

**CISC 3250: Systems Neuroscience**  
**Homework 2**  
**due February 24, 2020**

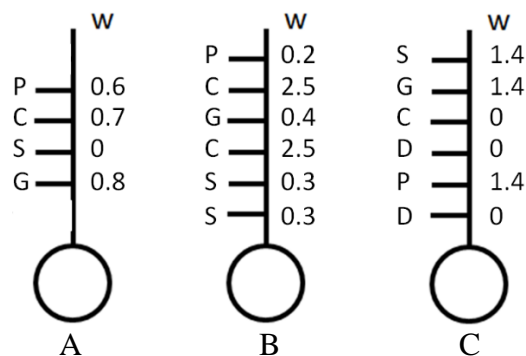
1. Mice do not like to get wet. I got a pet mouse in September. Throughout September and October, when I sprayed my pet mouse with water I saw that it would run away. Starting in November, I decided to play some music on my laptop (the song “Let It Go”) while spraying my mouse, hoping to make it feel better about the water. Unfortunately, by December I found not only did the mouse not let go of its fear of water, but it ran away every time I played “Let it Go” on my laptop.

- (a) What is the conditioned and unconditioned stimulus in this scenario?
- (b) In January, I gave up playing “Let It Go” while spraying my mouse with water. By March, I can anticipate the mouse will no longer run away when it hears “Let It Go.” Name a neural weight-learning mechanism (Marr’s second level) that can account for this “forgotten” association?

2. The three neurons below receive inputs of 1 or 0 on each dendrite:

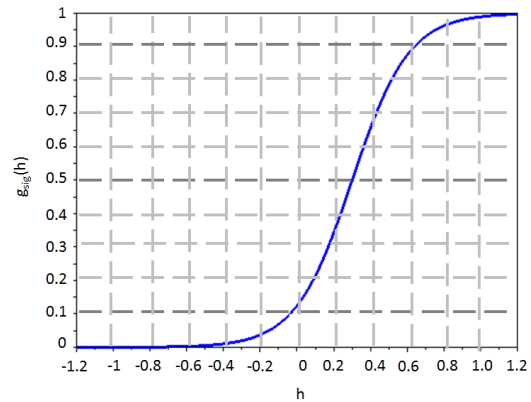
- Dendrites labeled G receive a 1 when a guitar is heard, and otherwise receive a 0
- Dendrites labeled P receive a 1 when a piano is heard, and otherwise receive a 0
- Dendrites labeled S receive a 1 when a singer is heard, and otherwise receive a 0
- Dendrites labeled C receive a 1 when a car is heard, and otherwise receive a 0
- Dendrites labeled D receive a 1 when a dog is heard, and otherwise receive a 0

For each neuron, the inputs are summed in the soma according to the equation  $h = \sum_j w_j r_j$  and the neuron fires (output a 1) on its axon if  $h > 2$ , otherwise the neuron does not fire (outputs a 0). The weights provided were learned from past training of the neuron. Note, we say that a band requires all three musical sounds (each input except the car and the dog) to be present.

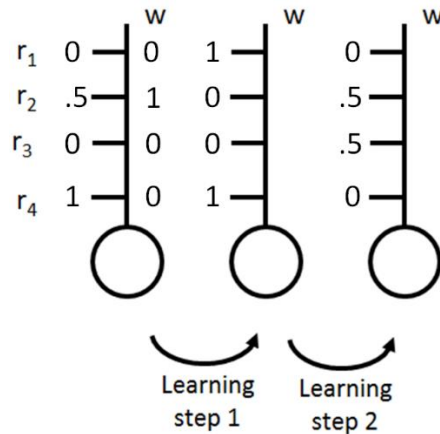


- (a) Which neuron (if any) is a pattern-completion neuron for bands, inferring a band must be present even if not all the band is heard?
- (b) Which of these neurons is tolerant of a subset of pre-synaptic neurons failing to fire (outputting 0 when they should have outputted 1)?
- (c) Draw a neuron with proper weights values to act as a prototype band detector.

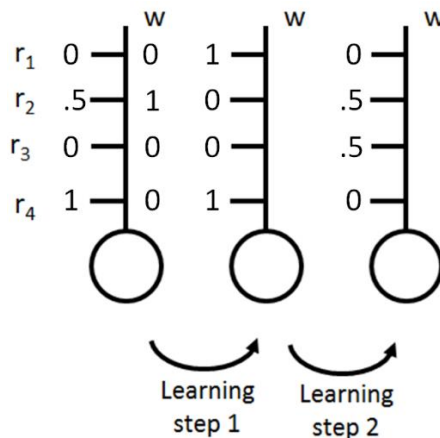
3. We have a neuron that takes input from 4 pre-synaptic neurons. The output of this neuron is computed as  $r_{out} = g_{\text{sigmoid}}(h)$  and  $h = \sum_j w_j r_j$ . Use the sigmoid function as defined to the right (slightly different from the traditional sigmoid).



(a) Use the Willshaw learning rule discussed in class to determine the new weights and new outputs of the current neuron after each of the 2 learning steps below. (The inputs from each pre-synaptic neuron at each learning step are depicted.)

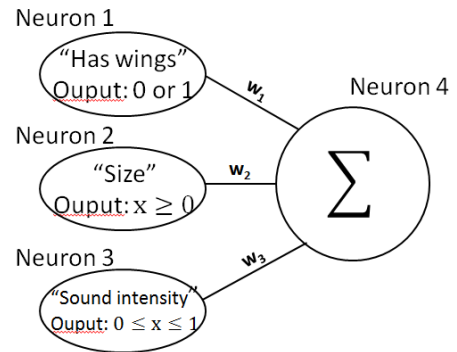


(b) Recompute the weights above for the two learning steps using the learning rule  $\Delta w = \epsilon(w)r_i r_j$ , with  $\epsilon(w) = \begin{cases} -0.5 & w < 0 \\ 0.5 & w \geq 0 \end{cases}$ , followed by weight normalization (dividing by the sum of the weights) at each step.



4. An object that may be a bird, a plane, or a flying superhero is standing in front of a person we are modeling. In this person's brain, there is a wing-detector neuron, a size-measurement neuron, and a sound-intensity neuron. The outputs of these neurons are modeled as non-negative firing rates.

- The wing-detector neuron outputs 1 for wings and 0 for no wings.
- The size-measurement neuron outputs size in feet.
- The sound-intensity neuron outputs a number between 0 and 1, with 0 corresponding to no sound and 1 corresponding to the loudest possible sound.



- (a) What kind of activation function, would best be used to model the wing-detector neuron?
- (b) Which neuron, if any, would be best described by the radial basis activation function?

Let us define Neuron 4 to add together the number outputs of the first three neurons. The output “firing rate” of neuron 4 is simply the weighted sum of the three inputs. Find the best available weight assignment in the **Weights** column **to allow** Neuron 4 to detect each of the objects listed in the **Object** column – i.e., for Neuron 4 to have the highest firing rate for the collection of most-desired properties.

**Object**

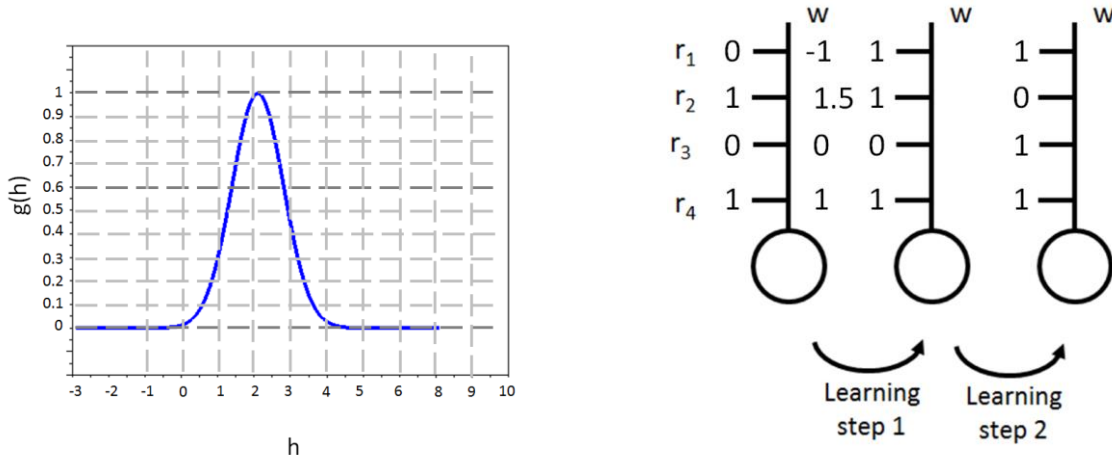
- (d) Superman (small, ignore his sounds, no wings)
- (e) Plane (big, loud, has wings)
- (f) Bird (small, quiet, has wings)

**Weights**

- $w_1=-2, w_2=-2, w_3=0$
- $w_1=0, w_2=-2, w_3=2$
- $w_1=0, w_2=0, w_3=2$
- $w_1=-2, w_2=2, w_3=-2$
- $w_1=2, w_2=2, w_3=2$
- $w_1=2, w_2=-2, w_3=-2$

5. We have a new neuron that takes input from 4 pre-synaptic neurons. We define the weighted sum of the inputs as  $h = \sum_j w_j r_j$ ; the output of neuron 5 is the result of the function  $g(h)$ , shown below.

Use the original Hebbian learning rule:  $\Delta w = \epsilon(w) r_i r_j$ ,  $\epsilon(w) = \begin{cases} -1 & w < 0 \\ 1 & w \geq 0 \end{cases}$  to compute the new weights and new outputs of neuron 5 after each of the 2 learning steps below. (The inputs from each pre-synaptic neuron at each learning step are depicted.)



6: In Matlab, load data from BrainData.mat , available on our web site.

Inside this file is a matrix variable called BrainMat.

- Provide a Matlab command to show a coronal slice
- Provide a Matlab command to show a sagittal slice.
- Provide an  $(x,y,z)$  coordinate BrainMat  $(x, y, z)$  for a location inside the inferior temporal lobe. We are looking for you to get in the right neural neighborhood in the brain.

BrainData.mat also contains a variable neuronVolts, giving the voltage recordings for a single neuron.

- Provide a command to show the largest voltage value reached by this neuron
- Let us now assume the largest value found in (d) is reached every time there is a spike/action potential. Provide a command to return the timing (vector index) of every spike.

(f) Provide a command to create `spikeVector` that contains a 1 at every time/index where `neuronVolts` peaks and a 0 at every other time/index. For example, if `neuronVolts` peaks at 5, 12, and 20, `spikeVector` would be:  
`[0,0,0,0,1,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,1,0,0,0]`

**You have now written code to convert a voltage signal to a spike train (1 when spiking, 0 when not spiking).**