APPROACHES TO VISION SCIENCE

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THIS CHAPTER WILL INCLUDE A REVIEW OF:

- Visual processes
- Approaches to studying vision
- Visual fields

VISUAL PROCESS

Our eyes work so well most of the time that we usually take vision for granted and have little appreciation for the complexity of the visual process. Yet, even after centuries of study, there are many aspects of human vision that we still do not understand.

In the optics curriculum, you learned how the eye functions as an optical instrument, and we began this section with a review of optical aberrations and formation of the retinal image. Doctors and patients often assume that good optics equals good vision, but optics alone do not provide vision. Optics are just the first step in the **visual process**. After formation of the retinal image, photoreceptor cells (the rods and cones) in the retina transform the retinal image into electrical signals that are relayed to the brain for processing. This is illustrated in Figure 3.1 below, which compares the human visual system to a digital video editing system.

While a video image sensor (electronic chip) inside the camera passively receives the optical image and outputs an electrical signal to the computer for processing, the human visual system begins to process the image *inside the retina, even before sending it to the brain*. Therefore, the signal that the brain receives is not an exact 1:1 representation of the optical image focused on the retina. In the rest of this chapter we will mainly study how the visual process works between the retina and brain; that is, the part of the process that begins after formation of the optical image on the retina.

VISUAL PROCESS (CONT.)

(a): *Optical image capture* ***(b):*** *Data transfer* ***(c):*** *Image processing and visualization*

Figure 3-1*: A man-made digital video system has similarities to the human visual system, but it is far less complex, less compact and less responsive than our visual system. (a) The video system consists of a digital video camera (similar to the eye) that captures an optical image on an electronic chip (similar to the retina), which converts the optical image to an electronic signal. (b) The electrical data must then be transferred over a Firewire or USB cable (similar to the optic nerve and visual tracts) (c) to a computer (like the brain) for processing and visualization*

APPROACHES TO STUDYING VISION

ANATOMICAL APPROACH

Using anatomic or histological dissection of the eye, optic nerve, visual cortex and other tissues, we can study how the visual system works.

Example 1: By measuring the curvature of the cornea, its structure, transparency and relationship to the rest of the eye, we can understand how it functions as the primary lens of the eye's optical system.

Example 2: By studying the decussation (crossing from one side of the brain to the other) of nerve fibers from the nasal retina at the optic chiasm we can learn how information from the right and left fields are segregated to opposite sides of the brain.

NEUROPHYSIOLOGICAL APPROACH

Many important studies of the retina, the lateral geniculate nucleus, or the visual cortex use electrodes to record the electrical activity of neurons in response to a stimulus located in certain parts of the visual field.

Example 1: By recording the electrical activity of retinal neurons, you can learn that ganglion cells respond to stimuli with action potentials, but the rods and cones respond with hyperpolarization of their electrical charge.

Example 2: Dr. Schwartz (Ch. 1, p. 2) mentions a technique now being used to study neurological activity called brain imaging. A scientist monitors metabolic activity of the brain while the subject performs a specific task. For example, positron emission transverse tomograms (PET) can monitor blood flow in the brain and detect increased activity as the subject observes a moving target. By this technique, scientists have been able to identify the motion-processing center in the brain.

APPROACHES TO STUDYING VISION (CONT.)

PSYCHOPHYSICAL APPROACH

This approach studies the relationship between a certain physical stimulus and its perception. Psychophysical experiments have been used to determine thresholds (smallest perceivable magnitude of a stimulus) for certain aspects of visual perception, such as the dimmest light, lowest contrast, smallest letter or smallest motion displacement you can see. There are several important advantages to using psychophysical, rather than anatomic or neurophysiological methods to study vision.

- Psychophysical techniques are non-invasive; it is not necessary to penetrate or damage the biological tissues.
- They enable you to study the visual system as a whole, without completely understanding the internal details of how it works. In effect, the visual system is treated like a 'black box'.(Fig. 3-2)

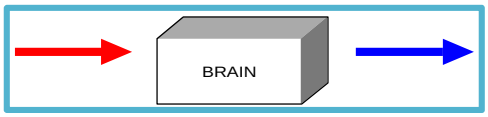

***Figure 3-2**: Psychophysical methodologies treat the visual system like a black box and record the response of the entire visual system to some physical stimulus. We don't need to understand how everything works inside the box, but we understand what it does. (Modified from Schwartz Fig. 1-1)*

APPROACHES TO STUDYING VISION

Much of our knowledge of the human visual system depends on psychophysical research. Psychophysical and neurophysiological research go hand-in-hand; findings from one type of research can generate new ideas for research in the other field. Also, many of our clinical tests use psychophysical techniques to assess visual performance and ocular health. For example, optometrists are very interested in early diagnosis of glaucoma, since it is a leading cause of blindness, and appropriate, timely treatment can preserve vision. We can test for early glaucomatous changes using an anatomic approach, for example by using the GDx device (Fig. 3-3 left, middle), and/or by using a psychophysical method, such as visual field testing (Fig. 3-3 right).

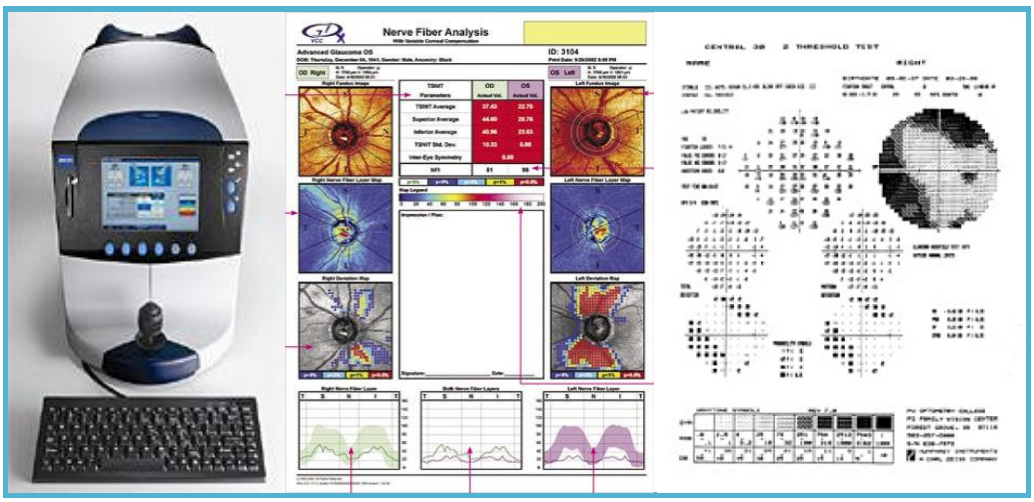

***Figure 3-3:**The GDx (left) provides digital images and computer analysis of the optic nerve head (middle),while the printout from a visual fields test shows were the patient's visual sensitivity has decreased (right)*

Q. What other clinical tests use a psychophysical method to evaluate the visual system? Which tests don't?

VISUAL FIELDS

Detailed visual field testing is very important in the management of glaucoma and other diseases affecting the visual system. In order to obtain accurate, repeatable, clinically useful data, the visual fields test must be well designed. When making the Humphrey Visual Field Analyzer, scientists and engineers had to consider many factors such as:

- Which visual function should we be testing to see whether or not the person is losing vision?
- Visual acuity, colour perception, detection of low contrast, detection of a light? They chose to use the detection of a spot of light.
- How big should the spot be? Should it be the same size in all parts of the visual field?
- What shape should the spot be?
- What color should it be?
- How bright should it be?
- Should you change target luminance from high to low, or start low and go high?
- What color should the background be?
- What should the background intensity be? This affects the level of light adaptation.
- How should you vary visibility when testing for threshold? Vary target size or brightness?
- What test distance should you use?
- Should you use a static or moving stimulus?
- How long should you expose the stimulus to the patient?
- In what order should you present the stimuli?
- At what retinal locus should you present it?
- How many times should you present it?
- How do you analyze variable responses?
- Should the patient be dilated or undilated? Does pupil size make a difference?
- Does the patient need to be wearing his/her spectacle prescription?
- What psychophysical procedure should you use to measure the thresholds?

There are many details that a scientist or doctor must consider when measuring visual thresholds. In order to know how to design a useful visual test, you must have a good understanding of the visual system and how we see. This is one of the purposes of this course.

Table 3.1 below summarizes the average extend of the visual field in the four cardinal directions, superior, nasal, inferior, temporal (SNIT) from lab experiments of Prof Thomas Salmon. For comparison, textbook values are also listed

Table 3-1: *Maximum extent of the visual field in degrees*

	SUPERIOR	NASAL	INFERIOR	TEMPORAL
THIS YEAR MEAN	43 ±7	57 ±3	67 ±4	86 ±4
LAST YEAR	46 ±12	54 ±3	66 ±4	86 ±5
TEXTBOOK VALUES	60	60	75	100
SIMPLIFIED VALUES	50	60	70	90

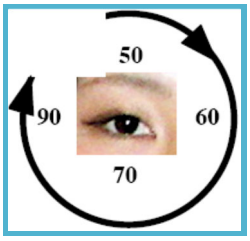

Figure 3-4: *The extent of the normal monocular visual field*

SELECTED READING/REFERENCES

- Schwartz SH. **Visual Perception - A Clinical Orientation, 3rd Edition**. Appleton & Lange, Stamford, Connecticut, 2004