Why can't my child see 3D television?

A child encountering difficulty in watching three-dimensional (3D) stereoscopic displays could have an underlying ocular disorder. It is therefore valuable to understand the differential diagnoses and so conduct an appropriate clinical assessment to address concerns about poor 3D vision.

Three-dimensional (3D) media production dates back to the 19th century and has since enjoyed fluctuating fortunes until a resurgence in 2009 with the release of the film *Avatar*. Generalists, physicians and paediatricians may be asked about 3D technology, particularly by those who have encountered difficulties in viewing 3D television. A child complaining about problems when watching 3D stereoscopic displays could indicate an ocular problem and it is therefore valuable to be able to explain the basics of 3D perception and to conduct an appropriate clinical assessment to address concerns about poor 3D vision.

How do we see three dimensions?

Depth perception is complex. Monocular depth clues are exploited by artists: distant objects are partially occluded by near ones and appear relatively smaller (Westheimer, 2011). When separate monocular retinal images are formed, neural processing of the horizontal binocular differences between these images (because of the lateral placement of the eyes) results in a single binocular image with stereoscopic depth (Harweth and Schor, 2011). This is explained further in *Figure 1*.

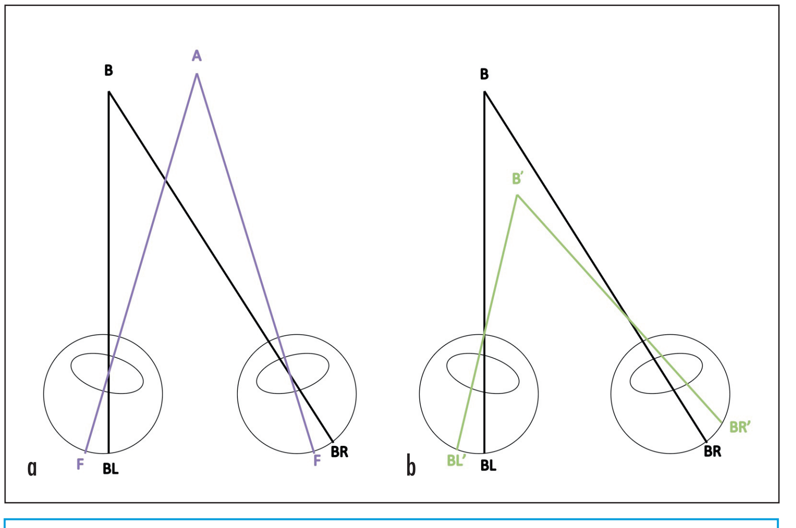
Stereoacuity, measured in seconds (") of arc, is the smallest difference in depth that can be perceived (Patterson and Martin, 1992). Stereoacuity can be classified into foveal (stereoacuity 15–60"), macular (80–200") or peripheral (300–30 000"). Most tests of visual acuity test foveal and macular stereopsis, but it may be possible for some people with reasonable peripheral stereopsis alone to appreciate some forms of 3D technology (Teping and Silny, 1987; Shimojyo et al, 2005), although Kim et al (2013) found that they may be more likely to experience ocular or systemic discomfort. The stereoacuity of children aged under 2 years is generally around 200" of arc, but may be as good as 56" of arc. This generally improves with age and by 9 years most children have adult levels (Ciner et al, 1991; Birch and Salomão, 1998). There are currently insufficient data to accurately quantify the level of stereoacuity required for 3D viewing and this is likely to vary depending on the technology used.

How is stereoacuity measured clinically?

Specialist tests are available to assess binocular vision and stereoacuity. In the UK these are normally performed by orthoptists. The Worth 4 dot test is a test for suppression of either eye, during binocular vision. Suppression is essentially when the brain ignores the information received from one eye. Glasses with a red lens and a green lens are worn and a modified torch is shone so that four dots are seen; some by only one eye and one by both eyes. In the case of normal binocular vision, four dots are seen (*Figure 2*). Suppression of one or other eye results in either two or three dots being seen and inability to fuse the images results in five dots being seen.

The Bagolini test is a test for retinal correspondence in which an object is viewed through striated plano lenses (i.e. lenses with no prescription). When a torch is shone at the subject, the striations (or scratches) produce a stripe at 45° in the right eye and 135° in the left, resulting in a cross of light being perceived by subjects with normal retinal correspondence (*Figure 3*) or abnormal, but harmonious correspondence. If one line, or part of a line, is

Figure 1. a. When the observer looks at A, the two images of A fall on the two foveas (F). B is judged to be the same distance away as A, therefore the two images of B (BL and BR) fall on corresponding points. b. B′ is judged by the observer to be closer than B. Therefore B′ produces two non-corresponding images (B1′ and B2′) and there is a perception of depth. From Hubel (1995).



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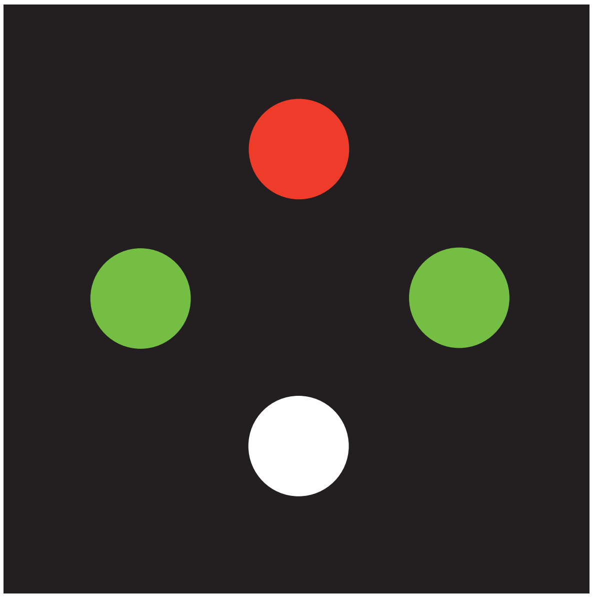


Figure 2. The Worth 4 dot test: appearance of a normal result.

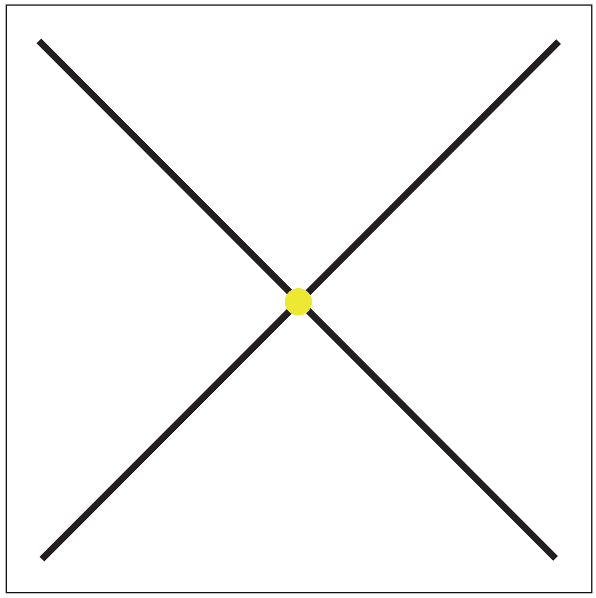


Figure 3. The Bagolini test: appearance of a normal result.

missing, this means there is suppression of the image from one eye (Hirai et al, 1998).

The random-dot stereogram is a standard test of stereo-acuity which, when viewed monocularly shows panels of dots, but when viewed binocularly produces the appearance of an apparently raised circle. This works because the image shown to the two eyes is the same apart from a patch of dots in the centre, which is displaced laterally in one eye compared to the other.

How does 3D technology work?

3D technology works by producing two slightly different two-dimensional images and showing one to the left eye and the other to the right, so that cortical representation will be of a 3D object. This requires either two attached cameras mimicking two eyes, or construction of two images from a single one using a computer. There are four common methods of doing this.

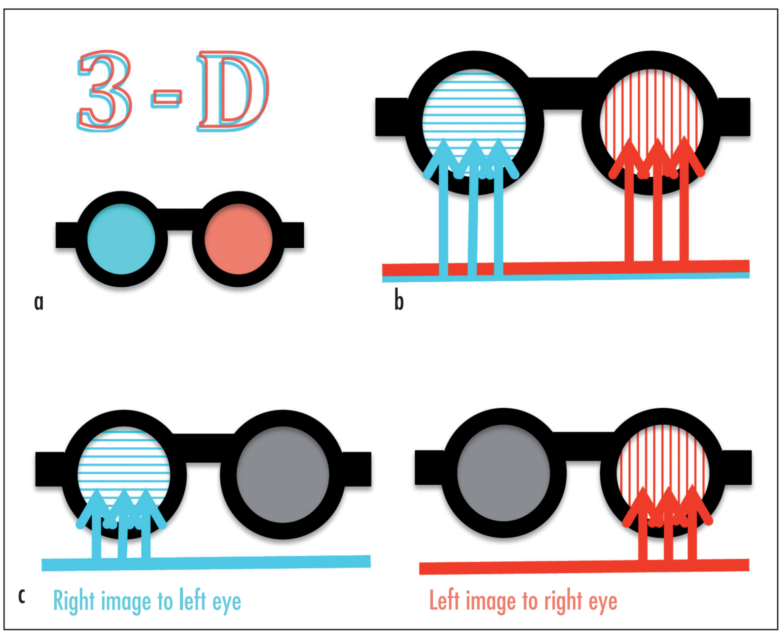
Anaglyph 3D uses glasses with different coloured lenses for each eye. The screen images are coloured differently (*Figure 4a*), resulting in each eye being able to see just one image. This works on a standard television but does not generally produce a high-quality image and limits colour range. This technology has been used for online 3D maps.

Parallax barrier technology is used primarily for small hand-held devices such as portable game consoles and seaside postcards. The screen shows both the left-eye and right-eye images simultaneously and has a thin barrier with slits above it that separates the two images. This is illustrated in *Figure 4b*. The user sits in a particular position so that the left image is presented to the left eye and vice versa (Minoli, 2011).

Cross polarisers project two images, each polarised in a different direction. The viewer wears glasses containing lenses that match the polarisation so that the lens over the right eye blocks the left image and vice versa. The 3D projector then shows a frame for each eye alternately at a high refresh speed. Cross polarisation is currently the commonest cinema technology and was used in *Avatar*.

Liquid crystal technology (LCD) shutter glasses use liquid crystal technology to alternate between opacity and transparency in response to a television emitter, so that when the image for the left eye is displayed, the lens of the right eye becomes opaque. This process alternates between the two eyes so rapidly (around 100 Hz) that the binocular cortical cells respond as if both eyes had been stimulated simultaneously. This is currently the most common technology found in home 3D systems and in many gaming computers and is shown in *Figure 4c*.

Figure 4. Diagrammatic representation of (a) anaglyph technology, (b) paralax barrier technology and (c) liquid crystal technology (LCD) shutter glasses.



Who can't see 3D and why?

Case example

Three-year-old William was brought to see his GP by his mother who was concerned that he sometimes looked 'spaced out' when tired, with one eye that 'wandered'. She also mentioned that when William first watched their new 3D TV he complained that the picture was 'fuzzy'. William was otherwise well. On examination William's vision seemed reduced in the left eye. Eye movements appeared normal. William's father had undergone eye surgery as a child but was not sure of the reason for this.

William was referred to the paediatric ophthalmology clinic, but while he was waiting for his appointment he saw an optician, who found that he was hypermetropic (long-sighted) in both eyes. Left visual acuity was reduced (6/24). He was prescribed glasses to correct this.

At the eye clinic he was seen by the orthoptist who recommended he start patching treatment for accommodative esotropia (inward turning squint). His pupils were dilated, but no other abnormality was found when he was examined by the paediatric ophthalmologist. He was kept under review.

Discussion

According to Williams et al (1988), the prevalence of stereoblindness in children is between 2 and 4%. Strabismus (or squint) is one of the commonest causes of impaired stereopsis in children. It is not usually accompanied by symptoms of diplopia (double vision). Usually idiopathic, or the result of uncorrected refractive error (often easily corrected with glasses), strabismus may very rarely be secondary to sensory deprivation (discussed below) or paralysis of eye movement as a result of tumour, trauma or stroke. Strabismus is more common in children with other congenital abnormalities (Creavin and Brown, 2009). Children may adopt an abnormal head posture and there is commonly a family history of strabismus. Up to 50% of children and adults with strabismus have reduced stereoscopic vision (Teping and Silny, 1987; Ip et al, 2008; Harweth and Schor, 2011; Kim et al, 2012). Prompt detection and treatment may facilitate development of normal 3D vision, but if left untreated, strabismus may result in amblyopia (poor vision in one eye) which, when dense, may preclude the development of stereoscopic vision.

Rare, but important causes of amblyopia include sensory deprivation, for example as a result of congenital cataract or intraocular tumour, e.g. retinoblastoma, which may be clinically evident by a white pupillary reflex (leucocoria). Therefore, impaired stereopsis should act as a red flag as it may very rarely indicate potentially harmful conditions.

Refractive errors including hypermetropia (long-sightedness), astigmatism (uneven corneal curvature), and anisometropia (a difference in the refractive errors of each eye) are associated with poor stereoacuity (Richardson et al, 2005; Harvey et al, 2007; Dobson et al, 2008; Ip et al, 2008). Refractive errors may be easily corrected with glasses in the majority of cases and if detected and treated promptly may allow development of normal stereoscopic vision.

In the UK, national guidelines recommend that all children should have a screening assessment of their vision, which is supervised by an orthoptist, either between the age of 4 and 5 years or at school entry (Royal College of Ophthalmologists, 2012). Children with apparently poor 3D vision should see an eye specialist to assess their acuity and check for refractive error, particularly when amblyopia or strabismus are suspected.

If a child who is severely sight-impaired in one eye wishes to attend a 3D film he/she should still wear the glasses, as these will block out one image allowing the child to view a single two-dimensional image. If the child does not wear the glasses the film will appear fuzzy.

Although an underlying physical cause of impaired stereopsis can be identified for many children, some may have no ocular or other abnormality and may simply lack the physiological capability (Hong and Park, 2008).

Conclusions

Three-dimensional media is likely to become increasingly mainstream and some children may notice difficulties with this that they were previously unaware of. Reduced 3D vision is not uncommon and may be congenital or acquired. Although no cause may be found, treatable conditions such as strabismus and refractive error should be excluded, as should rare but serious conditions such as cataract and retinoblastoma.

Where glasses are provided for the viewing of 3D media, those without good stereovision should be advised to wear the glasses as this will enable them to see a clear two-dimensional image. BJHM

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KEY POINTS

- Common, treatable conditions such as strabismus and refractive error should be considered as possible causes for impaired three-dimensional vision in children.
- Rare causes of poor stereopsis, such as congenital cataract or retinoblastoma should be excluded as they may be vision- or even life- threatening.
- Three-dimensional media may have a minor role as a self-screening tool for visual problems.

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