INTRODUCTION TO SPATIAL VISION

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THIS CHAPTER WILL INCLUDE A REVIEW OF:

- Spatial vision
- Basic stimulus used to study spatial vision

SPATIAL VISION

Vision is a complex process, but it can be broken down into sub-processes or discrete functional areas. For example:

- Visual adaptation
- Colour vision
- Temporal vision
- Motion perception
- Depth perception
- Binocular vision

Spatial vision is the study of how we perceive images without regard to colour, movement, time, etc. We are not concerned with how the optics of the eye (cornea, lens, etc.) formed the image—we will concentrate our attention on the image itself and how it is processed. For simplicity, we will ignore colour and assume that it is monochromatic. For convenience, we will make our images monochromatic by removing colour and using just black and white photos (even though, white is not monochromatic). We will use only static non-moving images.

All images, whether they are photographs, paintings, prints, images on a computer monitor or the retinal image, are made up of tiny picture elements or pixels. That is, any image may be considered an array of tiny dots. Usually the points making up an image are so small that they cannot be resolved individually, but blend together to form continuous tones of the whole scene. The image taken by a 9 mega-pixel digital camera contains 9 million tiny squares, each of which is a picture element or “pixel”.

Figure 11-1 shows how individual pixels make up a digital image. The entire picture is a rectangular area that contains many pixels, each of which has some light intensity value (between pure white and pure black). As far as the computer is concerned, each pixel has some numerical value and the monitor displays some luminance level for each pixel.

SPATIAL VISION (CONT.)

Figure 11-1: *Example of a spatial image and close up of pixels in the image*

Several years ago consumer digital cameras took 3 mega-pixel images. Today 12 mega-pixel cameras are common. The number of mega-pixels continues to increase. The highest resolution digital camera this authour has found is the Swedish-made Hasselblad H4D-200MS (Fig 11-2). It incorporates a shifting 50 mega-pixel sensor that produces 200 mega-pixel images! The Hasselblad web site (http://www.hasselblad.com/products/h-system/h4d-200ms.aspx) describes this camera thus:

> *The Hasselblad H4D-200MS's amazing 200 million-pixel resolution brings unprecedented detail and resolution to your still life and studio photography. The H4D-200MS is the ultimate tool for any photographic application where the absolutely highest degree of resolution is required, from demanding car photography to high-end product photography and museum archiving and reproduction*.

Figure 11-2: *The Hasselblad H4D-200MS professional digital camera.*
The camera body alone costs $36,000. Various lenses are available at additional cost

Even the apparently smooth brush strokes of a painting are made up of tiny particles. If you examine a painting under a microscope, you will find that the dried paint contains tiny pigment particles that give the paint its particular colour.

The eye's optical system forms images on the retina. What is actually on the retina? The retinal image is just a light distribution with varying degrees of brightness at different locations. What does each retinal photoreceptor see? It simply senses the retinal illuminance in one tiny part of the image. Therefore photoreceptors (via ganglion cells) contribute pixels to the complete image like the pixels in a digital photograph.

The image that the retina relays to the brain can therefore be thought of as a two-dimensional data array, which corresponds with the varying light intensity values contained in the retinal image. As we will learn later, the brain processes this data similarly to the way computers process two-dimensional data arrays. This will be an important part of our study of spatial vision.

The most common optometric test, Snellen visual acuity, measures one aspect of spatial vision. In this test, we determine how well patients see standardized images, specifically, how well they see high contrast black letters on a white background. Tests of spatial vision are important because:

- They allow us to evaluate visual performance (as in a physical examination)
- Guide us in measuring the subjective refractive error
- Help us diagnose diseases of the visual system

SPATIAL VISION (CONT.)

Many eye diseases can be diagnosed because of the way they affect spatial vision and, in fact, the main reason we are concerned about most eye diseases is because they may degrade spatial vision.

Q. What is the most common cause of poor spatial vision (i.e., poor visual acuity)?

A. _____

Q. Can you think of some eye diseases that do NOT affect vision?

A. _____

BASIC STIMULUS USED TO STUDY SPATIAL VISION

Visual acuity is one kind of spatial vision test, but it provides only limited information. In some cases, in spite of having a visual acuity of 20/20 some patients complain of poor vision. Snellen visual acuity tests spatial resolution; that is, the limit of the visual system to see small details. Basic features of a standard Snellen chart include:

- Stimuli composed of letters
- Black on white
- High contrast
- Several discrete sizes

If a patient can see the small, high contrast letters on a Snellen chart, we often assume that he/she can see everything well. This assumption however is sometimes incorrect because high contrast letters do not represent everything a person may see. Most of the images we see are not black high contrast letters on a white background. There are an infinite number of variations in the images we see, including differences in:

- Size
- Shape
- Pattern
- Brightness
- Contrast

It is impossible to completely evaluate how an eye sees everything since there are too many variables. Fortunately, all images can be broken down into fundamental components, and if we understand how the eye responds to these basic components, we can know how well it will see any image. This assumes that the visual system is a linear system, that is, the response of the eye to an image is just the sum of its response to each of the components.

Q. What are the fundamental components, that is, the basic buildings block of all images?

A. Sine wave gratings. One example of a vertical high contrast sine wave grating is shown in Figure 11-3.

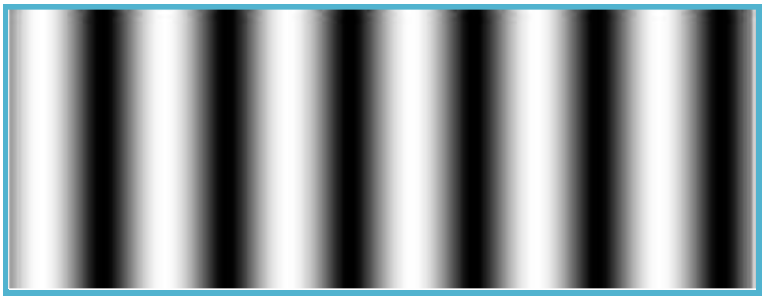

Figure 11-3: *Example of a vertical, high contrast sine wave grating*

SUMMARY

- Spatial vision is the study of how the visual system processes images
- An image is a distribution of intensity values across a two-dimensional surface
- There are many reasons that we are interested in spatial vision
- The most common spatial vision test is Snellen visual acuity

This leads us to the fascinating topic of Fourier analysis, which we will consider next.