# Neural correlates of two components of attention in rat auditory cortex

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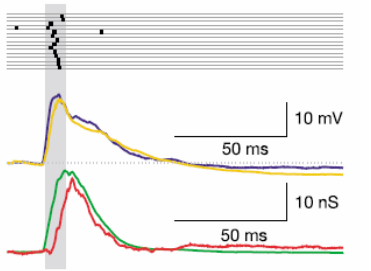
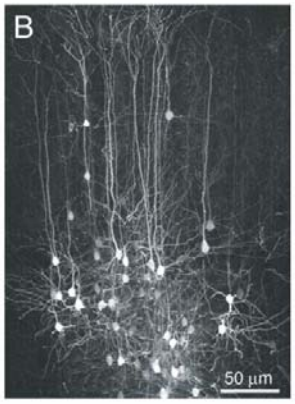
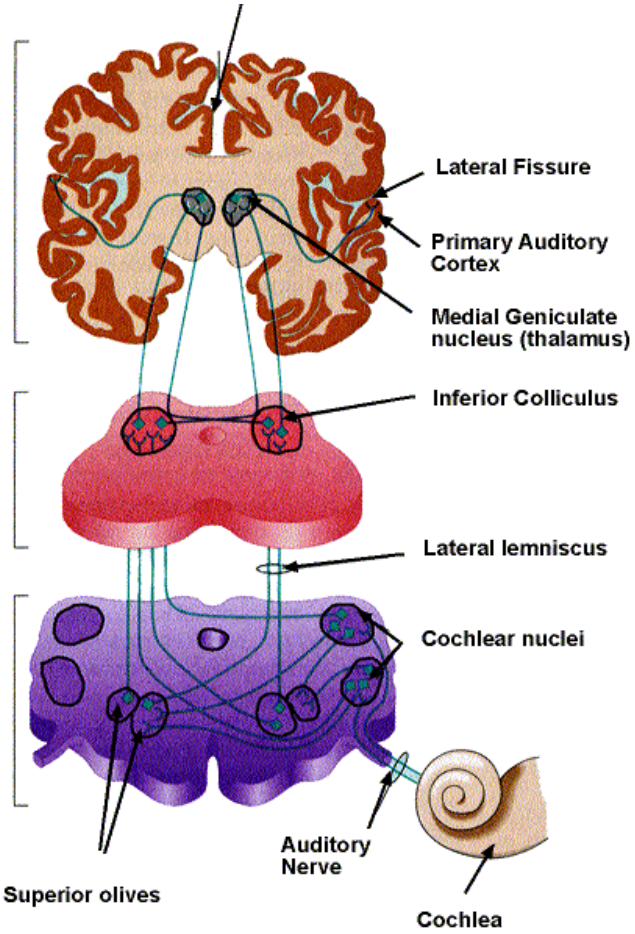
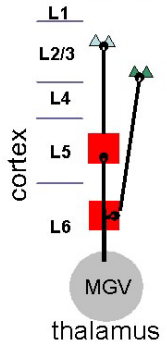
CSHL

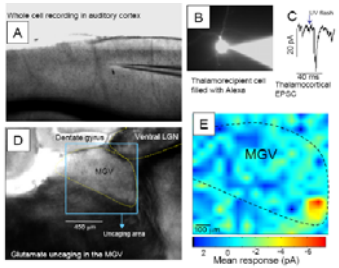
# Circuitry underlying auditory cortex responses

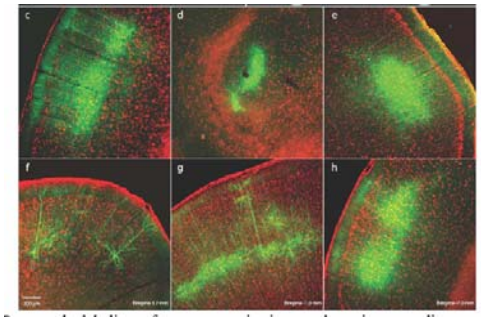


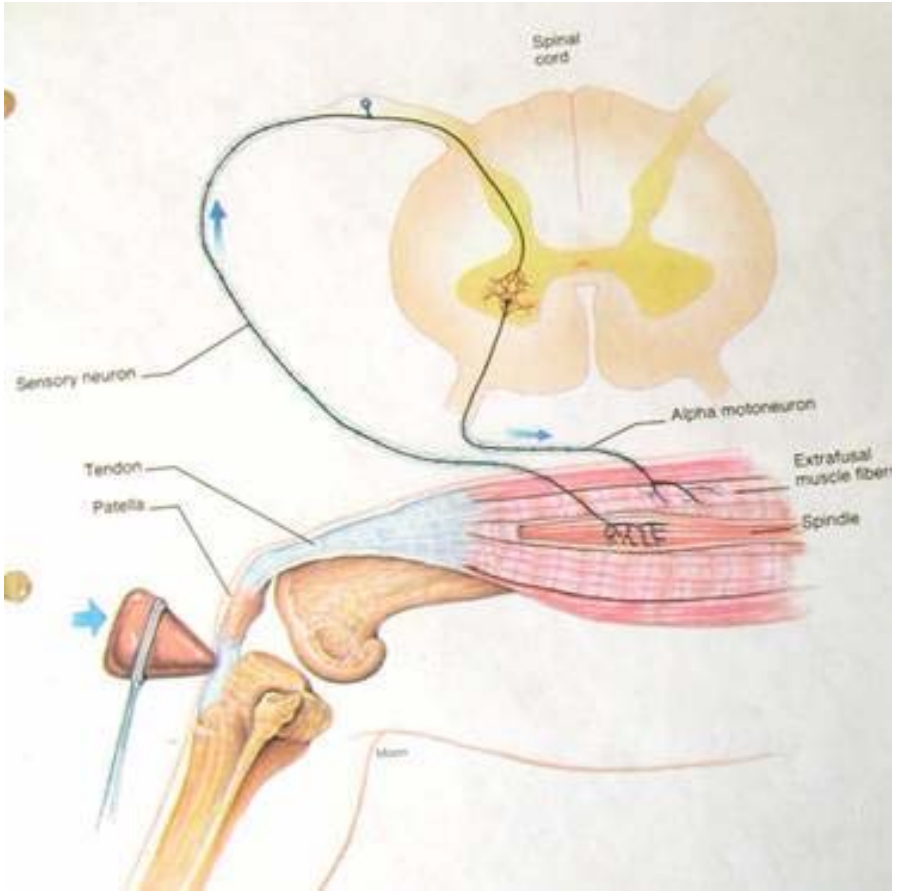



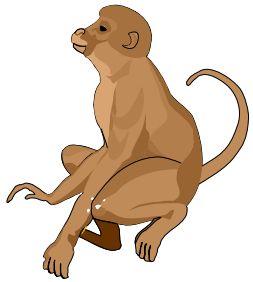
Sound →ear → […] → thalamus → auditory cortex

# Circuitry of a very simple behavior



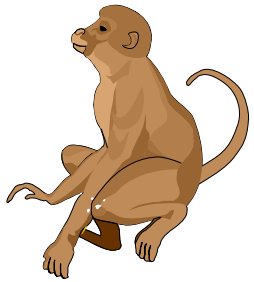

Hammer →stretch receptor → motor neuron → muscle contraction

# Why rodents?



More powerful tools

# Why rodents?

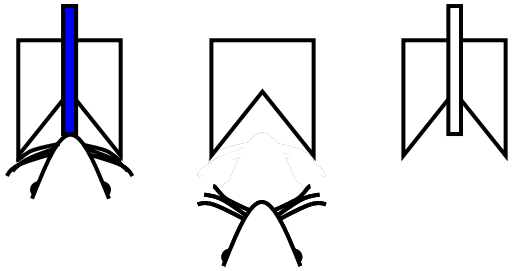


More complex behaviors

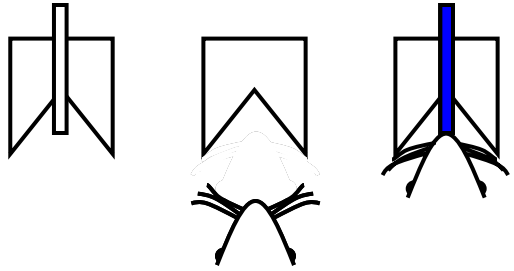
# A simple auditory behavior in the rat

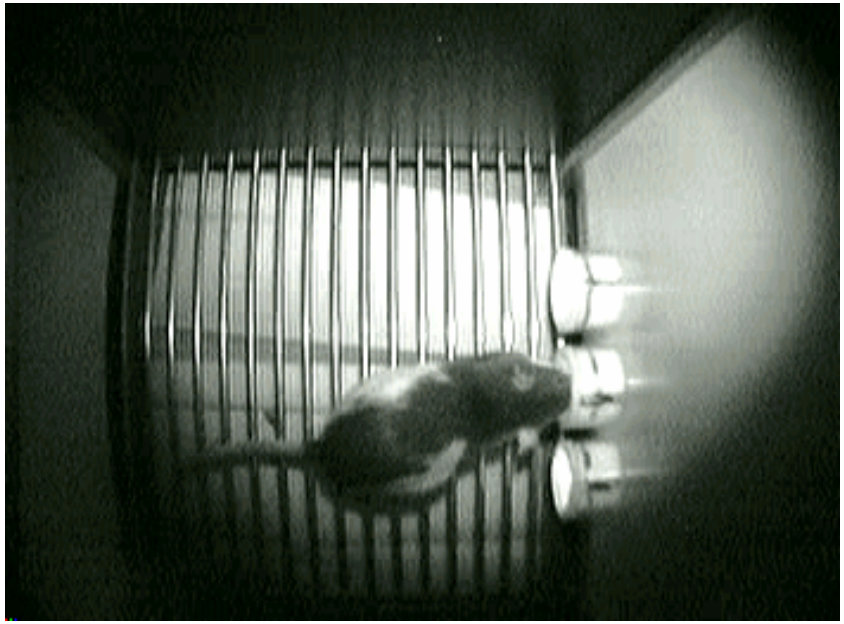
- Pure tone frequency discrimination
- Mild water deprivation

Tone 1: **Low Frequency**



Tone 2: **High Frequency**



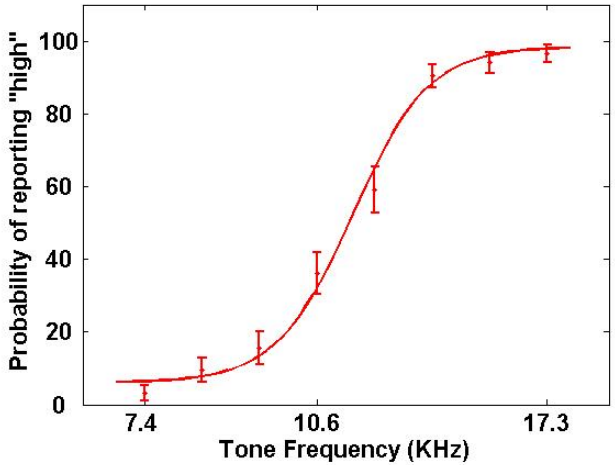


1 vs. 15kHz

Sound →ear → […] → thalamus → auditory cortex →[…] → paw

# Basic two-alternative forced choice behavior

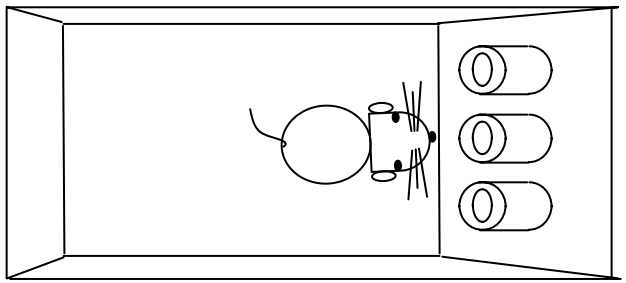
- Hundreds of trials per session
- Psychometric curve



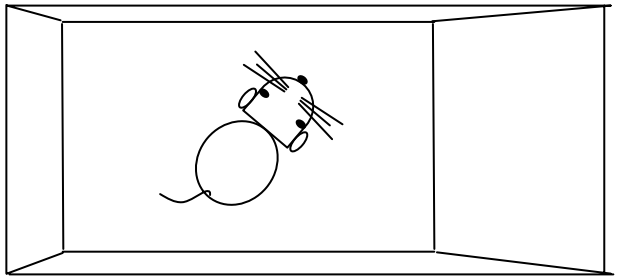

- Training is fast (3 days → 4 weeks)
- Many subjects can be trained in parallel (28 boxes)

# Task 1: Engaged vs. Idle

**Engaged in auditory task**

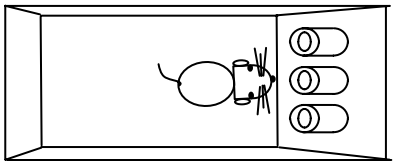


**Idle**



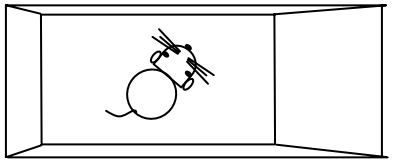
# Toward the circuitry of a simple auditory gate

**Engaged in auditory task**



Sound → […] → auditory cortex →[…] → paw

**Idle**



Sound → […] → auditory cortex →[…] → paw

**Sensory stimulus fixed--What modulates the neuron's firing rate?**

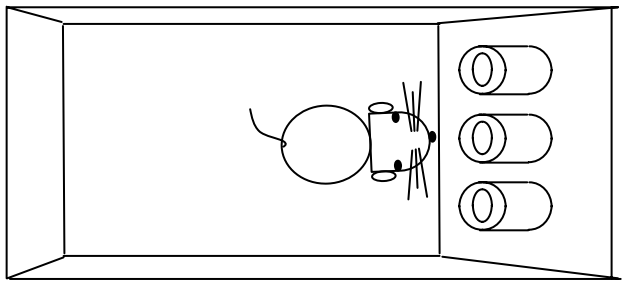
Excitation? Inhibition? Synaptic depression? Neuromodulation?

What layer does the attentional signal synapse onto?

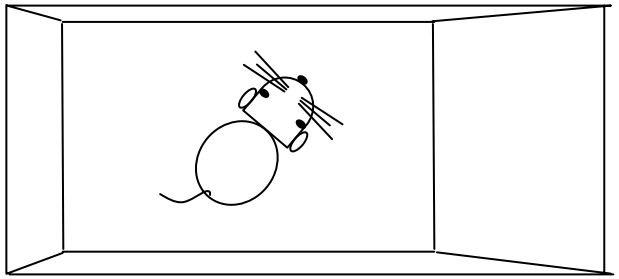
Etc…

# Task 1: Engaged vs. Idle

**Engaged in auditory task**



**Idle**

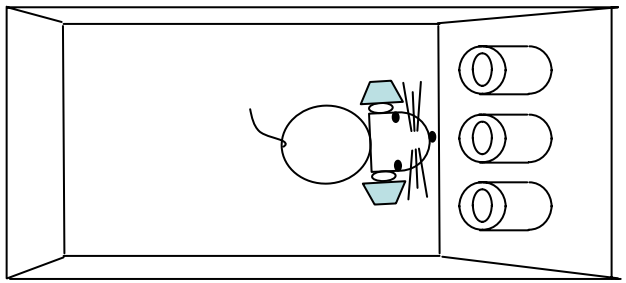


***Technical problem:***

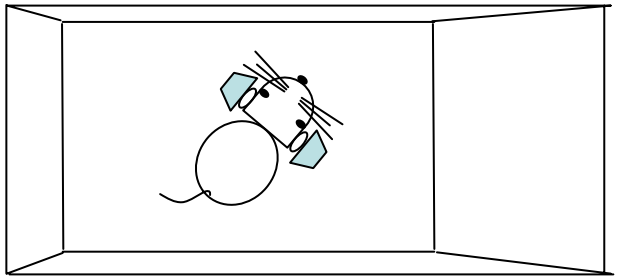
How do we hold the stimulus fixed when the animal is in the idle condition?

# Task 1: Engaged vs. Idle

**Engaged in auditory task**



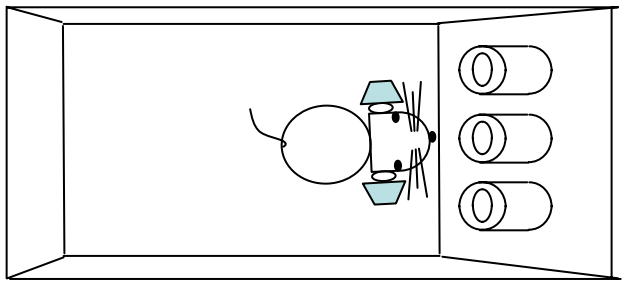
**Idle**



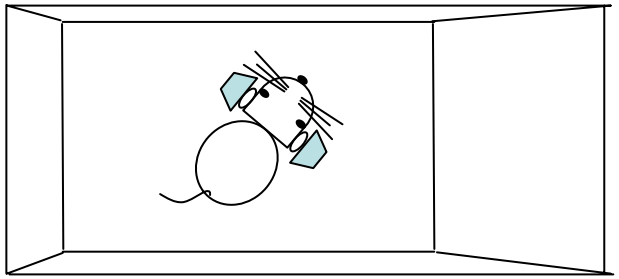
“rpod”

# Task 1: Engaged vs. Idle

**Engaged in auditory task**



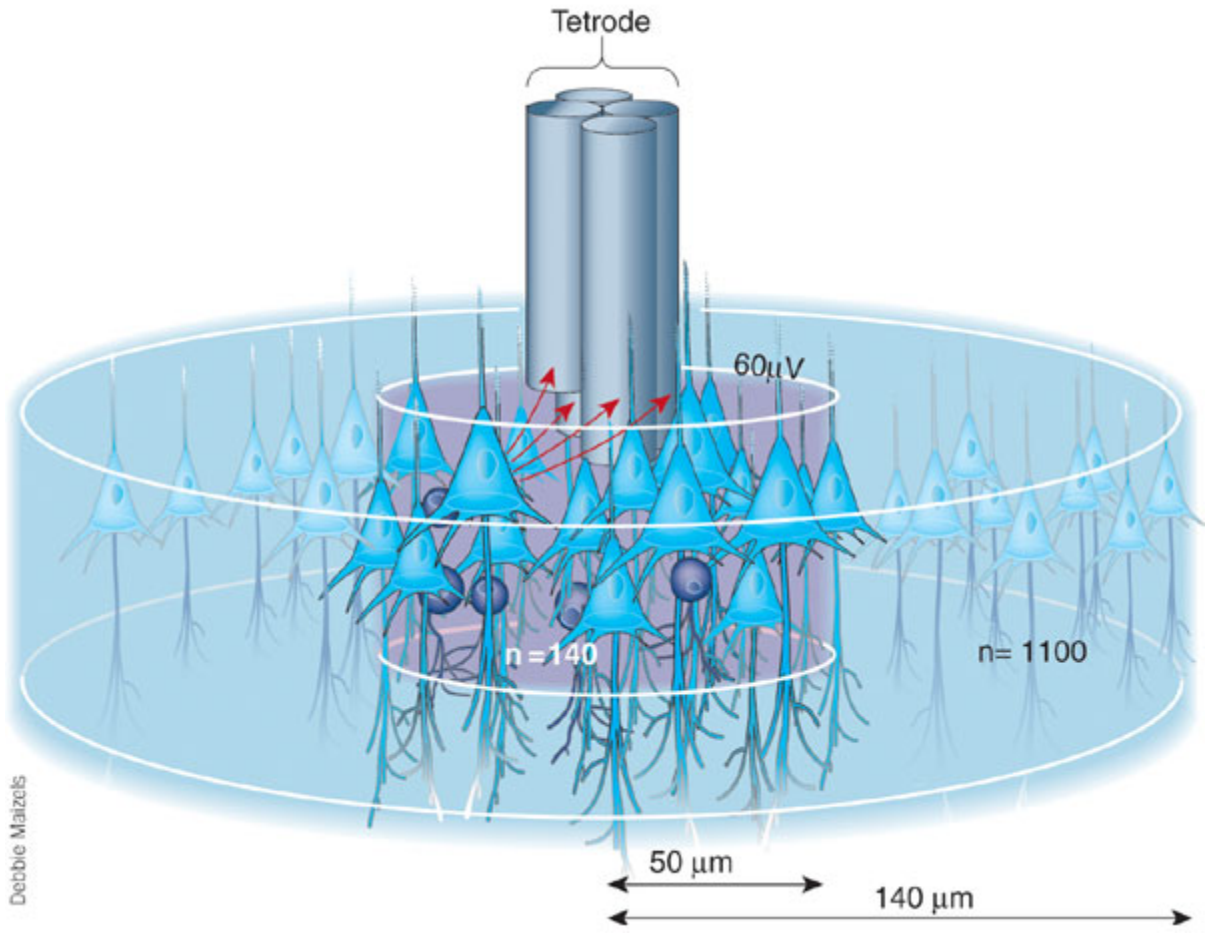
**Idle**



*Possible concerns:*

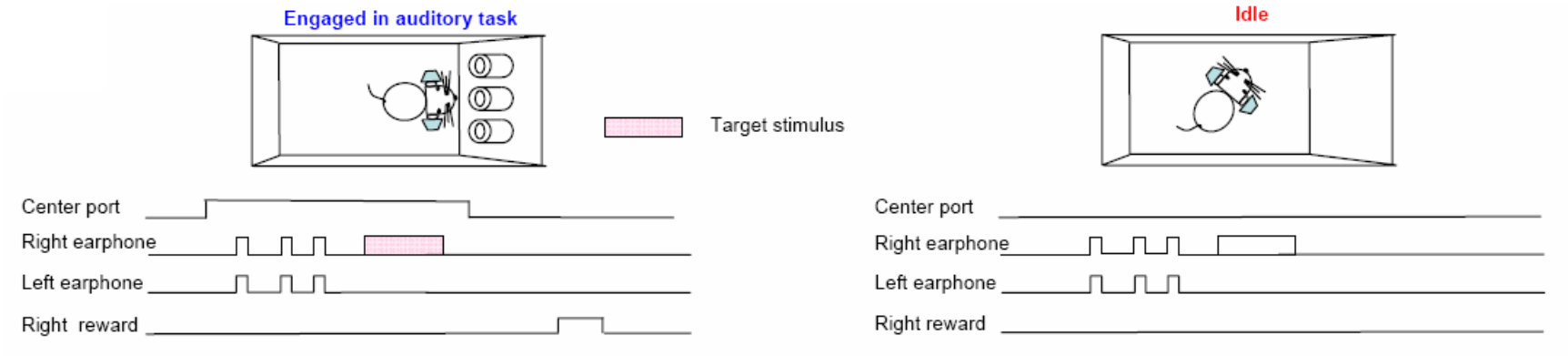
1. Task very easy → no attentional demand, so maybe no modulation?
2. Idle condition uncontrolled → results variable?

# Tetrode recording



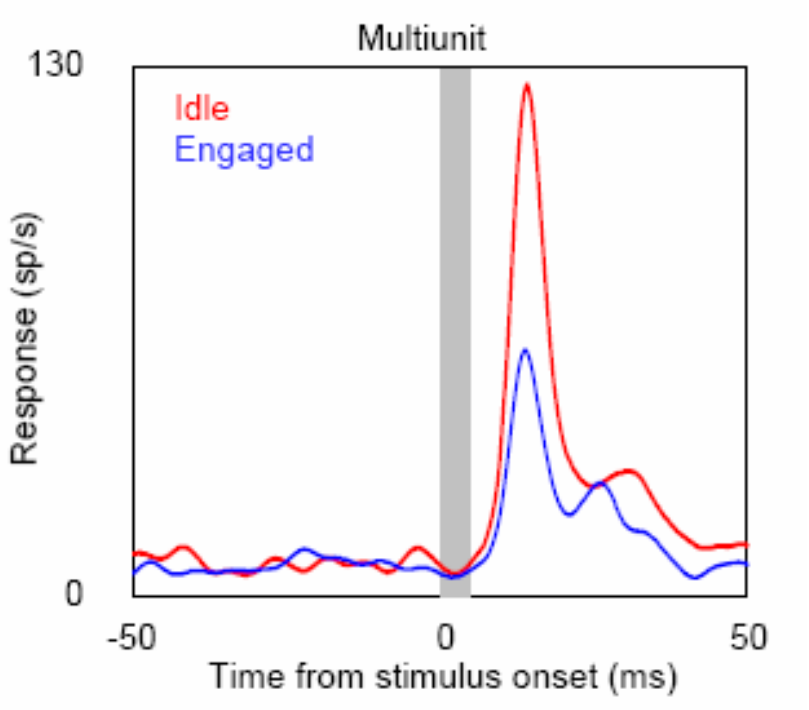

Buzsaki, 2004

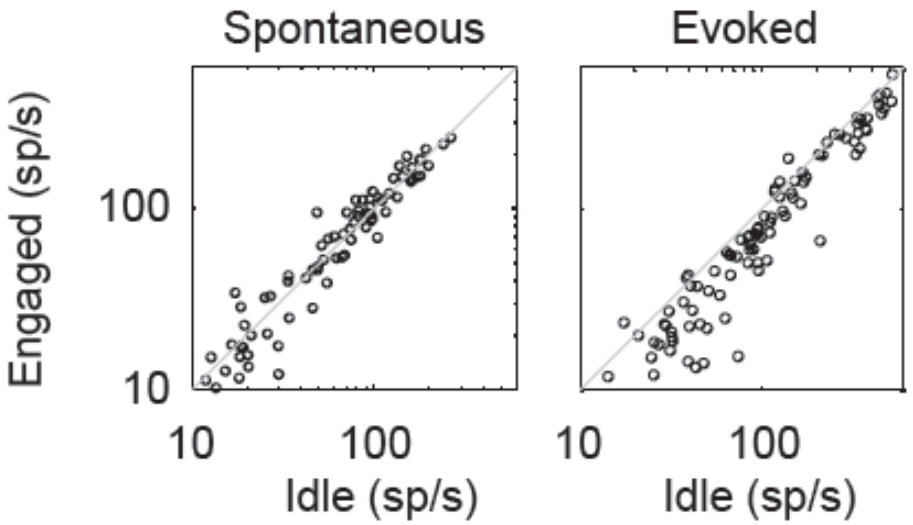
# Task 1: Engaged vs. Idle (*details*)

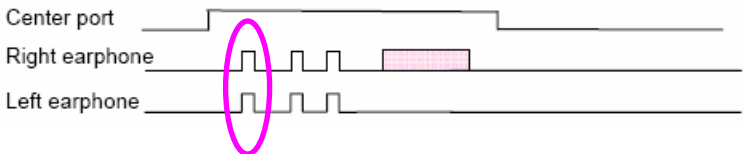



Binaural clicks – monaural target
Variable click rate (2 – 35 Hz)
Target onset after fixed 1.8 second delay
>95% performance

# Response to first click suppressed in engaged condition



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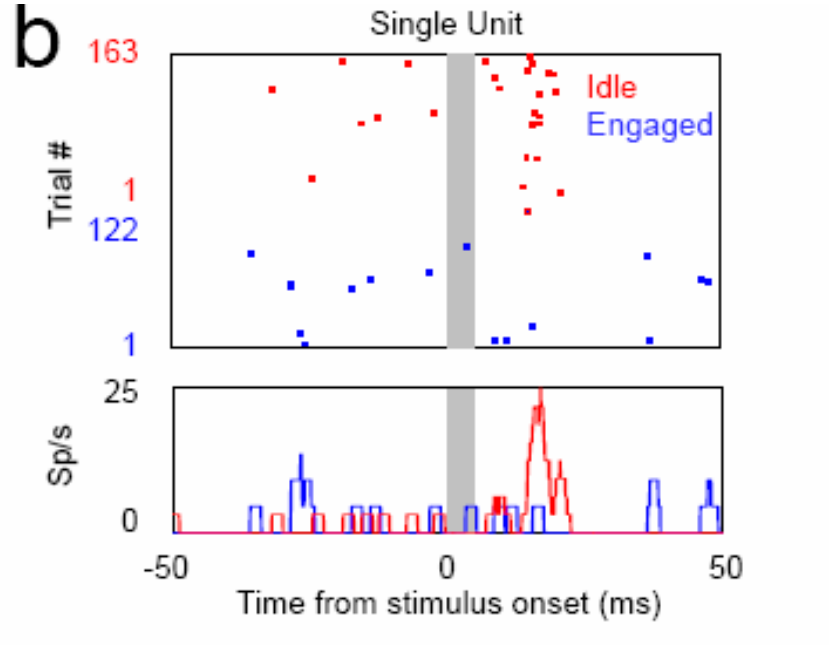


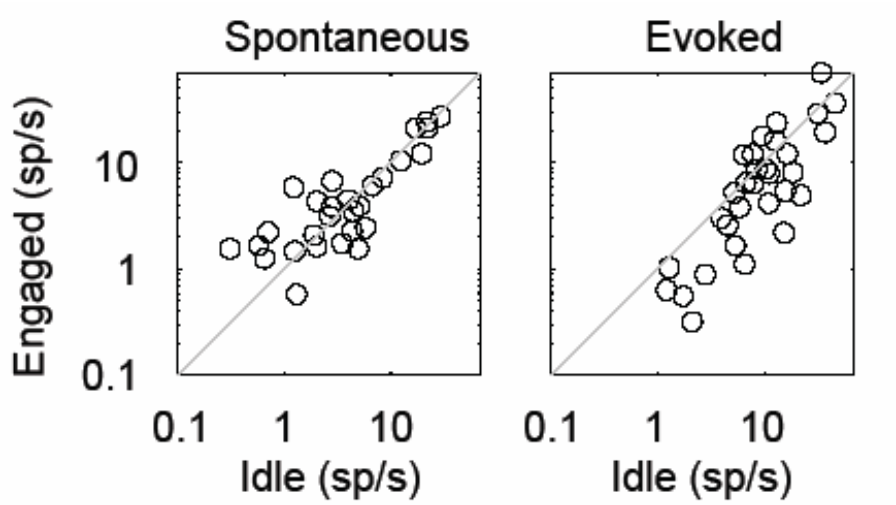


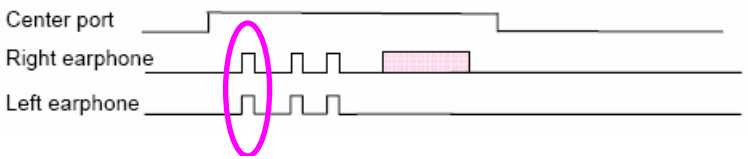

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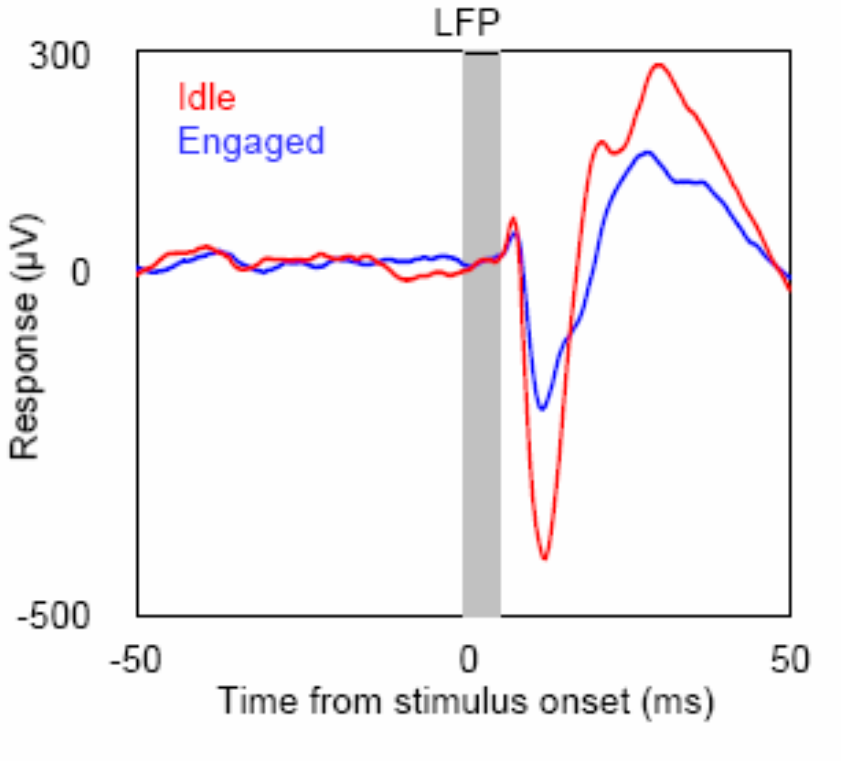
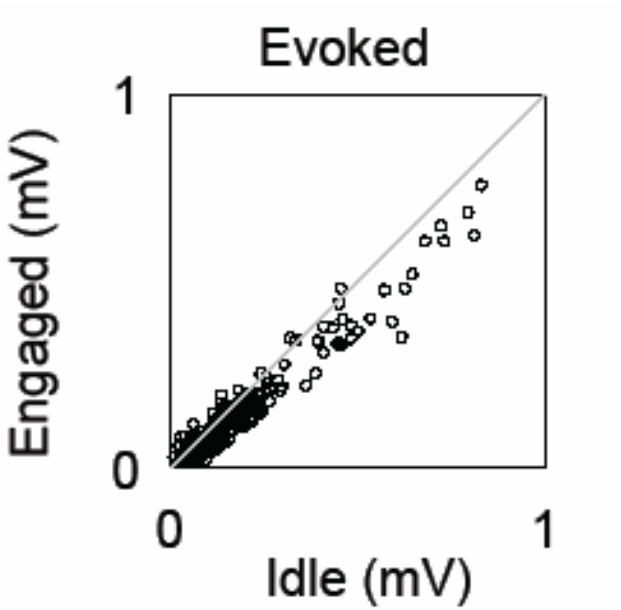
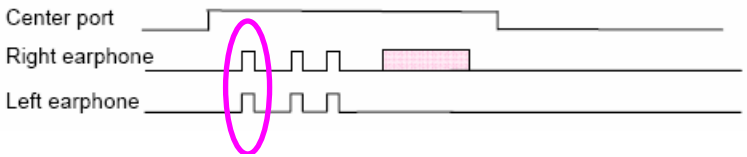


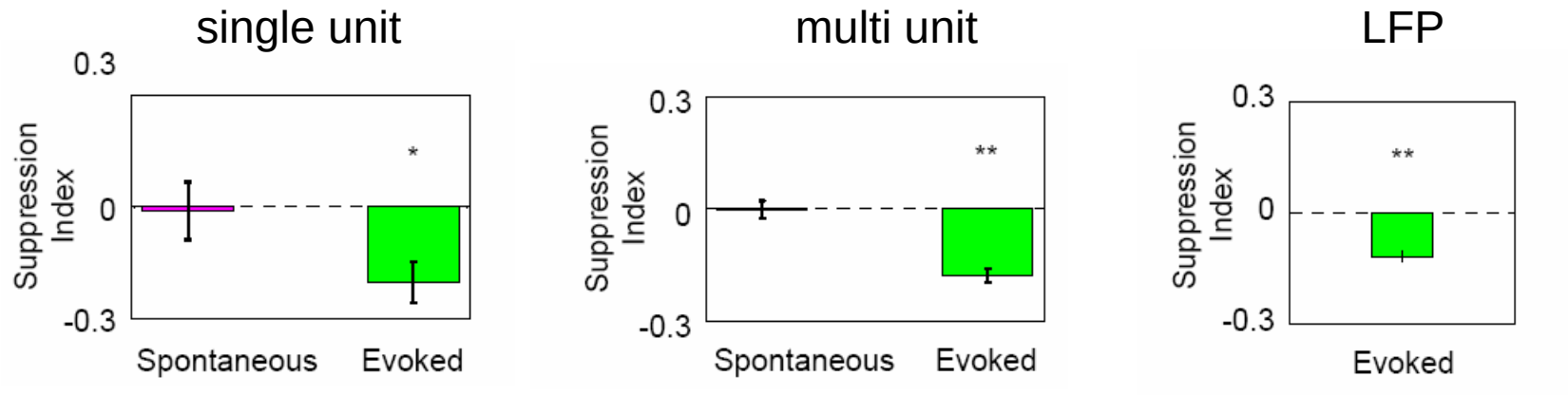



# Definition of suppression index

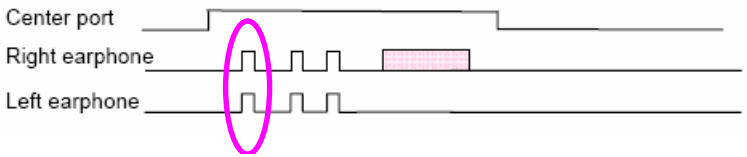
$$\frac{(\text{Auditory response} - \text{Olfactory response})}{(\text{Auditory response} + \text{Olfactory response})}$$

SI > 0 → response enhanced in auditory block

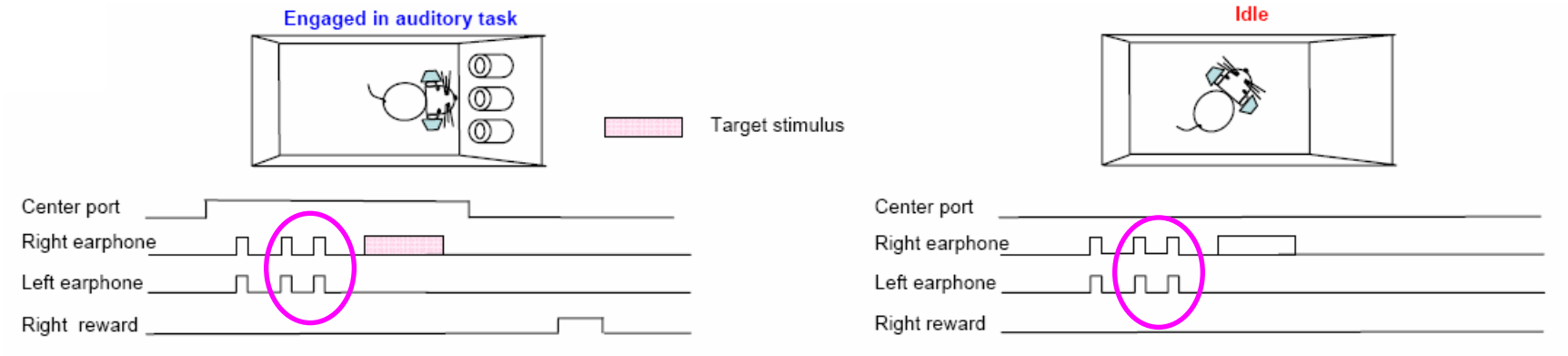
# Robust suppression in single unit, multiunit and LFP




…no change in spontaneous activity

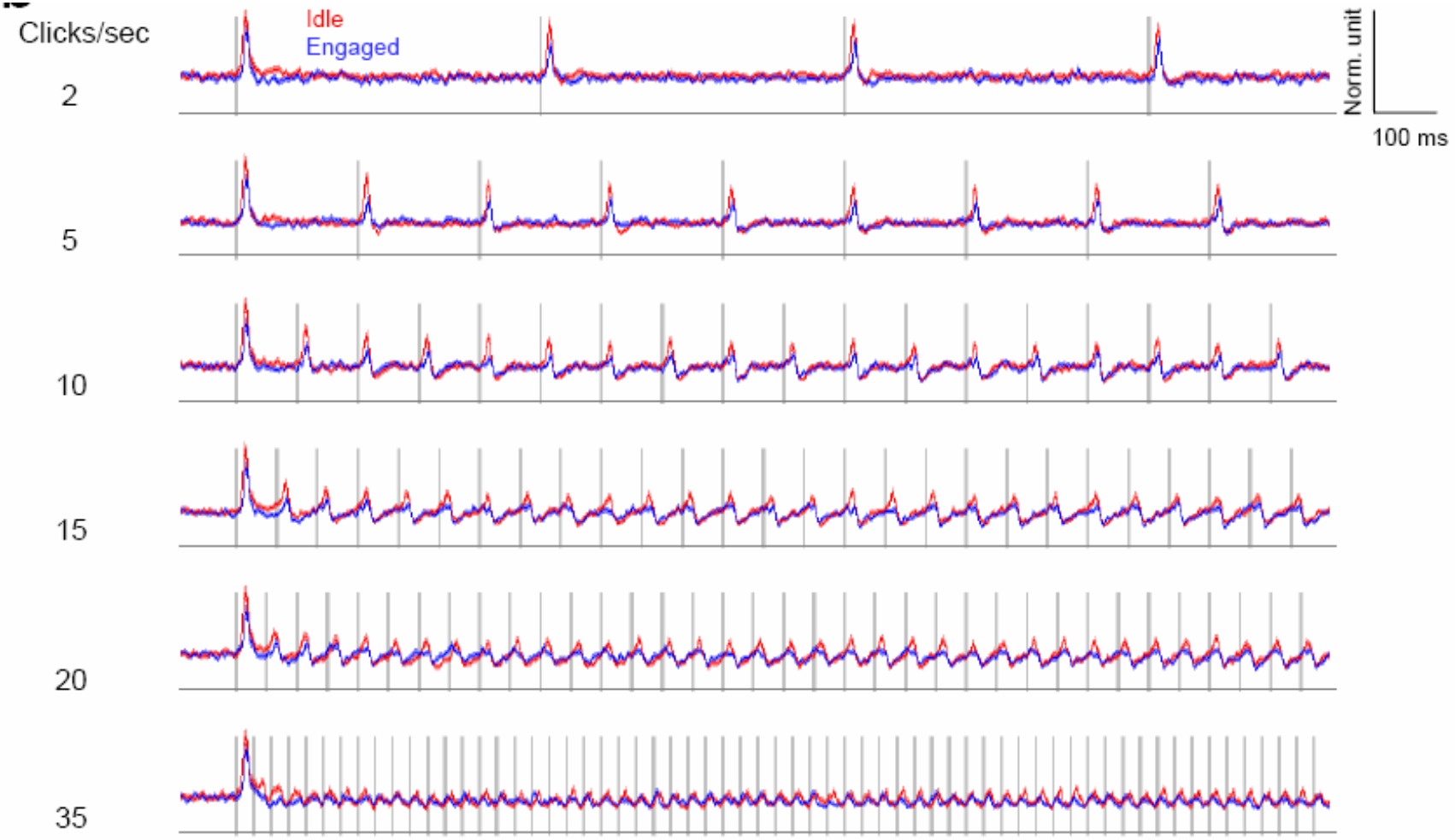


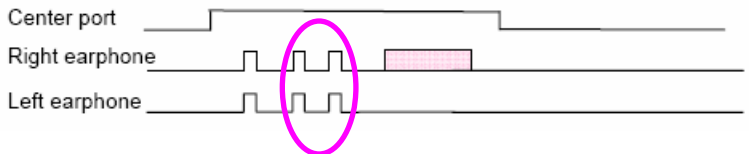
# Analysis of response to non-initial clicks




Binaural clicks – monaural target
Variable click rate (2 – 35 Hz)

# Response to non-initial clicks depress



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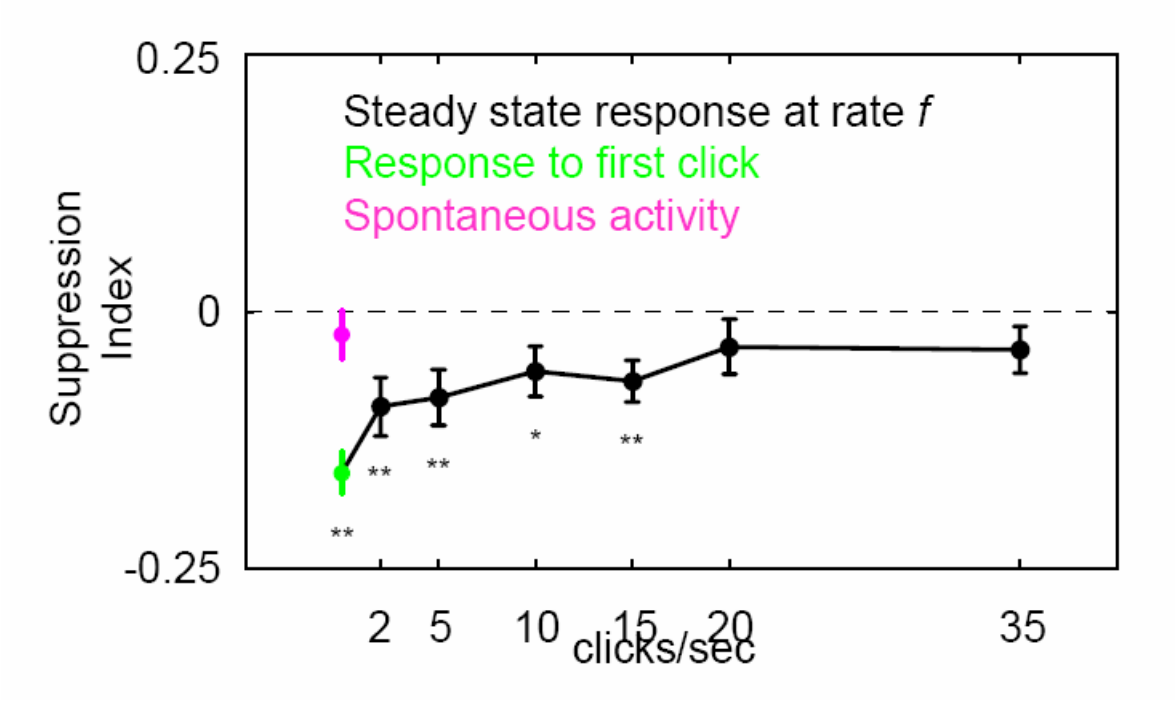
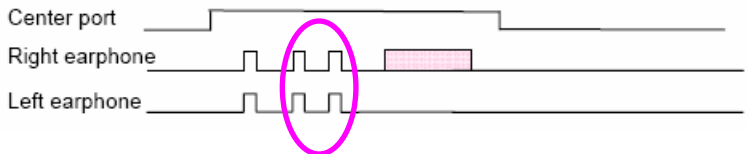
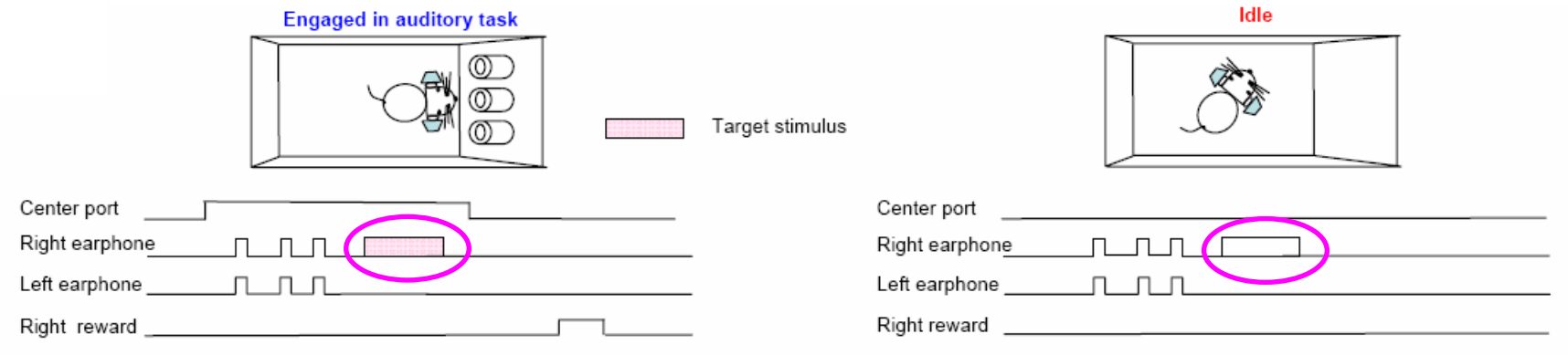


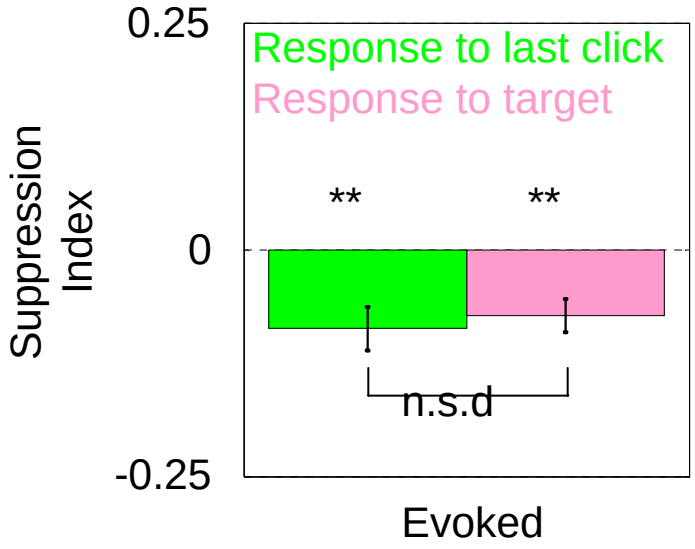
# Response to target



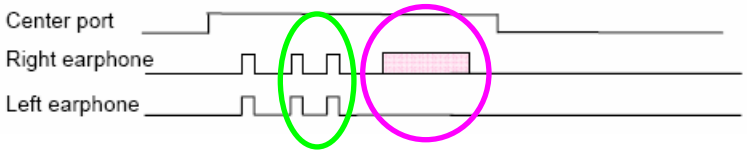

Analysis so far has been of *irrelevant* stimuli

Is suppression due to attention in time?

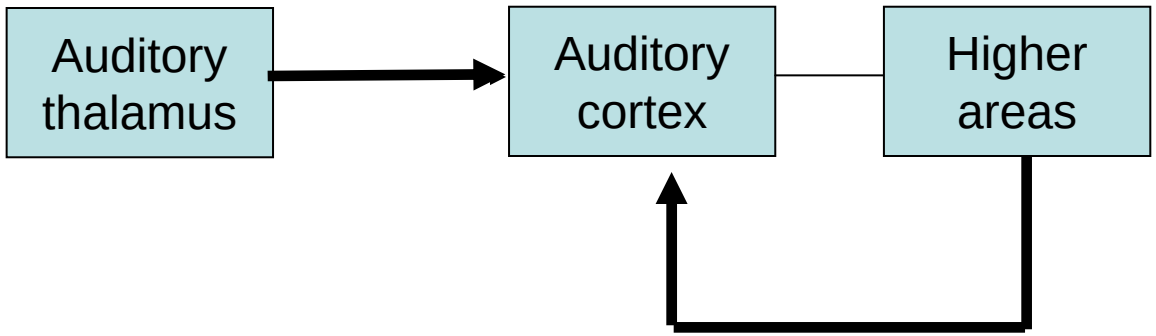
# Response to target is also suppressed



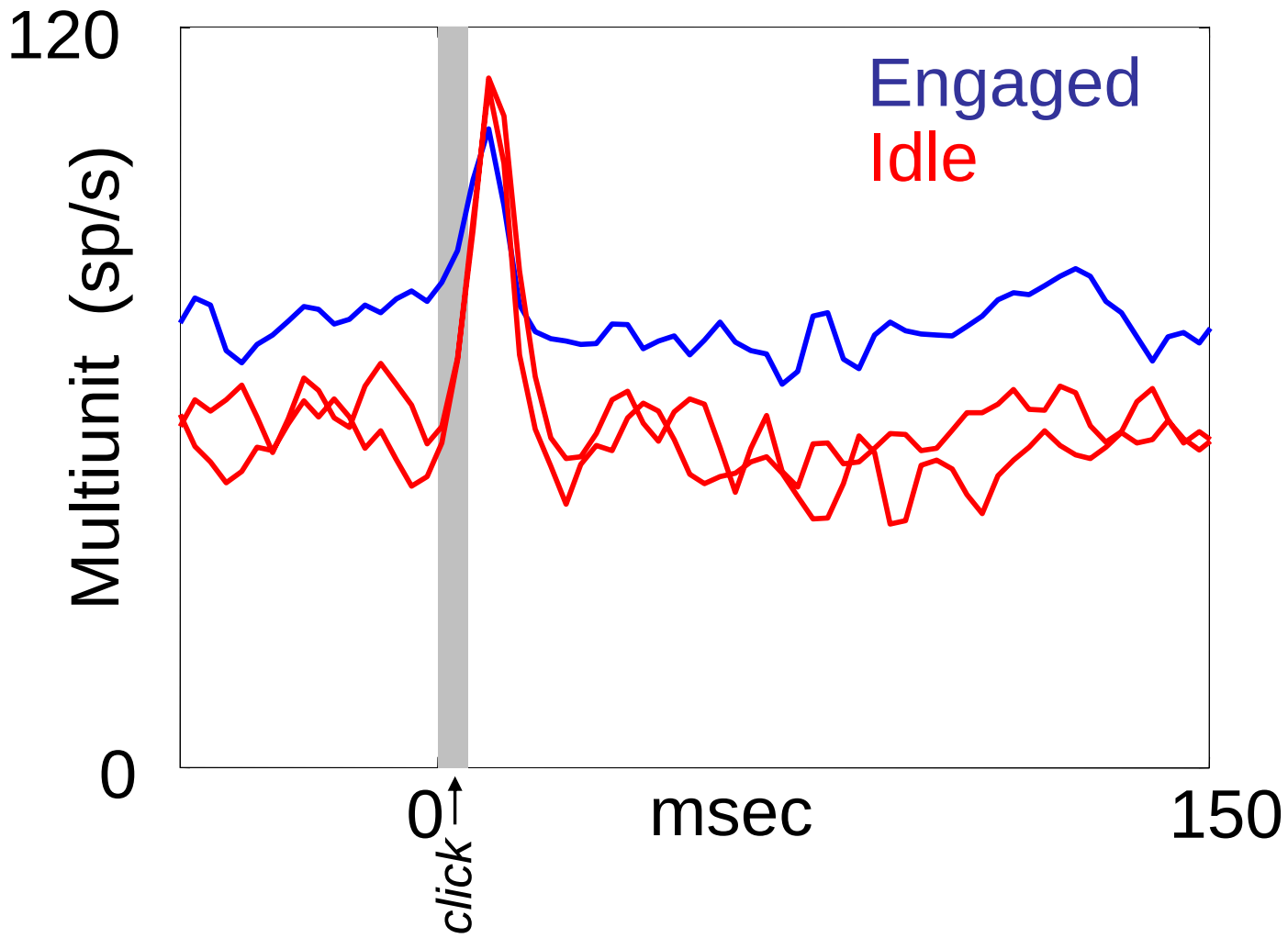

Not attention in time….



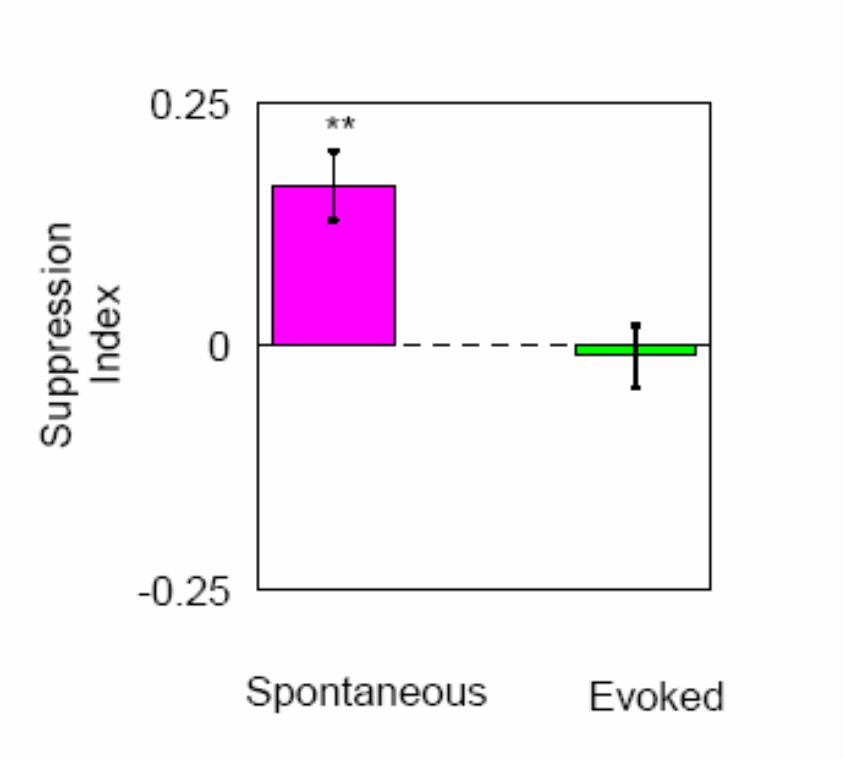
# Mechanism of suppression?



# Spontaneous activity is enhanced in engaged condition in thalamus



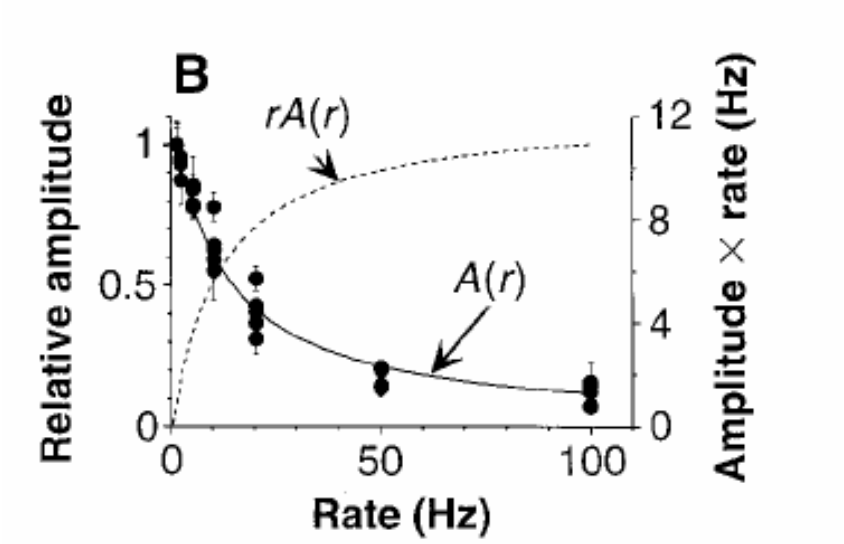
# Spontaneous activity is enhanced in engaged condition in thalamus




Otazu & Zador

Multiunit

# Possible mechanism of thalamocortical transformation



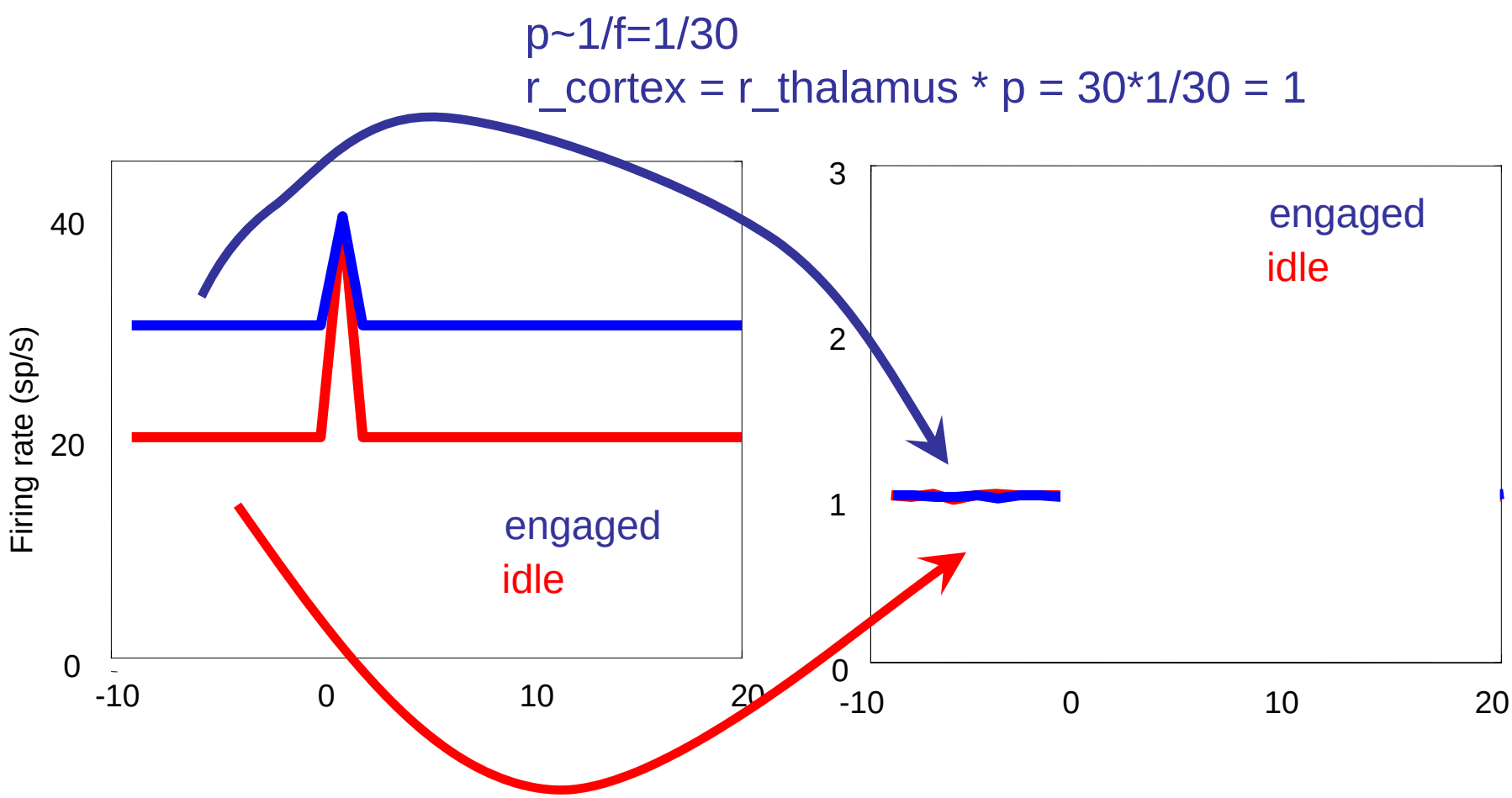

Synaptic release probability $p$ ~ 1/firing rate

**Synaptic Depression and Cortical Gain Control**

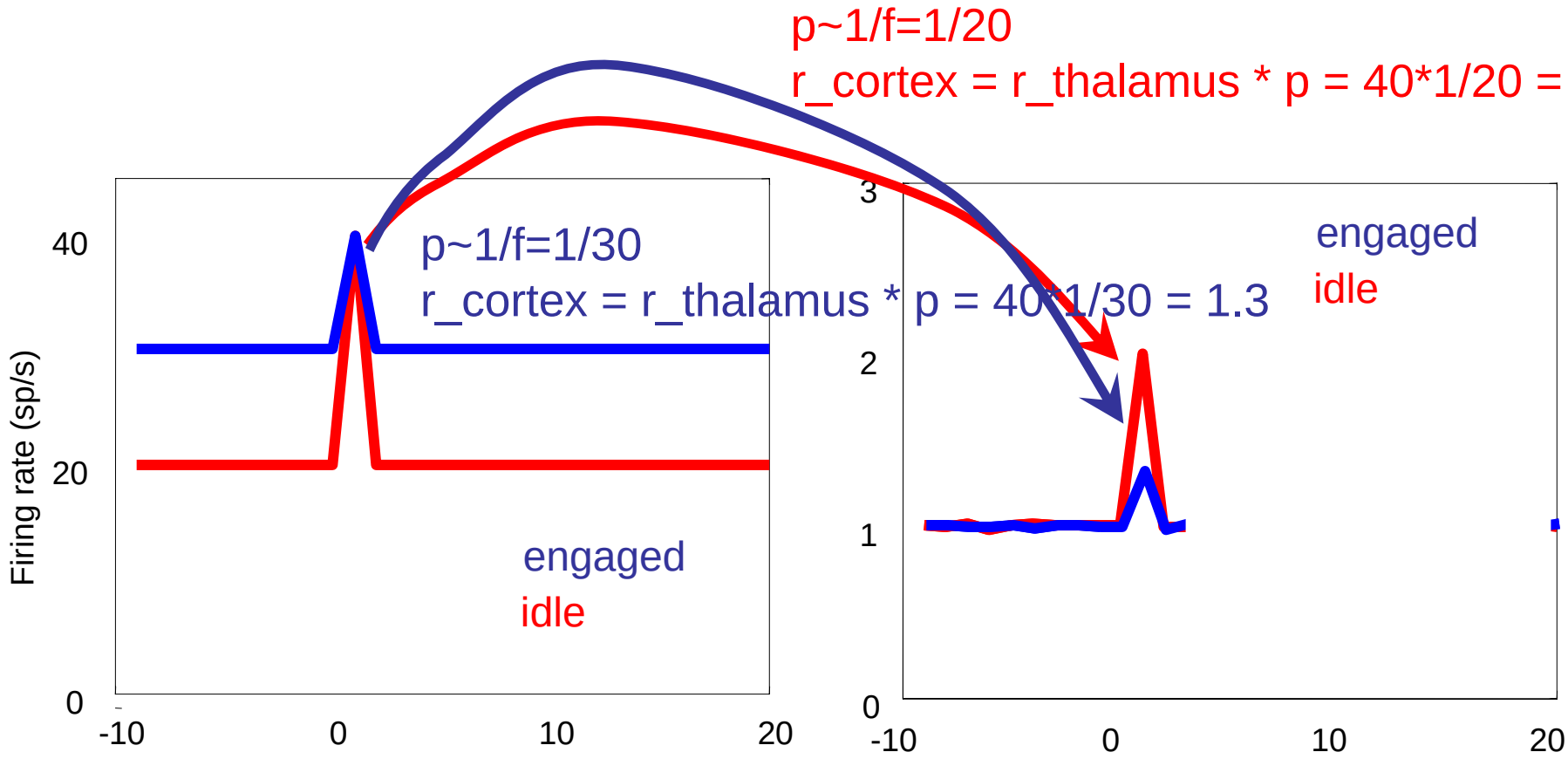
L. F. Abbott,* J. A. Varela, Kamal Sen, S. B. Nelson

SCIENCE • VOL. 275 • 10 JANUARY 1997

# Possible mechanism of thalamocortical transformation



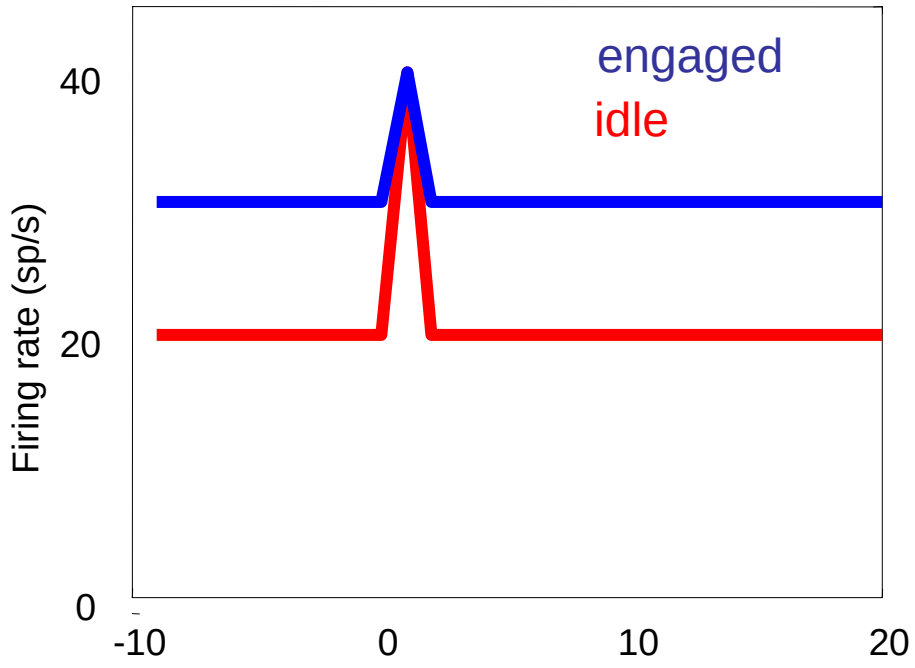
# Possible mechanism of thalamocortical transformation

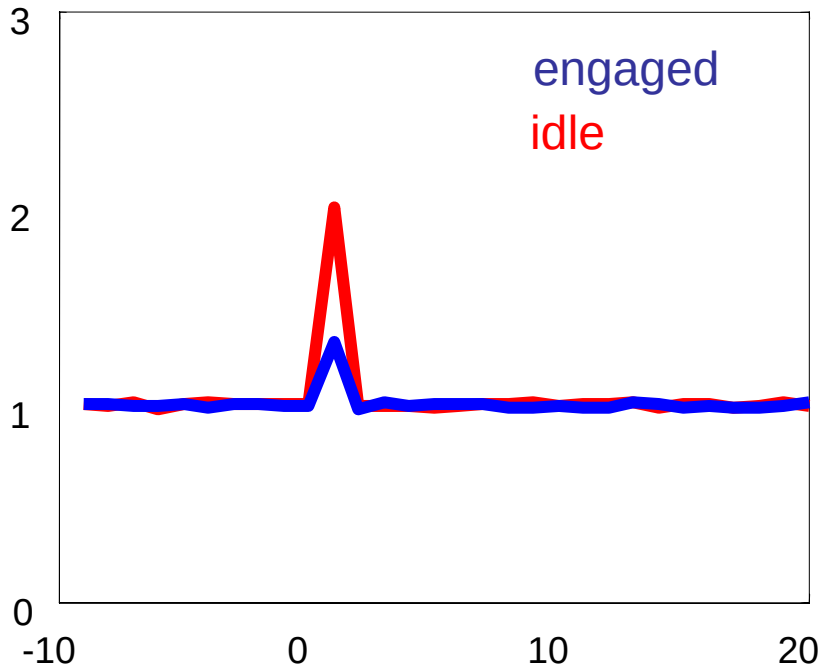



Thalamus

Cortex

# Possible mechanism of thalamocortical transformation



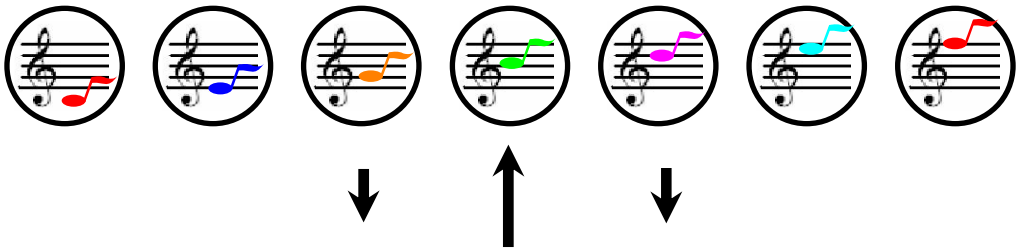

Thalamus

Cortex

Why are responses suppressed in the engaged condition?

# Hypothesis 1:
# Surround suppression elicited by non-optimized stimuli

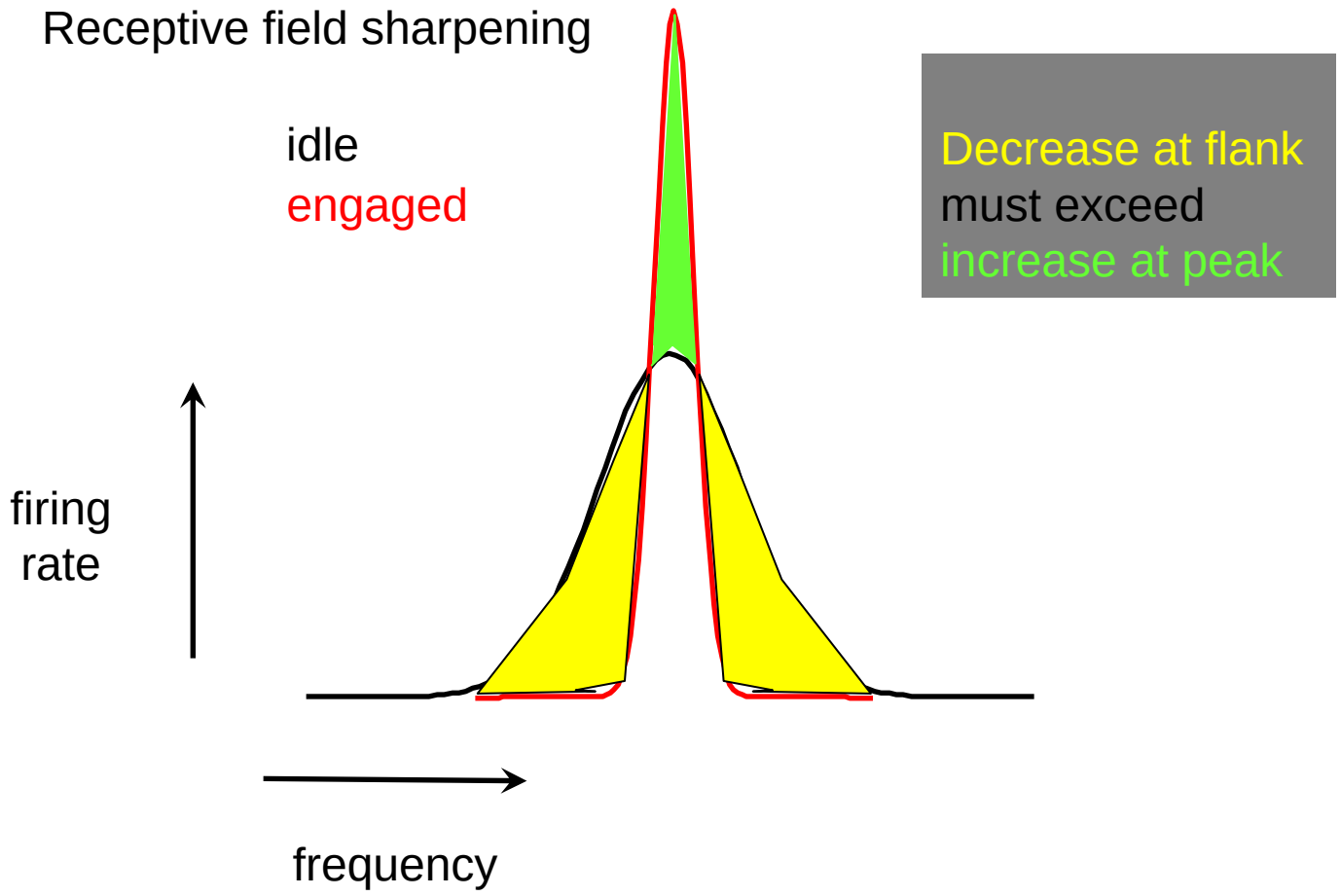
Tonotopic map



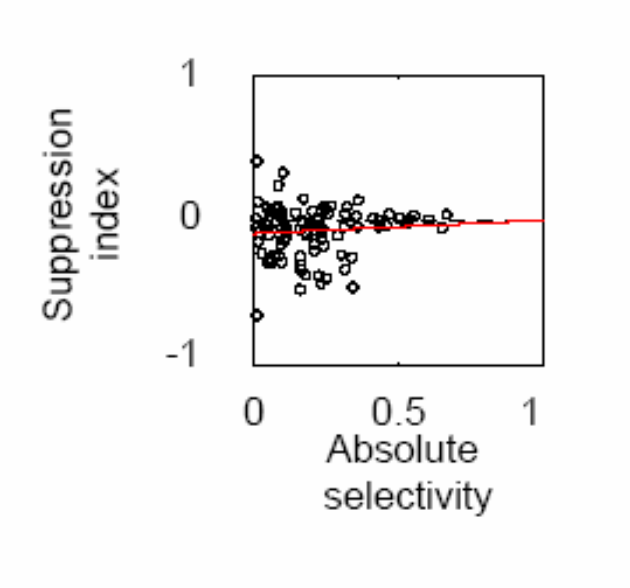
target

Receptive field sharpening:
Stimuli in receptive field flanks can show suppression

# Hypothesis 1:
# Surround suppression elicited by non-optimized stimuli

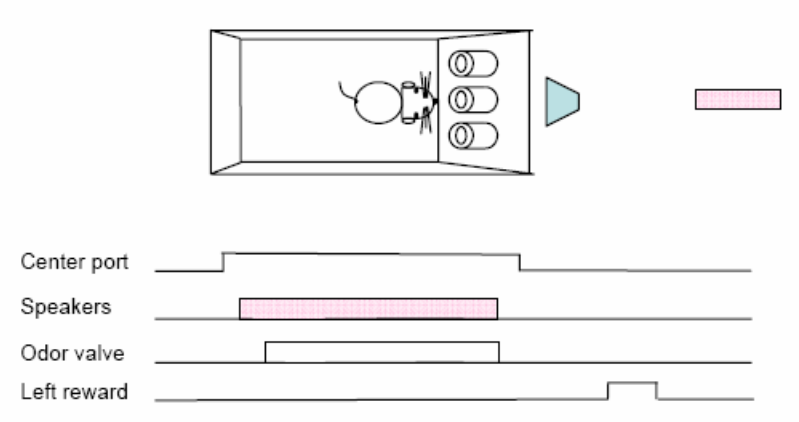


# Suppression index uncorrelated with neuronal selectivity

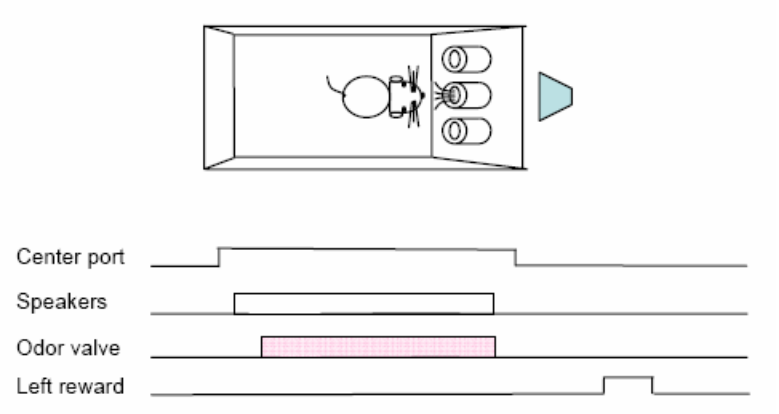



Selectivity = 2* (|ROC|-0.5)

# Task 2: Crossmodal attention task




Frequency discrimination

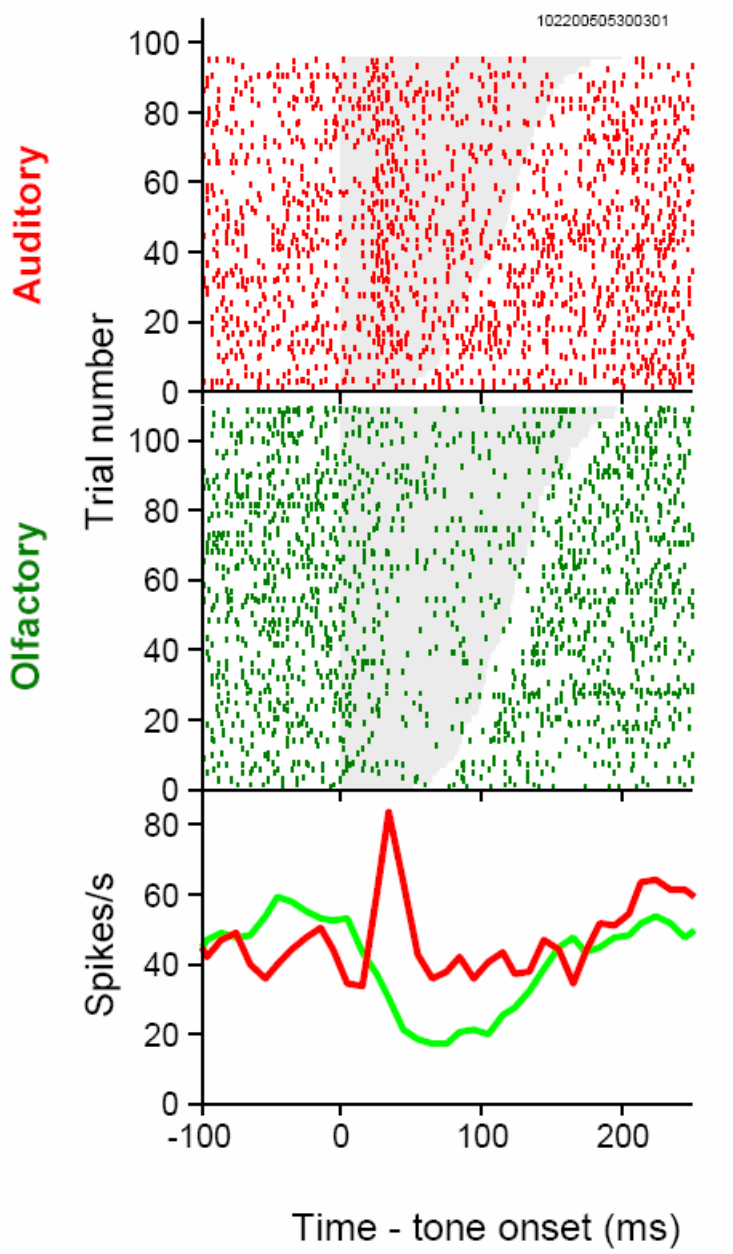



Odor discrimination

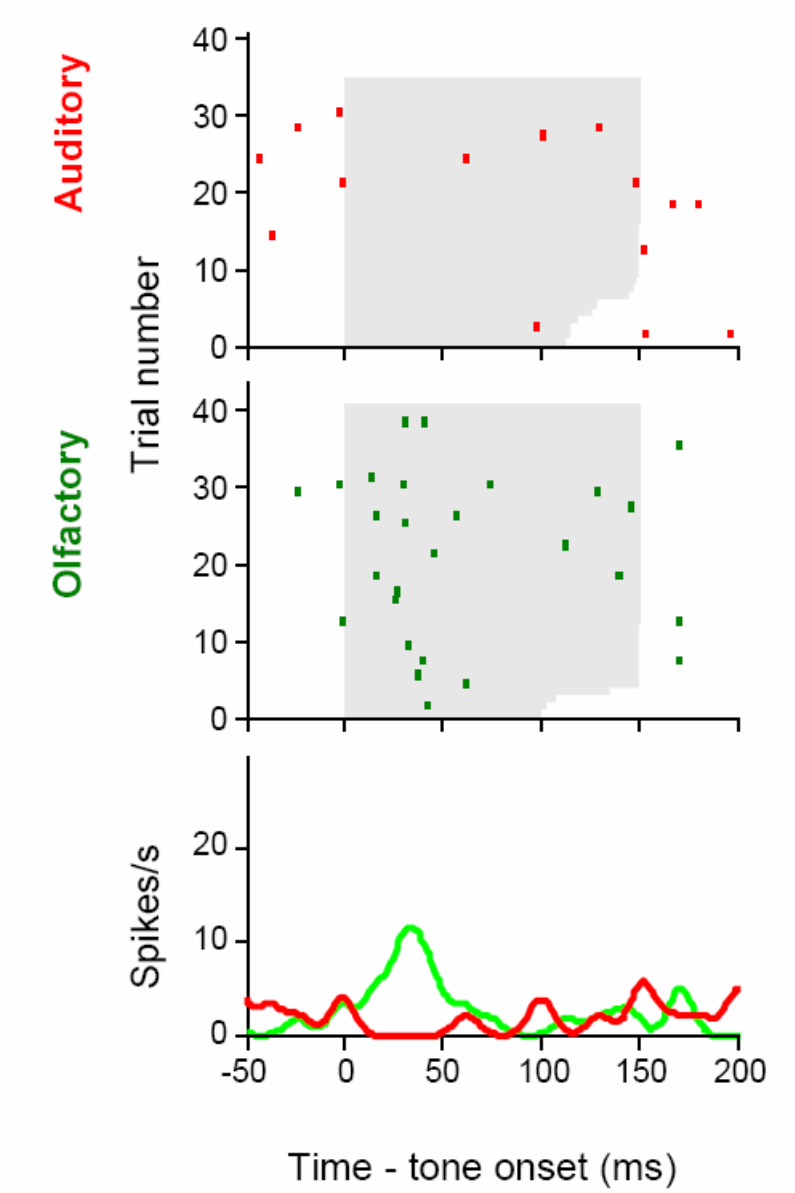
**Animal is *engaged* in a task both conditions**

Block design: A-O-A-O-A-O

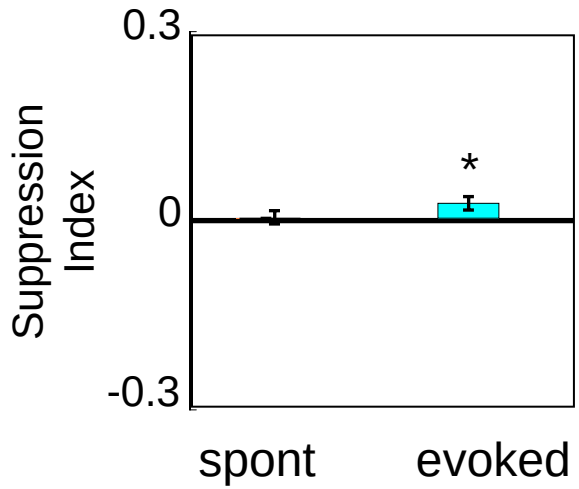
# Some auditory responses enhanced during auditory block



# Auditory responses sometimes suppressed during auditory block



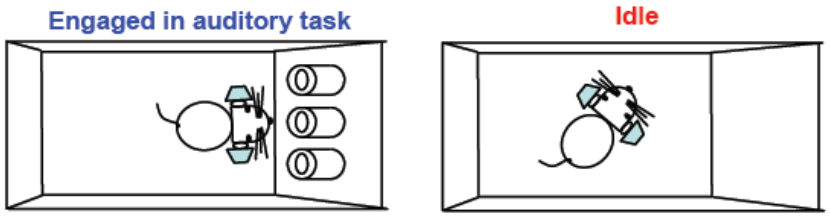
# Slight net enhancement of single unit activity in auditory block

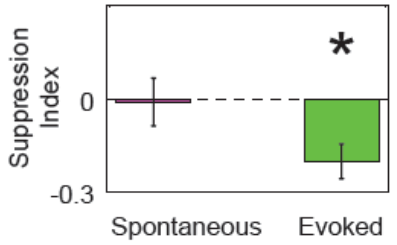



…no change in spontaneous activity

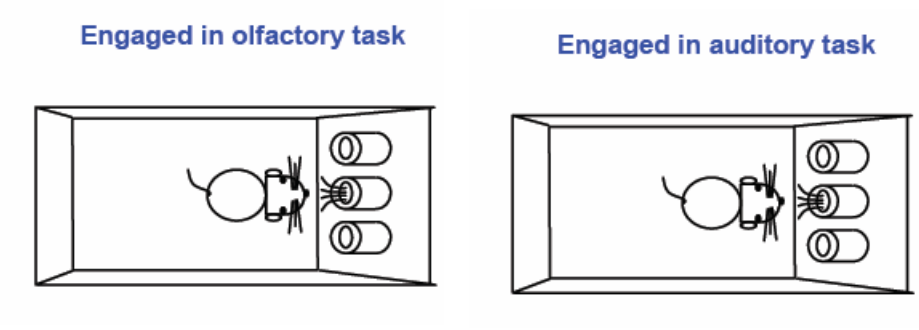
# Summary

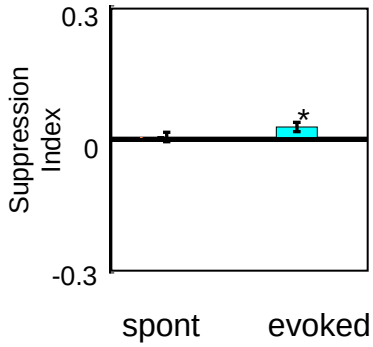
1. Engaging in an auditory task causes a **general suppression** of evoked responses in auditory cortex.




2. Selective attention **enhancements are superimposed** on this suppression.



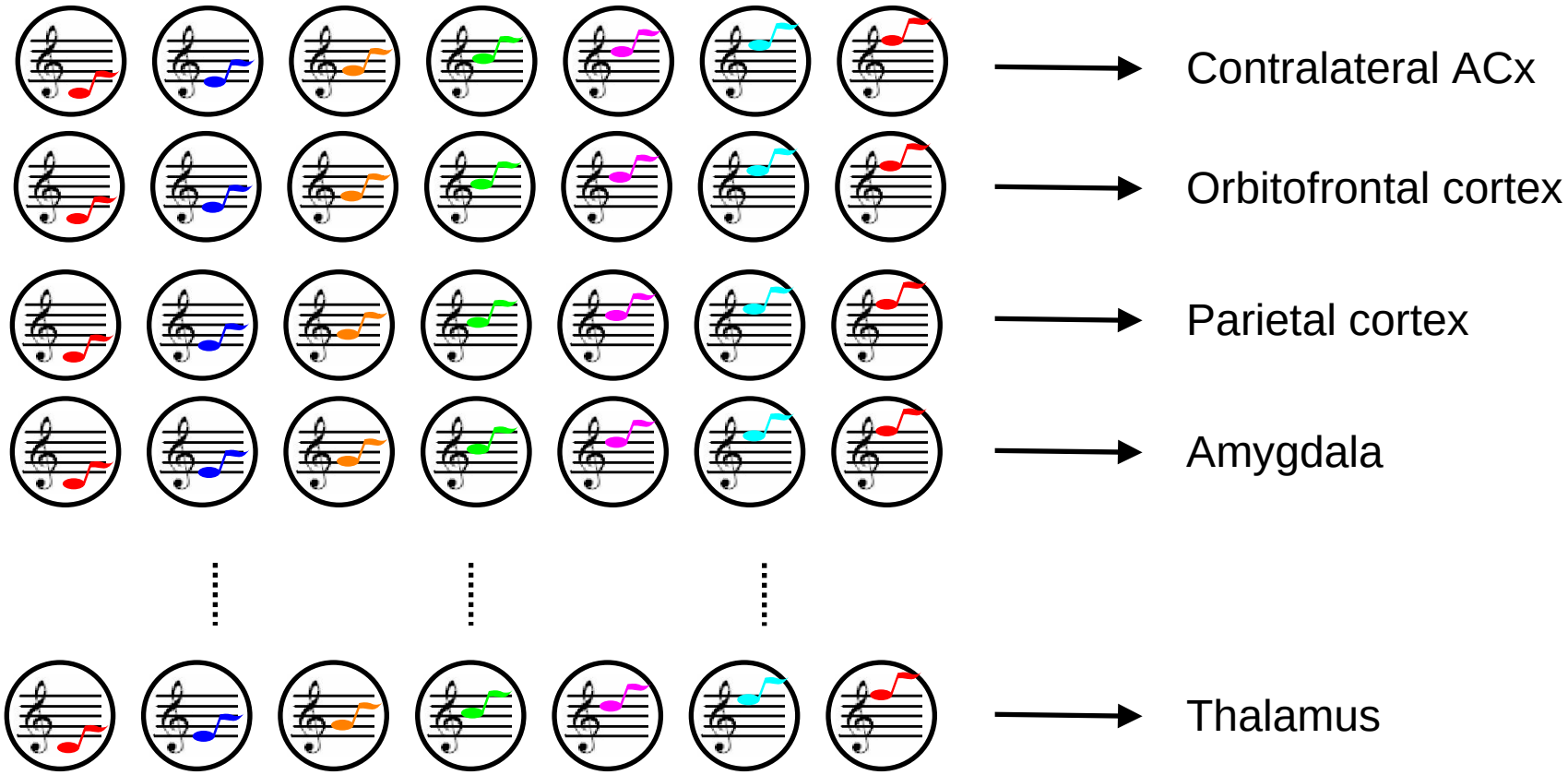



# SPECULATION

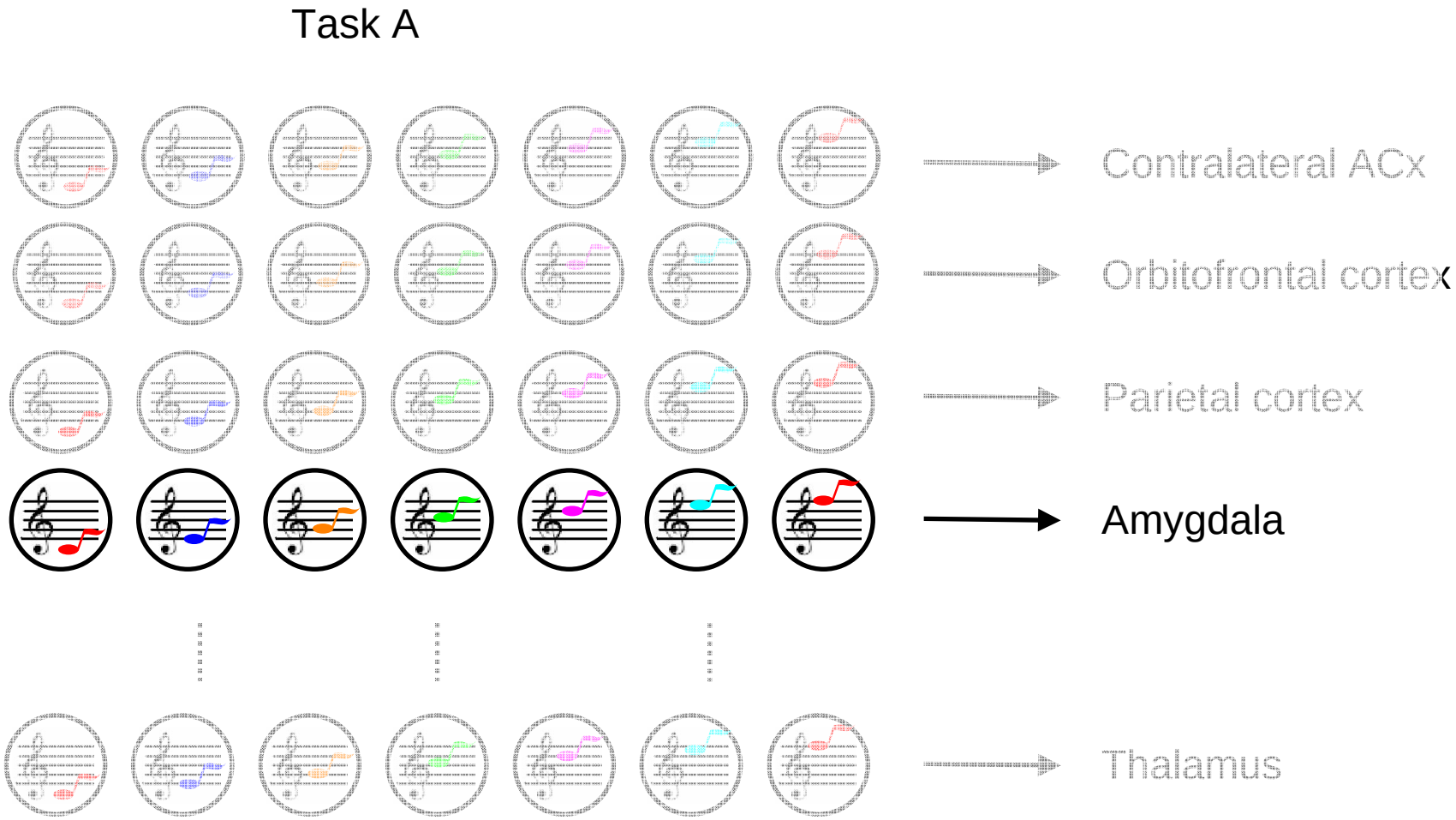
What is the function of this suppression?

Hypothesis: Limited attentional resource is **communication bandwidth** (i.e not every signal can be sent to every part of the brain)

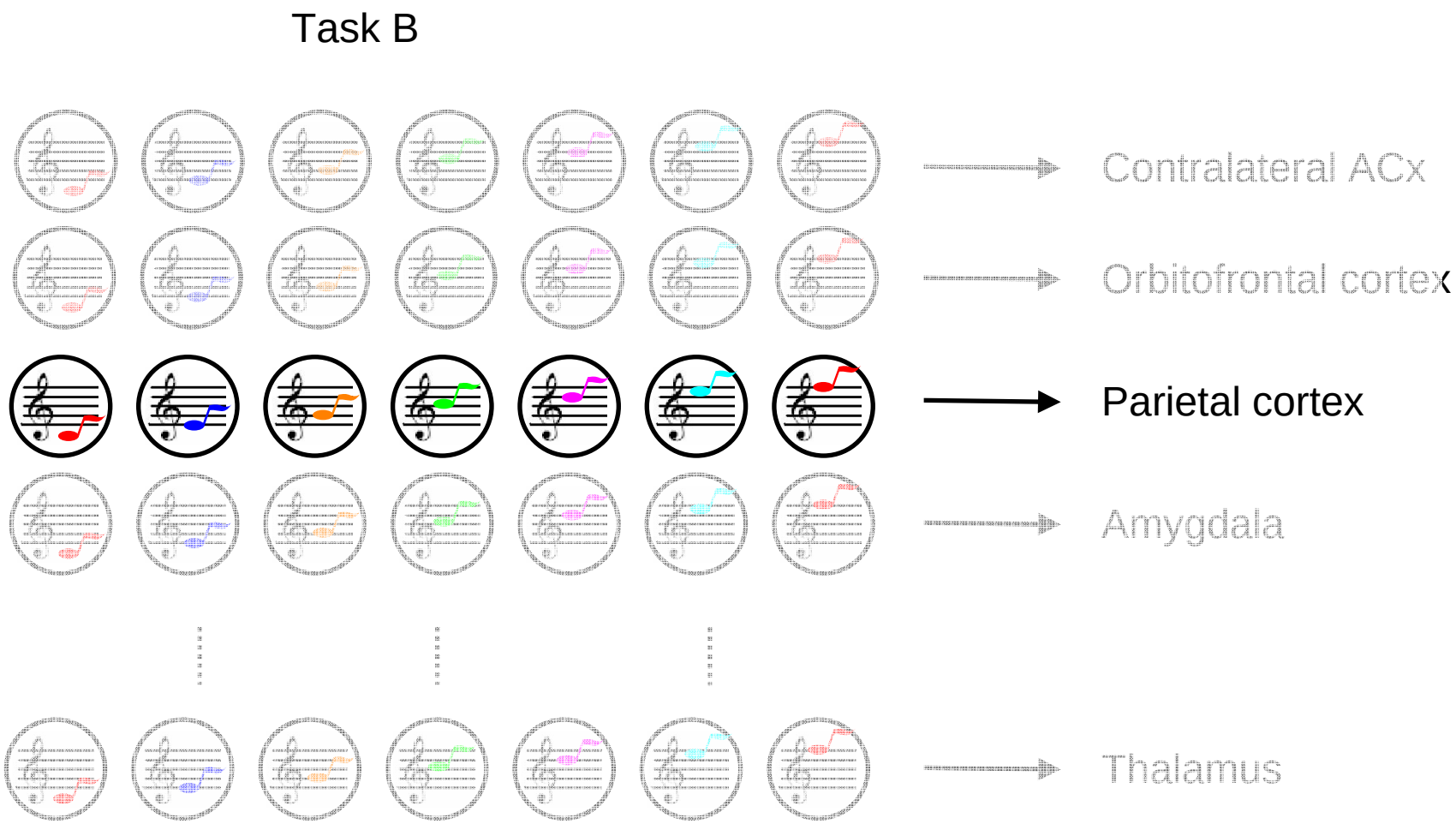
# Hypothesis 2: Task-dependent routing of auditory information



# Hypothesis 2: Task-dependent routing of auditory information



# Hypothesis 2: Task-dependent routing of auditory information



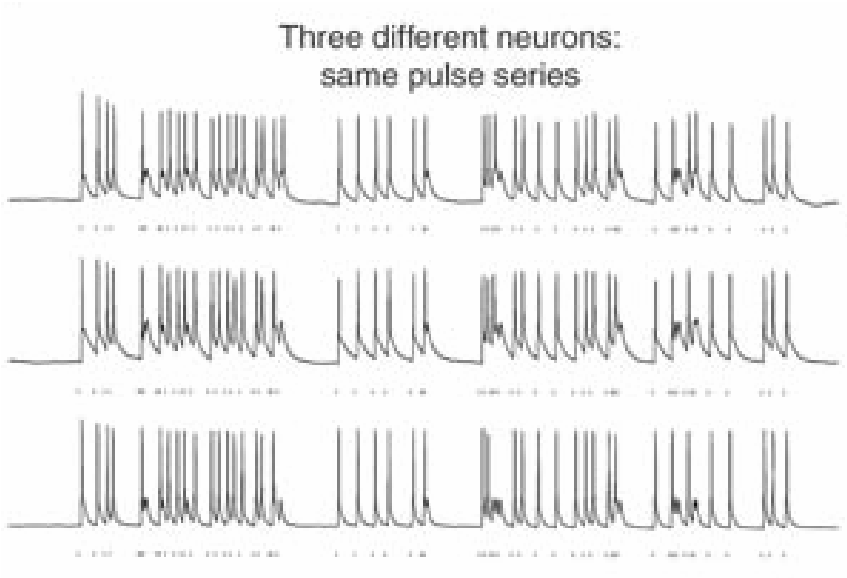
# Hypothesis 2: Task-dependent routing of auditory information

Task B + selective attention

Testing hypothesis 2

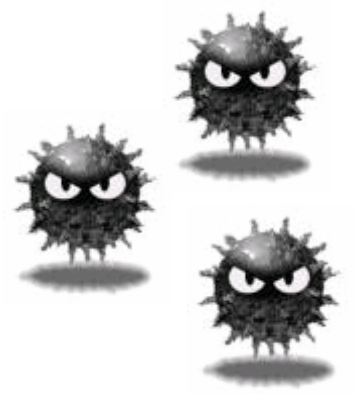
***Hypothesis***: Neural diversity reflects anatomical projection pattern

# Channelrhodopsin-2 couples light to neural activity



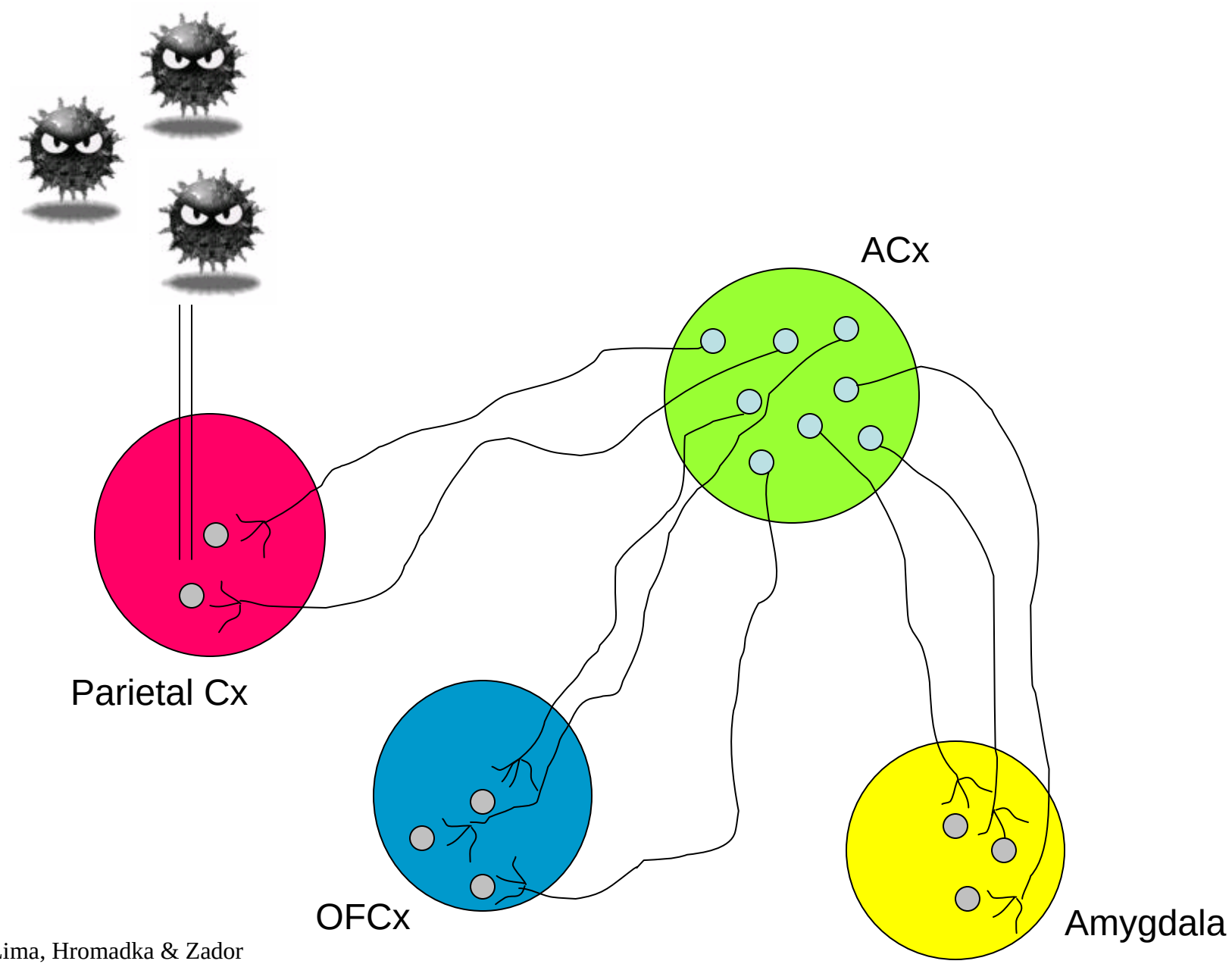

Boyden, Zhang, Bamberg, Nagel and Deisseroth (2005)

# Tagging neurons with ChR2



Herpes virus expressing Channelrhopsin2

# Tagging neurons with ChR2

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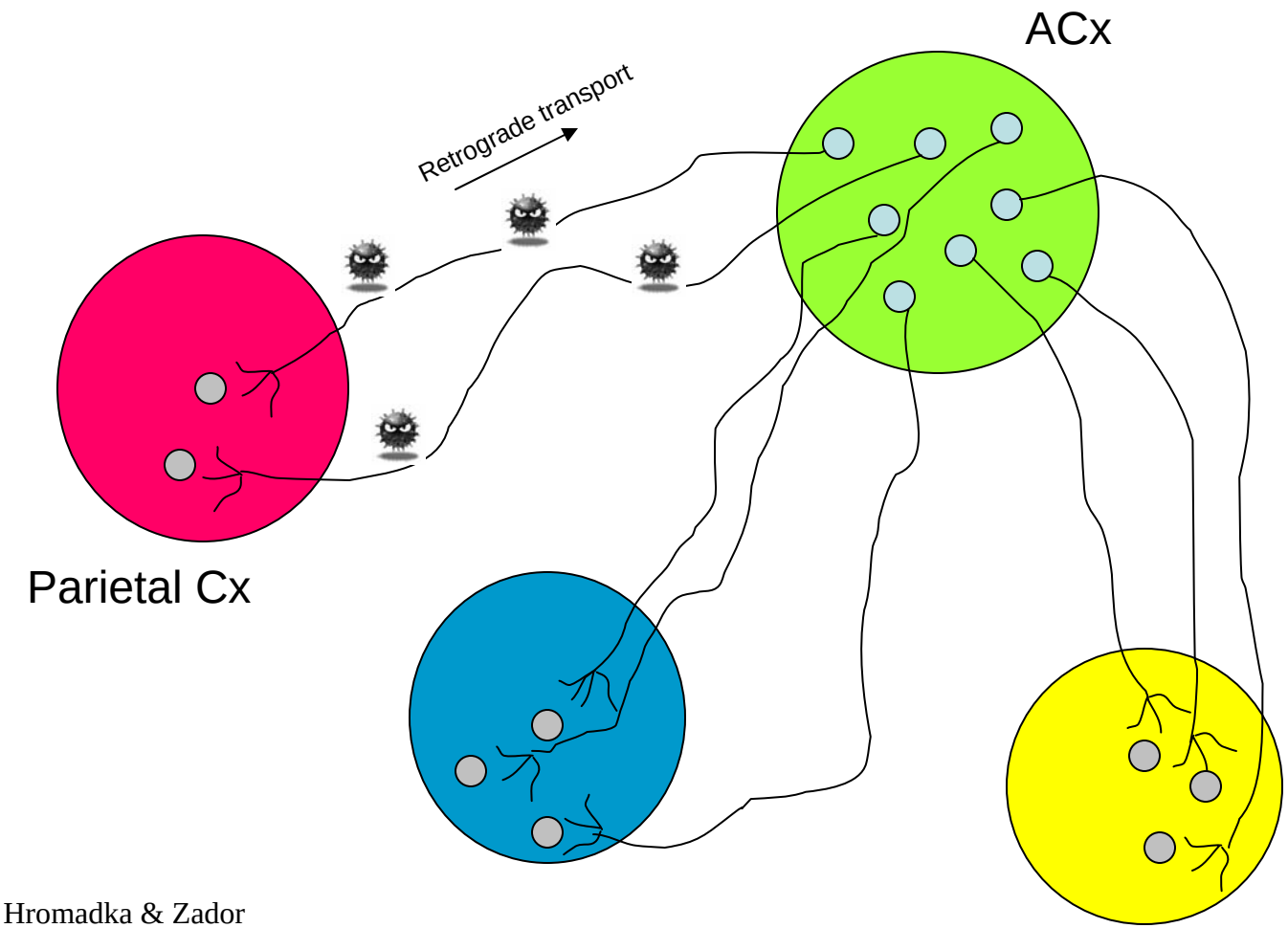
# Tagging neurons with ChR2

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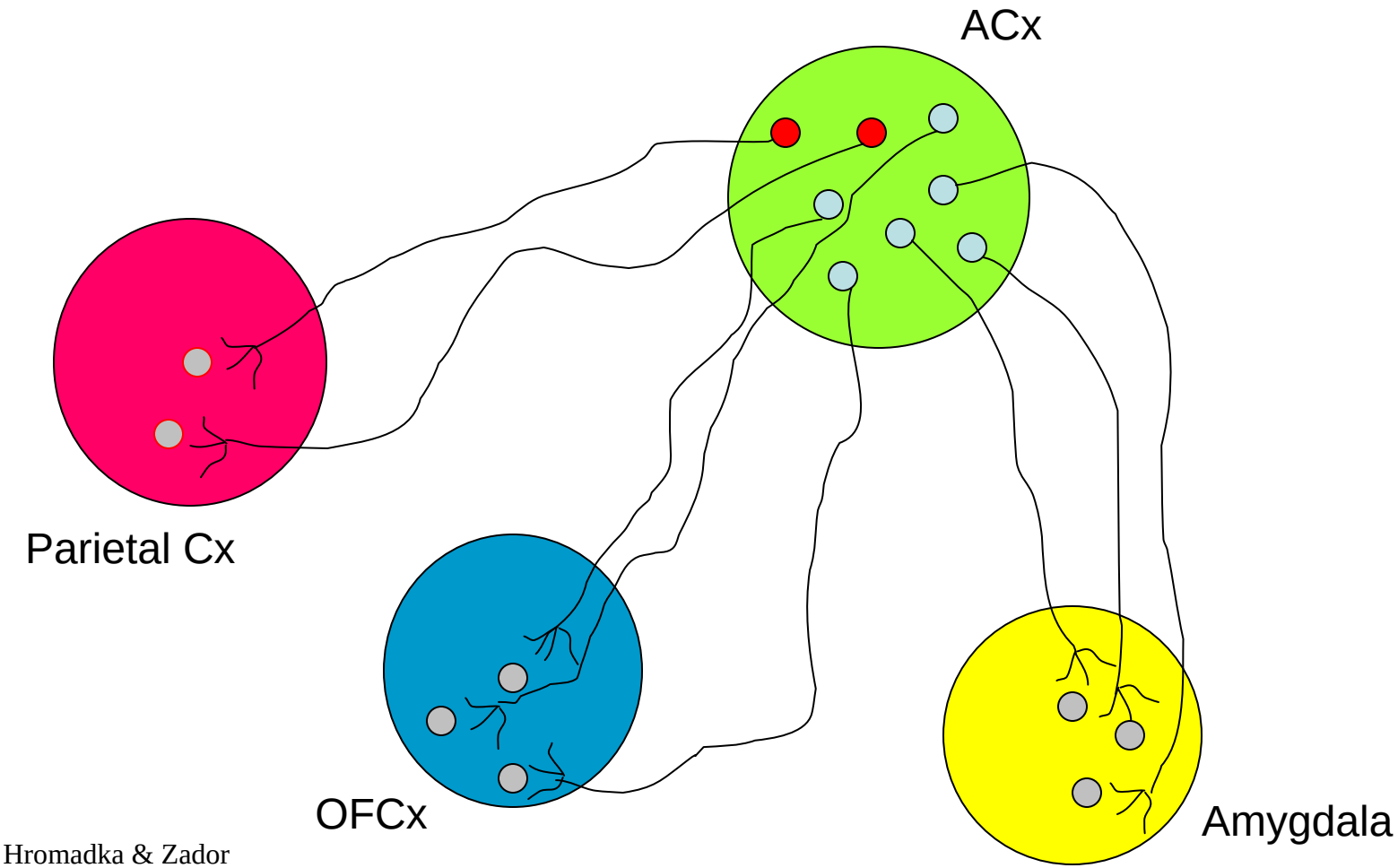
# Tagging neurons with ChR2

Only the cells in AC that project to parietal
will be ChR2 positive

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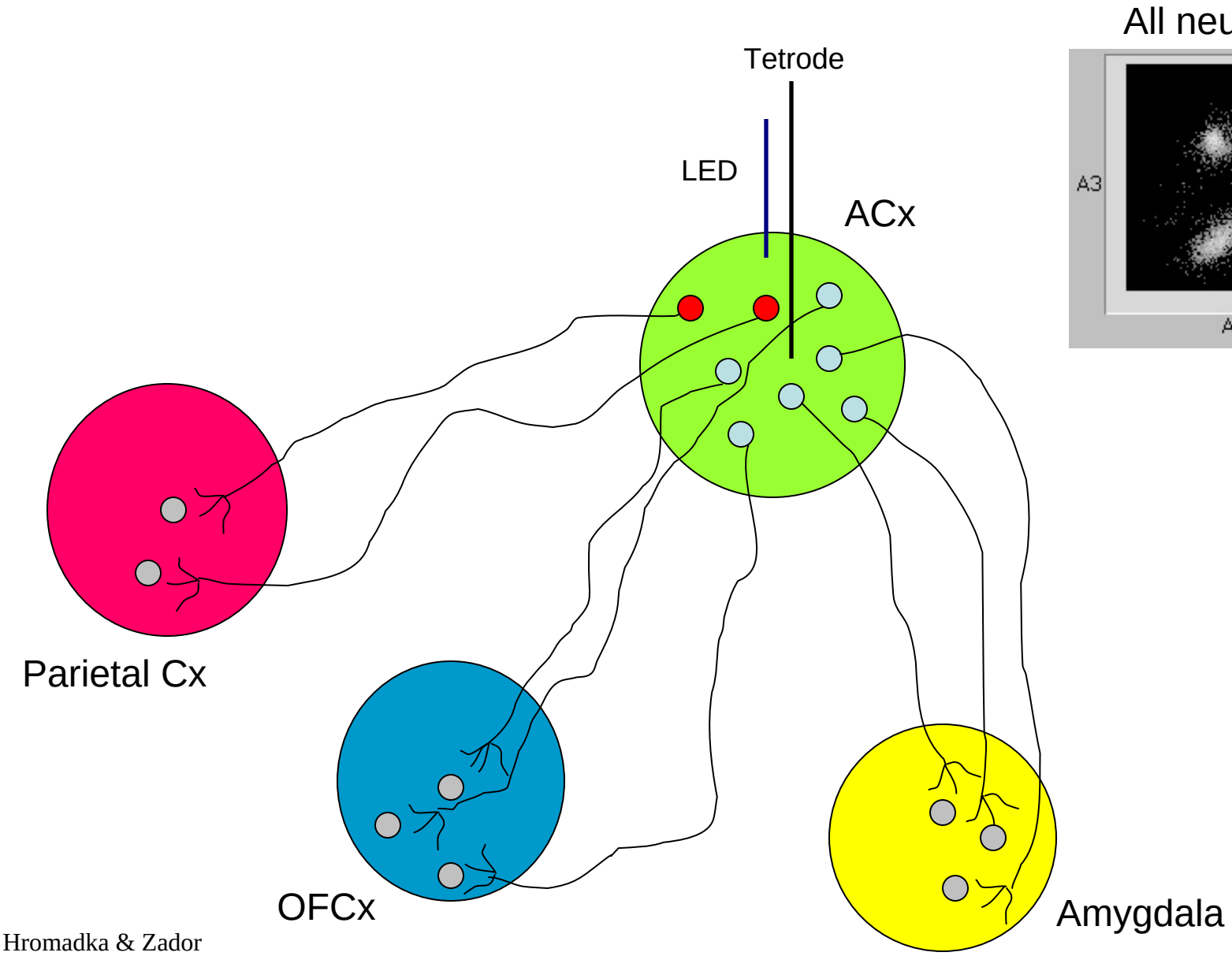
# Tagging neurons with ChR2

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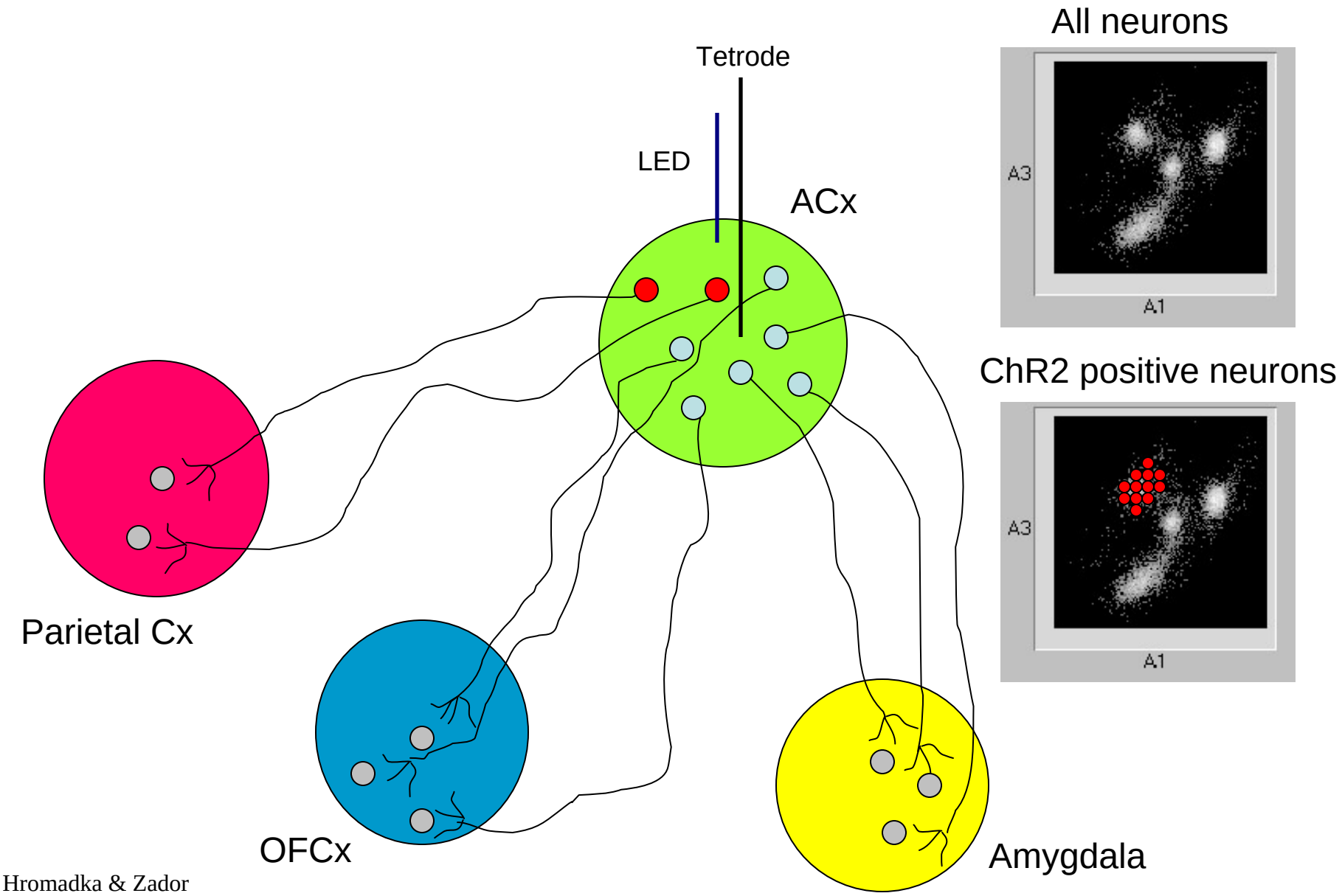
# Tagging neurons with ChR2

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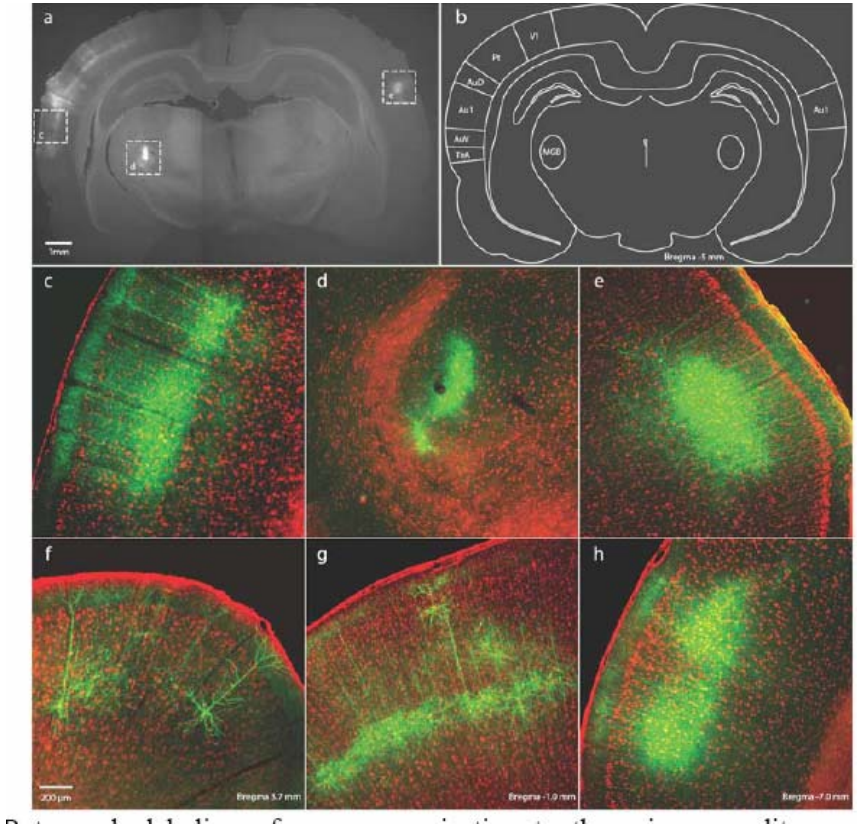
# Chr2-retrograde labeling after A1 injection





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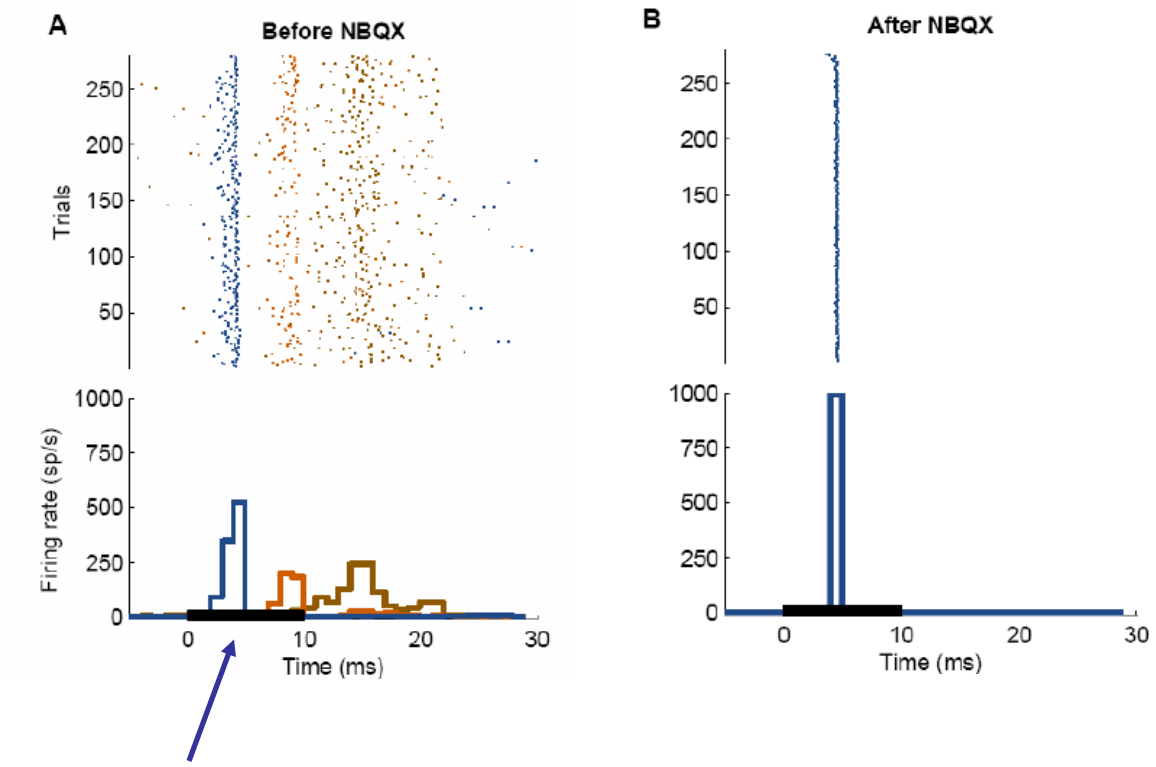
# Direct and indirect light-evoked responses




Light-flash

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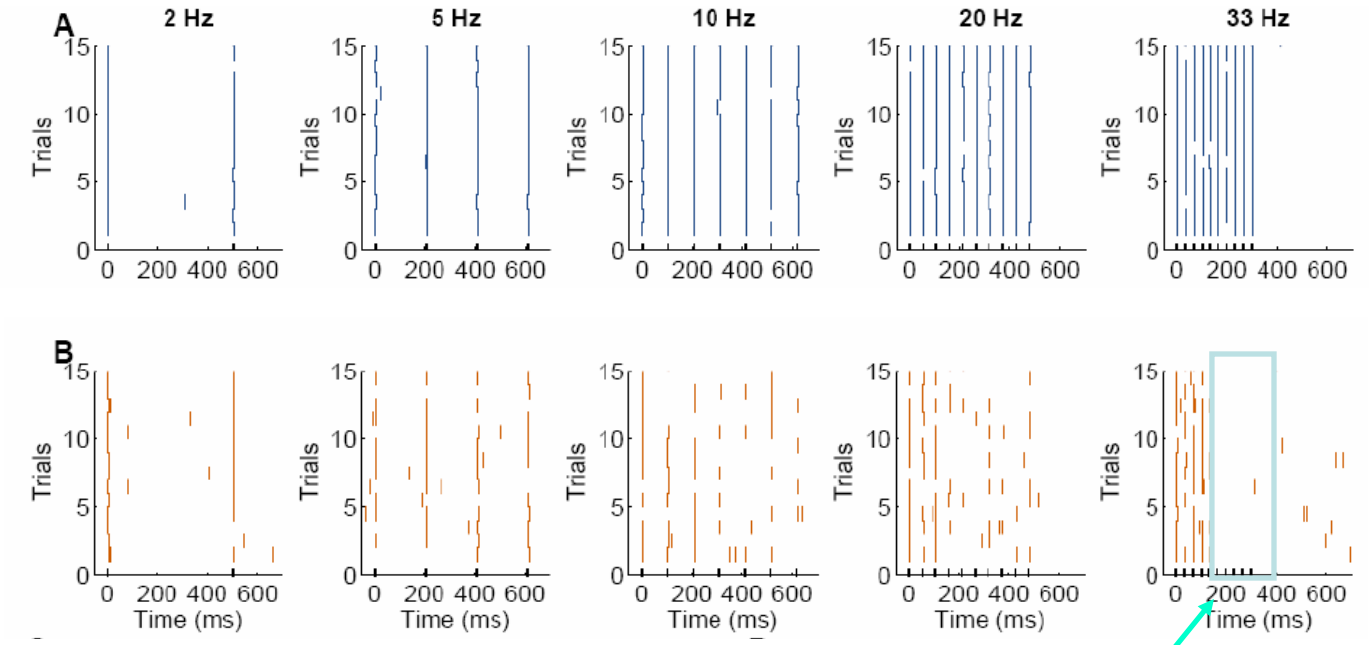
# Repetitive flashes distinguish direct and indirect light-evoked responses




Indirect response fades at high repetition rate

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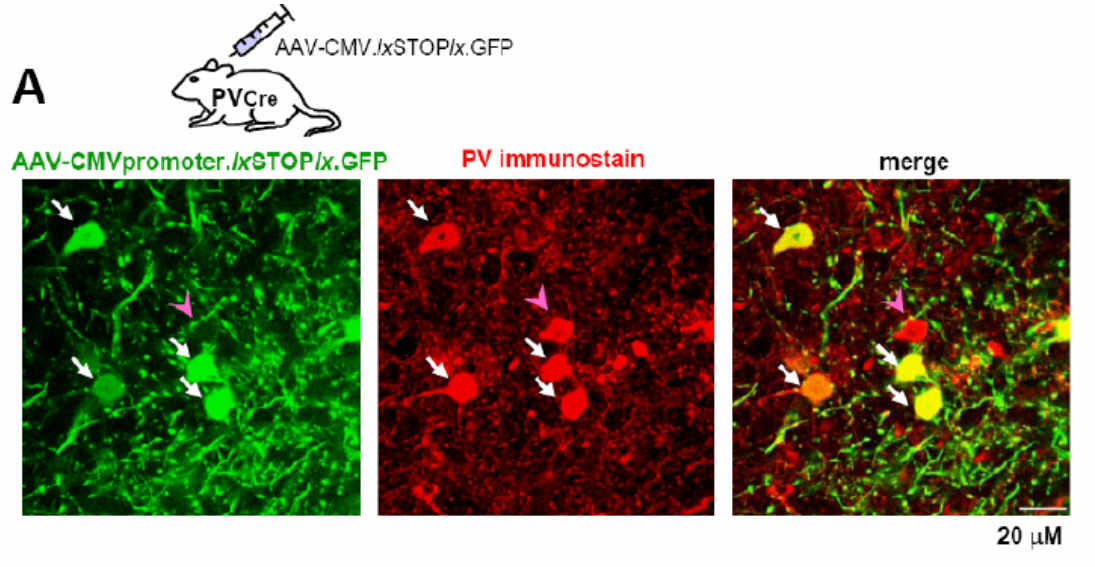
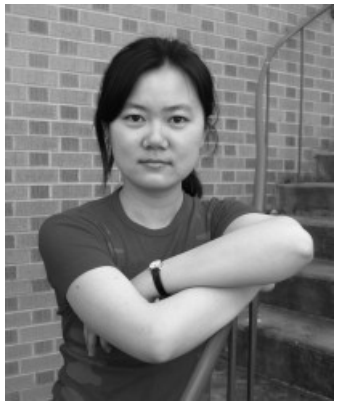
# ChR2 can also tag interneuron subpopulations



# Summary

A novel non-selective component of cortical attention is associated with a robust suppression, rather than enhancement, of activity.

# Zador lab



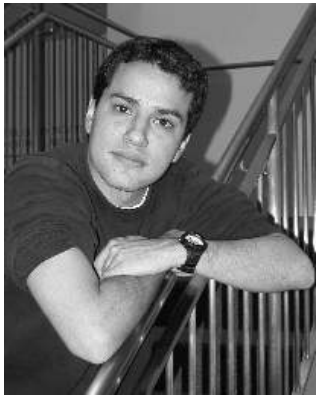
Katharine Borges

Ashlan Reid

Yang Yang

Susana Lima

Me



Lung-hao Tai

Tomas Hromadka

Gonzalo Otazu

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Hysell Oviedo

http://zadorlab.cshl.edu