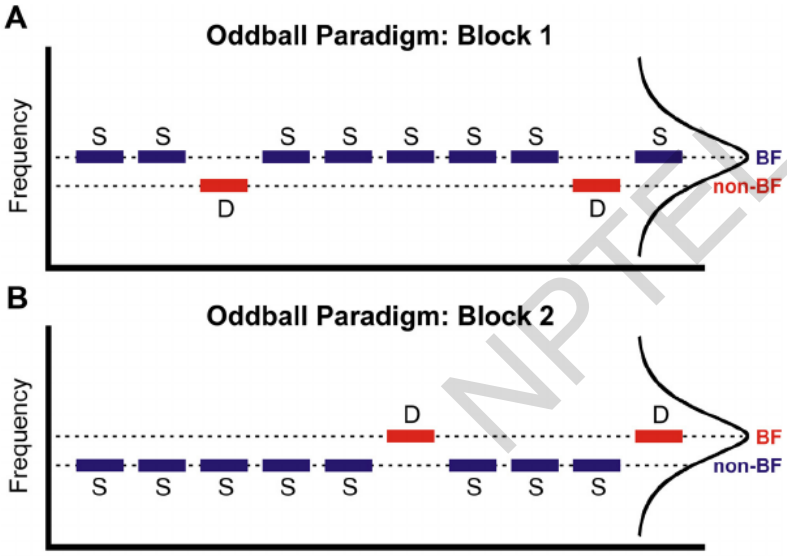
Lecture 51

- Adaptation

Adaptation is a fundamental process in the auditory system that dynamically adjusts the responses of neurons to unchanging and recurring sounds. This enables neuronal response properties to be matched to the constantly changing statistics of sounds that reach the ears.
Ref :- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3931124/

- Oddball paradigm

Example of an oddball paradigm



Ref:- DOI:10.1523/JNEUROSCI.2835-12.2012

- STIMULUS SPECIFIC ADAPTATION

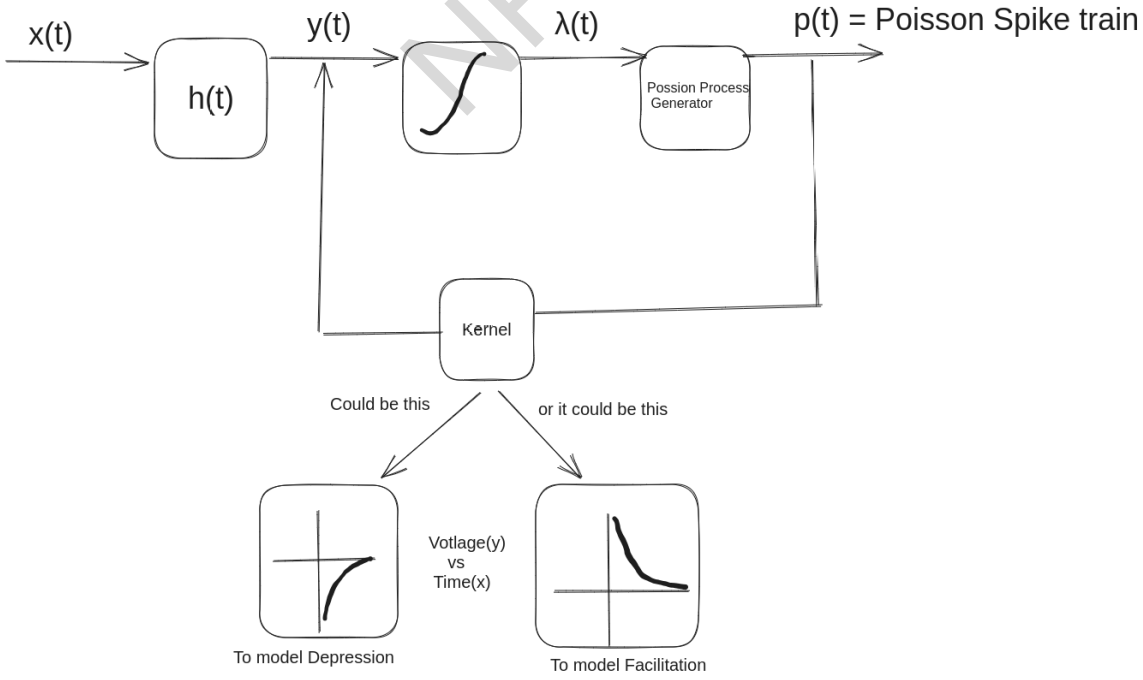
  Ref:- https://pubmed.ncbi.nlm.nih.gov/12652303/
  Neuronal adaptation is the decline of neuronal responses over specific sensory stimulation.
  - Adaptation is stimulus specific.
  - Consider the two blocks of odd ball paradigm with the frequencies denoted by f1 and f2 and D denotes deviant ad S denotes standard
  - Then the response measure , Common Selectivity Index\(CSI)
    $[(f1(D) + f2(D)) - (f1(S) + f2(S))]/[f1(D) + f2(D) + f1(S) + f2(S)]$

- CSI values and inferences
- CSi = +1, indicates there are no neuronal responses for the standard tones and it responds to the deviants.
- CSi = -1, indicates there are no neuronal responses for the deviant tones and it responds to the standards.

Mismatch negativity (MMN):- is an auditory event-related potential that occurs when a sequence of repetitive sounds is interrupted by an occasional “oddball” sound that differs in frequency or duration.

Lecture 52

We have seen how Short Term Plasticity(Depression) can be modelled with 3-state model(Neurontransmitter being in recovered state, effective state, inactive state). Here we discuss models of Short Term Depression and Short Term Facilitation using the linear model(which we discussed in previous lectures)



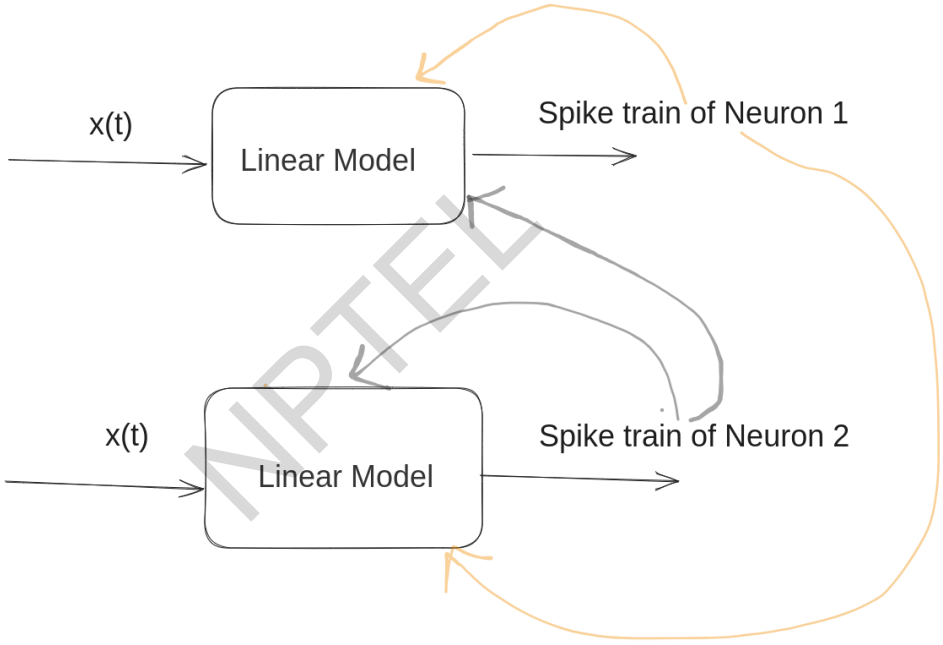
A modification to the existing model can be done by altering y(t) by operating it with a kernel. The kernel is inturn obtained from the generated poisson spike train.

If it is Short Term Depression, Then over time, the probability of spiking should decrease, that means over time the membrane should be lower(lower the membrane voltage ,the more difficult it becomes to elicit a spike) and over time should regain back to its original state(because its short term). Hence in the image above, the kernel slowly regains voltage value after some time.

If its Short Term Depression, then over time, the probability of spiking should increase, that means membrane voltage should be higher to elicit more spikes then slow over time should regain to original state.

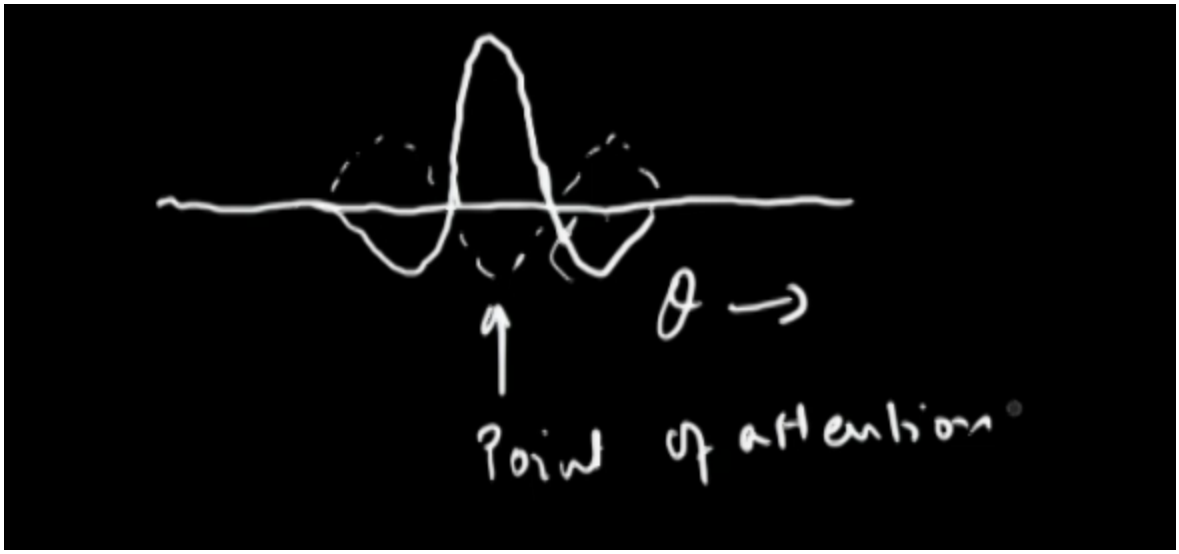
The kernel can be thought of as a push up or down to the membrane voltage making spikes more easy or difficult.

Another model is having two neurons and poisson spikes of one affects the other and also itself.

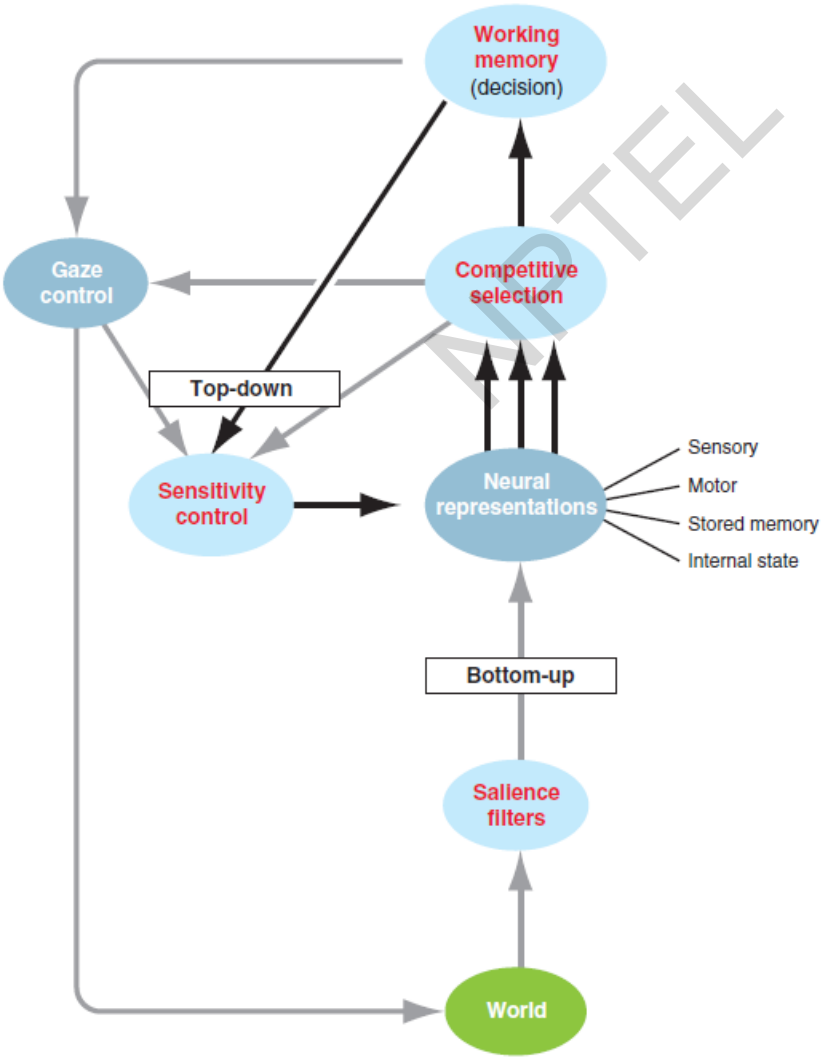


Lecture 53

- Attention at a single neuron level can be seen as a enhancement to a single stimuli and suppression of response to a other stimuli.



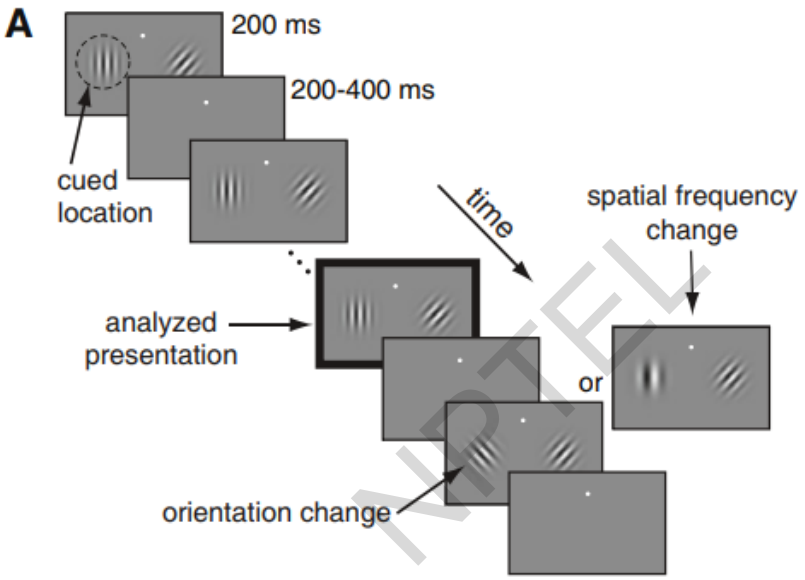
- A popular framework of attention model is given by Knudsen, which is depicted as below:



Source

Input from the sensory world when it reaches sensory organs, is filtered by “Saliency filters”. It would be difficult for the brain to process all the stimuli that we are being bombarded with. And then in brain, there are representations of the filtered stimuli, based on the inputs from top-down areas, there is a chosen stimuli that is important. You can think of it as a competition between the stimuli, and that chosen stimuli is held in working memory and altered. And based on that further, we respond which inturn leads to change of inputs and this cycle continues.

- A classic experiment to understand attention at population level activity of neurons is done by Cohen & Maunsell, 2011
 - A primate was trained to do an attention task. Below is the schematic from the paper:

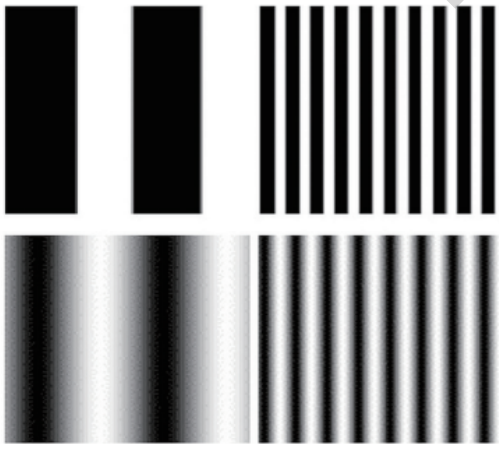


- The monkey had to attend to the cued location and check of the orientation of the stripes was changed.
- While primate was doing the task, the extracellular recordings were taken from V4
- The percentage correct in the task alters with the amount of orientation change. The lower the orientation change, the harder the task, hence less probability correct.
- With the neuron’s response data, they tried to find which factor was essential in decoding the behavioural response from population activity of neurons. They found that correlated activity(noise correlations) between neurons was an important factor. That means, that **lesser**

correlated activity between neurons leads to better performance in an attention task.
(Details of the analysis can be found in the paper - https://www.cell.com/neuron/pdf/S0896-6273(11)00434-X.pdf)
This hypothesis was further confirmed in the paper discussed in next lecture, where the same result is observed.

Lecture 54

- In an experiment, a mouse had to discriminate between horizontal stripes and vertical stripes. The difficulty of the task was increased by decreasing the contrast between the black and white stripes.



Source - https://m.gzzoc.com/Aes/Stage/ArticleShow.aspx?AID=597
- In some mice, ChR2(channel Rhodopsin) was expressed in choliergic neurons that project onto Visual Cortex.

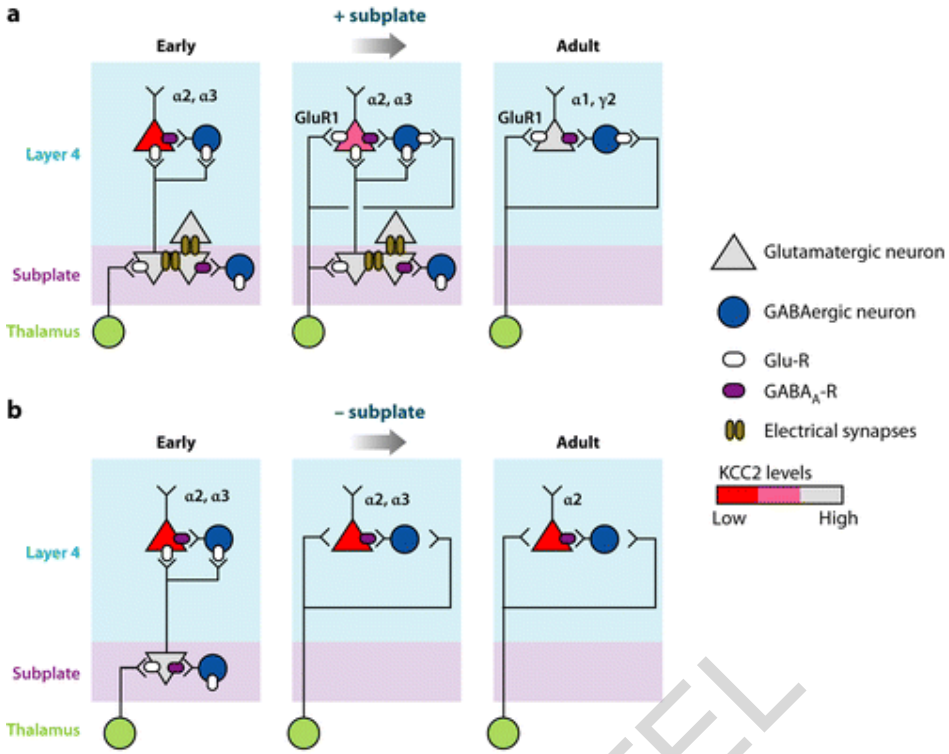
- When light of appropriate wavelength is shined on axon terminals of such neurons, they fire action potentials. In such mice, the task performance was observed to be better than other mice.
- This improved performance can be attributed to increased attention. If attention is increased due to increased cholinergic stimulation on visual cortex, then what are its correlates. The authors of the paper, found 2 interesting observations in the visual cortex neurons where cholinergic stimulation was done:
1. In a single trial, the neuron activiaty was less correlated. The physical significance of reduced correlated activity is that now neurons can essentially encode more information. The redundancy due to the correlated activity is now absent.
2. Across trials, the spiking activity of each neuron was more reliable. Spike trains of a single neuron for different trials varies due to stochasticity. But on cholinergic stimulation, the spike trains were more similar across trials. This means the fidelity of coding of a neuron has improved.

The above are just hypothesis of the neural correlates of attention. Interested readers can read the following papers to get an idea of the other work:
https://www.sciencedirect.com/science/article/abs/pii/030645229190170S
https://www.nature.com/articles/s41598-019-56608-3
https://www.frontiersin.org/articles/10.3389/fnsys.2014.00172/full?fbclid=IwAR0J9ErpCUNqhrQuhVv1IoLSoC_fu9L8G4S_Y3BOe9-pKkulxabUrANirw8

Lecture 55

- Subplate neurons (SPns) are a unique class in the developing mammalian cerebral cortex. SPns are crucial for early brain development.
- They are the first neurons generated and matured in the cerebral cortex.
- They receive inputs from both thalamus and neuromodulatory signals. SPns primarily project to layer 4 of the developing cortical plate.
- They form one of the first functional cortical circuits.
- Impairment or removal of SPns affects functional cortical development.
- SPn removal impacts thalamocortical synapse maturation, inhibition in layer 4, orientation-selective responses development, and formation of ocular dominance columns.
- Removal also alters ocular dominance plasticity during the critical developmental period.
- There is a potential link between SPn injury in development and later cognitive malfunctions.

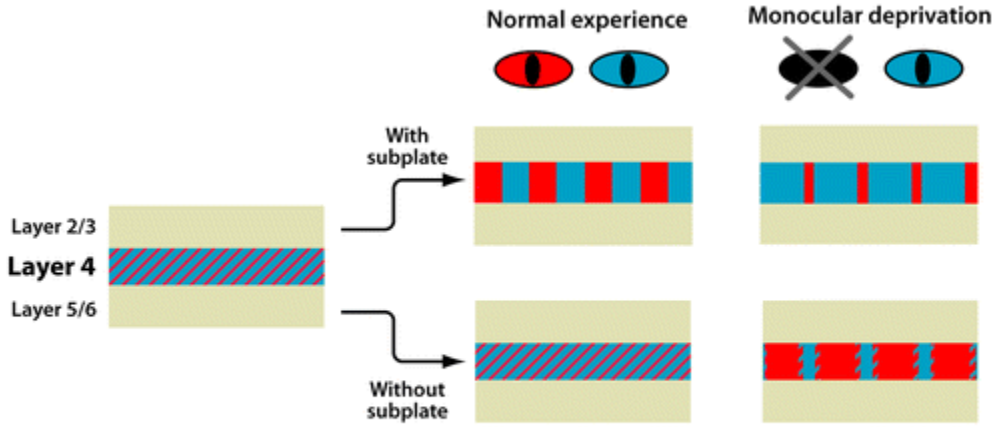
Role of subplate in establishing Thalamo-cortical connections



Kanold PO, Luhmann HJ. 2010.
Annu. Rev. Neurosci. 33:23–48

Source- [Subplate neurons review article]

Effect of Subplate damage during the critical period on the formation of ocular dominance columns



Kanold PO, Luhmann HJ. 2010.
Annu. Rev. Neurosci. 33:23–48

Source- Subplate neurons review article

Similarly, during Critical period, when a mouse is exposed to a sound of particular frequency, its tonotopical organization is disturbed. The region of neurons representing that particular frequency is over represented.