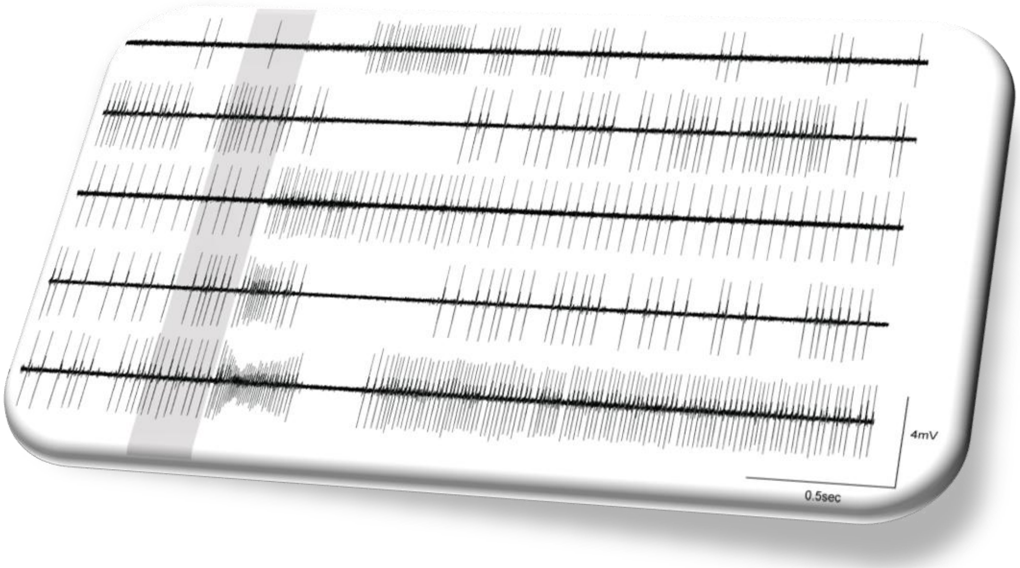
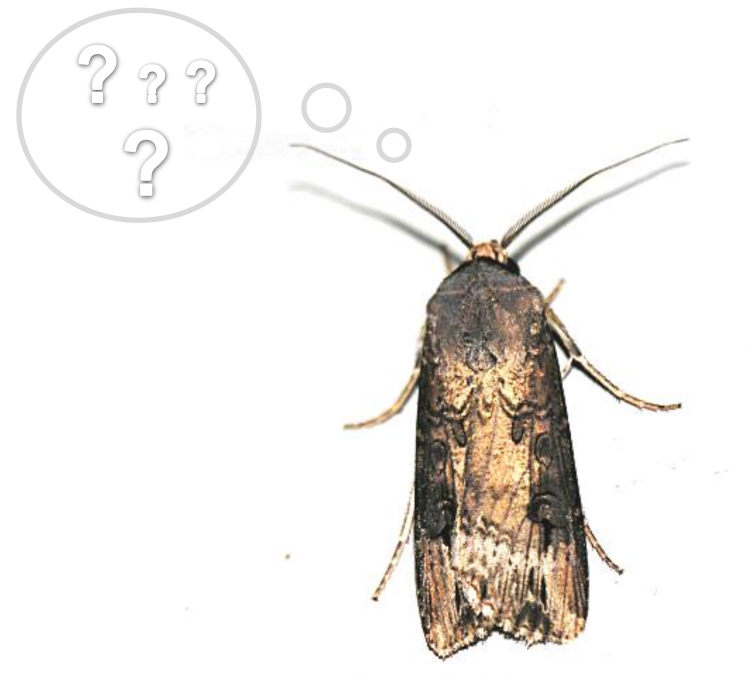
Spike timing precision of MGC neurons

A. Chaffiol, S. Anton, J.-P. Rospars and D. Martinez





Agrotis ipsilon male
(from W. Cook)

INRA
Physiologie de l'Insecte
Signalisation et Communication
VERSAILLES, FRANCE

Spike timing precision of MGC neurons

AIMS

• Describing pheromone sensitive neurons activity
→ stereotyped response patterns ?

• How precise and robust are these responses subtypes ?

• Is the code evolving and how, when pulsed stimulations are applied ?

→ effect on individual neurons (neuron scale precision)

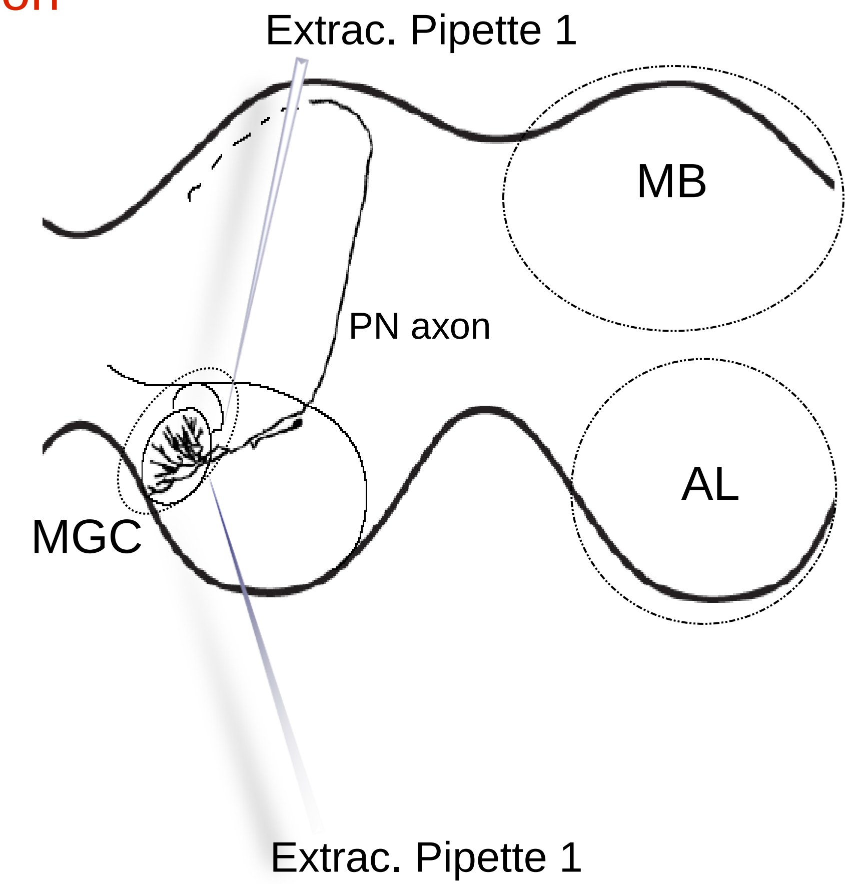
and synchrony (population scale precision) ?

Data acquisition

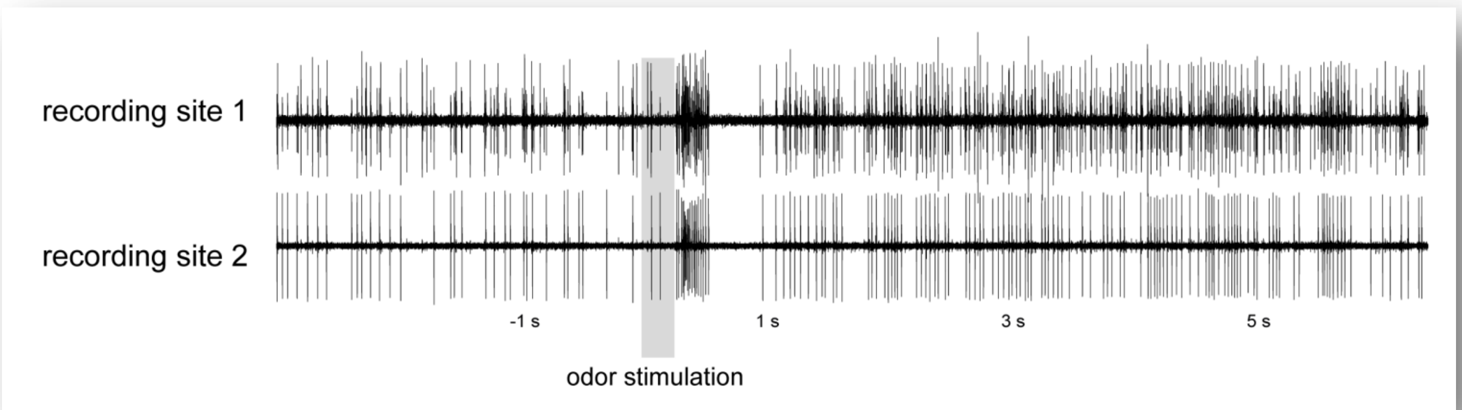
- Insect model: **noctuid moth** *Agrotis ipsilon* males

- MacroGlomerularComplex **extracellular recordings** of neurons sensible to the pheromone

- Long-lasting recordings of small neuron populations (1-5 neurons)



Insect brain and recording technique

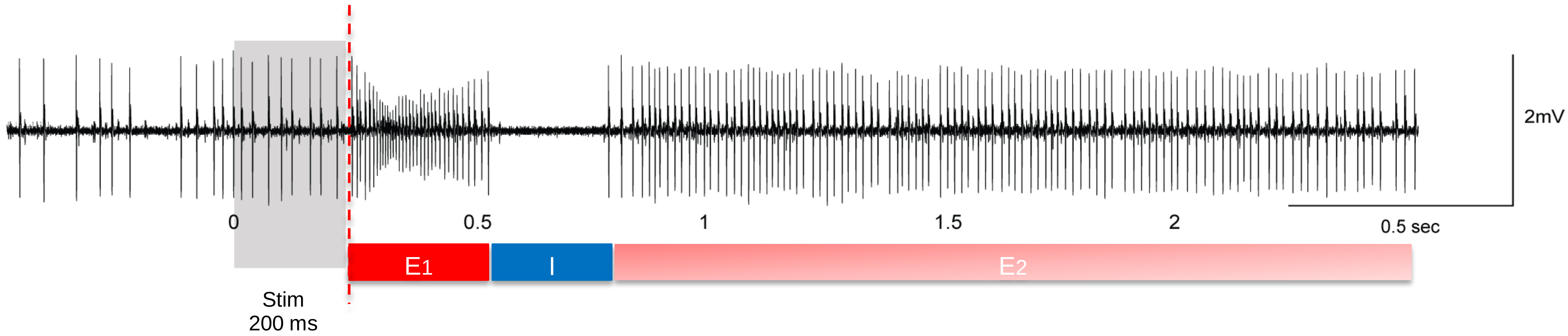


Raw data traces,
2 pipettes
3 neurons

Data analysis

Response segmentation

- Detection of changes between two ISI distributions ('detection of abrupt changes': Basseville and Nikiforov,1993)



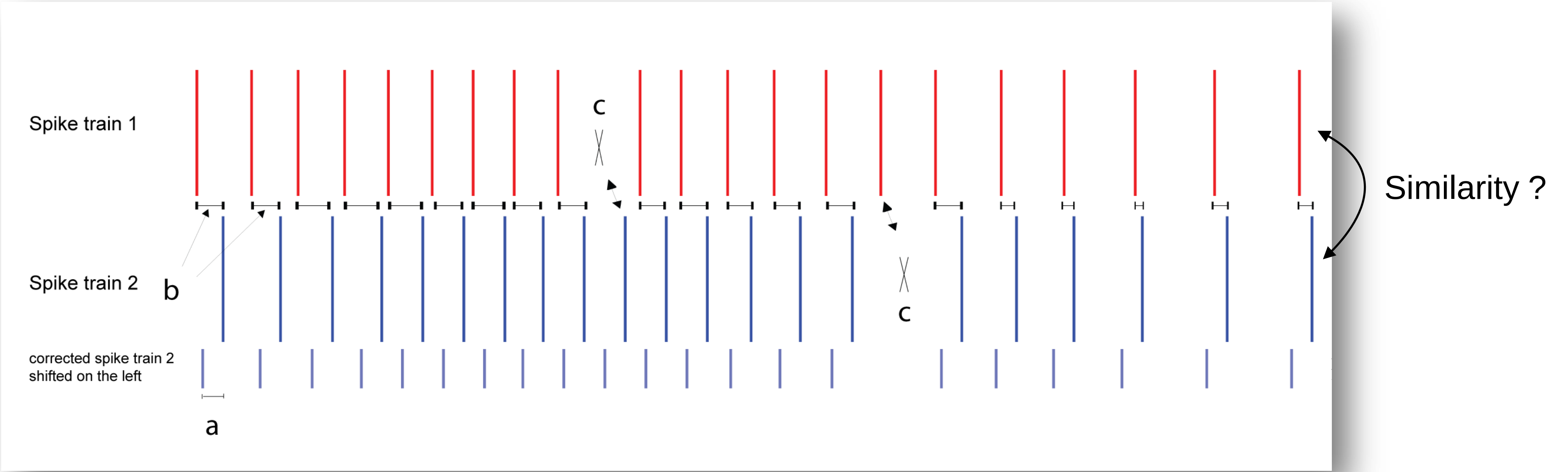
Response parameters

First excitatory phase latency	E1 latency	ms
First excitatory phase duration	E1 duration	ms
Time of last excitatory phase event	Time of E1 last event	ms
Inhibitory phase duration	I duration	ms
First excitatory phase mean frequency	E1 mean freq	spikes/sec
First excitatory phase max frequency	E1 max freq	spikes/sec
Post-inhibitory phase mean frequency	**Post I mean freq**	Spikes/sec
First excitatory phase spike count	Spike count	spike nb

Timing precision analysis
=
Quantification of spike trains homology

- Stochastic Event Synchrony (SES) algorithm from J.Dauwels (2007)

Ex: 2 repeated trials from 1 MGC neuron (E1 phase comparison)



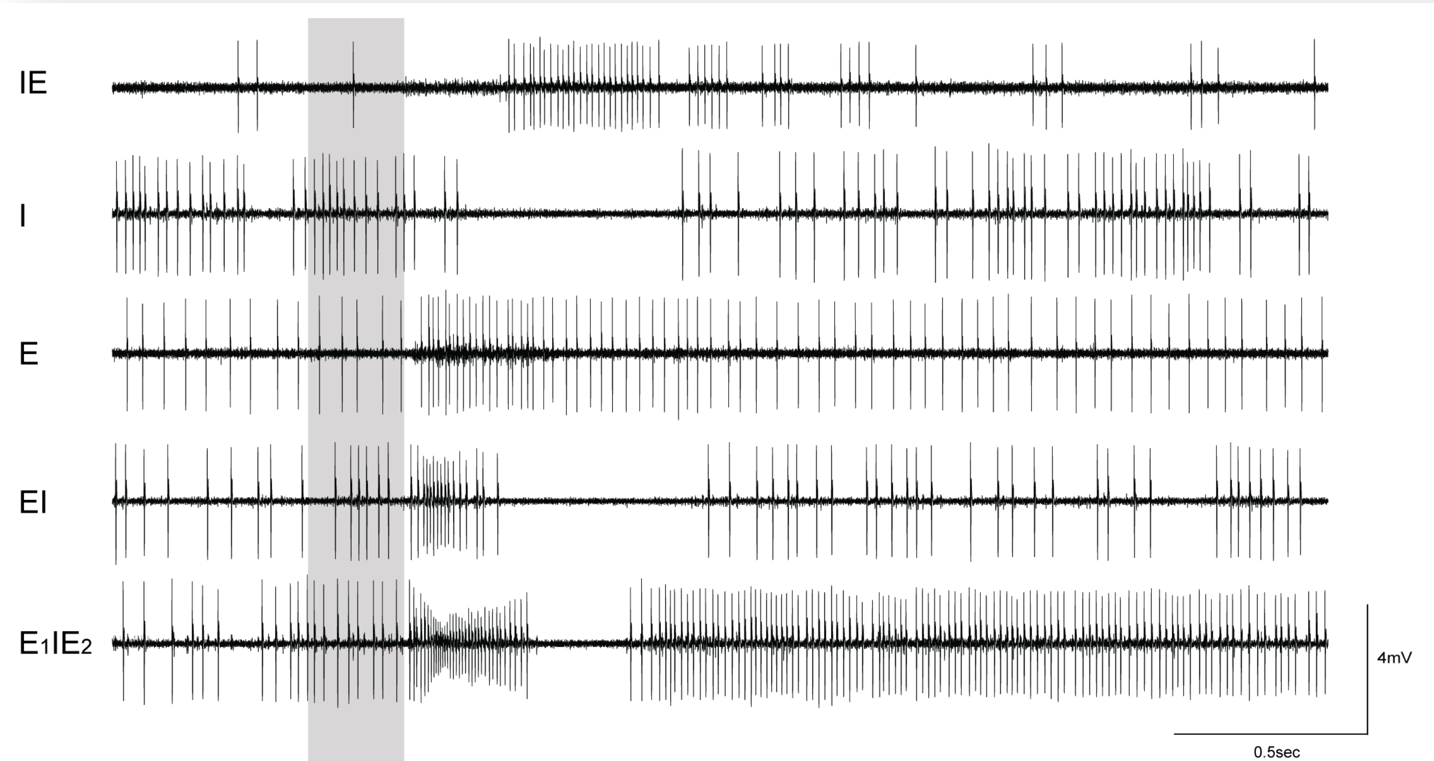
→ How similar are these spike trains ? : 3 timing precision parameters

- Global time shift (a, in msec)

- Spike jitter (b, in msec, mean value calculated over all spike pairs)

- Robustness parameter (c, probability p to loose / add spikes)

Pheromone response patterns



Inhibition/excitation (I/E)	1.7%
Inhibition (I)	3.3%
Excitation (E)	23.3%
<u>Excitation/inhibition (E/I)</u>	**<u>25%</u>**
<u>Excitation/inhibition /excitation (E1/I/E2)</u>	**<u>46.7%</u>**

Response patterns variability

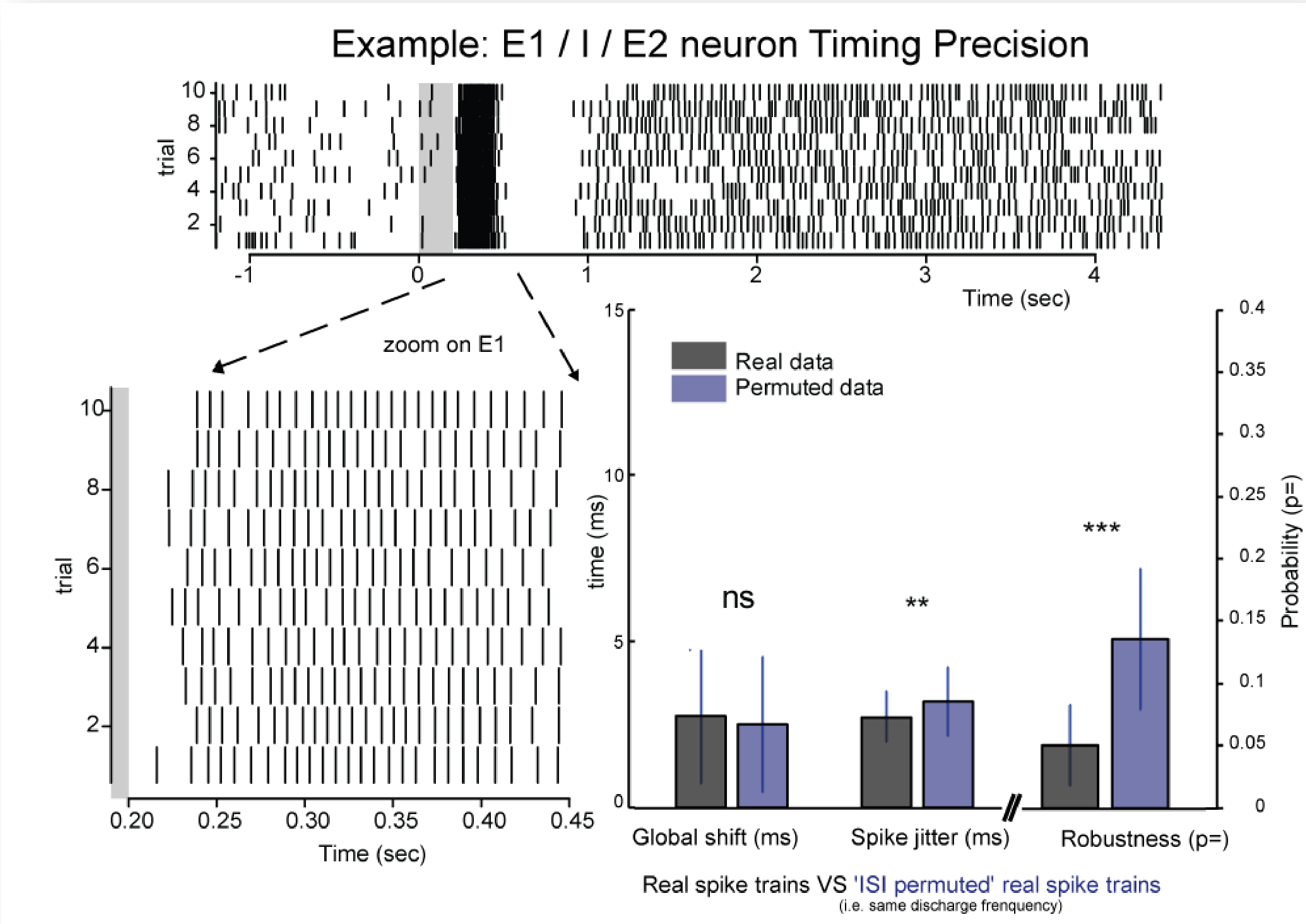
n=60 neurons stimulated with the pheromonal blend at c=1ng

Timing Precision Analysis

I. At the individual neuron level

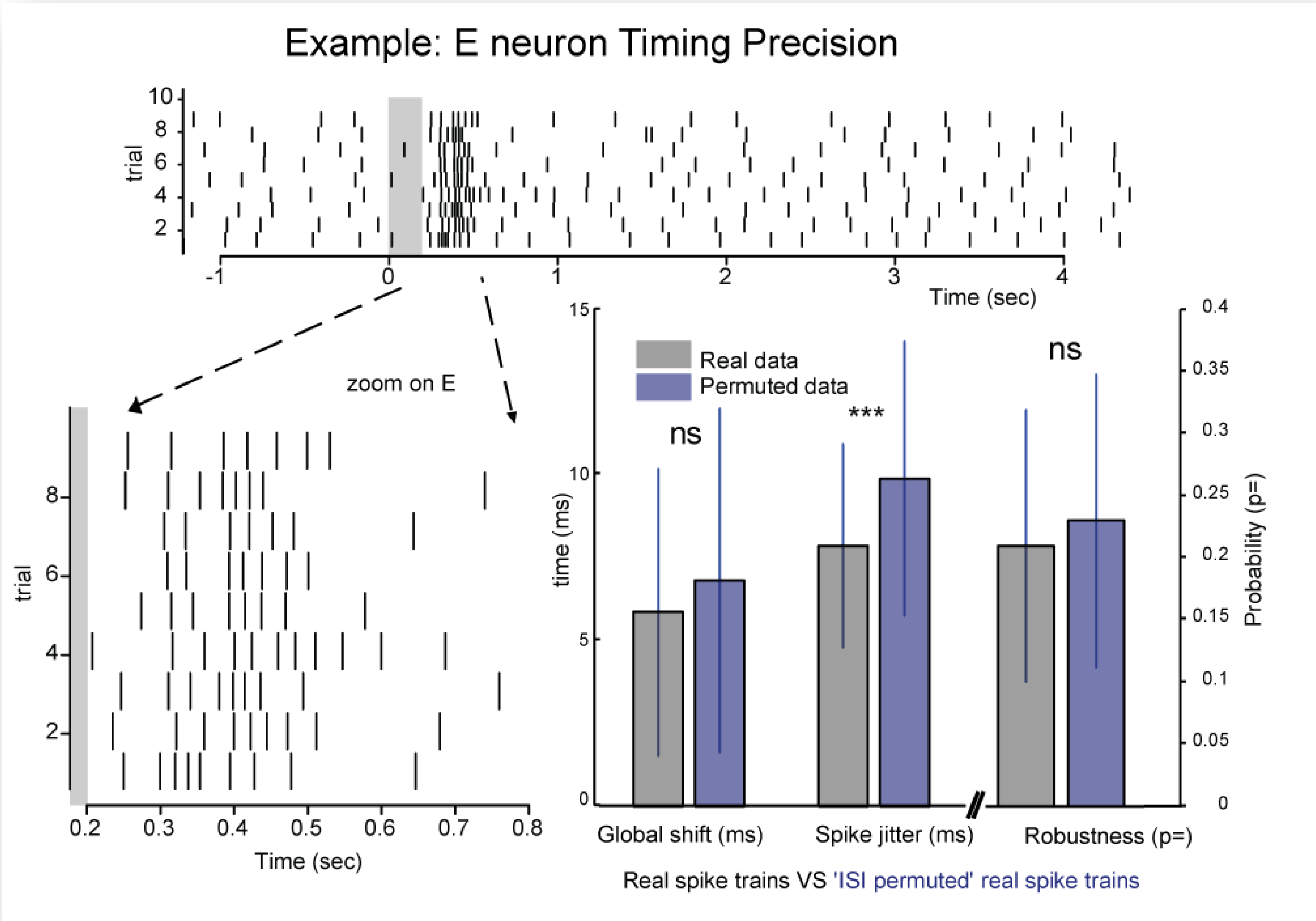
Timing Precision Analysis

reliability of spike sequences with the two main neurons subtypes E1/I/(E2) and E



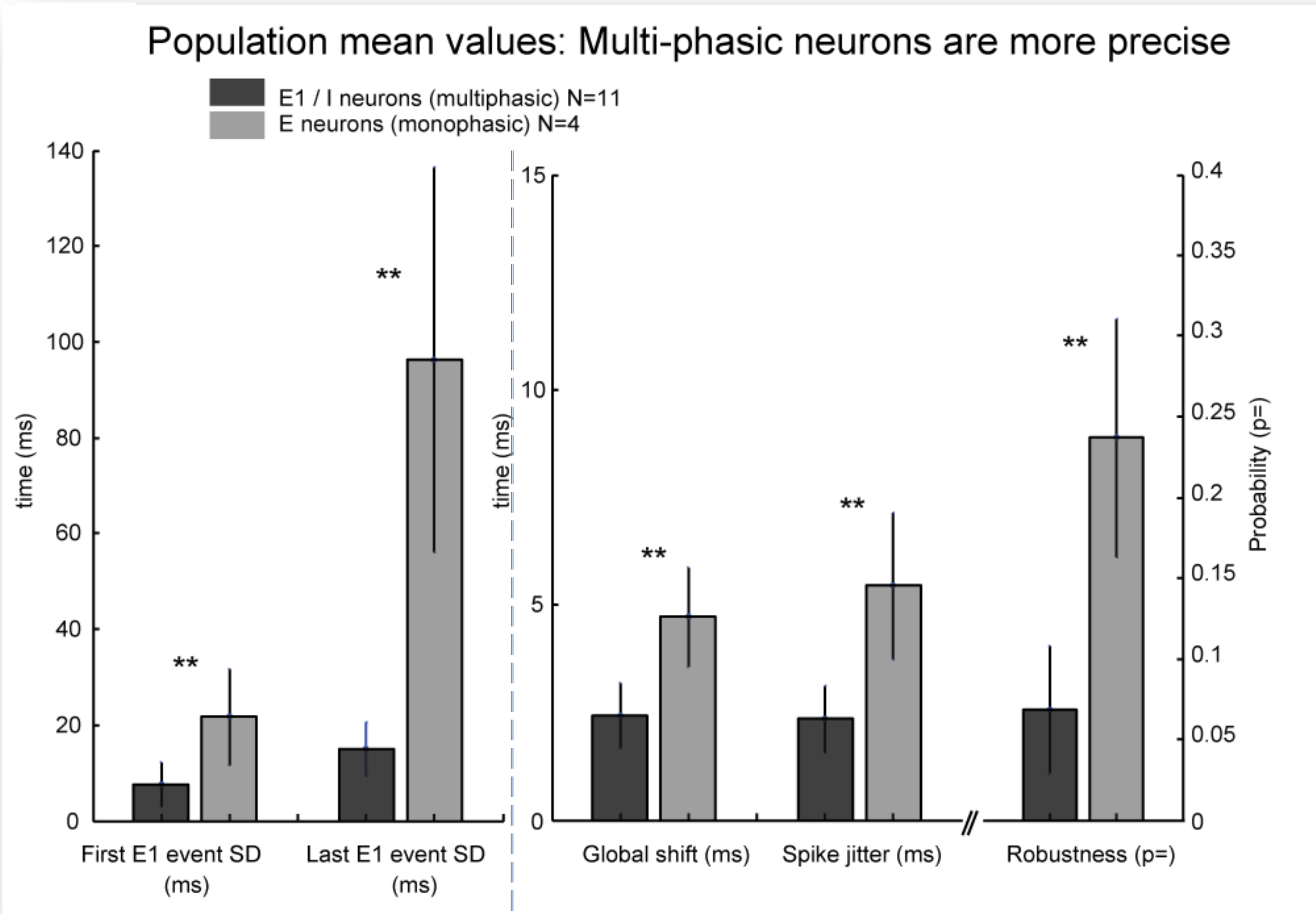
Timing Precision Analysis

reliability of spike sequences <u>with the two main neurons subtypes E1/I/(E2) and E</u>



Timing Precision Analysis

reliability of spike sequences <u>with the two main neurons subtypes E1/I/(E2) and E</u>



= Response **boundaries** precision

= Response **spike trains** precision

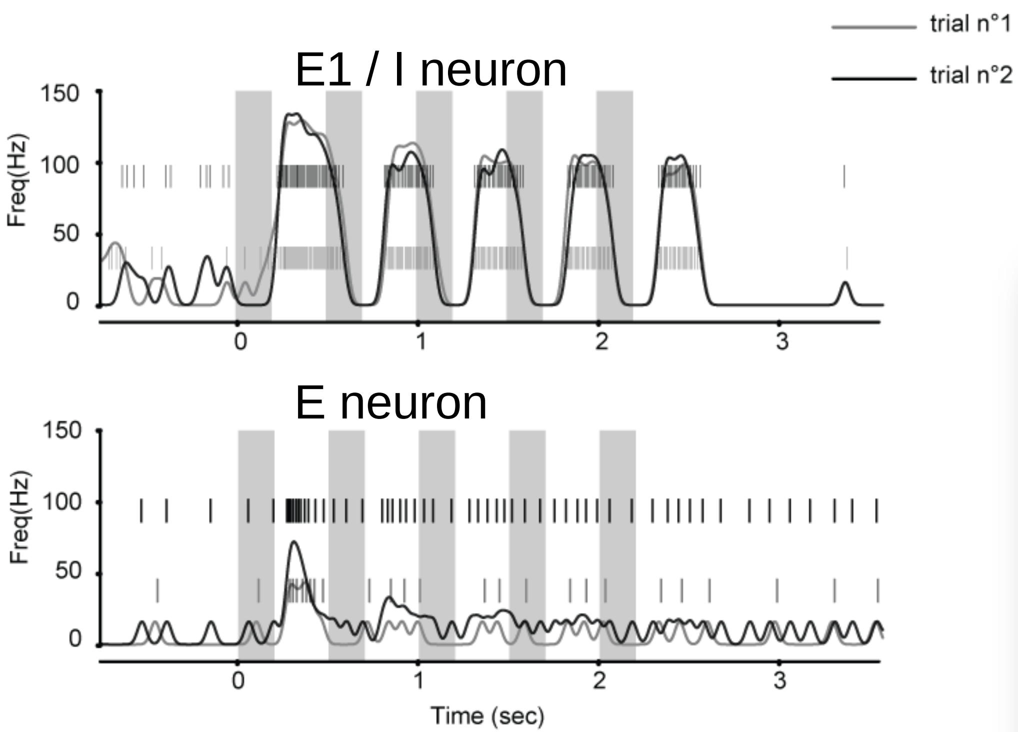
⇩

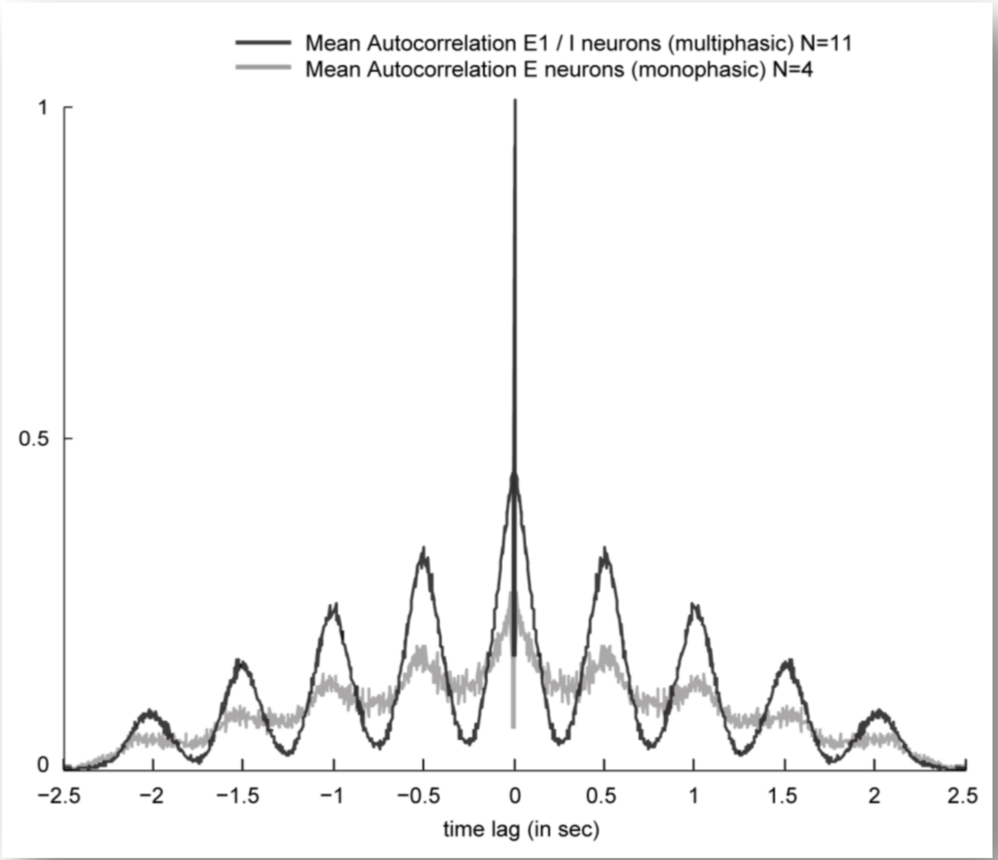
Clear difference

But if we normalize these 3 parameters, only the neuron <u>robustness</u>/mean(permuted robustness) remains significative

Timing Precision Analysis

Pulsed stimulations with the two main neurons subtypes E1/I/(E2) and E





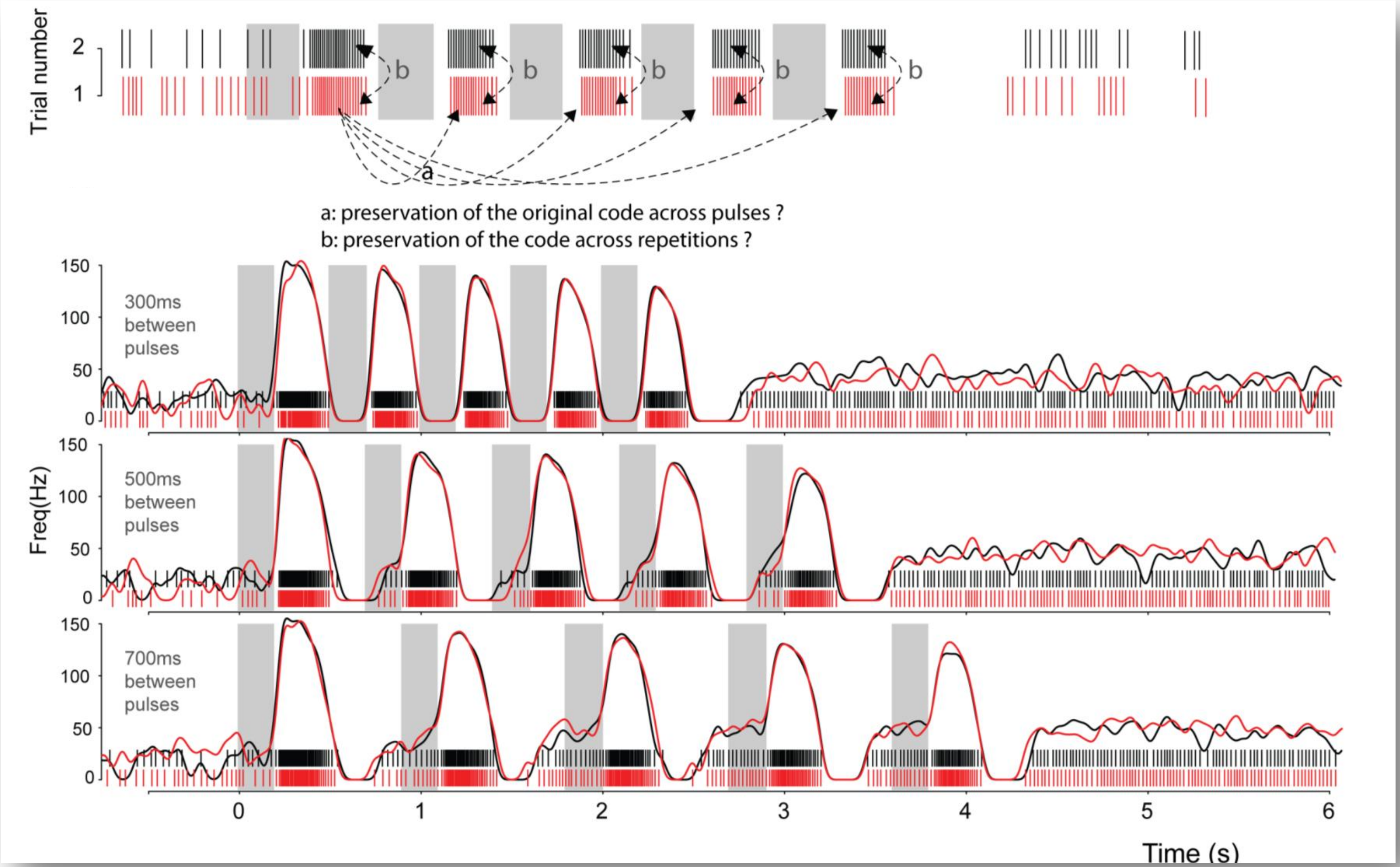
E1 / I neurons, E neurons
and pulsed stimulations

With 5x200ms, inter stim interval 300ms

→ Only multiphasic neurons can follow

Timing Precision Analysis

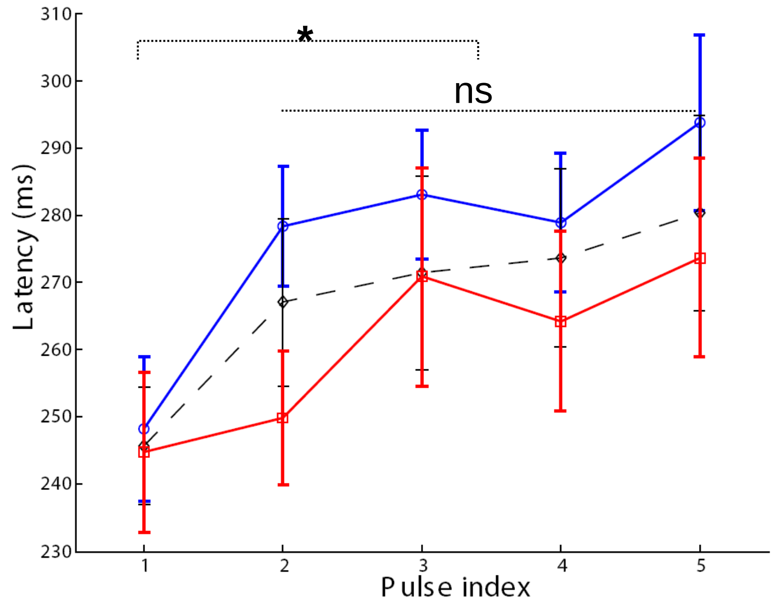
Pulsed stimulations and multiphasic neurons

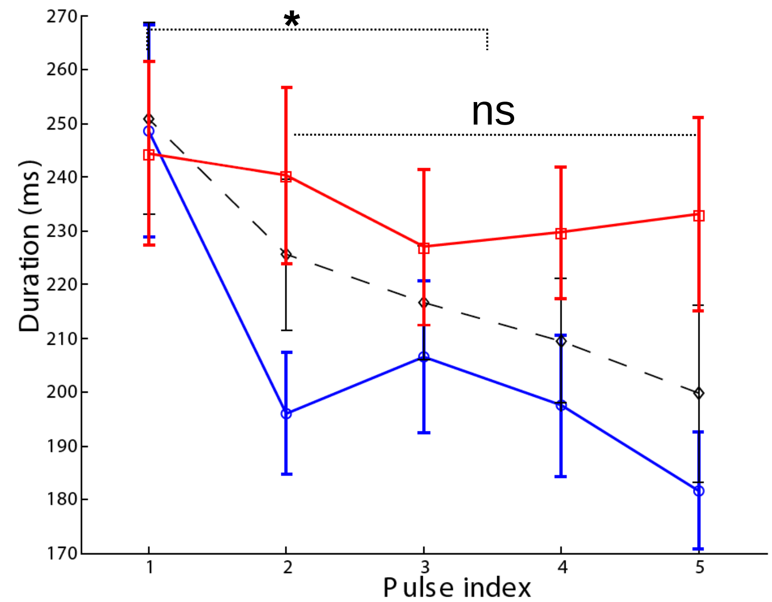


Ex: 1 neuron, 5 pulses with an inter stimulus duration of 300, 500 or 700 ms. Raster plots and firing frequencies (trial 1:red, trial 2:black)

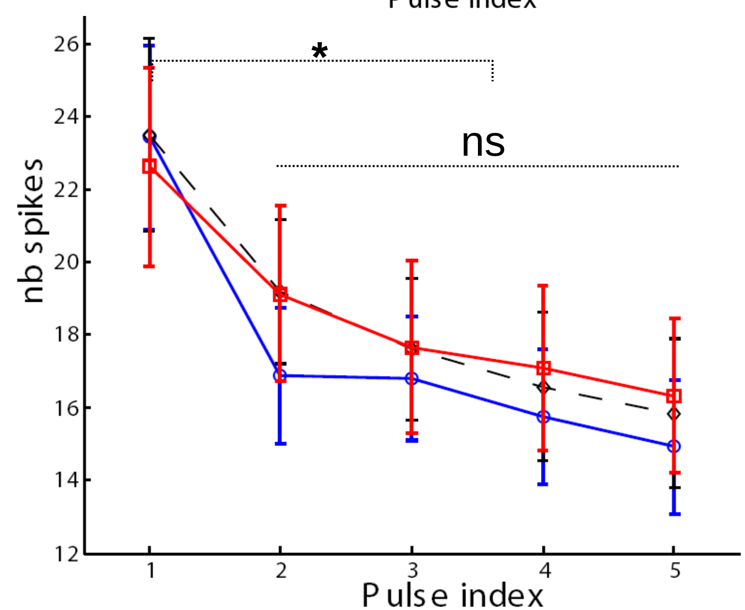
Effect of pulsed stimulations and time-interval between pulses on the response patterns ?

1. Effect on responses E1 latency, duration & spikes number





n=12



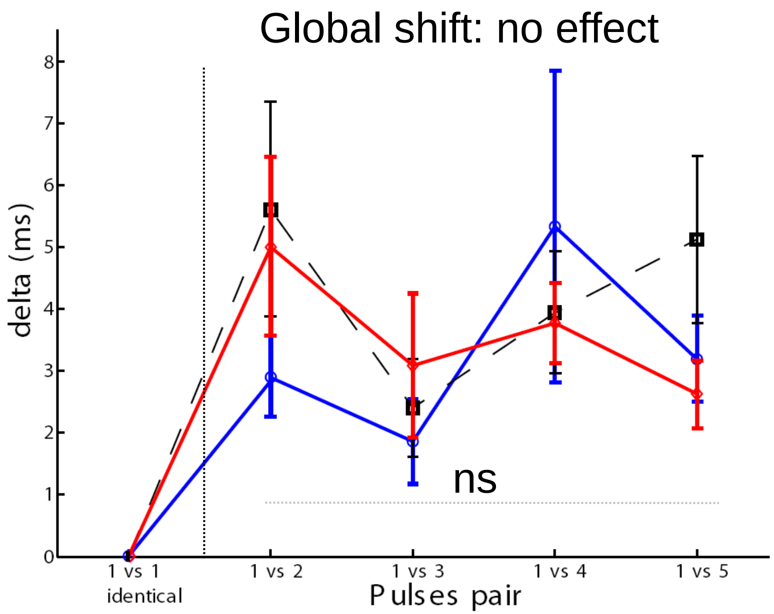
: 300ms
: 500 ms
: 700 ms

Interval between 2 pulses

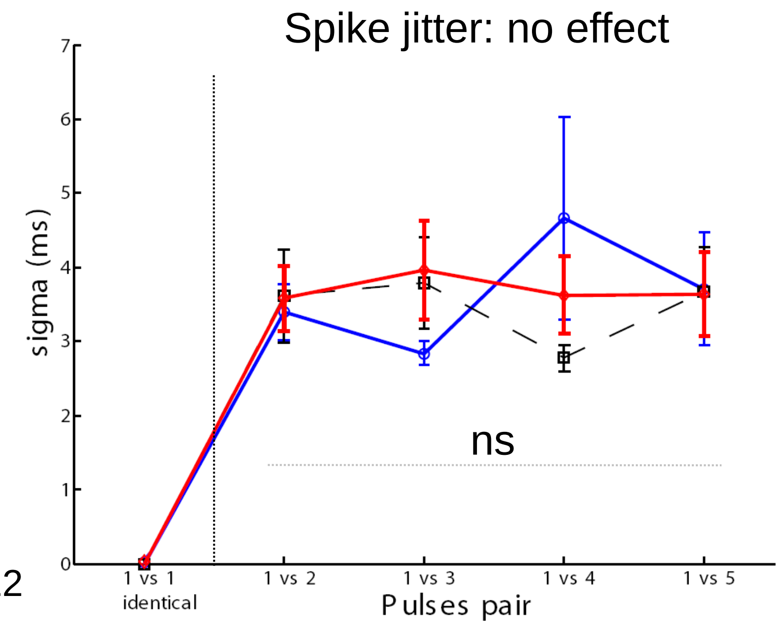
Three pulsed stimulations protocols

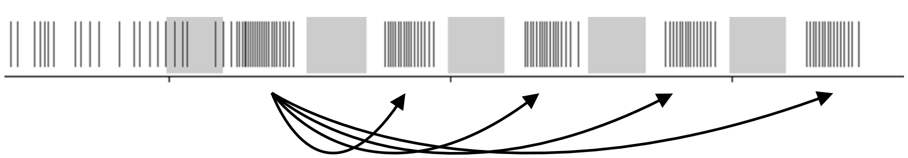
→ A significant effect for all parameters can be observed but only between pulse n°1 and the 4 others
And especially with Shorter inter stimulus intervals (blue curve)

2. Effect on ‘intra-series’ timing precision

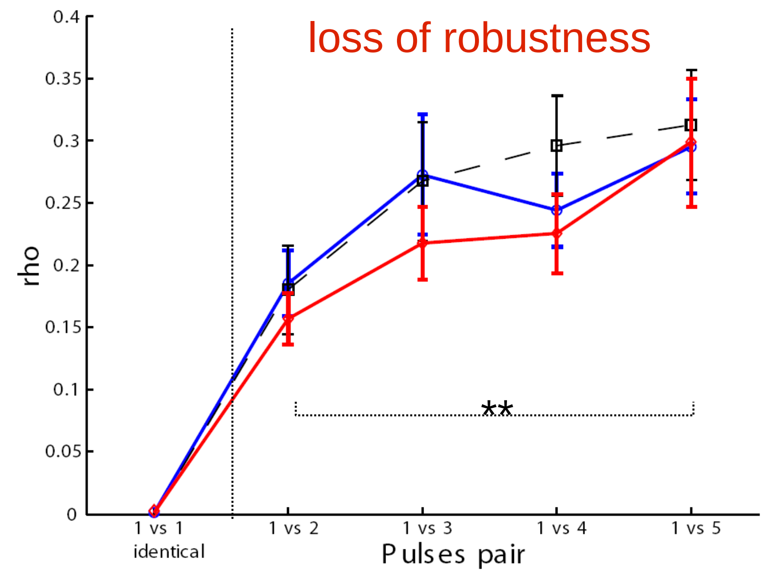


n=12





With pulse n°1 response as reference

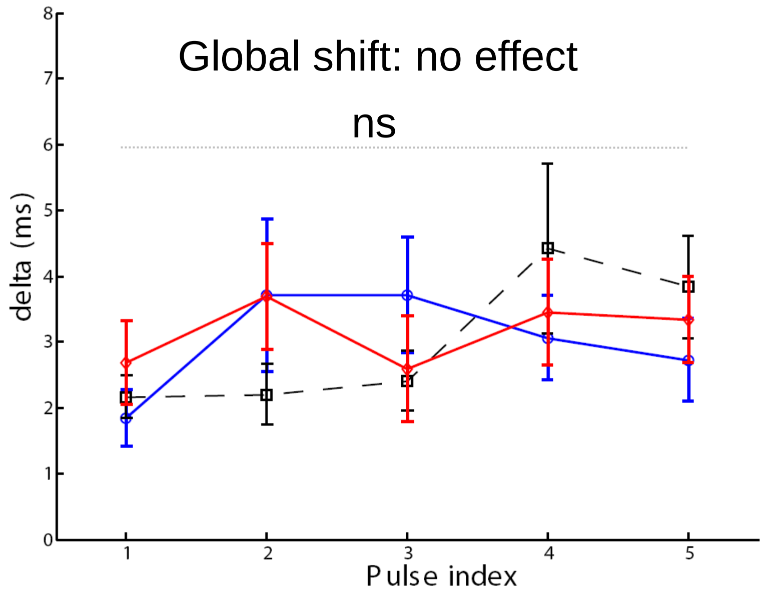


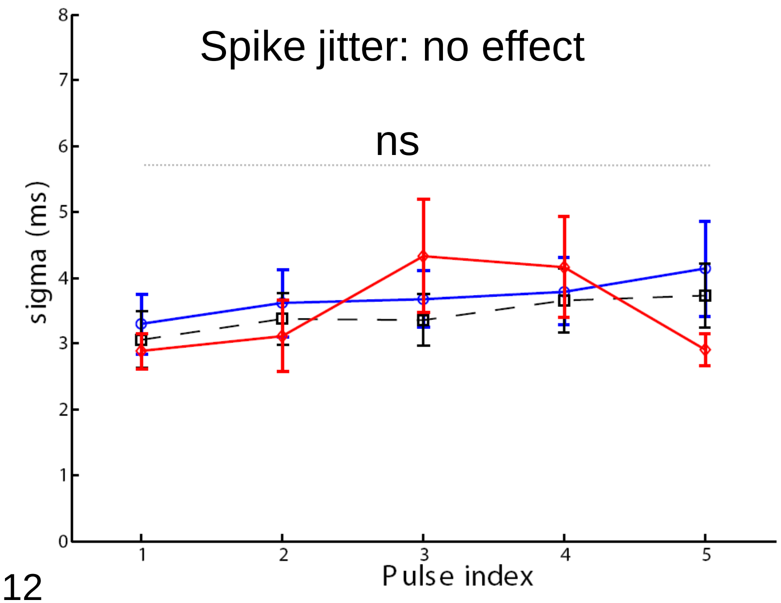
: 300ms
: 500 ms
: 700 ms

Interval between 2 pulses

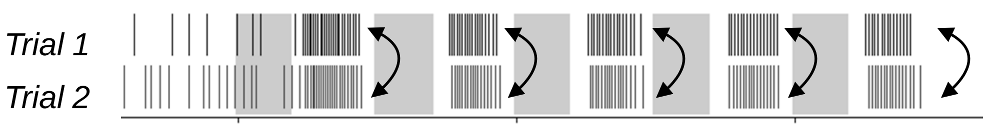
→ A high homology degree is kept between successive spike trains (jitter 3-4 ms)
→The loss of robustness is directly linked to the slight loss of spikes across pulses (adaptation)

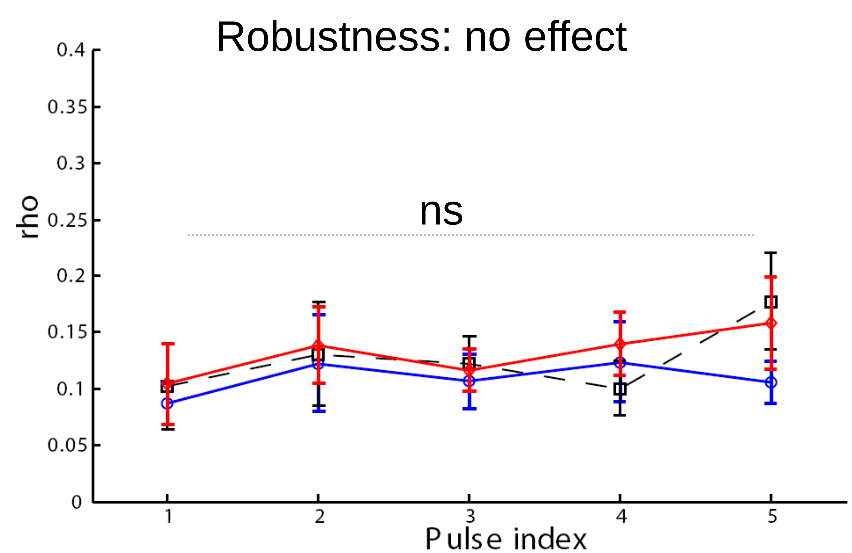
3. Effect on ‘inter series’ timing precision

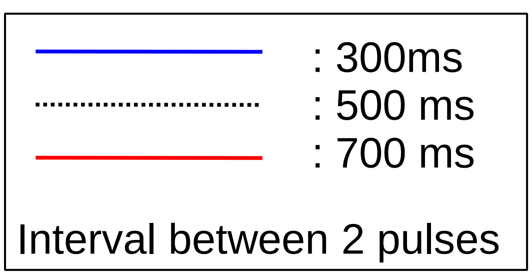




n=12





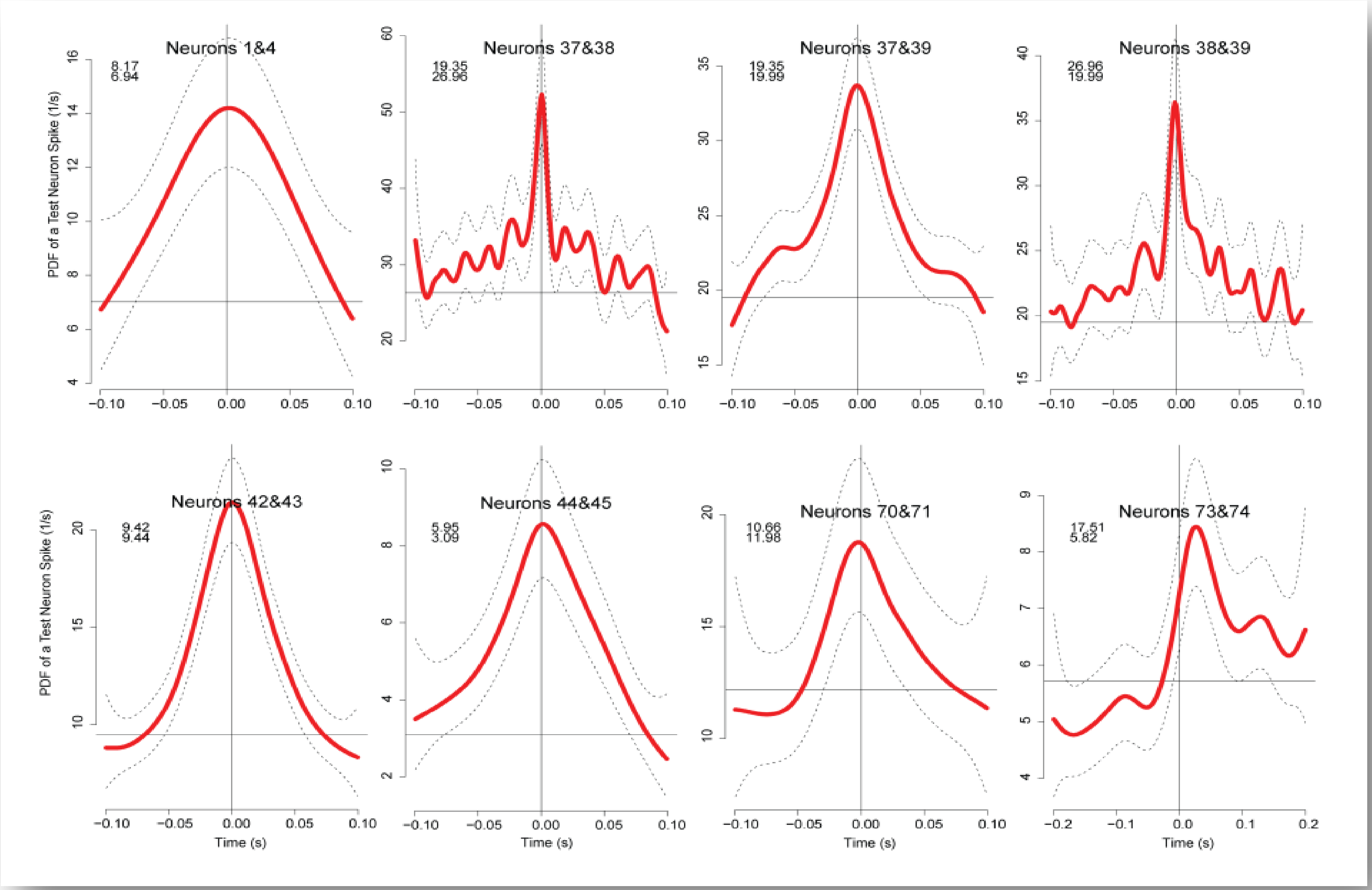


→ A high homology degree is kept between trials (pairwise comparison of 2 trials / neuron) from the first pulse to the last one

Timing Precision Analysis

II. At the population level

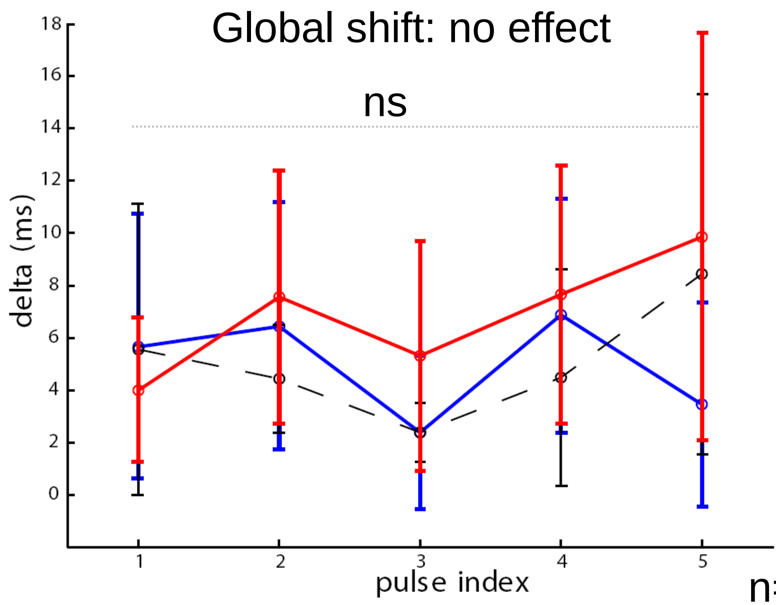
Timing Precision Analysis
Evidence of correlated spontaneous activity in MGC neurons

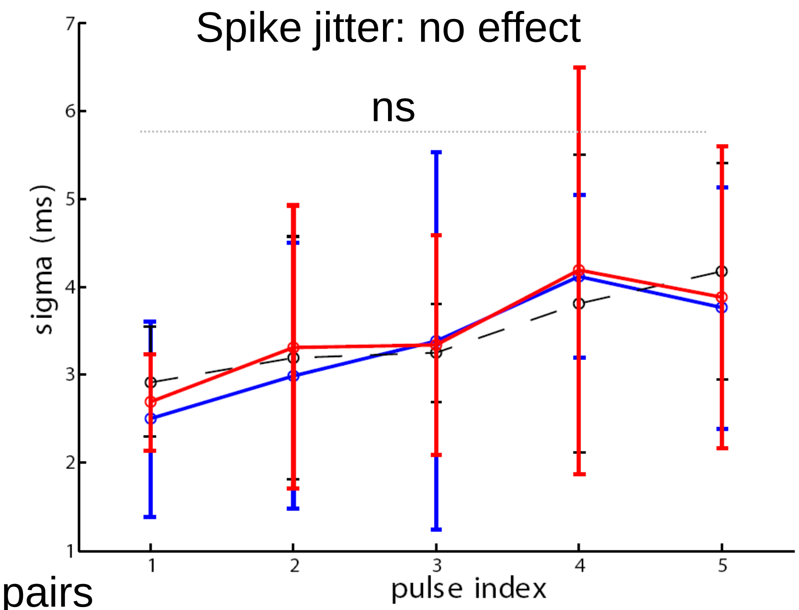


Cross-correlations analysis between simultaneously recorded neurons (n=8pairs)

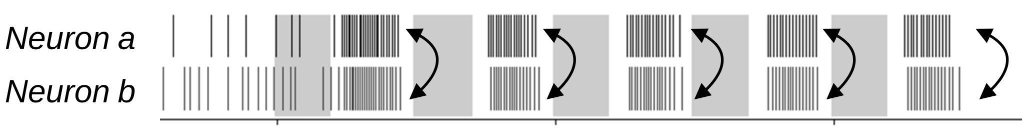
→CC analysis reveals **positive correlations during spontaneous activity**
Moreover all these neurons are E1/I (/E2) neurons

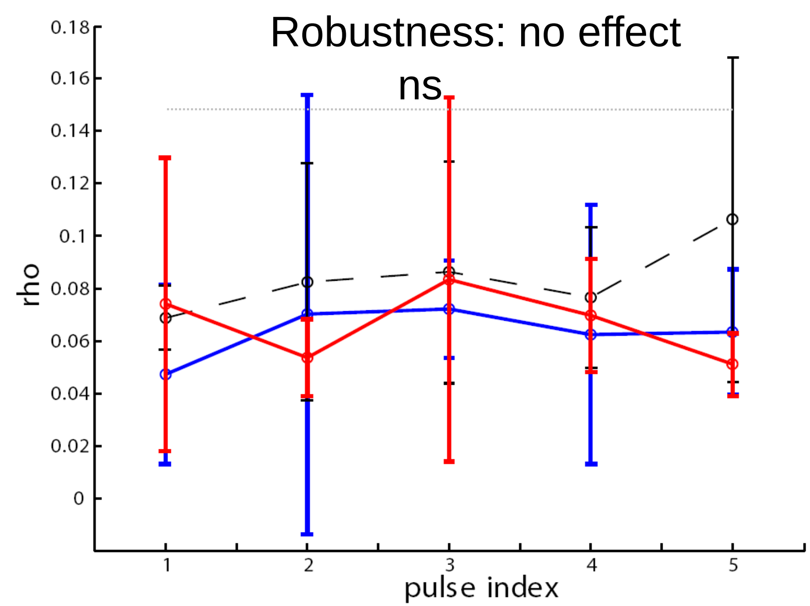
Timing Precision Analysis
pulsatile stimulations & synchronization





n=5 pairs





: 300ms
: 500 ms
: 700 ms

Interval between 2 pulses

→ **The synchronization level is maintained** over successive pulses despite neurons adaptation

Conclusions

Most of MGC recorded neurons present a stereotyped pheromonal blend response (projection neurons ?)

These responses are highly reliable compared to other pheromone sensitive neurons

-Fixed Excitatory phase boundaries (1st and last spike), spike jitter ≈3ms and only 7% of non-coincident spikes (robustness)

-Pheromone pulsed stimulations followed (PN's I phase is involved in efficient flight tracking of pheromone plumes, Lei *et al*., 2009)

-The response spike sequence is shortened across fast pulses.
Adaptation reduces spike-count reliability, but not spike-timing precision inside a pulsed series or between series (same results in auditory nerve trial to trial variability: Avissar *et al*., 2007).

The global output of the MGC is strengthened thanks to synchronization

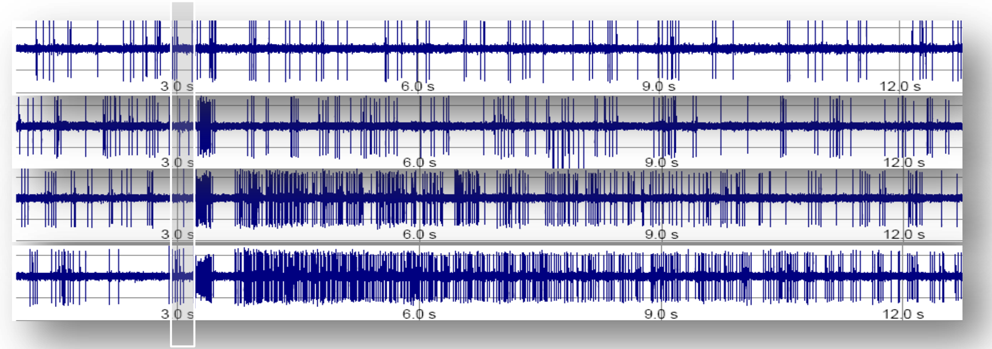
-Strong interactions between neurons both during spontaneous activity(Kazama and Wilson, 2009) and olfactory responses: Temporal coding strategy ? (rather than rate coding)

-Level of synchrony preserved when pulsed stimulations are applied

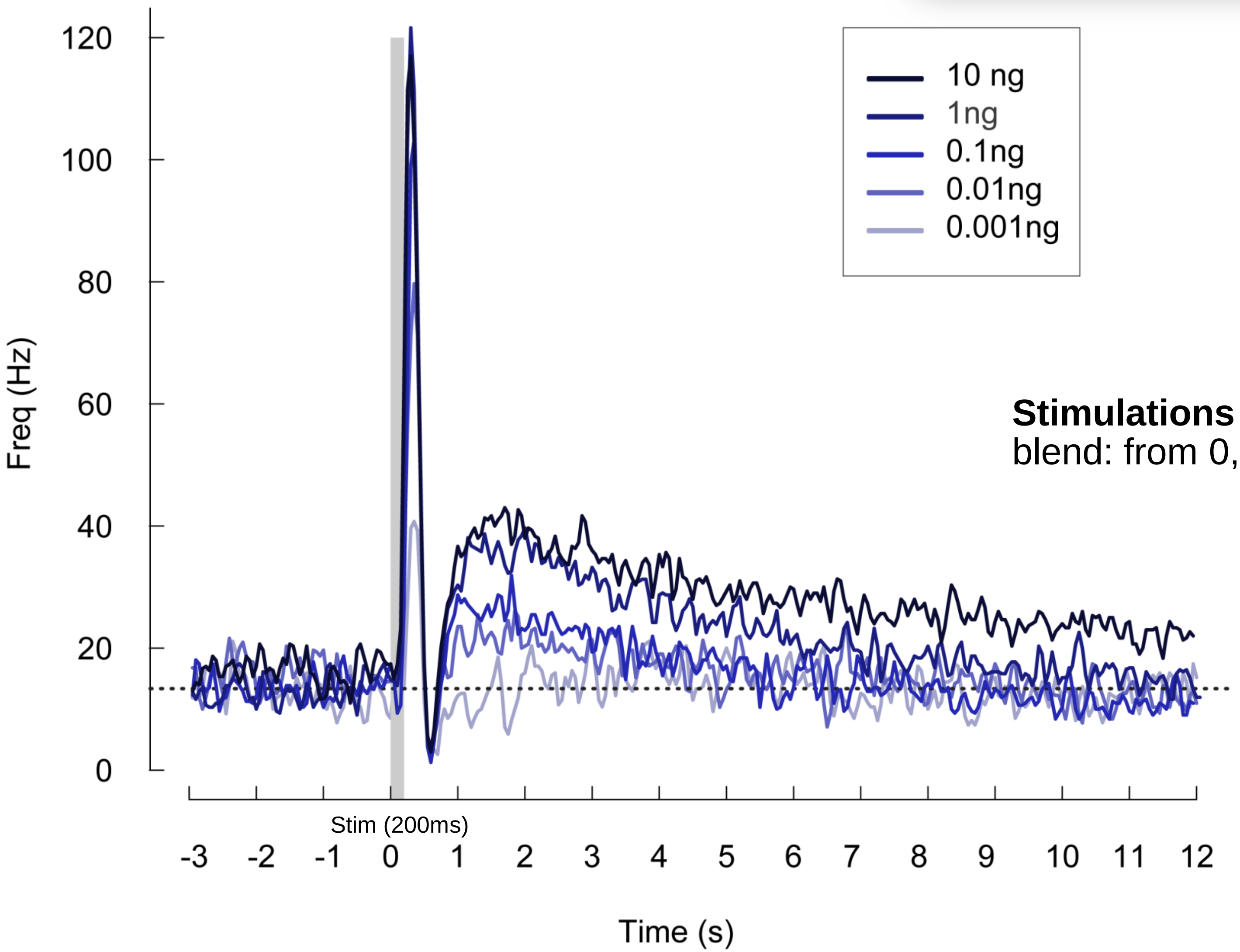
Thank You !

Quantitative coding: pheromone concentration

Concentration increase

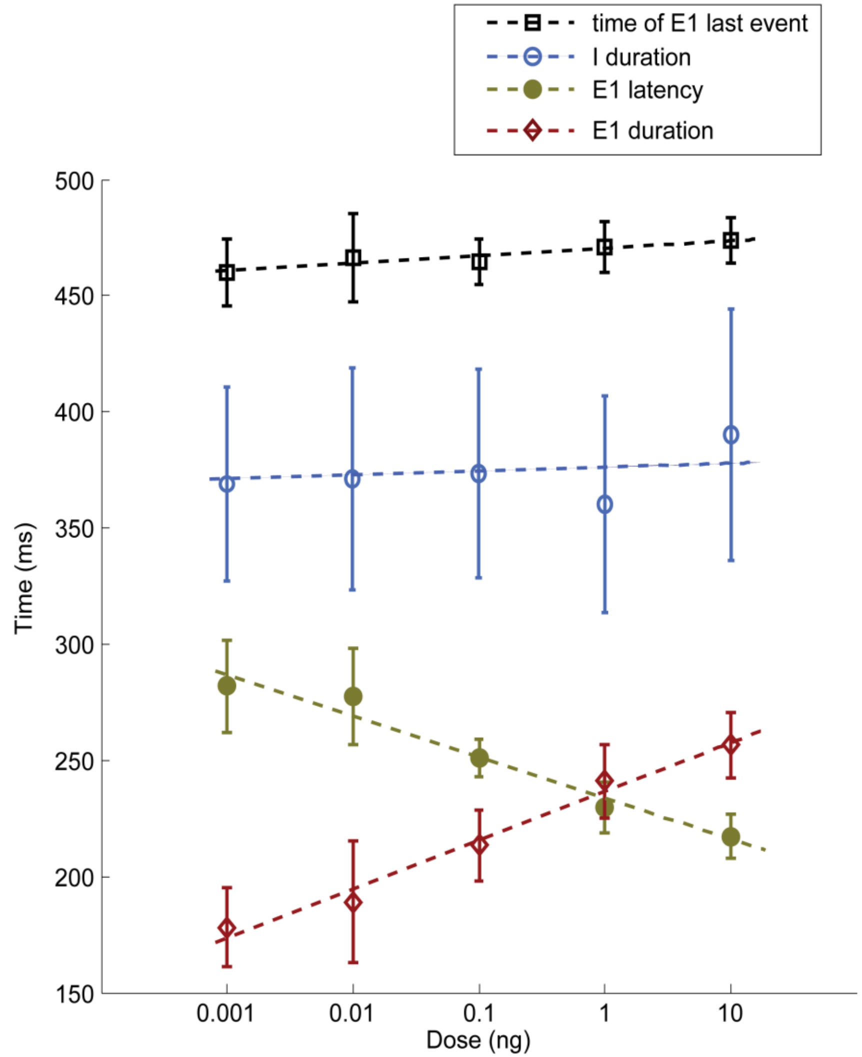


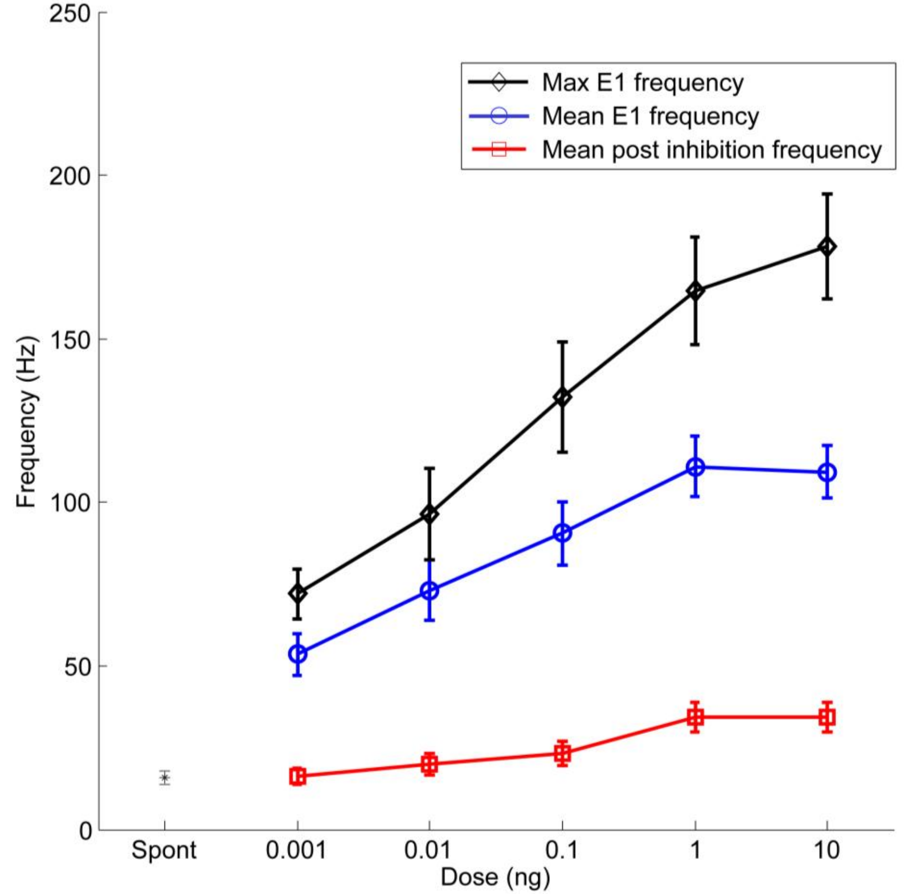
17 PNs - PSTHs [0.001:10]ng



Stimulations with the pheromonal blend: from 0,001 ng to 10 ng

Quantitative coding: pheromone concentration

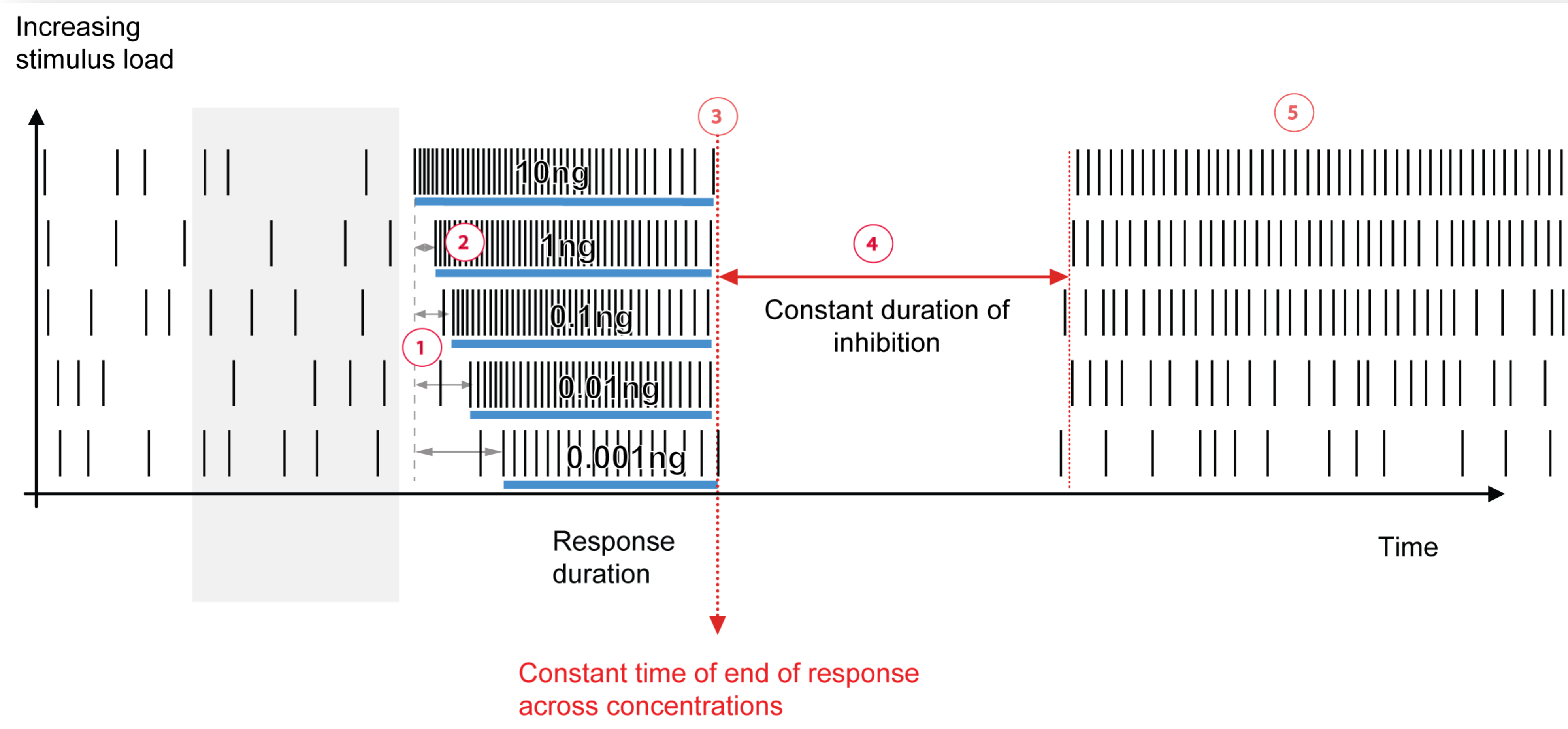




Dose-responses with the pheromonal blend: from 0,001 ng to 10 ng

Quantitative coding: pheromone concentration

Schematic summary



→ Response's latency, duration and frequency are concentration dependant
→ We observed a constant duration for the inhibitory phase