NROC64S COURSE SYLLABUS: WINTER ~~1999~~ 2000

SENSORY AND MOTOR SYSTEMS

Course Details

Instructor:

Professor N.W. Milgram
Room S-637
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Teaching Assistants:

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Classrooms And Scheduled Times:

Lectures:
Monday, Wednesday and Friday at 10:00 Room H305

Tutorials
Monday 2:00 Room R4208
Monday 4:00 Room H310

Course Description

This course is concerned with the neurobiology of sensory and motor systems. The goal will be to understand how the external world is encoded (sensory coding), recognized (perception) and manipulated (motor control). The course will start with a general discussion of neural coding and representation. We will then move on to vision. The topics will include: image formation, visual transduction, retinal coding and CNS processing.

We will then cover the other main sensory systems. These include the auditory system, somatosensory system (touch, thermosensitivity, kinesthesia,), olfactory system and gustatory system.

The last topic covered will be motor control. We will first look at muscle contraction, and the associated peripheral and spinal control mechanisms. We will then focus on the brain motor system and how this is involved in planning and triggering motor sequences.

Course Materials

Tests will be based on lecture notes and assigned readings. The readings will be articles from Scientific American that relate to topics covered in this course and can be discussed in the tutorials. If possible the lecture notes will be available from the internet through a course supplied password.

Tutorials

Tutorials will meet weekly or biweekly and will be used to discuss lecture material and assigned readings.

Grading

Grades will be based on two midterms (February 2th and March 10th) worth 25% each (50% in total), a comprehensive final exam worth 50% .

The exam questions will consist of multiple choice, fill in the blank, true false, matching and short answer questions.

ASSIGNED READINGS

Borg, E., & Counter, A. (1989). The middle-ear muscles. *Scientific American* (April), 261, 74-81.

Englert, B-G. Scully, M.O., & Walter, H. The duality in matter and light. *Scientific American* (December), 270, pp 86-92.

Evarts, E.V. (1979). Brain mechanisms of movement. *Scientific American* (September), 241, 164-179.

Freeman, W.J. (1991). The physiology of perception. *Scientific American* (February), 264, 78-87.

Grillner, S. (1996) Neural networks for vertebrate locomotion. *Scientific American* (January), 274, 64-69.

Hudspeth, A.J. (1983). The hair cells of the inner ear. *Scientific American* (January), 248, 54-64.

Konishi, M. (1993). Listening with two ears. *Scientific American*

Livingstone, M.S. (1988). Art, illusion and the visual system. (January), 258, 78-85.

Logothetis, N.K. (1999). Vision: a window on consciousness. *Scientific American* (November), 279, 69-75.

Melzack, R. (1990). The tragedy of needless pain. *Scientific American* (February), 262, 27-33.

Ramachandran, V.S. (1992). Blind spots. *Scientific American*, (May), 266, pp 86-91.

Rapoport, J.L. (1989). The biology of obsessions and compulsions. *Scientific American* (March), 260, 82-89.

Smith, D.V., & St John, S.J., (1999). Neural coding of gustatory information. *Current Opinion in Neurobiology*, 9, 427-435.

Weissmann, G. (1991). Aspirin. *Scientific American* (January), 264, 84-91.

COURSE SCHEDULE

Date	Topic	Assigned Reading
1- Jan 3	Introduction	
Jan 5	Sensory Codes and Representations	Englert et al
Jan 7	Vision: The Visual Stimulus, Structure of the Eye	
2-Jan 10	Vision: Formation of Retinal Images	Ramachandran
Jan 12	Vision: Transduction Mechanisms	
Jan 14	Vision: Retinal Coding	
3- Jan 17	Vision: Visual Pathways in CNS	Livingstone
Jan 19	Vision: Coding in VI	
Jan 21	Vision: Representations of Objects and Space	Logothetis
4- Jan 24	Audition: Physical Properties of Sound; Peripheral Mechanisms in Audition	Hudspeth
Jan 26	Peripheral Mechanisms in Audition – the Cochlea	
Jan 28	Peripheral Mechanisms in Audition - Transduction	Borg & Counter
5- Jan 31	Audition: The Auditory Nerve	
Feb 2	Anatomy of Brain Auditory System	Konishi
Feb 4	Cortical Processing of Sound	
6 – Feb 7	***First Midterm Exam***	
Feb 9	An Introduction to the Chemical Senses: Olfaction	
Feb 11	Chemical Senses Olfactory Transduction	Freeman
	Reading Week (Feb 14- 18)	
7- Feb 21	Central Nervous System Processing Odors	
Feb 23	Taste – Peripheral Mechanisms	Smith and St. John
Feb 25	Taste – Central Mechanisms	
8- Feb 28	Somatosensory Systems: Introduction and Historical Background	Weisman (1991)
Mar 1	Structure of the Skin, Receptors, Transduction	
Mar 3	Peripheral Coding of the Somatosensory system	
9- Mar 6	Cortical Processing - Somatosensory Plasticity	Melzack (1992)
Mar 8	Pain	
Mar 10	Movement: Organization of Motor Control	Grillner
10-Mar 13	Control of Muscle Contraction	
15	The Muscle Spindle System	
17	***Second Midterm Exam***	
11-Mar 20	Preprogrammed Response Sequences	Evarts
22	Efferent Pathways	
24	The Cerebellum	
12-Mar 27	Premotor Networks and Motor Cortex	Rapoport
29	Basal Ganglia and Cortical Processing Networks	
31	Motor Plans and Images	

NROC64: VISION- THE EYE

Sensory Transduction and Sensory Codes

- Sensory Organs and Receptors
- The Coding of Modality, Location, and Intensity
- Higher Level Codes

The Structure and Function of the Eye

- The Visual Stimulus
- Components of the Eye
- The Basic Retinal Circuit

Image Formation

- The Retinal Image and the Visual Field
- Positioning and Focusing the Image on the Retina

Transduction in the Photoreceptors

- The Structure of Rods and Cones
- Transduction Mechanisms of Rods
- Transduction Mechanisms of Cones
- Color Blindness

Visual Coding in the Retina

- Coding in Bipolar Cells
- Coding in Ganglion Cells
- Ganglion Cells in The Frog Retina
- Rod Pathways

Learning Objectives:

1. Discuss how the energy in physical stimuli is converted into the energy of neural activation.
2. Name the different types of sensory receptors.
3. Describe the properties of the visual stimulus, the components of the eye, and the neural circuitry in the retina.
4. Explain the function of a receptive field.
5. Explain how a visual image is brought into focus and its position maintained on the retina.
6. Describe population codes and representations.
7. Explain how light is converted into electrical potentials.
8. Describe the difference between the two major theories of color vision, and how we account for the fact that both theories are partly correct.
9. Explain how visual information is coded by the retina.

Glossary:

accommodation The process of changing the shape of the lens to maintain focus.
amacrine cell A laterally projecting retinal cell that make connections with bipolar and ganglion cells.
bipolar cells A retinal cell that synapses with rods and cones and relays signals to ganglion cells. The bipolar cells do not transmit action potentials.
blind spot A region in the back of eye where optic fibers exit. The blind spot lacks photoreceptors.
center-surround organization A common organization for receptive fields in which activation of a central group of receptors produces effects on target cells opposite to those triggered by activation of a group of receptors surrounding the central group.
channel A neural pathway that carries a specific type of information to higher levels of the nervous system.
ciliary muscle Circular muscle surrounding the lens that is responsible for accommodation of the lens.
cone A photoreceptor responsible for color vision. Each cone normally contains one of three different light-sensitive pigments; cones are concentrated in the fovea.
convergence A combining of input from lower level cells onto higher level cells.
cornea The transparent portion part of the sclera that provides an opening for light to enter the eye.
dark adaptation A gradual adjustment of the eye to low illumination.
fovea The region in the back of the eye that is the focal point of the lens. The fovea contains only cones.
ganglion cells The output cells of the retina. Ganglion cells receive input from bipolar cells and project axons that form the optic nerves.
horizontal cell A laterally projecting retinal cell that makes connections, across the retina, with nearby photoreceptors and bipolar cells.
iris Pigmented membrane that sits in front of the lens of the eye.
lateral inhibition Inhibitory effects directed to neighboring cells; enhances contrast and mediates the center-surround organization of receptive fields.
lens A transparent biconvex structure that completes the process of focusing images onto the light-sensitive "scfreen at the back of the eye.
light adaptation A gradual adjustment of the eye to an increase in illumination.
mach band Illusory dark and light bands.
magnocellular Characterizing large color-insensitive retinal geniculate ganglion cells that participates in the intiial stages of the processing of visual movement.
opponent process theory A theory of color vision that postulates four primary colors that are linked together in opponent pairs (red-green and yellow-blue).
optic disk The exit site of the optic nerve; the blind spot.
optic nerve A cranial nerve that carries fibers from the eye to the brain.
parvocellular Characterizing a small color-sensitive retinal ganglion cells or lateral geniculate cell.
population code A code in which the information is distributed in the pattern of activation of a large number of neurons.
pupil An adjustable central opening that controls the amount of light entering the eye.

pupillary reflex The constriction of the pupils in response to increases in illumination.
receptive field A subset of the receptor array that directly or indirectly affects a particular neuron.
receptor potential A depolarization or hyperpolarization that ultimately affects the level of activation of the next cell in a neural pathway.
representation A pattern of neural activity that codes for, and represents some information, such as a stimulus object.
retina The back part of eye where images are focused that contains the light-sensitive photoreceptors
retinal image The visual image projected onto the retina by the lens.
rhodopsin The visual pigment found in the rods.
rods Photoreceptors responsible for night vision.
sensory receptors Specialized cells that transduce sensory information into electrical potentials.
sensory transduction, the conversion of a physical stimulus - such as light, sound, or touch - to an electrochemical event to which neurons respond.
transducer Anything that converts one kind of energy to another.
transducin A G-protein that is activated by activated form of rhodopsin.
visual field The part of the visual scene that produces the retinal image.
Young-Helmholz trichromatic theory Theory of color vision that postulates the existence of three types of color detectors.

Italicized glossary

transducers Anything that converts one kind of energy to another.
coding The representation of features of the external world by specific patterns of neural activation within specific circuits.
receptor Chemically sensitive proteins on the surface of postsynaptic membranes. Receptors also refers to specialized sensory cells.
law of specfic energies The sensation (modality) of a stimulus depends on the properties of the nerve excited
spatial code The experience produced by activation of a circuit depends on the specific circuit that is activated.
photons Particles of light.
visible spectrum The range of electromagnetic radiation, in terms of wavelength, that the human eye can detect.
sclera A tough protective membrane that forms the outer covering of the eye.
acqueous humor A fluid filled chamber between the cornea and lens.
vitreous humor Fluid filled chamber in back of the lens that has a protective function.
choroid layer Retinal layer that contains the pigmented cells.
optic vesicle Embryological precursor to the retina.
macula Part of retina with the highest density of photoreceptor cells.
saccadic movements Very rapid shifts in gaze that function to place different parts of the visual field onto the fovea.
smooth pursuit movements Eye movements that involve tracking moving visual targets.
vergence movements Movements of the two eyes in opposite directions.
lateral rectus muscles Eye muscle responsible for laterally directed movements.
medial rectus muscles Eye muscle responsible for medially directed movements. The
superior rectus muscles Eye muscle responsible for controlling up and down movements.
inferior rectus muscles Eye muscle responsible for controlling up and down movements.
superior oblique muscles Eye muscle responsible for controlling up and down movements
inferior oblique muscles. Eye muscle responsible for controlling up and down movements.
trochlear nerve (IV) Cranial nerve that functions only to control eye position.
abducens nerve (VI) Cranial nerve that functions only to control eye position
sphincter Muscle that controls the size of the pupillary opening. It constricts the pupil when it contracts.
dilator Muscle that causes the pupil to enlarge when it contracts.
Edinger-Westphal nuclei Brainstem nucleus that provides efferent fibers associated with the oculomotor nerve.
ciliary ganglion Ganglion associated with the parasympathetic nervous system. Efferents control the sphincter muscle of the eye.
superior cervical ganglion Ganglion associated with sympathetic nervous system that innervates the dilator muscle.
zonules A ring of filaments that connects the lens to the ciliary muscle.
presbyopia A loss of near vision.

ciliary stalk Part of photoreceptor that connects inner and outer segments.
retinal Component of rhodopsin that is derived from vitamin A.
opsin Protein component of rhodopsin.
11-cis retinal The stable bent state of rhodopsin.
all trans retinal The unstable straight state of rhodopsin.
cyclic GMP phosphodiesterase (PDE) In this case, the effector enzyme targeted by transducin.
cyclic guanosine monophosphate (cGMP) Second messenger involved in regulating the ion channels in rods and cones
guanophosine monophosphate (GMP) Precursor to cGMP. cGMP is broken down to GMP.
guanylate cyclase The enzyme that controls the synthesis of cGMP.
trichromats People with intact three-cone systems.
Proteranopes People who are deficient in the long wavelength red-sensitive pigment
deuteranopes A type of color blindness characterized by a deficient in the middle wavelength, green-sensitive pigment.
tritanopes A type of color blindness characterized by a deficieny in the short-wavelength, blue-sensitive pigment.
S-cones Cones sensitive to short wave length light.
M-cones Cones sensitive to medium wave length light.
L-cones Cones sensitive to long wave length light.
Midget bipolar cells A type of bipolar cell located in the central retina. Each such cell is connected to a single cone, only.
Diffuse bipolar cells A type of bipolar cell located the central retina that is connected to several cones.
ON cells Cells that show a depolarization in response to light projected onto the center portions of their receptive fields.
OFF cells Cells that show hyperpolarization in response to light projected onto the center portion of their receptive fields.
ommatidia The separate units that collectively make up the compound eye of Limulus.
color opponent Pairs of complementary colors.
color saturation The density of color present in an image.
Spatial frequency sensitivity A way of characterizing the receptive fields of visual system cells in terms of their sensitivity to visual gratings.
visual gratings Patterns consisting of alternating bright and dark elements.
AII amacrine cells A type of amacrine cell associated that synapses with rod bipolar cells.