ATTENTION

Akanksha Saran
Krishna Kumar Singh

How do biological beings process ***visual*** information for a specific ***task*** with ***time*** constraints?

VISUAL OVERLOAD!

Need to filter out some information..

Attention to the rescue?

Two types of attention

Bottom Up Attention - Visual Saliency

Top Down Attention

Top-down Attention

Feature-based attention in visual cortex

John H.R. Maunsell and Stefan Treue

2006

Top-down Attention

- Task driven

- Two types:
  - Space Based
  - Feature Based

Space-based Top-down Attention

when we are looking for traffic light our attention will be at top.

Space-based top-down Attention

while pressing door bell, attention will be 3-4 foot above ground.

Feature-based top-down Attention

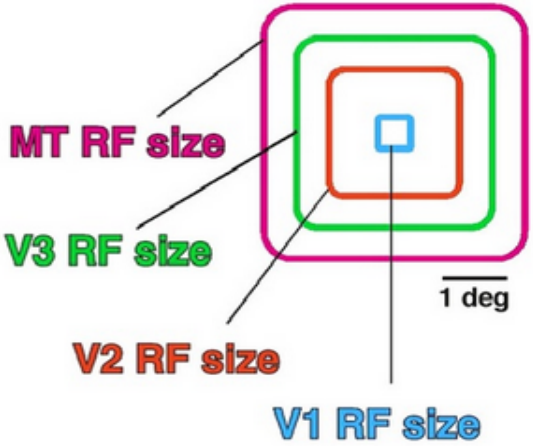
Feature-based top-down Attention

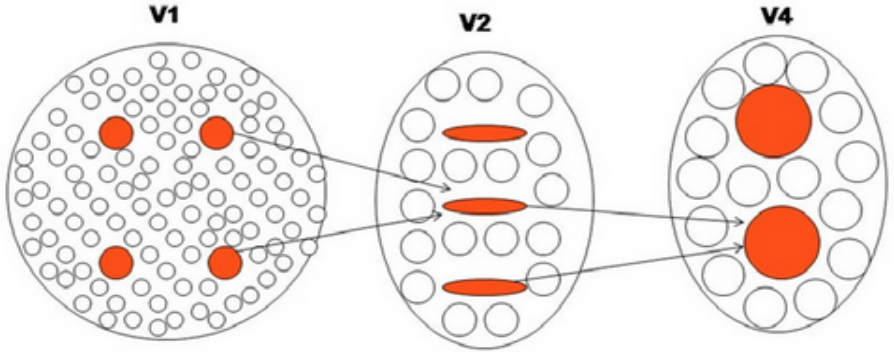
Feature-based top-down Attention

Feature Attention example

What role does attention play in visual Information processing?

Visual Pathway

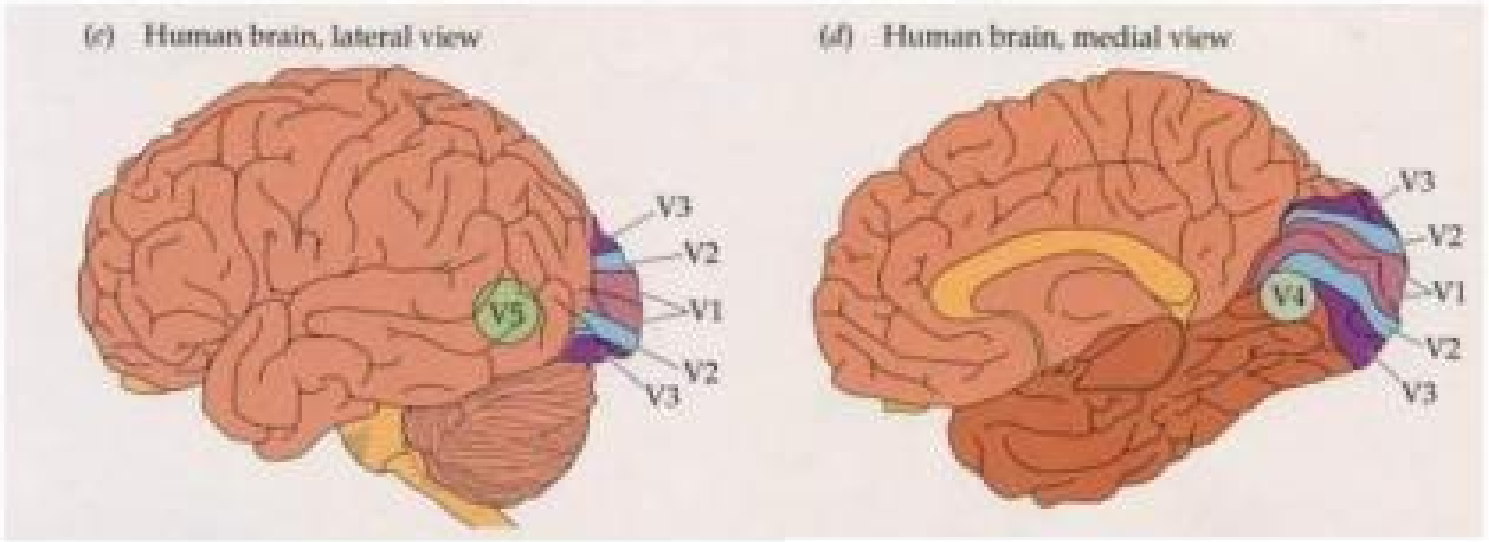




V4 and V5(MT) have RF large enough to talk about attention.

V4 and MT have large RFs - deal with attention

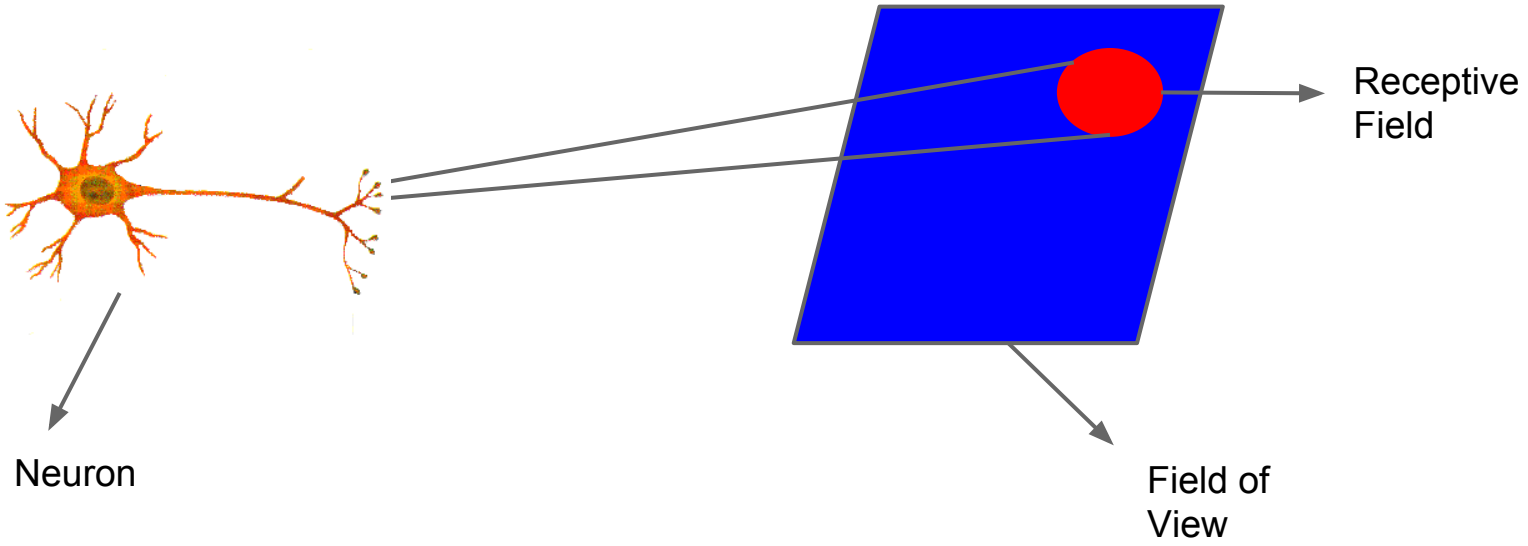
Human Cortical Visual Regions: V1, V2, V3, V4, V5 (MT)



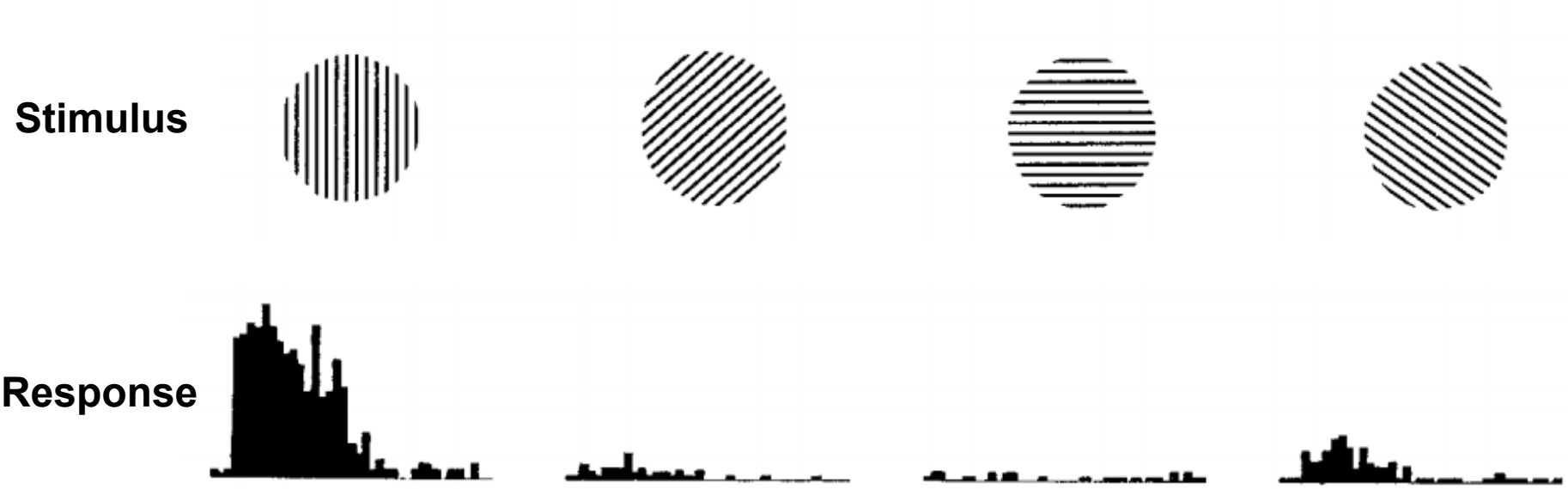
Factors affecting neuron response while performing visual recognition in the brain

- Receptive Field
- Feature Selectivity
- Attention

Receptive Field

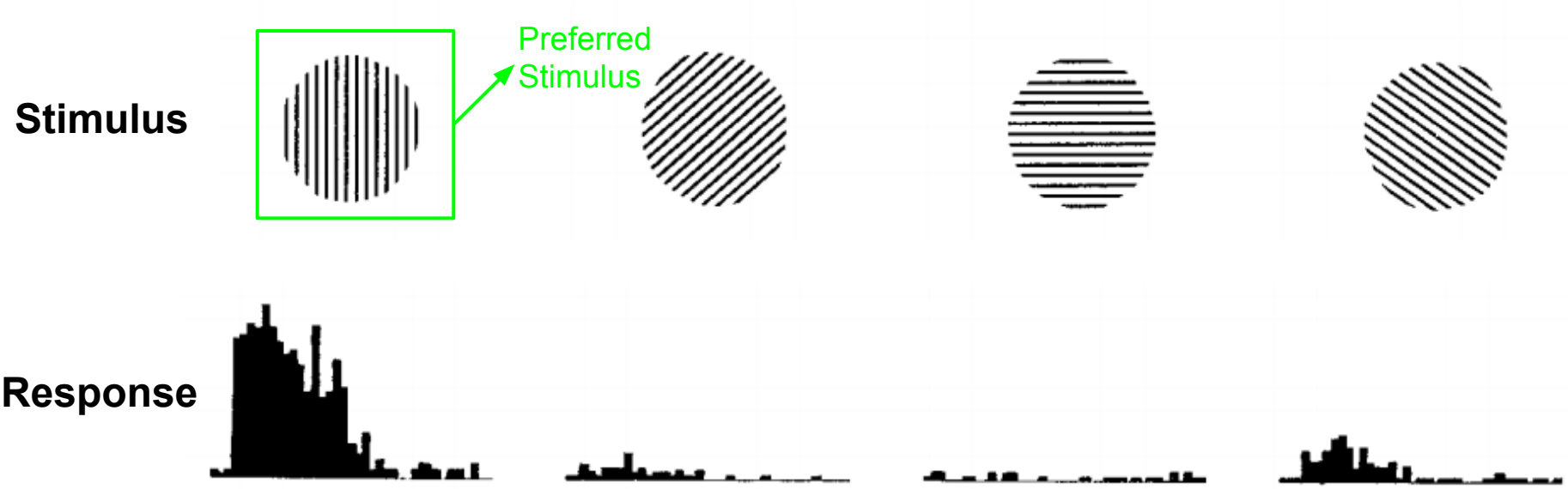


Feature Selectivity



Neurons are selective to orientation (features).
They have some preferred stimulus.

Feature Selectivity

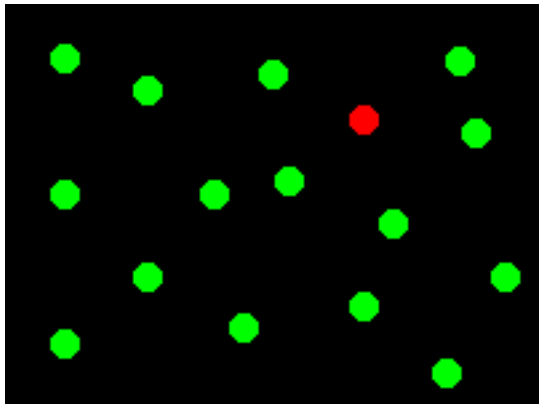


Neurons are selective to orientation (features).
They have some preferred stimulus.

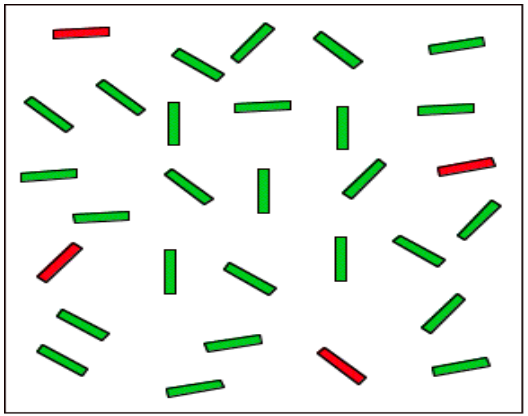
Feature Based Attention Experiments

Visual Search

- Help to study feature based attention.
- Ability to detect target (cue), among the distractor items.
- Distractor and target differ by at least one feature.



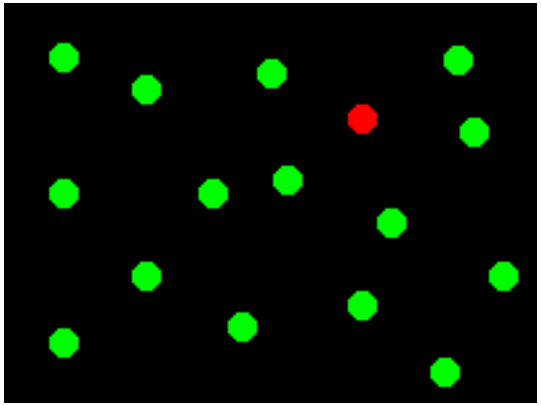
find the circle with red color



find the vertical rectangle with green color

Visual Search

- Target : Features we are searching.
- Distractor : Features other than target features.



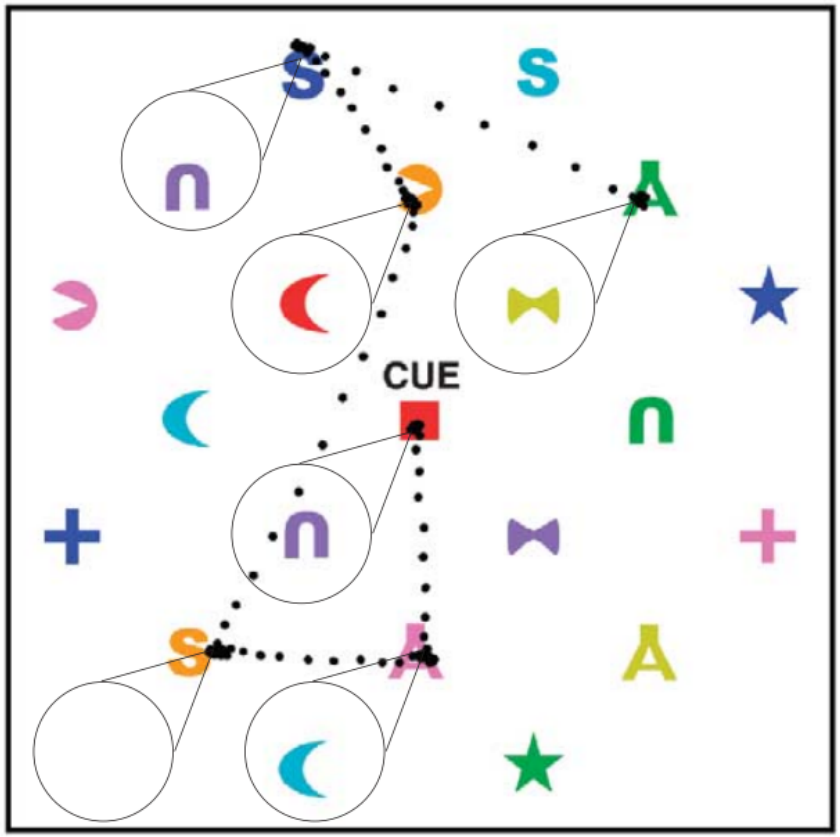
We have to find the circle with red color.

Target is **red** color.

Distractor is **green** color.

Target can be associated with attention.

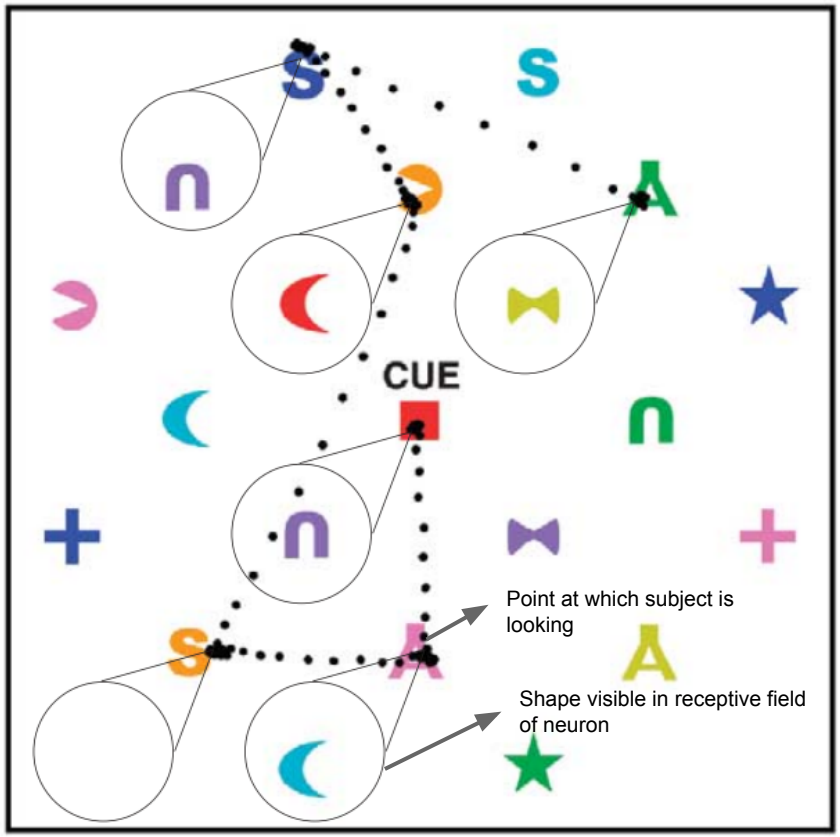
Visual Search Experiment For V4



Monkeys were trained to search for a target with a particular color or a particular shape in a crowded display

For example:-
Find the shape with red color

Visual Search Experiment For V4



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For example:
Find the shape with red color

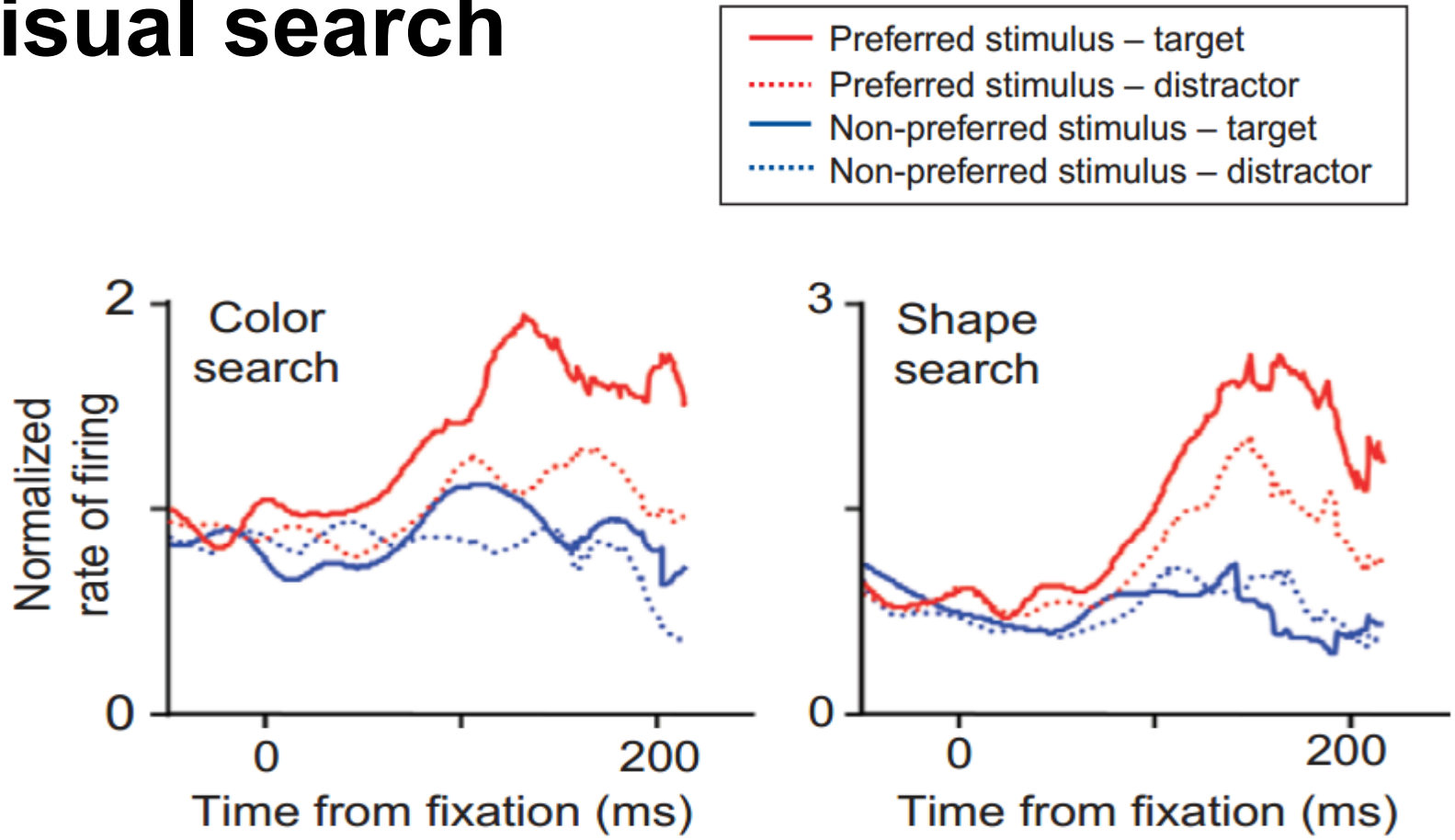
Visual Search Experiment For V4

- There were multiple trials of the experiment.

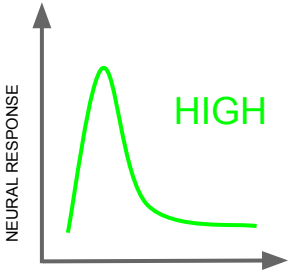
- In some trial preferred stimulus and target were same.
  - For example:- We are looking for red color and preferred stimulus of neuron is also red color.

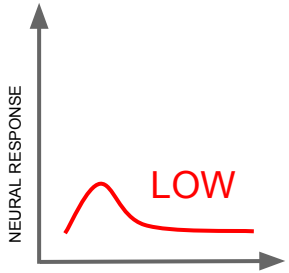
- Whereas in some trial preferred stimulus and target differed.
  - For example:- We are looking for red color but preferred stimulus of neuron is green color.

Feature based attention during visual search



RESULTS





- Preferred Stimulus (without attention)
- Non-Preferred Stimulus (without attention)
- Preferred Stimulus + Target (with attention)
- Preferred Stimulus + Distraction (without attention)

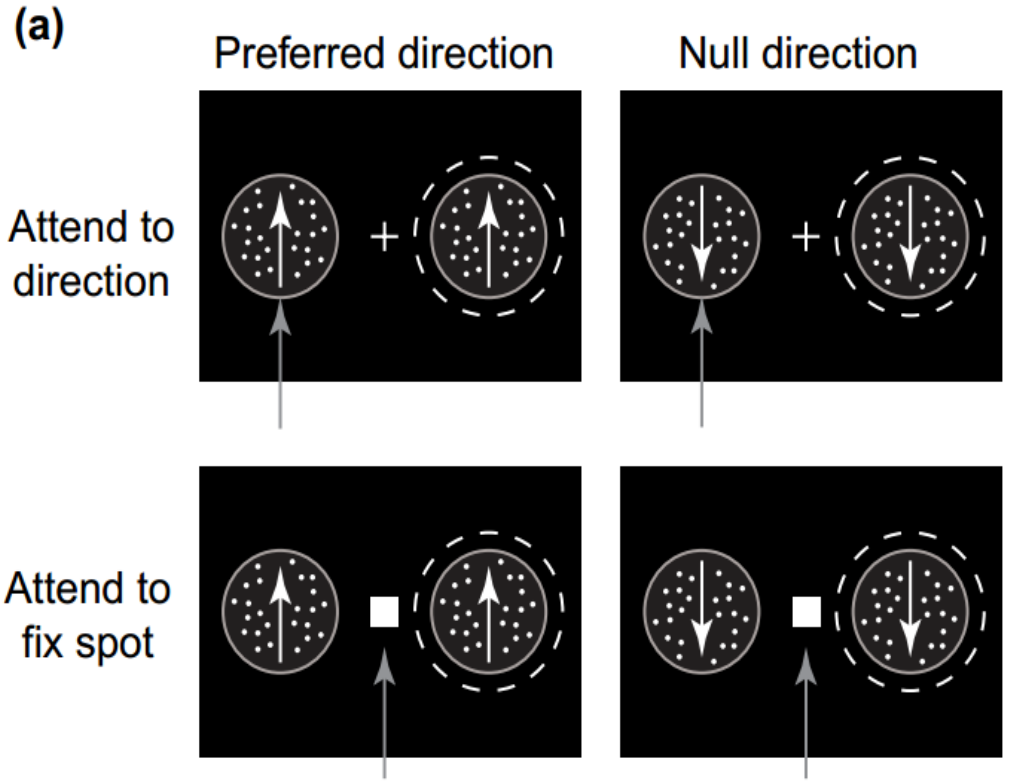
Preferred Stimulus + Attention gives maximum neuron response

Motion Based Attention

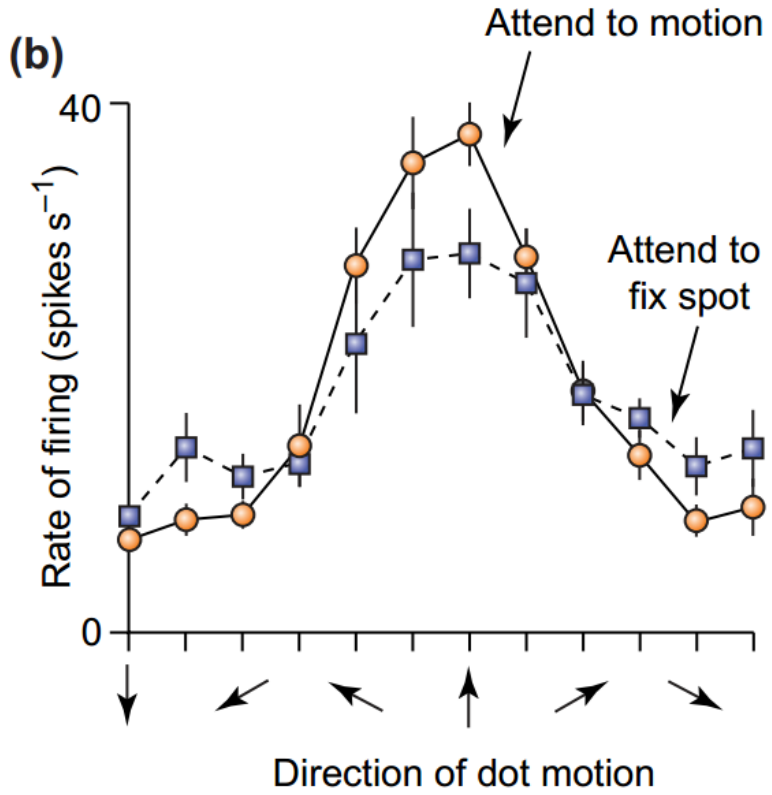
- Till now, we have seen feature based attention using shape and color.
- Feature based attention could be attending to a specific type of motion.
- MT has neurons specific to motion.

Feature (Motion) Based Attention In MT

- MT is sensitive to visual motion.
- Two patches of random dots were presented.
- The patches always moved in the same direction (white arrows).
- one within the receptive field of the neurons being record (broken white line).
- the attention is shown by gray arrows.

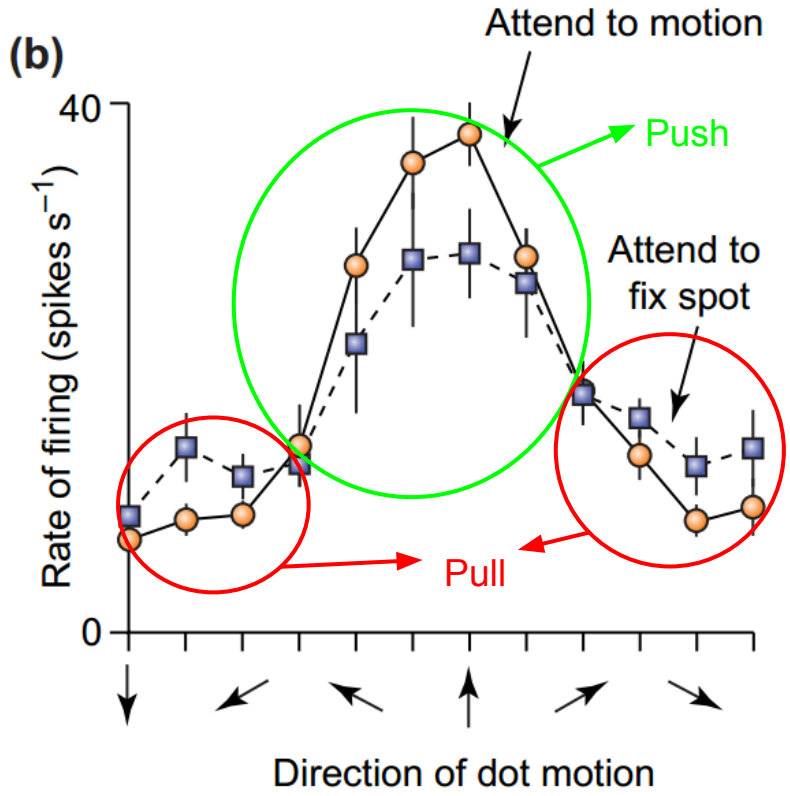


Feature based attention in MT



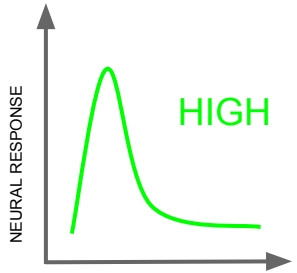
- preferred direction responses were on average 13% stronger.

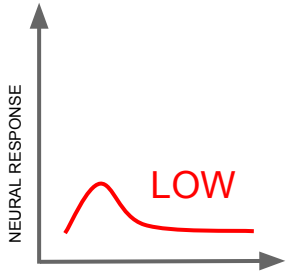
Feature based attention in MT



- Attention has push-pull effect (increases responses only for neurons that prefer motion close to the attended direction)

RESULTS (Motion)





- Preferred Direction (without attention)
- Non-Preferred Direction (without attention)
- Preferred Direction (with attention)
- Preferred Direction (without attention)
- Non-Preferred Direction (without attention)
- Non-Preferred Direction (with attention)

Preferred Direction + Attention gives maximum neuron response

Attention amplifies the inherent response of the neuron.

Summary

- Two methods of Top-Down attention
  1) Space-based
  2) Feature-based

- **Attention increases the sensitivity of neurons!**

But what **mechanism** in the brain allows for this **increased sensitivity** of neurons with **attention**?

Interacting Roles of Attention and Visual Salience in V4

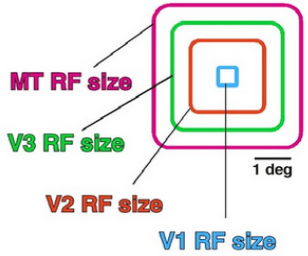
John H. Reynolds, and Robert Desimone

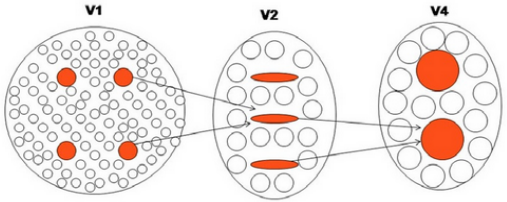
2003

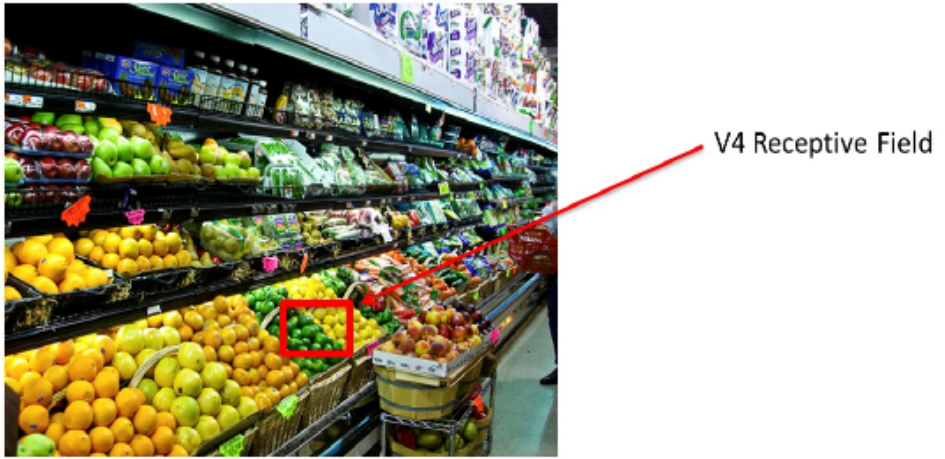
Neuron Sensitivity

What can modulate the response of neurons?

- Receptive Field
- Feature Selectivity
- Top-down Attention
- Visual Saliency such as **Contrast** (Bottom-up attention)







Visual Salience

Contrast - Visual Salience

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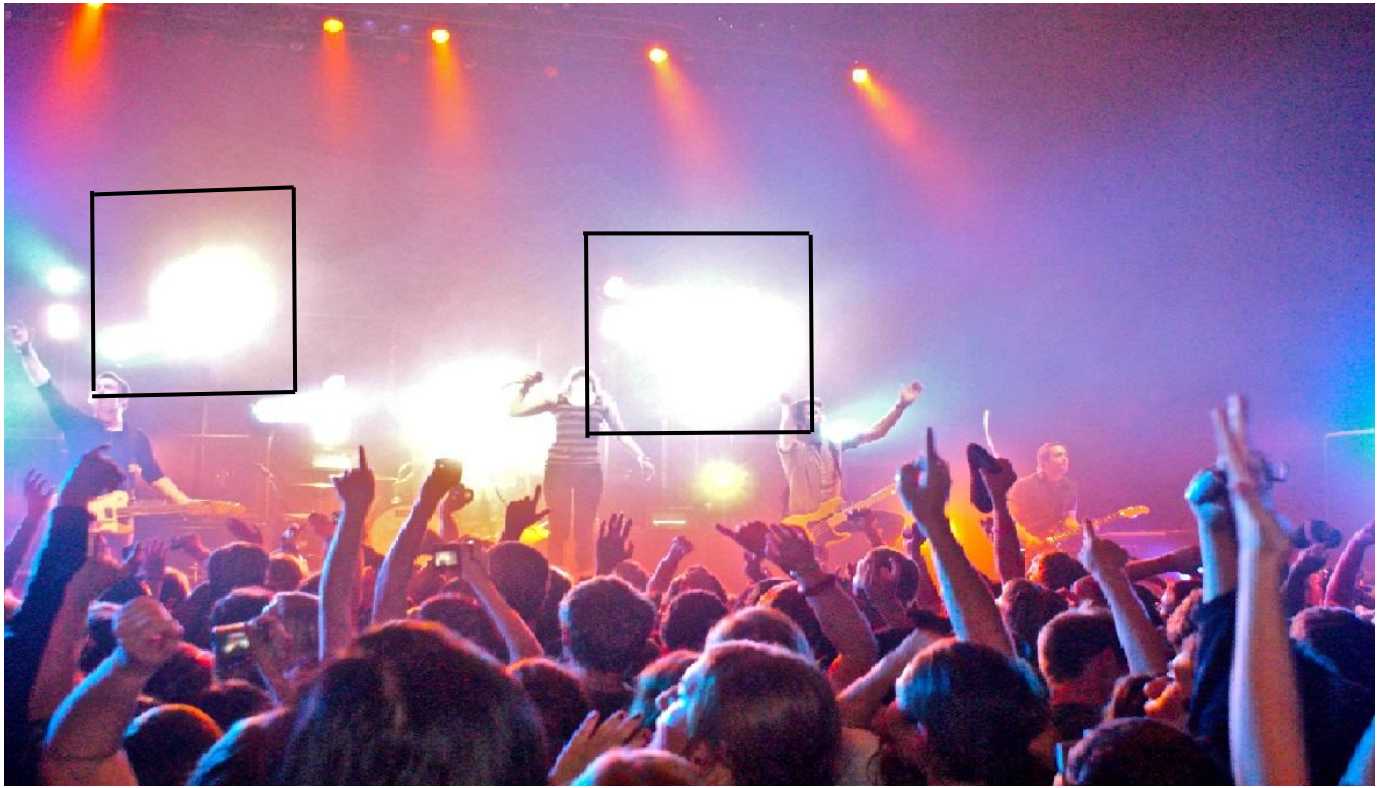


Impact of contrast on neural activity

Experiments - Stimuli

50 V4 neurons from two monkeys

Reference stimulus : preferred stimulus of the neuron population

Probe stimulus : non-preferred stimulus of the neuron population

Pair of stimuli : in the same RF

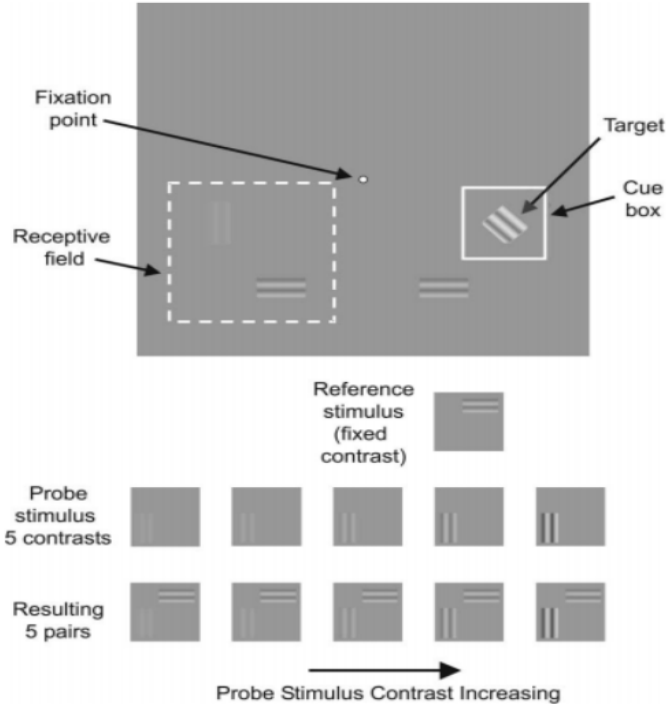
Experiments - Task

Monkeys trained to attend on cue box

Task: detect diamond shaped target

Two trials:

1. attend right (away from RF)
2. attend left (RF)



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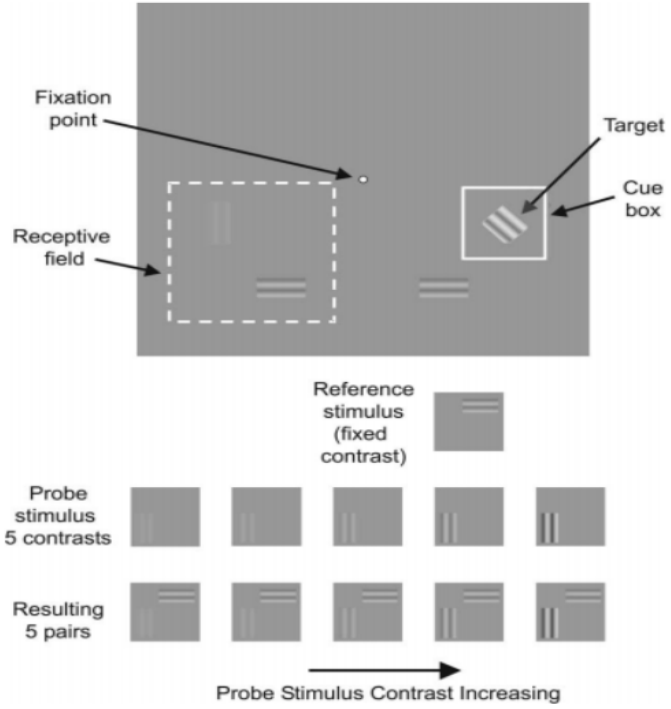
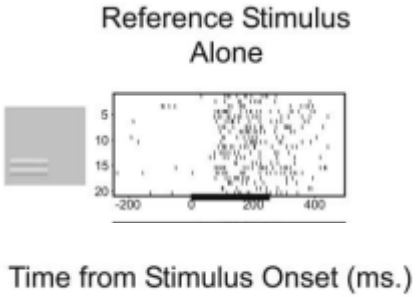


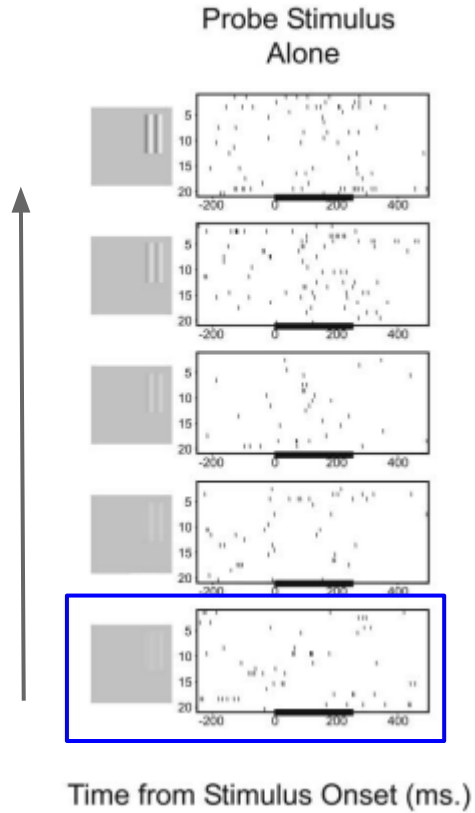
Preferred Reference Stimulus

- high response of neuron population for reference stimulus



Non-preferred Probe Stimulus

- Low response of neurons for probe
- As contrast increases response higher
- Higher contrast creates bottom-up attention



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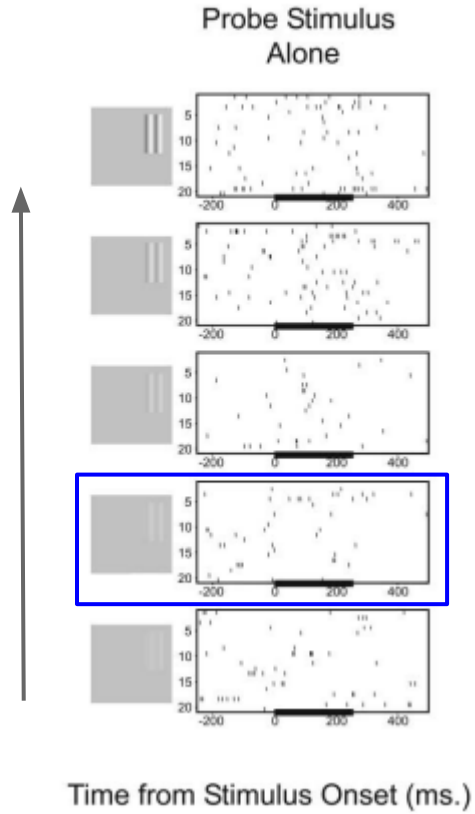

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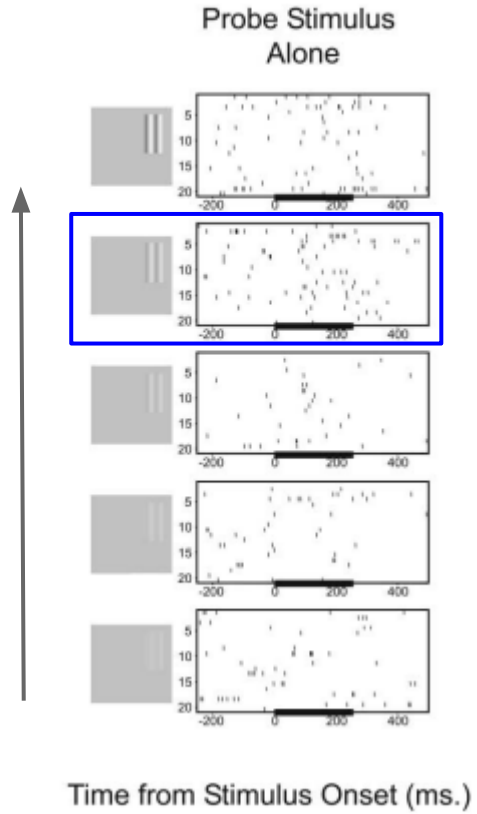

What happens when both stimuli are within the same receptive field of the neuron?

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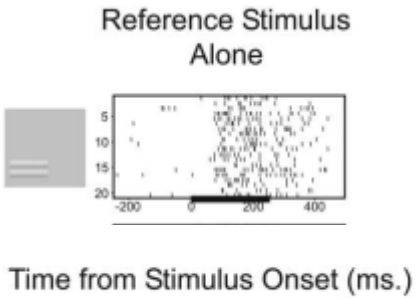
- fires a lot for the reference stimulus (preferred)

Reference stimulus (fixed contrast)



What happens when both stimuli are within the same receptive field of the neuron?

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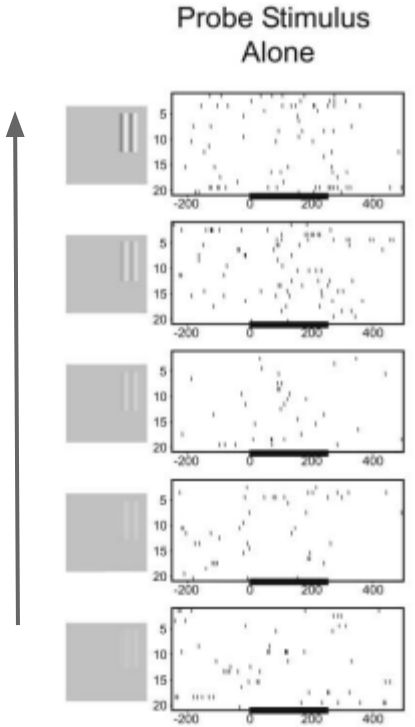
Reference stimulus (fixed contrast)

- increasing contrast of the probe stimulus creates bottom up attention that the neuron responds to as well



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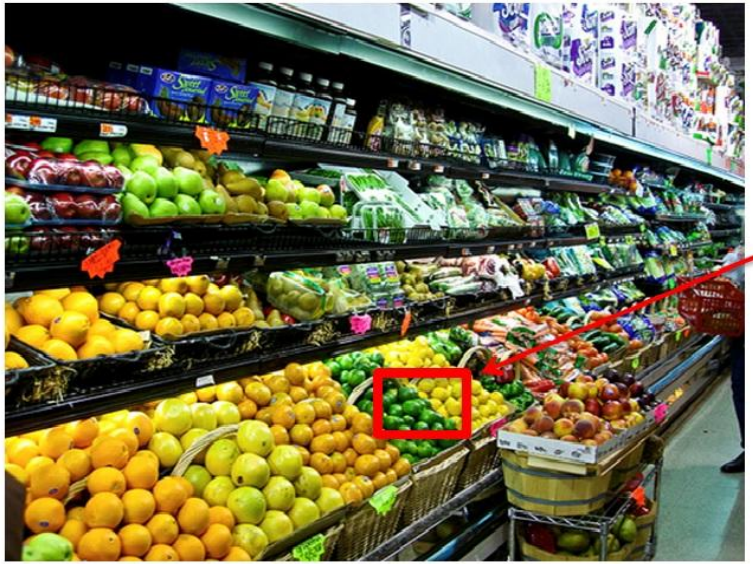
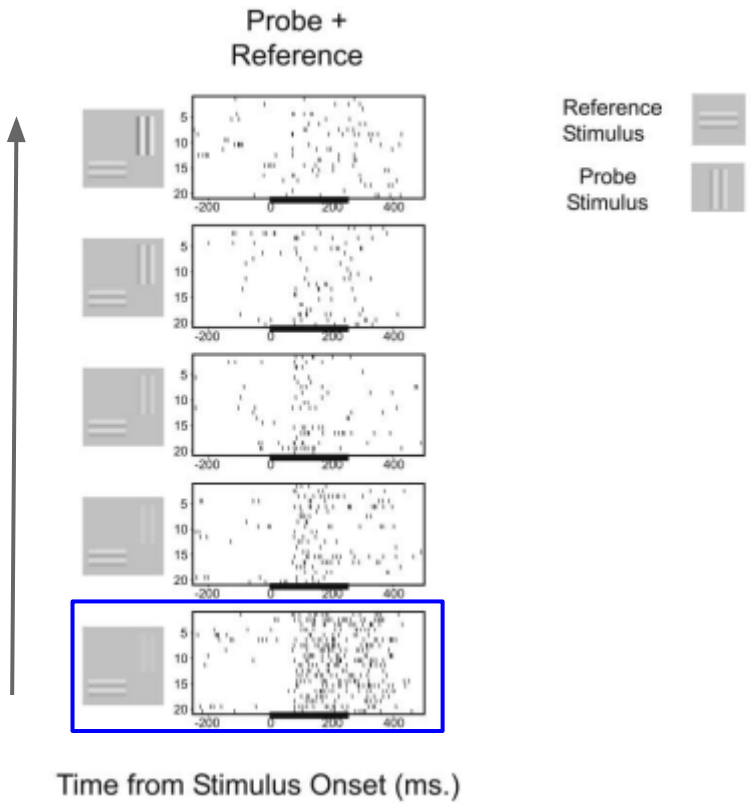


How should the neuron respond when 2 things are **competing** for the neuron's response within the space of the receptive field?

Probe and Reference in same RF

- Initially weak probe with low contrast has no impact
- As contrast of probe increases, the net effect is similar to probe
- A non-preferred probe **suppresses** the response of preferred reference stimulus



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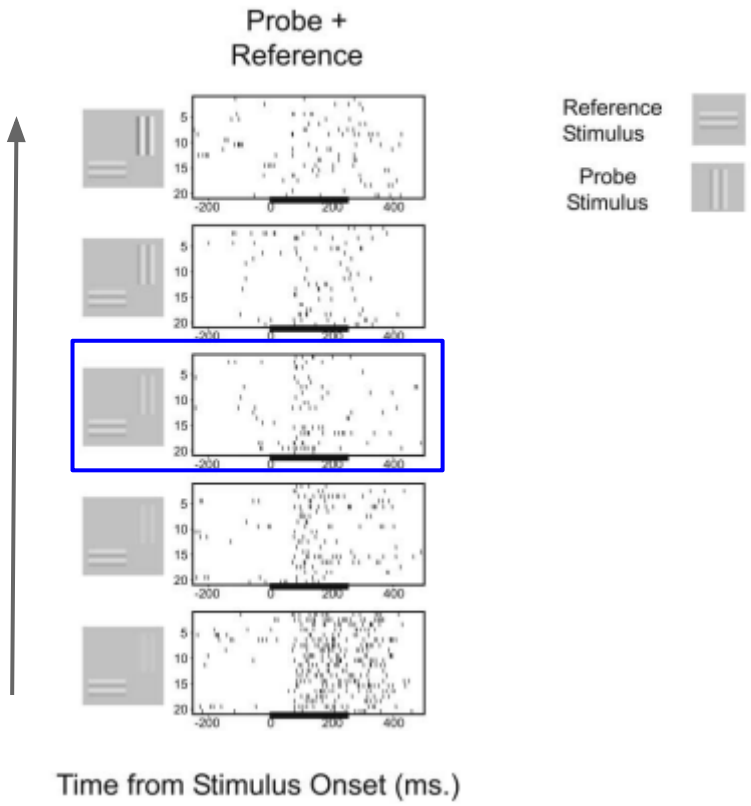

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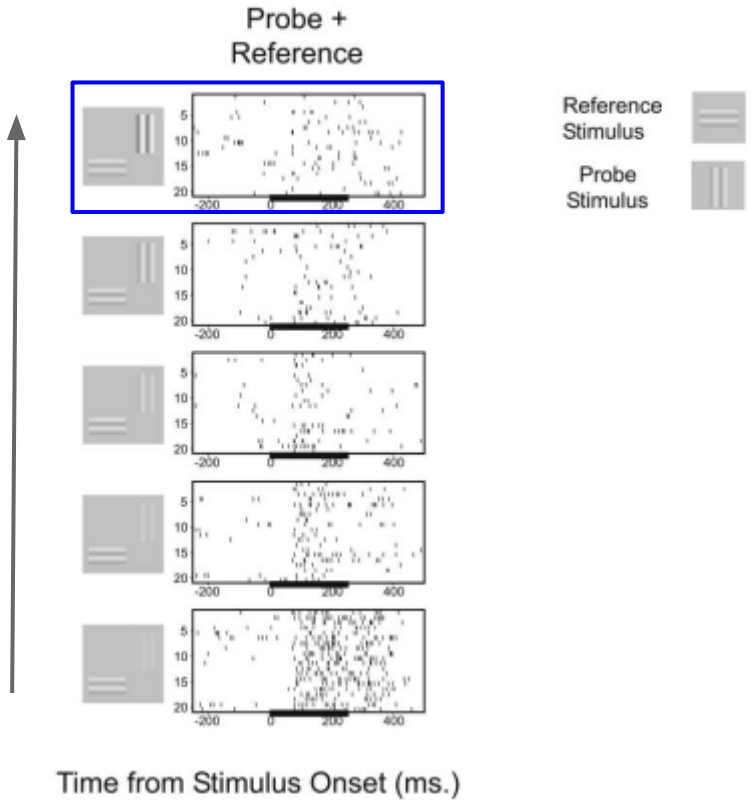
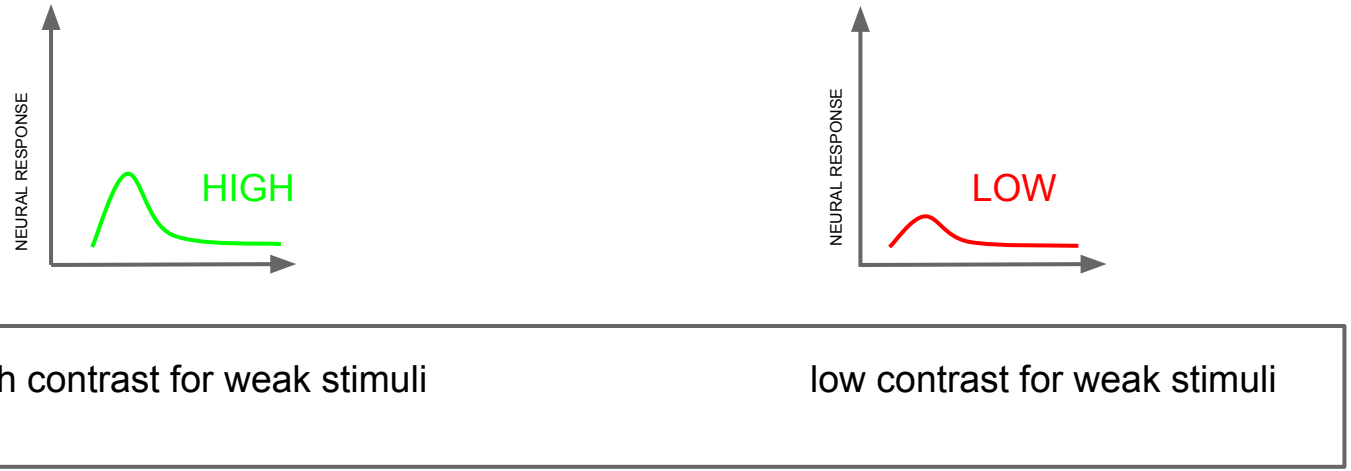


What just happened?

- For unattended stimuli V4 neurons preferential to high contrast stimuli
- **Contrast modulates neuron sensitivity!**



Now lets go back to top-down attention

Neuron Sensitivity

What can modulate the response of neurons?

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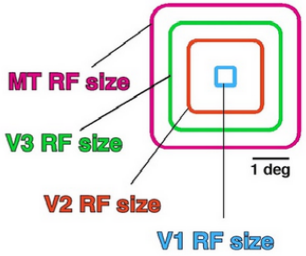
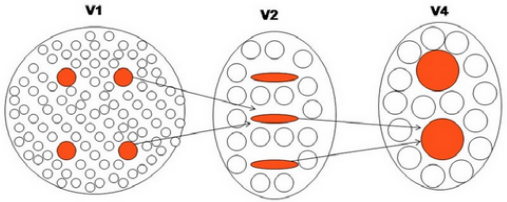
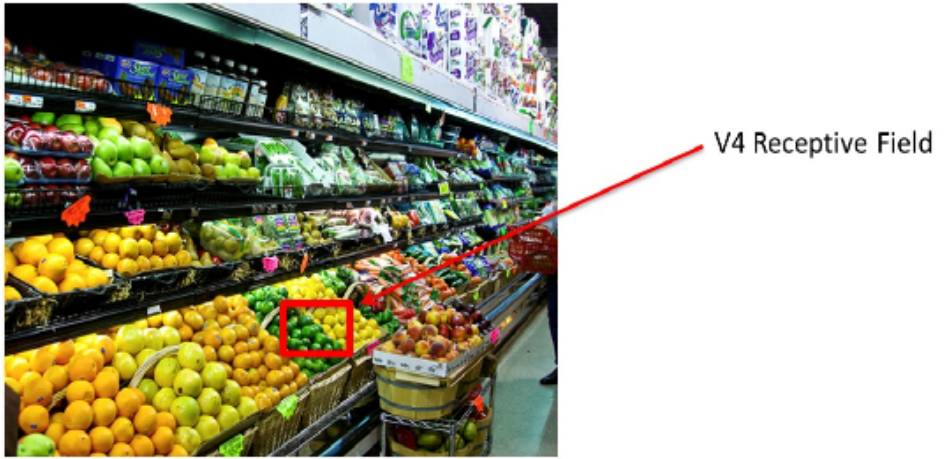
- Feature Selectivity
- **Top-down Attention**
- Visual Saliency such as Contrast (Bottom-up attention)







What **mechanism** in the brain allows for the **increased sensitivity** of neurons with **attention**?

Attention mimics contrast

Attention increases contrast gain of V4 neurons

- Response to attended stimulus as though contrast increased

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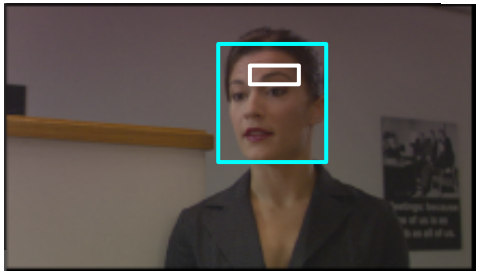
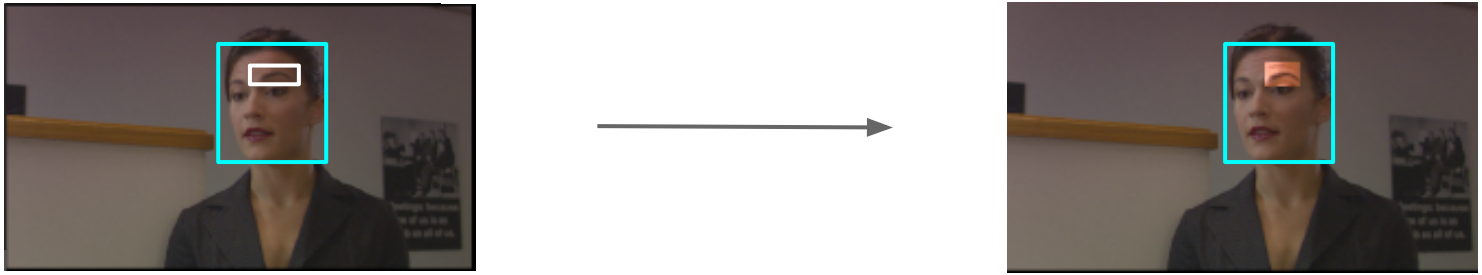


Attention increases contrast gain of V4 neurons

- Response to attended stimulus as though contrast increased



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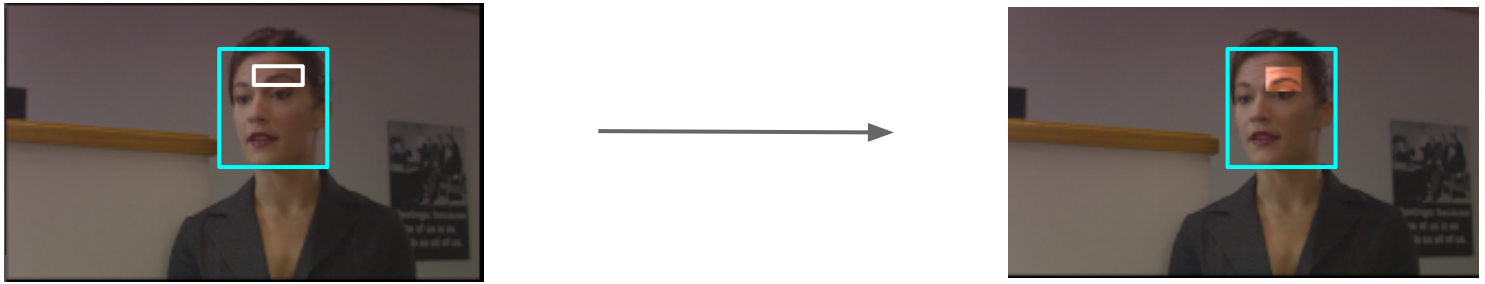
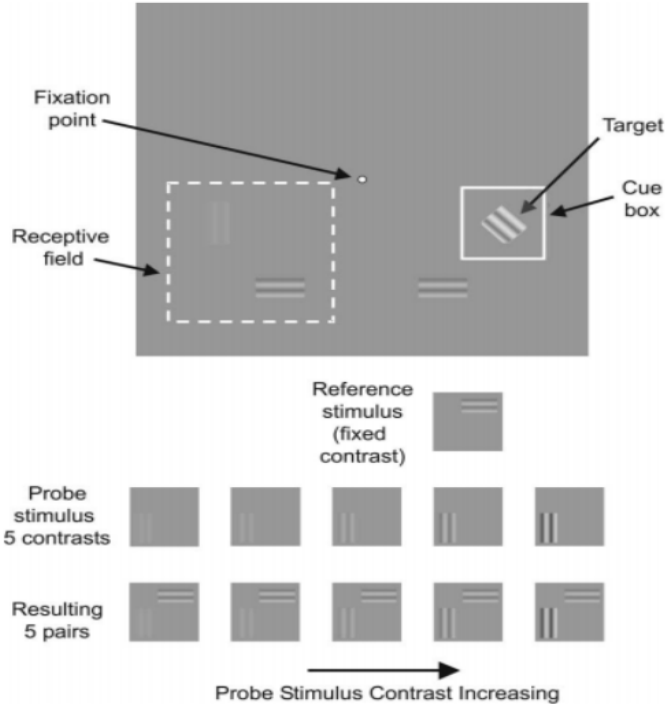


- Brain hard-wired to respond “preferentially” to highest contrast stimulus
- High contrast (without attention) or attention to a stimulus suppresses other stimuli

Experiments with attention

Two trials:

1. **attend left (RF)**
2. attend right (away from RF)

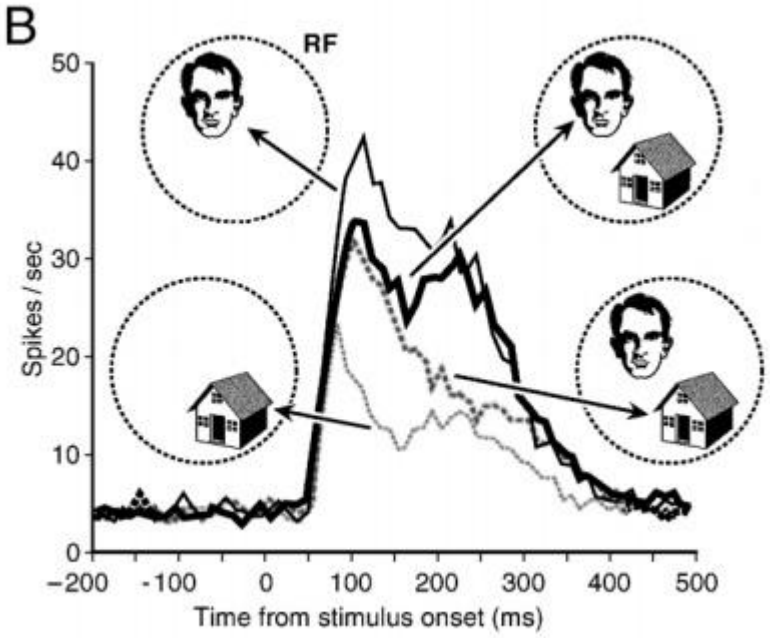


Attention - Bias Competition Model

face : preferred

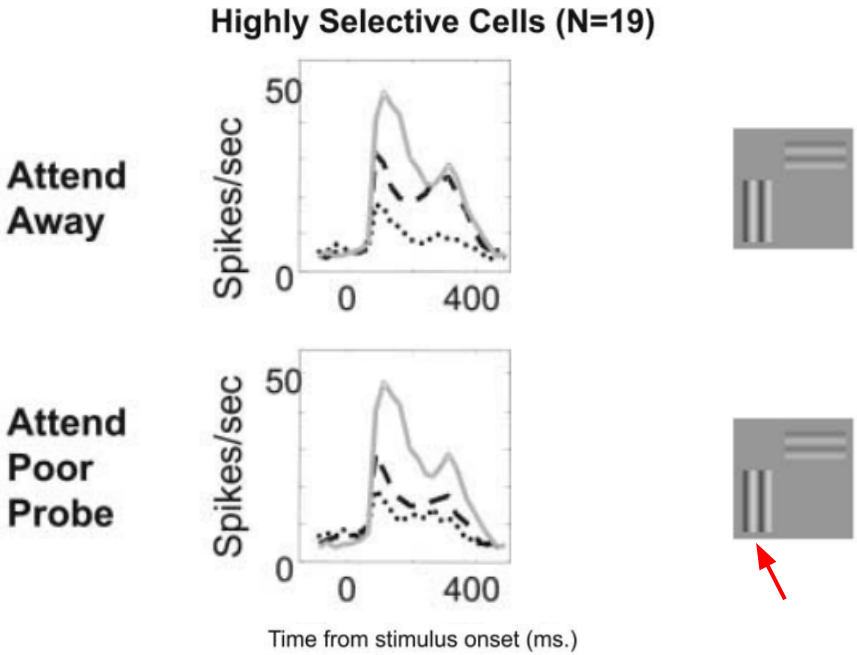
house: non-preferred

- magnified signals from attended stimuli suppress unattended stimuli



Attention and contrast together?

Attention and contrast are additive



Suppression is **highest** with **high contrast and attention** to probe

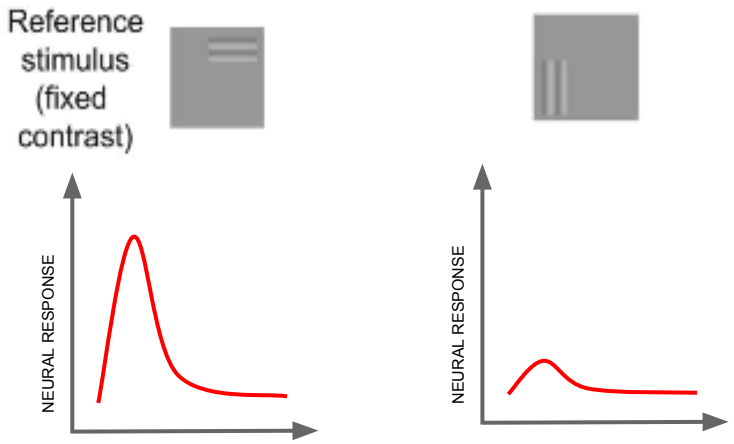
Suppression effect

1. contrast
2. difference in selectivity of stimuli

Experiments

Three sets of neurons:

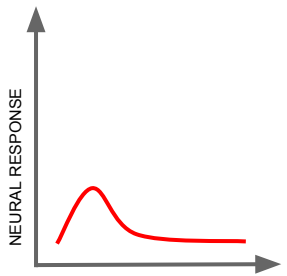
1. highly selective to reference
2. weakly selective to reference
3. selective to probe

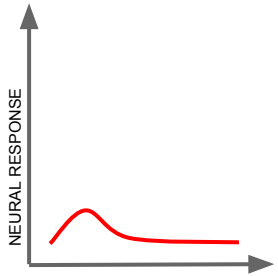


Experiments

Three sets of neurons:

1. highly selective to reference
2. weakly selective to reference
3. selective to probe





Experiments

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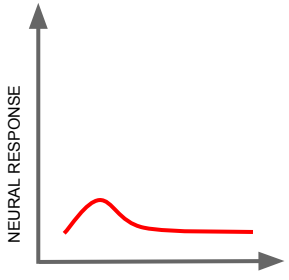
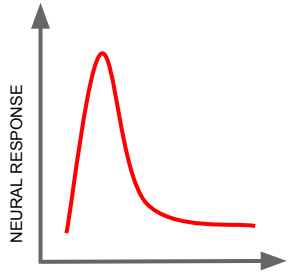




Attention, contrast and selectivity

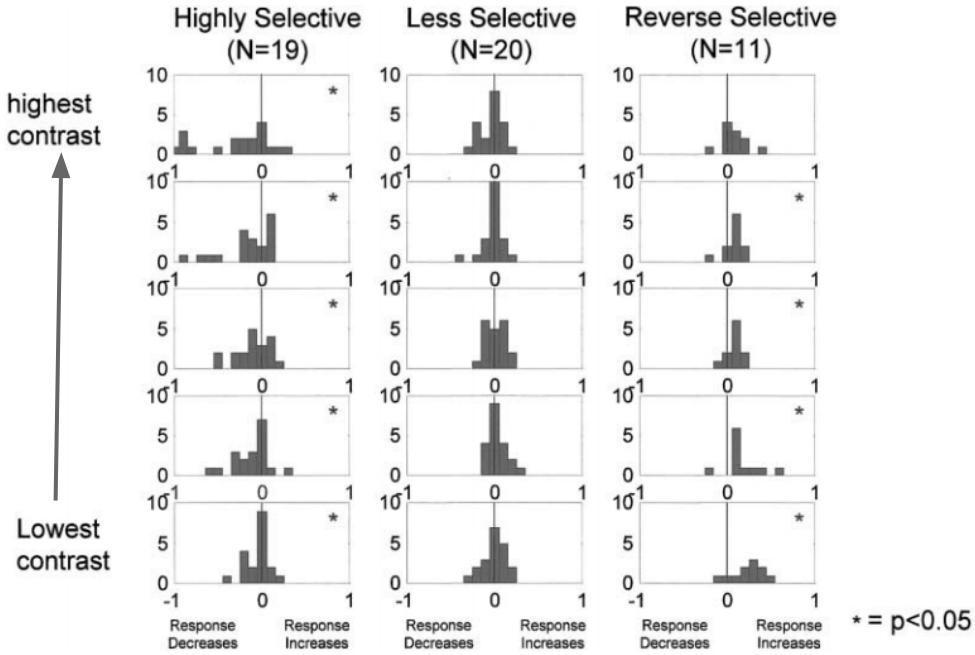
As attention and contrast for probe increased, pair and probe responses converge

Top-down attention to probe:

1. **reduced** pair response by **26.2 %** (highly selective)

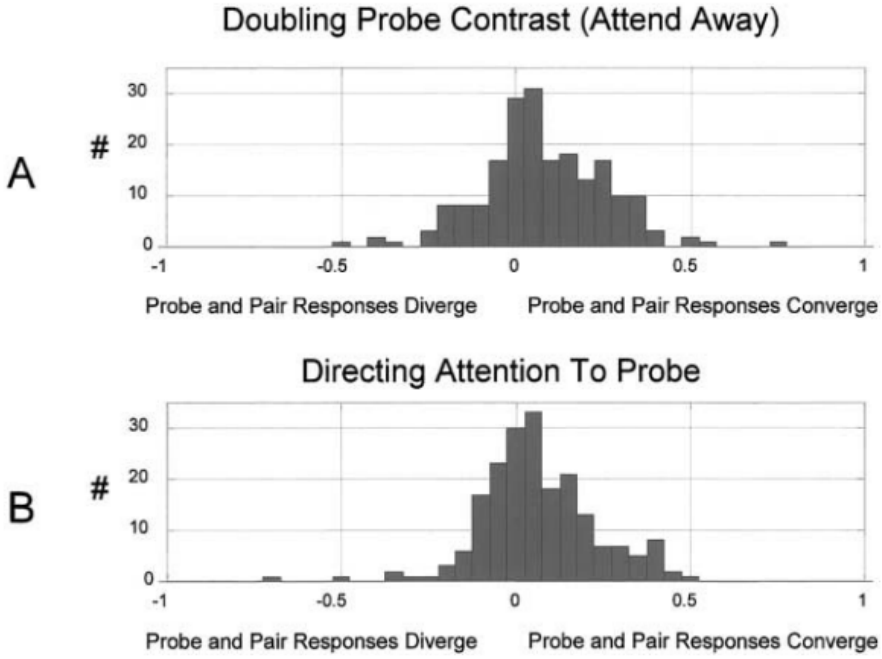
2. **reduced** pair response by 0.8% (weakly selective)

3. **increased** pair response by **29.1**% (reverse selective)



Attention v/s contrast

Increasing attention by 100% ~ Increasing contrast by 52-75%



Salience and Visual Search

Lesion studies show that **V4 is essential** to boost low salience points with attention in presence of highly salient stimulus distractors

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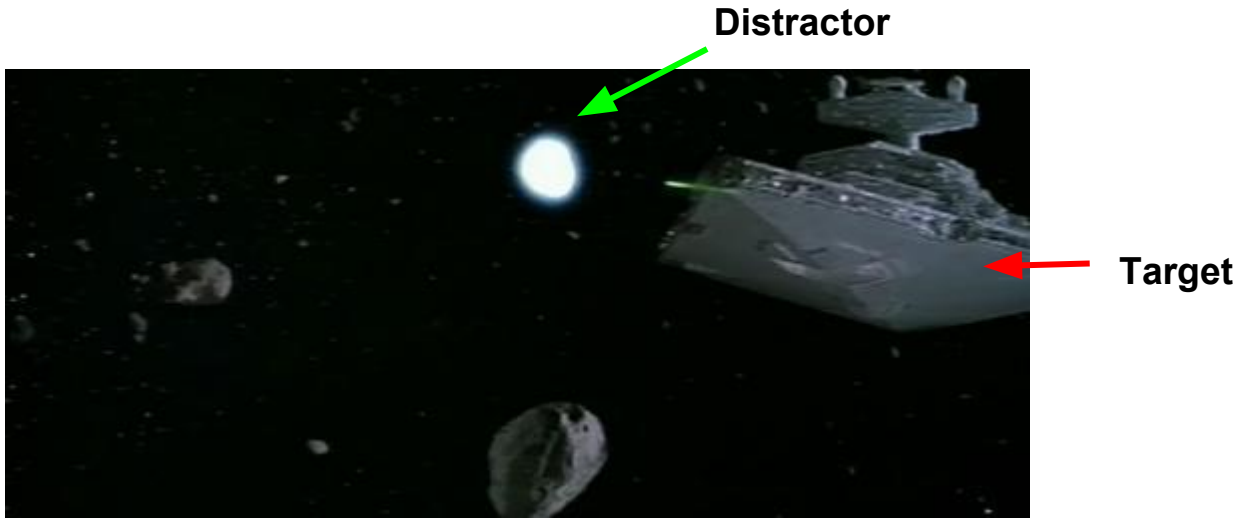


Conclusion

- Sensation ≠ Perception
- Attention : throws away irrelevant data for a task
- Top-down attention: pull
  out a less salient stimulus
  from more salient distractors

Discussion

- Role of attentional feedback in Computer Vision
- Task based overruling of standard visual search policies in computer vision - too early?

In the last two papers we look at Top-down Attention

Other features apart from contrast that can create bottom up attention?

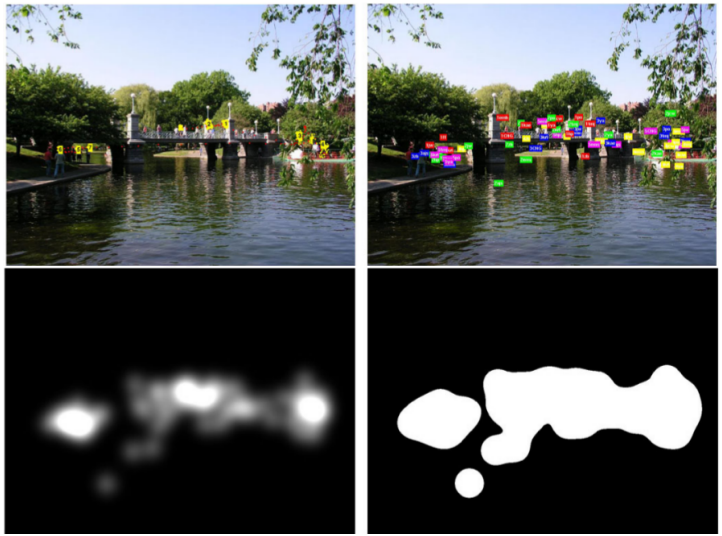
Learning to Predict Where Humans Look

Tilke Judd, Krista Ehinger, Frédo Durand, Antonio Torralba

Goal

eye tracking ground truth data

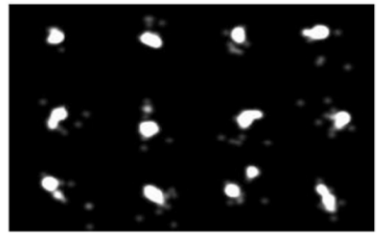
- 15 viewers
- 1003 images
  (LabelMe + Flickr)
- Passive viewing



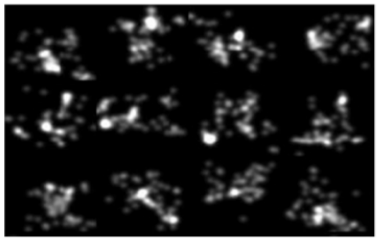
- learn a linear SVM to predict saliency maps for other users (**passive viewing**)

Analysis of the dataset

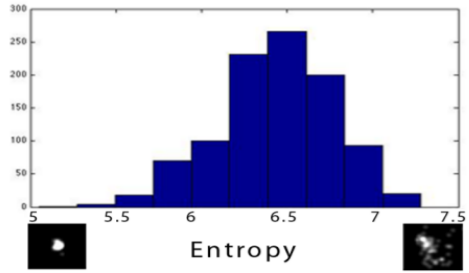
Analysis of fixation locations

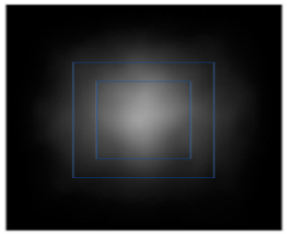


Low entropy saliency maps



High entropy saliency maps

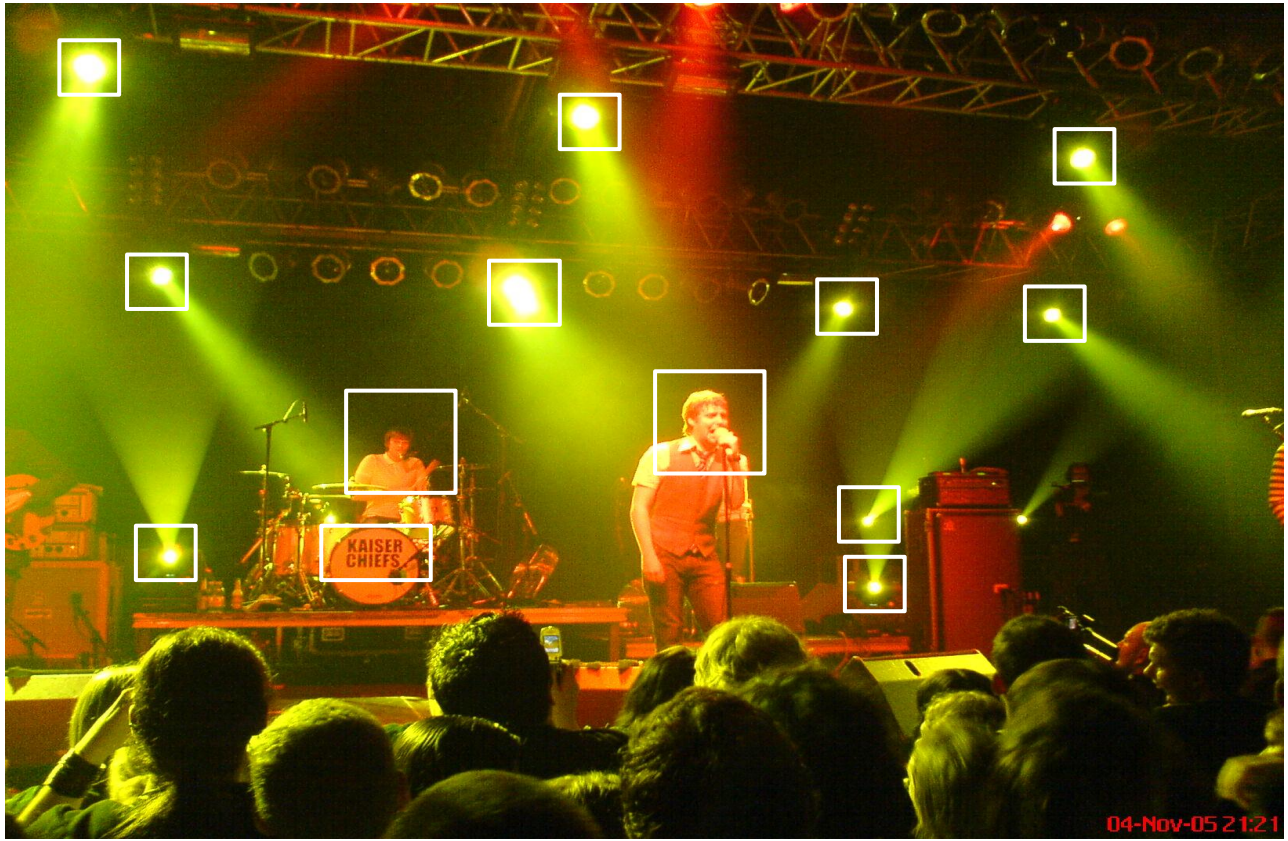




Avg of all saliency maps

Common Fixations

Common Fixations



Common Fixations

Faces

People

Text

Body parts

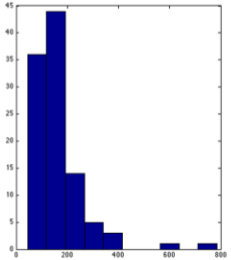
Cars

Animals

Hand Labelled Data

Faces - 10% Text - 11%

On close-up, fixation at specific part of face



Radius of ROI

Certain ROI on which user fixates

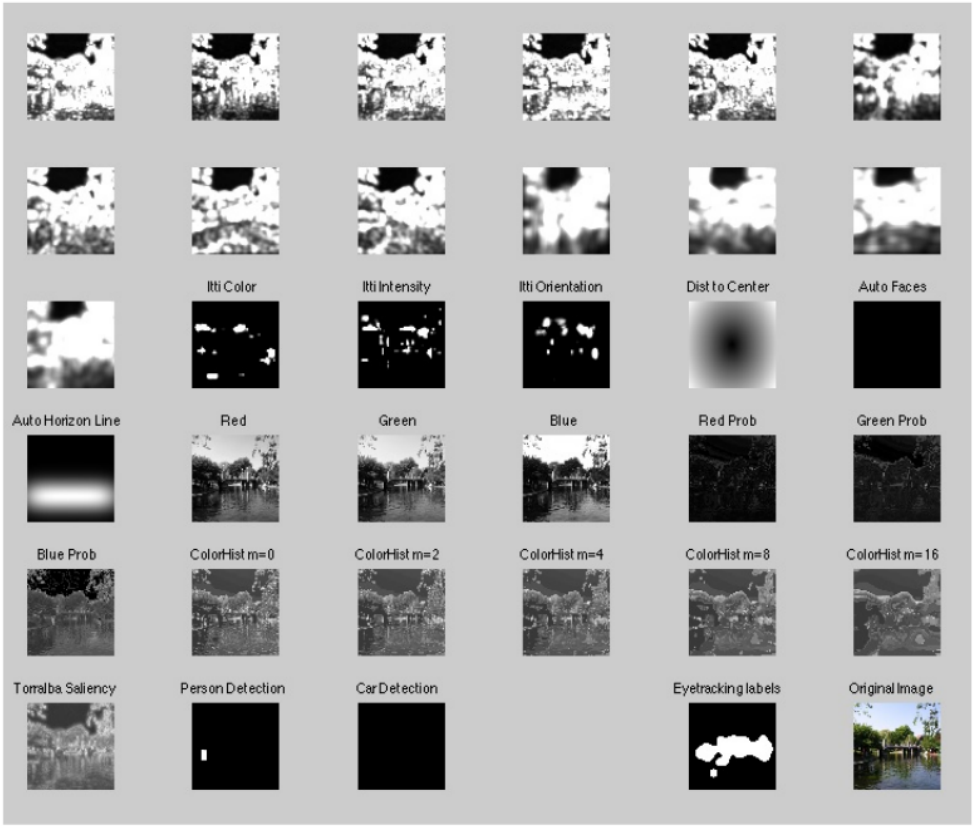
Learning the model

Combine Top Down and Bottom Up Features

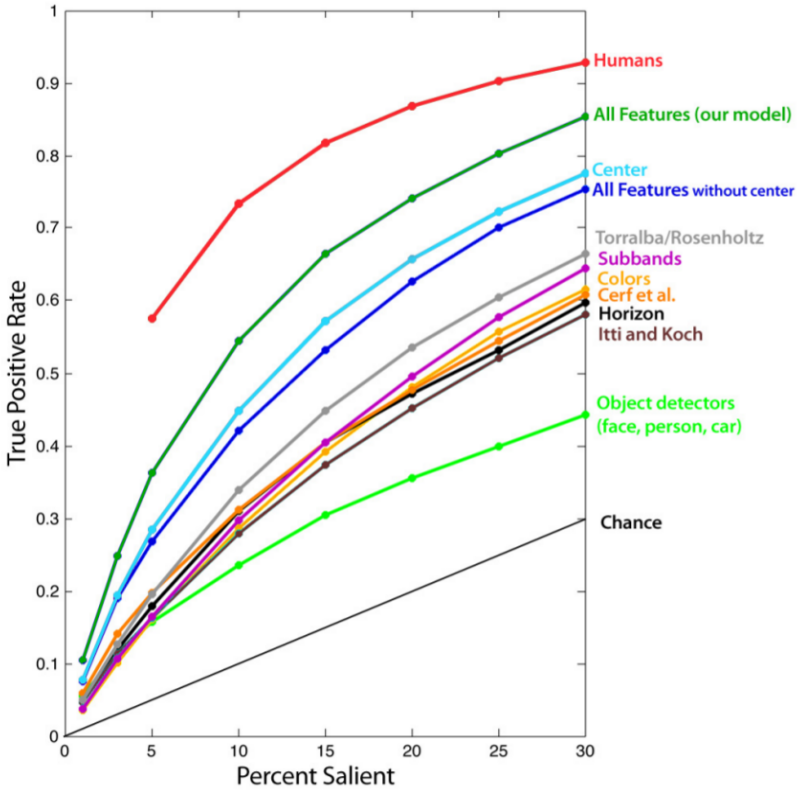
- Low level - intensity, orientation, color contrast
- mid-level - gist features
- high-level - face, person, car, horizon detectors

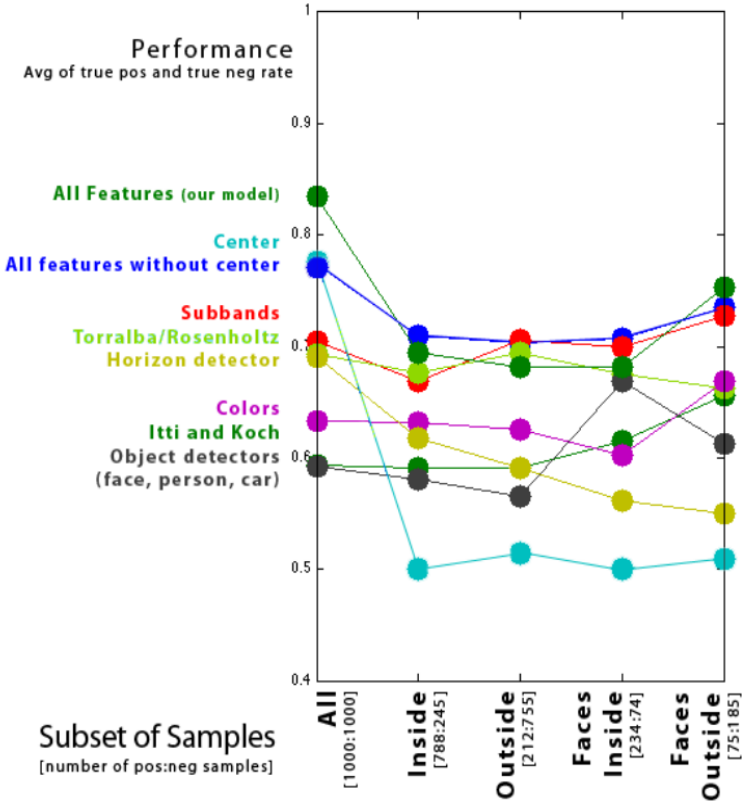
- center prior - 70% of fixations lie within center 25% of image

Features


Itti Color
Itti Intensity
Itti Orientation
Dist to Center
Auto Faces
Auto Horizon Line
Red
Green
Blue
Red Prob
Green Prob
Blue Prob
ColorHist m=0
ColorHist m=2
ColorHist m=4
ColorHist m=8
ColorHist m=16
Torralba Saliency
Person Detection
Car Detection
Eyetracking labels
Original Image

Comparison of different features





Takeaways

- Center performs well over all images but not different subsets.
- Every feature contributes, as they perform better than chance.
- Combining features of different levels gives the best saliency predictions.

Discussion

- Saliency for visual search in computer vision v/s passive viewing?
- Other attributes like visual novelty, uniqueness?
- How to use attention during algorithm design to solve computer vision problems ?

Thank you!

extras

Features and Intensity

- ❏ features - orientation, color, direction of motion, spatial frequency
- ❏ intensity - luminance contrast

- play different roles in the bias competition model
- untuned feature - decreases poor stimulus response, suppress pair response
- high intensity - increases poor stimulus response, suppress pair response

Spatial Attention

- Receptive field
- Changes strength of neurons' response without changing underlying response properties
- Enhances synchronization of neuronal activity
- Spatial attention will increase the gain of all neurons whose receptive field overlaps the current attentional focus, creating an enhanced representation at that location that is akin to a local increase in contrast

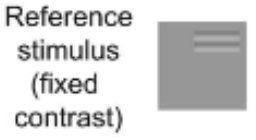
Experiments

Monkeys trained

Reference stimulus - selective to neuron population

probe stimulus - not selective to neuron population

Pair of stimuli - in the same RF



Feature-based attention in visual cortex

Saliency Map

-- homogeneous, if only space attention

an attention map. Such a representation of behaviorally relevant locations might be activated by knowledge of the environment

-- after considering feature attention, depends on:-

- -- Receptive field
- -- Stimulus selectivity
- -- Target feature

Relation between spatial and feature attention

--feature-based and space-based attentions are very similar.

-- space can be considered one of the feature

-- may be spatial locations identified by

the animal as behaviorally relevant based on color luminance.

-- feature-similarity gain model responses would be enhanced for all neurons whose sensory selectivity matched the current attentional state (i.e. feature similarity for the non-spatial feature); similarly

Topographic organization of feature

-- For spatial location, these requirements are fulfilled by the retinotopic organization and the well-defined spatial receptive fields in early areas of the visual pathways.

-- topographic organization of the feature

-- issues

    -- number of features

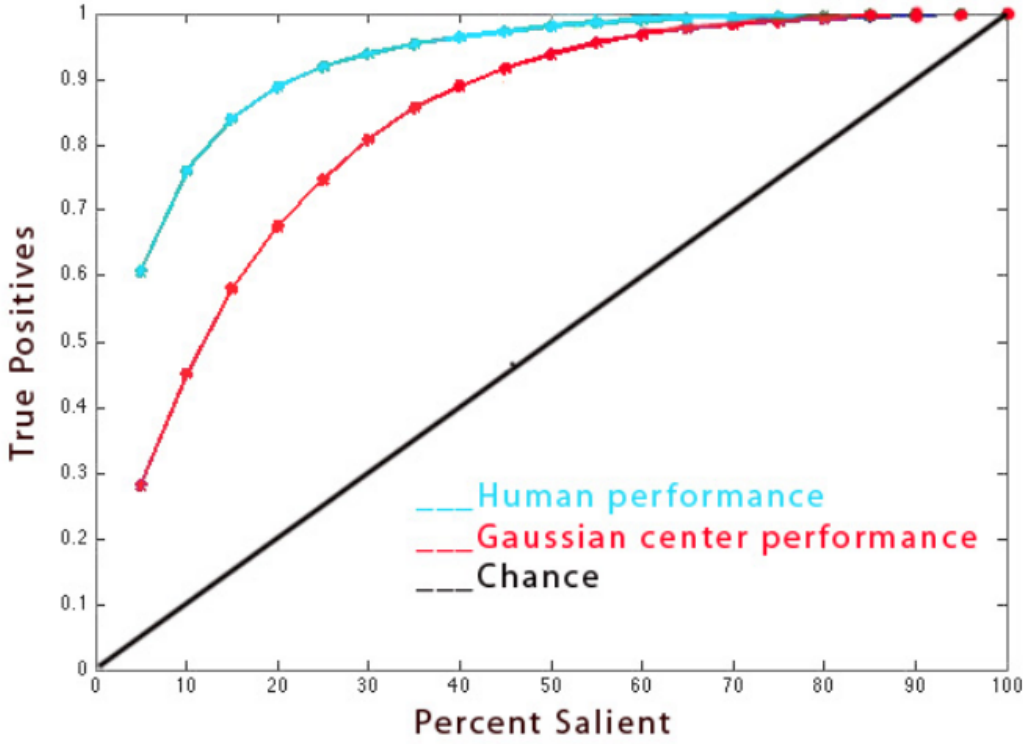
    -- number of neurons required

    -- lack of understanding about feature representation

-- limits feature based attention study, learn about combination of features.

Average ROC Curve For All Users

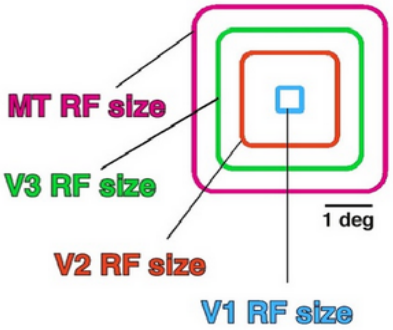
90% ground truth fixations within top 20% salient locations

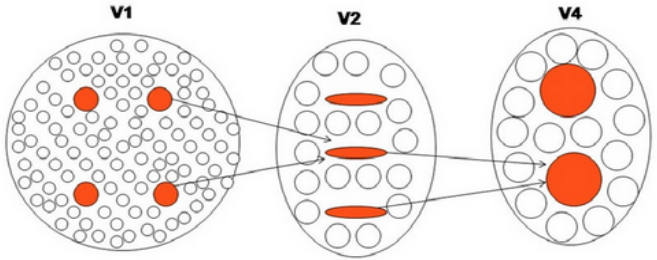


Performance of single user compared to remaining 14 users.

Suppression of unattended stimuli

The RF of V4 is large enough that both attended and unattended stimuli reach there





Suppression of unattended stimuli

The RF of V4 is large enough that both attended and unattended stimuli reach there

How does the brain deal with **competing** signals?

Suppression of unattended stimuli

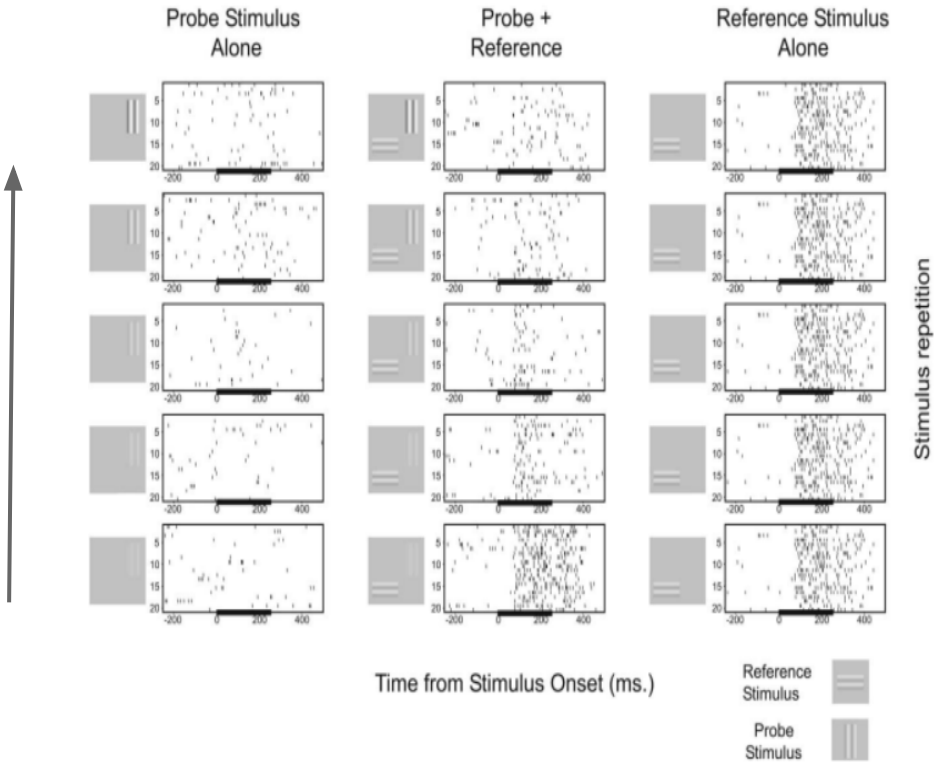
The RF of V4 is large enough that both attended and unattended stimuli reach there

How does the brain deal with **conflicting** signals?

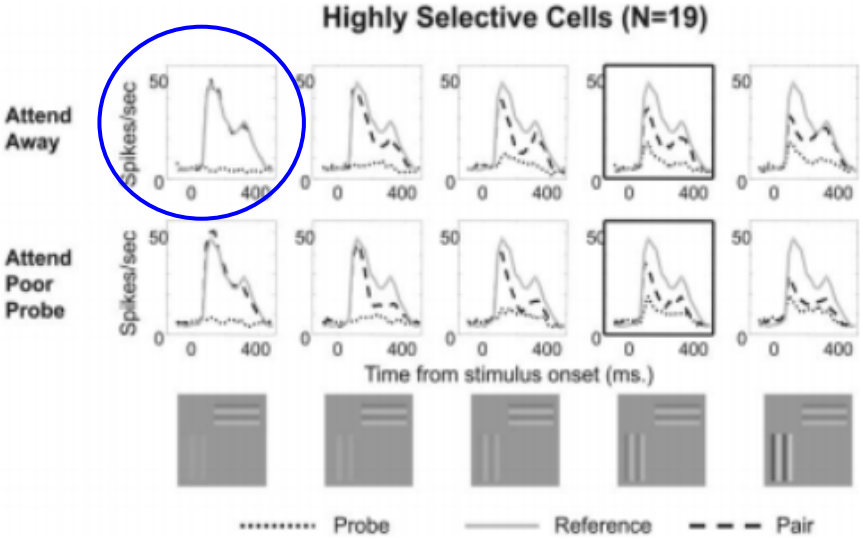
- Attended stimulus **suppresses** the unattended stimuli in the same RF **by increasing contrast** of attended stimuli

Suppression by weaker probe

As contrast of probe increases, its suppressive effect increases

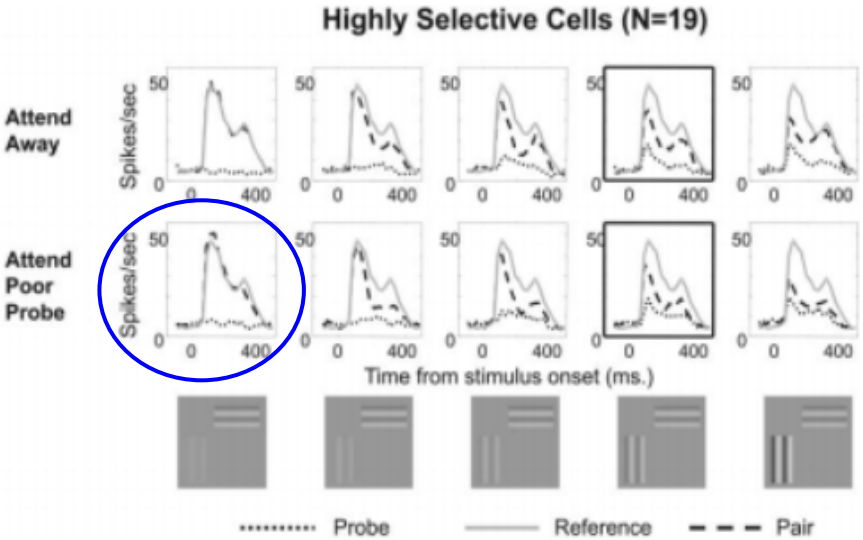


Attention and contrast



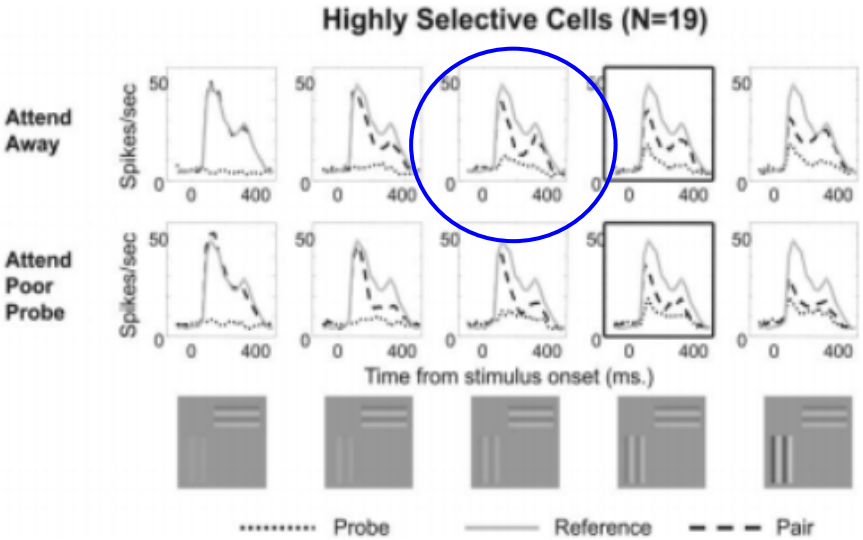
No suppression when **weak contrast** of probe **without attention**

Attention and contrast



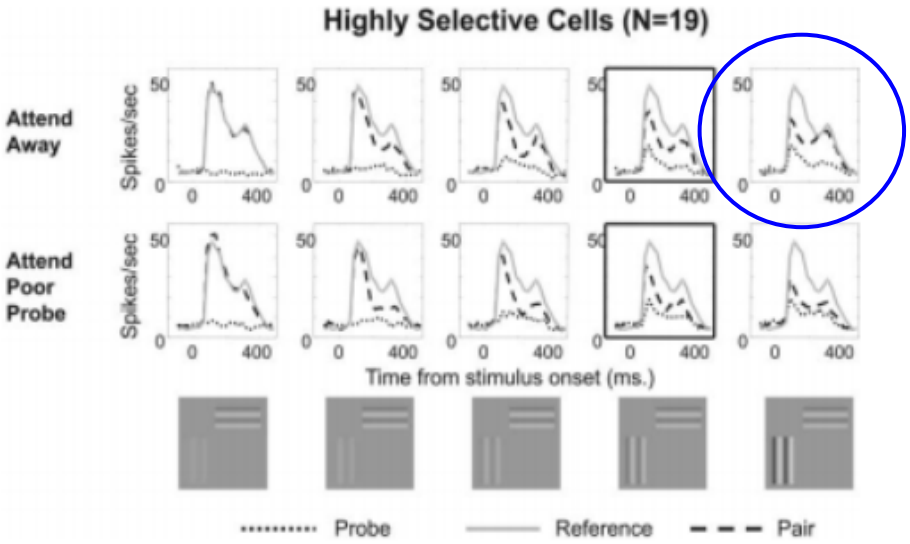
Low suppression with **weak contrast** of probe with **attention**

Attention and contrast



Suppression increases as **contrast increases** for weak probe

Attention and contrast



Suppression increases as **contrast increases** for weak probe

Attention and contrast are additive