THE FRISBY STEREOTEST: AN INTRODUCTION AND A REVIEW

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Optometrists are trained to test for stereopsis for a variety of good reasons, including:

- In paediatric optometry, to pick up early binocular vision problems
- The College of Optometry has recently highlighted the importance of thorough vision assessment in the elderly to help reduce the chances of falls - a lack of stereopsis could possibly be a contributing factor (e.g. incorrect perceptions of the height of steps and curbs[1]).
- The recent interest in 3D media, which will probably grow at pace with technology advances, has led some to express their concerns to optometrists about why they, or their children, don't seem to get the enhanced depth that their friends and family report. They then understandably seek assessment of their binocular vision by an optometrist for reassurance.

For these and other reasons, it is good optometric practice to routinely check for binocular single vision (BSV).

An optometrist deciding to check BSV is able to choose from a wide variety of stereotests. Different tests have different advantages and disadvantages in dealing with different types of patients. It is not the aim of this article to review the pros and cons of all stereotests. Rather, my goal is to improve practice in using the Frisby (fig. 1) and by so doing help optometrists decide if and when to use it. The discussion will be organised around some issues of general relevance when using stereotests.

Test Understanding

If a patient immediately points at the target in the thickest (6mm) plate of the Frisby all well and good - the patient has demonstrated they know what they are looking for and thereby shown test understanding. However, if they fail to do this, is it because of a lack of stereopsis or could it be that the patient hasn't understood what they are searching for? It is possible with the Frisby, as it should be for all stereotests, to demonstrate test understanding independently of deciding if stereopsis is present, and Fig 2 explains how this can be done in three ways.

Fig. 1 The Frisby Near Stereotest

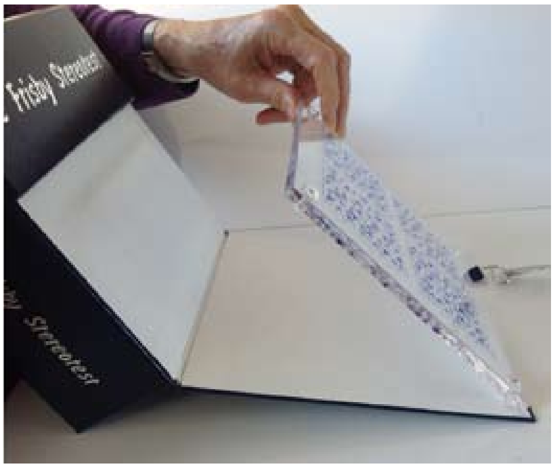
The test presents real objects and hence is a test of natural vision. No special glasses are required as for most other stereogram tests.

It has three transparent plates, which are presented to the patient one at a time a few cm above the clear background provided by the fold-down flap of the storage box, as shown in (a) for the thickest plate, 6mm.

The other plates are 3mm and 1.5mm thick. The plates can be shown at different distances (a tape measure is provided) to vary the disparity they present.

The target (b) is a randomly arranged pattern of arrowheads of various sizes. It is printed on one side of the plate in one of the four quadrants; on the other side of the plate similar pattern elements are printed around the target and also in the other three quadrants.

An observer with normal binocular stereovision can readily detect the target because it appears to stand out from the background or to recede from the background, depending which way round the plate is shown.



(a)

(b)

Such an observer is essentially seeing the thickness of the plate by virtue of the texture elements printed on the two sides.

An observer lacking normal binocular stereovision (or a normal observer viewing with one eye only) fails to detect the target.

This is because it can be distinguished only on the basis of binocular disparity cues to depth, as long as the plate is shown correctly (stationary, viewed square-on with head still, and placed about 5-10cm in front of a clear background).

Overcoming language barriers by exploiting repeatability

It is not necessary when using the Frisby to be able to describe verbally what is required. It is sufficient just to draw the attention of the patient to the target by pointing at it and then presenting the plate again after having discreetly altered the plates' orientation so that the target appears in a different position. This process of 'training by pointing' can be continued as necessary because of a unique feature of the Frisby - its repeatability in a single testing session.

This advantage of the Frisby's repeatability can be exploited not only in non-shared-language contexts but also with young children, the elderly, and the mentally infirm.

Preferential Looking

Sometimes the patient is reluctant to point or to respond verbally. Indeed they may be unable to do so if they are very young (fig.2). In such cases a judgement can still be made by carefully noting where the patient looks. If they choose to look at the target over a series of presentations with the target in different positions then a conclusion of *Stereopsis Demonstrated* is feasible.

The tester can concentrate on observing the patient and still know where the target is by discretely feeling the protective studs at the corners of each plate. The stud on the target quadrant has a flat head that easily identifies it. Hence testers can 'play the game' of holding the plate behind their back, changing target position and still know where the target is by feeling the stud with flat.

Fig. 2 The Frisby Screener Stereotest
Here it is being used to test a very young child. This version of the Frisby has a quick-to-use presentation box that reveals just two quadrants of the 6mm plate. See www.frisbystereotest.co.uk. Notice how the tester is checking where the child is looking to use preferential looking to decide her clinical judgement.

Fig. 3 Checking Test Understanding

If the patient does not spontaneously point at or look at the target then try one of the following (illustrations show the *Frisby Pocket Stereotest*):

1. Use Monocular Shading Cues
Hold the plate with the target pressed against the wallet which makes the target visible by monocular shading cues (see photo). This provides a way of demonstrating what the target looks like to a patient who does see it spontaneously or who lacks stereopsis.

Do this a few times swapping the target left/right. If the patient finds it each time then test understanding has been demonstrated.

2. Use Monocular Parallax Cues
Rest the target on a corner about 5cm from a clear background and **twist it to & fro with slow rotary movements** to create monocular parallax cues. (Try this for yourself with one eye covered.) Test understanding is confirmed if the patient then sees the target-in-depth.

3. Show the target (below) printed on the wallet and ask the patient to find it in the plate.

AFTER TRAINING present the plate normally with a series of varied target positions to check for stereopsis via pointing or preferential looking. During this test phase, be sure to hold the plate still a few cm in front of its background and, if necessary for a young child and with the permission of its carer, hold the head steady with an outstretched hand.

The tester can also try using an auditory reward such as a squeaky toy if they point to the target.

Descend the Disparity Staircase Quickly
If a patient makes a confident and speedy correct response to the first presentation of the 6mm plate of the Frisby (at say c.40cm) then the 3mm plate should be immediately presented. If that is also passed confidently in a single presentation then assessment should proceed immediately using the 1.5mm plate.

The point here is that multiple presentations of each plate, with careful attention to viewing distances, are needed only at threshold. Using a single correct, speedy and confident criterion for moving quickly down the disparity staircase is to avoid patient fatigue, or in the case of young children, to cope with short attention spans.

The tester should in general be wary of concluding BSV present if a patient finds a stereo target only after atypically slow unconfident responding (unless of course special factors apply, such as learning difficulties). Such responding, for any test, can indicate that the patient is trying to find the target using non-disparity cues and they may get lucky on the odd presentation from random responding.

Monocular Cues
It should not be possible to pass a stereotest on the basis of cues other than binocular disparity. Holmes and Leske[2] concluded that the Frisby was the least prone in their study to false responding using monocular cues. They contrasted it favourably with the Circles part of the Wirt test whose first few levels of stereoacuities can be passed by noting monocularly visible circle misalignments. Fricke et al[3] pointed out that an early report of monocular cues problems with the Frisby when testing were statistically flawed and should be ignored.

Of course, it is crucial that the Frisby, just like any other test, is presented correctly. Deliberately introducing monocular cues for finding the Frisby test target is fine when checking test understanding (fig.3) but due care should be taken to avoid them completely when testing stereoacuity. This is easily done by holding the plate stationary a few cm in front of a clear background (fig. 1) and by ensuring the patient's head is kept still.

There are three versions of the Frisby. A full description of these tests can be found at www.frisbystereotest.co.uk. The 3-plates test shown in fig.1 is the original test introduced over 35 years ago. There is also a single plate Screener test and a recently launched Frisby Pocket Stereotest which has smaller plates with just two quadrants, one of which contains the target (fig. 3).

Test/Re-test Reliability
Adams et al[4] reported for several stereotests low test/re-test correlations between repeated presentations of a given test. Their conclusion was that if the clinician is trying to decide whether a treatment has led to an improvement in stereoacuity then it is necessary in general to demonstrate a 2-octave or bigger change as smaller values could be due to chance. However, they found that due to its more reliable measurements their recommended value for the Frisby was just 1-octave.

Disparities in Octave Steps (sec arc) Approx values	**Distances for each Plate Thickness**		
	6mm	**3mm**	**1.5mm**
600	**30**		
300	**42**		
150	**58**	**42**	
80	**82**	**58**	**42**
40		**82**	**58**
20			**82**
10			**115**
5			**165**

Note: disparities are approximate but sufficient for normal clinical needs. Manufacturing variations in plate thickness can be allowed for using the usual formula for calculating disparities provided in the test booklet.

With this in mind, current versions of the Frisby are provided with an octave-based table of stereoacuities (table above) that provides distance/plate combinations covering the stereoacuity range in (roughly) doubling steps of 20, 40, 80, 150, 300, 600 sec arc.

There is a case for saying that for clinical purposes the clinician will *not* need to explore the finest end of the stereoacuity range (10-5 sec arc). Instead, regardless of test used, clinicians might be content to put a patient in one of four categories, whose stereoacuity values for the Frisby could be:

no stereopsis;
weak stereopsis (≥300 sec arc);
mid-quality (150-80 sec arc);
good (≤ 40 sec arc).

Test Norms
Various studies have shown that normal young adults typically score 20 sec arc or better on the *Frisby Stereotest*. A recent substantial study by Bohr & Read[9] reported medians for participants with no visual problems of 20, 20 and 80 sec arc respectively for age groups 5-10 years, 11-49 years and 50-82 years.

Anketell et al[10] recently compared stereoacuities when the target is shown protruding with those when it is shown receding, for children in the age range 6-16 years. The table below shows the main features of their data. Given the ranges of stereoacuities found for their participants, the authors concluded:

> "*These data identify the range of normal stereoacuity scores that should be anticipated clinically in 95% of typically developing children .....Broadly, a Frisby stereoacuity score of 85 arcsec of better is within normal limits.*"

Frisby Stereoacuities (sec arc): Medians and Inter-Quartile Ranges from Anketell et al[9]

Groups	N	Protruding-Medians	Receding Medians
6-10 yrs	97	20 IQR 20-40	25 IQR 20-40
12-16 yrs	89	10 IQR 5-20	10 IQR 10-25

The medians found when showing the target protruding vs receding are similar although Anketell et al suggest recording which type of presentation was assessed in view of some variations in the ranges found.

Crossed vs Uncrossed Disparities
The two conditions of target protruding or receding are quite often referred to in the clinical literature as presenting crossed vs uncrossed disparities. However, the terms crossed and uncrossed are geometrically defined[6] with respect to the observer's prevailing fixation point in 3D - yet fixation is usually uncontrolled when clinical stereotests are presented.

For example, when scanning a Frisby plate fixation could, at different moments, be on the target or on the surround. If an element at the edge of the protruding target is fixated then it will have zero disparity and an adjacent element in the surround will have an uncrossed disparity - for that particular fixation. If fixation is transferred to the adjacent surround element, the target element will then have a crossed disparity.

The point here is that texture elements of the Frisby on any given presentation can have zero, crossed or uncrossed disparities depending on the observer's plane of fixation which is uncontrolled. It is misleading therefore to label the protruding target as always having crossed disparity. The same consideration applies when the target recedes, *mutatis mutandis*.

Of course, it can be useful to vary whether the target is set to be protruding or receding when explaining the Frisby because asking a child to 'find the hole' may work better for some children than 'find the ball sticking out'.

These considerations do not apply uniquely to the Frisby but are relevant to all stereotests.

Should stereotests pick up amblyopia?
The Frisby has by design a test texture with some large elements that are relatively easy to resolve with (non-severe) amblyopia. Their inclusion was to permit the detection of stereopsis even if non-severe amblyopia is present. This is useful to know because if a patient has stereopsis then it is enhances the prospects for the success of treatment as even a weak level of stereoacuity will help avoid a strabismus developing.

It is by no means clear that stereotests should be asked to bear the burden of picking up amblyopia. Visual acuity tests are usually regarded as the proper way to detect amblyopia.

It is of interest in this connection that the very fine random dot texture used in the TNO test has been welcomed by some because if it is passed at a good level of stereoacuity then it suggests that 'all is well' in terms of BSV, amblyopia and acuity. There is not a rigorous study of this claim in the literature as far as I am aware. Moreover, Westheimer[11] has argued that random dot stereotests with fine textures risk false negatives when judging presence/absence of BSV and this needs always to be borne in mind (see also later remarks).

To summarise this section, it is far from clear to this author that a very fine texture is appropriate for a clinical stereotest, particularly if visual acuity is to be tested anyway.

Random Dot Stereograms vs Real Depth Stereotests
Random dot patterns are the basis of several stereotests that present binocular disparities using stereograms. However, the use of the term random dot can be misleading as many kinds of random element patterns have been used to create stereograms[5, 6]. Indeed, the Frisby was conceived as a real-object equivalent of a random element stereogram in which the elements are jagged triangular shapes.

Hence the defining property of a random 'dot' stereogram for present purposes is not that it uses dots but that the target shape is seen only after binocular fusion. That is, the target is not discernible in either half-stereogram. Seeing this kind of 'hidden' 3D target is called achieving *global* stereopsis as it often entails resolving ambiguities in matching up elements in the left and right images, i.e. choosing which of the potential *local* matches are the correct ones.

The Frisby demands global stereopsis in this sense because the roughly circular pattern of elements comprising the target cannot be discriminated as a distinct circular entity except by stereopsis. It is a false antithesis therefore to contrast random dot and real depth stereotests as is sometimes done.

Random Dot vs Contour Stereotests
A distinction is sometimes drawn between stereogram tests that require global stereopsis, as just defined, from those in which the contours of the target are discriminable monocularly so that there is no ambiguity problem in matching up local texture elements.

An example of the latter is the Wirt in which the contours of the fly's wings, are clearly visible as distinctively-shaped elements prior to achieving stereo depth, so that the process of achieving global stereopsis from multiple ambiguous local element matches does not arise. Some plates of the TNO test use monocularly-visible elements superimposed on a texture of random dots.

The presence of monocularly visible contours in stereotests might assist appropriate vergence (motor fusion). This attribute is present when viewing most everyday scenes but is lacking stereotests made of fine random dots which is one reason why the latter might be harder than contour tests.

The Frisby can be regarded as a hybrid case in this regard in that it demands global stereopsis in the sense that its ball-shaped target cannot be discriminated as such before binocular single vision (BSV) is achieved. But equally, its relatively large and sparse texture elements offer help for motor fusion mechanisms. This could be one reason why the Frisby is often easier for patients to deal with than random dot stereogram tests.

The lack of prominent monocularly discernible contours able to guide vergence could have a bearing on the difficulty some people have with stereograms using fine random dot patterns[7]. Indeed, Westheimer[11] has argued against random dot stereogram tests of binocular vision, saying that although a successful response is conclusive evidence of stereopsis the fact that some patients struggle with fine random dot patterns increases the chances of falsely concluding BSV absent. He singles out the Frisby as a test not subject to this criticism because of its coarse well-separated elements.

Coarse vs Fine Stereopsis
It is sometimes the case in assessing BSV that the clinician will begin by assessing its presence or absence using the two-finger test in which the patient is asked to bring a finger from one outstretched hand into vertical alignment with a finger from the other hand. This can be done with an error of a mm or so in the anterior-posterior (depth) direction if BSV is present but errors of a cm or so can arise if stereopsis is lacking. (Some practitioners prefer to ask to the patient to do this task with two pencils held in outstretched hands, rather than with two fingers, but the principle is the same.)

The two-finger test is usually regarded as a test of coarse stereopsis, a term used to refer to very large disparities (such as the 3000 sec arc of the Fly test) that may be processed using different mechanisms from small disparities[8].

The Frisby does not provide the very large disparities of the Fly. Its maximum is 600 sec arc (6mm plate shown at 30cm). However, this value is large enough for most clinical needs in judging presence/absence of low quality stereopsis.

Optimal stimulus conditions for stereoacuity
Westheimer[11] concluded that "......to be most effective in the measurement of stereoacuity

targets should be:

> few in number, and well articulated,
>
> sharply delineated and in good focus binocularly,
>
> with high contrast and, at a minimum, medium photopic luminance,
>
> minimally encumbered by the influence of prediction, memory, and
>
> as far as possible devoid of non-stereoscopic cues to depth."

Optometrists and clinicians can judge for themselves how well these conditions are met by their own favourite stereotest(s). Westheimer picked out the Frisby as satisfying these criteria.

One question prompted by these optimal conditions for stereoacuity is: what range of disparities should be explored clinically?

At the fine end of the range, the Frisby goes down to 5 sec arc (the 1.5mm plate viewed at 150cm) but it is arguable whether it is clinically useful to explore such fine discriminations (see earlier remarks on page 3). Indeed, it is worth reiterating that there is a case for saying that the clinician will usually be content to put a patient in one of four categories: *no stereopsis; weak stereopsis, mid-quality,* or *good.*

Occupational Health Screening

Some types of employment require good stereopsis, e.g. fork lift truck drivers. Hence screening for stereopsis is important for those sorts of jobs. The Frisby is now being used by the French railway system for screening their train drivers. Curiously, it seems stereopsis screening is not done routinely for dentists for whom good stereopsis is highly desirable.

Why Triangular Texture Elements?

I have often been asked why I chose 'boring' triangular texture elements. Why not use little faces or animals likely to interest children? The answer is that we tested such shapes and children were so attracted to them that their attention was not captured by the stereo target. A 'boring' texture makes the stereo target the 'most interesting' thing to look at.

Concluding Remarks

It is hoped that this article will assist clinicians by raising some general issues that apply to all clinical stereotests and hence help them choose which test to use on which types of patient.

Also, it is clear that not all users of the Frisby present it correctly (e.g. certain *YouTube* clips show a Frisby test plate not being held a few cm away from its background: fig. 1). I hope this article will help improve practice.

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