

# Modelling Cortical Activity for Perceptual Grouping Formation

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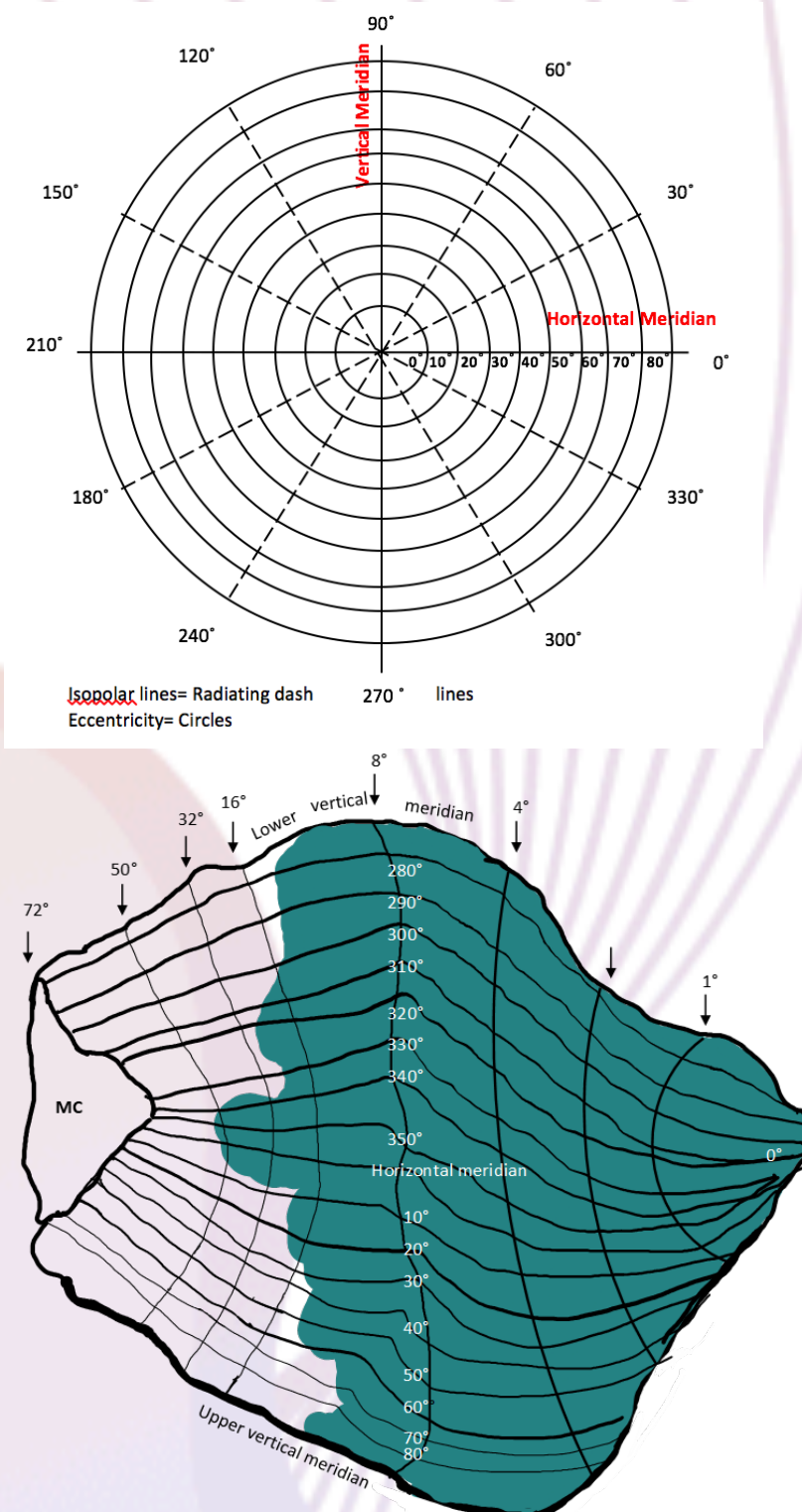
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## Introduction

- Perceptual grouping allows individual components of an image to be perceptually connected according to Gestalt principles.
- The neural process by which grouping occurs, as well as the timescale of grouping, are not understood.
- Experiment Goal:** In order to explore possible neural circuitry that mediates grouping, three hypothetical models were developed by comparing predicted dynamics to existing data.

- Visual Field Coordinates:** a numerical system to specify locations in the visual field.
- The polar axis is the angle from the central point (in this case the fovea) and the radius is the distance from the fovea (eccentricity).

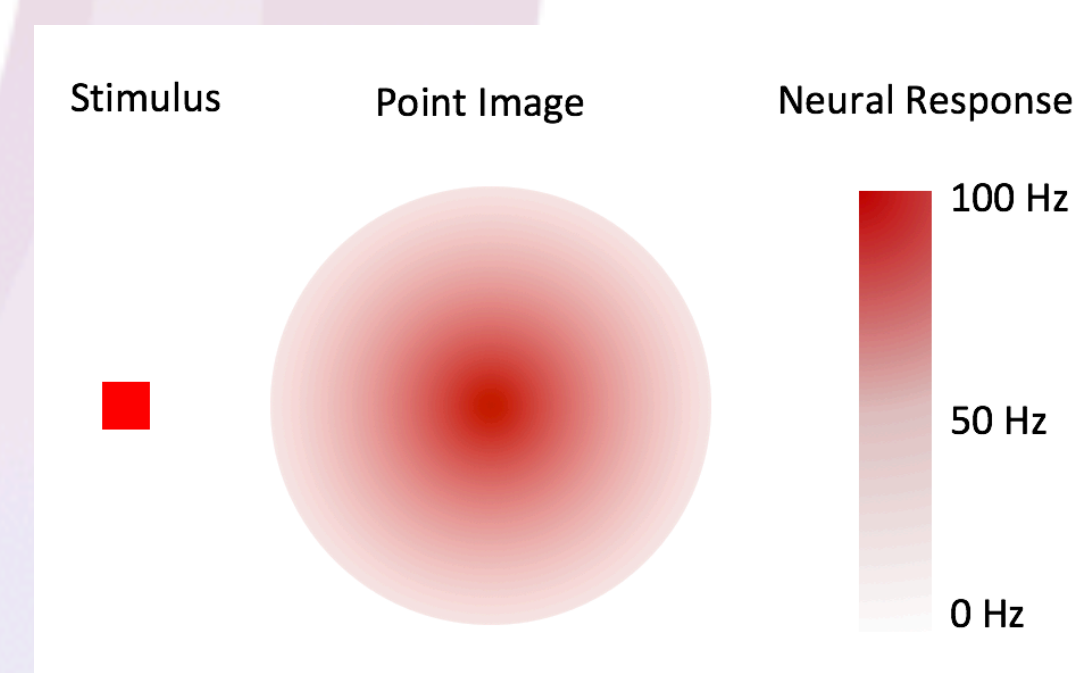


- Retinotopic Organization:** where adjacent areas in visual space are represented at adjacent areas on the cortical surface.

## Cortical Point Image

### Receptive Field:

- The area of the visual field at which a single neuron responds.
- If a stimulus falls within this area, action potentials are fired facilitating neuronal communication → information originally from sensory receptors are processed within the brain.
- When multiple, adjacent neurons possess overlapping receptive fields, they generate a **point image**.



### Cortical Point Image:

- Distribution of neural activity on the cortex in response to a point of light.
- Rather than one neuron, a cluster of neurons respond to stimulus altogether.

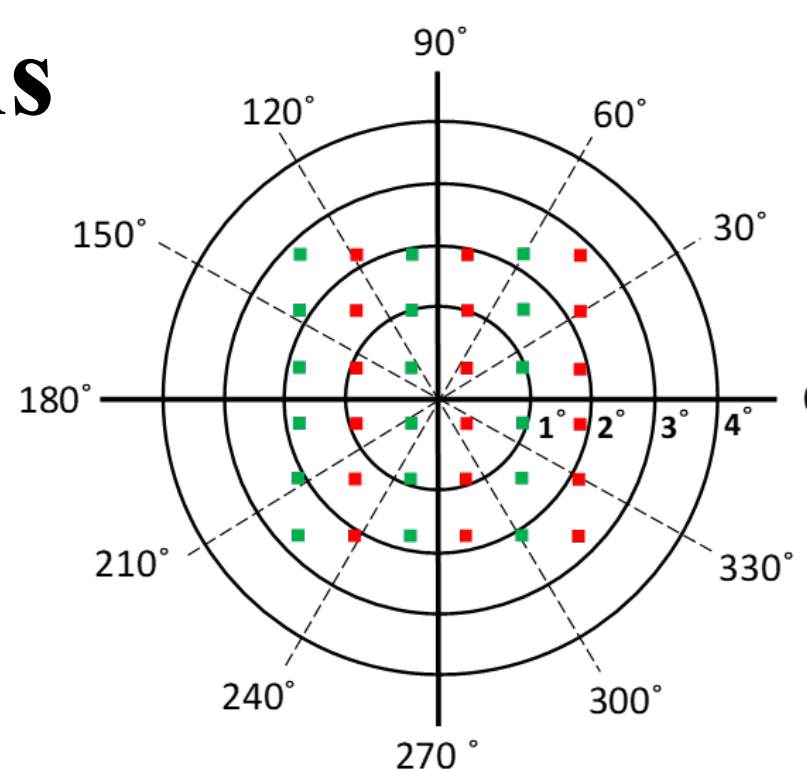
- Center of point images contains greatest neural activity → Stimulus applied to the center results in high neuronal activity. Application to the point image but not in the center, results in low activity.

## References

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## Stimulus Mapped on Visual Cortex

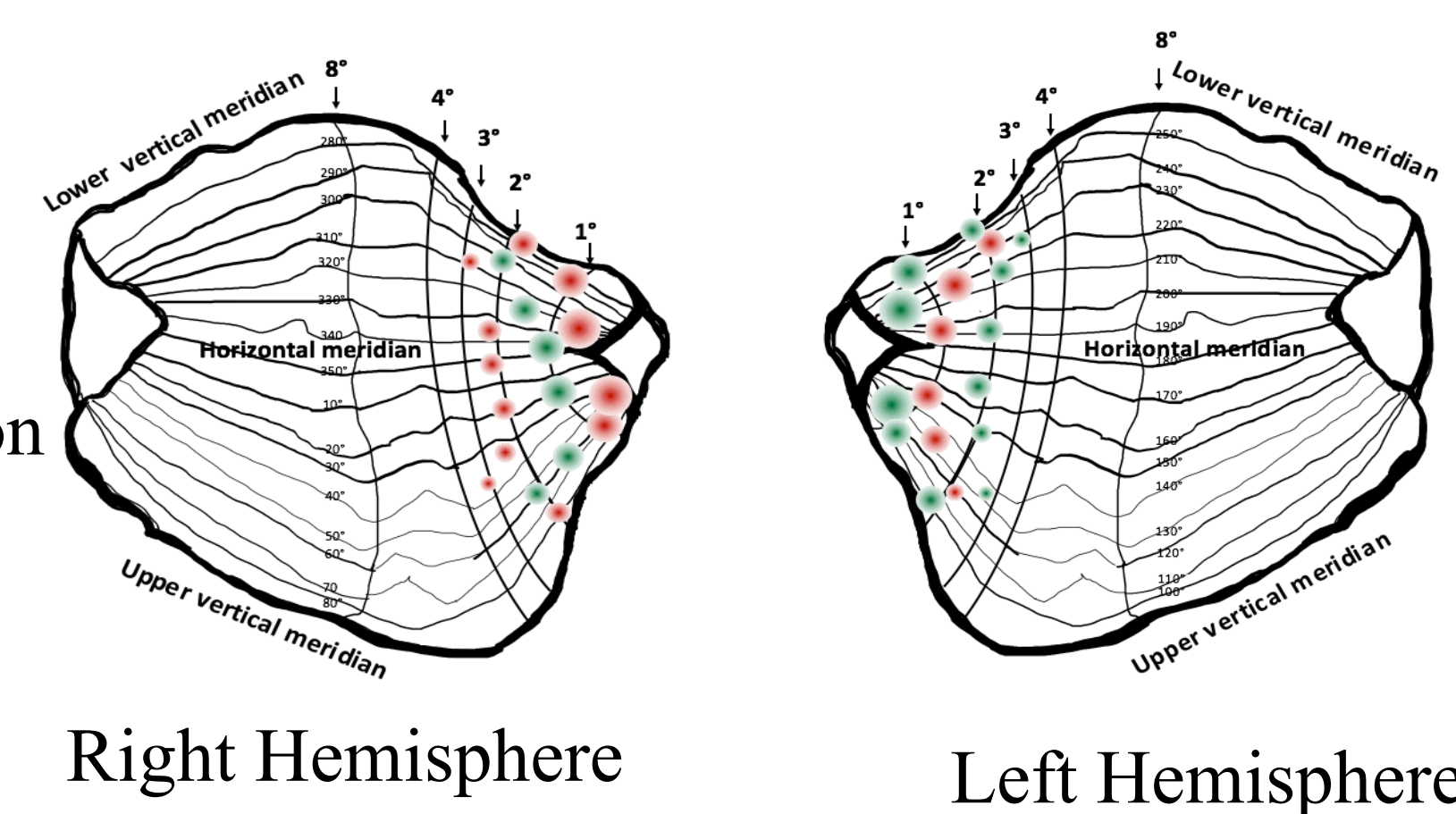
### Stimulus



- Grid of 6x 6 squares.
- Individual squares of 0.13°.
- Alternated between colors green and red.

### Cortex

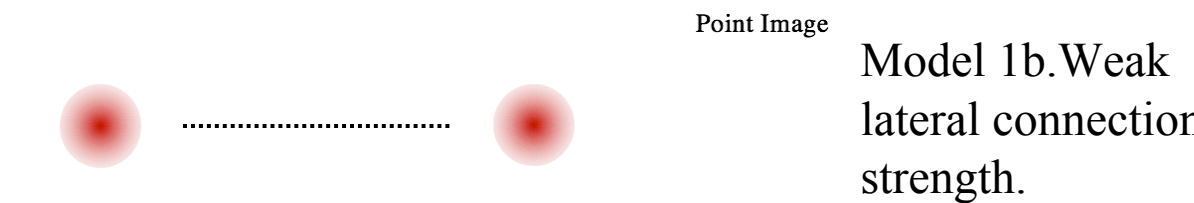
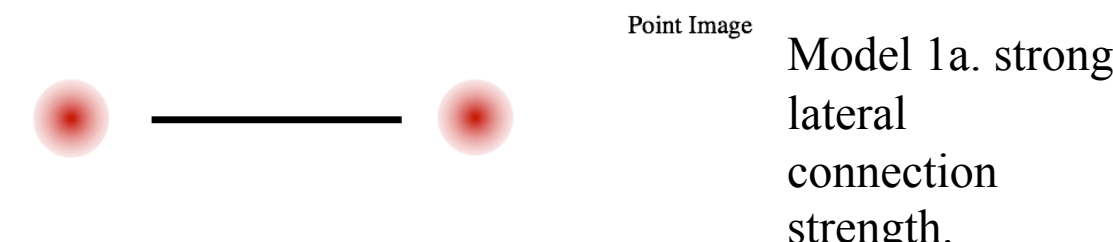
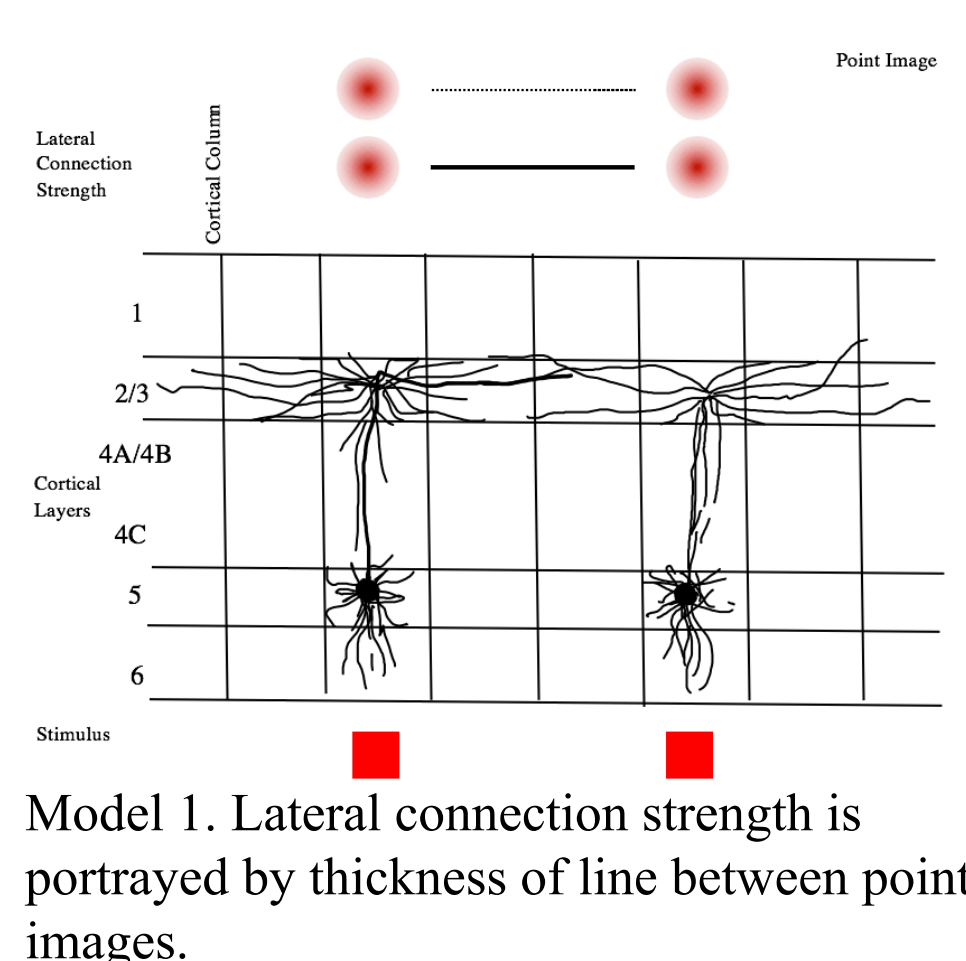
- Stimulus components presented as point images on retinotopic organization.



## Models

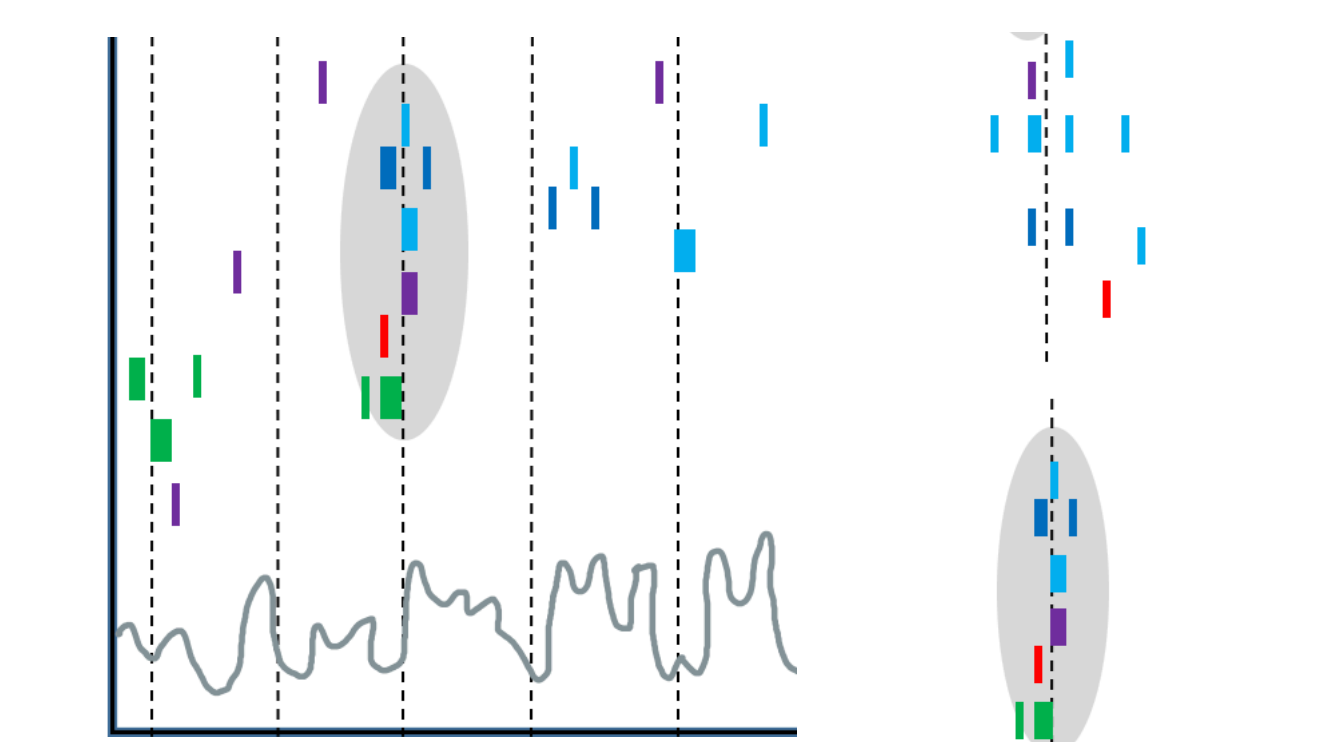
### Model 1:

- Point images become associated by lateral connections.
- Lateral connections are neurons that link cortical columns as neurons extend laterally across a cortical surface.
- So, perceptual grouping is more complete when there is an strong connection strength among point images.



### Model 2:

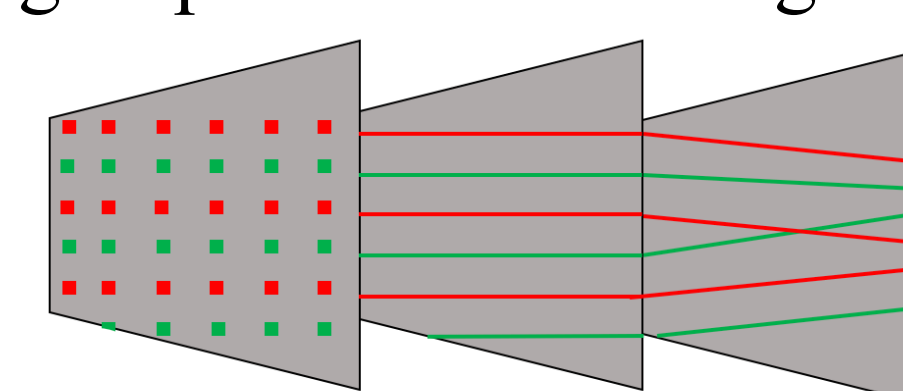
- As point images become associated, neural firing becomes coherent either by firing at the same time, or patterns of oscillations



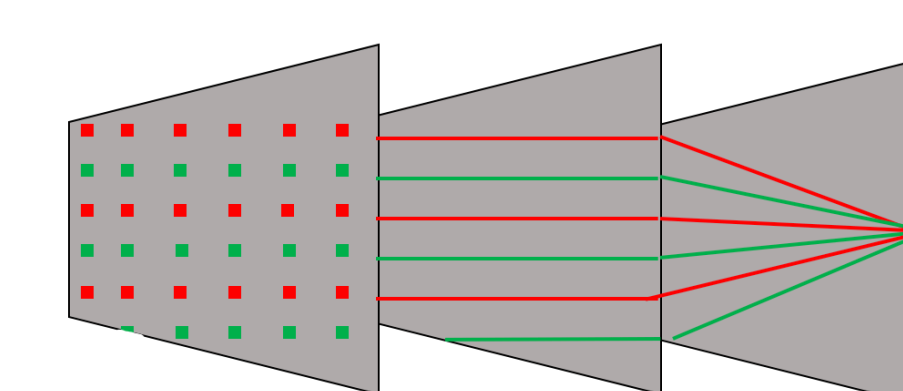
Model 2. Point images that fall within the grey ovals are strong oscillations, while those outside of it, are weak oscillations.

### Model 3:

- Point images become associated by converging onto higher cortical areas.
- Point images that are successfully formed into groups converge onto the same set of neurons, while point images that are not grouped fail to converge.



Model 3b. Showing weak grouping, only a few point images have converged as one set of neurons, while the rest have failed to converge unto that set.



Model 3b. Showing strong grouping, point images have converged as one set of neurons.

## Methods

- To explore neural circuitry mediating grouping, three hypothetical models were tested by **comparing predicted dynamics to existing data**.
- The following questions were then addressed; 1) **How does grouping develop across time?** 2) **How does grouping respond to brief stimulus duration?**

## Model Predictions

### Grouping initiation:

- Model 1** predicts grouping begins right after the afferent signal arrives, since lateral connections activate while point images form.
- Model 2 and 3** predict a delay in grouping initiation, as neural activity becomes coherent, or connections have to project to higher cortical areas.

### Brief stimulus duration:

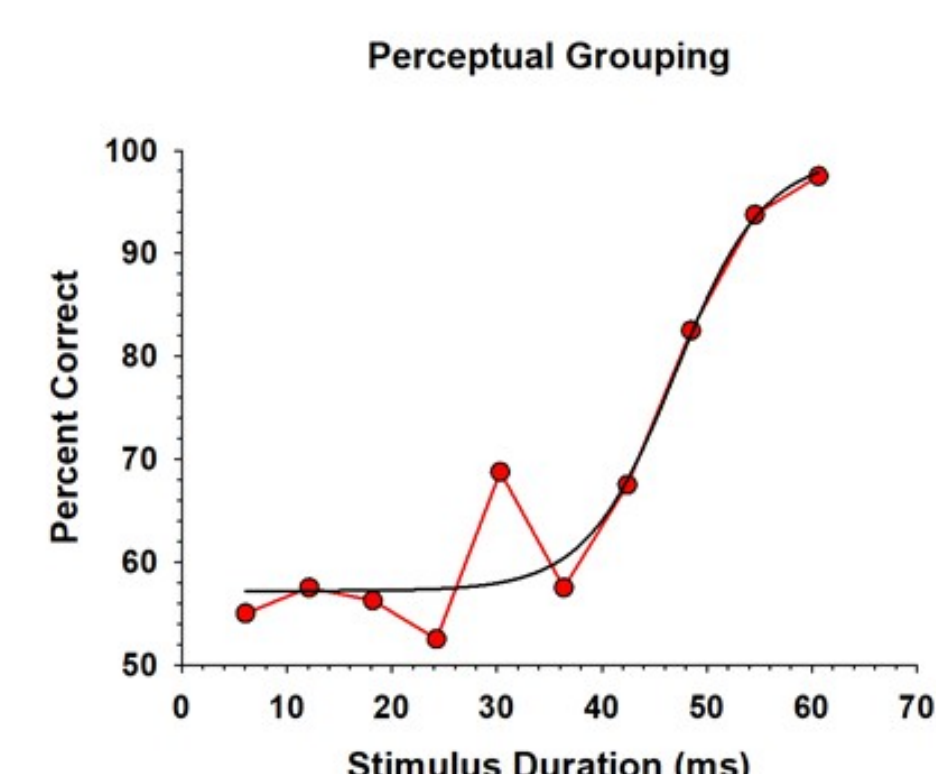
- For **Model 1**, grouping should not continue after the afferent signal has vanished since the encoding of point images happens quickly.
- For **Model 2**, additional time is needed to form coherence. In this case, brief afferent signal may continue to be processed after it has vanished.
- For **Model 3**, the afferent signal is not needed once point images have been passed to higher areas, where feedback can correct earlier stimulus representations.

## Results

1) At stimulus duration of 60 ms, grouping is complete (100%) → supported by **model 1**; grouping is a non-progressive process where point images are associated with lateral connections.

2) Grouping occurs after 42 ms → point images are forming, but grouping incomplete till oscillations are coordinated, further extending time of grouping initiation; **model 2**.

3) At a stimulus duration of 50 ms, grouping is 80% complete → Point images become associated, but need to access higher areas to converge. After the signal has disappeared, feedback processes and neural persistence continue to facilitate this process; **model 3**.



Percent correct in discrimination of stimulus plotted across stimulus duration.

## Discussion

- Components of each model are successful at predicting neural mechanisms of grouping, and overlap with each other.
- Therefore, grouping is mediated through coherence of neuronal activity as well as lateral connection strength, leading to convergence of point images. This allows access both lower and higher orders of processing.