2nd NEUROMAT WORKSHOP

STOCHASTIC MODELING AND SPIKE DATA ANALYSIS

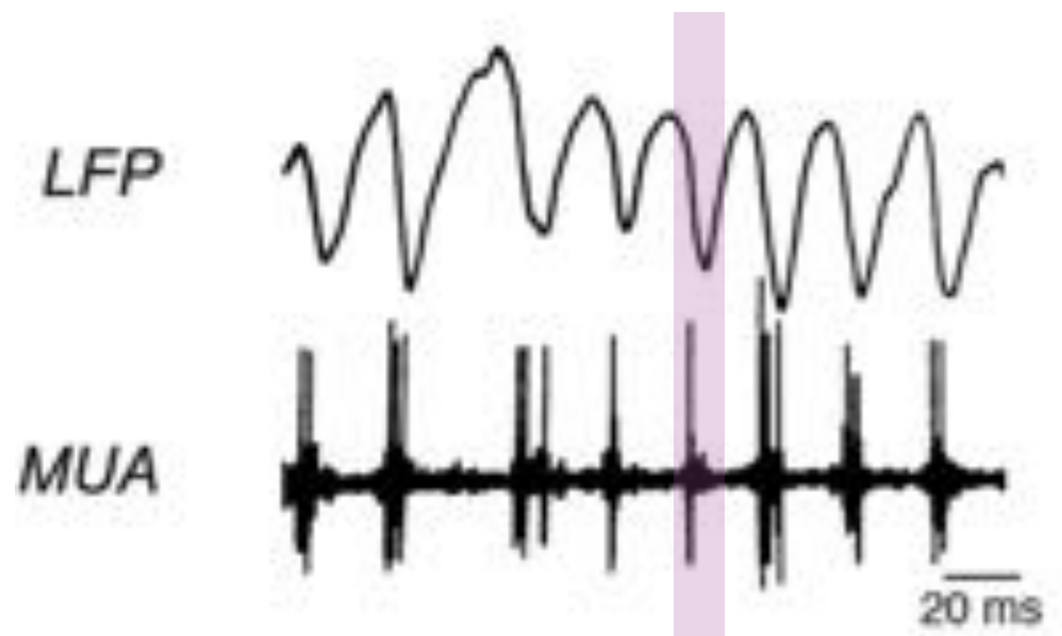
NEURONAL RHYTHMS

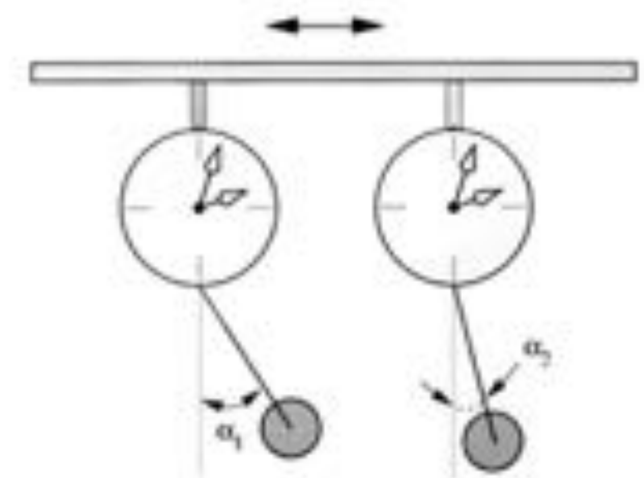
A FRAMEWORK FOR UNDERSTANDING INTERACTIONS IN THE BRAIN

Sergio Neuenschwander

Instituto do Cérebro - UFRN
NATAL

GAMMA SYNCHRONIZATION
PHASE RELATIONSHIPS





How does the brain orchestrate the symphony

of **emotions**, **perceptions**, **thoughts** and **actions**

that come together effortlessly from neural processes across the brain?

— By **synchrony** over multiple frequency bands.

Francisco Varela

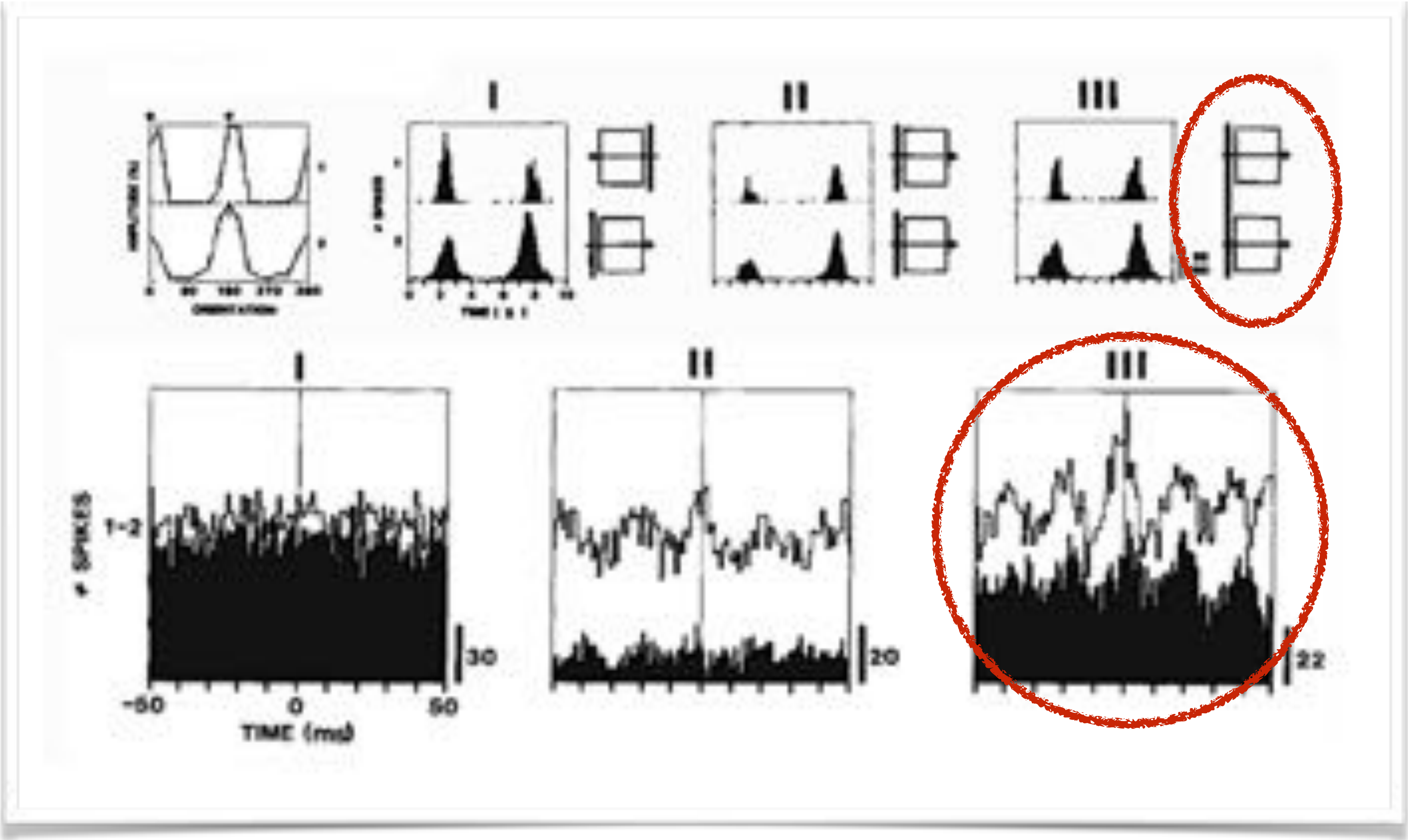
Nature Reviews, 2001

γ

What is special in gamma synchronization?

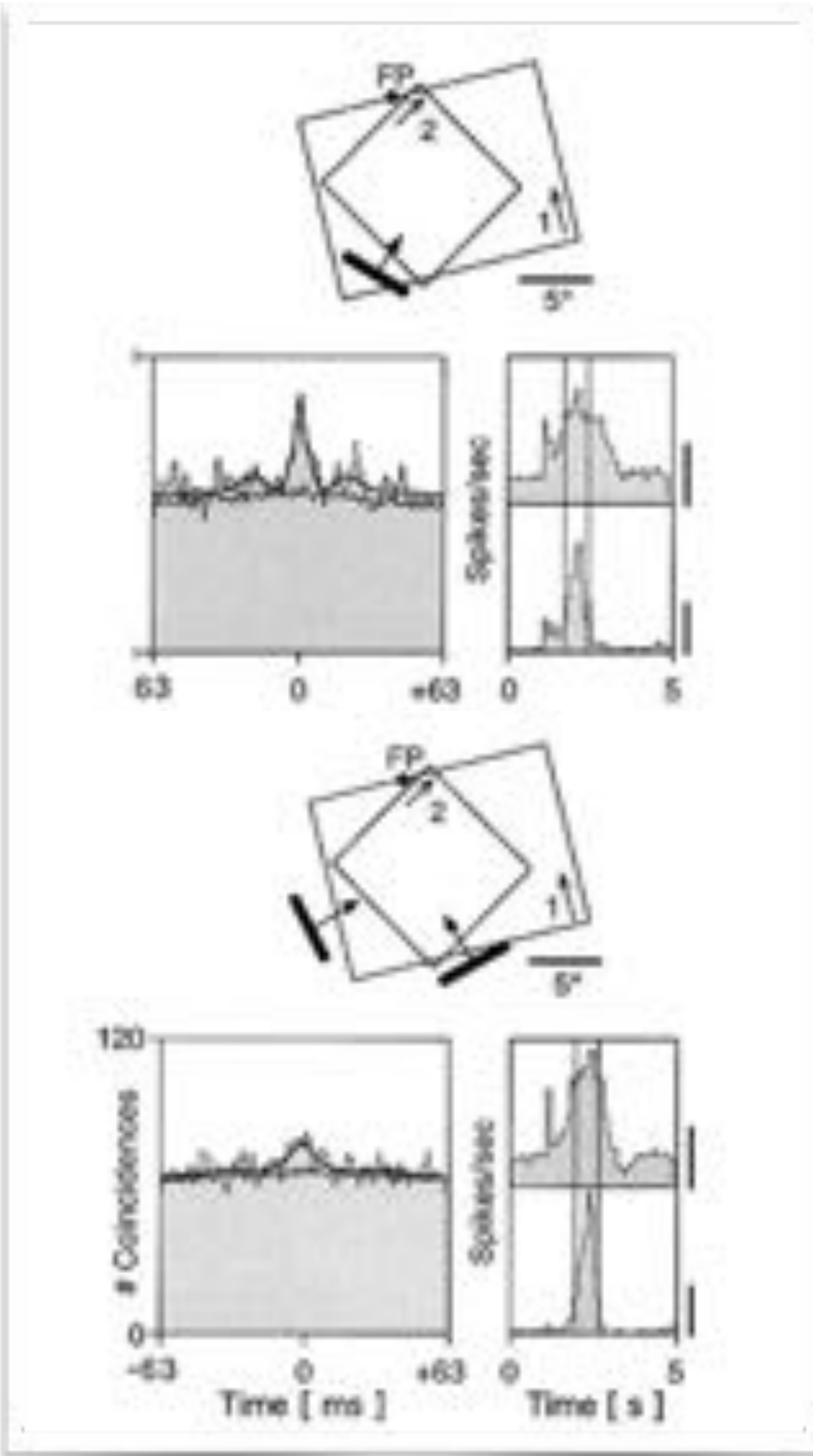
BINDING BY SYNCHRONIZATION

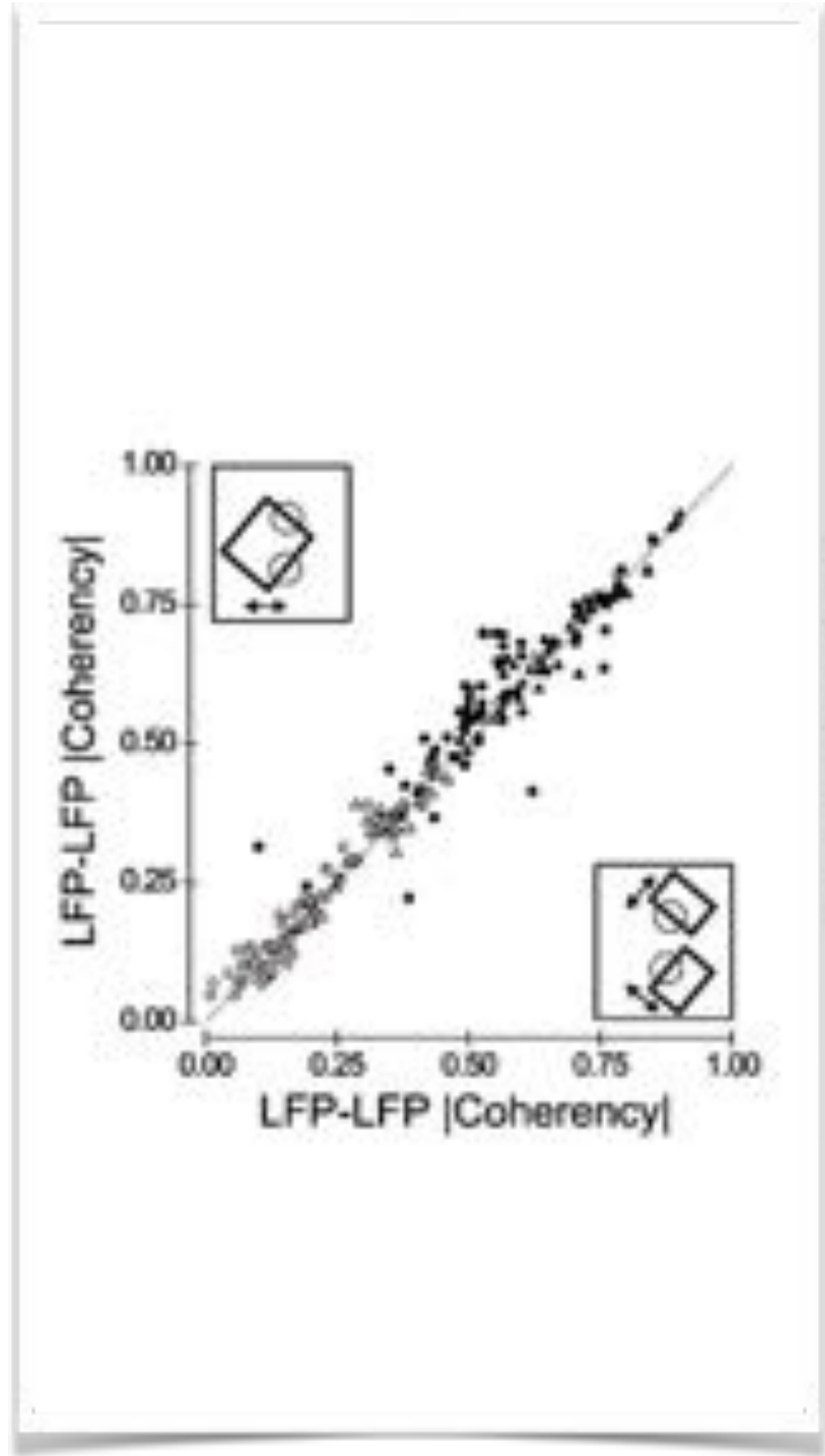
THE LONG-BAR EXPERIMENT



GRAY et al., Nature, 1989

BINDING BY SYNCHRONIZATION
CONTROVERSIES

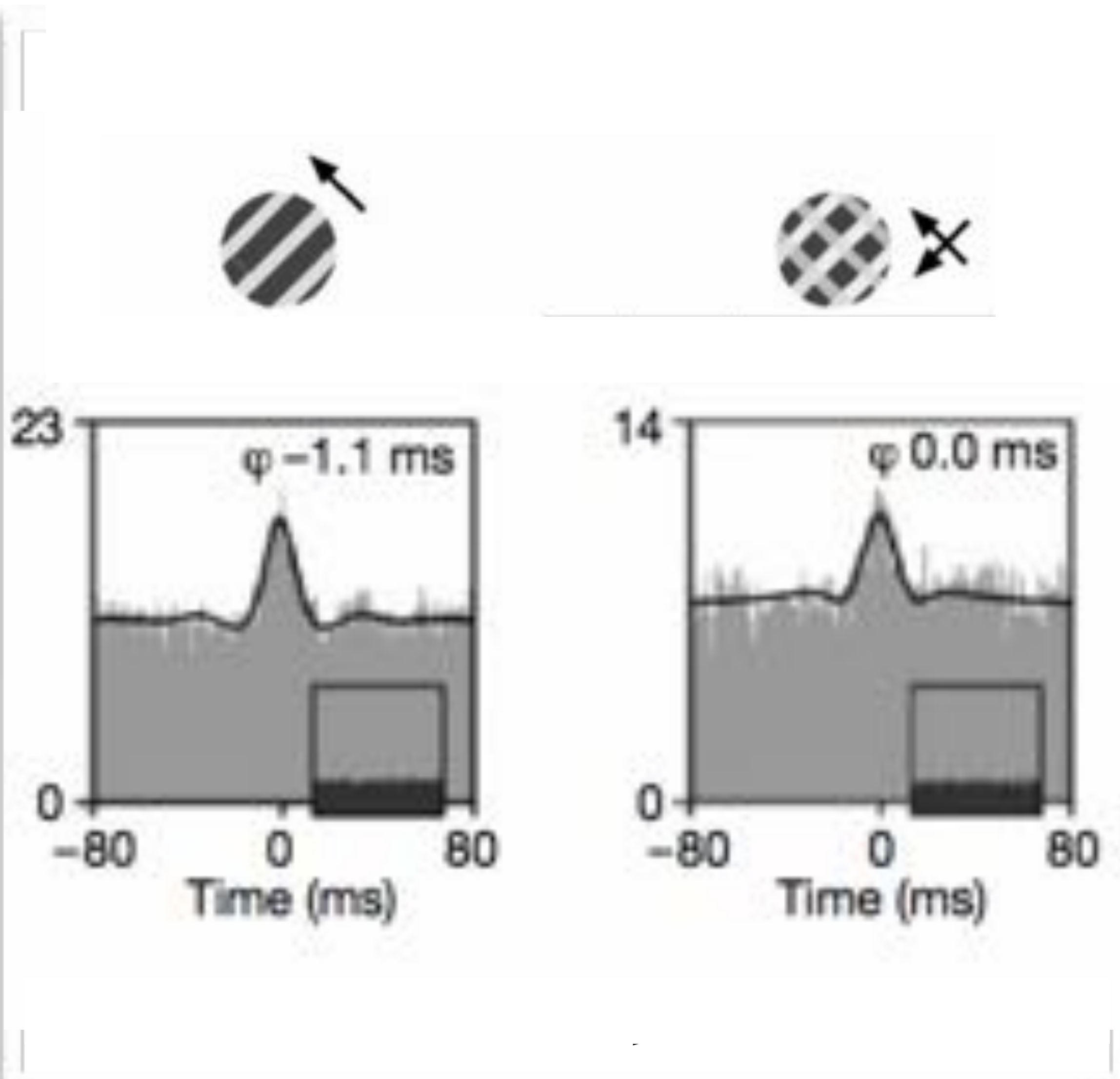




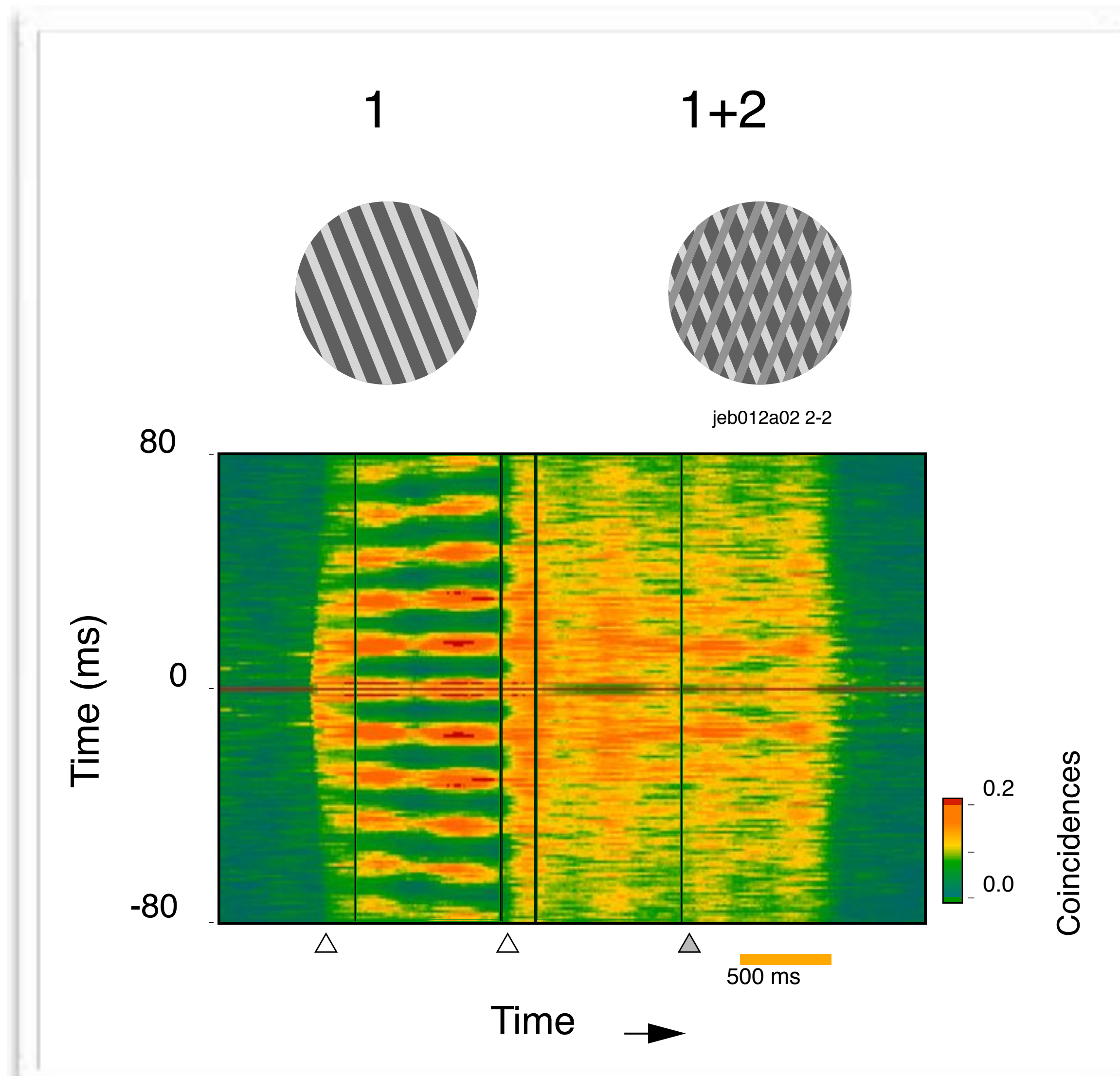
KREITER and SINGER, JNS 1996

PALANCA et al., Neuron 2006

BINDING BY SYNCHRONIZATION
CONTROVERSIES



CASTELO-BRANCO..NEUENSCHWANDER...
Nature,2000



LIMA ... NEUENSCHWANDER
Ceb Cortex, 2010

Opinion TRENDS in Cognitive Sciences Vol.9 No.10 October 2005

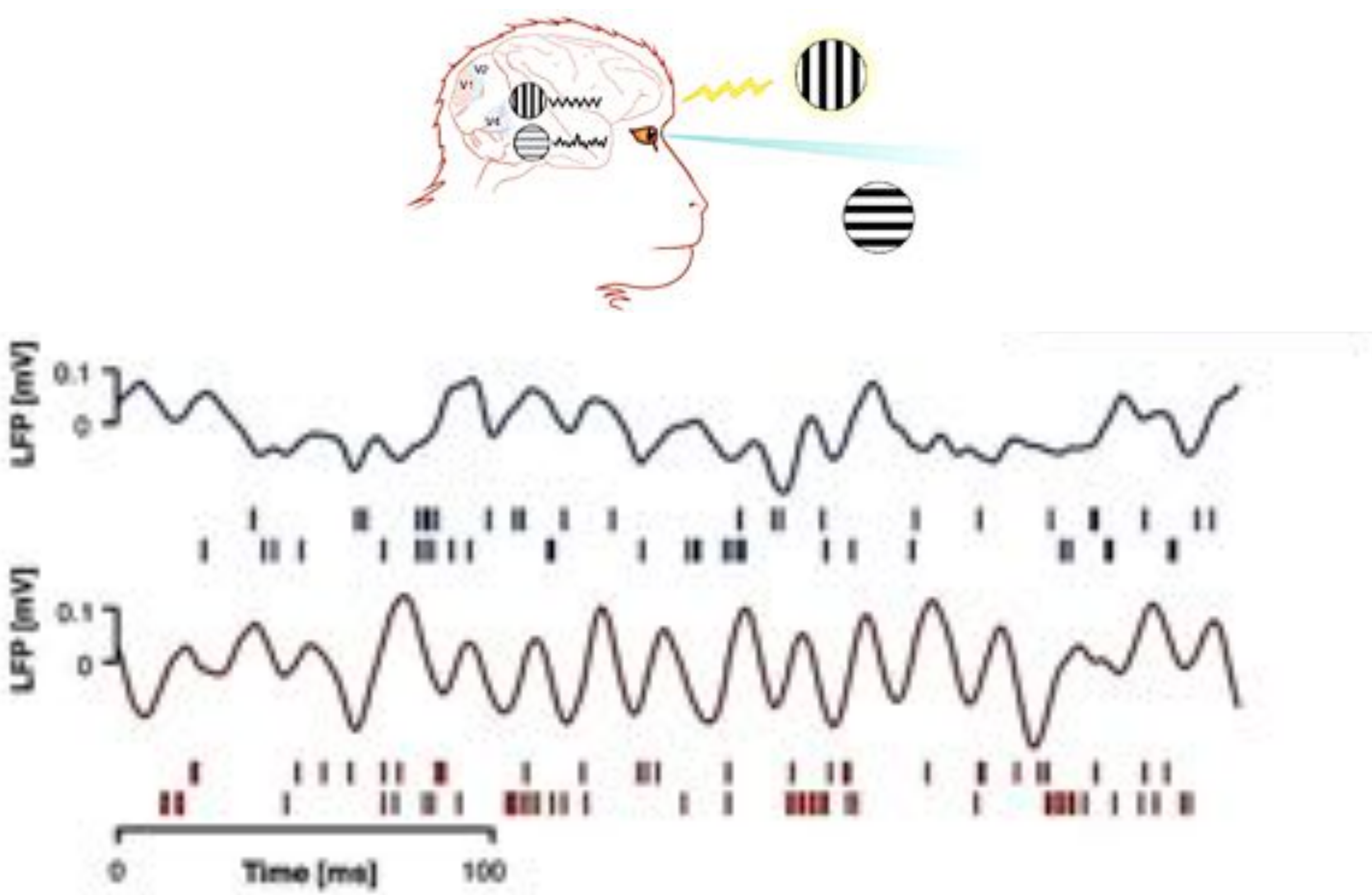
A mechanism for cognitive dynamics: neuronal communication through neuronal coherence

Pascal Fries[1,2]

[1]F.C. Donders Centre for Cognitive Neuroimaging, Radboud University Nijmegen, 6525 EN Nijmegen, The Netherlands
[2]Department of Biophysics, Radboud University Nijmegen, 6525 EZ Nijmegen, The Netherlands

At any one moment, many neuronal groups in our brain are active. Microelectrode recordings have characterized the activation of single neurons and fMRI has unveiled brain-wide activation patterns. Now it is time to understand how the many active neuronal groups interact with each other and how their communication is flexibly modulated to bring about our cognitive dynamics. I hypothesize that neuronal communication is mechanistically subserved by neuronal coherence. Activated neuronal groups oscillate and thereby undergo rhythmic excitability fluctuations that produce temporal windows for communication. Only coherently oscillating neuronal groups can interact effectively, because their communication windows for input and for output are open at the same times. Thus, a flexible pattern of coherence defines a flexible communication structure, which subserves our cognitive flexibility.

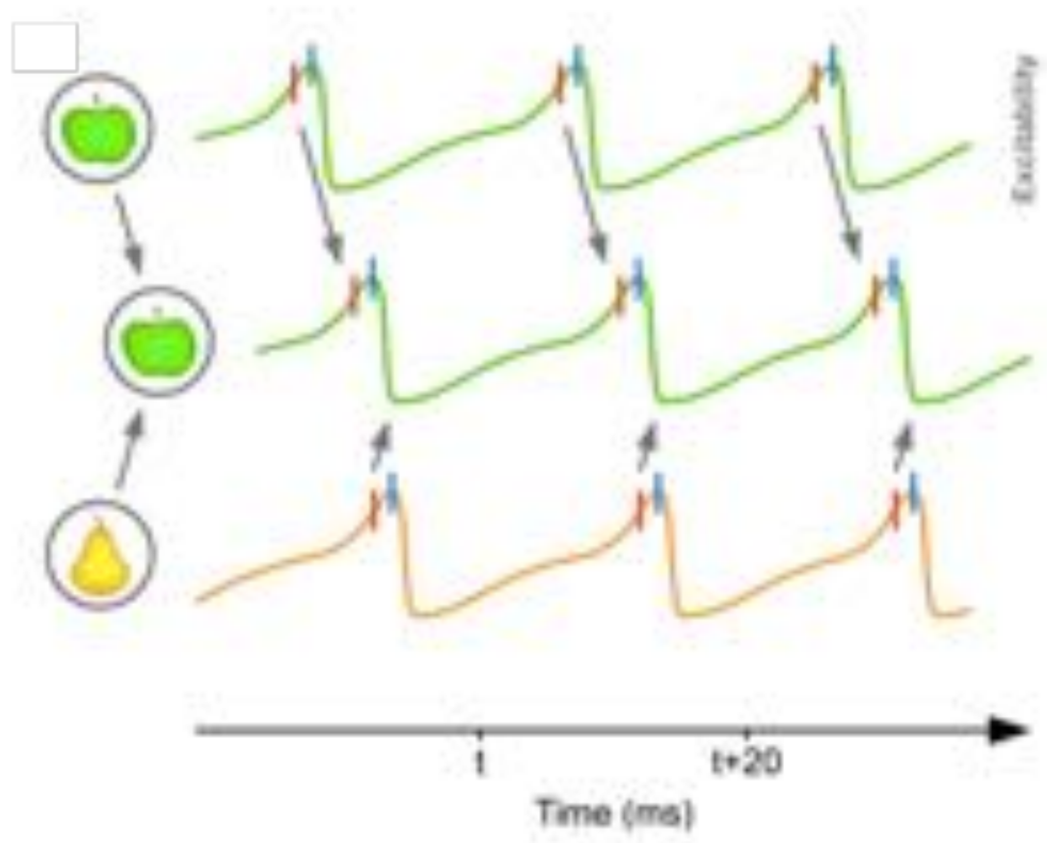
SELECTIVE ATTENTION
ROLE OF GAMMA OSCILLATIONS



In V4 cells activated by the attended stimulus show increased gamma-frequency (35 to 90 hertz) synchronization compared with neurons activated by distracters.

FRIES ET AL., SCIENCE 2001

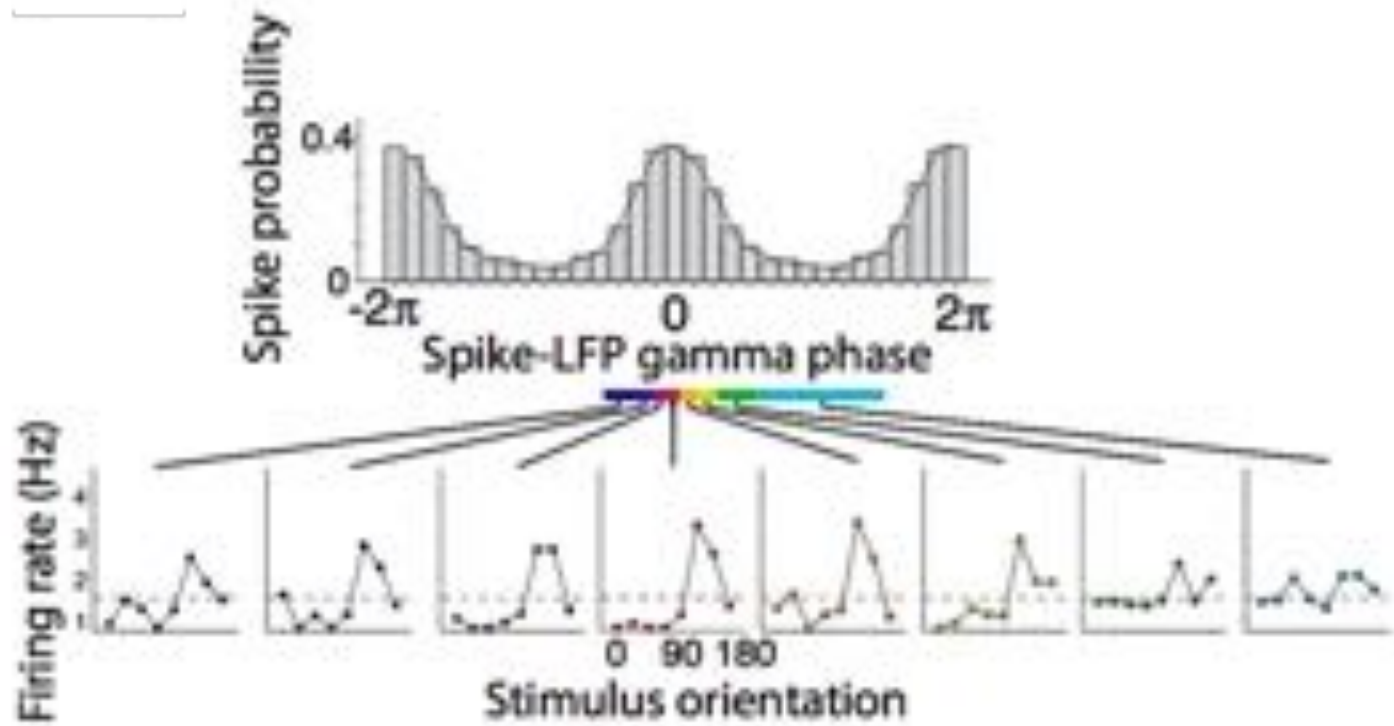
SELECTIVE ATTENTION
ROLE OF GAMMA OSCILLATIONS



Selective coherence implies into selective communication.

FRIES, NEURON 2015

STIMULUS ENCODING WITH GAMMA
PHASE CODING



In V1, orientation is encoded by phase relationships between spike and LFP signals.

modified from
WOMELSDORF, VINCK, LIMA, ..NEUENSCHWANDER, FRIES
PNAS,2012

BINDING BY SYNCHRONIZATION

CONTROVERSIES

Opinion

CellPress

Do gamma oscillations play a role in cerebral cortex?

Supratim Ray[1] and John H.R. Maunsell[2]

[1] Centre for Neuroscience, Indian Institute of Science, Bangalore 560012, India
[2] Department of Neurobiology, University of Chicago, 5812 South Ellis Avenue, MC0912 Chicago, IL 60637, USA

Gamma rhythm (which has a center frequency between 30 and 80 Hz) is modulated by cognitive mechanisms such as attention and memory, and has been hypothesized to play a role in mediating these processes by supporting communication channels between cortical areas or encoding information in its phase. We highlight several issues related to gamma rhythms, such as low and inconsistent power, its dependence on low-level stimulus features, problems due to conduction delays, and contamination due to spike-related activity that makes accurate estimation of gamma phase difficult. Gamma rhythm could be a potentially useful signature of excitation–inhibition interactions in the brain, but whether it also provides a mechanism for information processing or coding remains an open question.

potential of pyramidal cells, such that the excitability of those cells varies within each cycle of the rhythm. The inhibitory network could generate the rhythm by itself or through periodic excitation arising from the pyramidal cell population (see [20] and references therein for a detailed discussion of cellular mechanisms). Several models have been proposed to explain this phenomenon [22–26]. In most of these models, gamma oscillations are generated due to excitation–inhibition interactions as a consequence of simple network dynamics and time constants associated with excitatory postsynaptic potentials and inhibitory postsynaptic potentials. We focus on two recent proposals that rely on rhythmic inhibition from an interneuronal network for specific signaling mechanisms.

One of these proposals is the communication through

TICS, 2015

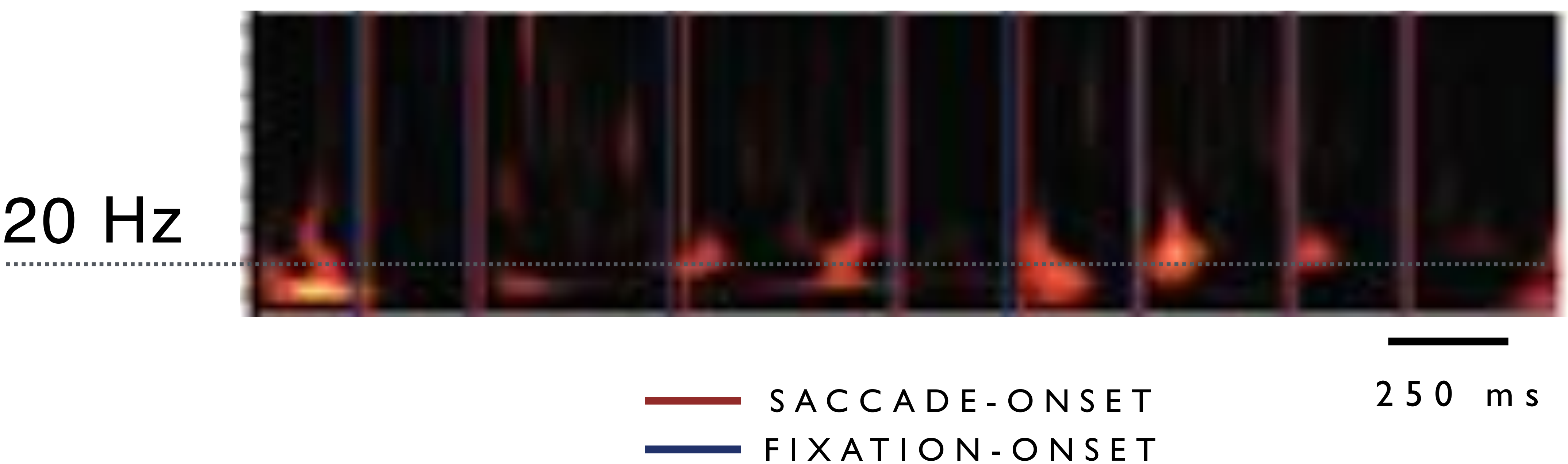
Do gamma oscillations play a role in vision?

ARTIFICIAL vs. NATURAL

FIXED GAZE

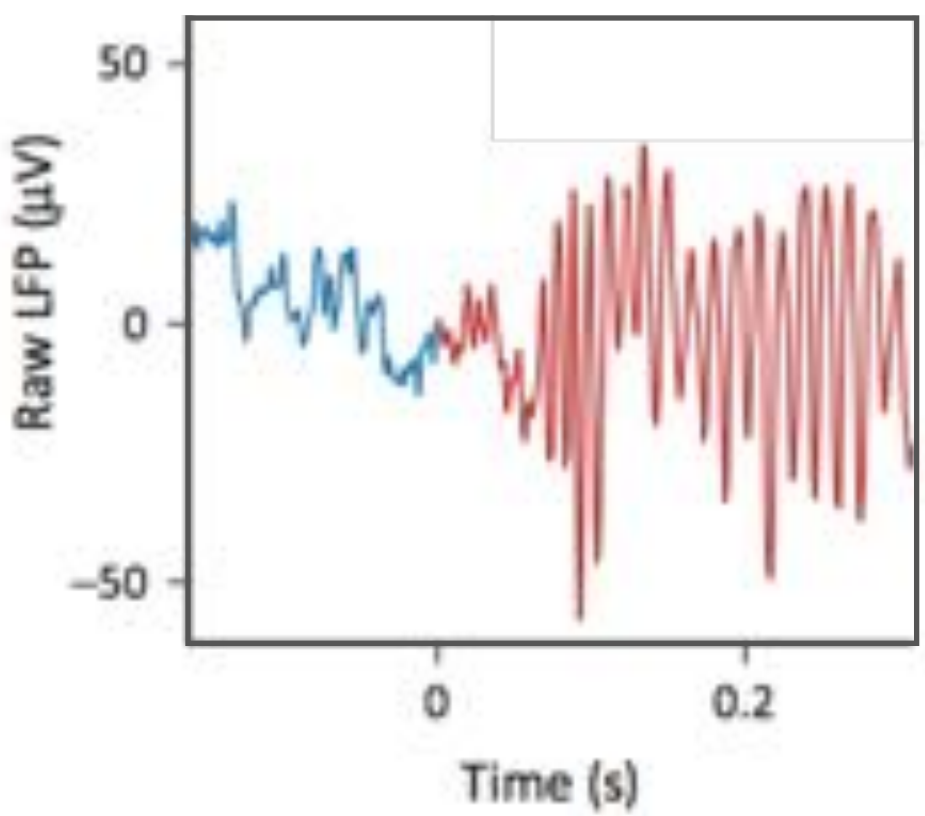
SEEING

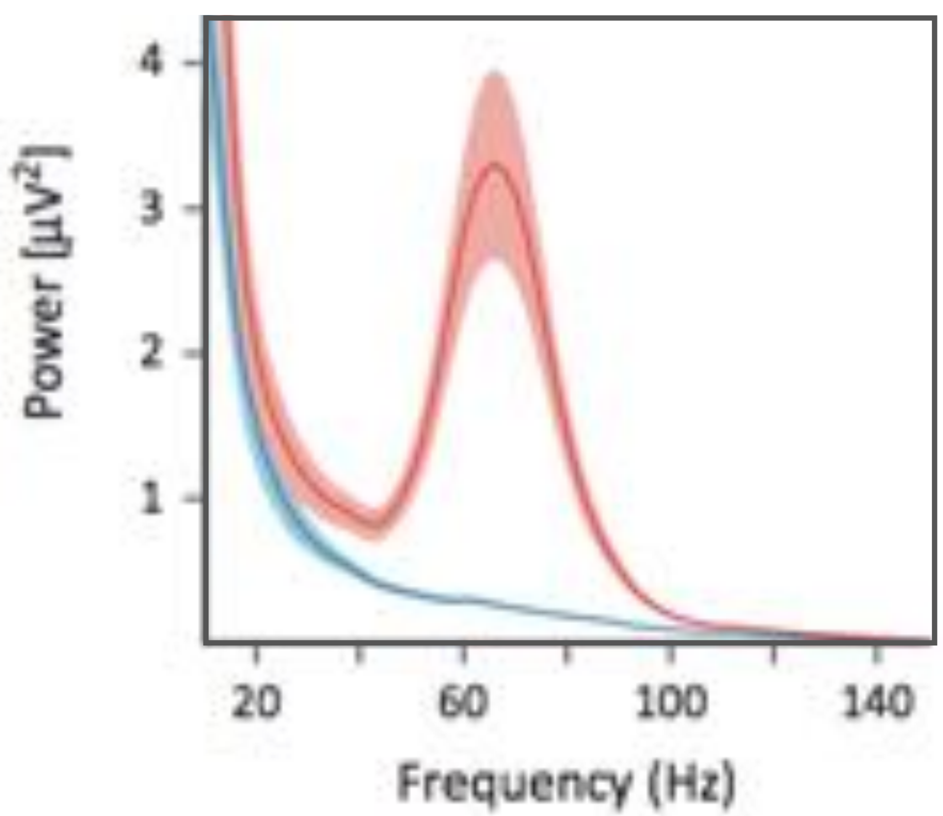
BETA RESPONSES
CAPUCHIN MONKEY



ITO, MALDONADO, SINGER, GRÜN
Cerebral Cortex., 2013

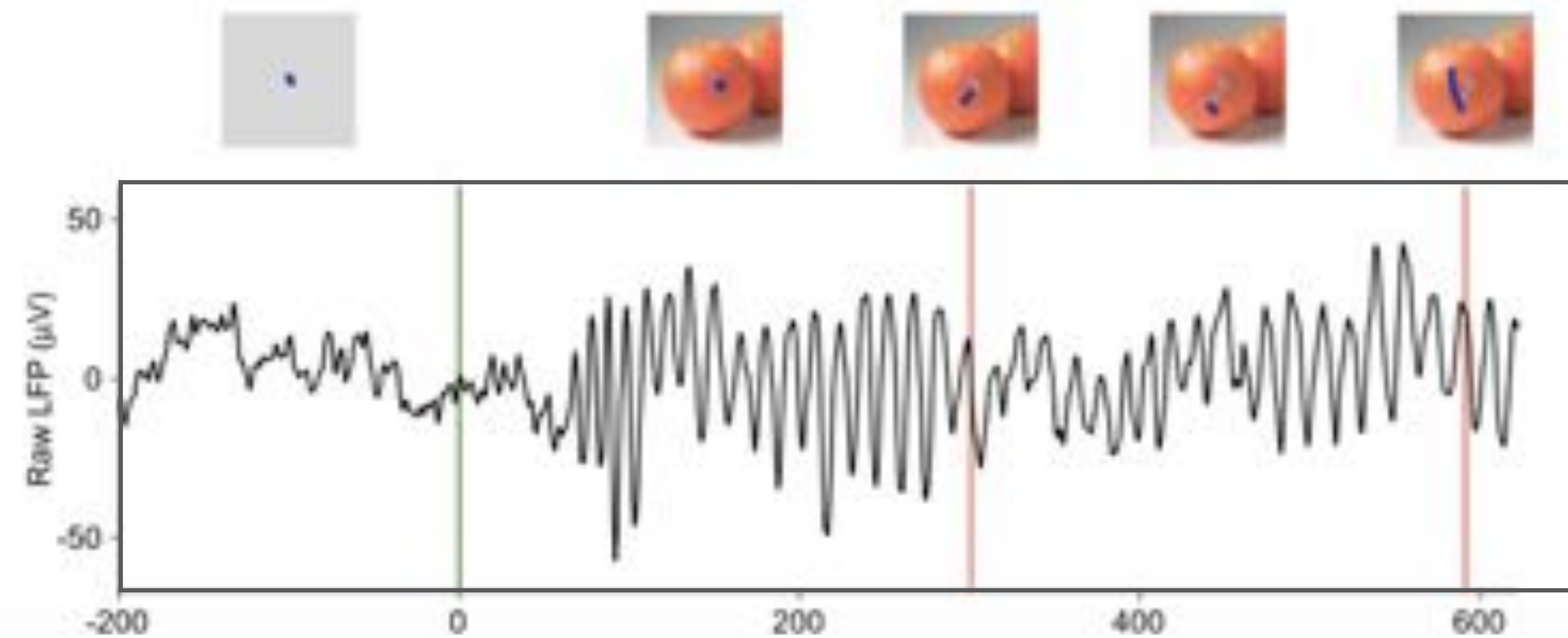
GAMMA RESPONSES
MACAQUE MONKEY





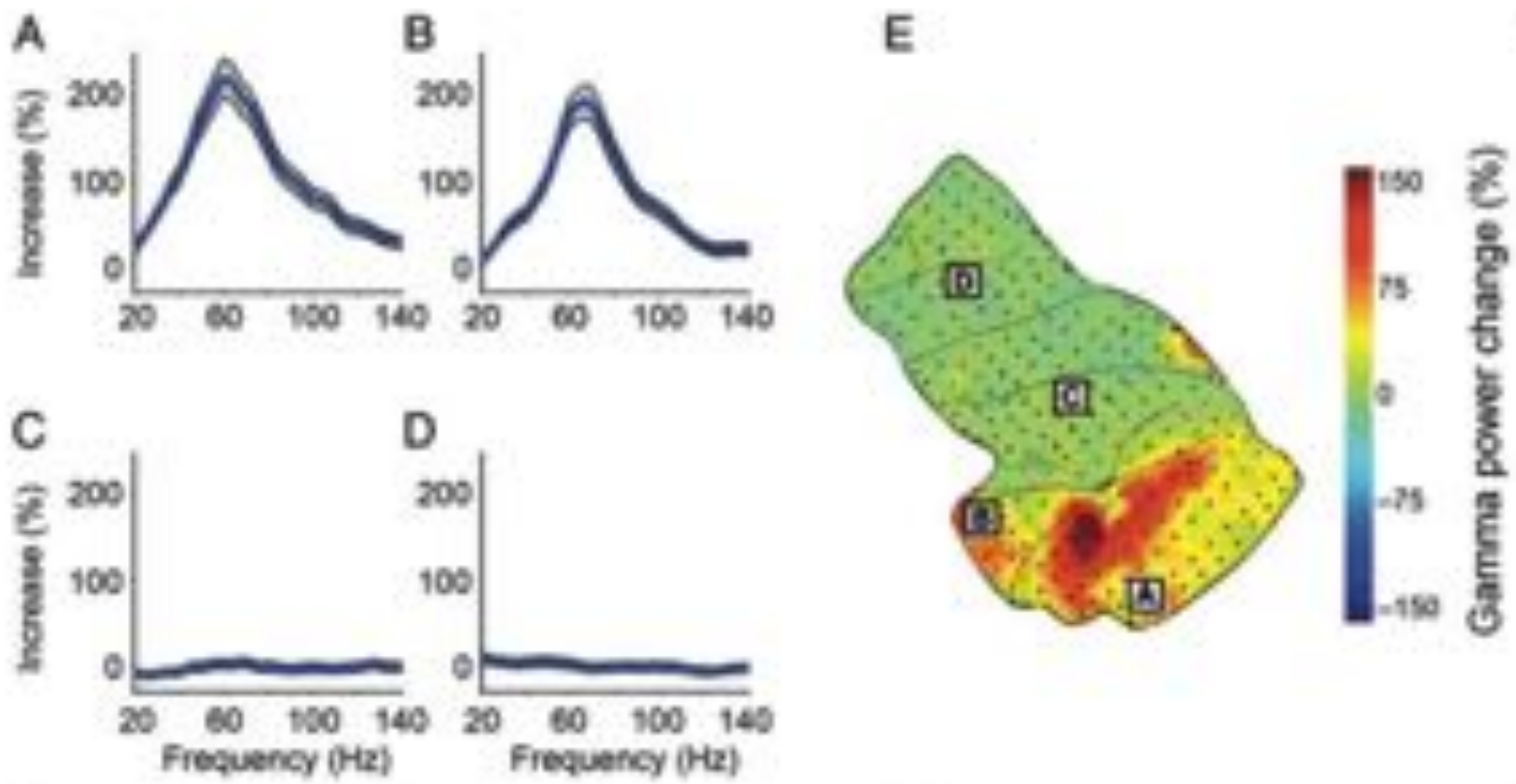
BRUNET… FRIES
Cerebral Cortex., 2013

GAMMA RESPONSES
MACAQUE MONKEY



BRUNET… FRIES
Cerebral Cortex., 2013

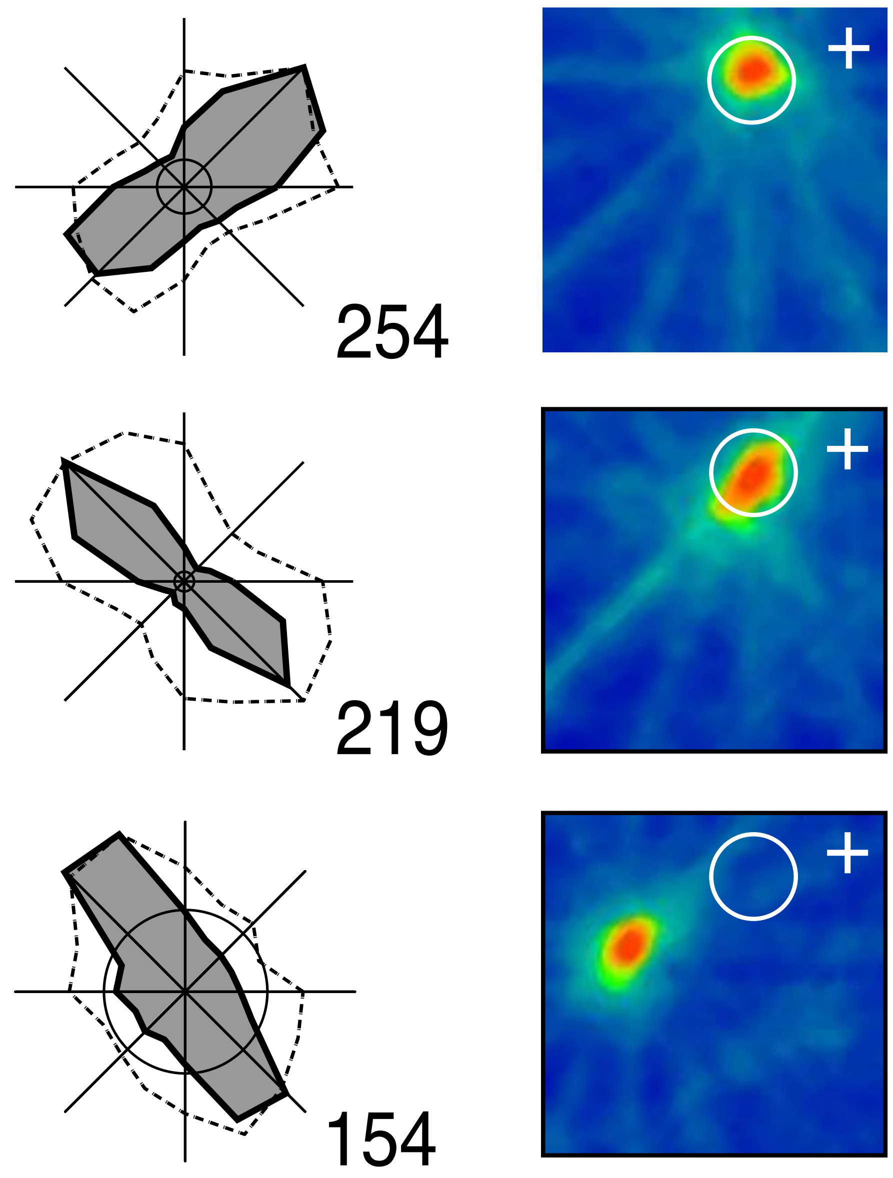
GAMMA RESPONSES
MACAQUE MONKEY



BRUNET… FRIES
Cerebral Cortex., 2013

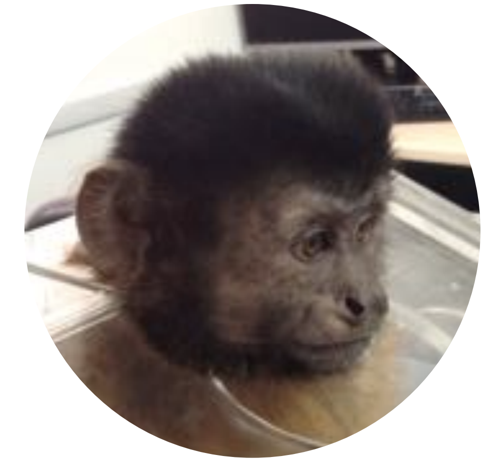
GAMMA OF LFP

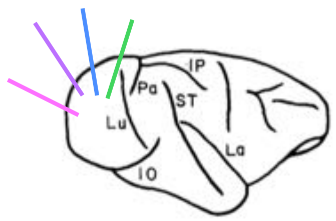
STIMULUS DIRECTION OF MOVEMENT



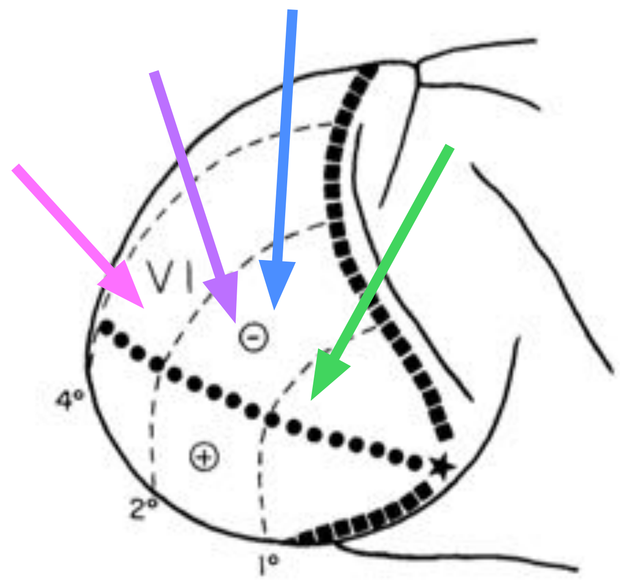
Gamma modulation depends strongly on stimulus properties, such as orientation.

RECORDINGS FROM CAPUCHIN V1

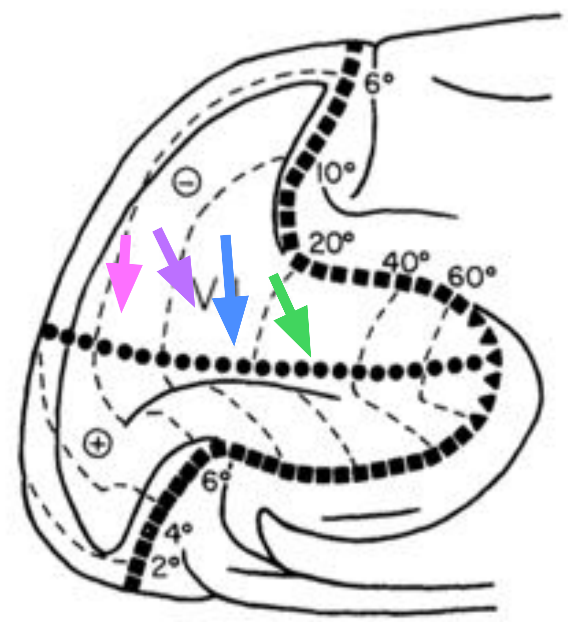




Center

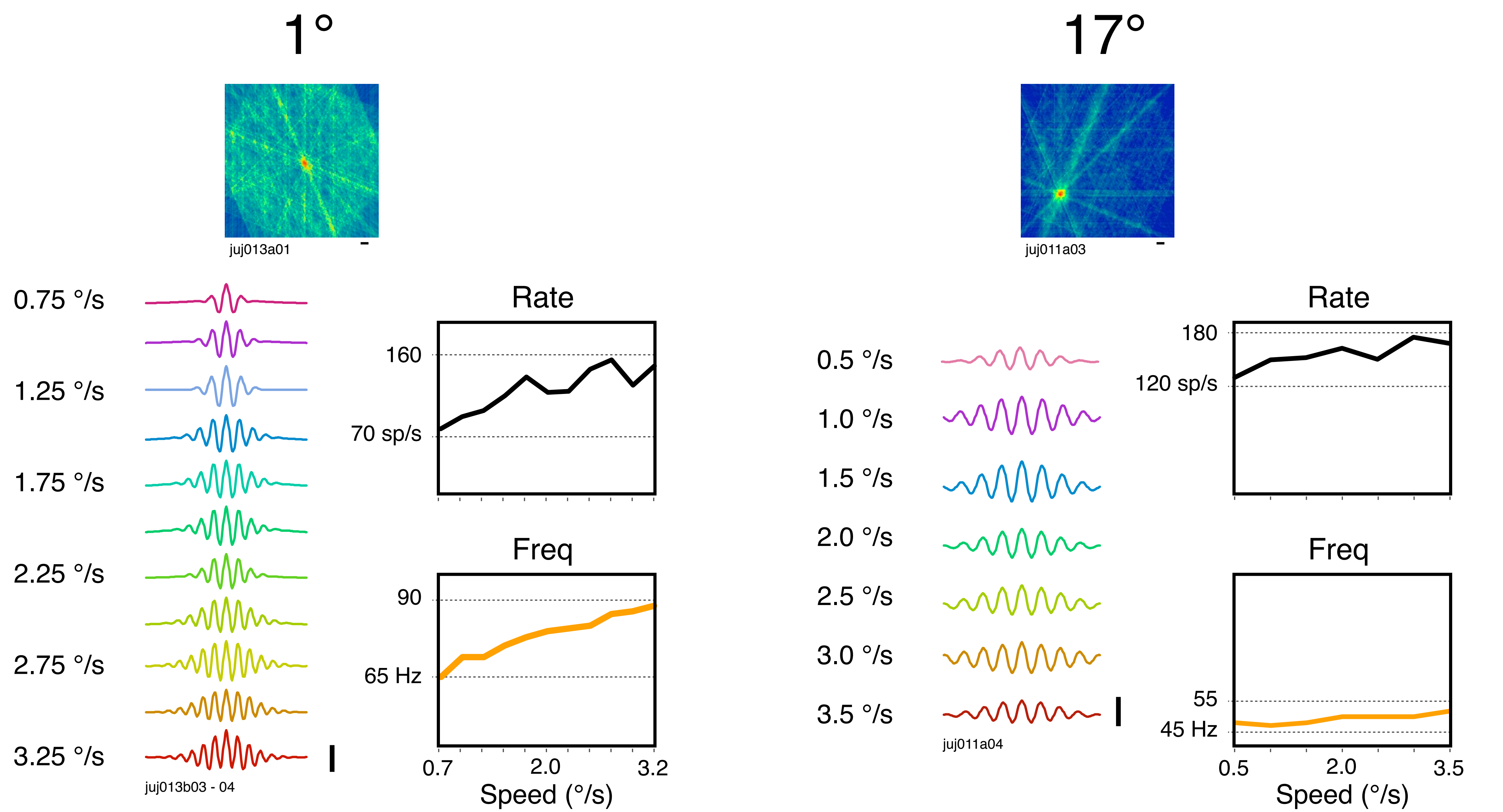


Periphery



CENTER vs. PERIPHERY

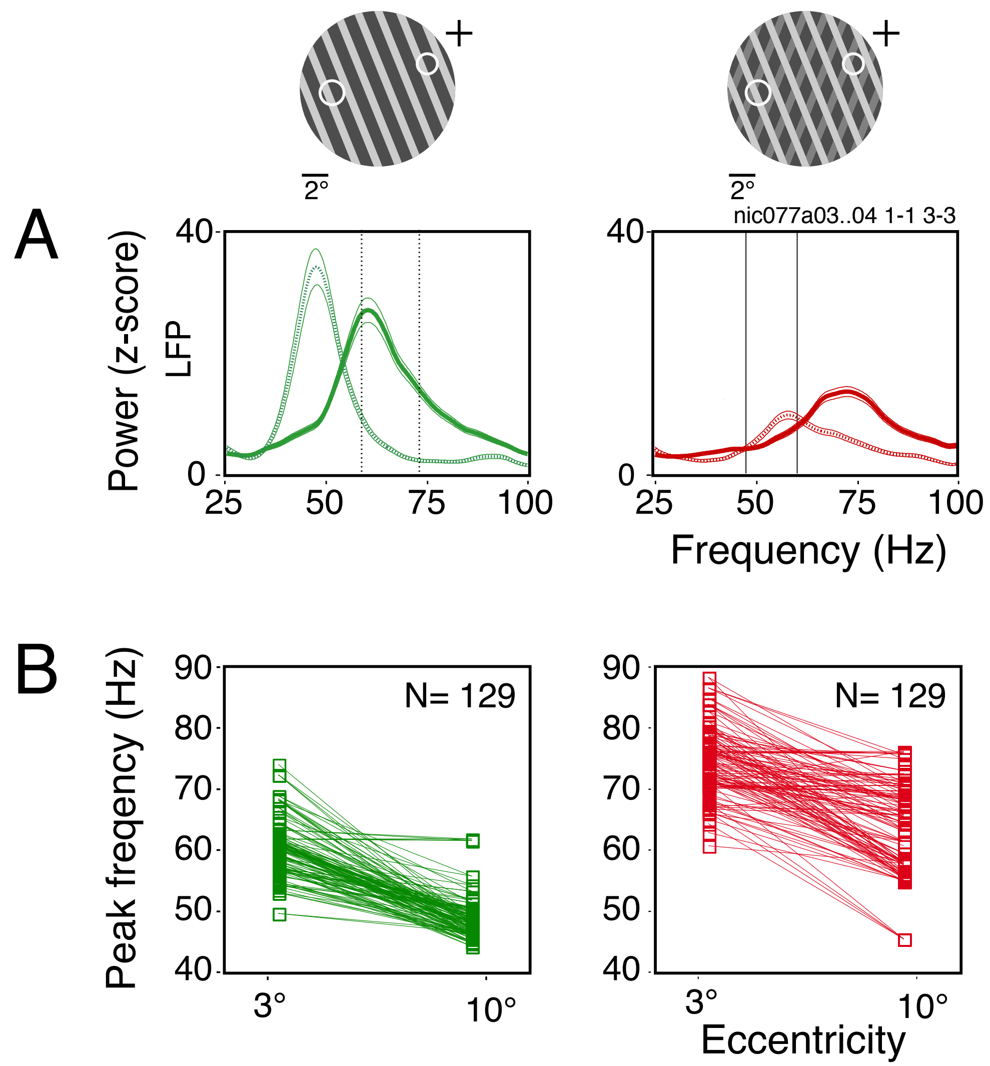
GAMMA FREQUENCY DEPENDS ON SPEED



Gamma oscillation frequency is much high for central representation.

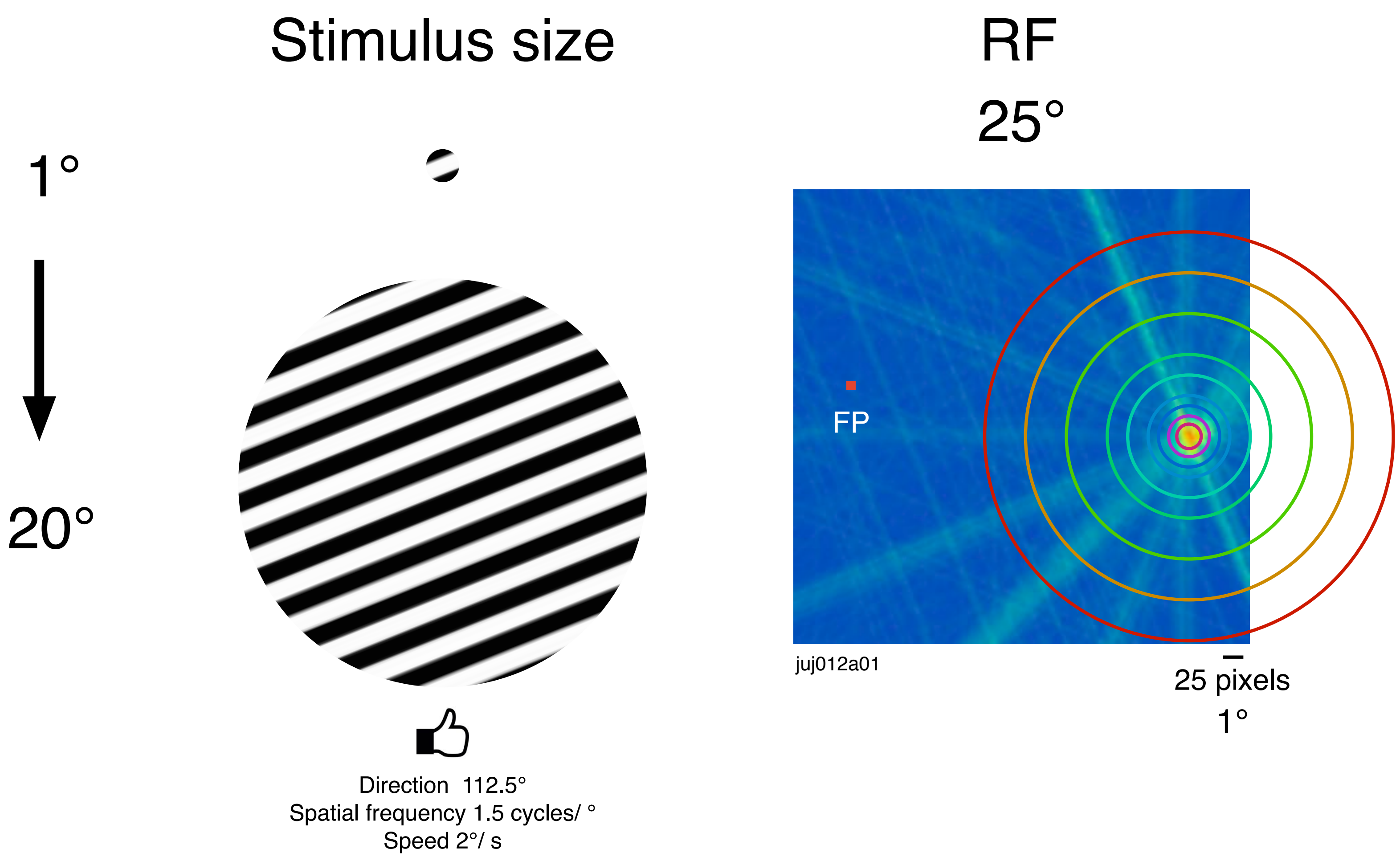
CENTER vs. PERIPHERY

MACAQUE MONKEY

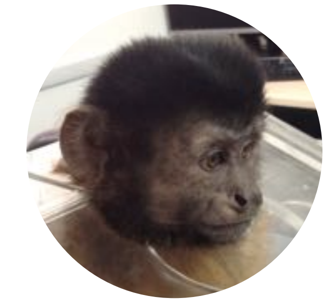


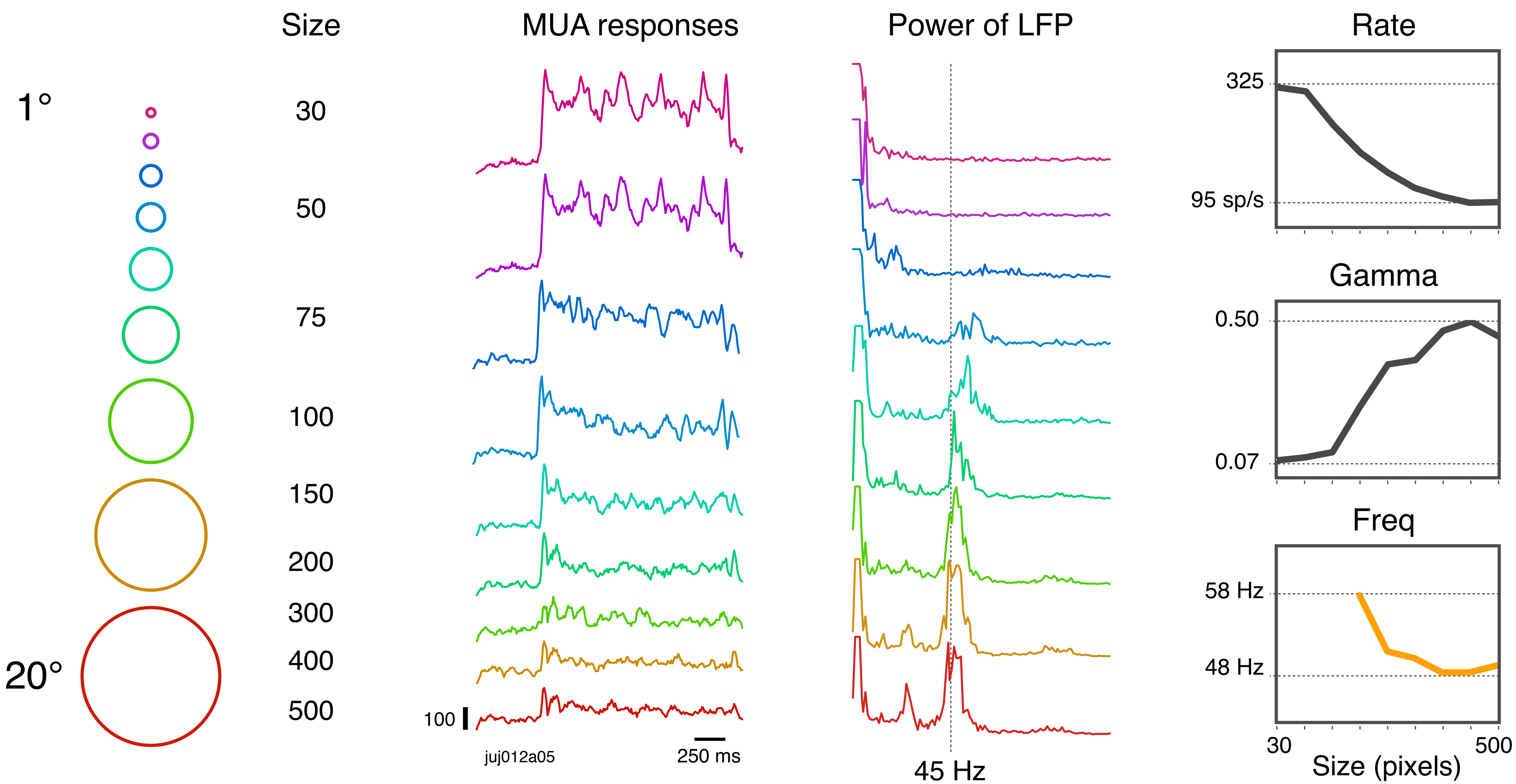
Does gamma oscillation frequency depends on visual map?

LIMA, CHEN, SINGER, NEUENSCHWANDER
CEREBRAL CORTEX, 2010


Stimulus size
RF
25°
1°
20°
FP
juj012a01
25 pixels
1°
Direction 112.5°
Spatial frequency 1.5 cycles/ °
Speed 2°/ s

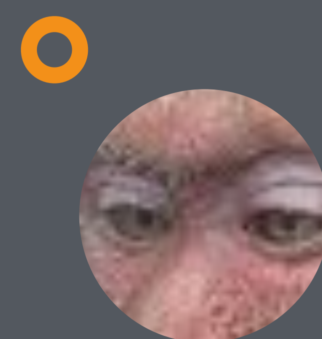
GAMMA DEPENDS ON SIZE





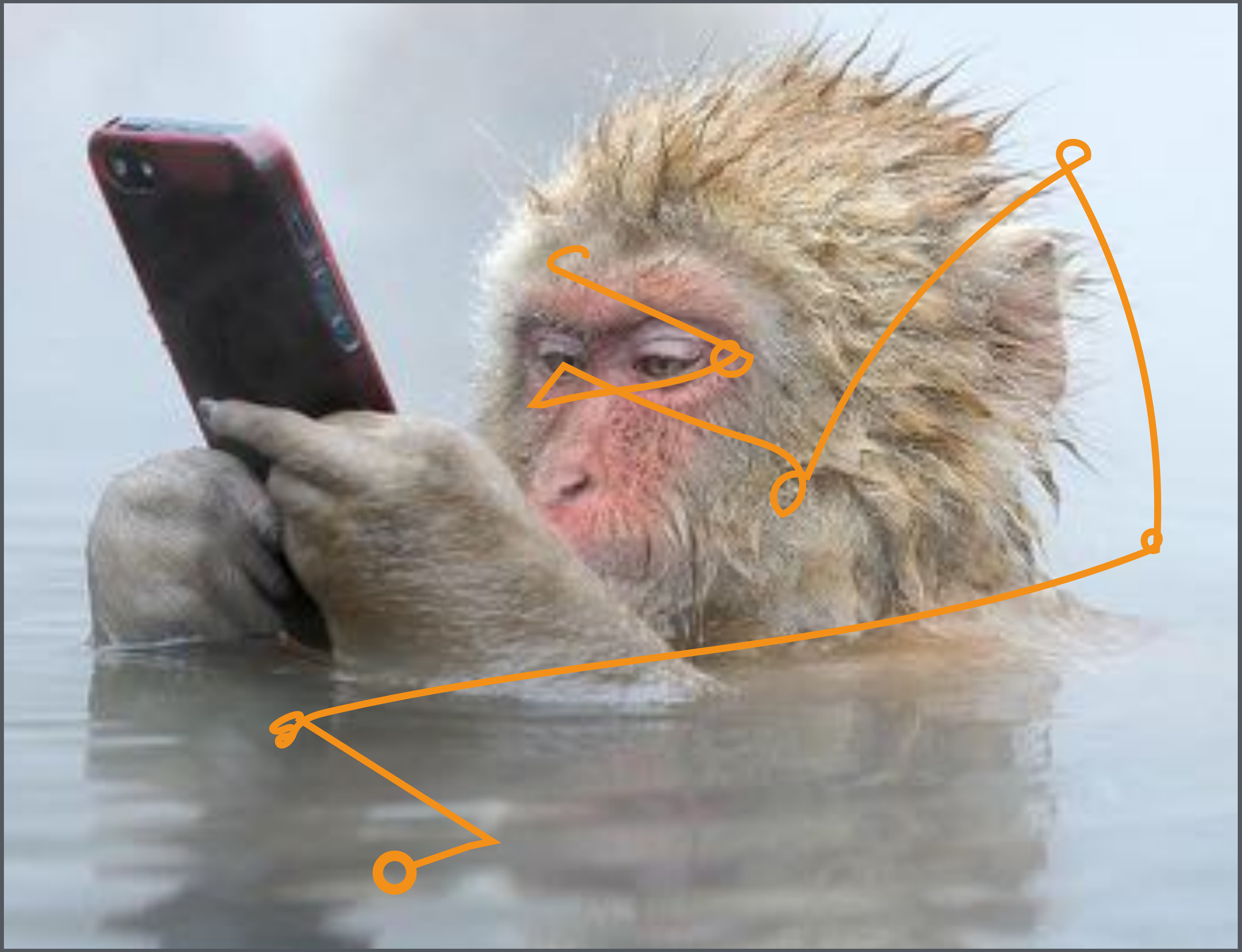
Gamma modulation increases dramatically with stimulus size. Frequency decreases.

FIXATION EPOCH



TRIAL 1

FREE-VIEWING EPOCH

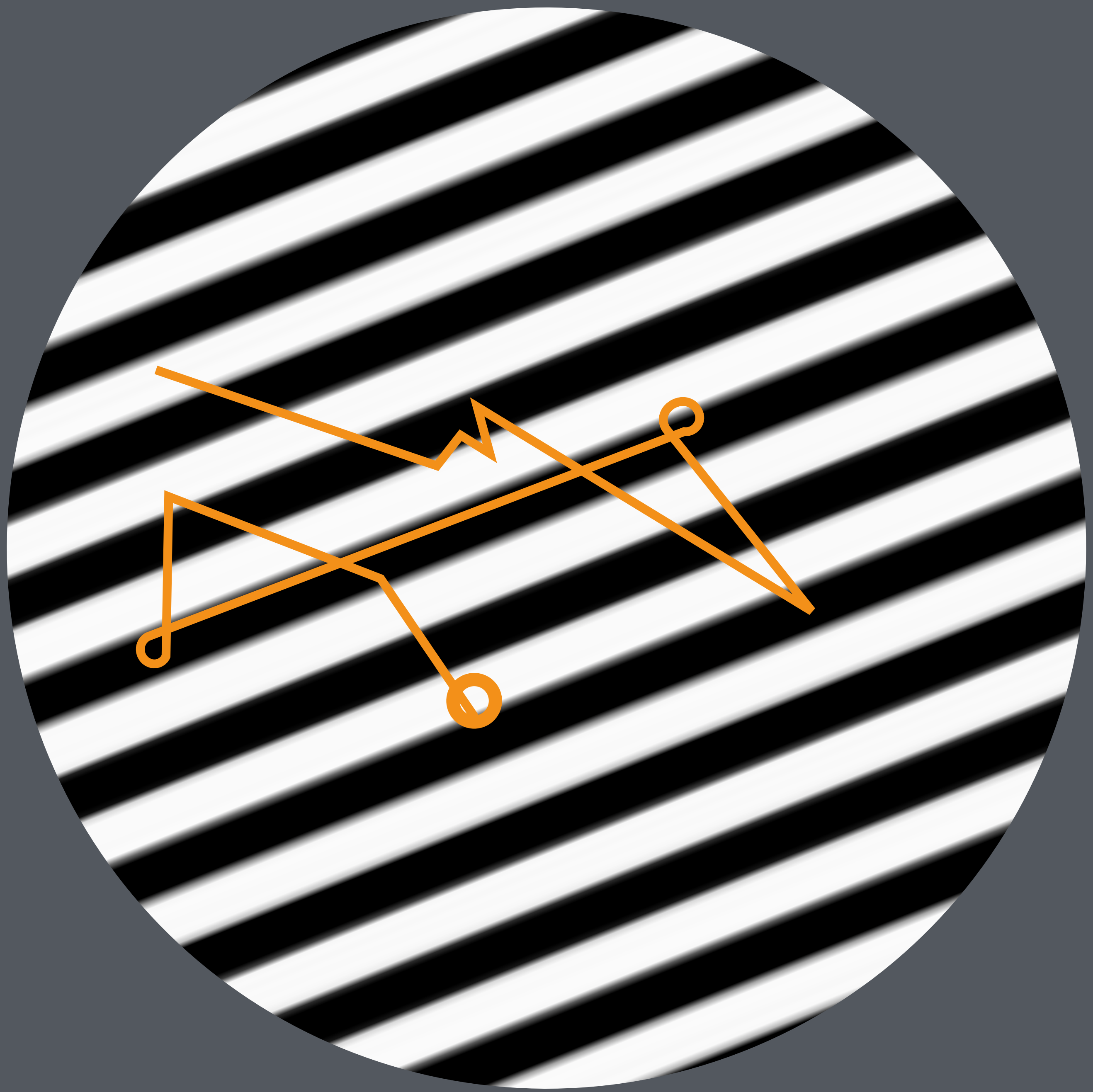


TRIAL 1

FIXATION EPOCH
GRATINGS

TRIAL N

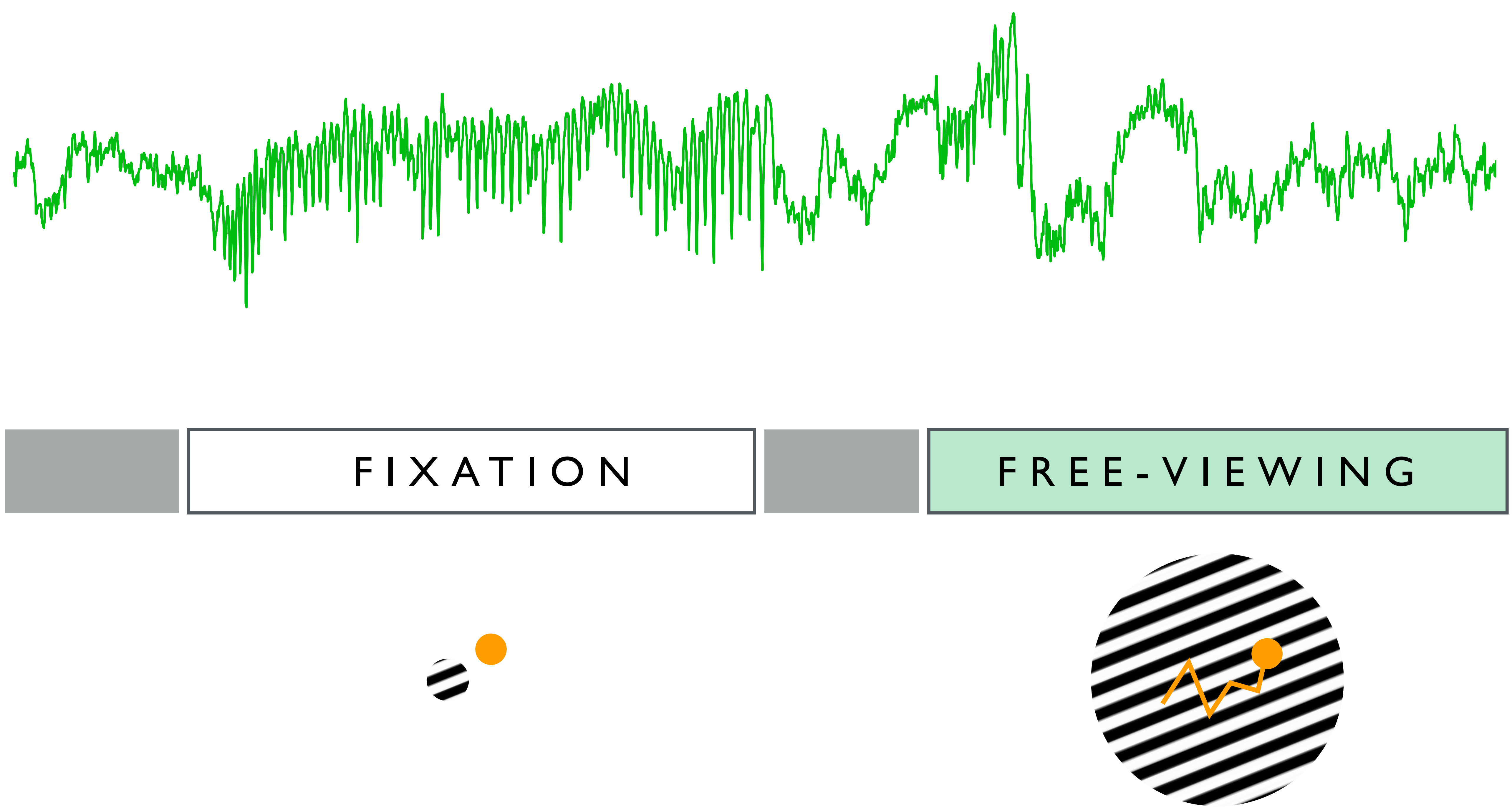
FREE-VIEWING EPOCH
GRATINGS



TRIAL N

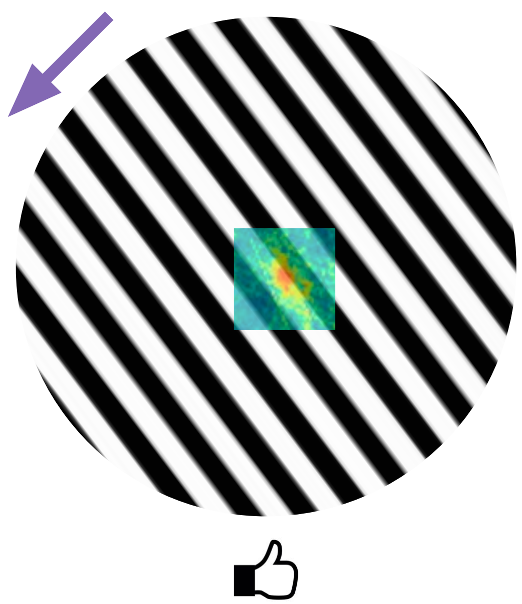
GREAT RESPONSES TO GRATINGS

LFP GAMMA IN CAPUCHIN V1



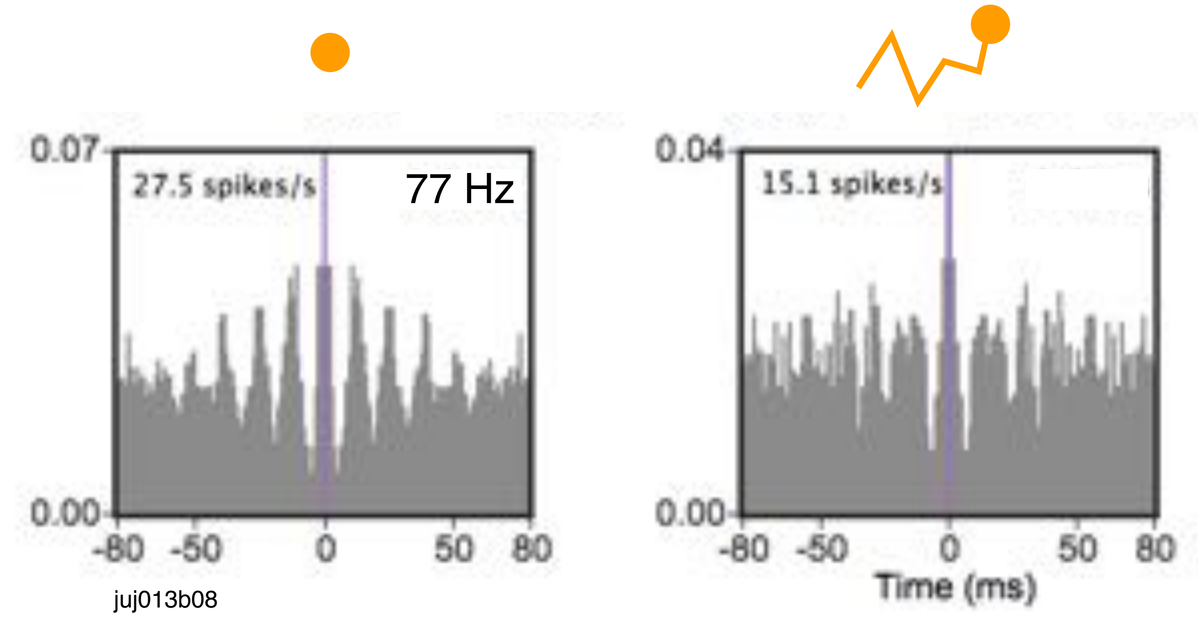
FRO x CORTICAL GAMMA
OSCILLATION FREQUENCY DECREASE

1°



FIXATION

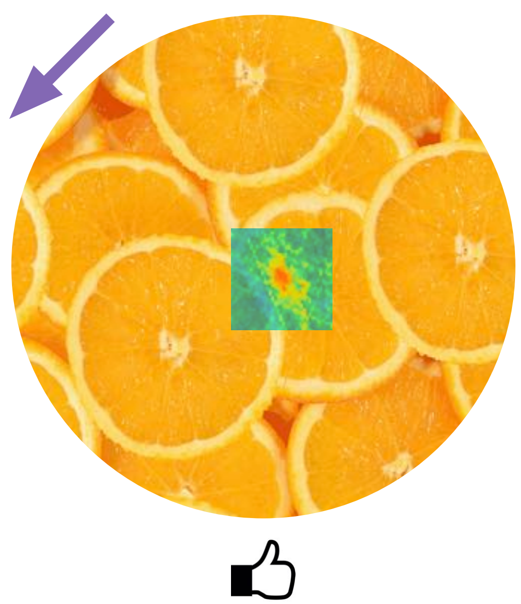
FREE-VIEWING



NATURAL SCENES

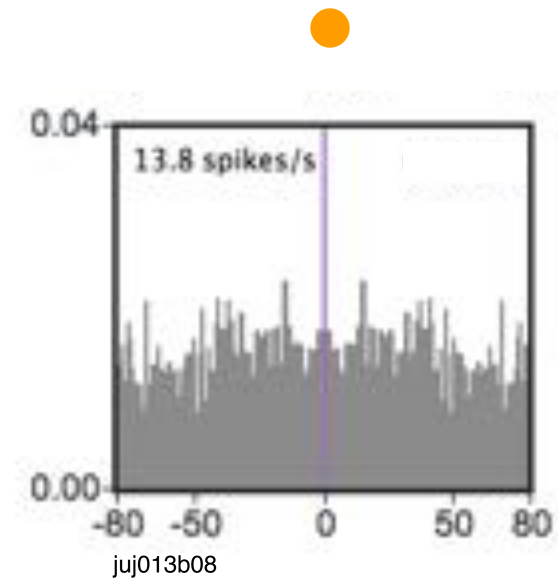
OPTIMAL DIRECTION

1°

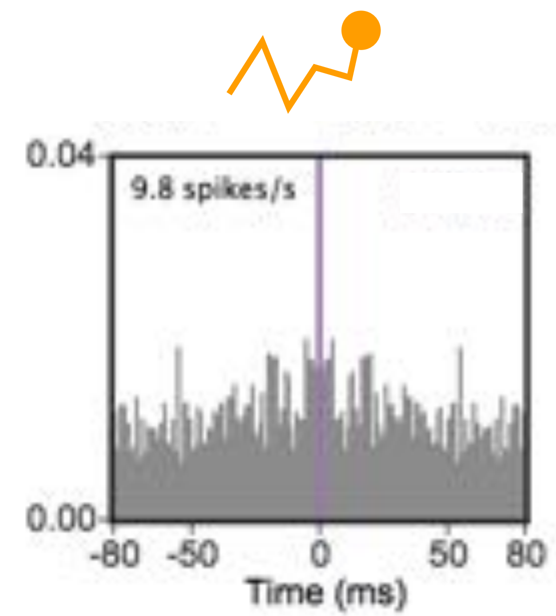


Direction 225°
Speed 2°/ s

FIXATION



FREE-VIEWING



VISLAB

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