman, BA., Garzia,RP. Foundations of binocular vision.,McGraw Hill, New York, pp58-61, 2000.
10. Sheedy,JE. Actual measurement of fixation disparity and its use in diagnosis and treatment. J Am Optom Assoc51, 1079-84,1980.

11. Wesson, MD., Koenig,RA. A new method for direct measurement of fixation disparity.SouthJ Optom. 1,48-52, 1983.
12. Saladin, JJ. Near point balance card. Ferris State University Campus News, 2004.
13. Richards, W. Independence of Panum's near and far limits. Am. J of Optom. & Archives Am.Acad,Optom, 48, 103-9, 1971.
14. Carter, DB. Fixation disparity with and without fusion contours. Am J Optom Physiol Opt. 59, 658-69, 1982.
15. Verhoeff, FH. Fixation disparity. Am J Ophthalmol.48,339-41, 1959
16. Wick, B. Forced vergence fixation disparity at distance and near in an asymptomatic young adult population. Am J Optom Physiol Opt 62, 591-9 1985
17. Hess, WR Arch.Augenheilk., 62,233., 1908.
18. Lancaster,WB. Arch. Ophthal.22,867, 1939.
19. Brock, F. A clinical measure of fixation disparities.J.Am.Optom.Assoc.33, Feb 1962
20. Duke-Elder, S., Wybar,K. System of ophthalmology, vol VI Ocular motility and strabismus, London, Kimpton, 274, 1973.
21. Hering E. Die lehre vom binocularen sehen. Verlag von Wilhelm Engelmann, Leipsig, 1868.
22. Super, S. Super Fixation Disparity test manual, , S.Super,Los Angeles, 2002.

Disclosure: The author has a financial interest in the Super Fixation Disparity Test, that is supplied by Super Instrument Co in the U.S. and under license by VTE, Italy.

*Author:Selwyn Super D.Optom., Ph.D
super@usc.edu
310 207 0012