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STEREOPSIS II

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MAXIMUM DISTANCE OF STEREOPSIS

What is the furthest distance at which 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 ask, 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?

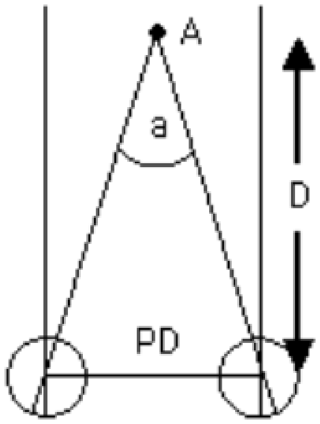

Figure 27.1 *Maximum distance at which stereopsis is possible.*

Since the binocular parallax angle for infinity is zero, object A in Figure 27.1 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:

$$\angle a \quad \frac{PD}{D} \quad \rightarrow D \quad \frac{PD}{\angle a}$$

If the PD = 0.064m and angle ‘a’ is 20 arc seconds (9.696 x 10-5 radians), distance D is equal to 660 meters.
Table 27.1 shows the maximum distance of stereopsis, given other stereoacuity thresholds.

Table 27.1 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 27.2. 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 27.2 Maximum distance of stereopsis for different PDs, assuming η = 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/she 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 27.1 above, an 80-arc-second threshold means that stereopsis would be possible only within about 165 meters. If the aircraft were flying 320km/h, 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 were close enough to the runway to be able to use stereopsis, he would have had only 1.65 seconds to correct his position. It is doubtful that the reduced stereopsis caused by monovision had any role in the accident.

HYPERSTEREOPSIS

The US Army is developing 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 (now canceled). It was designed so aircraft and weapons information is superimposed on the pilot's vision, so he/she can see can see the battlefield and data at the same time. Figure 27.2 shows another example of a developmental wide-field-of-view night vision goggle.

Figure 27.2 *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 their 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 will appear to be the same for both eyes. The angular size of the object will also be the same for both eyes. 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 larger with the left than right eye. In theory, vertical geometric disparity should not contribute to stereopsis, but when the vertical size of one eye's image is magnified, binocularly viewed surfaces appear to slant or become curved. Your patients may experience this when they begin wearing new spectacles. 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.

SUB-CATEGORIES OF STEREOPSIS

As with many other visual functions, stereoscopic depth perception is probably integrated 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 neurological centers 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 27.3, below. The image seen by the right eye is a single line, while the left eye sees two lines. 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.

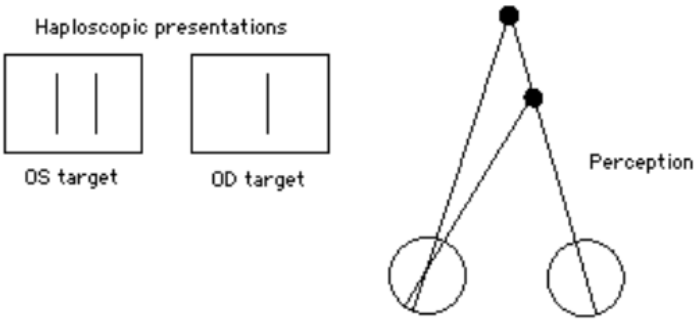

Figure 27.3 *Panum's limiting case.*

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
- Liquid crystal stereo-goggles

Stereopsis is important in the clinical diagnosis of 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.

A 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 The pair of slides is viewed in a stereoscope that presents the different slides to each eye. If taken correctly, the disparity between the two images stimulates senses of stereoscopic depth.

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