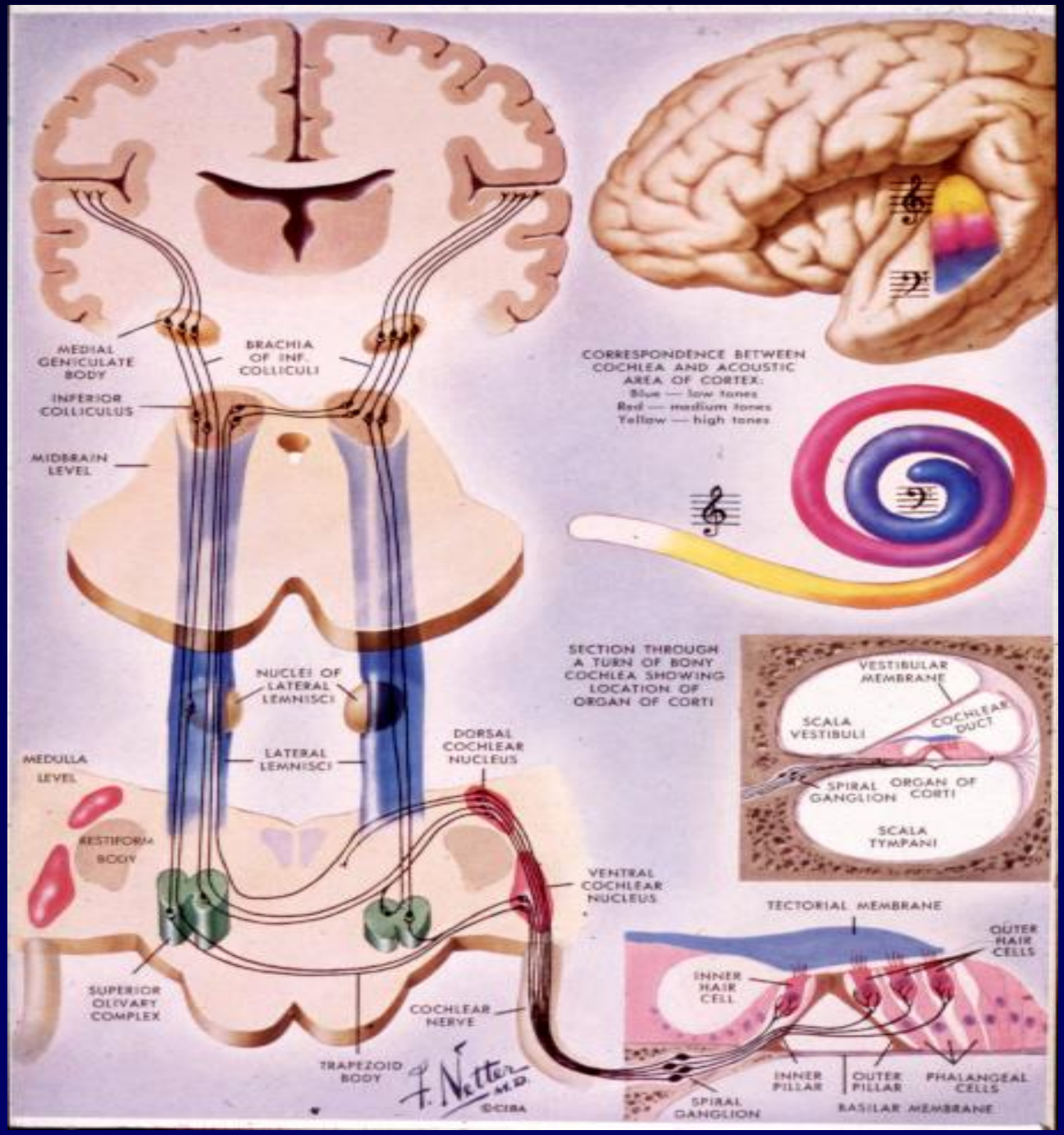
Functional mechanisms that mediate stimulus-specific adaptation in subcortical auditory nuclei

Manuel S. Malmierca

VNiVERSiDAD D SALAMANCA

INSTITUTO DE NEUROCIENCIAS CASTILLA Y LEÓN


MEDIAL GENICULATE BODY
BRACHIA OF INF. COLLICULI
INFERIOR COLLICULUS
MIDBRAIN LEVEL
CORRESPONDENCE BETWEEN COCHLEA AND ACOUSTIC AREA OF CORTEX:
Blue — low tones
Red — medium tones
Yellow — high tones
NUCLEI OF LATERAL LEMNISCI
LATERAL LEMNISCI
DORSAL COCHLEAR NUCLEUS
MEDULLA LEVEL
RESTIFORM BODY
SECTION THROUGH A TURN OF BONY COCHLEA SHOWING LOCATION OF ORGAN OF CORTI
VESTIBULAR MEMBRANE
SCALA VESTIBULI
COCHLEAR DUCT
SPIRAL GANGLION
ORGAN OF CORTI
SCALA TYMPANI
VENTRAL COCHLEAR NUCLEUS
TECTORIAL MEMBRANE
OUTER HAIR CELLS
INNER HAIR CELL
SUPERIOR OLIVARY COMPLEX
COCHLEAR NERVE
TRAPEZOID BODY
INNER PILLAR
OUTER PILLAR
PHALANGEAL CELLS
SPIRAL GANGLION
BASILAR MEMBRANE
F. Netter M.D.
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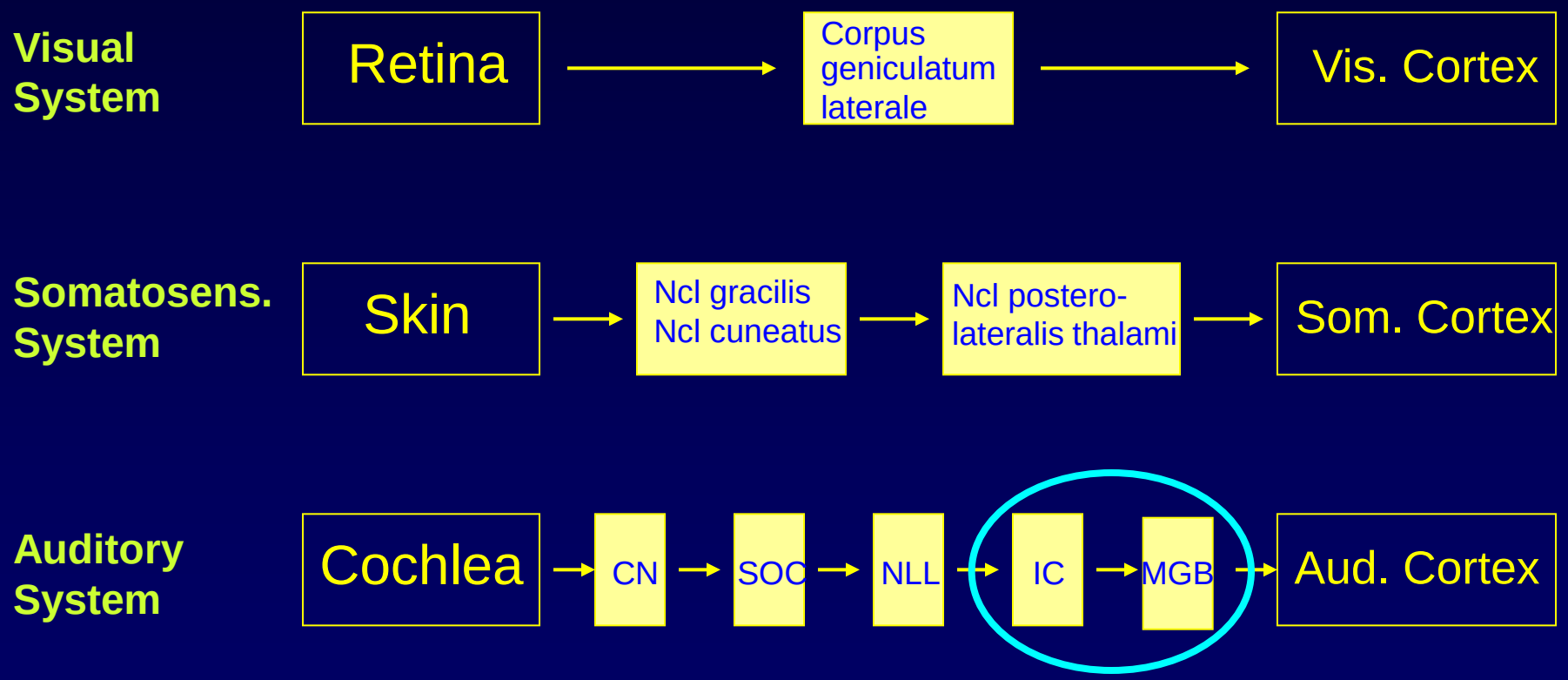
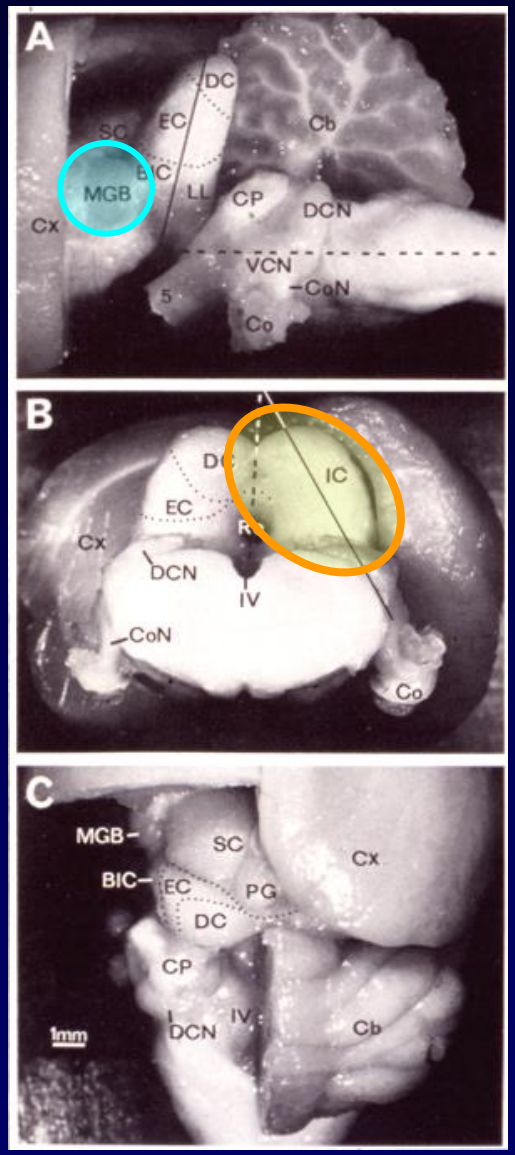
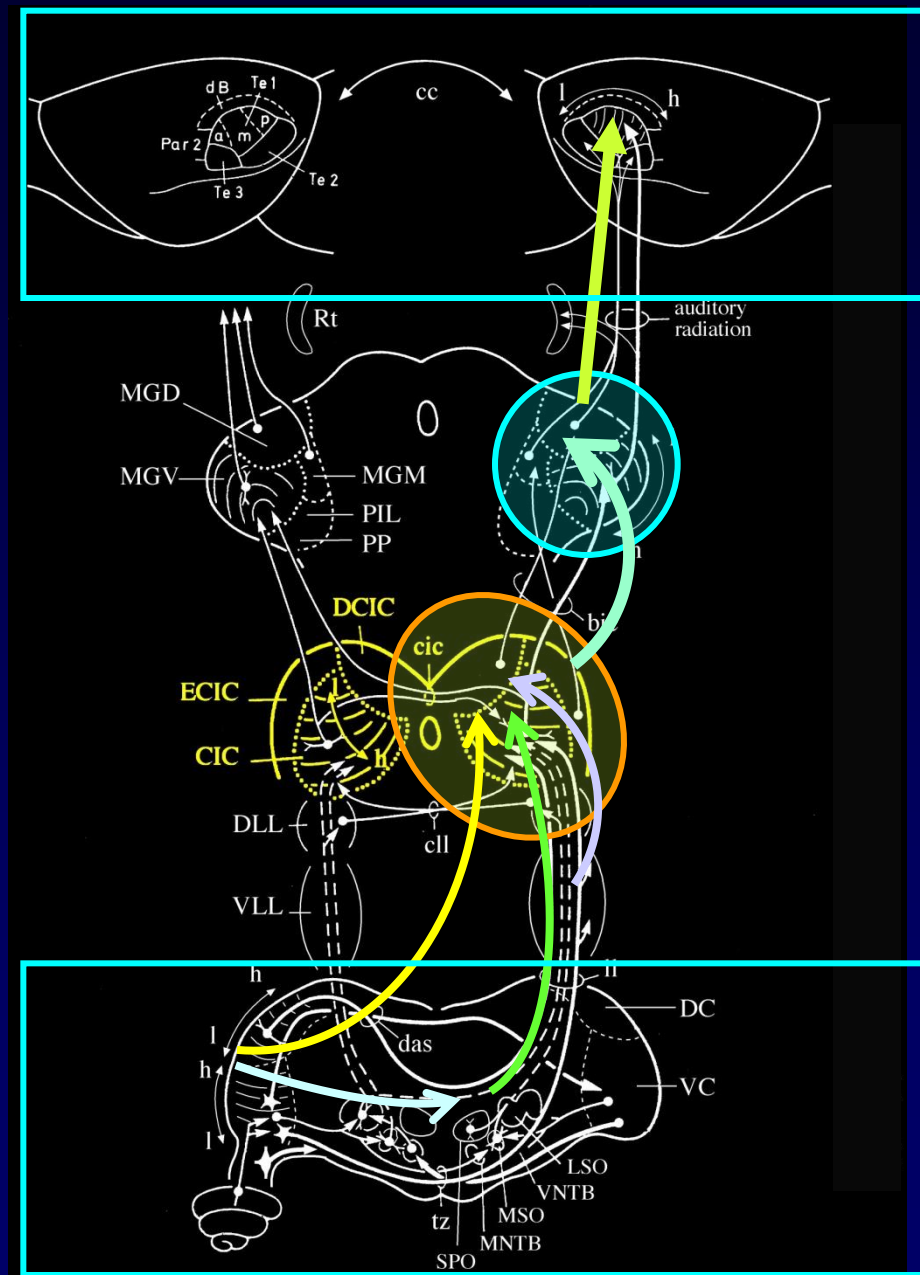
Complexity of the auditory system



AUDITORY PATHWAY IN RAT





AUDITORY COTEX

MEDIAL GENICULATE

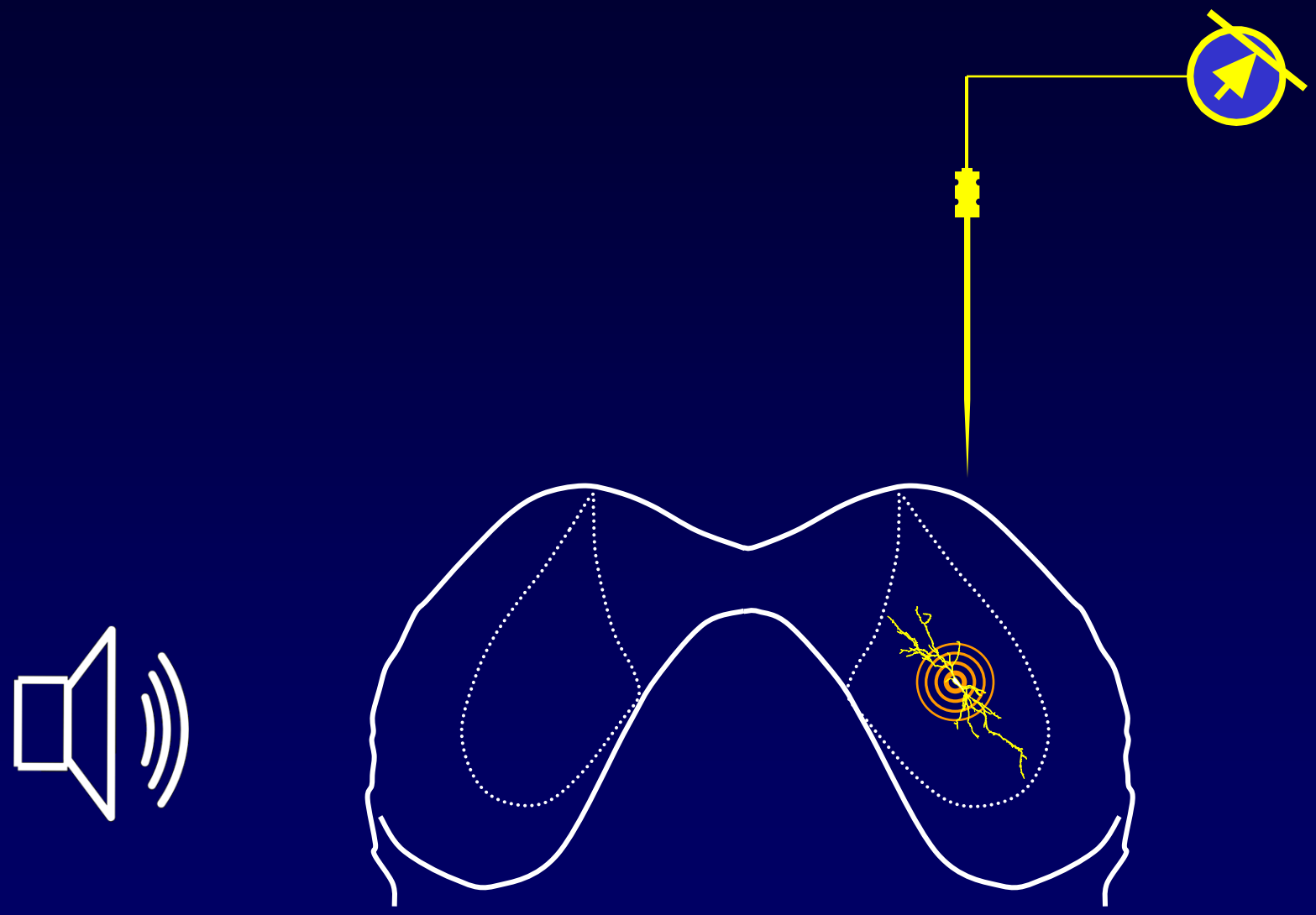
INFERIOR COLLICULUS

LATERAL LEMNISCUS NUCLEI

COCHLEAR NUCLEI

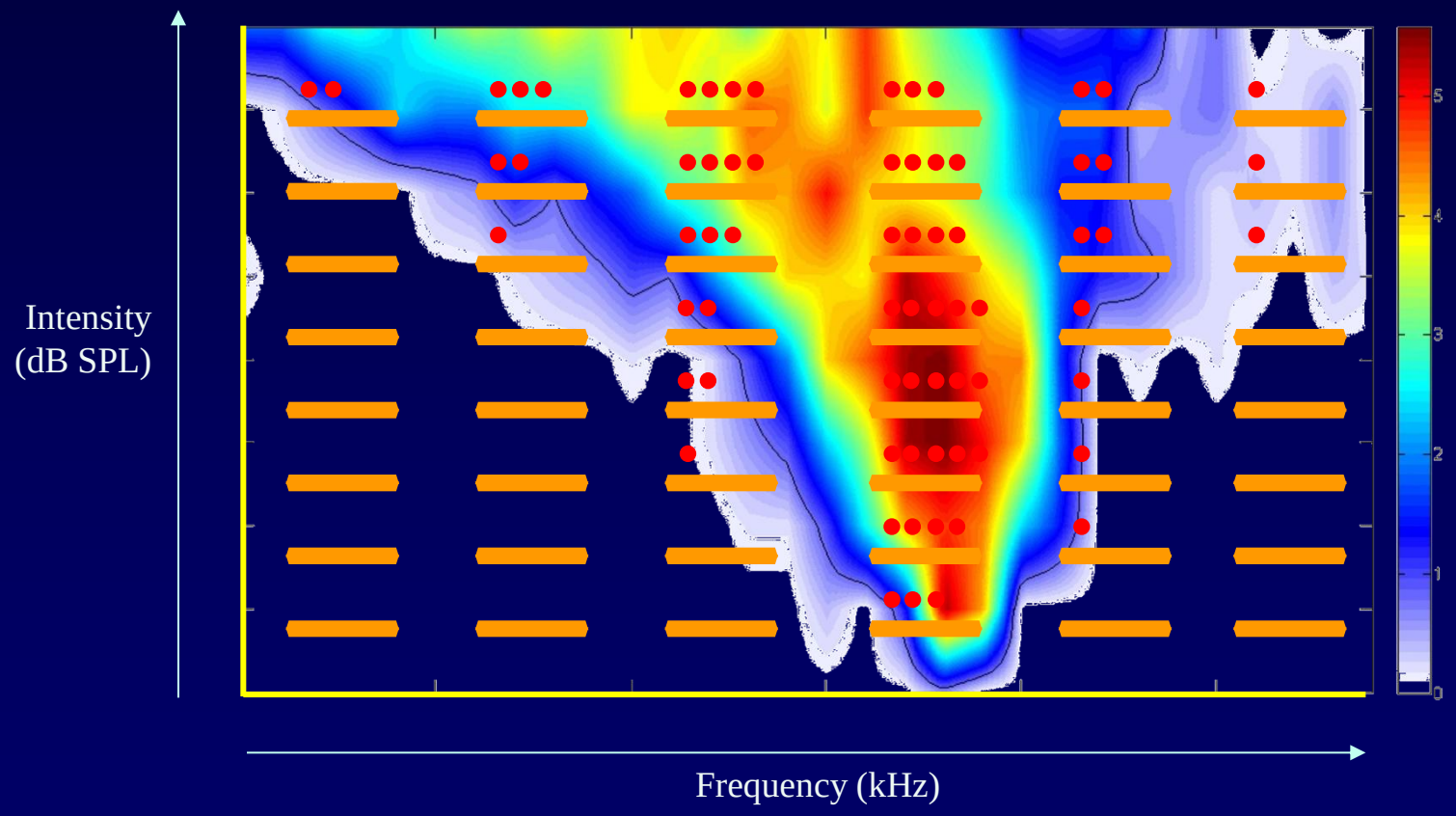
SUPERIOR OLIVARY COMPLEX

ORGANIZACIÓN FUNCIONAL DEL COLÍCULO INFERIOR

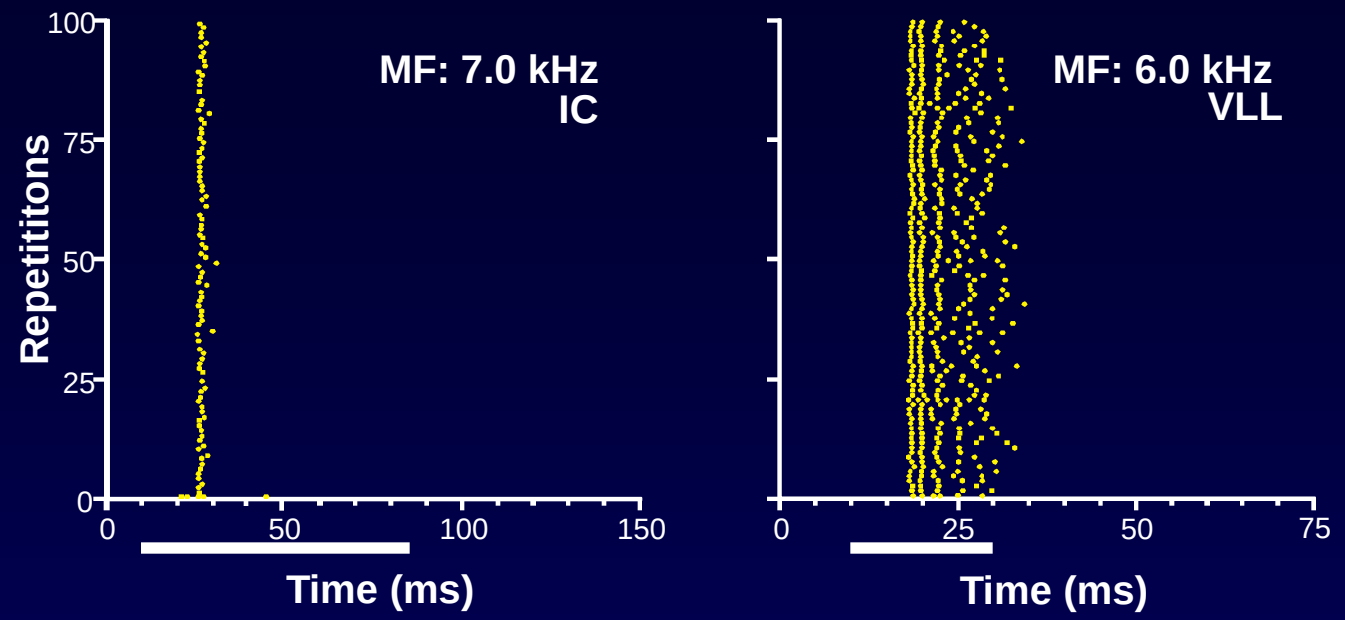


Recording

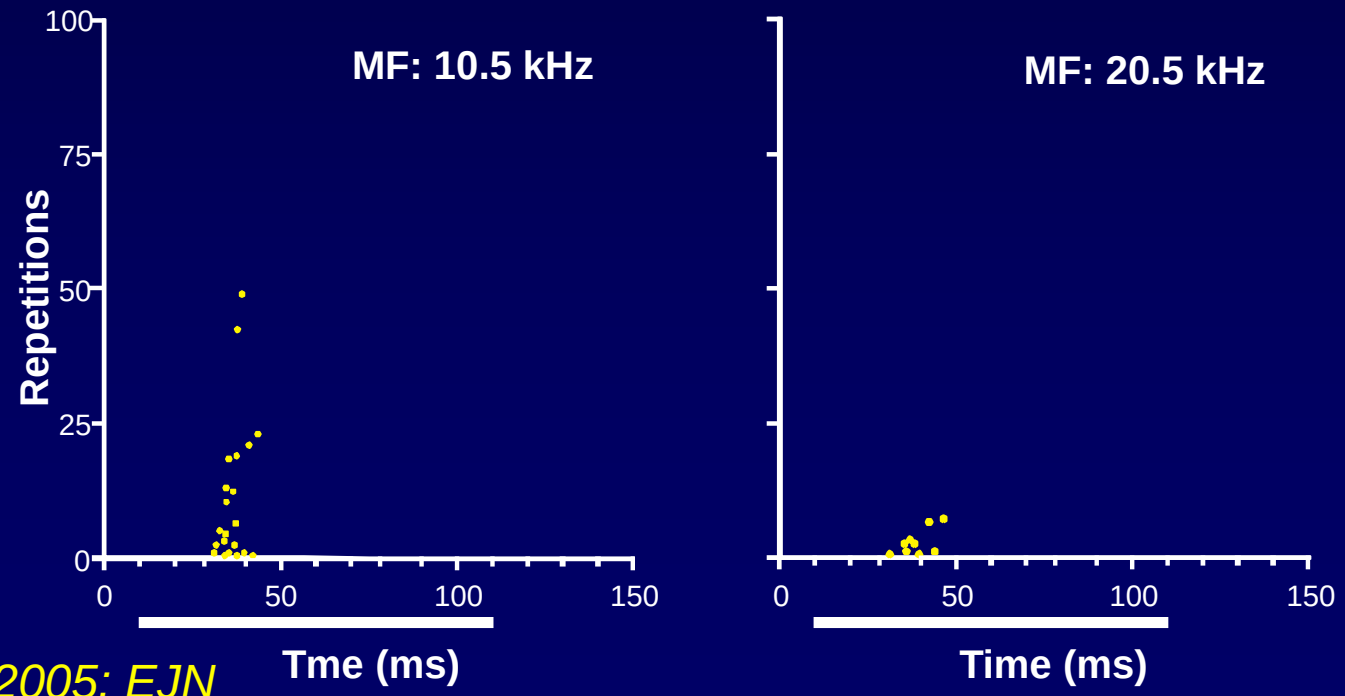
- Calculate the frequency response area (FRA).



Non-Habituating

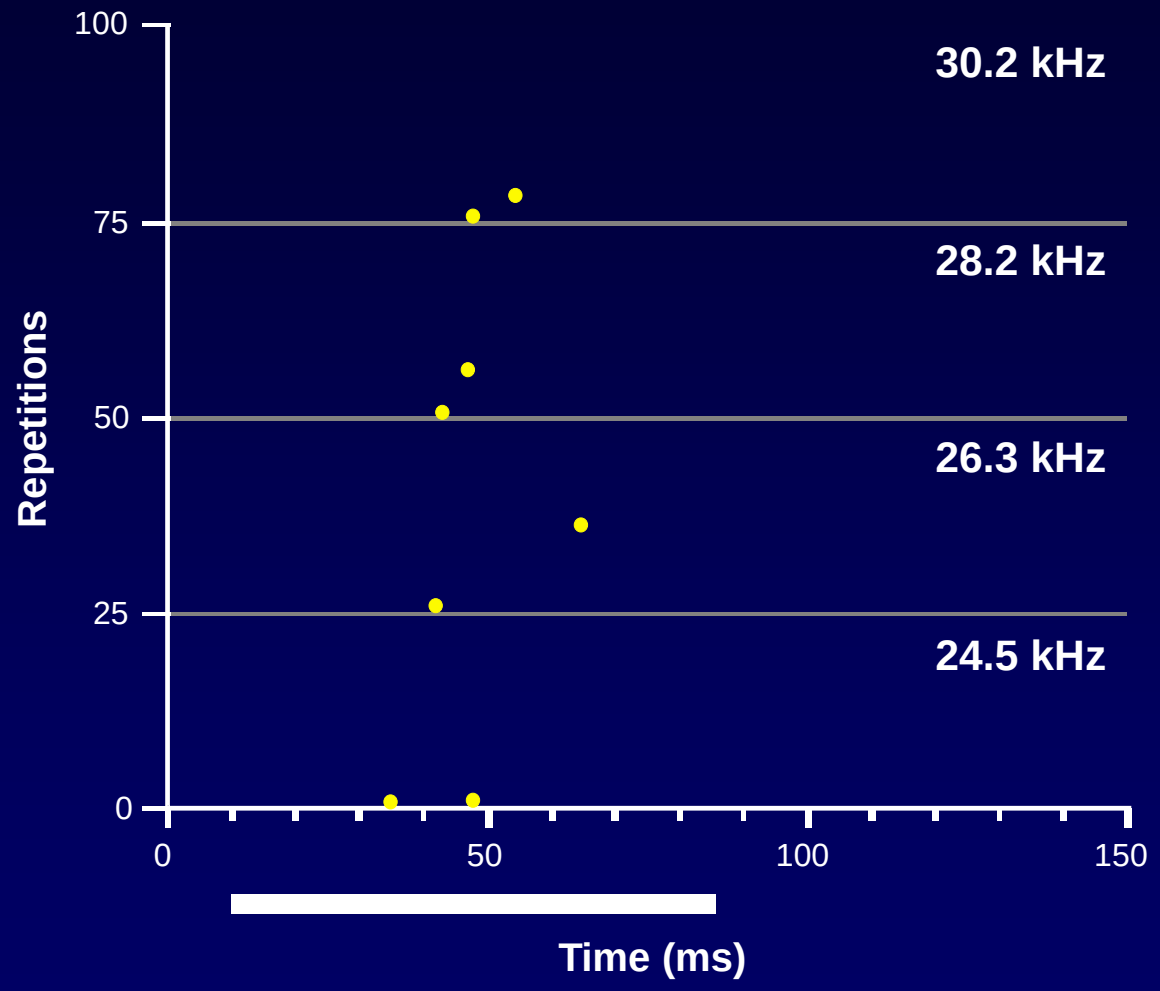


Habituating



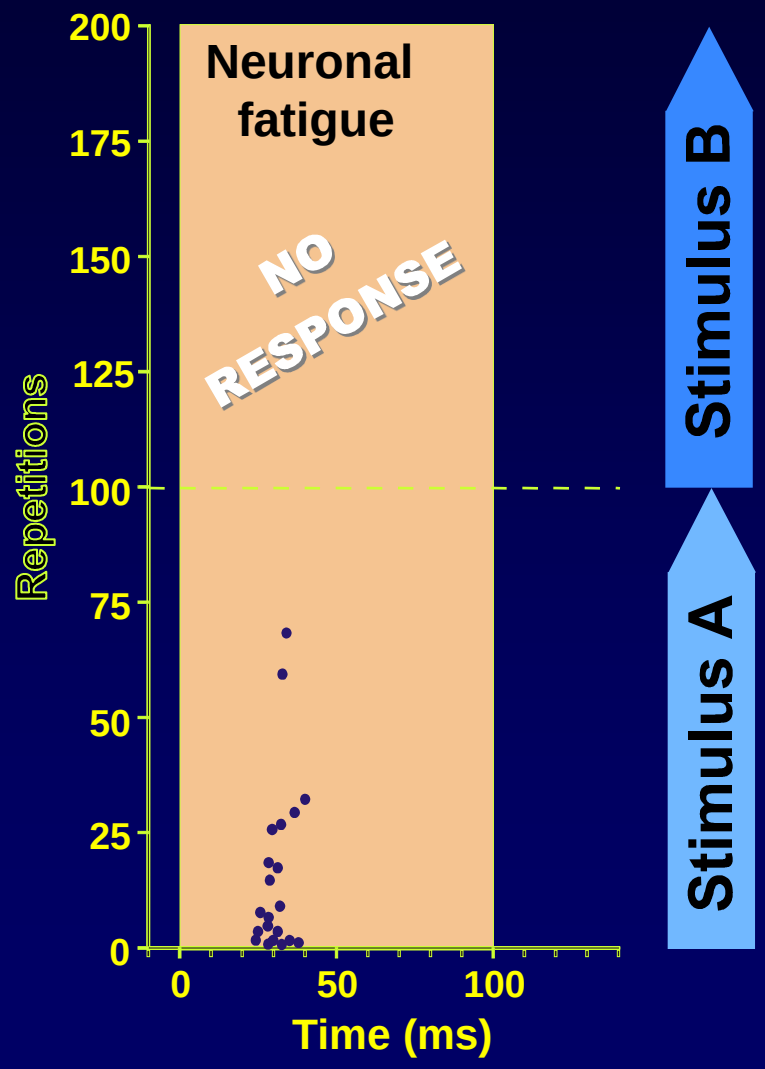
Pérez-González et al. 2005; EJN

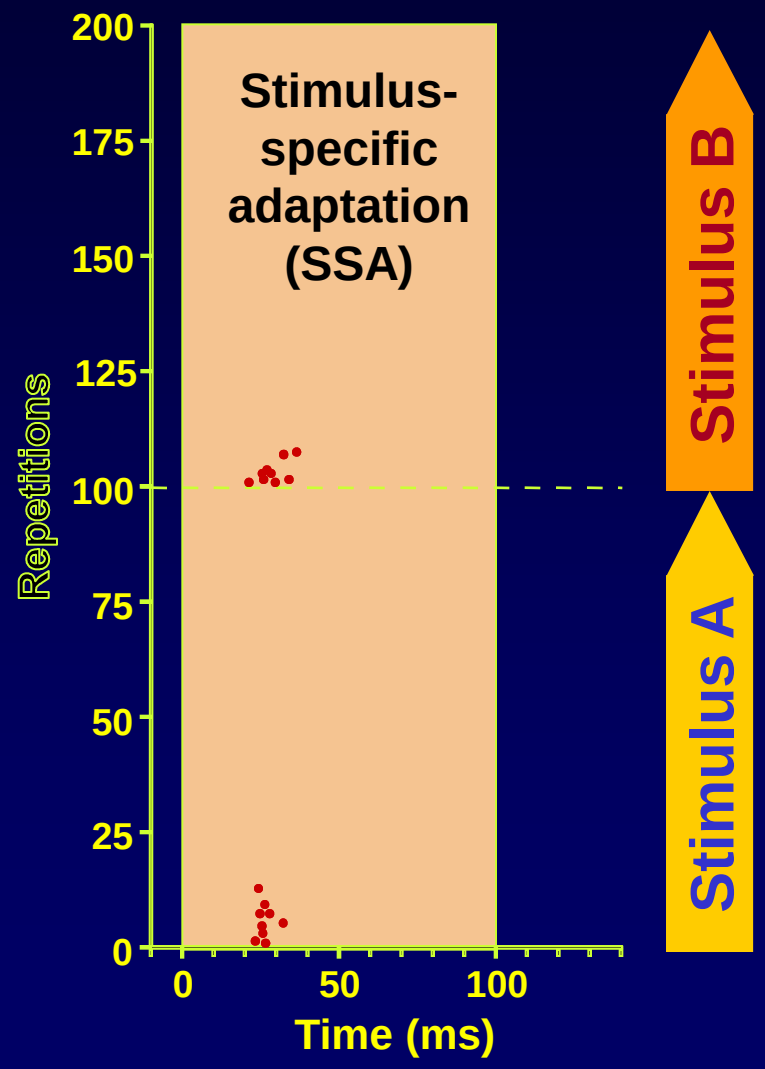
Habituating



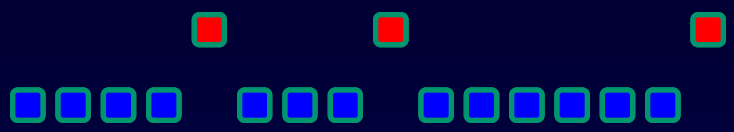
Pérez-González et al. 2005 ; EJN

Types of Adaptation



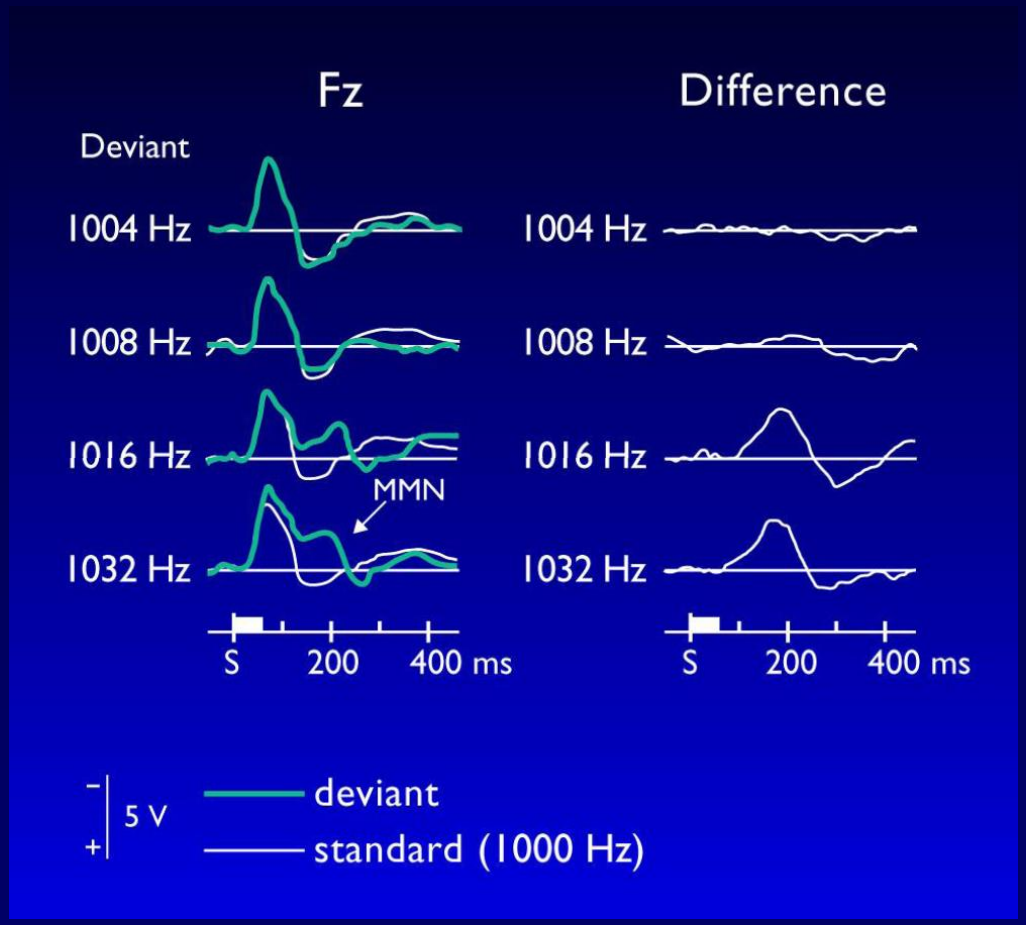


Oddball paradigm



f1 (deviant)

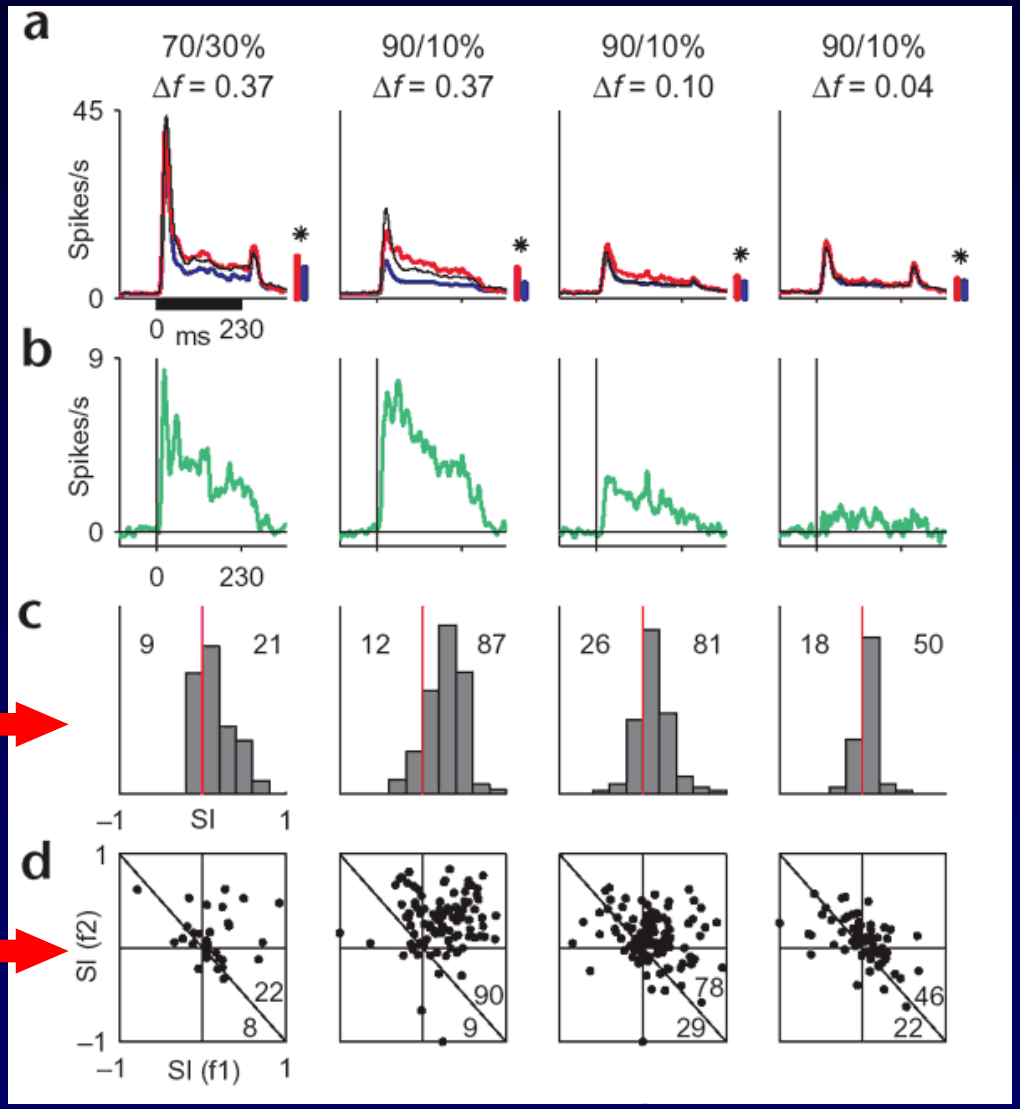
f2 (standard)



Audiory cortex neurons exhibit Stimulus-Specific Adaptation

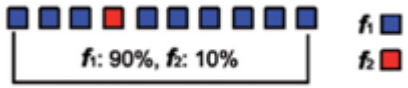
Common-specific Index
CSI

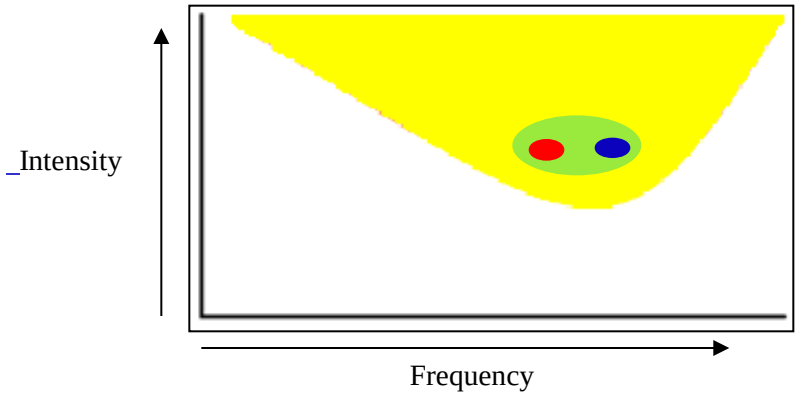
Frequency-specific SI
SI(f1) & SI (f2)

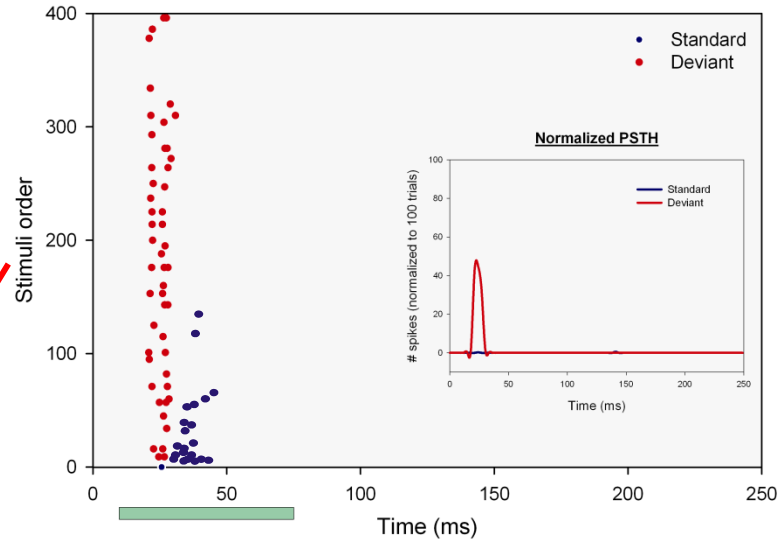


Ulanovsky et al. 2003; Nat. Neuroscience

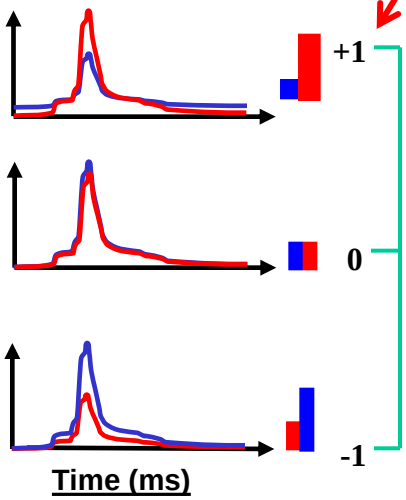
Oddball paradigm

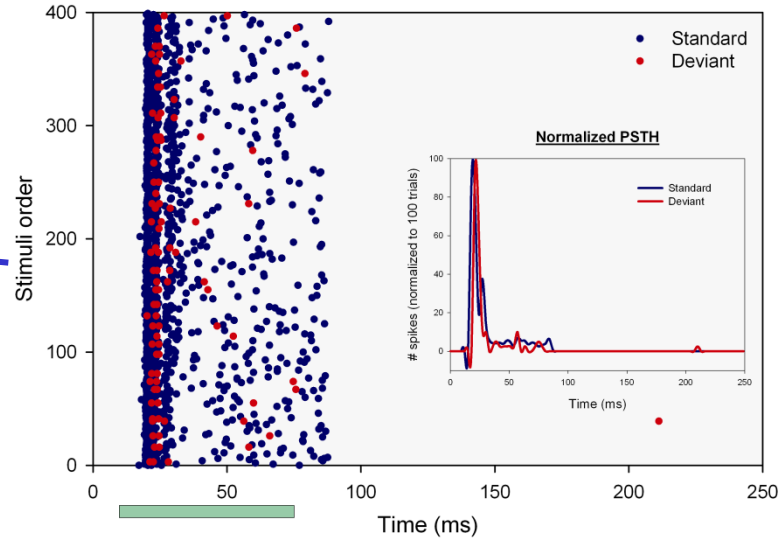






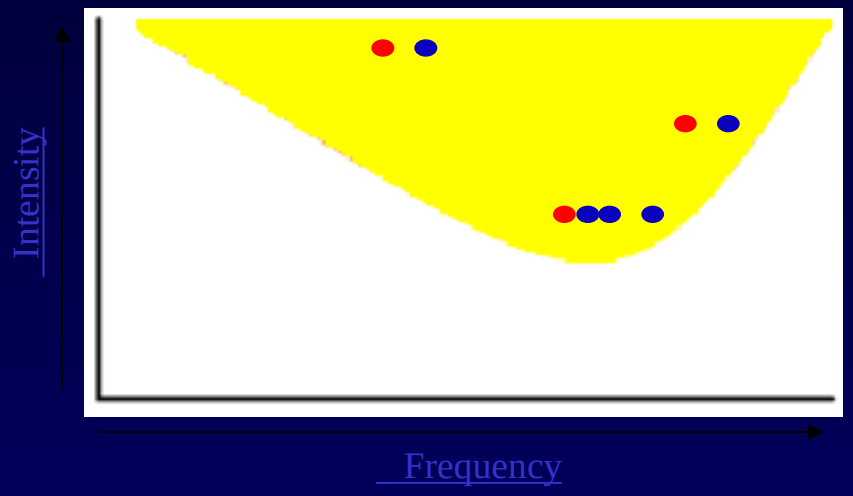
$$CSI = \frac{d(f_1)+d(f_2)-e(f_1)-e(f_2)}{d(f_1)+d(f_2)+e(f_1)+e(f_2)}$$



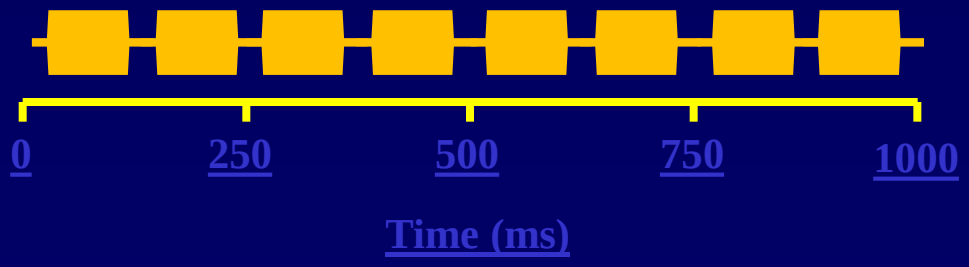


Experimental protocol

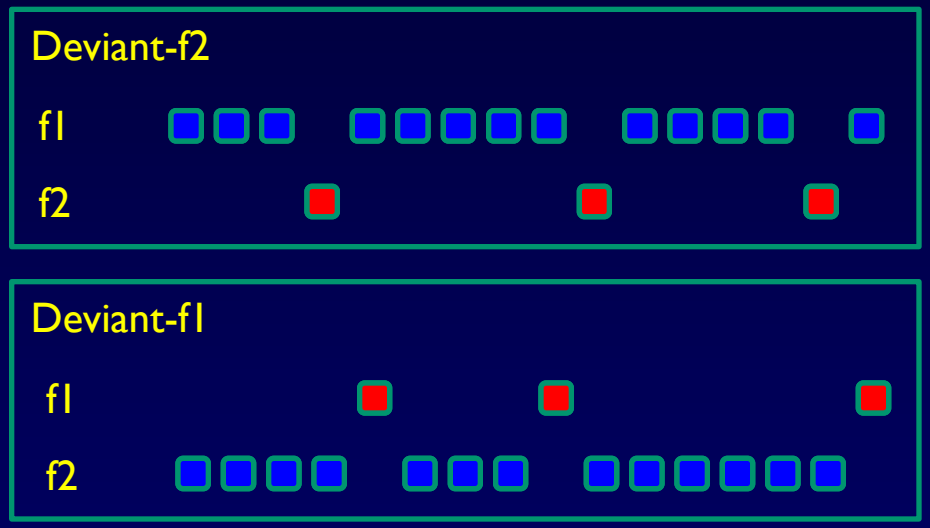
- Different frequency contrasts (Δf) and interstimulus intervals (ISI):
- Δf
  - 0.04
  - 0.1
  - 0.37
- ISI
  - 125 ms (8 Hz)
  - 250 ms (4 Hz)
  - 1000 ms (1 Hz)

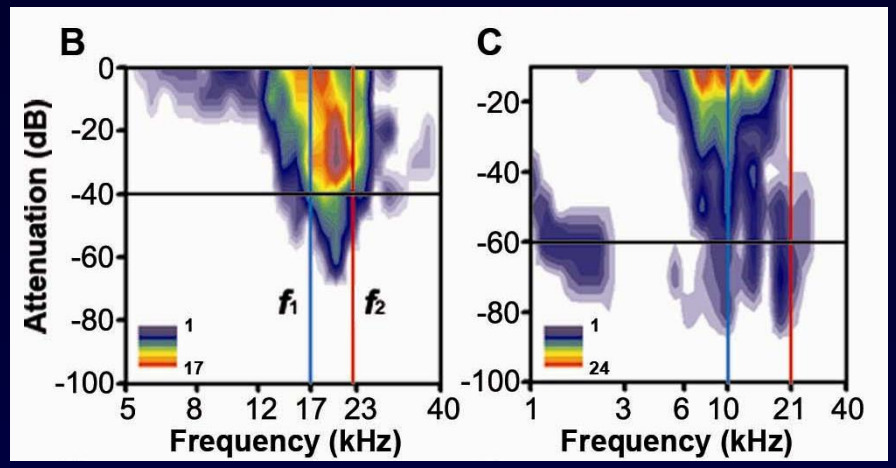


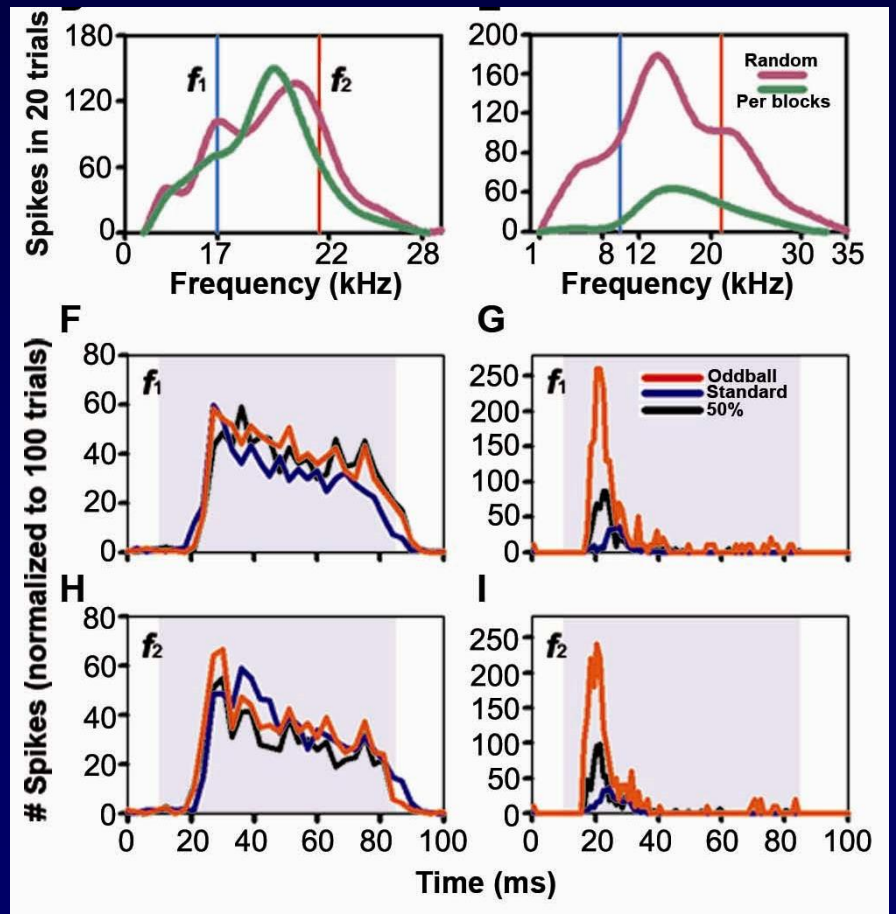
- Different pairs of frequencies within the FRA



IC neurons exhibit SSA

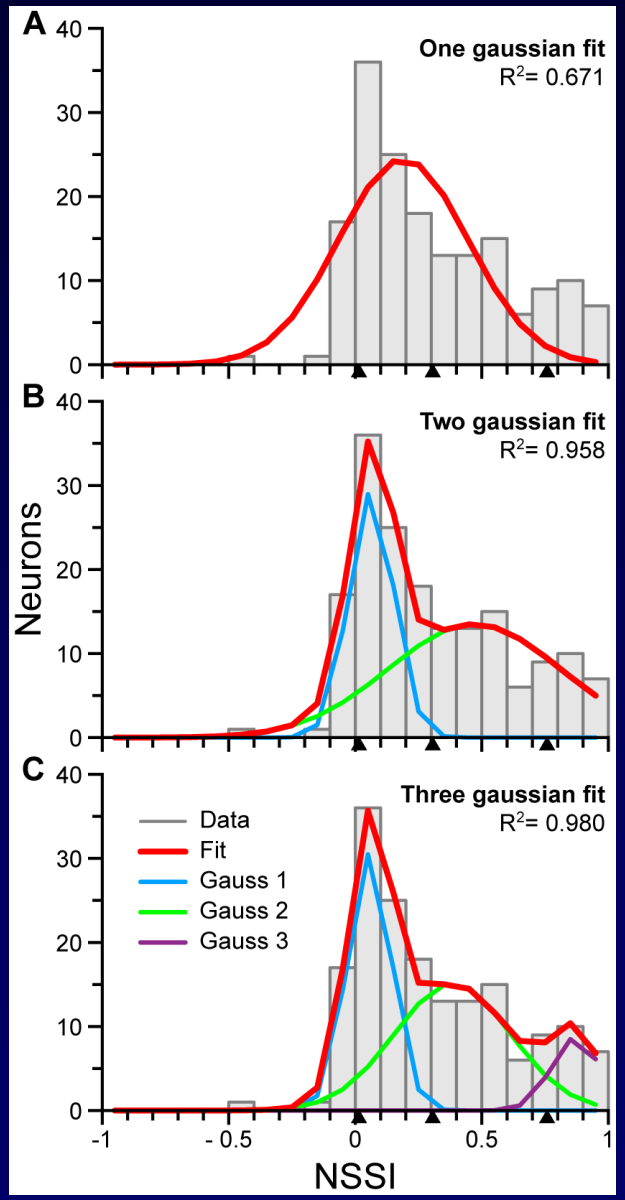


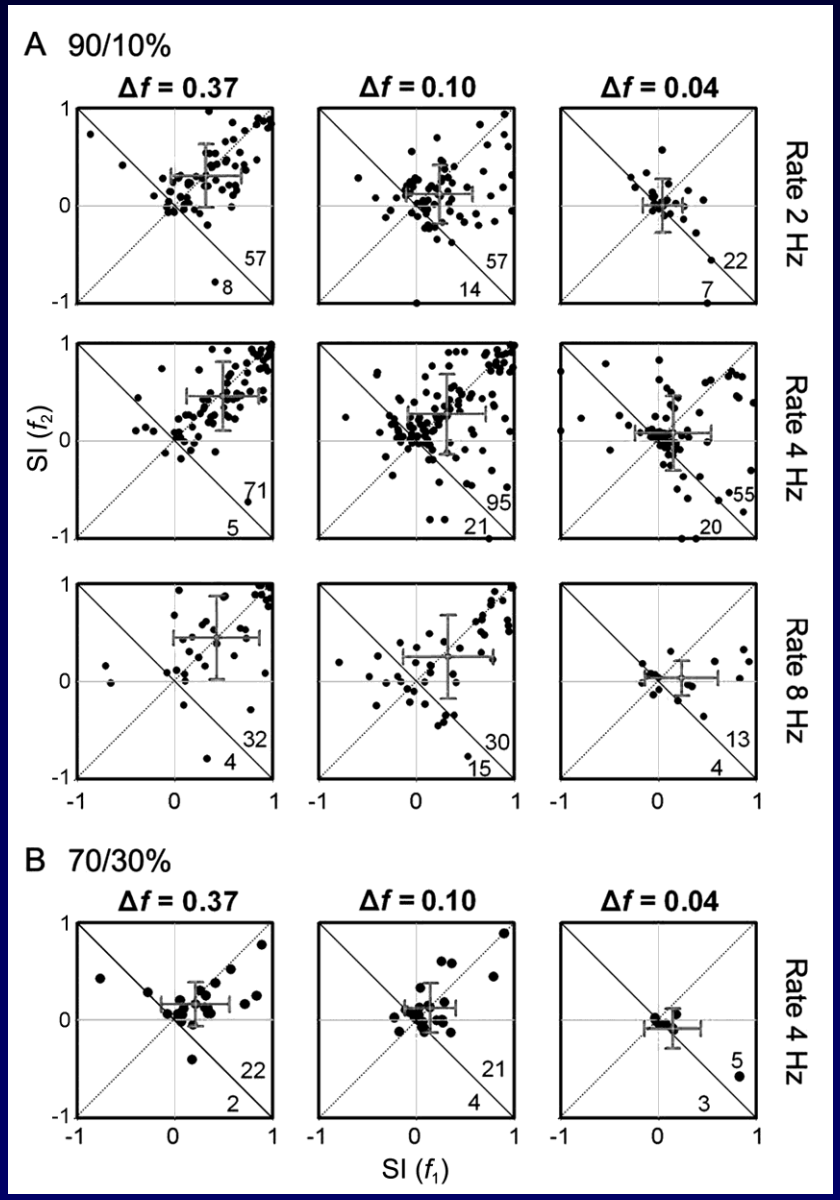




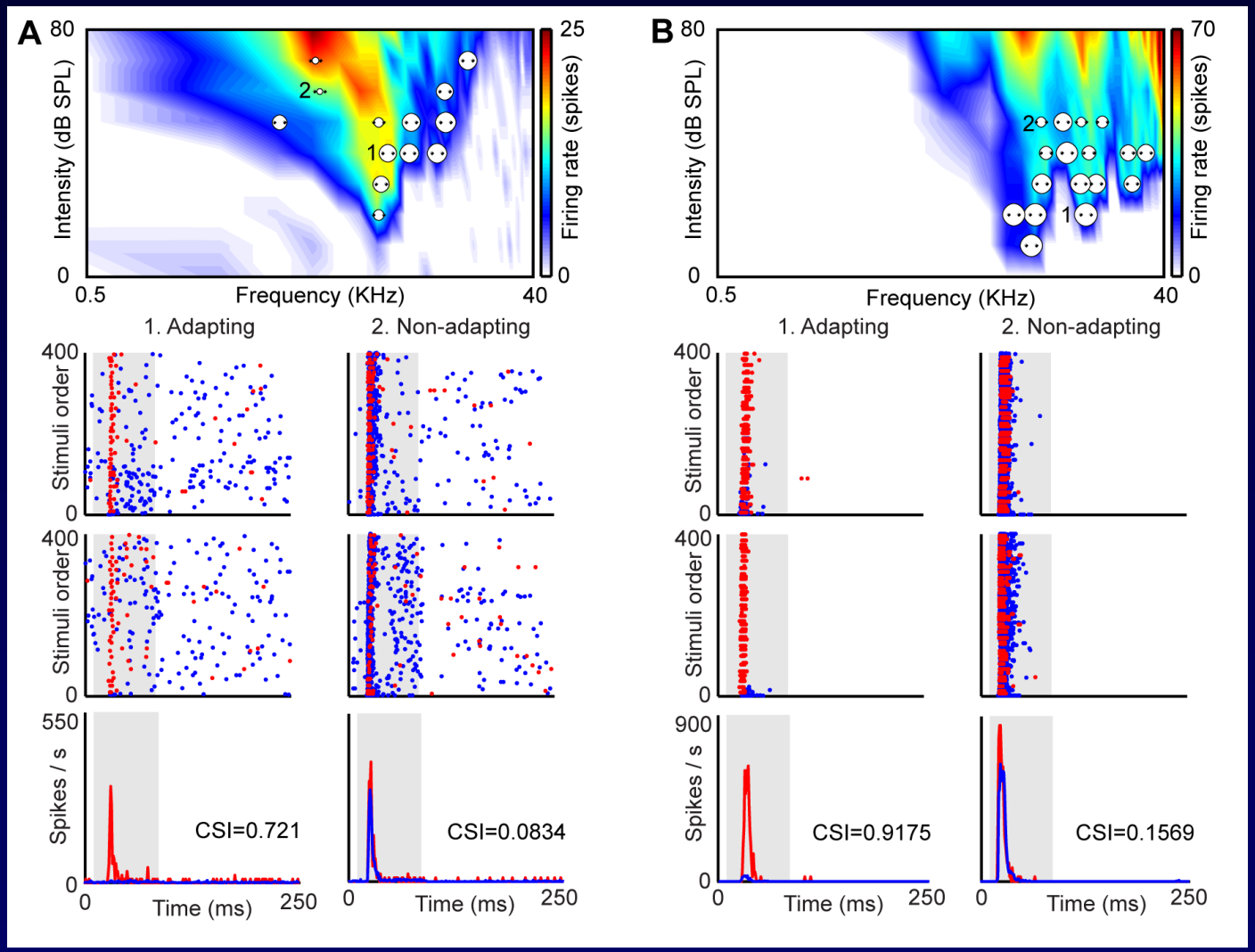
Malmierca et al. 2009; J. Neurosci.

IC neurons exhibit SSA



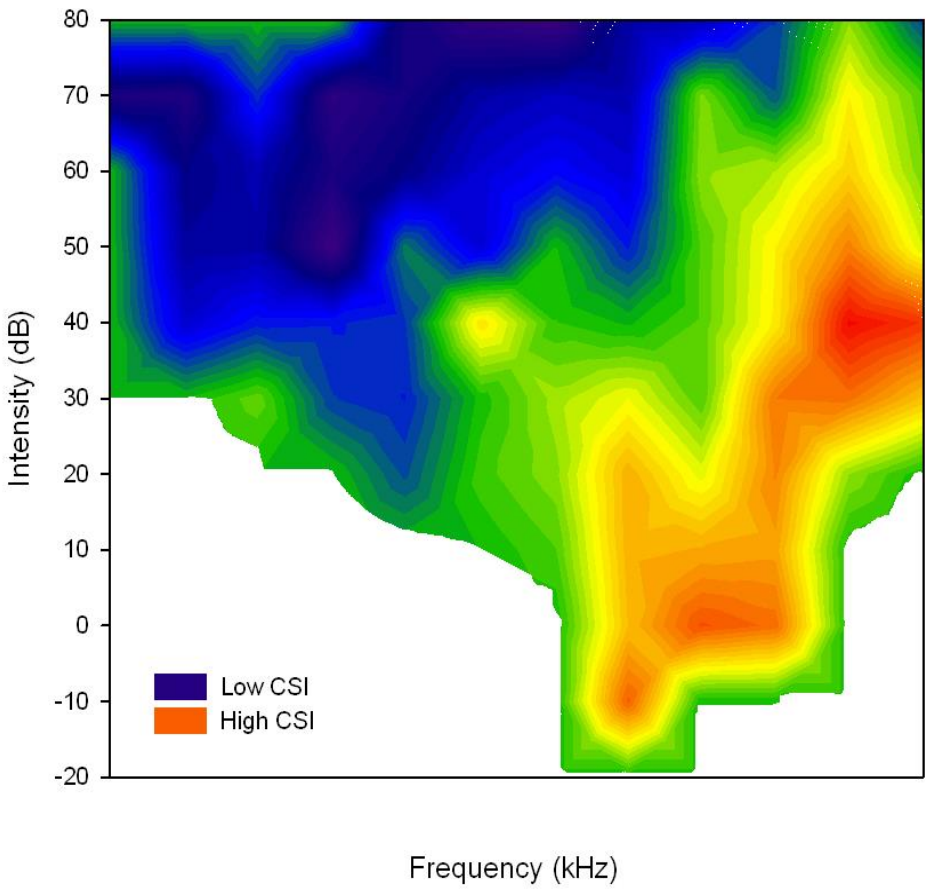


Is SSA a homogeneous feature throughout the receptive field?

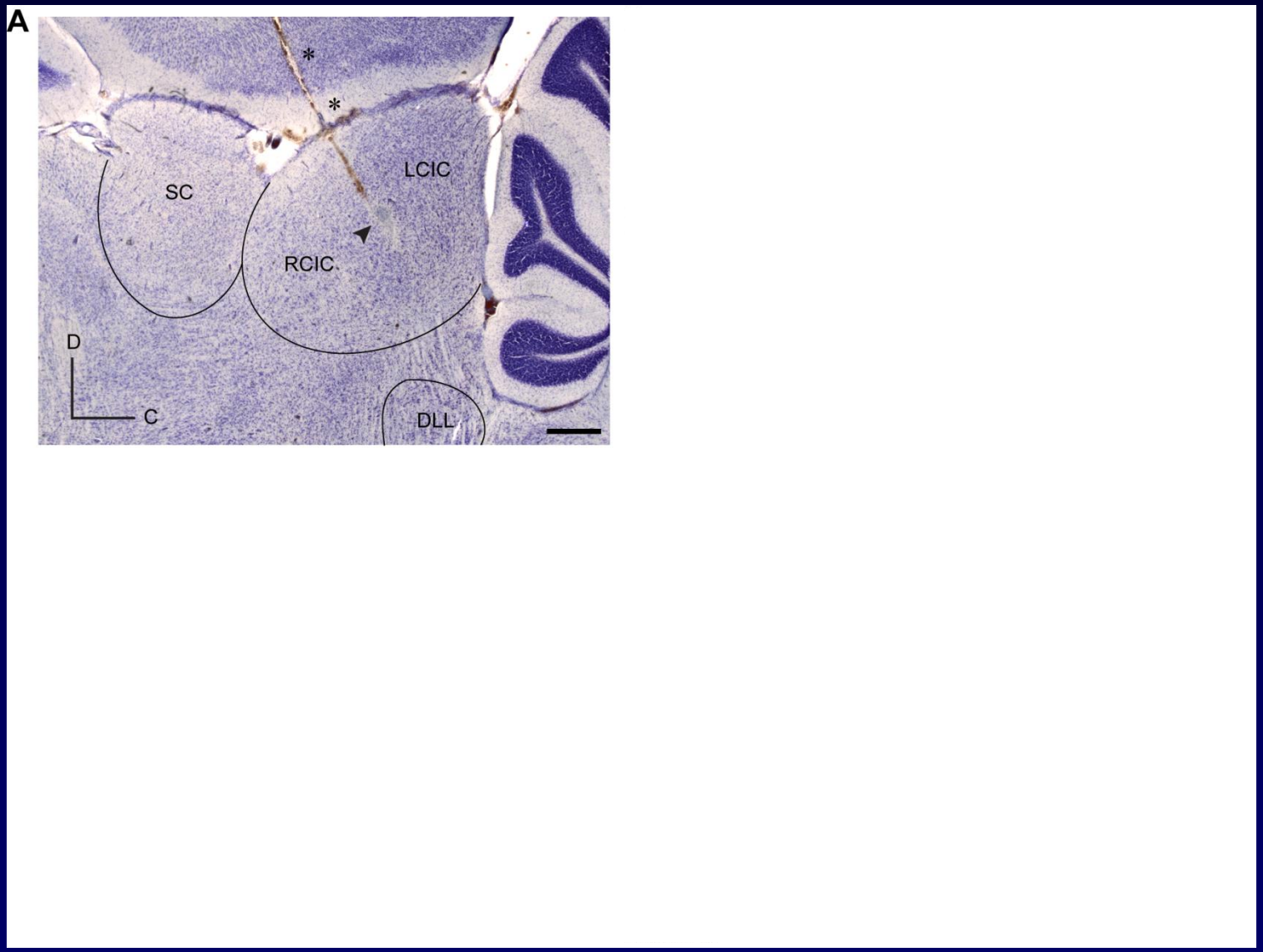


Duque et al, 2012; J. Neurosci.

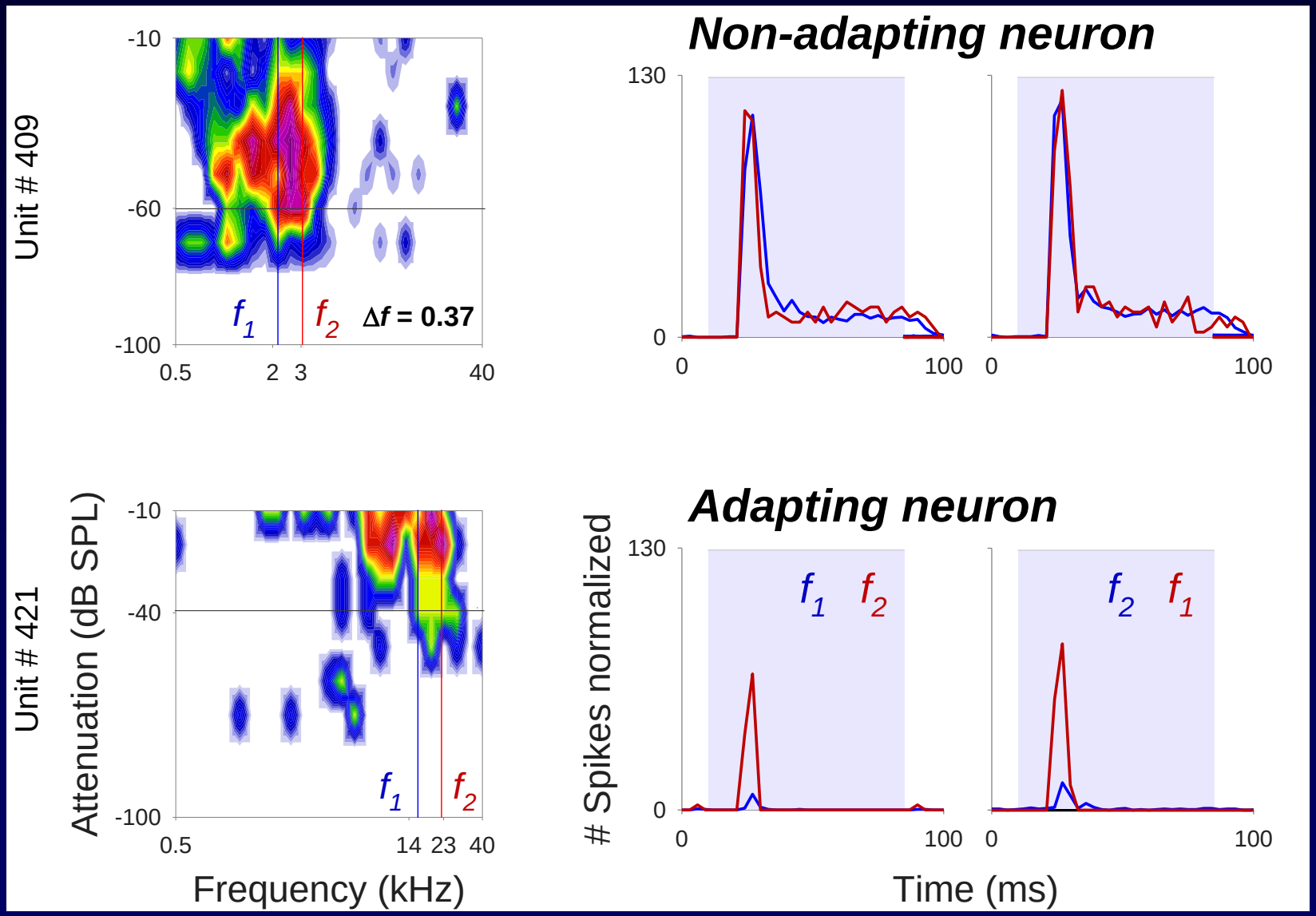
SSA is not a unique feature of IC neurons



Duque et al, 2012; J. Neurosci.

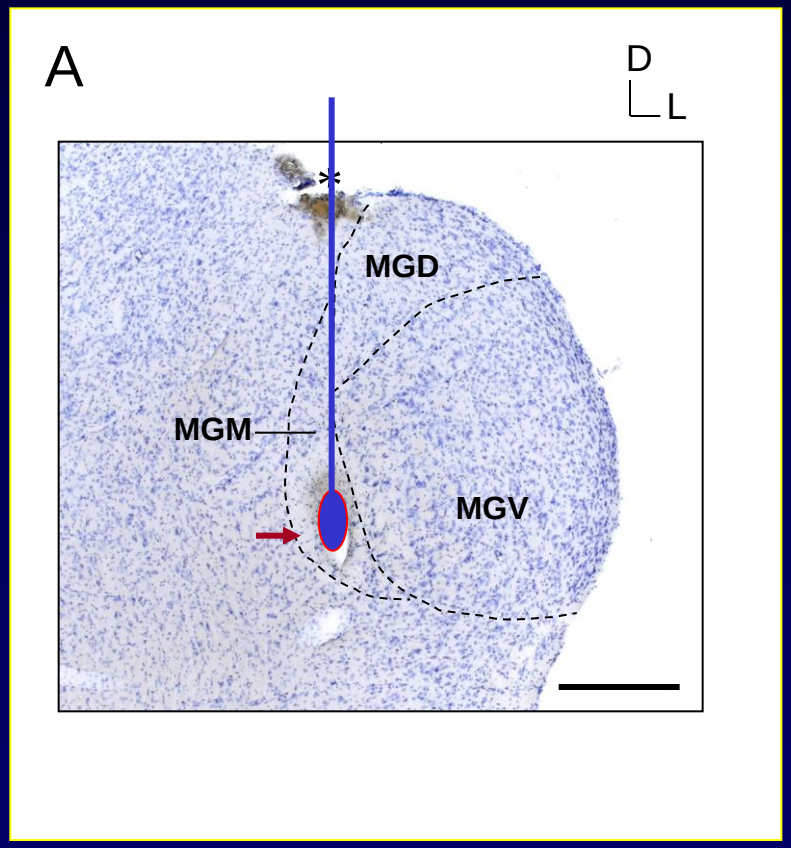


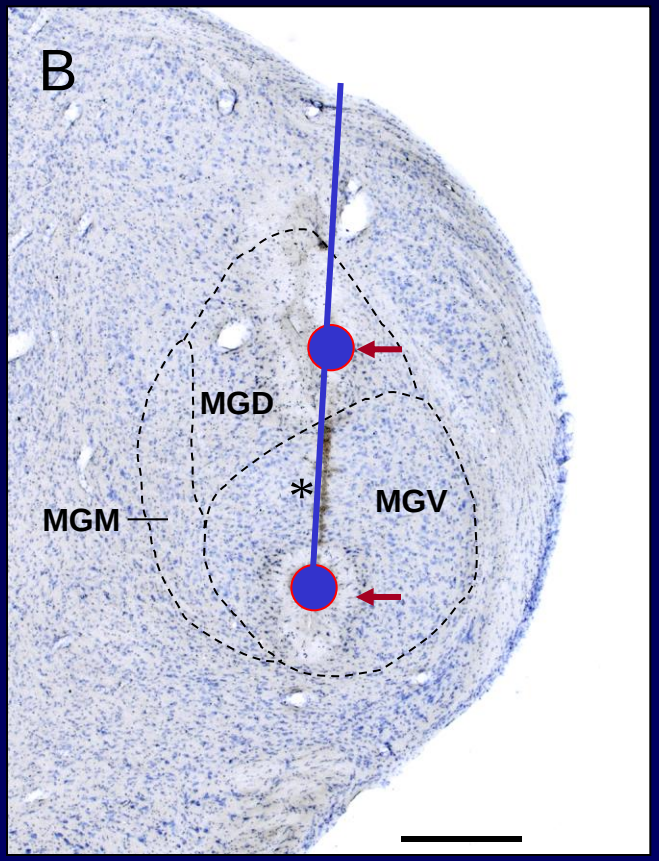
Duque et al, 2012; J. Neurosci.



Antunes et al. 2010; PLOS ONE

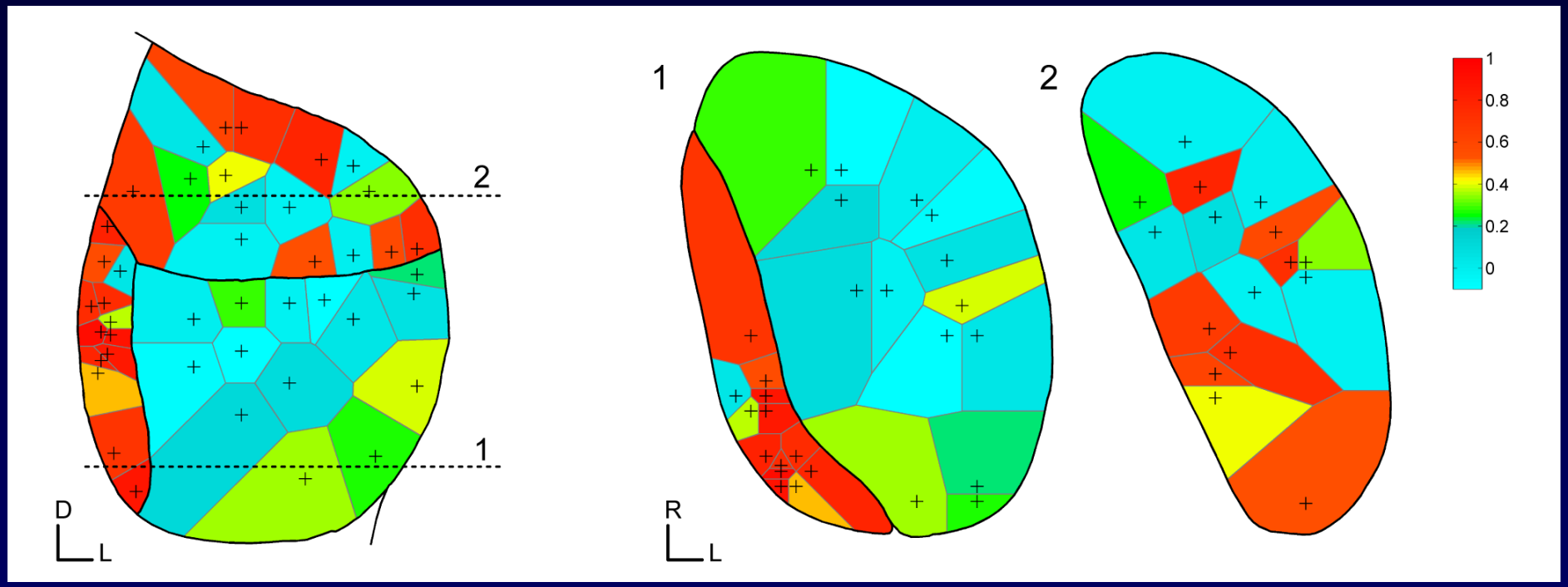
Histogolical location of neurons in the MGB





Antunes et al. 2010; PLOS ONE

Topographic maps of SSA constructed using Voronoi Tessellations

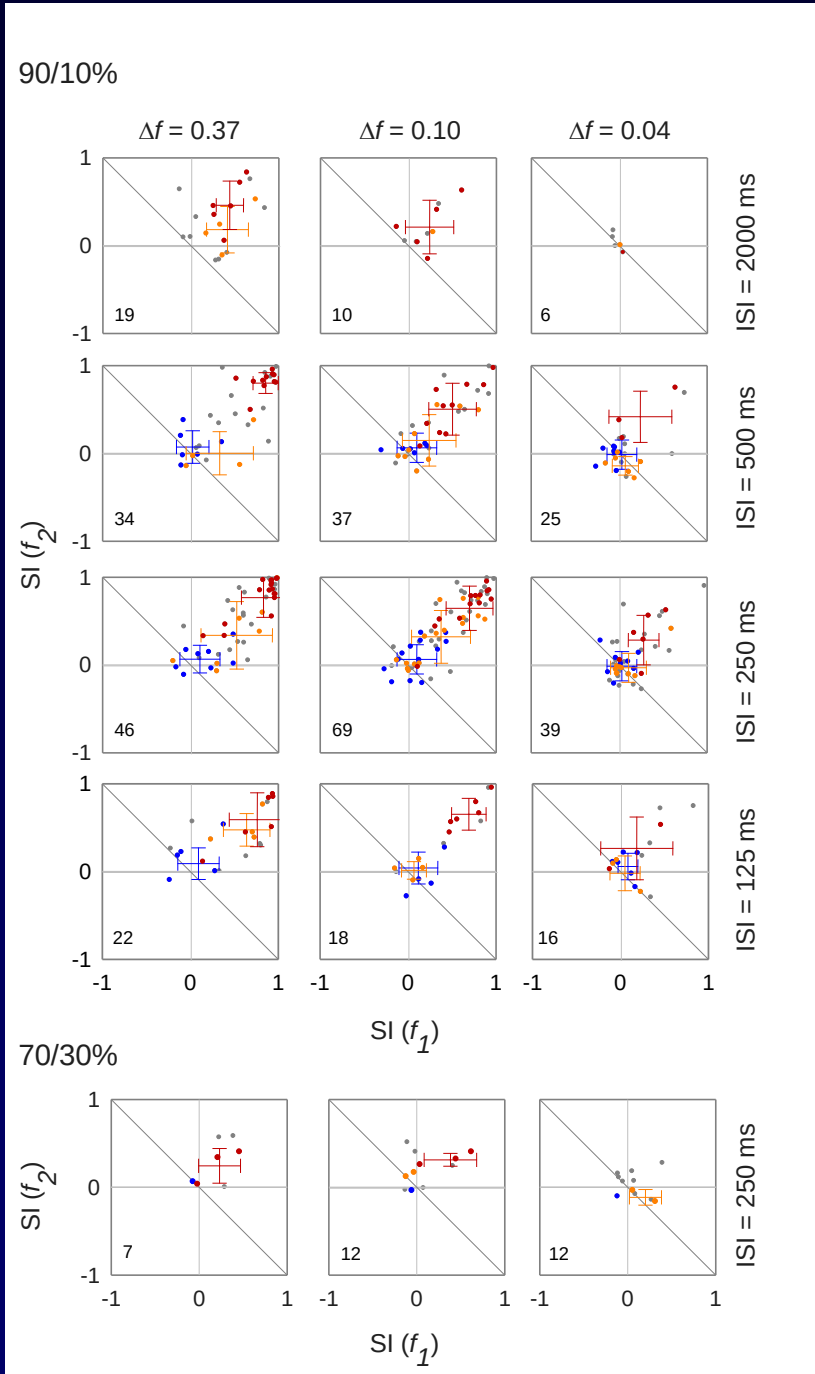


SSA is more prominent in the MGM and MGD

Antunes et al. 2010; PLOS ONE

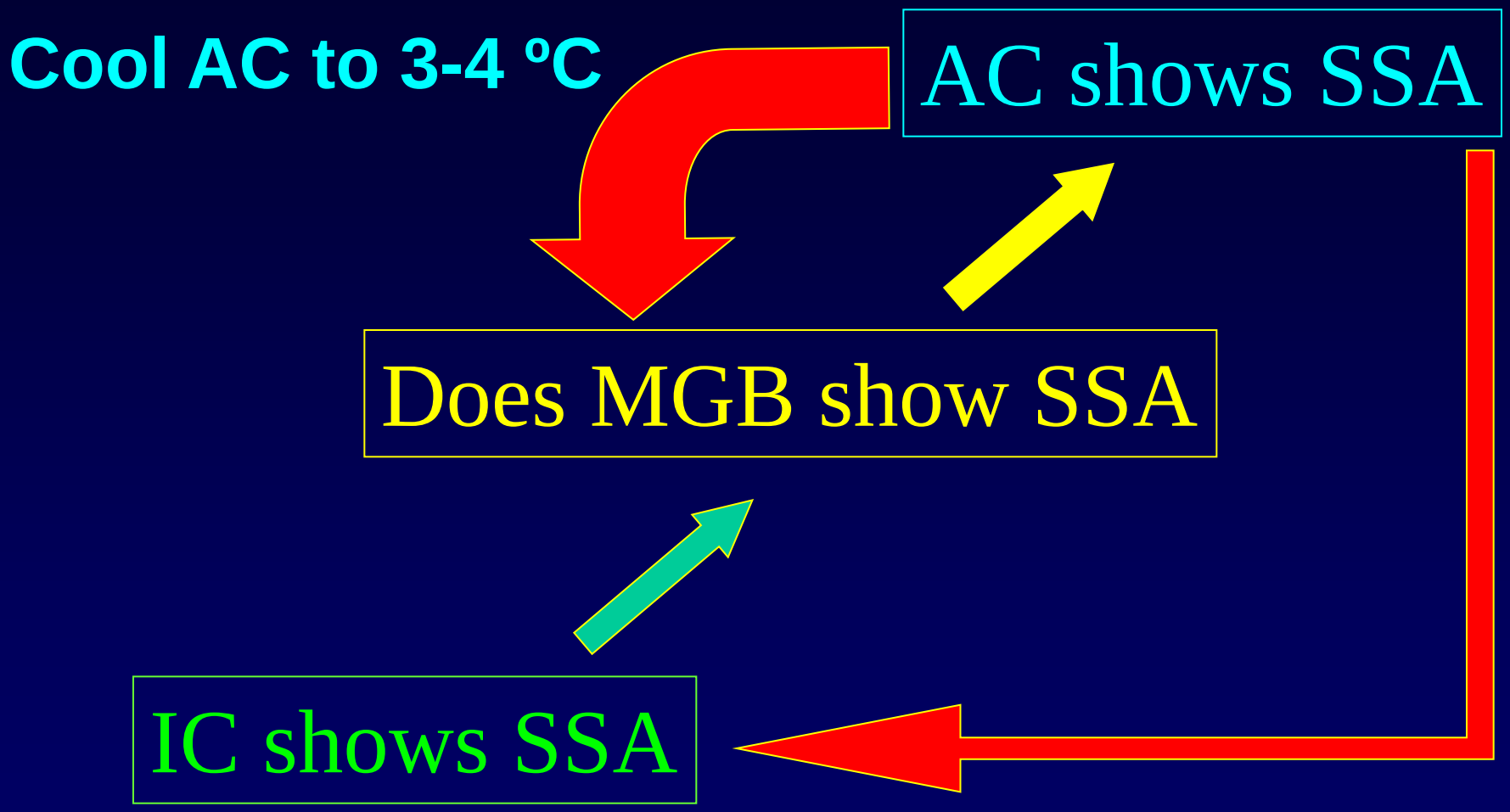
SSA varies as a function of

-ISI
-Δf,
-Probability, and
-MGB subdivision

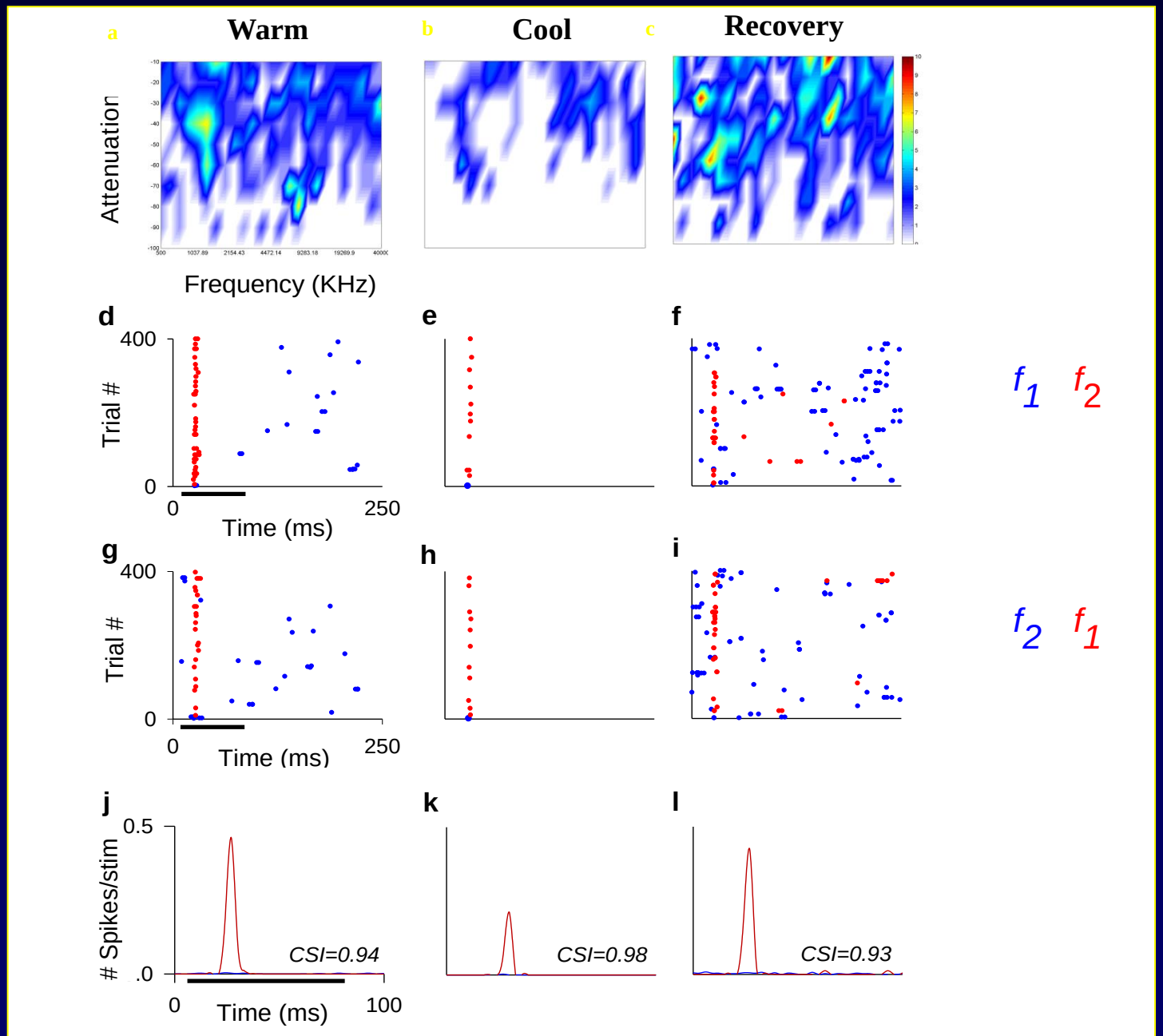


Antunes et al. 2010; PLOS ONE

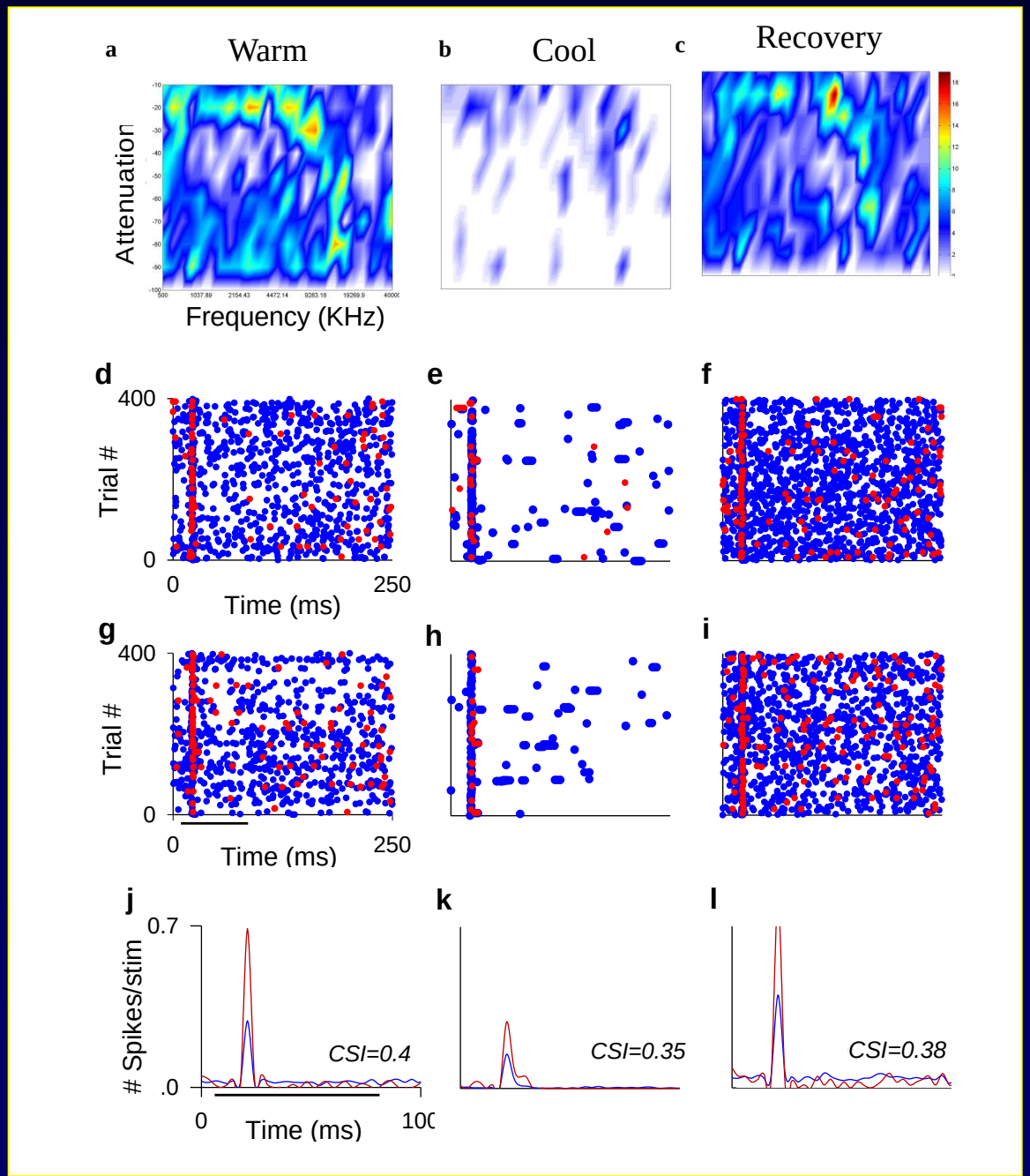
Is SSA a *bottom-up* or a *top-down* process?



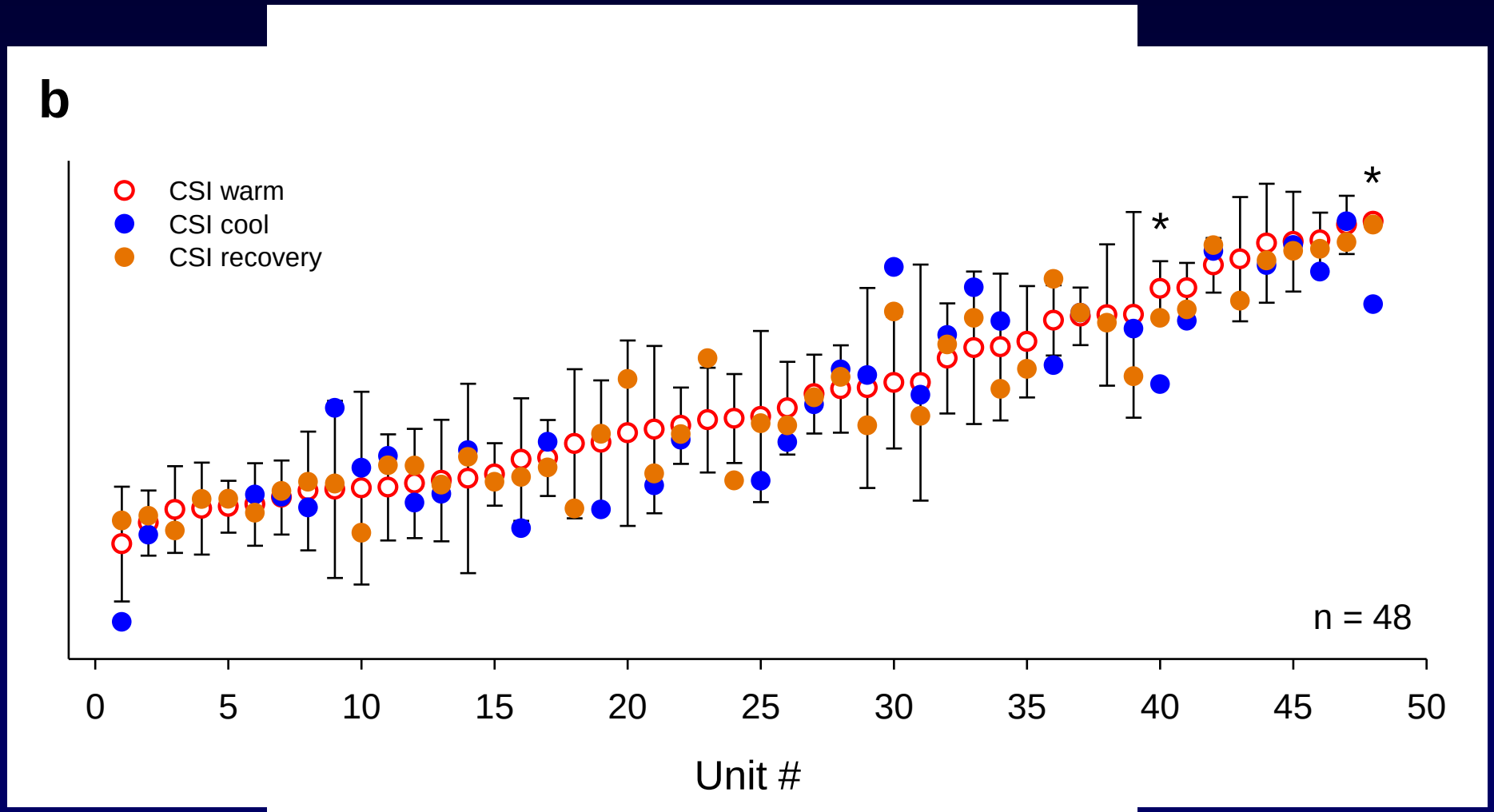
MGM adapting unit supressed during AC deactivation



MGD adapting unit suppressed during AC deactivation

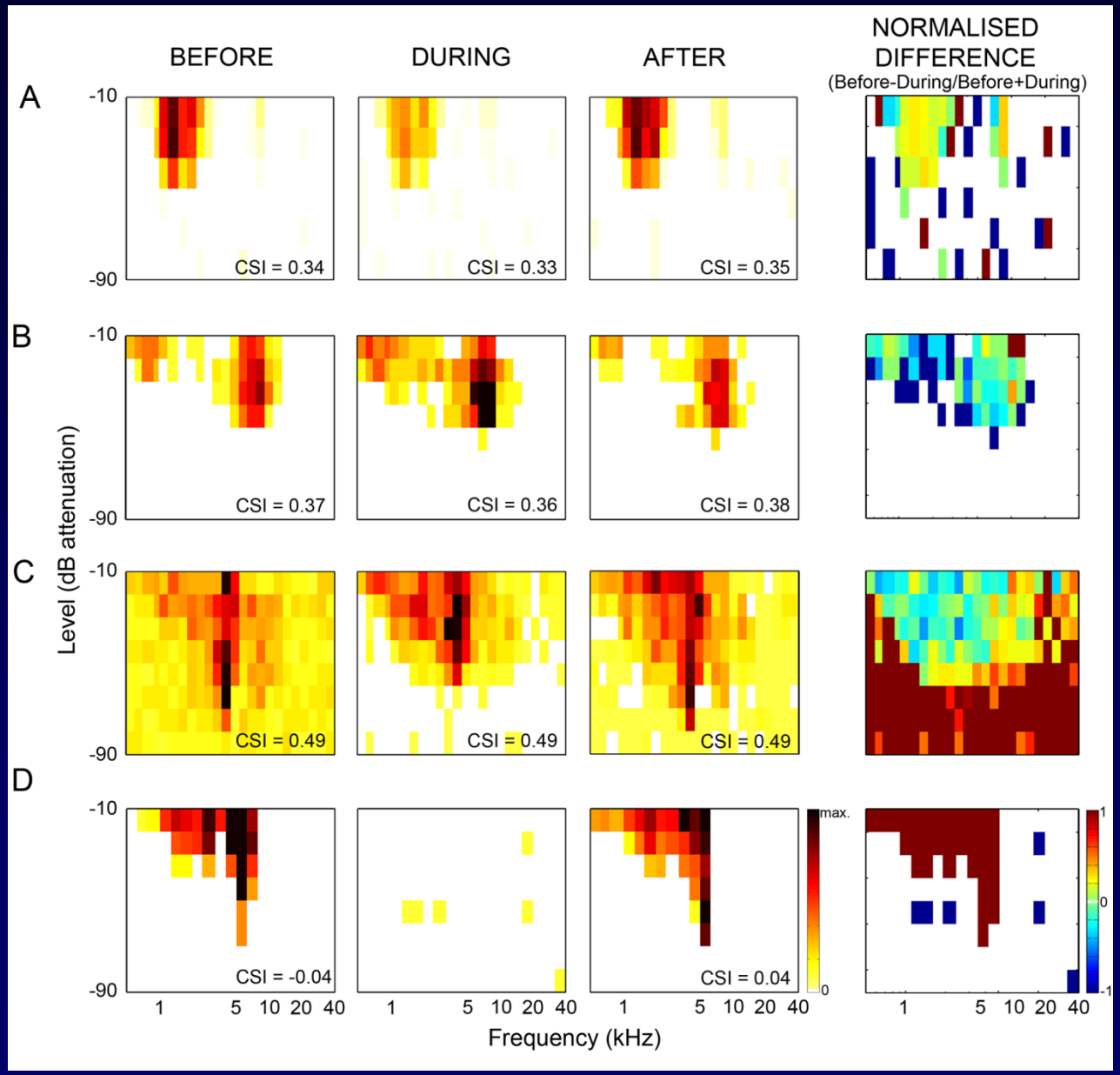


Neurons maintained their SSA levels during cortical deactivation

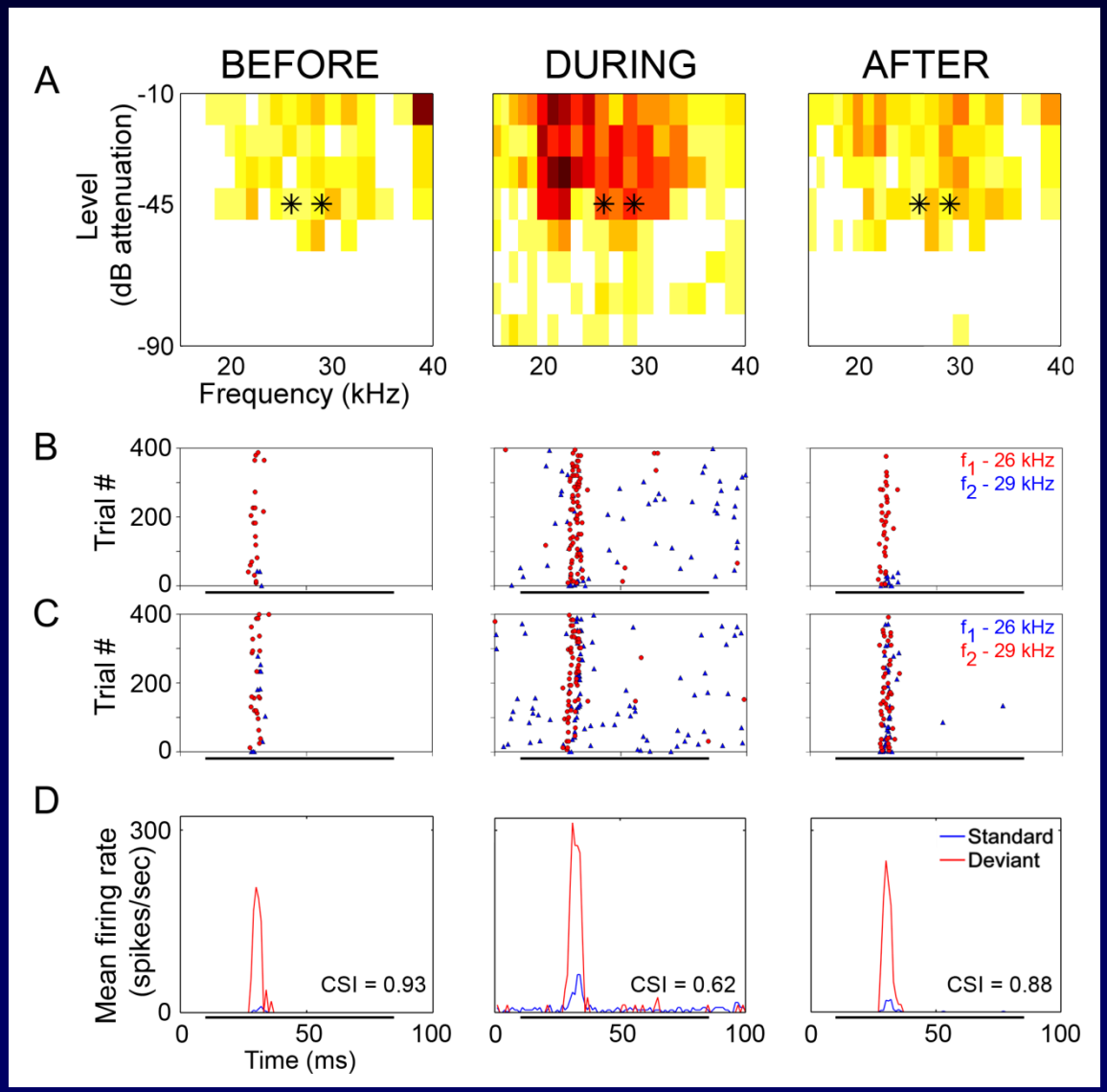


NO SIGNIFICANT DIFFERENCES IN CSI BETWEEN CONDITIONS

Cortical deactivation 'do not' change SSA in Inferior colliculus neurons

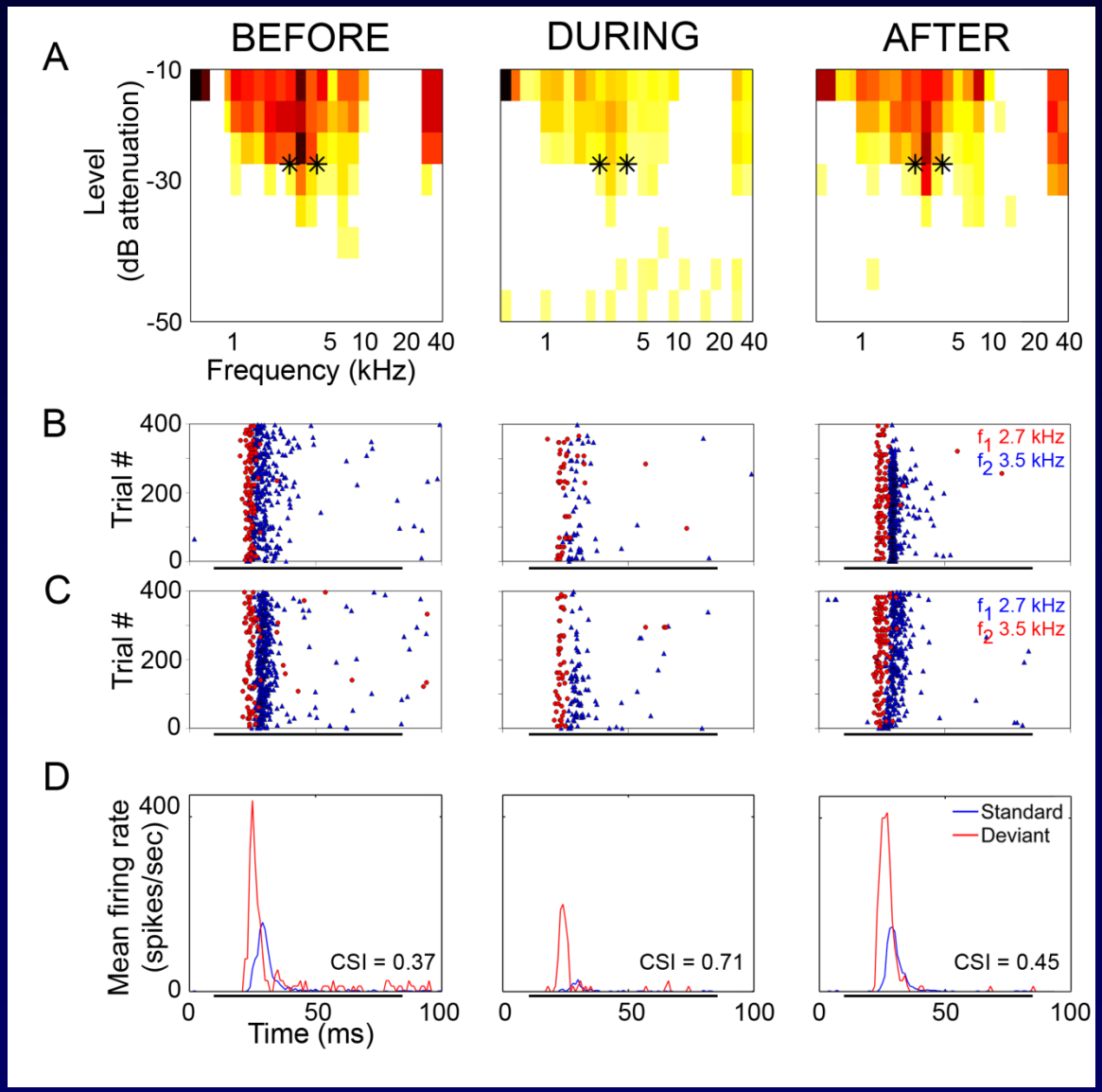


Inferior colliculus neurons maintain 'significant' SSA levels during cortical deactivation



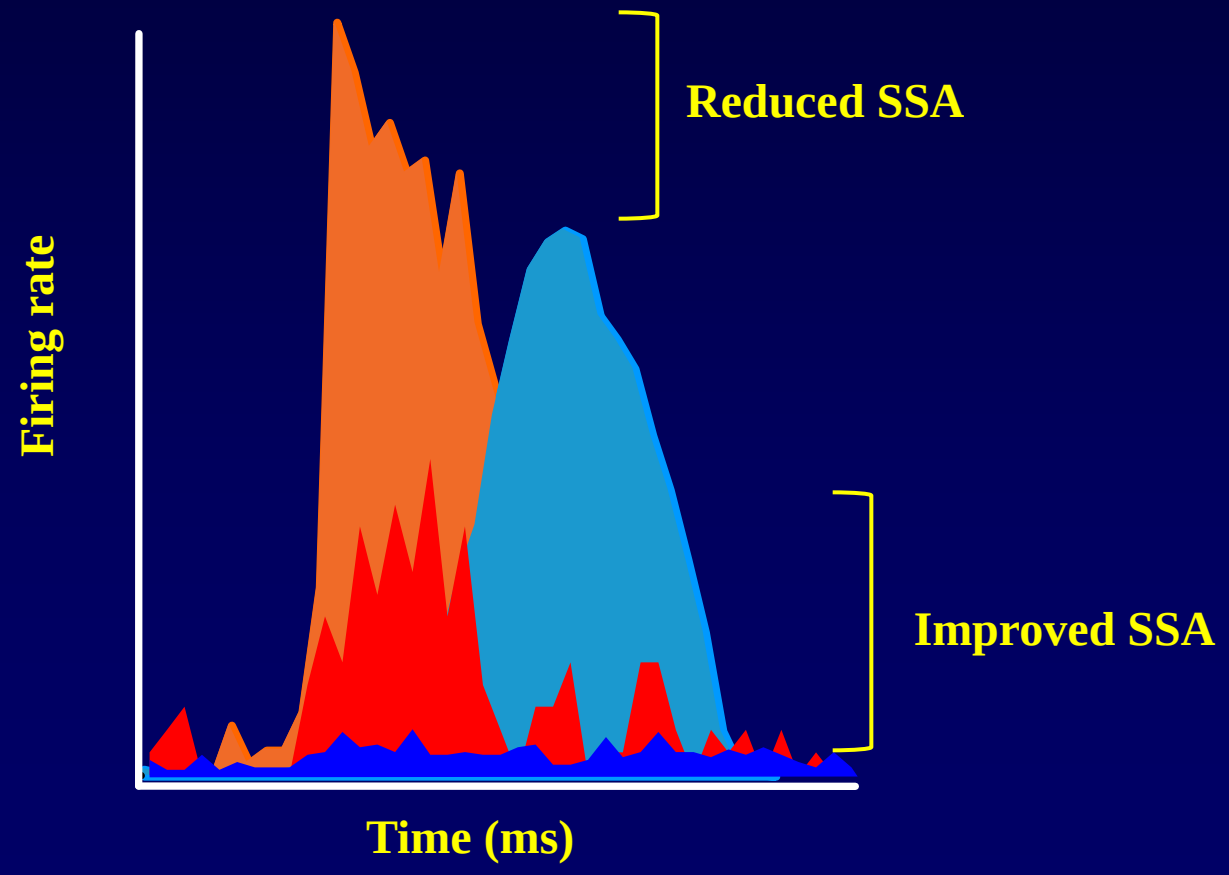
Anderson and Malmierca 2012; EJN.

Inferior colliculus neurons maintain 'significant' SSA levels during cortical deactivation

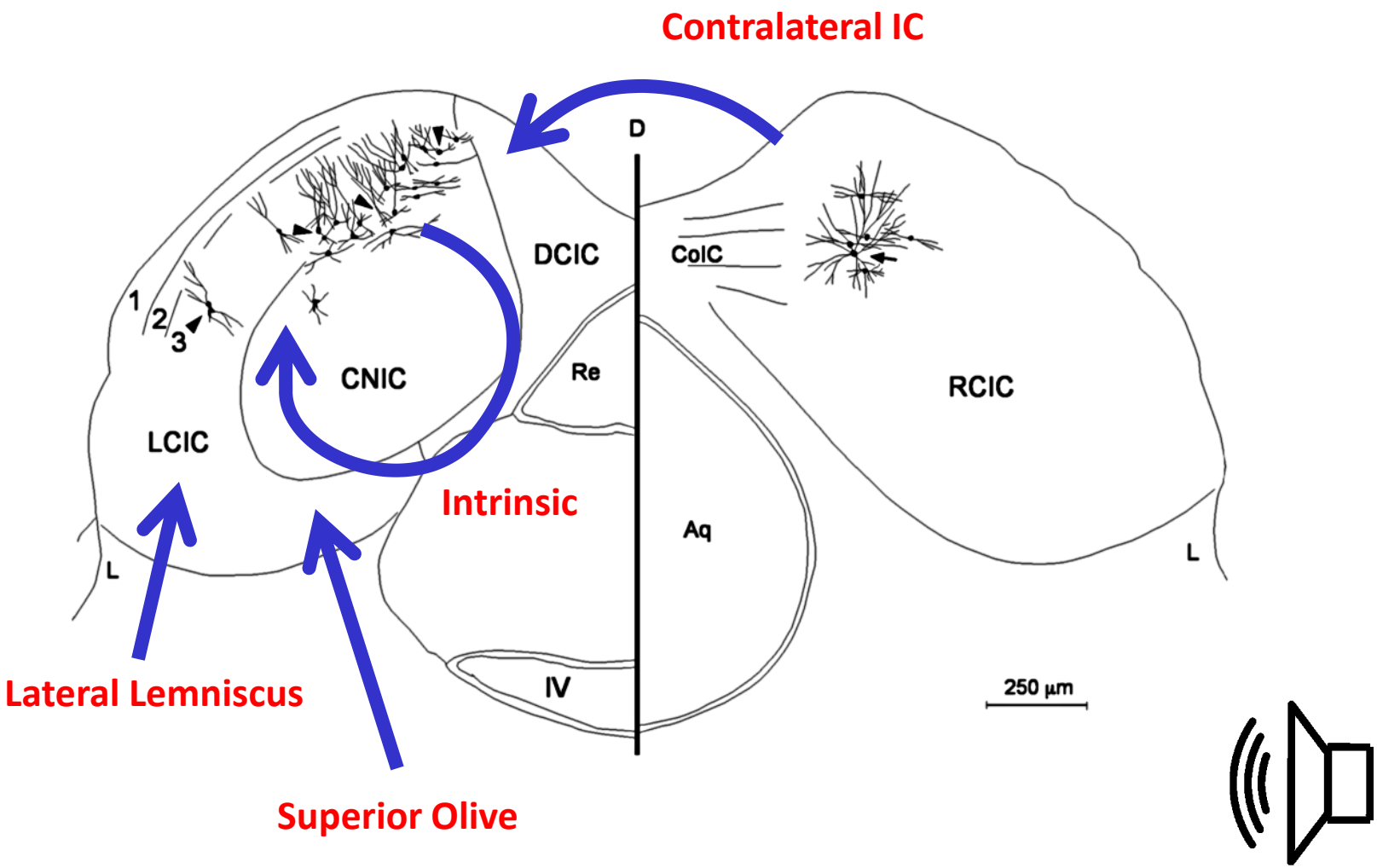


Anderson and Malmierca 2012; EJN.

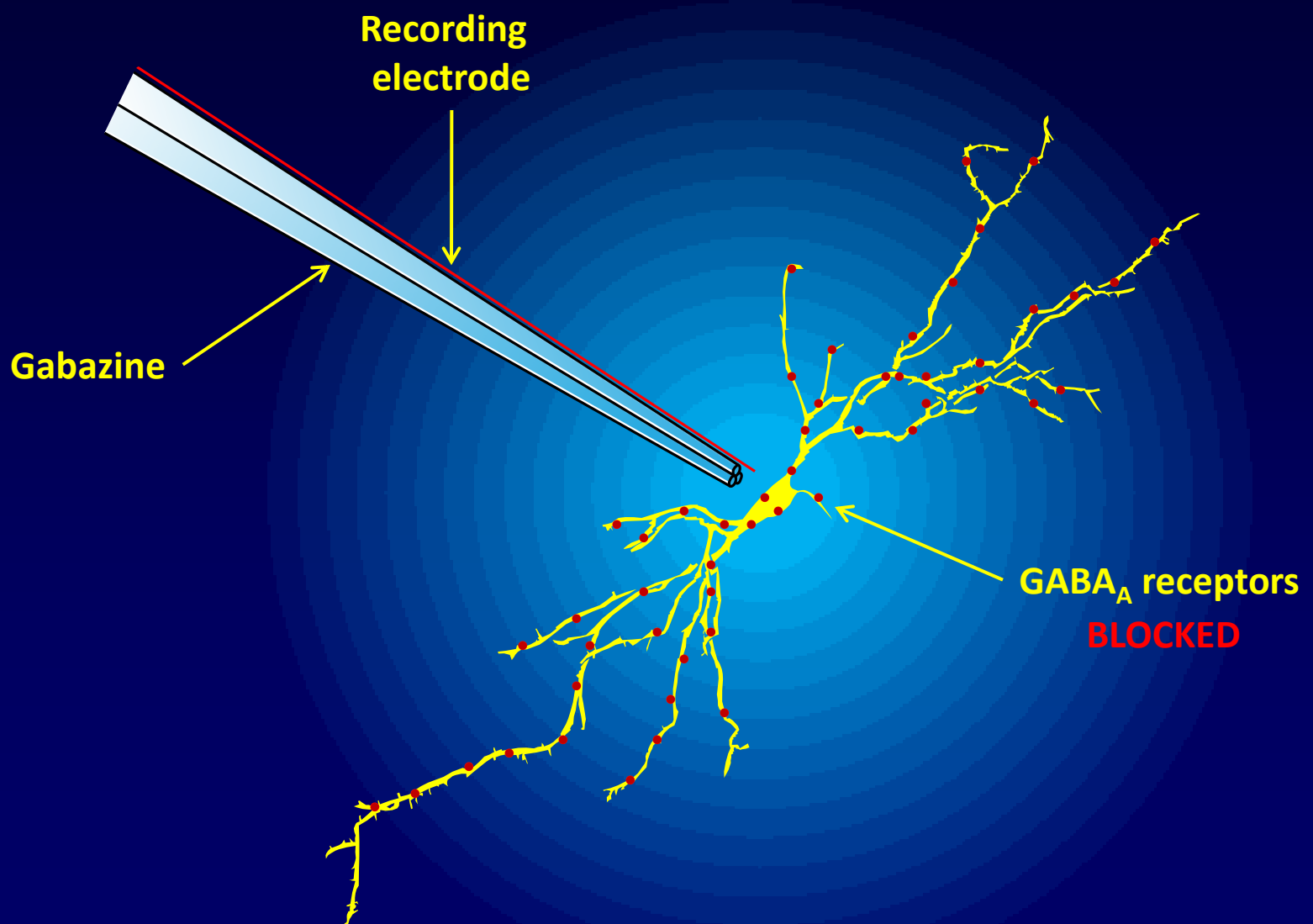
AC produces a GAIN CONTROL



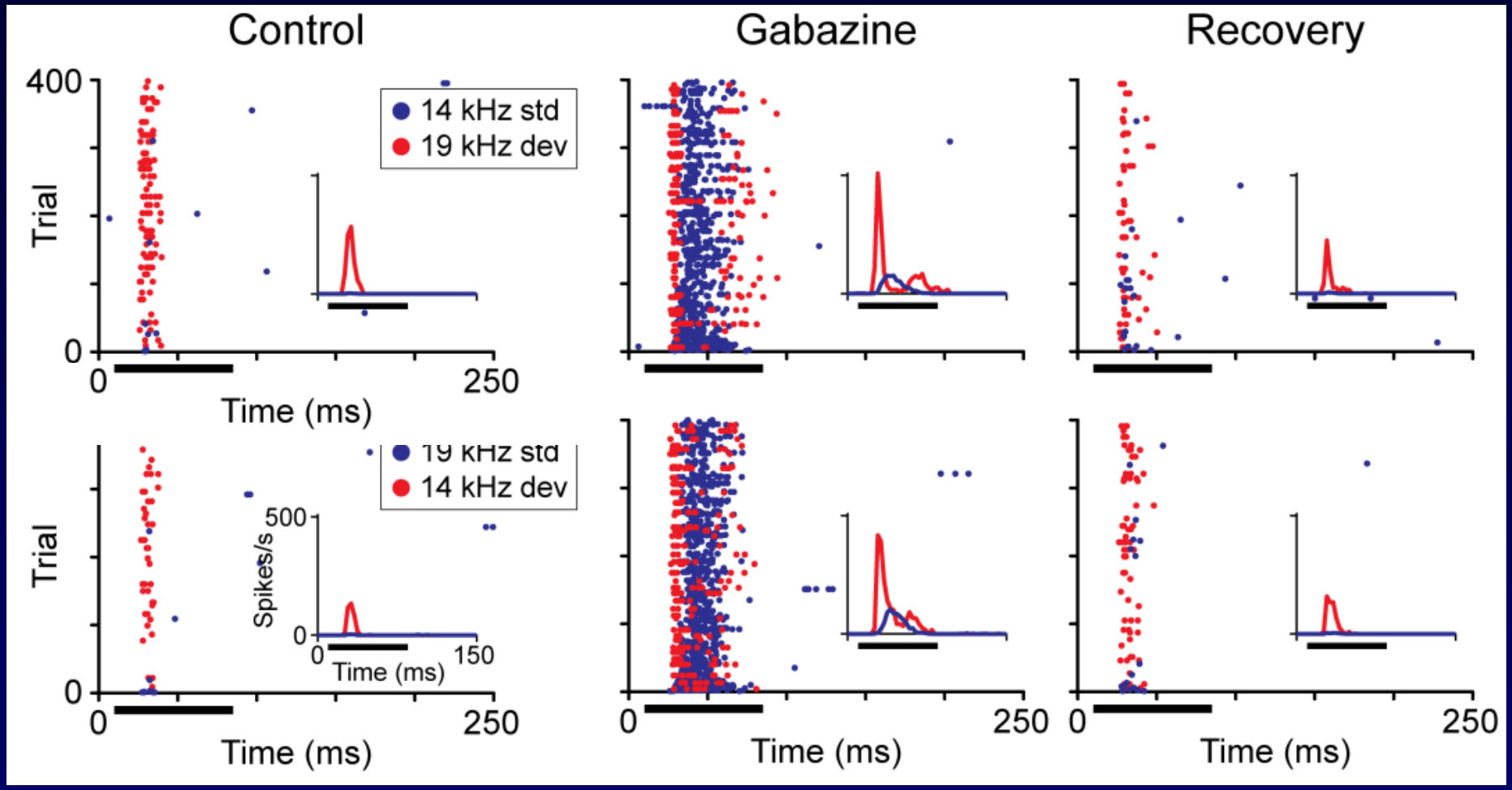
SOURCES OF GABA TO THE IC



MICROIONTOPHORESIS



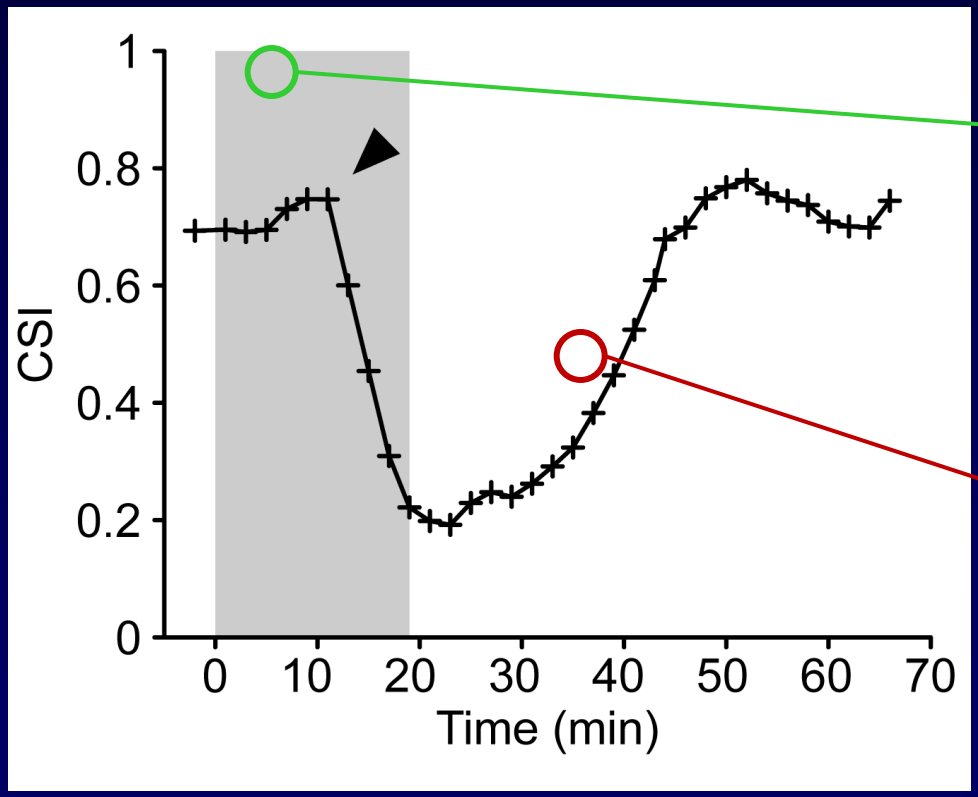
FIRING RATE

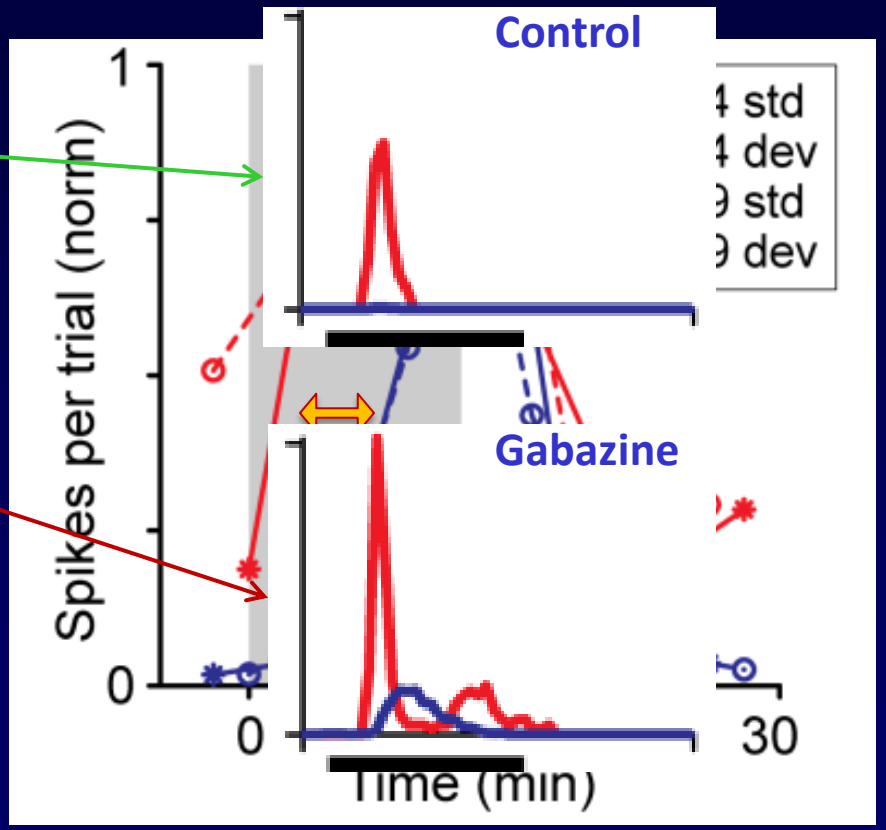


Perez-Gonzalez et al., 2012; PLOS ONE

SSA INDEX

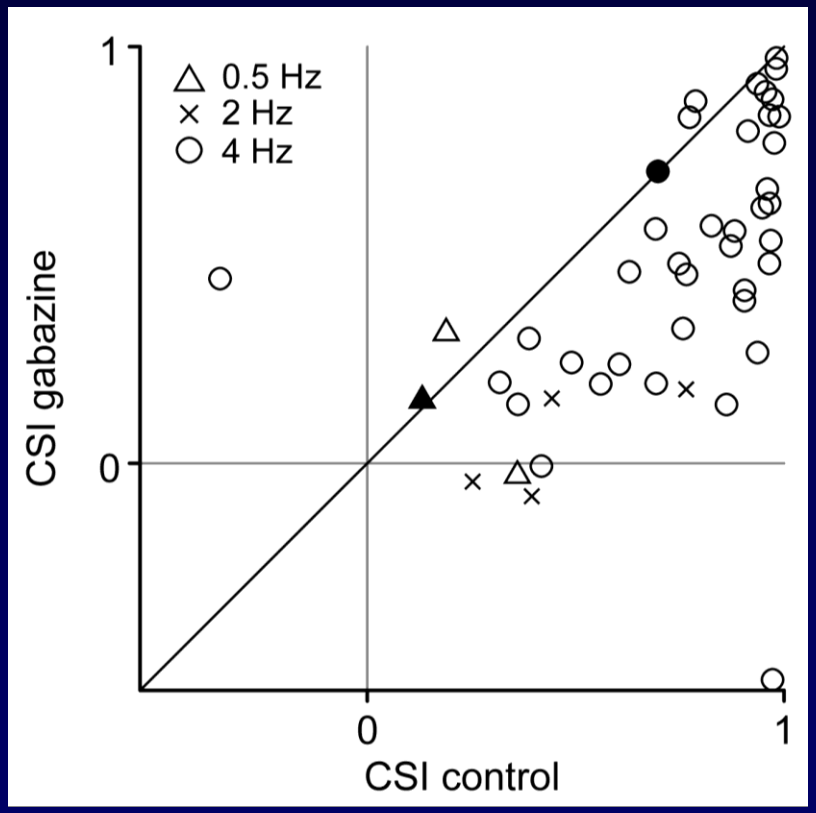
GABAZINE does not complitely abolish SSA

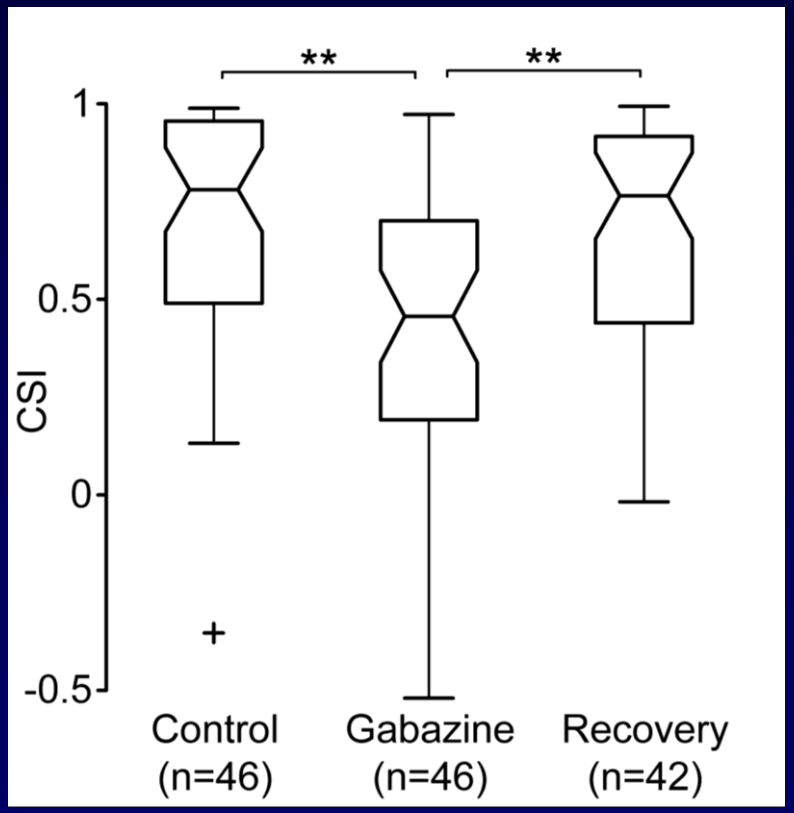




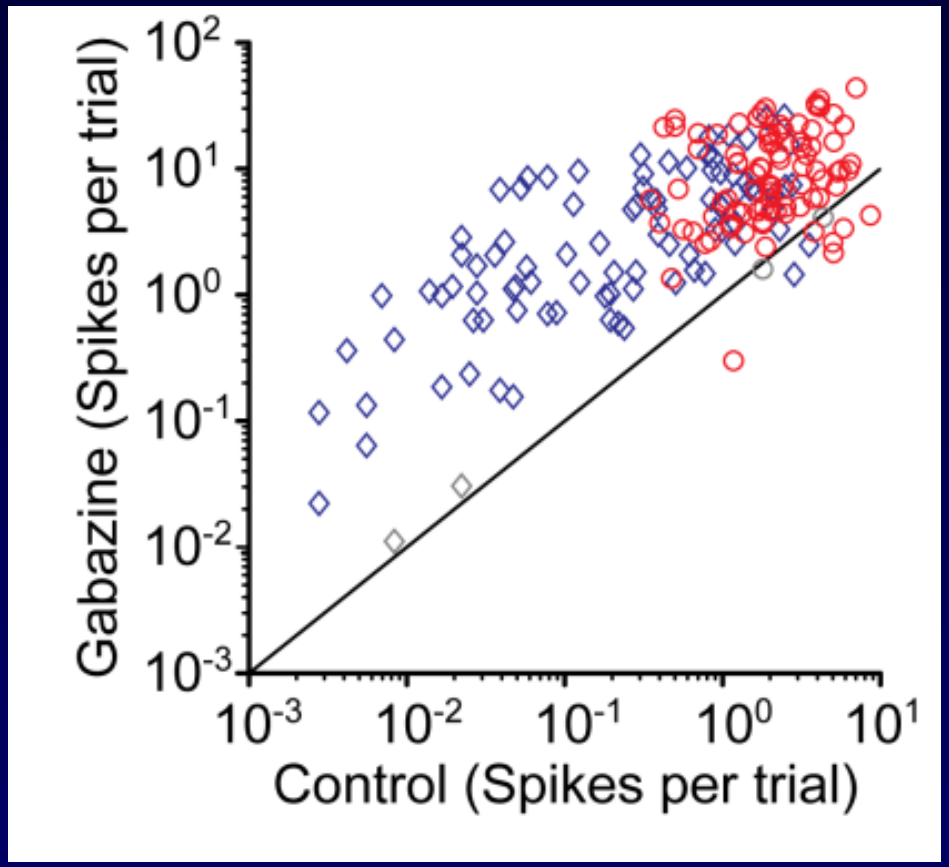
Perez-Gonzalez et al., 2012; PLOS ONE

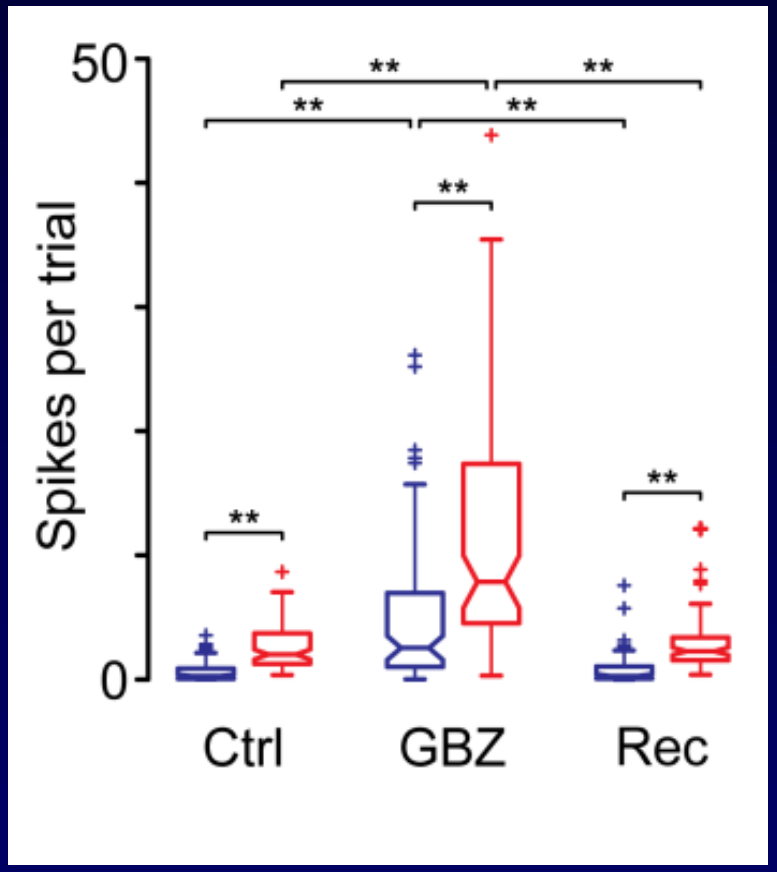
SSA INDEX


0.5 Hz
2 Hz
4 Hz
CSI gabazine
CSI control
1
0
0
1


**
**
CSI
1
0.5
0
-0.5
Control
(n=46)
Gabazine
(n=46)
Recovery
(n=42)

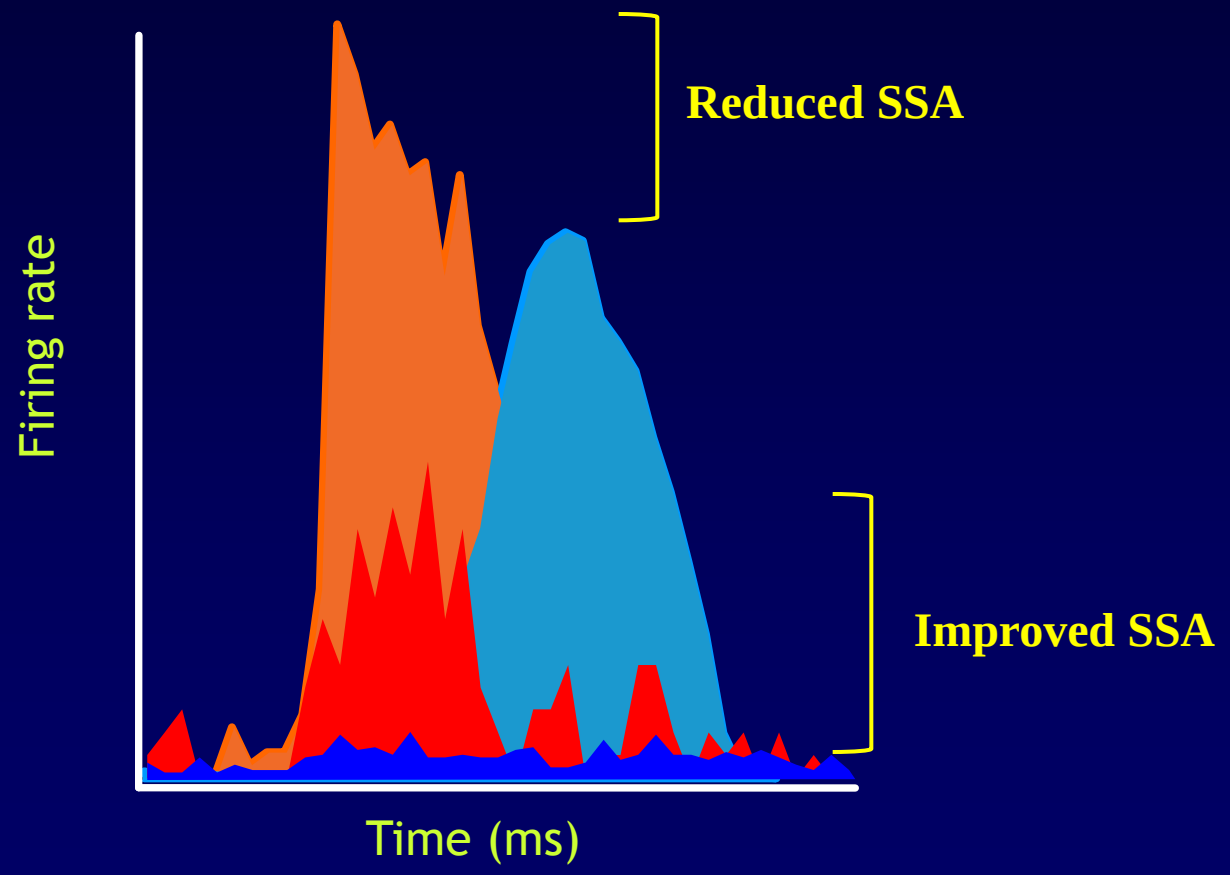
FIRING RATE





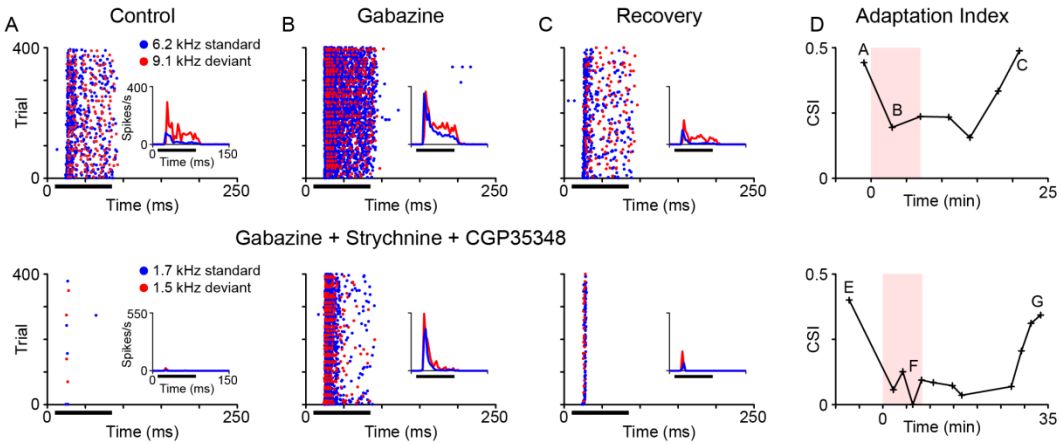
No differential effect

GABA produces a GAIN CONTROL

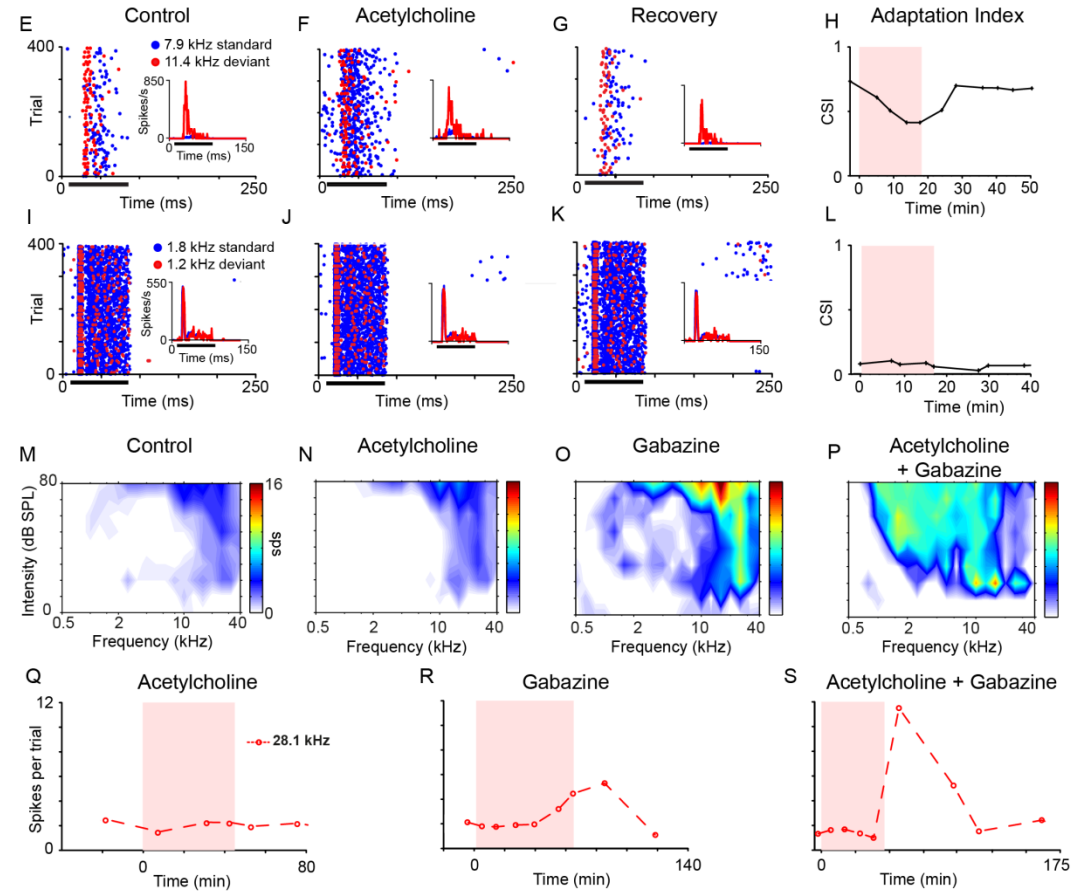


Perez-Gonzalez et al., 2012; PLOS ONE

EFFECT OF THE INHIBITION BLOCKADE ON SSA



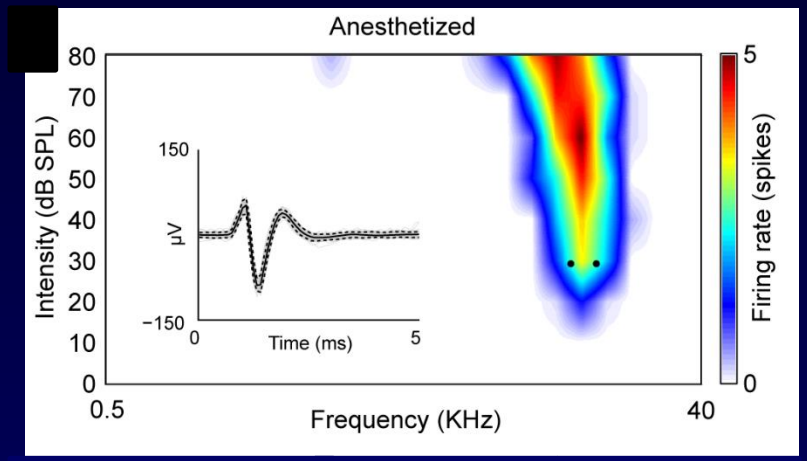
EFFECT OF THE NEUROMODULATOR ACETYLCHOLINE ON SSA

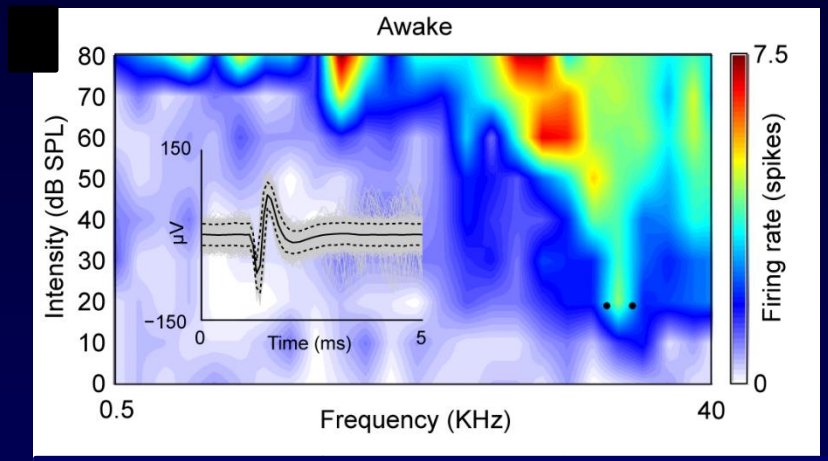


Anesthetized vs. awake procedures

- Awake
  - Taming and habituation
    - 3 days of handling
    - Taming with condensed milk
  - Surgery
    - Isofluorane anesthesia (rapid recovery)
    - Custom head-post fixed to the scalp with light-cured adhesives
    - Craneotomy
  - Recording
    - Maximum of 3 hours per session
    - Maximum of 4-5 recording sessions
    - Mouse sedated it struggling

Neuronal examples

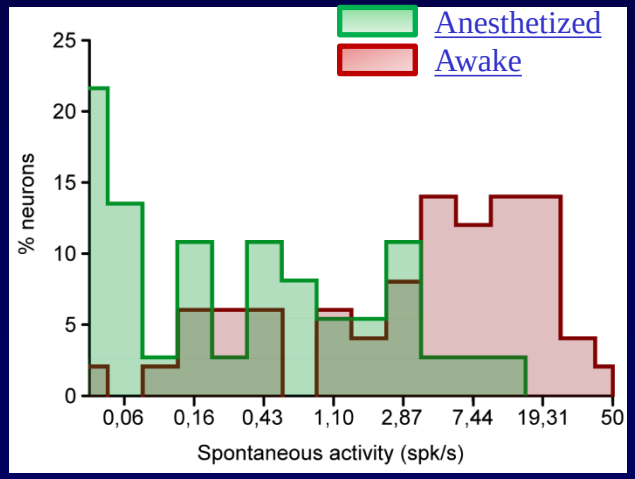




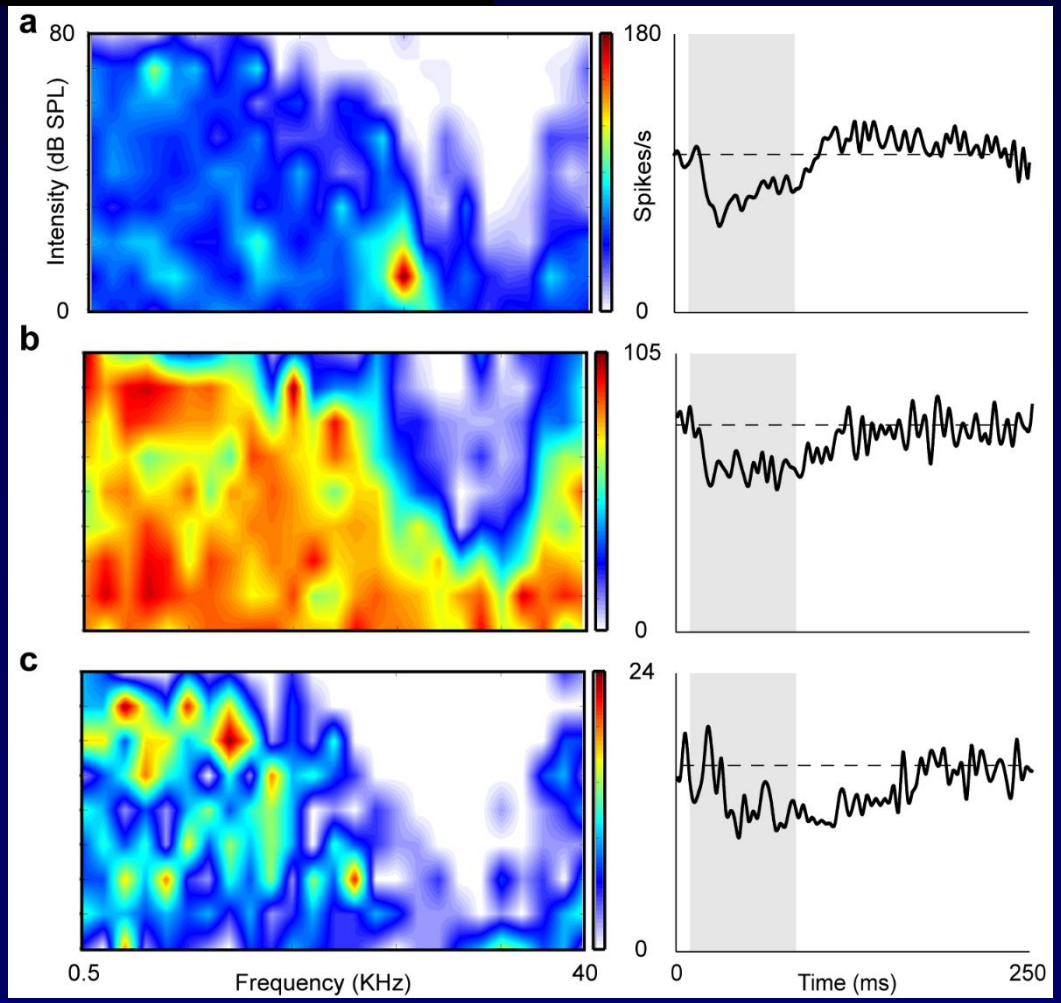
Spontaneous activity

[redacted]

- Awake recording show higher levels of SR…

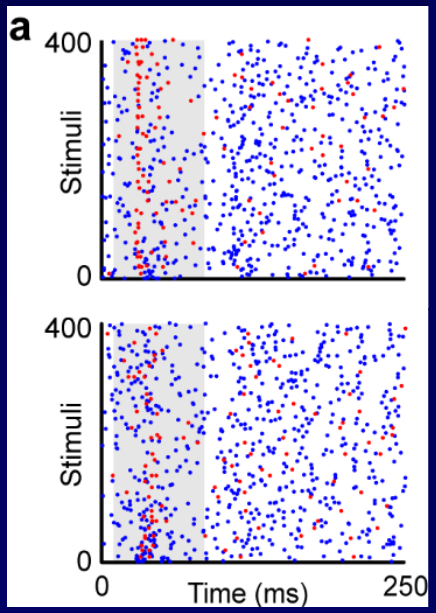


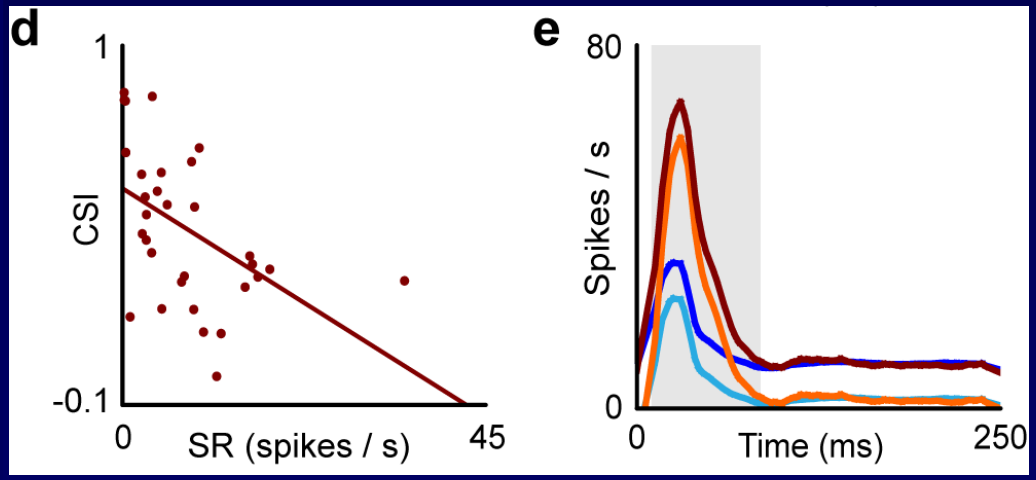
… that reveal a high incidence of iFRA

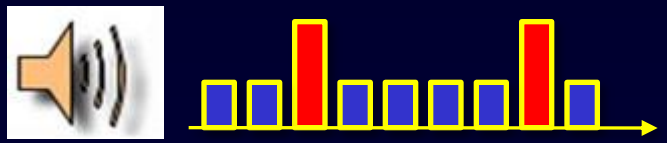


SR, sleep and responses to danger

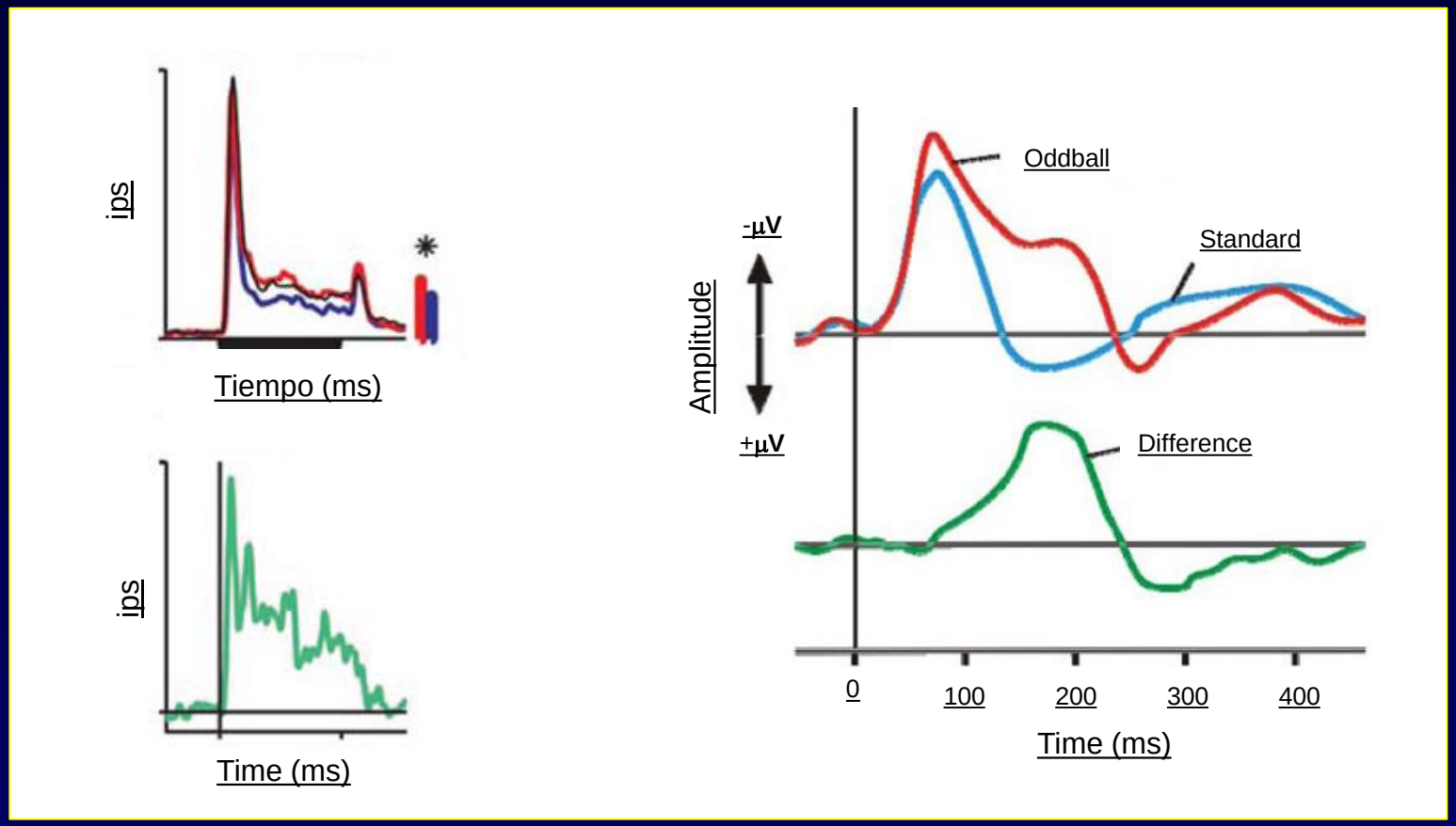
- SSA may especially important when nervous system activity is suppressed during sleep-like states…
- … so there is an inverse correlation between Spontaneous activity and SSA sensitivity







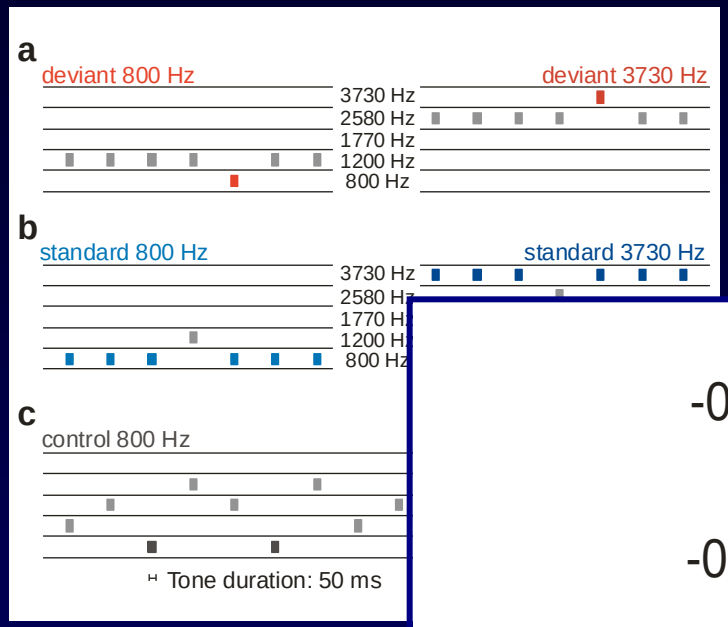
Single Unit Recording **Missmatch Negativity Potential**

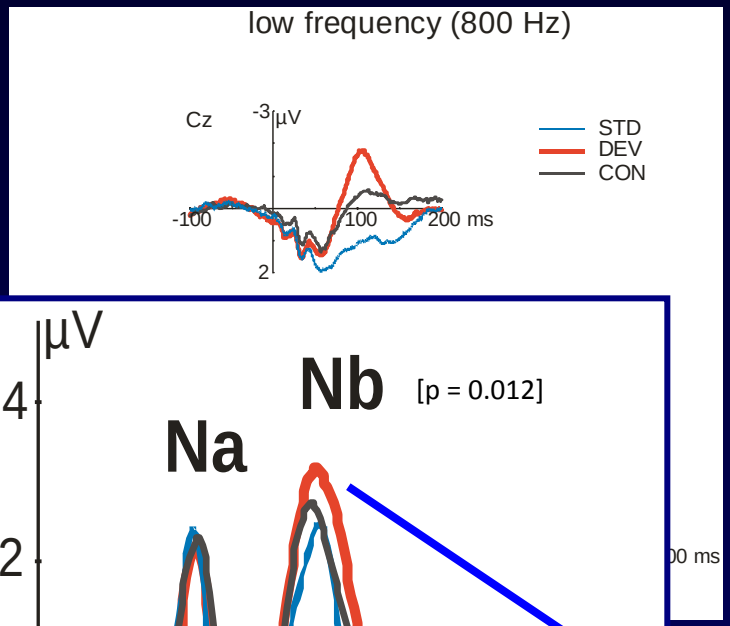


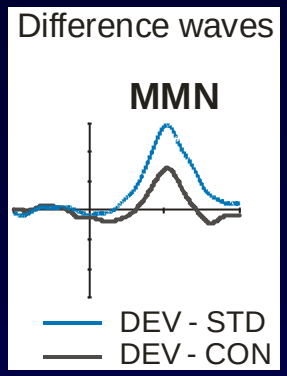
Ulanovsky et al., 2003
Pérez-González et al., 2005
Malmierca et al., 2009
Antunes et al., 2010

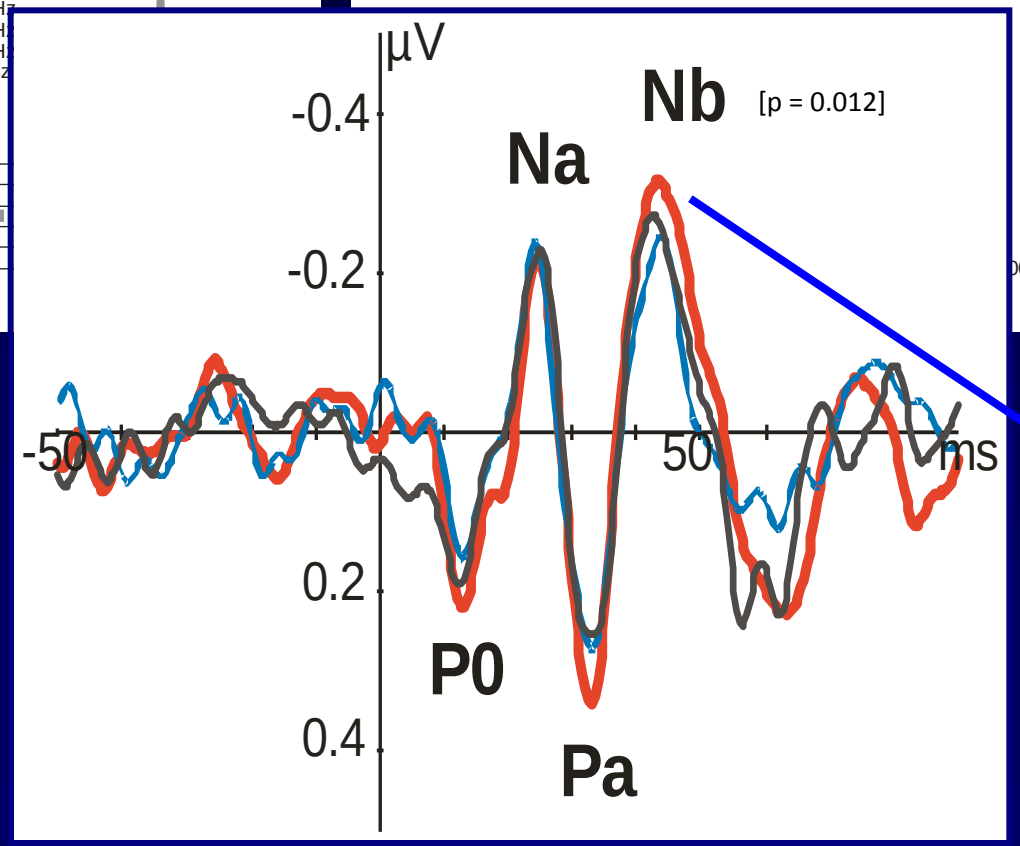
Näätänen, 1978

Subcortico-cortical contributions … – 1: frequency deviants









~ 40 ms !!

N =20.
Age= 22 yr.
Gender= 11 females

Grimm et al. (2011). Psychophysiology, 48, 377-384.

CONCLUSIONS

- Neurons in the IC and MGB show SSA, somewhat similar to that seen in the cortex.
- GABA does not shape SSA in the inferior colliculus, but rather it acts as a gain control mechanism
- SSA in the MGB and IC is not inhereited from AC.
- SSA, at least in part, is created *de novo* at the levels of the IC and/or MGB and may lies upstream MMN.


Thanks to the people that do
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¡MUCHAS GRACIAS!