Week 08 lecture 36

For a detailed discussion, read Theoretical Neuroscience by Dylan and Abbott -Textbook Pg. 107 - Last paragraph, Pg. 108, 109.

Extra: To know about Fisher information at population level decoding, you can read Pg. 110, 111.

Summary:

- It is possible to decode the stimulus from the responses of a single neuron with a decent accuracy.
- **Definition of likelihood:** For a given stimulus "s", if "r" is the response. The **likelihood** is defined as the Probability of "r" given "s"
- **Definition of Score:** Based on likelihood, we define score, which is considered as $\frac{\partial\, ln(p(r/s))}{\partial s}$. The score is basically the slope of the log of likelihood.
- When a true stimulus "s" is played in many trials, from the responses you estimate stimulus, which can be labelled as s_{est}
- The difference between mean estimate $< s_{est} >$ and true stimulus s is called bias.

  bias(b) = $< s_{est} >$ - s
- The estimates also have a variance. If they have a large variance, the estimates could be spread more about the mean, which means neuron responds similarly to a broad range of stimuli. If they have a small variance, the estimates are more sharply peaked at a single stimulus, which means neuron responds more to only a specific stimulus.
- If the bias is zero, there is a theoretical minimum on the variance of estimates. This limit is defined by what is called Cramer-Rao Bound.
- Cramer-Rao bound basically tells that for an unbiased estimator, variance is always greater than or equal to the inverse of Fisher information.
- Fisher Information is defined as the mean of the square of scores. Fisher information = $< (\frac{\partial\, ln(p(r/s))}{\partial s})^2 >$

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For a detailed discussion about Britten et al, Two-alternative forced-choice task and ROC curve, read [Theoretical Neuroscience by Dylan and Abbott]() - Textbook Pg.87 - 94.

Summary:

- Decoding is the method of inferring stimulus from neural responses. Discrimination is a special case of decoding, where from a response you try to infer the stimulus is one or the other.
- In Britten et al., a monkey was given the task of choosing stimulus “+” or “-” on different values of Coherence of motion of dots

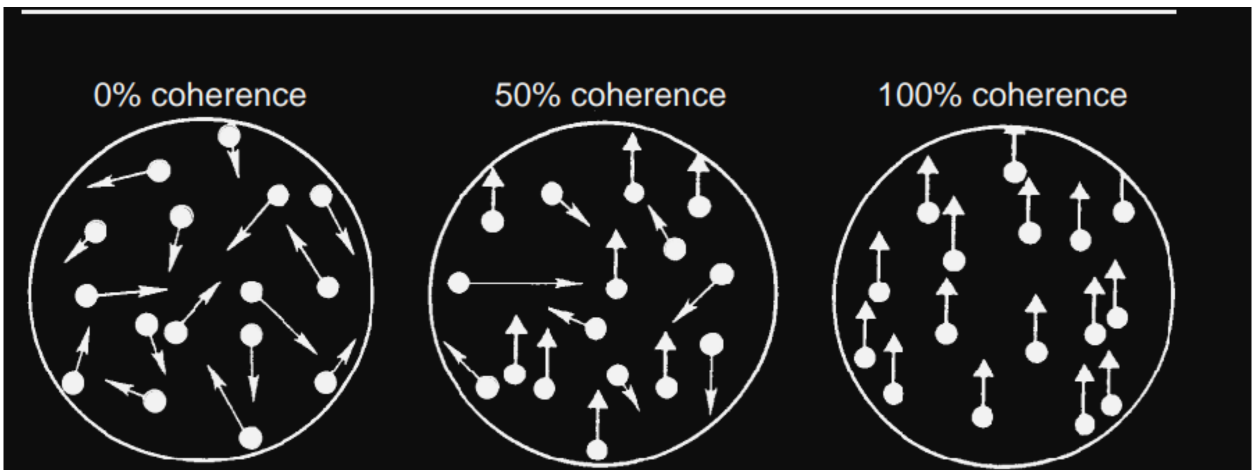

Figure 3.1 The moving random-dot stimulus for different levels of coherence. The visual image consists of randomly placed dots that jump every 45 ms according to the scheme described in the text. At 0% coherence the dots move randomly. At 50% coherence, half the dots move randomly and half move together (upward in this example). At 100% coherence all the dots move together. (Adapted from Britten et al., 1992.)

Source - Theoretical Neuroscience by Dylan and Abbott.

- A simple rule for decoding the stimulus based on simple responses can be - if the response is greater than a threshold, the stimulus is “+”. If less than the threshold, it is “-”.
- Now the accuracy of decoding depends on the value of the threshold. ROC curves are useful to evaluate how good a threshold is.

- For each of the two stimuli, there are two cases - animal choosing the correct option or the wrong option. A table can be constructed based on the scenario

$$\alpha(z) = P[r \geq z|-] \quad \text{is the size or false alarm rate of the test}$$
$$\beta(z) = P[r \geq z|+] \quad \text{is the power or hit rate of the test.} \tag{3.5}$$

The following table shows how the probabilities of the test giving correct and incorrect answers in the different cases depend on α and β.

	probability	
stimulus	correct	incorrect
+	β	$1-\beta$
−	$1-\alpha$	α

Source - Theoretical Neuroscience by Dylan and Abbott

- Based on the above table, Probability of correct can be defined as

$$P[\text{correct}] = \int_0^\infty dz\, p[z|-]\beta(z)\,.$$

Source - Theoretical Neuroscience by Dylan and Abbott

- And false alarm can be defined as

$$\alpha(z) = \int_z^\infty dr\, p[r|-]\,.$$

Source - Theoretical Neuroscience by Dylan and Abbott

- Take the derivative of the above equation and from the probability of correct, one can obtain. This means the area under the curve with beta on the Y-axis and alpha on the X-axis gives the probability of correct.

$$P[\text{correct}] = \int_0^1 d\alpha\, \beta\,.$$

Source - Theoretical Neuroscience by Dylan and Abbott

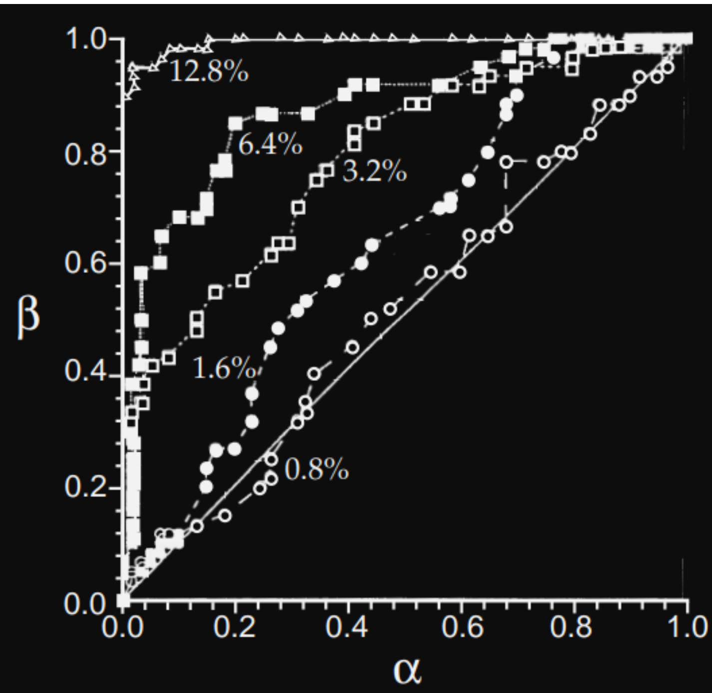

Figure 3.3 ROC curves for a variety of motion coherence levels. Each curve is the locus of points $(\alpha(z), \beta(z))$ for all z values. The values of α and β were computed from histograms such as those in figure 3.2B. The diagonal line is the ROC curve for random guessing. (Adapted from Britten et al., 1992.)

Source - Theoretical Neuroscience by Dylan and Abbott

- The above figure shows that for better coherence, the area under the curve is higher, which is consistent with the expectation that better coherence will have chances of more correct choices.

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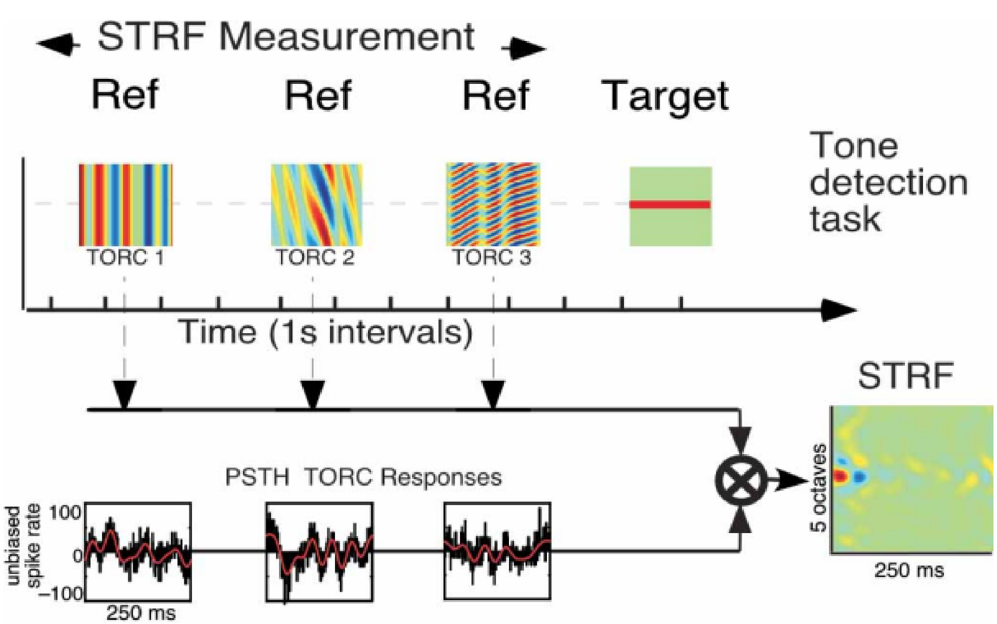
Reference:- Fritz J, Shamma S, Elhilali M, Klein D. Rapid task-related plasticity of spectrotemporal receptive fields in primary auditory cortex. Nat Neurosci. 2003 Nov;6(11):1216-23. doi: 10.1038/nn1141. Epub 2003 Oct 28. PMID: 14583754.

- STRF describes a neuron's response properties to auditory stimuli across both frequency and time.

- The spectrotemporal response field (STRF) of an auditory neuron is a time-frequency measure of the dynamic responses of an auditory neuron to impulsive energy delivered at various frequencies. As such, it simultaneously gives two types of information about the neuron. The first is its frequency tuning, or more specifically which frequencies excite the cell best and which inhibit it. The other is the nature of its temporal response, i.e., whether it is sustained in time or is rapidly adapting. This measure is linear and takes the stimulus spectrogram as its input and hence is often found to be useful in predicting responses of a neuron to unseen stimuli.

Tuning properties of auditory cortex in behaving animals :-

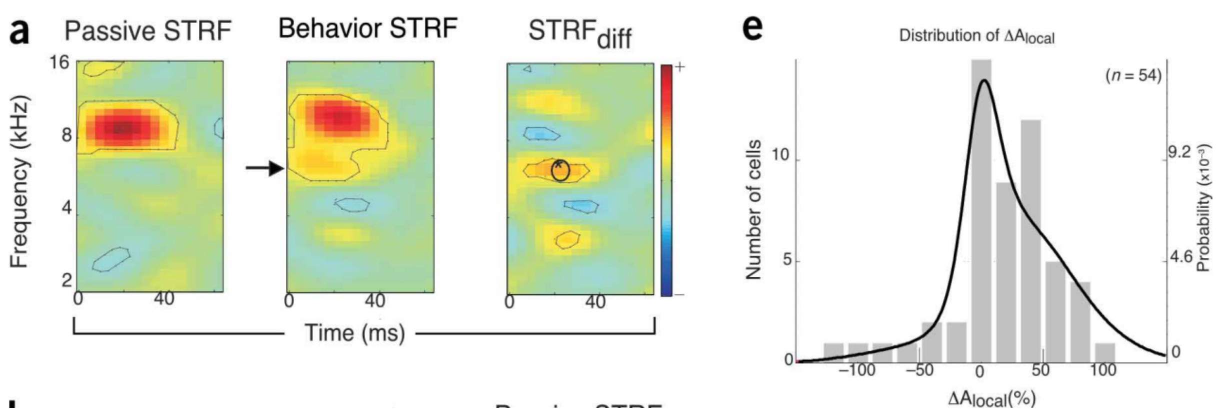
- Animals(ferrets) were water deprived
- TWO TYPES OF STIMULI :- TORC (broadband noise like stimuli) and pure tones as targets .
- Operant conditioning avoidance task :- animal should stop licking when target is played
- Tone is associated with a small amount of shock , which makes the animal learn the avoidance task
- Experimental design

- 

- Responses to each TORC collected as PSTH was cross correlated with the TORC spectrogram to get STRF.
- Calculated passive STRF (when the animal is not performing the task) and behavioral STRF (when the animal is performing the task)

  Rapid task Related plasticity

  - Plasticity was observed in A1 .
  - STRF shape change was observed during task performance.
  - Enhancement of excitatory field of the STRF or by a weakening of its inhibitory sidebands.
  - When the target was placed near an excitatory region of the STRF it created a new excitatory extension of the original region.



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  - Figure shows , pre behavior STRF(left), behavioral STRf(middle) , the STRF diff .
  - An asterisk marks the location of maximal local change , and the circle marks the global change.
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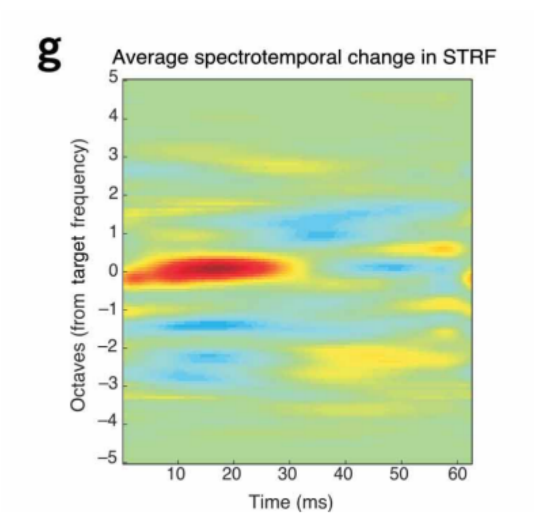

- The above figure shows the average spectrotemporal change in STRF across all units . This shows the facilitation and suppression around the target frequency and relatively rapid onset of the STRF changes

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Main reference:- [Task reward structure shapes rapid receptive field plasticity in auditory cortex | PNAS]

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