Neurons Don't Just Integrate!
An alternate approach for music perception using Spiking Neural Networks

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Overview

Postinhibitory Spikes

- Strong enough inhibitory pulse can induce a rebound spike
- Observed in mesencephalic V neuron of the rat's brainstem
- Integrator models do not exhibit these characteristics

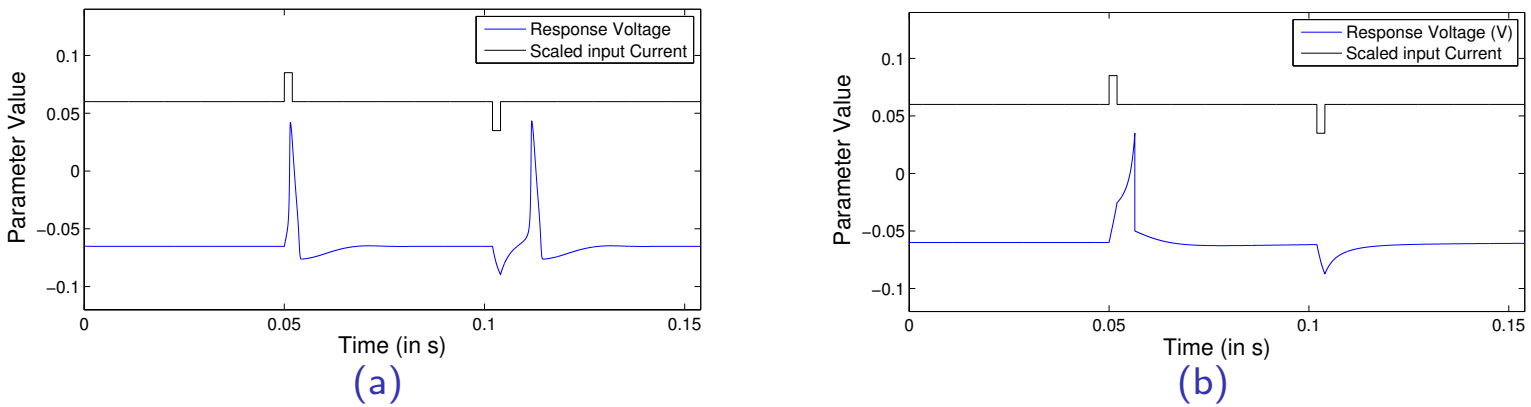


Figure: Response of Hodgkin-Huxley's neuron model (a) and the Izhikevich's neuron model (b) to excitatory and inhibitory pulses of the same magnitude

Activation Mechanism

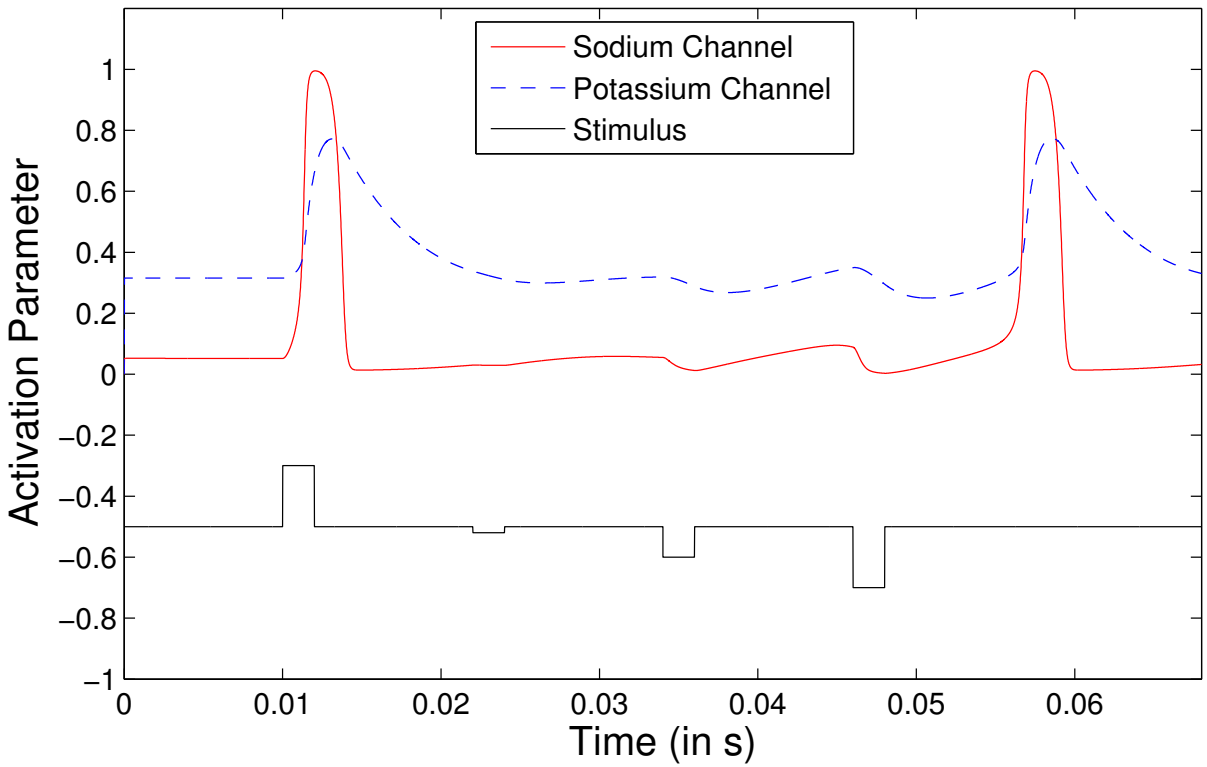


Figure: Variation of Sodium, Potassium activation parameters as we apply a series of inhibitory pulses with increasing magnitude

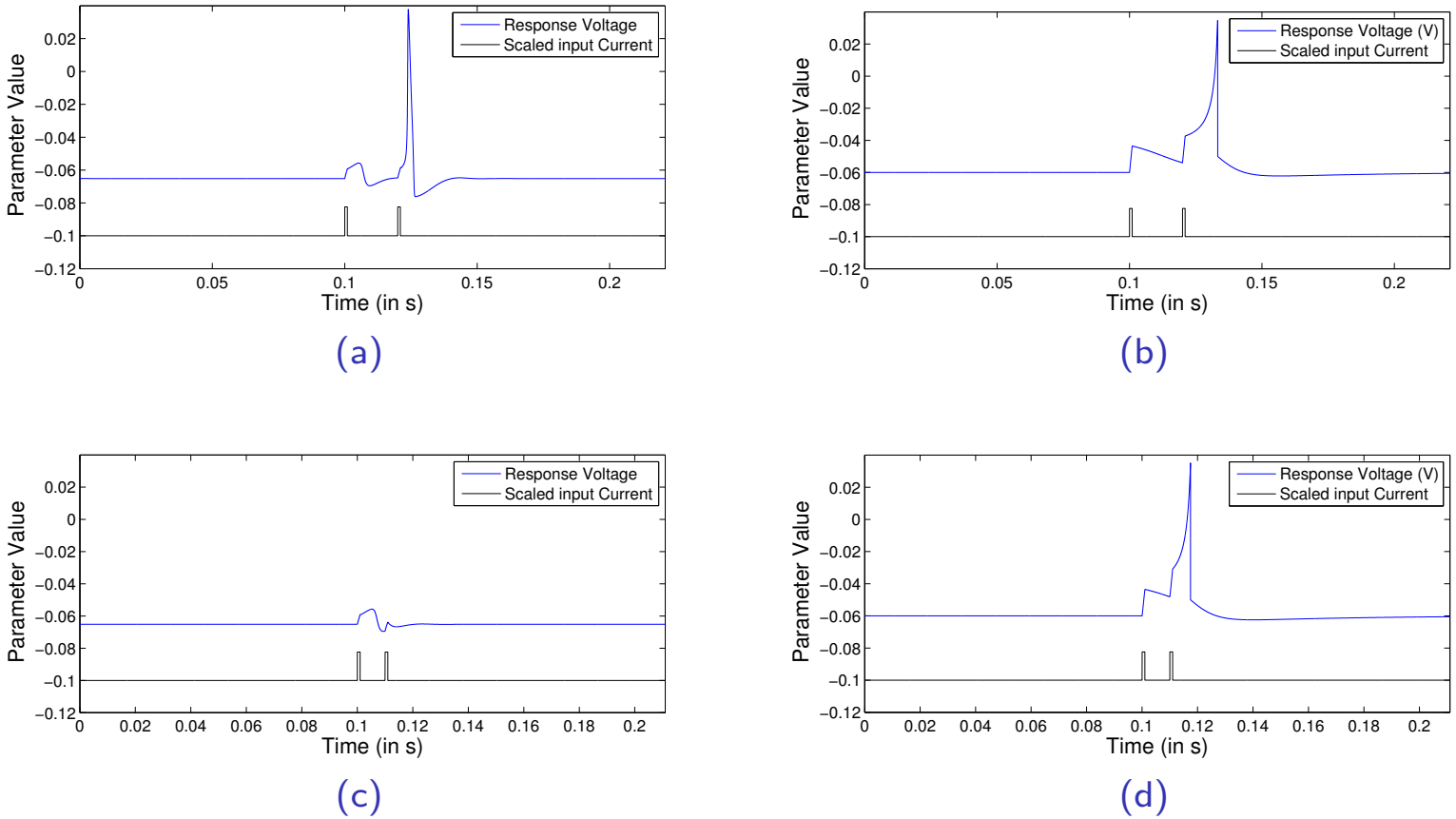
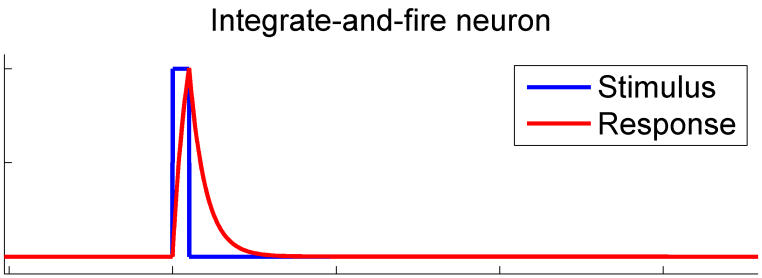


Figure: Subthreshold oscillations and interference in neurons which Integrate and Fire models fail to capture. Figures (a) and (b) show the response of HH and Izhikevich neurons to stimuli seperated by 20 ms, whereas Figures (c) and (d) capture the deviation in behavior when stimuli are placed closely together, at a gap of 10 ms

Resonate-and-Fire neuron model



$$\dot{x} = bx - wy$$

$$\dot{y} = wx + by$$

If $y \geq y_{th}$, then

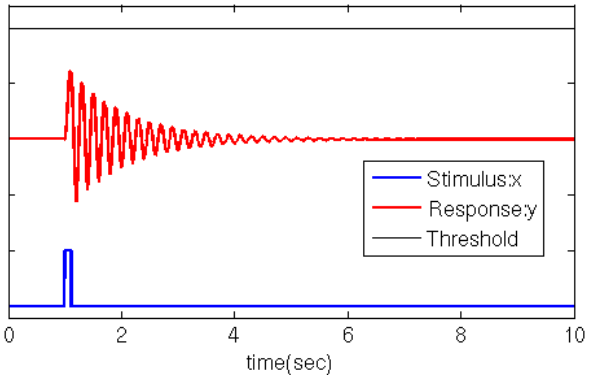
$$x \to x_0$$

$$y \to y_0$$

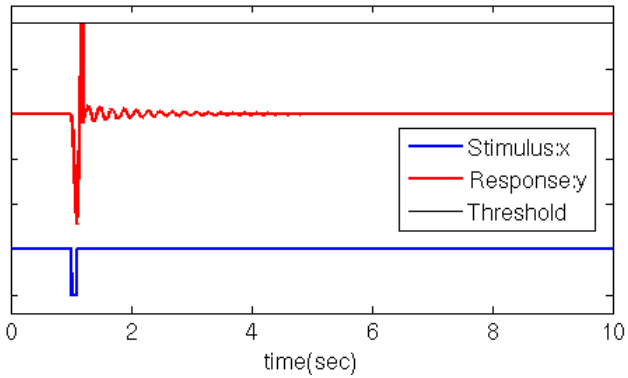
x- current-like variable
y- voltage-like variable
b- rate of attraction to the rest state
w- frequency of oscillations

Source: Izhikevich 2001

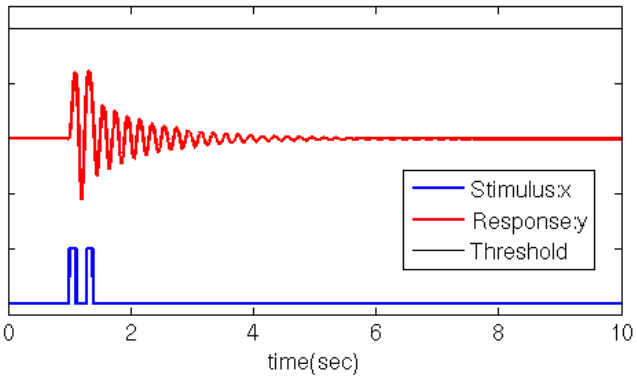
Properties



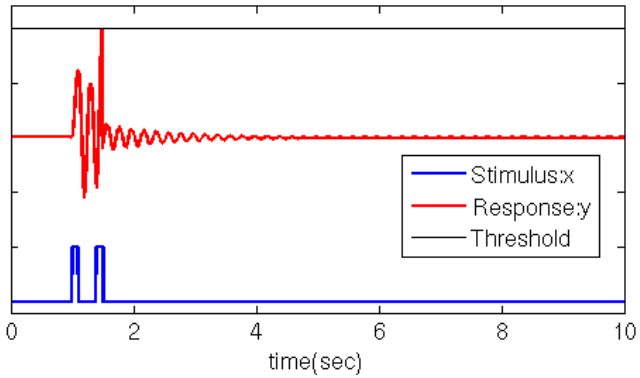
(a)



(b)



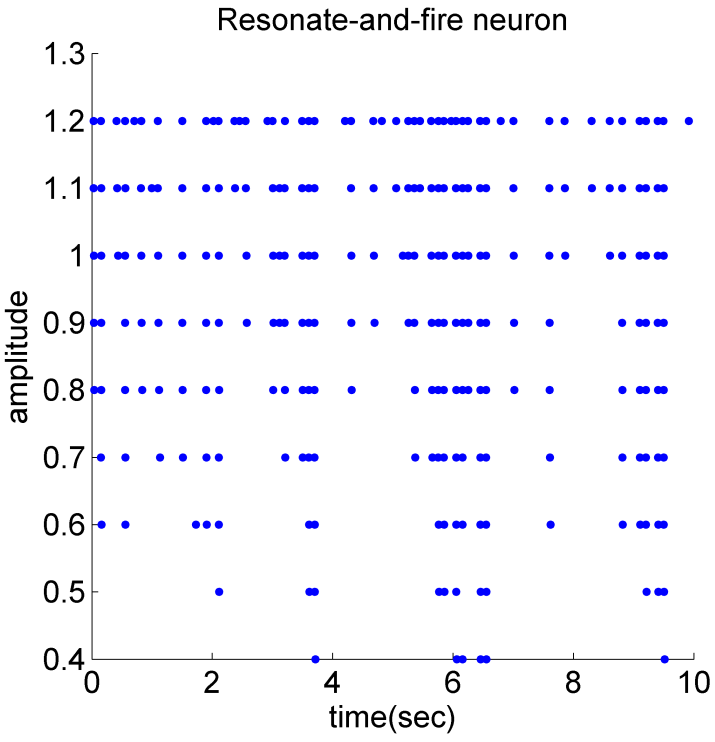
(c)

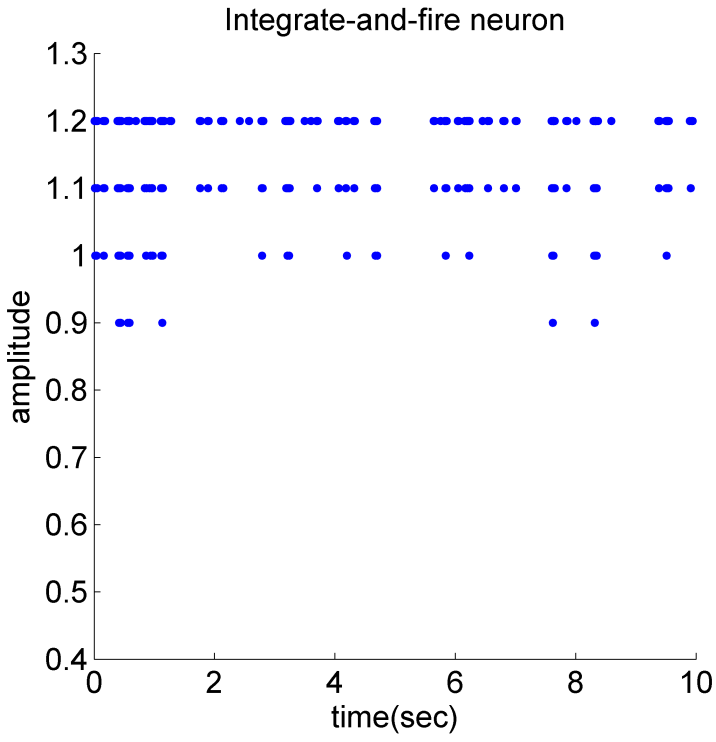


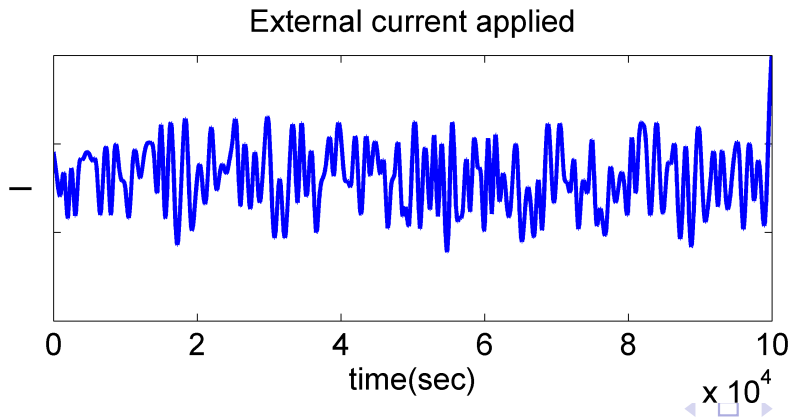
(d)

Figure: Selectivity of resonate-and-fire neurons to inter-spike interval: (a) Subthreshold oscillations (b) Post-inhibition spike (c) No spike elicited for small inter-spike inteval due to out-of-phase arrival (d) spike elicited for larger interspike interval due to in-phase arrival

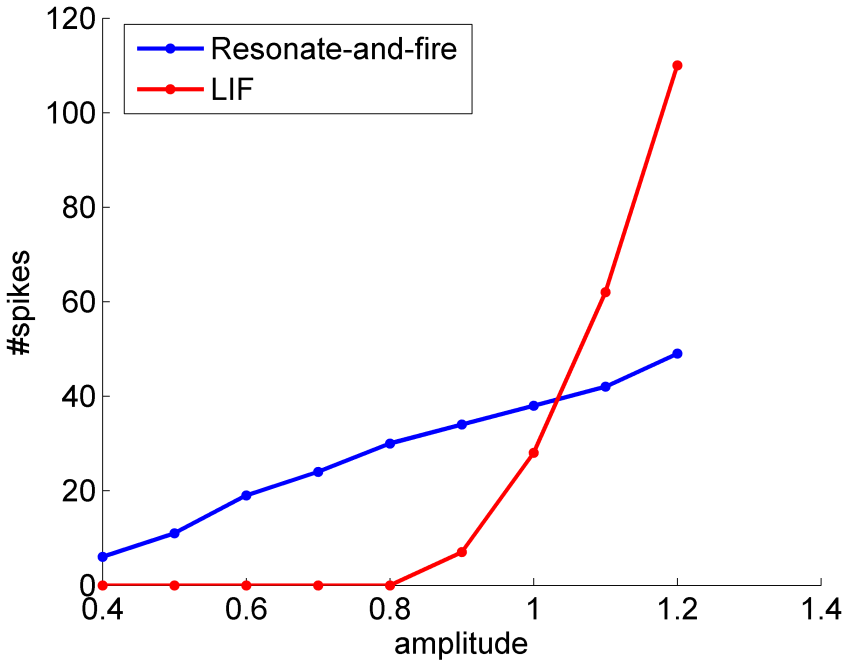
Scaling Invariance



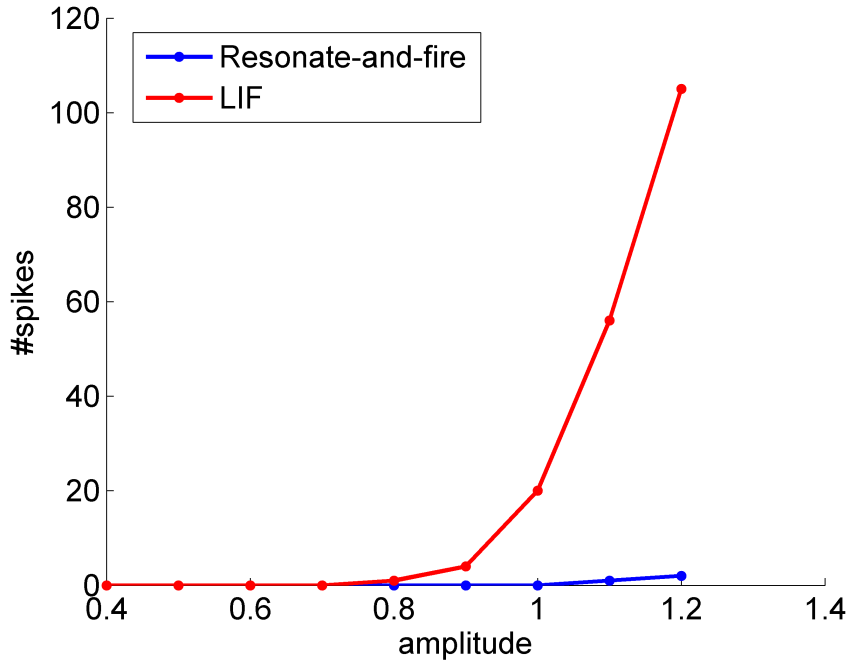




Sensitivity to Temporal Structure



Stimulus bandwidth=10Hz



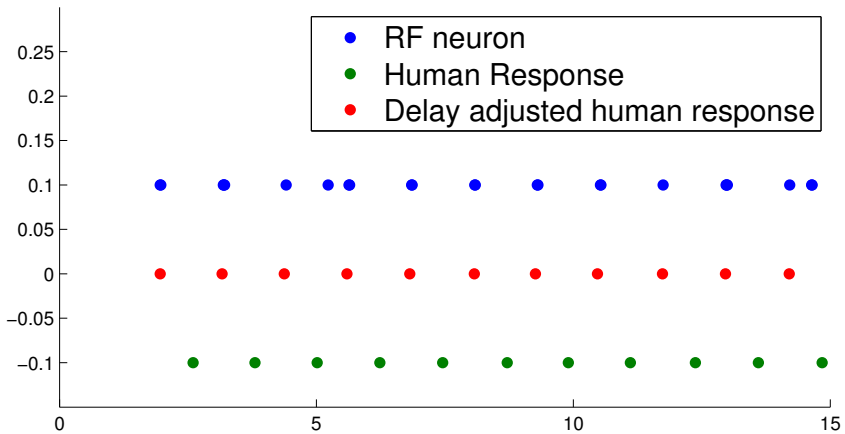
Stimulus bandwidth=5Hz

- Relatively insensitive to amplitude
- Sensitive to the temporal structure of the stimulus

Simulation and Results

Ideology

Frequency components have certain temporal patterns that the RF model can extract. If these patterns are responsible for beats, the spike pattern of the neuron should resemble beats



- Single RF neuron
- Attraction rate -75
- Resonant Frequency 50 Hz

Figure: Experimetal results

Delay Adjustment

A constant phase delay is observed in the spike timings and the subject response. The delay between the first spikes of the two sequences is adjusted and redrawn

Gammatone Filters

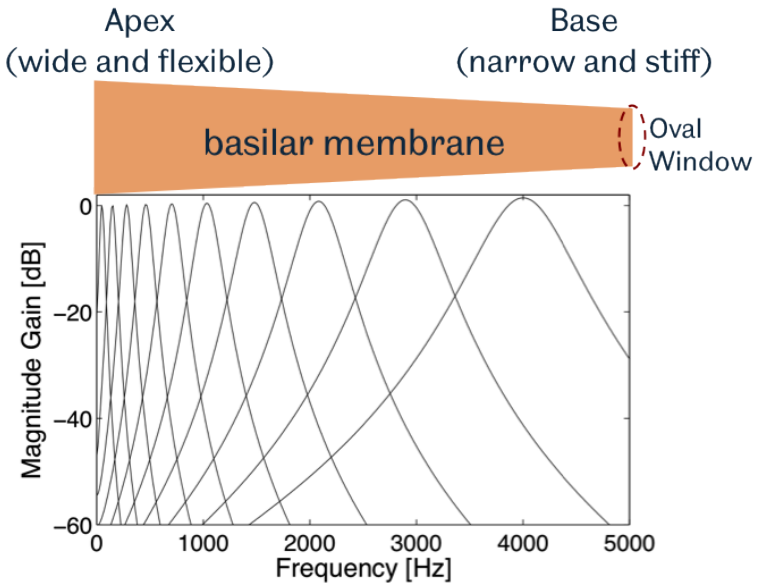


Figure: Frequency Response of Gammatone Filter Bank

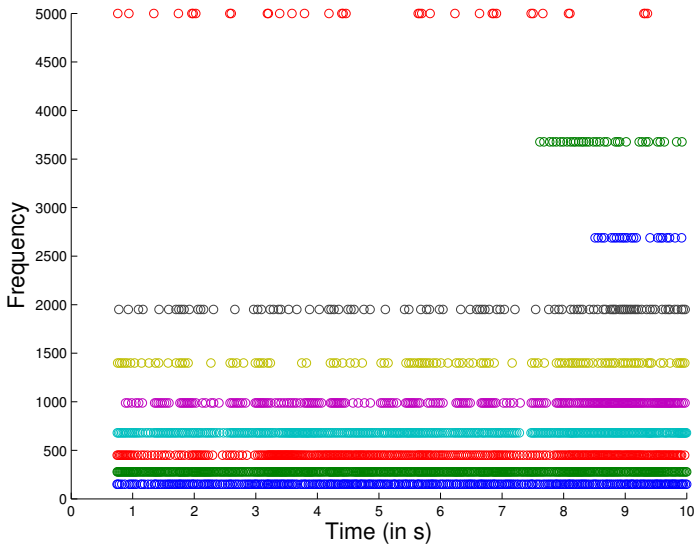


Figure: Spike raster for neurons being fed by seperate filter banks

- Frequency response of cochlea is modelled by a Fourth-order Gammatone filter bank
- Response from each filterbank is fed to a seperate neuron after rectification and scaling via synapses with fixed weights

Conclusion

- LIF, AEF etc. fail to exhibit some of the neural properties
- Some of these properties are possibly the basis of cognition
- Alternate models and their networks should be studied in greater depth to better understand cognition and perception