Vision Science III - Ocular Motility & Binocular Vision

Lab 2 - The Apparent Fronto-Parallel Plane (AFPP) Horopter

THE THEORETICAL HOROPTER

A **horopter** is a set of points in space where an object must be placed if it is to stimulate exactly **corresponding points** on the two retinas. The horopter also represents a set of points that cause **zero disparity** on the retinas. If a visual line is projected out of one eye, and the corresponding visual line is projected out of the other eye, the intersection of these is a point on the horopter.

In theory, the horopter is an arc that lies on a circle that goes through the fixation point and the nodal points of the two eyes. This theoretical horopter is known as the **Vieth-Müller Circle**; each different fixation distance has its own its own Vieth-Müller Circle.

The Vieth-Müller Circle (theoretical horopter) is based on certain geometric assumptions about the eyes. These are:

- Each retina may be represented by a perfect circle.
- Corresponding points are evenly space across the nasal and temporal retinas of each eye.
- Both retinas are the same size and corresponding points are perfectly matched for their locations in the two eyes.

These are reasonable assumption for model eyes. Based on these assumptions, if you project corresponding visual lines out of the two eyes and plot their intersection points, they should form a circle—the Vieth-Müller Circle.

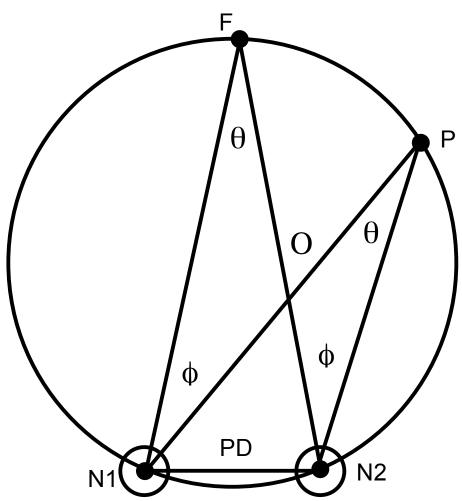

Figure 1. Geometry of the Vieth-Müller Circle

This geometry has some interesting characteristics, as illustrated in Figure 1. Since all points on this circle are projections from a common chord (PD), the binocular convergence angle between the eyes to any point on the circle is always the same (Angle θ). The alternate angles at Point O formed by the crossing of the visual axes are equal, and two similar triangles are created-—triangles FON_1 and PON_2. Then Angle ϕ, the angular span between any two points (i.e., F and P) on the horopter, to one eye, is equal to the corresponding (Angle ϕ) in the other eye.

For an object on the horopter that extends between any two points F and P, its angular size on the retina of each eye will be equal to ϕ. If this object is moved to other locations on the horopter, its angular size will not change. Therefore, an object placed anywhere on the horopter, will have a **constant image size** on the retina. If image size is constant (angular size on the retina), and the binocular disparity remains zero (object stays on the horopter), then any object that is moved along the horopter should always appear to be the same distance away from the observer. That is, stereopsis is not stimulated to tell you that it is either farther or nearer than the fixation point.

This is the theoretical basis for measuring a person's horopter using the apparent fronto-parallel plane (AFPP) method. Using a **Howard-Dolman apparatus**, you should be able to locate a person's horopter by asking him to place all the rods at the same distance as the fixation point (while fixating the central fixation point binocularly). You can instruct the subject, "While staring at the central rod, line up the others so they are just as far away from you as the middle one." It may be easier for the subject to understand and perform this task if you instruct him, "While staring at the central rods, line up all the others so they line in the same plane as the middle rod, and are parallel to your face." They will be measuring the location of the apparent fronto-parallel plane, hence the name for this technique. This method for measuring the horopter was developed by Hering, and is the most popular way to measure the horopter.

PROCEDURE

1) Align the Howard-Dolman apparatus.
- Disinfect the brow and chin rest.
- Adjust the chin elevation so that the subject is level with the viewing slit.
- Center the fixation rod on the subject's midline, 400 mm from the bridge of his nose. Assume that this is the location of his egocenter.
- Verify that the front of the box is parallel to the subject's frontal plane.
- Throughout the measurement, the subject should maintain this head position.

2) Prepare the apparatus
- Have the subject close his eyes while you randomly shift each test rod in front of or behind the **objective (true) fronto-parallel plane (OFPP)**.

3) Measure the apparent fronto-parallel plane
- The subject must *maintain binocularly fixation* on the central rod throughout the measurements.
- Have the examiner randomly select a test rod, and move it in and out until the subject is satisfied that it is in the same fronto-parallel plane as the fixation point.
- Randomly select another rod and repeat the procedure until all rods are aligned.

4) Record the rod positions
- Define an (x,y) grid on the top of the apparatus for the purpose of recording rod positions. The fixation point is the origin, and the x-axis is in the objective fronto-parallel plane. The y-axis is in a line connecting the fixation point and egocenter.
- Carefully record the (x,y) coordinates of each rod, observing + and - signs.
- Repeat and compute the mean (x,y) for five measurements of the AFPP.

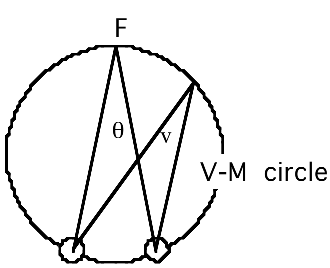

Figure 2.

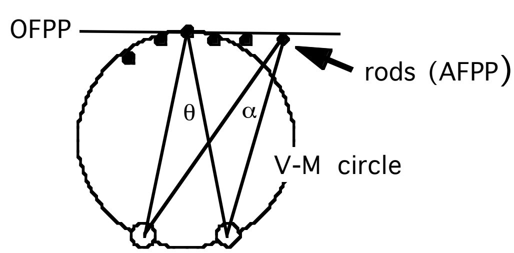

Figure 3.

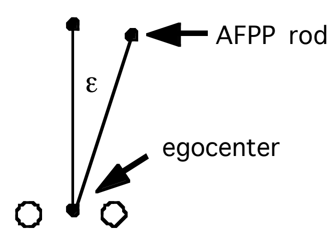

Figure 4.

RESULTS (Table 1)

Record the raw data in Table 1 using the coordinate system described above and compute means. Enter the PD, fixation distance and results of the computations below on Tables 2 and 3 and on the Excel spreadsheet on the laboratory computer.

DATA ANALYSIS (Table 2 & 3)

1) Compute binocular convergence Angle θ (See Fig. 2) in arc minutes.
2) Compute the angular eccentricity (ε in Fig. 4) from the egocenter to each AFPP rod in degrees.
3) Compute the binocular convergence angle (α) to each rod (Figure 3).

4) Compute the disparity to each rod. Disparity (d) is defined as:

$$d = v - \alpha,$$

where v is the binocular convergence angle to a point on the Vieth-Müller Circle (Fig. 2) at the same eccentricity as the rod, and α is the convergence angle to the rod. By this formula, the disparity angle will be negative for points inside the Vieth-Müller Circle and positive for points beyond the circle.

Note that, according to the geometry of the Vieth-Müller Circle, angles θ and v are equal. This simplifies the computation of disparity for each rod to:

$$d = \theta - \alpha$$

5) For comparison, also compute the disparity if the rods had been located in the OFPP (See Fig. 3).

Table 1. Record (x,y) position data here. All units in mm. *Be careful to observe signs.* Place (x,y) data in cells correspnonding in position to the location of the rods, as seen from above. For example, put the (x,y) coordinates for the far left rod in the far left cell, etc.

Series	Left rods				Fixation	Right rods			
	Far left				Middle				Far right
1					(0,0)				
2					(0,0)				
3					(0,0)				
4					(0,0)				
5					(0,0)				
mean					(0,0)				

Table 2.

PD (mm)	
Fixation distance (mm)	
Convergence angle to fixation (arc min)	

Table 3. Data analysis.

	Left rods				Fixation	Right rods			
Eccentricity (ε; deg)									
Angle v (min)									
Angle α (min)									
AFPP Disp									
OFPP angle α (min)									
OFPP Disp									

PLOT THE DATA

Plot disparity on the y axis, in arc minutes, as a function of visual direction (eccentricity in degrees; x axis) for the AFPP, OFPP and Vieth-Müller Circle. Turn in this plot for full credit for this lab.

DISCUSSION QUESTION

How does our AFPP horopter compare with the Vieth-Müller Circle? Why?