## Eye Movements - High Level March 24, 2004 J. Schall

#### **READING:**

Schall JD, Thompson KG, Bichot NP, Murthy A, Sato TR (2003) Visual processing in the frontal eye field. In *The Primate Visual System*. Edited by J Kaas, C Collins. CRC Press, Boca Raton, FL. Pages 205-230.



The organs which concur in muscular contraction are the brain, the nerves and the muscles. We have no means of distinguishing in the brain those parts which are employed exclusively in sensibility and in intelligence from those that are employed alone in muscular contraction. The separation of the nerves into nerves of feeling and nerves of motion is of no use: this distinction is quite arbitrary. C. Magendie (1824) *An Elementary Compendium of Physiology* 

# Brainstem Saccade Generator



How does the brain choose where to look?

How does the brain control when to move?

How does the brain correct errors?





Superior colliculus

Visual input from retina and visual cortex Neurons have receptive fields



Expanded view

Responses of some cells enhanced if stimulus is target



#### Superior colliculus There is map of the visual field



Superior colliculus

Deeper layers have neurons active before saccades Innervate saccade generator circuit in brainstem "Movement fields" are broad



#### Superior colliculus Population coding of saccade direction





EPANAL.

In the 19th century David Ferrier discovered that electrical stimulation of the frontal lobe around the arcuate sulcus evoked movements of the eyes.

He called this the Frontal Eye Field



The frontal eye field projects to ocular motor structures to produce movements of the eyes and is reciprocally connected with extrastriate visual areas.

Frontal Eye Field



SC & FEF neurons select the target when it can be found automatically.



Thompson, Hanes, Bichot, Schall (1996) Perceptual and motor processing stages identified in the activity of macaque frontal eye field neurons during visual search. *Journal of Neurophysiology* 76:4040-4055.

### Gaze is guided by knowledge as well as vision



Remember the location of the objects in the room.



Remember the ages of the people in the room



Yarbus, A. L. 1967 Eye Movements and Vision. New York: Plenum Press.

FEF neurons also select the target when knowledge must be combined with vision.



Bichot, N.P. & Schall, J.D. (1999). Effects of similarity and history on neural mechanisms of visual selection. *Nature Neuroscience* 2:549-554.

The time of target selection does not specify when gaze will shift. This means another neural process must intervene between target selection and saccade initiation and that process is of randomly variable timing.



# The control of movement can be studied with the countermanding (stop signal) task

**NO STOP SIGNAL Trials** 



## Countermanding paradigm: Race model



Logan, G.D. & Cowan, W.B. (1984) On the ability to inhibit thought and action: A theory of an act of control. *Psychological Review* 91:295-327.

Hanes DP and Schall JD (1995) Countermanding saccades in macaque. Visual Neuroscience 12:929-37`

### Frontal Eye Field (as part of a network!) Controls when gaze shifts



### Frontal Eye Field (as part of a network!) Also controls whether gaze shifts

Movement neuron



Hanes, D.P., W.F. Patterson, J.D. Schall (1998) The role of frontal eye field in countermanding saccades: Visual, movement and fixation activity. *Journal of Neurophysiology* 79:817-834.