PSY 407: Neural Coding
Winter 2010

last updated Wednesday, January 6, 2010

Overview	How is information from the world represented by neural activity? The nature of the neural code remains a topic of intense debate. Topics include tuning curves and receptive fields, the rate coding and temporal coding hypotheses, oscillations and synchrony, sparseness and population codes, information theory, and the neural basis of decision making.
Objectives	To learn how to read and critically discuss scientific papers. To learn how to present a paper to an audience. And finally, to learn about some of the key concepts and questions in the field of neural coding.
Time and Place	Thursdays 12:00–2:00 PM; 317 Huestis
Instructor	Mike Wehr wehr@uoregon.edu office hours: Mondays 2:00-3:00 PM in 206 Huestis or by appointment.
Textbook	none
Readings	All course readings will be available on Blackboard. https://blackboard.uoregon.edu
Cell Phones	If it rings in class, or if you're talking on it, it's mine.

Grading

Presentation	50%
Questions	25%
Class participation	25%

Format
This course will follow a seminar format. Each day we will discuss a paper. You must read the paper before class. When you read the paper, write down any questions you have about the paper: things you are confused about, things you want to know more about, or critiques of the methods or conclusions in the paper. Bring to class at least one written question, which is worth up to 10 points; I will grade it on the spot and hand it back to you so that you can refer to it during the discussion. One student will present the paper to the rest of the class, preferably using a powerpoint presentation. The presentations should be roughly 40 minutes in length (this usually corresponds to 10-15

slides). This student will also lead a group discussion of the paper following the formal presentation. Everyone is expected to participate by asking questions both during the presentation and afterwards in the discussion. The questions you have prepared ahead of time should serve as a starting point to help kick off the discussion. Most days we will need to fit in two presentations, although depending on the final number of students we will probably have a few days with only one presentation.

Papers:
The papers here have been divided into four units, which we will go through in sequence: Temporal Coding, Population Coding, Sparse Coding, and Neural Coding and Cognition. We will spend about 2-3 weeks on each unit. There are many more papers than students & presentations, so you have a lot of choices. Also, you don't need to limit your choices to this list — you can choose any relevant article, recent or classic. If you'd like to choose from outside this list, you should check with me first.

•Background
These review papers are great reading to get some background on the field of neural coding, but they're probably not well suited for presentations.

Stevens & Zador – Neural Coding: The Enigma of the Brain
> A short introduction to what Neural Coding is all about.

DeCharms & Zador - Neural Representation and the Cortical Code.
> Overview of neural coding and representation, specifically dealing with cortex and the relationship to perception and behavior.

•Temporal Coding
Konig et al - Integrator or Coincidence Detector? The Role of the Cortical Neuron Revisited.
> A theoretical discussion of how the biophysical properties of cortical neurons may or may not affect how they encode information into action potentials. Depending on the integration window, neurons could either act as temporal integrators or as coincidence detectors on their synaptic inputs.

Wehr & Laurent - Neural Coding of Odors by Oscillatory Sequences of Firing.
> A study of neural coding in the grasshopper olfactory system, where neurons synchronize to a global oscillation in a stimulus-dependent fashion.

Mehta, Lee & Wilson - Role of Experience and Oscillations in Transforming a Rate Code into a Temporal Code.
> This paper looks at a form of temporal coding called phase precession, and relates it to firing rates at different time scales, in the context of sequence learning.

Harris et al - Spike Train Dynamics Predicts Theta-Related Phase Precession in Hippocampal Pyramidal Cells.

Like Mehta et al., this paper demonstrates that phase precession doesn't necessarily encode spatial information. They suggest that phase precession is essentially a consequence of the biophysics of dendritic integration.

Bialek et al - Reading a Neural Code.

The seminal reverse correlation paper, which shows how one can decode the information transmitted by single spikes.

VanRullen, Guyonneau, and Thorpe – Spike times make sense

One of the problems of firing rate codes is that they are slow, since the requure averaging over time. This paper argues for a rank-order code, in which the relative timing of first-spike times is what encodes information. Since the code only uses a single spike, it's as fast as possible.

Hanloser, Kozhevnikov, & Fee - An Ultra-Sparse Code Underlies the Generation of Neural Sequences in a Songbird

Recent data from the zebrafinch song system, showing that pre-motor neurons use a temporally sparse and precise code.

•Population Coding

Butts and Goldman - Tuning curves, neuronal variability, and sensory coding

Which is the important part of a tuning curve, the peak or the sides? This study shows that both parts are important, but under different noise conditions.

Jazayeri and Movshon – A new perceptual illusion reveals mechanisms of sensory decoding

Here again we ask which is the important part of a tuning curve, the peak or the sides? Using one or another represents a different decoding strategy. This study shows that one decoding strategy leads to an optical illusion, but the other does not. In this way they can tell which strategy the brain is using, and that subjective experience is not mediated directly by the responses of sensory neurons, but after those responses are decoded.

Dean, Harper, and McAlpine – Neural Population coding of sound level adapts to stimulus statistics

Adaptation is a change in the coding properties of a neuron to match the structure of the stimulus. This study shows that this kind of adaptation works for a number of different statistical properties of the stimulus.

Pouget, Dayan, and Zemel - Inference and Computation with Population Codes.

What kinds of computation is population coding good for? Does distributed activity just represent the stimulus? This paper reviews the idea that a distributed population code uses neuronal variability to represent uncertainty about the stimulus, and that the computations done on this representation can best be understood as Bayesian inference. This is a thorough review paper.

Ma, Beck, Latham, and Pouget - Bayesian inference with probabilistic population codes.
Similar to the review by Pouget, Dayan, and Zemel, but this is a research paper rather than a review (so it's much shorter).

•Sparse Coding

Olshausen & Field - Sparse Coding of Sensory Inputs
A review of sparse coding in sensory systems. What does sparseness mean, what is it good for, and what's the evidence for it?

Smith and Lewicki – Efficient auditory coding
What is efficient coding, and what is it good for? This model shows that if we assume that the auditory system uses an efficient code, we get neurons that look a lot like those in the real auditory system. This suggests that the auditory system may be as efficient as possible, and that the structure of speech may be adapted to this kind of code.

Yen, Baker, and Gray – Heterogeneity in the Responses of Adjacent Neurons to Natural Stimuli in Cat Striate Cortex
The columnar organization of cortex is based on the observation that nearby neurons have similar tuning to orientation, ocular dominance, spatial frequency, and so on. This is true for simple stimuli used in laboratory experiments. However, when more natural stimuli are used (such as movies of natural scenes), nearby neurons are not so similar, suggesting that we may need to rethink some conclusions that have been drawn about columnar organization.

•Neural Coding and Cognition

Machens, Romo, and Brody – Flexible Control Of Mutual Inhibition: A Neural Model Of Two-Interval Discrimination
Opponent processing is a recurring motif in sensory systems. This model suggests that a similar organization could be responsible for both working memory and decision making.

Iacoboni and Dapretto – The mirror neuron system and the consequences of its dysfunction.
This is a review of mirror neurons, which fire not only when an animal performs an action (such as reaching for a piece of food), but also when the animal observes others performing the same action. Dysfunction of this system could be involved in autism.

Platt & Glimcher - Neural Correlates of Decision Variables in Parietal Cortex
If sensory neurons represent sensory stimuli, and motor neurons represent motor output, what about the neurons in the middle? What do they represent, and with what code? This paper proposes that brain areas in between the sensory and motor sides are involved in decisions, and that in addition to sensory and motor information, their activity represents decision-theoretic variables such as expected gain (how much reward you can expect for a given sensory-motor

decision).

Schedule (the schedule will change during the term, as students volunteer to present papers, so please be sure to check Blackboard for the current schedule and readings)

1. Thursday, January 7
Introduction
Presenter: Mike Wehr
Reading: none

2. Thursday, January 14
Presenter:
Reading:

3. Thursday, January 21
Presenter:
Reading:

4. Thursday, January 28
Presenter:
Reading:

5. Thursday, February 4
Presenter:
Reading:

6. Thursday, February 11
Presenter:
Reading:

7. Thursday, February 18
Presenter:
Reading:

8. Thursday, February 25
Presenter:
Reading:

9. Thursday, March 4
Presenter:
Reading:

10. Thursday, March 11
Presenter:
Reading: