BrienHoldenVisionInstitute

FREQUENCY DOUBLING PERIMETRY

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THIS CHAPTER WILL INCLUDE A REVIEW OF:

- Frequency doubling perimetry
- Psychophysical methodology
- Thresholds
- Fechner's techniques for measuring thresholds

FREQUENCY DOUBLING PERIMETRY

Glaucoma is difficult to diagnose and manage because in the early stages it is essentially a symptomless disease, and in some cases, the patient with glaucoma may have normal IOPs. Definitive diagnosis based on ophthalmoscopy or fundus biomicroscopy (90 D lens, etc.) can be difficult.

White-on-white static automated perimetry is the current standard for making a final diagnosis of glaucoma, but standard perimetry may fail to detect early damage. Because glaucoma is one of the leading causes of blindness, a major part of modern eye research is being devoted to finding a better way to diagnose glaucoma. There are two ways to approach early detection of glaucoma:

- Structural (anatomic)
- Functional (psychophysical)

Even though the HRT (Heidelberg Retinal Tomography), GDx (nerve fiber layer analyzer), OCT (Optical Coherence Tomographer), RTA (Retinal Thickness Analyzer) or SWAP (short wavelength automated perimetry) are designed to improve glaucoma diagnosis, there are some practical problems with these instruments:

- HRT - expensive
- GDx – expensive
- OCT – expensive
- RTA – expensive, hard to learn
- SWAP – long and difficult test for the patient to do

Ideally a test designed to detect early glaucoma should be:

- Sensitive to subtle glaucomatous changes
- Not prohibitively expensive
- Easy, convenient and fast to use

FREQUENCY DOUBLING PERIMETRY (CONT.)

New psychophysical tests are also being developed to detect early glaucoma. One of them takes advantage of the discovery that the magnocellular ganglion cells are among the first neurons to be damaged in glaucoma. Therefore, a test that isolates the magno ganglion cells should be very useful. One such test is the **Humphrey Frequency Doubling Perimeter (FDT)**. A new version of the FDT, known as the **Matrix**, became available several years ago (Fig. 30-1). The basic principles of testing with the Matrix are the same as the FDT, except it tests more points, with smaller test areas than the FDT. Also, its data printout is similar to the well-known Humphrey Field Analyzer printout, which makes it easier for doctors to interpret the results. For more details on this instrument, refer the data sheet on the Zeiss-Humphrey web site:

(http://www.meditec.zeiss.com/)

Figure 30-1: *The Zeiss- Humphrey MATRIX, which uses frequency-doubling technology*

The Humphrey Instruments website described the FDT in this way:

> *[It is] the first visual field instrument that's simple enough, and compact enough to be used even in pre-test. Affordably priced, FDT has years of research and clinical trials behind it to validate performance. The instrument produces screening results in only 45 seconds and full threshold results in under 4 minutes per eye. Weighing only 19 pounds, FDT is the most portable and user-friendly automated visual field instrument ever created.*

The stimulus in this instrument has been designed to specifically stimulate neurons in the magnocellular system. It consists of a small counter-phase flickering sine wave grating (Fig. 30-2).

- The magno system can detect rapid flicker, so the grating targets are flickered at a relatively rapid rate of 15 Hz. This is above the CFF for the parvo system
- The magno system has a non-linear response, so if detected, the magno system alters the perception so that the grating appears to have double its true spatial frequency, hence the name frequency doubling. If the response were linear (parvo system) then the target would be a uniform gray area — the counterphase gratings are fused over time into a uniform gray area
- Large gratings are used since the magno system has poor spatial resolution. Only the parvo system can see high frequency gratings
- Contrast is varied until the person cannot detect the gratings. If significant numbers of the magnocellular fibers are damaged, the person will require higher contrast to see the gratings. This is essentially a contrast sensitivity test (Fig. 30-3)

FREQUENCY DOUBLING PERIMETRY (CONT.)

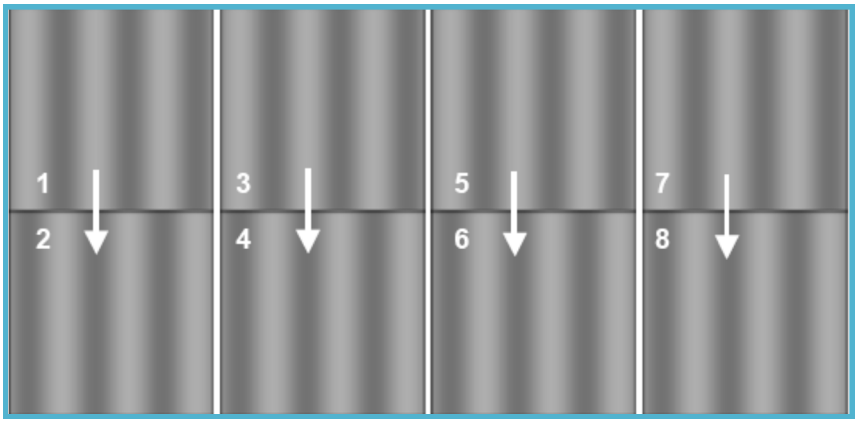

Figure 30-2: *The target used in FDT machines is a sine-wave grating that is flickered at 15 HZ with alternate frames presented out of phase (counterphase flicker). Numbers show the time sequence of frames*

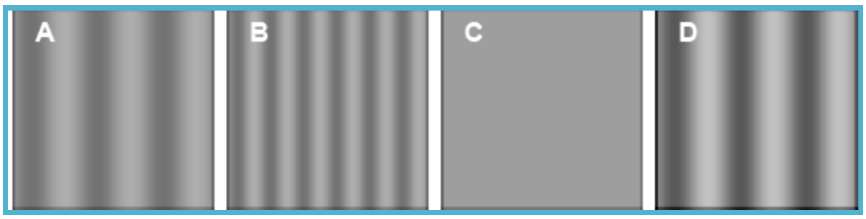

Figure 30-3: *If the magnocellular neurons are intact, the actual stimulus (A) will appear like a sinewave grating with double the frequency (B). If the magnocellular neurons are damaged, as in glaucoma, the stripes will not be visible, and the patient will just see an empty gray field (C). The machine will have to then increase contrast of the stripes for the patient to see them (D)*

This instrument appears to be a very useful for glaucoma testing since it is fast, simple to use and may even be more sensitive than standard perimetry for detecting early glaucoma. The full threshold test takes only a few minutes. The instrument is small and easily transportable and the manufacturer claims that you can test the patient with up to 3 diopters of uncorrected refractive error.

PSYCHOPHYSICAL METHODOLOGY

(Schwartz, 2004 Ch. 11)

Vision scientists and optometrists are interested in evaluating visual performance. Familiar examples of clinical vision tests include:

- Spatial resolution limit tested by Snellen visual acuity
- Increment threshold tested by static automated perimetry
- Dark adaptation tested by the photostress test
- Contrast sensitivity by the Frequency Doubling Perimeter or Matrix
- Colour vision tests

FREQUENCY DOUBLING PERIMETRY (CONT.)

Q. Why is it so important to be able to assess visual performance?

A. When testing performance in any field, we often try to determine the limits of performance. For example, when describing the performance of a sports car, you are not so interested in how well it cruises, but how fast it can go at full power. You probably would not choose the winner in a bench press contest by how well he/she lifts during routine training, but by the maximum weight he/she can lift. Similarly, when testing vision, we usually try to test the extremes of visual performance and this requires the measurement of thresholds. For example, the:

- Smallest letter
- Minimum contrast
- Dimmest light
- Minimum time for recovery
- Smallest difference

All of these tasks measure a person's perception of some physical stimulus. This falls within the branch of science known as psychophysics. An important basic concept in psychophysics is the idea of a **threshold**, and scientists have developed sophisticated techniques to measure thresholds.

THRESHOLDS

In the case of vision, the word "threshold" implies that there is some clear-cut stimulus magnitude, which separates seeing and non-seeing (Schwartz, 2004 Fig. 11-1B). However, as you may recall from some of our labs, it can be very difficult to determine an exact threshold. In addition, the estimate of the threshold may vary from moment to moment.

What would happen if you tried to measure a visual detection threshold, and you repeated an experiment many times? For example, you would preset the stimulus intensity at some low level and see if the person detects it. If you repeated the experiment many times, you would probably find that sometimes the person sees the stimulus, but sometimes not. For very low stimulus levels, the person might detect the stimulus only, for example, 10% of the time. With slightly higher levels of intensity, the person would detect it more, for example 50% of the time, but not every time. Finally, if the intensity is set high enough, the person would be able to see it every time it is presented. If you plot the percent detection as a function of stimulus intensity, you would probably get a curved function like that shown in Schwartz, 2004 Fig. 11-1C. It shows that, rather than a clear-cut threshold, there is an intensity range over which the person's probability of detection gradually increases from zero percent to 100%.

When plotting the frequency of detection (y-axis) as a function of stimulus intensity (x-axis), for many psychophysical experiments, the data plot looks like an S-shaped curve. This type of a plot is known as a psychometric function. The S-shape of the function is referred to as an ogive curve, which is a cumulative normal distribution.

Q. Why do you think that many psychophysical experiments yield data that fits a cumulative normal distribution?

A. _____

Q. Why is there a gradual increase in probability of detection, instead of a clear-cut threshold? (See Schwartz, 2004 p. 239, fifth paragraph)

A. When testing thresholds, the magnitude of the neural response to the stimulus is usually so weak that it is just barely larger than the background random noise in the neurons. In order to be seen, the neural response must exceed the background noise; since the background noise is variable, the neural response required at any moment to detect the stimulus will also vary. Over time, the magnitude of the background noise will have some mean value with a probability distribution for values above and below the mean. If the probability distribution is a normal distribution, the psychometric function will have an ogive shape

FECHNER'S TECHNIQUES FOR MEASURING THRESHOLDS

Until about 150 years ago, knowledge about thresholds was limited and based largely on speculation rather than on well-designed scientific studies. In the 19th century, two German scientists, **Weber** and then **Fechner**, began to develop scientific techniques specifically designed to study perception (Fig. 30-4).

Ernst Weber (1795-1878), a physiologist and professor at the University of Leipzig, tried to determine the minimum weight increment added to a starting weight that a person could feel. He found that as the starting weight became heavier, a greater increment was required for the person to detect a difference. However, when expressing the difference as a fraction of the starting weight, it was a constant fraction over a large range of weights (Weber fraction).

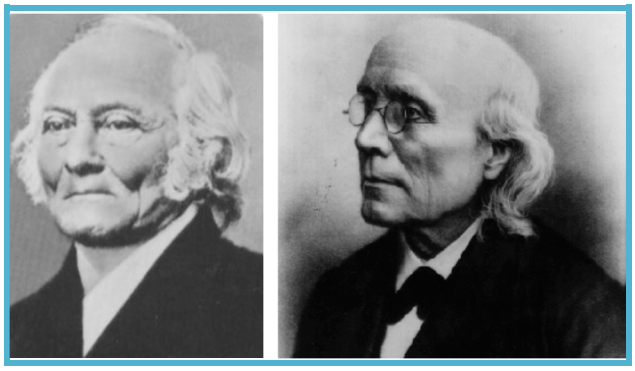

Figure 30-4: *Ernst Weber (left) and Gustav Fechner (right)*

Gustav Fechner (1801-1887) was a physicist who studied sensory responses to physical stimuli. He tried to analyze and predict perceptual responses based on mathematics and physics. His famous book entitled, Elemente der Psychophysik (Elements of Psychophysics) in 1860, and his work in perception established the scientific field of psychophysics.

Quoting from the Grolier's encyclopedia, 1994:

> *Although Fechner's Psychophysik is well over a century old, it still provides the basis for modern psychophysics. First, it systematized the notion of sensory thresholds. The absolute threshold is the smallest amount of stimulus energy necessary to make that stimulus detectable. The difference threshold (also called the just-noticeable difference) is the minimum amount of energy that must be added to a stimulus to make a detectable change. Second, Fechner's book established methods for determining these thresholds*.

Fechner developed the three main methods for measuring thresholds:

- Method of constant stimuli
- Method of limits
- Method of adjustment

Each method consists of an experimental procedure and a mathematical analysis procedure.

SELECTED READING/REFERENCES

- Schwartz SH. **Visual Perception - A Clinical Orientation, 3rd Edition**. Appleton & Lange, Stamford, Connecticut, 2004
- **The New Grolier Multimedia Encyclopedia**, Grolier Electronic Publishing. 1994
- http://www.meditec.zeiss.com/