NGG598: Advanced Systems Neuroscience
Time/Place: Barchi Library 10am to 12 noon, Mondays and Fridays

Course Directors:
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Course Description:
How does neuronal firing represent sensory and motor information? What attributes of the physical world or movement execution are represented in spike trains? How is sensory and motor information evaluated in order to make a decision? These are questions without definitive answers but under aggressive scrutiny. The Advanced Systems course explores a vast array of neuronal strategies for encoding sensory and motor information, as well as their interface which is involved in decision making. It reviews evidence favoring opposing views of the same problem and highlights the difficulties in ascribing functional interpretations to neuronal recordings. The course will review literature using a variety of approaches from detailed cellular studies to psychophysics.

The topics are divided in blocks of three weeks each, with lectures on Monday and student presentations on Friday based on the suggested papers. Each block is led by two Faculty, which present, separately, opposing, contradicting or complementary views of a problem during the first two weeks and then explore, jointly, those contradictions and possible solutions in the third week.

Evaluation:
Grades for the course will be based on a combination of student presentations, class participation and short written assignments. Details will be provided on the first day of class.

Week 0  Friday, 9/9  Introduction to the course

BLOCK 1: Encoding information in Primary Visual Cortex  
(Instructors: Diego Contreras & Larry Palmer)

Week 1  Monday, 9/12  
Friday, 9/16
Week 2  Monday, 9/19  
Friday, 9/23
Week 3  Monday, 9/26  
Friday, 9/30

BLOCK 2: Detecting and Encoding Information in the Auditory Cortex  
(Instructors: Yale Cohen & Maria Geffen)

Week 4  Monday, 10/3  
Friday, 10/7
Week 5  Monday, 10/10  
Friday, 10/14
Week 6  Monday, 10/17
Friday, 10/21

**BLOCK 3: Reinforcement Learning, Vocal learning and the Basal Ganglia**  
(Instructors: Long Ding & Marc Schmidt)

**Week 7**
- Monday, 10/24
- Friday, 10/28

**Week 8**
- Monday, 10/31
- Friday, 11/4

**Week 9**
- Monday, 11/7

No classes Friday, 11/11 through Wednesday 11/16 [SFN2011]

Friday, 11/18

**BLOCK 4: DECISION MAKING**  
(Instructors: Josh Gold & Joe Kable)

No classes Monday, 11/21 through Friday 11/25 [Thanksgiving]

**Week 10**
- Monday, 11/28
- Friday, 12/2

**Week 11**
- Monday, 12/5
- Friday, 12/9

**Week 12**
- Monday, 12/12
- Friday, 12/16
SECTION 1: Processing in the Visual System

Instructors: Diego Contreras and Larry Palmer

Week 1 (Diego Contreras)

Monday, September 12, 2011

Lecture #1: Feature Creatures

**Feature detection** is a process by which specialized nerve cells in the brain respond to specific features of a visual stimulus, such as lines, edges, angle, or movement. Although they never formalized the term, feature detection was discovered by David Hubel and Torsten Wiesel of Harvard University, an accomplishment which won them the 1981 Nobel Prize.

**Background reading:**


Friday, September 16, 2011 (Student presentations)

**Papers:**


Week 2 (Larry Palmer)

Monday, September 19, 2011

Lecture #2: Frequency Freaks

Images are commonly analyzed and processed in the spatial frequency domain (e.g. NASA images, digital microscopy). Although visual cortex is clearly not performing a global Fourier transform, the receptive fields of certain cell types suggest the possibility that their firing rates may encode the coefficients of local two-dimensional spatial frequency components.

**Background reading:**


Friday, September 23, 2011 (Student presentations)

**Papers:**

**Week 3 (Larry Palmer & Diego Contreras)**

**Monday, September 26, 2011**

**Lecture #3: Equivalence (for a linear system)**

In a linear system, pure spatial processing (receptive fields are designed to encode features) and pure spectral processing (receptive fields are designed to encode spectral coefficients) are just two ways of looking at the same phenomenon. But is the system linear? Also, consider that the concept of detection implies a nonlinearity.

**Friday, September 30, 2011 (Student presentations)**

**Papers:**


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**SECTION 2: Detecting and Encoding Information in the Auditory Cortex.**

**Instructors:** Yale Cohen and Maria Geffen

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**Week 4 (Yale Cohen)**

**Monday, October 3, 2011**

**Organization of the auditory cortex**

- Tonotopic organization.
- Spectro-temporal processing.
- Feature detection or object recognition?
- Auditory cortex: Belt vs parabelt regions.
- Speech processing.

**Background reading:**


**Friday, October 7, 2011 (Student presentations)**

**Paper #1:**


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**Week 5 (Yale Cohen)**

**Monday, October 10, 2011**

**Task-related modulation of responses in the auditory cortex**

- Modulation of spectro-temporal receptive fields
- Attention-based modulation of auditory processing

**Background reading:**


**Friday, October 14, 2011 (Student presentations)**

**Paper #1:**


**Paper #2:**


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**Week 6 (Maria Geffen)**

**Monday, October 17, 2011**

**Efficient encoding of information in the auditory cortex. (Maria Geffen)**

- The efficient coding hypothesis
- Contrast gain control
- Context adaptation in A1
- Differential processing of natural sounds
Background reading:


Friday, October 21, 2011 (Student presentations)

Paper #1:


Paper #2:


SECTION 3: Reinforcement learning, vocal learning and the basal ganglia

Instructors: Long Ding and Marc Schmidt

Week 7 (Long Ding)

Monday, October 24, 2011

Background Reading:


(i) Introduction to reinforcement learning

Three general types of decision algorithms
  Dynamic programming
  Supervised learning (e.g., error-correction learning)
  Reinforcement learning

Basic Elements of RL
  Policy
  Reinforcement
  Valuation
  Model of environment

Example implementation of RL
  Policy: exploration vs. exploitation
  Valuation: temporal difference learning
  Actor-critic model

(ii) Introduction to BG organization

  Basic anatomy
  Dis-inhibition mechanism for motor generation
  Direct/indirect pathways
  Matching onto actor-critic diagram
Neural correlates of RL in BG pathway

- Dopamine - reward prediction error
- Striatum – reward-modulated spatial activity
- OFC – reward-related activity
- Difference of learning-related activity in PFC and striatum

Friday, October 28, 2011 (Student presentations)

(iv) Causal roles of BG in learning

Paper #1:


Paper #2:


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Week 8 (Marc Schmidt)

Monday, October 31, 2011

Background Reading:


(i) Introduction to vocal learning in songbirds

- Vocal ontogeny
- Song learning consists of tow phases: acquisition & sensorimotor
- Auditory feedback is necessary for sensorimotor learning
- Song maintenance is dependent on auditory feedback & error correction

(ii) Song production in zebra finches: Stereotyped but variable

- Acoustic and temporal features of adult zebra finch song
- Directed vs. undirected song
- Acoustic variability in adult and juvenile song

(iii) The song system as a specialized circuit for song production and learning

- Auditory pathway
- Song motor pathway
- Anterior forebrain pathway (AFP)
- Hypothetical circuit model for vocal learning

(iv) Functional organization of the avian basal ganglia (compare with mammals)

- Anatomy
- Neurochemistry
- Projection patterns/cell types
d. Dopamine-dependent plasticity

(v) Neural properties of the AFP during vocal learning

a. Lesions of HVC turn adult song into variable juvenile song (Aronov et al.)

b. Effect of AFP lesions on song learning (Area X vs. LMAN lesions)

c. Zenk expression and neural activity (direct vs. undirected song)

d. VTA activation during singing and its connection to avian striatum.

e. AFP as an instructive signal: Stimulation of LMAN during singing

Friday, November 4, 2011 (Student Presentations)

(vi) The AFP as a generator of motor variability: Role in motor exploration?

Paper #1:

Paper #2:

Week 9 (Long & Marc)

Monday, November 7, 2011 (MARC + 1 student presentation)

(i) Vocal exploration as a strategy for error-correction based learning


(ii) Transferring learning from the striatum to the song motor pathway

Student Presentation:

Paper #1:

Friday, 11/11 through Wednesday 11/16: SFN 2011
Friday, November 18, 2011 (STUDENTS BRAINSTORMING)

**Background Reading:**


**PROBLEMS TO ADDRESS:**

- How to detect and characterize reinforcement learning-related signals in the avian AFP?
- How to test for a role of BG in exploration of sensory/motor space in mammals?
- What are the major caveats to expect?

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**SECTION 4: Neural bases of decision making**

**Instructors:** Josh Gold and Joe Kable

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**Week 10 (Josh Gold)**

**Monday, November 28, 2011**

**Perceptual decision-making**

*Session 1. Lecture.* Bayesian inference; signal detection theory; statistical decision theory; accumulator models; neurometric and psychometric functions; choice probability; interneuronal correlations

**Background reading:**


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**Friday, December 2, 2011 (Student Presentations)**

**Paper # 1**


**Paper # 2**

Week 11 (Joe Kable)

Monday, December 5, 2011

Value-based decision making

Session 1. Lecture. Utility theory and value maximization; economic choice models; curve fitting vs. axiomatic tests; reinforcement learning; action and stimulus value signals; examples from studies of time discounting.

Background reading:


Friday, December 9, 2011 (Student Presentations)

Paper #1:


Paper #2:


Week 12 (Gold and Kable)

Monday, December 12, 2011

Are value-based and perceptual decisions subserved by the same neural mechanisms?


Background readings:


Friday, December 16, 2011 (Student Presentations)

**Paper #1:**


**Paper #2:**