Medical Neuroscience | Tutorial Notes

Visual System: Central Visual Processing

MAP TO NEUROSCIENCE CORE CONCEPTS[1]

NCC1. The brain is the body's most complex organ.

NCC3. Genetically determined circuits are the foundation of the nervous system.

NCC7. The human brain endows us with a natural curiosity to understand how the world works.

LEARNING OBJECTIVES

After study of the assigned learning materials, the student will:

1. Describe the distribution of the axons of retinal ganglion cells to major processing centers in the forebrain and brainstem.
2. Discuss the major receptive field properties of V1 neurons.
3. Discuss the functions of parietal and temporal "extrastriate" visual pathways.

TUTORIAL OUTLINE

I. Functional organization of V1

   A. the primary visual cortex (V1) is also known as the "striate cortex"

      1. "striate" because of a prominent band of white matter (stria of Genari) that runs through the middle of cortical layer 4, giving this region of the cortex a distinctive appearance

      2. Brodmann recognized this cortical region as Area 17

   B. neurons in V1 show response properties that are not elaborated at previous stages of neural processing (some of the best examples of "computational" functions of the cerebral cortex are known from neurophysiology studies of V1)

   C. receptive field properties of cortical neurons in V1

      1. V1 neurons respond best to moving edges of light and shadow

         a. small spots of light that evoke vigorous discharges in retinal ganglion cells and LGN neurons are not very effective in driving V1 neurons

         b. V1 neurons respond best to a moving edge that is within a narrow range of orientations in space (e.g., horizontal, vertical, oblique); this property is known as **orientation selectivity** (see **Figures 12.8, 12.10 & 12.12**[2])

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[1] Visit **BrainFacts.org** for *Neuroscience Core Concepts* (©2012 Society for Neuroscience) that offer fundamental principles about the brain and nervous system, the most complex living structure known in the universe.

c. many V1 neurons respond best when a particular orientation moves in only one direction (e.g., a vertical edge moving from right to left); this property is known as **direction selectivity**

2. ocularity

a. the retinal inputs to the LGN terminate in separate layers, so that individual neurons in the LGN are **monocular**

b. the projections of these monocular LGN neurons to layer 4 of V1 remain segregated within layer 4 (see **Figure 12.13**)

(i) LGN afferents terminate in alternating bands or columns in layer 4, called **ocular dominance columns**

(ii) monocular neurons in the ocular dominance columns of layer 4 converge onto neurons in layers 2 and 3, where **binocularity** is first established in the visual pathway

3. stereopsis

a. because neurons in V1 (after layer 4) are binocular, neural signals are generated that take advantage of the fact that, for near objects, the lines of sight of the two eyes are slightly different (see **Figure 12.14**)

b. for all objects near or far from the plane of fixation, images of the objects fall on "non-corresponding" locations in the two retinas

c. many cells in V1 (and in other visual cortical areas) are sensitive to such **retinal disparities**

d. these neural signals are the basis of **stereopsis**, which provides one important cue about the location of objects in depth (this computational property in V1 is necessary for the 3D effect in visual media!)

e. other cues about depth include motion parallax and size constancy

D. parallel pathways

1. there are distinct anatomical and physiological classes of retinal ganglion cells, each of which is organized into ON and OFF center-surround subtypes

2. three important classes are the **M, P** and **K ganglion cells** (see **Figure 12.15**)

a. M ganglion cells have larger cell bodies, dendritic arbors and axons compared to P cells; thus, M cells have larger receptive fields and their axons conduct faster than P cells

b. M cells respond transiently (phasically) to visual stimuli, while P cells show a more sustained (tonic) response

c. P cells are sensitive to color, while M cells are "color-blind"

(i) receptive field centers and surrounds of P cells are driven by different types of cones (e.g., red and green)

[2] Figure references to Purves et al., *Neuroscience, 5th Ed.*, Sinauer Assoc., Inc., 2012. [click here]

(ii) P cells respond best to differences in color striking their centers and surrounds (e.g., red center and green surround)

(iii) the centers and surrounds of M cells are both driven by different types of cones

3. M and P ganglion cells terminate in different sets of layers in the LGN, the **magnocellular** ("large cell") **layers** (layers 1 and 2) and **parvocellular** ("small cell") **layers** (layers 3-6), respectively

4. In V1, the inputs from magnocellular and parvocellular LGN neurons are partially segregated into functional "streams" of processing, a **magnocellular stream** for detecting quickly moving stimuli and a **parvocellular stream** for detailed examination of form (acuity) and color (see below)

5. there are also **K ganglion cells** that project to small clusters of "konio" cells that reside between the major laminae of the LGN; this so-called **koniocellular pathway** is conveyed to V1 in projections that terminate in patches in layer 2/3 (an exception to the thalamus-to-layer 4 rule)

VIII. Extrastriate Visual Cortex

A. beyond V1 (= "striate cortex"), there are multiple areas in the occipital, parietal and temporal lobes that process visual information (see **Figure 12.16-12.18**)

B. these areas are arranged into two broad functional pathways that feed visual information from V1 into associational cortical areas in the parietal and temporal lobes (see **Figure 12.18**):

1. **dorsal** or **lateral parietal pathway**: responsible for spatial aspects of vision, such as the relationships between objects and ourselves and the movements of objects (including ourselves) through the environment (i.e., "**where?**")

2. **ventral** or **inferior temporal pathway**: responsible for high-resolution form vision, color processing and object recognition (i.e., "**what?**")

C. although both pathways receive input from both parvocellular and magnocellular streams in V1, there tends to be more 'magnocellular' influence on the parietal pathway and more 'parvocellular' influence on the temporal pathway

D. damage to cortical areas in the parietal and temporal pathways produce different visual deficits, such as the selective loss of color vision or an inability to recognize a familiar face (ventral temporal pathway), or the loss of motion perception (parietal pathway, involving lesions in visual areas MT/MST in particular)

STUDY QUESTION

The **primary visual cortex** (V1) performs a number of important functions in visual encoding and visual perception. However, which of the following functions is best attributable to higher-order visual cortical areas beyond V1?

A. the recognition and identification of complex visual stimuli, such as human faces
B. provision of neural input to the parietal and temporal visual processing streams
C. binocular vision; i.e., bringing together in a binocular pathway the neural signals derived from the two eyes
D. stereopsis; i.e., computations about depth based on slight differences in the views of the two eyes
E. the analysis of simple elements of visual stimuli, such as the orientation of contours, their direction of motion, and their location in visual space