Spatial Frequency Theory

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Spatial-Frequency Theory

Hubel and Wiesel barely had time to place their Nobel Prizes on their mantel before an important qualification to their theory was proposed. DeValois, DeValois, and their colleagues (see DeValois & DeValois, 1988) proposed that the visual cortex operates on a code of spatial frequency, not on the code of straight lines and edges hypothesized by Hubel and Wiesel.

In support of the **spatial-frequency theory** is the observation that visual cortex neurons respond even more robustly to sine-wave gratings that are placed at specific angles in their receptive fields than they do to bars or edges. A **sine-wave grating** is a set of equally spaced, parallel, alternating light and dark stripes that is created by varying the light across the grating in a sine-wave pattern—see Figure 7.22. Sine-wave gratings differ from one another in frequency (the width of their stripes), amplitude (the magnitude of the difference in intensity between the dark and light stripes), and angle.

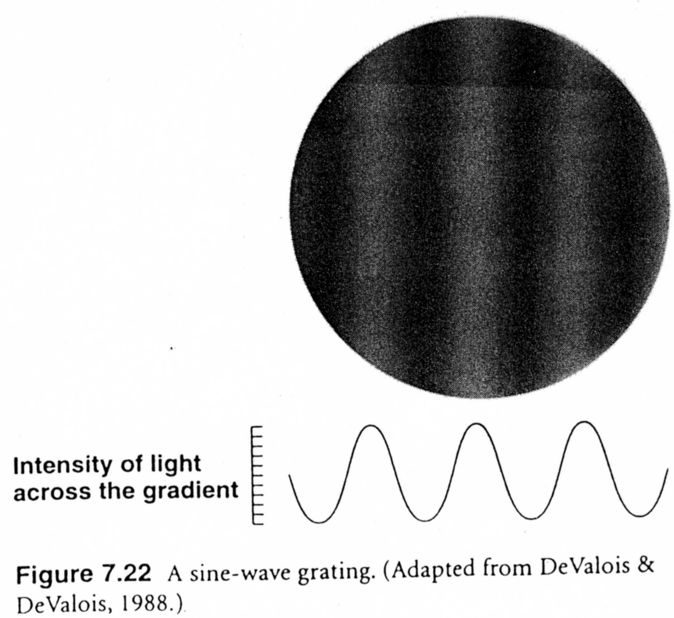
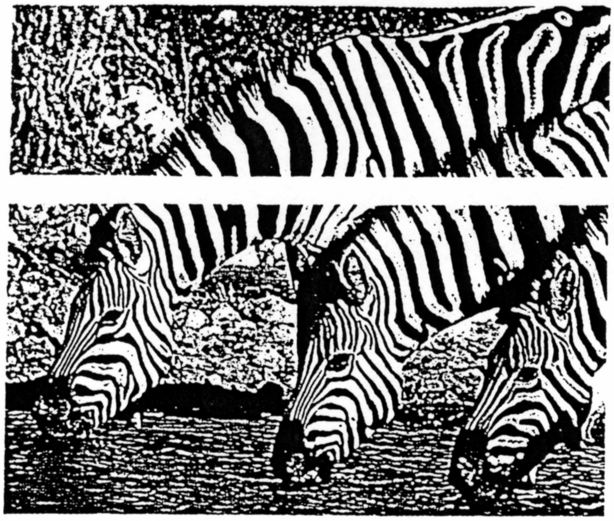


Figure 7.22 A sine-wave grating. (Adapted from DeValois & DeValois, 1988.)



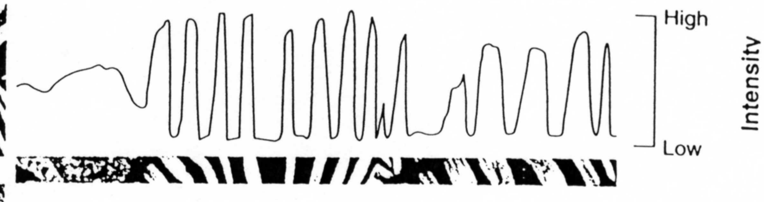


Figure 7.23 A visual stimulus represented by the plotting of changes in the intensity of light along slices running through it. For example, plotted here are the changes in intensity along one slice of a scene that would interest any hungry lion.

The spatial-frequency theory is based on two physical principles. The first is that any visual stimulus can be represented by a plotting of the intensity of light along lines running through it (see Figure 7.23). The second is that any curve, no matter how irregular, can be broken down into constituent sine waves by a mathematical procedure called **Fourier analysis** (see Figure 7.24).

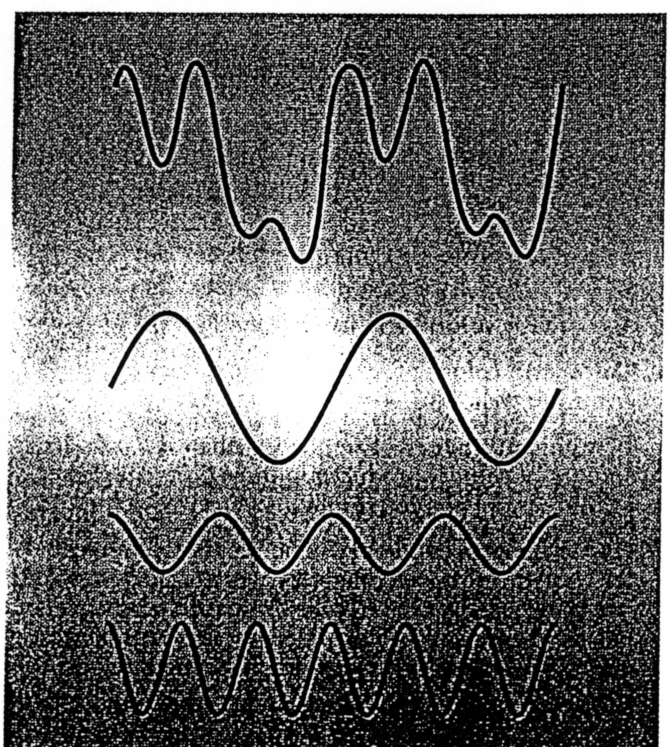


Figure 7.24 Any wave can be broken down into component sine waves by Fourier analysis. For example, the complex wave at the top is the sum of the sine waves shown beneath it. (Adapted from DeValois & DeValois, 1988.)

The spatial-frequency theory of visual cortex function (see DeValois & DeValois, 1988) is that each functional module of the visual cortex performs a sort of Fourier analysis on the visual pattern in its receptive field; the neurons in each module are thought to respond selectively to various frequencies and orientations of sine-wave gratings. When all of the visual cortex neurons that are influenced by a particular scene respond together, a perception of the scene is created by the summation of its various constituent sine-wave gratings.

The primary support for the spatial-frequency theory is that primary visual cortex neurons are more responsive to sine-wave gratings than they are to straight lines. Most neurons in the primary visual cortex respond best when a sine-wave grating of a particular frequency is presented at a particular angle in a particular location of the visual field. However, straight-edge stimuli, which have been used in most studies of visual cortex neurons, can readily be translated into component sine-wave gratings of the same orientation. Thus the research on spatial-frequency detection by visual neurons extends and complements previous research rather than refuting it.

Spatial-frequency theory. The theory that the visual cortex encodes visual patterns in terms of their component sine-wave gratings.

Sine-wave grating. An array of equally spaced, parallel, alternating dark and light stripes that is created by varying the light across the grating in a sine-wave pattern.

Fourier analysis. A mathematical procedure for breaking down a complex wave form (e.g., an EEG signal) into component sine waves of varying frequency.