

MAXIMUM DISTANCE OF STEREOPSIS

What is the furthest distance that the location of objects can be judged using stereopsis? For example, using stereopsis, Can you tell that the moon is nearer than the stars? Can a pilot tell that another aircraft is nearer than the horizon using stereopsis? To compute the maximum distance at which stereopsis is possible, you must consider, "If an object is located at infinity, how close must it come to you before you can tell that it is nearer than infinity, using only stereopsis?"

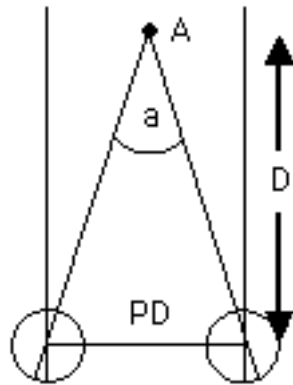


Figure 1. Maximum distance at which stereopsis is possible.

Since the binocular parallax angle for infinity is zero, object A in Figure 1 will first be seen in stereoscopic depth when angle a is equal to the stereoacuity threshold. Since angle a is known, and PD is known, it is easy to compute the distance D. In radians it is:

$$\angle a = \frac{PD}{D} \therefore D = \frac{PD}{\angle a}$$

If the PD = 0.064 m and angle a is 20 arc seconds (9.696×10^{-5} radians), distance D is equal to 660 meters. Table 1 shows the maximum distance of stereopsis, given other stereoacuity thresholds.

TABLE 1. Maximum distance of stereopsis for different stereoacuity thresholds (PD = 64)

Threshold (arc seconds)	Radians	Maximum distance (m)
2	9.696×10^{-6}	6600
10	4.848×10^{-5}	1320
20	9.696×10^{-5}	660
40	1.939×10^{-4}	330
80	3.879×10^{-4}	165

For different PD's the distance will change, as shown in Table 2.

From this, you can see that, assuming a stereoacuity threshold of 20 arc seconds, it is impossible to judge the relative position of objects stereoscopically if they are located more than about 700 meters away. Beyond that distance, angular disparity angles are smaller than the stereoacuity threshold. Therefore, a pilot, who sees an approaching aircraft from several miles away, will not be able to use stereopsis to judge the distance to that aircraft.

TABLE 2. Maximum distance of stereopsis for different PDs, assuming $\eta = 80$ arc seconds.

PD (mm)	Maximum distance (m)
56	134
60	155
64	165
68	175

Let's reconsider the case of Delta flight 554. The 2-10 arc second threshold is for ideal laboratory test conditions but the smallest measurable stereopsis using a clinical test is 20 arc seconds. On the Titmus Stereo Fly, if the person can see 9/9 targets, he has a stereoacuity of 40 arc seconds. Since visibility was poor and the pilot was viewing under dynamic conditions, we can probably assume that his stereoacuity was worse than 40 arc seconds, perhaps 80 arc seconds. Referring to Table 1 above, an 80-arc-second threshold means that stereopsis would be possible only within about 165 meters. If the aircraft were flying 200 mph, it would be traveling at about 100 meters per second, which corresponds to only 1.65 seconds of traveling time. That is, if the pilot was close enough to the runway to be able to use stereopsis, he would have had only 1.65 seconds to correct his position. I doubt that the reduced stereopsis caused by monovision had any role in the accident.

HYPERSTEREOPSIS

When I was working at the US Army Aeromedical Research Lab (USAARL) in Fort Rucker, Alabama, scientists and engineers were experimenting with new helmet-mounted imaging and display systems for helicopter pilots. One example is the Helmet Integrated Display and Sight System (HIDSS) designed for the RAH-66 Comanche helicopter, which was in development then. The Comanche has since been canceled. The HIDSS was designed so aircraft and weapons information is superimposed on the pilot's vision, so he can see the battlefield and data at the same time. Figure 2 shows another example of a developmental wide-field-of-view night vision goggle.



Figure 2. Experimental Army night vision optical system.

What do you think would happen to the sense of stereopsis, if the pilot were seeing through telescopes mounted in the sides of the helmet, effectively increasing his/her PD to about 120 mm? This would drastically increase the binocular parallax angles and it would increase retinal disparities. This would give a radically enhanced sense of stereopsis or **hyperstereopsis** and extend the person's maximum range of stereopsis from about 660 meters to over 1,200 meters. The person would also be able to judge much smaller depth intervals in stereopsis.

VERTICAL DISPARITY

When both eyes view an object on the midline, the vertical size is the same for both eyes. The angular size of the object will also be the same for both eyes. However, if the object is moved to the right or left of the midline, it will be nearer to one eye than the other. In that case, the vertical angular size will be different for the two eyes. This is called the vertical geometric disparity.

For example, while holding your head steady, move your pen into your left field of view. Alternately look at it with each eye. You should notice that the pen looks slightly large with the left than right eye.

In theory vertical geometric disparity should not contribute to stereopsis, but when the vertical size of the one eye's image is magnified, binocularly viewed surfaces appear to slant or become curved. Your patients may experience this when they begin wearing a new spectacle Rx. It may be that vertical disparities indirectly affect depth perception, and this was called the *induced effect* by Ogle. We will study more about this when we study aniseikonia.

SUBCATEGORIES OF STEREOPSIS

As with many other visual functions, stereoscopic depth perception is probably integrated in the brain from several sub-functions. Stereopsis has been divided into fine and coarse stereopsis.

Fine stereopsis responds to higher spatial frequencies (fine details), retinal disparities less than 30 arc minutes, and to stationary or slowly moving targets. Fine stereopsis is mainly found in foveal vision and is supported by the *parvocellular* system. The system provides for high quality stereopsis (patent stereopsis) and may also contribute to fine disparity vergence control.

Coarse stereopsis mainly responds to lower spatial frequency targets (large objects), operates with larger retinal disparities (30 - 600 arc minutes), and moving targets. It is active in both foveal and peripheral vision and may also be related to coarse disparity vergence control. This appears to be supported by the *magnocellular* system.

Other specific centers in the brain may specialize in other subcategories of stereopsis. For example, motion-in-depth stereopsis, lateral motion stereopsis and static stereopsis appear to be processed differently. These can be further divided into separate processes that deal with crossed and uncrossed disparities. Damage to certain areas in the brain can create specific forms of stereo blindness. For example, a person might suffer from coarse motion-in-depth stereopsis, yet have completely normal static stereopsis.

PANUM'S LIMITING CASE

It is possible to create a sensation of stereoscopic depth using a very simple stimulus illustrated in Figure 3, below. The image seen by the right eye is a single line, while two lines are seen by the left eye. The visual system fuses the single line (seen by OD) with the two lines seen by OS to stimulate a sense of stereopsis. This gives the perception of two objects located in depth as shown in the figure. This is called **Panum's limiting case** because it is the minimum stimulus necessary to elicit a sense of stereopsis. If you remove one of the lines, then stereopsis ceases.

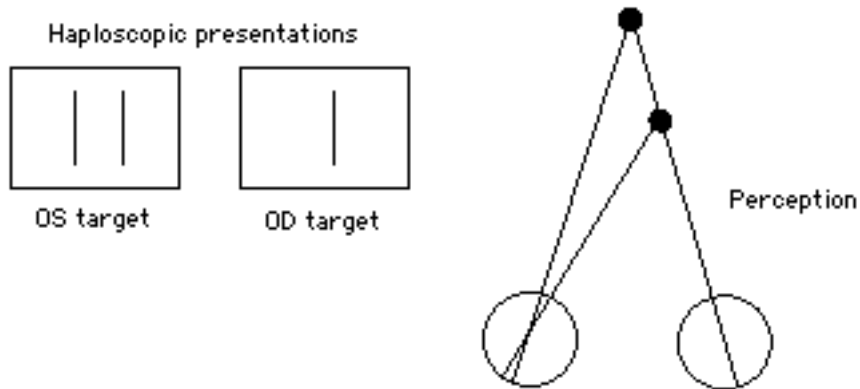


Figure 3. Panum's limiting case

STEREOPSIS IN MEDICAL DIAGNOSIS

In Chapter 7, Steinman described different kinds of stereoscopes and methods used to create a sense of stereoscopic depth perception.

- Wheatstone stereoscope using mirrors to put a different flat image before each eye.
- Brewster stereoscope using lenses and prismatic effect
- Various methods that use polarized filters
- Anaglyph figures and glasses. These are used VT equipment and in 3-D movies.
- Liquid crystal stereogoggles. These are used in 3-D televisions.

Stereopsis is important in clinical diagnosis, in conditions such as glaucoma. While direct ophthalmoscopy gives you a nicely magnified view of the optic nerve head, it is sometimes difficult to appreciate the actual depth of the cup without stereopsis. This is an important advantage of fundus biomicroscopy (using a 90D, 78D or Superfield lens). If you correctly fuse the fundus image, stereopsis will give you a vivid picture of the three-dimensional depth of the optic cup.

A 78D lens provides a more magnified view of the fundus than a 90D lens, and a 60D lens provides even greater magnification. The lower power lenses also enhance stereoscopic depth more than the factor you would expect from the transverse magnification alone. Do you know why?

Stereo fundus photos are also valuable in the management of glaucoma for the same reason. In order to take a pair of stereo nerve head photographs, you first take a normal photo of the nerve head, then shift the camera slightly to the side and take a second photo.

Q. Why?

A.

Until recently, fundus photographs were usually developed into color slides. A pair of optic nerve head slides, taken as described above, can be viewed in a stereoscope that presents a different slide to each eye. The disparity between the two images stimulates a sense of stereoscopic depth.

Q. What will happen to the binocularly perceived image if you incorrectly put the right and left slides in backwards?

A.