General Optical Council Approved CET For Optometrists
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# Binocular vision

## Part 5 – Binocular sensory status and miscellaneous tests

In the latest addition to our occasional series on the assessment and management of binocular vision in practice, **Priya Dabasia** looks at sensory status and its measurement. Module C16058, one general CET point for optometrists and dispensing opticians

The preceding accounts in this mini series of binocular vision (BV) testing have detailed procedures for the cover test (CT), ocular motility and heterophoria compensation. The final two articles aim to outline the assessment of binocular sensory status, stereopsis and convergence.

Having two frontally positioned eyes separated by approximately 65mm enhances many aspects of our visual performance – a wide panorama, higher acuity, and three-dimensional perception to a distance of 200 metres, provided both eyes are fully functional and coordinated together. Anomalies of binocular function have often been described as 'the hidden learning disability' as they impair academic performance in young children, often resulting in a permanent visual impairment when left untreated. Early detection, using appropriate tests and exercising proper management is of paramount importance, but often seen as a challenging aspect of daily practice.

Binocular single vision (BSV) occurs when the image from each eye contributes to a single, common percept. It is considered in three grades:

- **Sensory** – the ability to perceive an image formed with each eye simultaneously
- **Motor** – the facility to maintain sensory fusion through a range vergence
- **Stereopsis** – the perception of depth based on binocular disparity.

To gain a more in-depth understanding, it is necessary to appreciate the concept of retinal correspondence, a function of higher processing that takes place at the visual cortex. Normal retinal correspondence is the most favourable condition in which the fovea of one eye corresponds with the fovea of the other, sharing a common visual direction during binocular viewing. This correlation continues for every locus of the retina so that a point nasal to the fovea of one eye corresponds to a point temporal to the fovea in the other eye. In reality, BSV can still be achieved with misaligned visual axes provided the disparity occurs within the limits of 'Panum's fusional area'; a horizontally oval group of retinal elements that increase in size with eccentricity from the fovea. When our visual system is subjected to undue stress such as in decompensated heterophoria, the axes may deviate outside Panum's area, resulting in one of the following:

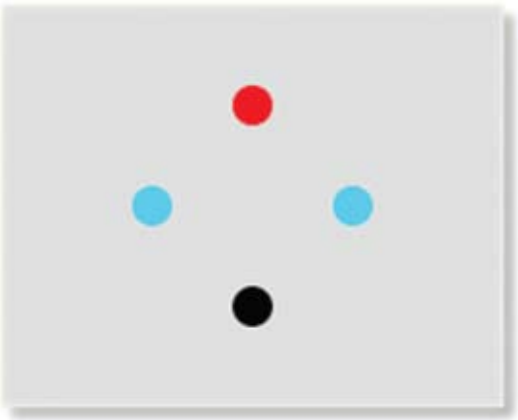


**Figure 1** Worth 4-Dot test

- **Diplopia** – the perception of two different, non-fusible images of the object of interest as they stimulate the fovea of the fixing eye and parafoveal elements of the deviated eye. Double vision is generally experienced in later life where the stability of BSV prevents suppression of one image
- **Suppression** – sensory adaptation that develops in early onset conditions up to the age of eight years to avoid undesirable symptoms such as diplopia, by inhibiting the image of one eye in favour of the fellow eye during binocular viewing. In heterotropia, it tends to occur in larger deviations misaligned by greater than 40Δ. At the onset, two suppression zones develop at the fovea and fixation point of the deviated eye, eventually joining to span a larger area if left untreated. Suppression that swaps between the eyes such as in alternating heterotropia can also be described as 'complete' or 'total lack of retinal correspondence'
- **Confusion** – the superimposition of two dissimilar images in higher processing, experienced predominantly on observing complex scenes such as 'a room'. The same patient is more likely to report diplopia on viewing a small, bright target such as a penlight
- **Retinal rivalry** – the observation of alternating percepts or a combined 'mosaic' so that images from each eye are never seen simultaneously.

Anomalous retinal correspondence (ARC) is considered a more efficient sensory adaptation to heterotropia as suppression occurs in localised zones rather than spanning the binocular field. It facilitates a weaker form of BSV, relieving diplopia while enabling a good level of depth perception of up to 100". ARC is believed to develop from an abnormal enlargement of foveal suppression in the deviated eye to encompass the image of the fixation object. An alteration in correspondence takes place so that the fovea of the fixing eye is now paired with a new parafoveal locus of the deviated eye. This change in common visual direction continues across the retina so that a small area nasal to the fovea of the fixing eye now correlates with elements temporal to the new extrafoveal point of the deviated eye. As a prerequisite to any sensory adaptation, the heterotropia must present early, typically under the age of six years when the binocular system is amenable to change. It should also be small in angle, unilateral and constant in presentation, resulting in a higher prevalence of ARC in esotropia.

### Tests for sensory status

The most recognised tests for sensory status are Worth 4-Dot, Bagolini and the Modified OXO tests. Details of procedures, how to interpret the results and suggestions of recording the findings are detailed in turn.

- **Worth 4-Dot test** – a dissociative test comprised of four circular lights in a diamond formation viewed against a black-grey surround (Figure 1). The test ▶

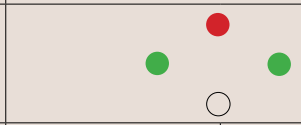
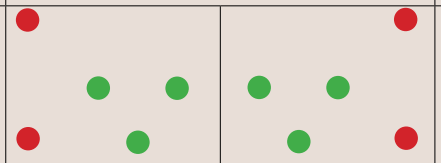
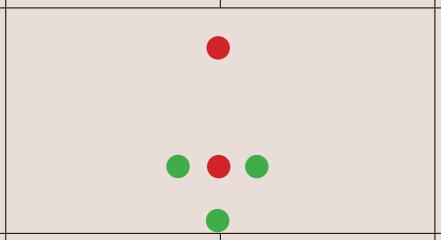
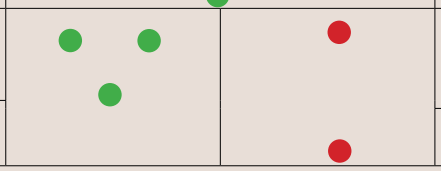
| Patient response | | Observation | Diagnosis/recording | |
|---|---|---|---|---|
| **'Four lights'**<br>• One red<br>• Two green<br>• Bottom light – yellow mixture, red or green | |  | NRC or ARC | |
| **'Five lights'**<br>• Two red lights on the left<br>• Three green lights on the right | **'Five lights'**<br>• Three green on the left<br>• Two red lights on the right |  | Exotropia with heteronymous 'crossed' diplopia | Esotropia with homonymous 'uncrossed' diplopia |
| **'Five lights'**<br>• Two red lights above<br>• Three green lights below | |  | L/R hypertropia with vertical diplopia | |
| **'Three green lights'** | **'Two red lights'** |  | Right suppression | Left suppression |
| **'Lights changing between 2 and 3'** | | | Alternating suppression | |

**Figure 2** A summary of patient responses and interpretation of the Worth 4-Dot test

can be wall-mounted, arranged over the glass plate of a flashlight for near testing or displayed on a computerised chart such as Test Chart 2000. Red-green goggles are used to separate the images of each eye – the right eye observing through the red filter perceives the top red circle, while the left eye views the two central green circles. The bottom white target provides a fusional stimulus for binocular viewing as it is common to both eyes, perceived either as a yellow mixture, red/green depending on ocular dominance or an alternation of the two colours in retinal rivalry.

a) Place the R/G goggles over any near spectacles, taking care that the target is not seen without these filters

b) Turn the room lights off

c) Hold the flashlight 40cm from the patient's eyes just below the horizontal midline to mimic the reading position. Check it is correctly oriented with the red and white circles at the top and bottom respectively

d) Ask the patient to report how many dots they see, confirming the colours and relative positions of each. Possible outcomes are illustrated in Figure 2

e) Repeat the test for distance fixation with any required spectacle correction.

● **Bagolini test** – a lens made up of fine parallel striations that distort a spotlight target into a line image perpendicular to their axis (Figure 3). It supersedes the Worth 4-Dot test in detecting central suppression and is more conducive to natural viewing through minimal dissociation as it is performed under ambient illumination. It is also a perfect illustration of the cost efficiency of BV tests – a lens can be 'created' by smearing the surface of a low power trial lens with a finger using Vaseline or any suitable alternative to mimic the Bagolini striations.

**Figure 3** Bagolini lens

a) Clean a Grade 2 Bagolini lens with a microfibre cloth to avoid more than one image being perceived

b) Position one lens in front of each eye with the striations at 45° and 135°, either mounted in a lorgnette or placed in a trial frame with refractive correction as required. The test can also be conducted with the lens oriented horizontally before one eye only so that it perceives a vertical streak, while the fellow eye observes the spotlight. For demonstration purposes, two Bagolini lenses have been used to illustrate the results in Figure 4. This arrangement is also vital for investigating alternating heterotropia.

c) Direct the patient to fixate on a spotlight held 33cm from the eyes

d) Ask the patient to report the number of lines and spots seen, their relative positions and whether any gaps are perceived along the streaks

e) Repeat for 3m and 6m as required using a Grade 4 lens at far distance to produce a brighter streak for easier viewing, reducing the room illumination accordingly.

● **Modified OXO test** – a near Mallet unit test comprised of two green strips positioned above and below the 'X' of an OXO panel (Figure 5). It is essentially a larger version of the disparity test, as smaller markers are more likely to fall into a central suppression zone, rendering it unsuitable for detecting ARC and global suppression.

a) Ask the patient to hold the unit at their normal reading distance and angle of viewing

b) Direct the patient to fixate on the Modified OXO target

c) Position the cross-polarising visor before the eyes, over any near correction

d) Ask the patient to report the number of strips perceived and their relative positions. The responses of patients

| Patient response | | Observation | | Diagnosis/recording | |
|---|---|---|---|---|---|
| **'One spotlight with two lines'** – lines intersect at the middle of the light with no gap | |  | | NRC | |
| **'One spotlight with two lines'** – lines intersect at the middle of the light with gap in one line around the central spotlight | |  | | ARC with central suppression | |
| **'Two lights with two lines'** – separated horizontally, crossing below the central point | **'Two lights with two lines'** – separated horizontally, crossing above the central point |  |  | Exotropia with heteronymous 'crossed' diplopia | Esotropia with homonymous 'uncrossed' diplopia |
| **'Two lights with two lines'** – separated vertically crossing at the side | |  | | Hypertropia with vertical diplopia | |
| **'One light with one line' or 'One streak lighter than the other'** | |  |  | R or L suppression | |

**Figure 4 A summary of patient responses and interpretation of the Bagolini test**

with heterotropia are summarised in Figure 6

e) Repeat the test for far viewing by directing the patient to observe the distance FD target at a reduced distance of 1.5 metres.

Further testing to rule out a smaller zone of suppression can be evaluated using the Foveal Suppression Test also found on the near Mallet unit.

On detecting suppression using any of the three tests described, the level can be quantified using a neutral density bar held in front of the non-suppressing eye. The depth of absorption is increased incrementally until diplopia is reported or in the case of the Bagolini lens test, a light streak is perceived by the previously suppressed eye.

## Stereopsis

Once the basic grades of BSV have been established, it is now prudent for the examiner to evaluate the quality of stereopsis, defined as the perception of depth based on the horizontal disparity of visual axes within Panum's fusional area, as each eye receives a slightly dissimilar view of the same object. It is often described as the 'thermometer of BV' since any reduction is indicative of a recent-onset anomaly. Some practitioners also use it as an indirect measure for foveal suppression as the highest stereoacuity can only be achieved with both central and peripheral fusion. For this reason, it serves as an ideal screening tool for BSV in children as young as six months of age. Rudimentary depth perception can be demonstrated from 3-4 months although synaptic connections continue to optimise up to two years after birth. As a guide, stereoacuity of 40" or better is considered normal, while any

measure less than 60" is suggestive of inaccurate bifoveal fixation.

The range of tests at your perusal varies widely in both design and grading levels (Figure 7). The ideal test should be devoid of any monocular cues such as 'relative size' that also contribute to the patient's perception of depth. Each of the tests outlined is undertaken with the patient wearing their appropriate spectacle correction wherever possible, with the target held perpendicular to their line of sight. Any external light source must be adjusted to ensure even illumination removing any shadows or glare to facilitate natural binocular viewing. The Lang and Frisby tests are particularly useful for screening children under the age of four years as they do not require goggles to be worn. A summary of the five tests is provided in Figure 8.


**Figure 5** Modified OXO test of the near Mallet unit

● **Lang I and Lang II tests** – a test card comprised of a series of cylindrical gratings superimposed on a random dot image that creates two fine strips of the picture viewed by each eye. The Lang II integrates a monocular 'star' to attract the child's attention when viewed at the designated distance of 40cm. The practitioner observes the child carefully for fixation movements or 'grab responses' that indicate perception of the 'hidden' horizontally disparate images. More responsive children can be asked to name or point at the objects.

● **Frisby test** – the only test based on 'actual depth' as it employs two Perspex sheets printed with random patterns of shapes, separated by 1mm, 3mm and 6mm. Each plate is held against a white background at a distance of 40cm, with the option to evaluate crossed or uncrossed disparity by reversing the orientation accordingly. Begin with the 6mm plate, asking the patient to identify the position of the hidden circle from the four boxes. Rotate the plate out of the patient's view and repeat the test for verification. If the patient responds correctly, use the 3mm and 1mm plates in turn to determine the highest level of stereoacuity. Theoretically, any level of stereopsis can be evaluated using different permutations of plates and testing distances.

● **Titmus test** – also known as a Polaroid Vectograph where crossed polarised filters mounted in goggles are used to separate the images received by each eye. The visual task is comprised of two superimposed patterns polarised 90° to one another and horizontally separated in areas to create crossed and uncrossed disparities. The Vectograph is divided into three sections:

– *'Fly' target*: indicates gross stereopsis in young children asked to 'catch its wings'

– *Animals*: measures three levels of crossed disparity by identifying the creature that appears to 'jump out of its box' in each row

– *'Wirt test'*: a series of nine targets used to grade finer levels of stereoacuity by recognising the circle in the diamond of four that is perceived in depth.

● **TNO test** – the only test completely devoid of monocular cues, based on a series of randomly generated red and green dots. Certain aspects are horizontally disparate, thereby perceived in depth when viewed through the appropriate red and green goggles as follows:

– *Plates 1-3*: used for quick screening in which the patient identifies the correct pattern or shape

– *Plate 4*: suppression test consisting of three discs; the central target is seen with both eyes while the outer discs with one eye only

– *Plates 5-7*: designed to grade higher levels of stereoacuity using a series of circular targets with a missing ▶

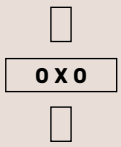
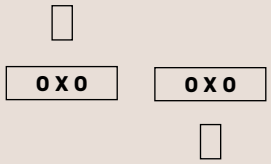
| Patient response | | Observation | Diagnosis/recording | |
|---|---|---|---|---|
| **'Two markers approximately in a straight line with the central X'** Patients may report the marker of the deviated eye to be a 'different size, misaligned or dimmer' relative to the other strip | |  | ARC | |
| 'One marker above and in line with the central X' | 'One marker below and in line with the central X' |  | R suppression of the binocular field | L suppression of the binocular field |
| 'One marker temporarily disappears' | | | Intermittent R or L suppression | |

**Figure 6** Interpretation of Modified OXO test in a patient with heterotropia using a standard British standard Mallet unit

**Figure 7** Stereopsis tests: Frisby plates (left) and Titmus fly test

| Name of test | Method of separating images seen by each eye | Working distance | Level of stereoacuity | Other details |
|---|---|---|---|---|
| Lang I | • Cylindrical gratings (24 per cm) superimposed on a series of random dots<br>• No goggles required | 40cm | Cat - 1200"<br>Star - 600"<br>Car - 550" | • Monocular cues present if card is tilted relative to the line of sight<br>• Ideal for screening in young children |
| Lang II | | | Moon + Star - 200"<br>Car - 400"<br>Elephant - 600" | |
| Frisby | • Random patterns of shapes printed on perspex sheets separated by 6mm, 3mm + 1mm<br>• No goggles required | Variable 40cm - 80cm | 600" - 15" | • Monocular cues apparent with movement of the patient's head and/or plate, or if held at an oblique angle |
| Titmus | • Superimposed images polarised 90 degrees to one another<br>• Cross polarised filter goggles required | 40cm | Fly - 4000"<br>Animals - 400"-100"<br>Circles - 800"-40" | • Strong monocular cues with horizontally separated images evident without goggles |
| TNO | • Red/green randomly generated dots with areas of horizontal disparity<br>• Red/green goggles required | 40cm | Plates 1-3 - screening<br>Plates 5-7 - 480" - 15" | • Devoid of monocular cues |

**Figure 8** A summary of the main stereopsis tests used in practice

quadrant. The patient is asked to find 'the missing piece of the pie,' allowing time for a second attempt if an incorrect response is given at the first effort. Each grade is comprised of two targets so that if one is resolved inaccurately, the stereoacuity is recorded as the previous level where both responses were correct.

The practitioner also has the option to evaluate lower levels of depth perception by doubling the testing distance from 40cm to 80cm so that a target of 2,000" becomes 1,000".

When recording the results, it is crucial that the name of the test is detailed alongside the stereoacuity in seconds of arc. The sensitivity has been found to vary significantly whereby a 480" measure using the TNO test equates to 200" on the Lang card. If you do not have a stereopsis test at your disposal, the Lang 2 pencil test can be used to establish rudimentary depth perception. Patient responses are compared with one eye covered and both viewing when asked to place a pencil vertically on top of another held stationary below. A similar response indicates suppression and a lack of stereopsis.

● The final part of this series will look at the measurement and interpretation of convergence.

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## MULTIPLE-CHOICE QUESTIONS - take part at opticianonline.net

**1 Which of the following statements is TRUE?**
**A** Stereopsis is defined as the perception of depth based on horizontal and vertical disparity
**B** Sensory status is the ability to maintain fusion through a range of vergence
**C** Stereopsis is the highest indicator for binocularity
**D** Motor status is the weakest indicator for binocular function

**2 Which of the following tests for binocular sensory status is considered the least conducive to natural binocular viewing?**
**A** Bagolini lens
**B** Modified OXO
**C** Frisby
**D** Worth 4-Dot

**3 Which of the following statements is FALSE in consideration of ARC?**
**A** The fovea of one eye corresponds to a non-foveal area of the deviated eye
**B** At the onset a suppression zone develops at the fovea of the fixing eye
**C** It is more likely to present in early-onset esotropia
**D** It gives rise to moderate to good stereoacuity

**4 On conducting the Bagolini test with a lens positioned before each eye at 45° and 135°, the patient reports seeing 'two lines and two spotlights crossing above the central point'. Which of the following is the most likely diagnosis?**
**A** Exotropia with homonymous diplopia
**B** Esotropia with heteronymous diplopia
**C** Esotropia with homonymous diplopia
**D** Hypertropia with diplopia

**5 Which of the following is NOT an indicator of suppression?**
**A** A stereoacuity of 50" using the TNO stereotest
**B** A 'gap' in the line image around the central point in the Bagolini test
**C** Disappearance of the top nonius marker of the fixation disparity test
**D** A 'jump' in the vertical line to the left at the break point on measuring NPC using an RAF rule

**6 Which of the following tests would be your ideal choice to assess stereoacuity in a two-and-a-half-year-old?**
**A** TNO Plates 5-7
**B** Lang II card
**C** Lang 2 pencil
**D** Wirt Polarised Vectograph

Successful participation in this module counts as one credit towards the GOC CET scheme administered by Vantage and one towards the Association of Optometrists Ireland's scheme. **Deadline for responses is April 7 2011**