Systems Bioengineering II

Exam 2

April 7th, 2014

Dr. Wang: 28 points
Dr. Young: 10 points
Dr. Connor: 16 points
Dr. Shadmehr: 46 points

Dr. Shadmehr:	**Q1____/2**	**Dr. Wang:**	**Q1____/5**
	Q2____/4		**Q2____/6**
	Q3____/5		**Q3____/11**
	Q4____/2		**Q4____/6**
	Q5____/10		
	Q6____/2	**Dr. Connor:**	**Q1____/8**
	Q7____/5		**Q2____/8**
	Q8____/2		
	Q9____/6	**Dr. Young:**	**Q1____/10**
	Q10____/4		
	Q11____/4	**Total:**	

You are reminded that you are under an Honor Code at Johns Hopkins. You are not permitted to use any of your own electronic equipment during the exam. All work on this exam must be entirely your own.

<u>You are not permitted to discuss this exam with anyone until the next day.</u>

Print Name: _____

Signature: _____
Please write your name on every page of the exam.

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Exam 2 Questions by Prof. Wang

Question 1 (5 points)
What is the physiological basis of our ability to hear different frequencies of sound?

Question 2 (6 points)

(a) [2 points] What is "phase-locking" of auditory nerve responses?

(b) [4 points] What is the source of this phase-locking phenomenon seen in the discharge of auditory nerve?

Question 3 (11 points)

(a) [5 points] Assume that an auditory nerve has a characteristic frequency of 100 Hz and that the cochlea is stimulated by a pure tone (frequency: 100 Hz, duration: 1 sec). Sketch the inter-spike interval histogram of this auditory nerve's responses. Please mark all axes.

(b) [6 points] Repeat the above question 3(a), but now let the characteristic frequency of the auditory nerve be 5,000 and 10,000 Hz, respectively, and the pure tone with frequency of 5,000 and 10,000 Hz, respectively. Sketch the corresponding inter-spike interval histograms (i.e. two separate ISI histograms).

Question 4 (6 points)
An English vowel /i/ can be represented by the auditory nerves in more than one way. What are the two ways that the auditory nerve uses to represent a vowel's spectrum?

Exam 2 Question by Prof. Young

Question 1 (10 points)

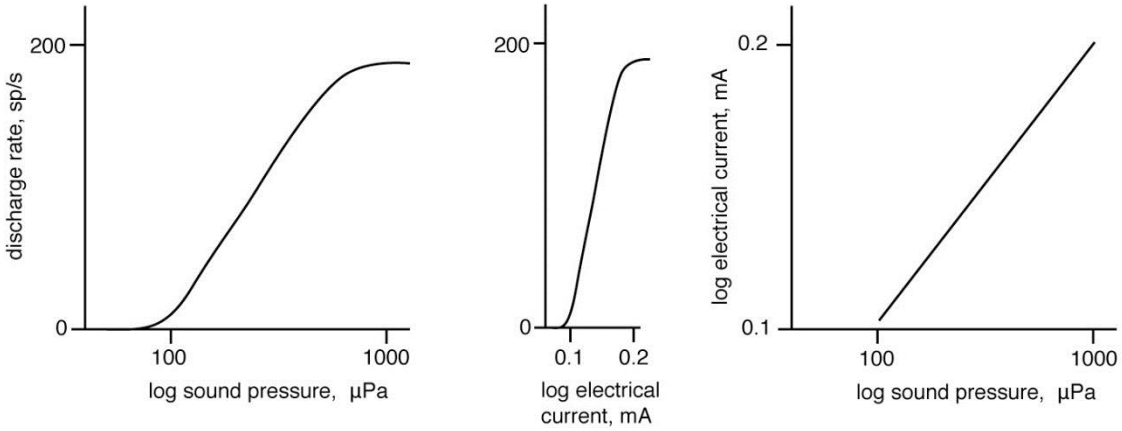
Part a) [6 points] Cochlear implants are used in patients that are missing the neural elements necessary to make the cochlea work. Would an implant work in a patient with the following conditions? Tell why or why not.

(1) No hair cells in the cochlea.

(2) No auditory nerve fibers in the cochlea.

(3) No eardrum or middle ear bones (necessary to get sound from the air into the cochlea).

Part b) [4 points] A problem in cochlear implants is that electrical current is a very strong stimulus for nerve fibers. The graphs below show how the discharge rate (Y-axis) produced in an auditory-nerve fiber varies with the strength of the stimulus (X-axis). For sound (left plot) the sound pressure evokes a rate that rises from minimum (0) to maximum (200 spikes/s) over about an order of magnitude increase in sound pressure (from ~100 to ~1000 μPa for this example). The middle plot shows the same curve for the rate produced by an electrical stimulus, as in a cochlear implant. Notice that the fiber is driven over its entire output range (0 to 200 spikes /s) for only a factor of 2 increase in the stimulus current.



The graph at right shows the necessary relationship between sound pressure (say at the microphone on the cochlear implant) and the electrical current strength in an electrode in the cochlea. NOTICE THAT STIMULUS STRENGTH IS PLOTTED ON LOG AXES IN ALL THREE PLOTS. The plot at right shows the input/output relationship of the electrical amplifier in a cochlear implant.

Which one of the following input/output relationships is needed for the amplifier described above? A and B are constants. Explain why.

(1) Current level = A*(Sound intensity) + B
(2) Current level = A*(Sound intensity)^B (i.e. sound intensity to the power B)
(3) Current level = A*exp(Sound intensity + B)

Exam 2 Questions by Prof. Connor

Question 1 (8 points)
This question is about signal polarity in the retina.
Part a) (4 points) Briefly explain why light absorption leads to a *decrease* in transmitter release by photoreceptor cells in the retina (rods and cones). (It is not necessary to outline the entire phototransduction pathway.)

Part b) (4 points) Explain how this decrease in transmitter release by a photoreceptor cell can lead to an *increase* in spike activity of an on-center retinal ganglion cell.

Question 2 (8 points)
Visual information is originally represented in retinotopic spatial coordinates, i.e. an eye-centered reference frame.
Part a) (4 points) The ventral, object-processing pathway of visual cortex transforms visual information into a different reference frame. What is this new reference frame, and why is this transformation useful for object vision?

Part b) (4 points) The dorsal visual pathway transforms visual information into other spatial reference frames. Name one such reference frame, and explain how it is useful for a dorsal pathway function.

Exam 2 Questions by Prof. Shadmehr

Question 1 (2 points)
The cashier at the local supermarket turns to you and, unexpectedly, gives you a beautiful smile. You are surprised, and delighted. When you saw the smile, what neurotransmitter was released in your brain? Which part of your brain is the major recipient of this neurotransmitter?

Question 2 (4 points)
You are at a wedding and a waiter approaches with a tray of drinks. He is holding the tray with one hand, and asks whether you'd like one. Consider two possibilities: 1) You reach out and pick up a drink. What is likely to happen to the tray? Why? 2) The waiter reaches and pick up a drink and hands it to you. What is likely to happen to the tray? Why?

Question 3 (5 points)
For each condition listed below, indicate which area of the brain may be damaged. If possible, indicate whether it is the left or right side of that structure.
(1 point) A mouse is dropped into a pool of water. There is a platform hidden, and its location is constant. Even after days of training, the animal does not learn the spatial location of the platform.

(1 point) The patient writes in exceedingly small letters.

(1 point) The patient holds a basket in one hand and holds a ball in the other hand. When she drops the ball into the basket, the basket slips out of her hand.

(1 point) When asked to copy a drawing of a clock, the patient copies only the right side.

(1 point) When given a tooth brush, the patient uses it to comb their hair.

Question 4 (2 points)
Describe two events that take place in the spinal cord in the hours following spinal cord injury.

Question 5 (10 points)
True or False (1 point each):

(a) In Polio, the number of muscle fibers in a given motor unit tend to be smaller than normal.

(b) For a given neuronal input to a muscle, force produced by that muscle tends to be larger at longer muscle length.

(c) When vibration artificially excites the spindle receptors on the biceps muscle, we have a sensation that our elbow is flexing.

(d) If in a split brain patient an image is flashed to the left of fixation, the patient will not be able to name that image, but will be able to draw that image with the left arm.

(e) With increased use, the proportion of slow type I fibers increases in a muscle.

(f) Golgi tendon organ afferent neurons respond to increased force in the muscle by increasing their discharge. They excite an inhibitory interneuron which in turn inhibits the motor neuron that goes to the same muscle.

(g) In the premotor cortex, cells represent the target of the movement with respect to fixation.

(h) Likely or unlikely: Activation of the pontine reticulospinal tract will inhibit leg muscles.

(i) Likely or unlikely: Suppose that you have asked a split brain patient to look at your nose (fixate). You raise your left hand, holding a pencil. You ask the patient to tell you what you are holding. She says she does not know.

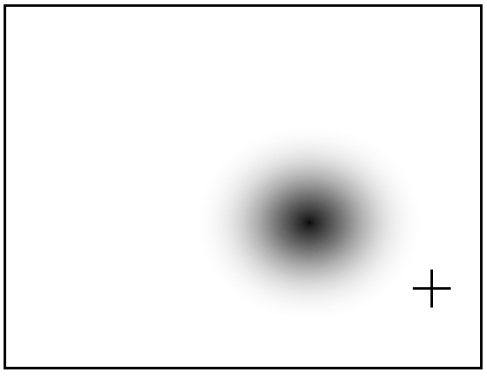
(j) Likely or unlikely: Cells in the posterior parietal cortex will discharge differently in the following two conditions: moving a lever against a heavy load vs. a light load.

Question 6 (2 points)
Name the four divisions of the spinal cord from rostral to caudal.

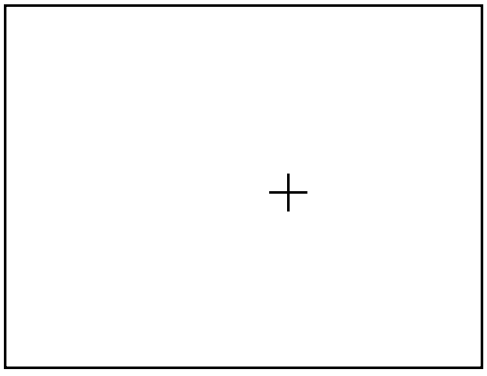
Question 7 (5 points)
You are working on a project to help restore some function to the hand of patients who have suffered spinal cord injury in the cervical regions, as is typical in automobile accidents where whiplash takes place. You will try to electrically stimulate the hand muscles so that they can form a grip. However, you need to give the patient a way to turn the stimulation on and off. You are considering two candidate approaches: in the first approach, you will implant a sensor in the shoulder so that raising it will turn the sensor on or off. In the second approach, you will implant a sensor on the bottom of the foot, so that tapping the foot will turn the stimulation on or off. Which is a better idea? Explain.

Question 8 (2 points)
A monkey is fixating a cross on the screen. A cell in the posterior parietal cortex that has a retinocentric receptive field discharges when a spot of light appears in the area shown below in **A**. The discharge is strongest in the area that is darkest in color. Now the monkey shifts his eyes to the new fixation point in **B**. Draw the region where the cell will have its receptive field.

A)



B)



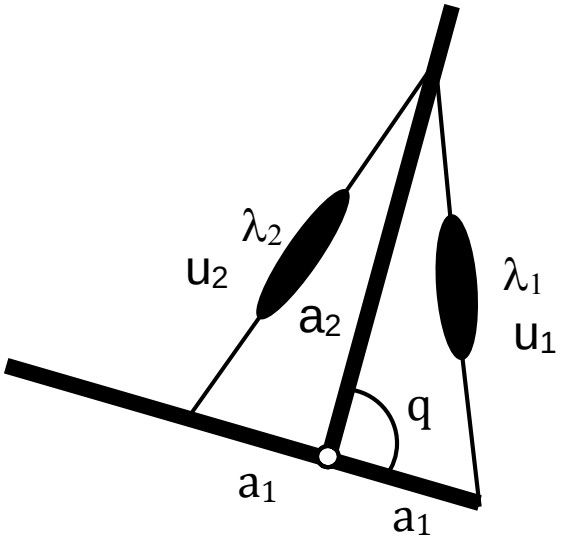
Question 9 (6 points)
A stroke has affected the hand region on the **right motor cortex** of a patient. She now relies solely on the unaffected arm. You suggest that she enrolls in a constrained motion rehabilitation program. When she enrolls, which arm will be constrained (left or right)? Why?

Question 10 (4 points)
A neuron in the posterior parietal cortex is sensitive to location of a visual stimulus on the retina, location of the eyes in the orbit, and location of the head on the shoulder.
Part a) [2 points] Suppose we keep the head and eye positions fixed and flash the visual stimulus along a line that goes through the center of the visual receptive field of the neuron. Plot the response of the neuron as a function of the distance of the visual stimulus to the center of the receptive field (you can assume the distance to go from -1 to 1).

Part b) [2 points] Now suppose that we move the fixation point to the left (so the eyes move to the left) and we repeat the experiment by moving a flashing stimulus along a line through the center of the visual receptive field. On the figure that you made for part (a), now plot a new trace that shows the response of the cell at this new eye position. Make sure you label it. (They are two possible answers, either one is acceptable)

Question 11 (4 points)

For the two muscle system below, length of each muscle is λ_i, joint angle is *q*, force produced by each muscle is ϕ_i, and torque produced by each muscle is τ_i. (note that $q \neq \frac{\pi}{2}$)



Part a) [2 points] Write λ_1 as a function of joint angle *q*

Part b) [2 points] If muscle 1 is producing force ϕ_1, what is the torque that this muscle is producing?

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