Lecture 3/3/15 – Motor Control

**Q:** *What is the ratio for motor cortex neurons synapsing to alpha motor neurons? What about the ratio for alpha motor neurons synapsing to a muscle?*

**A:** Alpha motor neurons project out of the ventral horn of the spinal cord and have a 1:1 ratio to muscles, but connect to many different fibers of the same type. Since only one alpha motor neuron connects to only one muscle, the muscle can only be either slow twitch or fast twitch.

In convergence, many motor cortex neurons connect to a single alpha motor neuron. In divergence, one motor cortex neuron connects to many alpha motor neurons.

**Muscle Synergies by Different Spinal Tracts**

<table>
<thead>
<tr>
<th>Spinal Tract</th>
<th>Motor Control</th>
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</table>
| Corticospinal | ❖ Neurons from the primary motor cortex have axons that travel to the spinal cord  
               | ❖ Directly related to immediate actions  
               | ❖ Motor cortex influences the musculature |
| Vestibulospinal | ❖ Relays sensory information from the otolith organs and semicircular canals  
                 | ❖ Related to reflexive movements |
| Reticulospinal | ❖ The medulla, pons, and midbrain make up the reticular formation (net-like structure)  
                 | ❖ Contains gigantocellular neurons that are interconnected with each other at the core of the brain stem  
                 | ❖ Contains the mesencephalic locomotor region that produces the fixed action pattern for walking when activated |
| Rubrospinal | ❖ Originates in the red nucleus of the midbrain  
             | ❖ Receives output from the cerebellum for fine motor control |
**Q: What experiment did Georgopoulus do to prove his idea about motor neurons?**

**A:** Georgopoulus hypothesized that primary motor cortex neurons are not generating patterns that activate muscles, but instead are encoding targets for movements. He stated that the direction and speed you wish to move your muscles reflect the activity patterns of populations of neurons.

In the experiment, a monkey was trained to use a joystick to move its hand to a target that randomly appeared in a circular formation. Using the arm requires certain muscles, which all have different muscle synergies or patterns. Suppose this neuron had a preference for the East or left direction. The recorded activity of the primary motor cortex (M1) neuron will create a directional tuning vector in which it generates the largest amount of activity for its preference to the left direction. Therefore, the length of a vector reflects the amount of firing rate of the cell at that particular direction.

The left shows the directional tuning vector for a single M1 neuron that favors the left direction. This is different than a population vector.

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**Lecture 3/5/15 – Prefrontal cortex, Attention, Top-Down Processing**

**Indirect Activities of the Premotor Cortex**

<table>
<thead>
<tr>
<th>Role</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action mapping</td>
<td>✓ Primary motor cortex neurons firing for the present action</td>
</tr>
<tr>
<td>Action planning</td>
<td>✓ Premotor neurons firing before the performance of an action</td>
</tr>
<tr>
<td>Sequence dependent action mapping</td>
<td>✓ Premotor neurons firing for the specific order of an action sequence</td>
</tr>
<tr>
<td>Perceived actions</td>
<td>✓ Mirror neurons firing for some action that was perceived</td>
</tr>
</tbody>
</table>
**Q: How is working memory represented in the cue-delay and delay-action responses?**

**A:** Working memory is the type of short term memory that allows you to hold $7 \pm 2$ items or pieces of information in your head and “work” with them.

Working memory also represents a transition from plans to actions. In the experiment, a monkey is placed in front of a screen with a fixation cross. The monkey stares at the center of the screen where the cross is while a cue or stimulus appears on the side of the screen. The cue goes away and once the fixation cross disappears as well, the monkey’s task is to make a saccade (swift eye movement) to where the cue appeared. Prefrontal cortex neurons are recorded.

The cue-delay response of a neuron correlates to working memory that is needed to hold the information for the cue. The delay-action response of a different neuron correlates to working memory in retaining the necessary information to make the correct saccade after the delay.

**Q: How are the dorsolateral prefrontal cortex neurons represented in the cue-delay and delay-action responses?**

**A:** The dorsolateral prefrontal cortex neurons have firing properties related to abstract features, such as tracking time intervals. In the experiment, the monkey’s task is to press a key and associate the different colors of the cue for different time periods it must wait and hold the key before releasing it.

Some neurons fire to the onset of a cued time interval (cue-delay), while some neurons fire following the onset of the cue (delay-action).

**Q: Why is there an extra peak of activity during a behavioral episode or motor task?**

**A:** In the experiment, the monkey stares at a fixation point or cross and moves its eyes to each target that appears on the screen (T1, T2, etc.). The firing rate of the neurons increase or peak with each saccade because eye movements have different muscle synergies.

Suppose only four targets show up on the screen (T1, T2, T3, and T4). This means the monkey makes only four saccades and there should only be four “peaks” recorded from the dorsolateral prefrontal cortex neurons. However, that is not the case since there is a fifth peak. This final activity peak does not refer to the eye movements, but instead marks the end of a trial. That is why there is also an additional peak even to a task with just one saccade or target.
Q: How do the dorsolateral prefrontal cortex neurons actually “count”?

A: These neurons mark abstract features of motor tasks by associating an amount for “numerosity.”

To test this, an experiment similar to a delayed match-to-sample task displays an image with 1-5 dots. Suppose the trial displayed an image with 3 dots. The monkey fixates on the cross while the image with 3 dots appears then disappears on the screen, and then the task is followed by a delay period. During the test period, images with different numbers of dots appear and the monkey must make a choice from the sample that matches the image with 3 dots. The monkey therefore has to maintain a working memory for how many dots there were and what it has to do with them. Neurons also fire different patterns that represent their preferences for different numerosities.

Q: How does a monkey remember to perform a task in the order it appears?

A: The dorsolateral prefrontal cortex neurons map out action sequence categories. Three lights (for push, pull, and turn) flash four times in different combinations and are followed by a delay period. In the experiment, the monkey uses its working memory during the delay to remember the order of the lights, and then it must perform the actions in the order in which the indicated lights appeared.