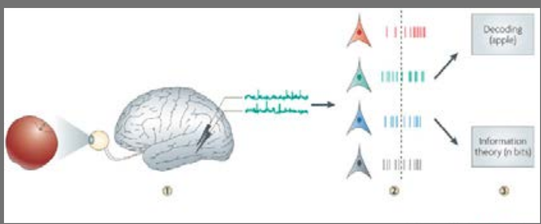
Neurociencia de Sistemas

- Clase 1. Introducción
- Clase 2. Registros extracelulares y Spike sorting.
- Clase 3. Procesado de información visual.
- Clase 4. Percepción y memoria.
- Clase 5. Decodificación – Teoría de la información.
- Clase 6. Electroencefalografía – Análisis de tiempo-frecuencia y Wavelets.
- Clase 7. Potenciales evocados – Análisis de ensayo único.
- Clase 8. Dinámica no-lineal – Sincronización.

Nature Reviews Neuroscience 10, 173-185 (March 2009) | doi:10.1038/nrn2578
Extracting information from neuronal populations: information theory and decoding approaches
Rodrigo Quian Quiroga & Stefano Panzeri

Single-trial population analysis



Single neuron → Multiple neurons

Multiple trials → Single trials

More information BMI (clinical) applications

Nature Reviews Neuroscience 10: 173-185; 2009

Population analysis
information theory or decoding

- Considers the information of a population as a whole.
- Single-trial analysis
- We can discover the stimulus features encoded by the population.
- We can evaluate which features of the spike trains encode relevant information.
- We can combine different signals (e.g. spikes and LFPs)

Information theory

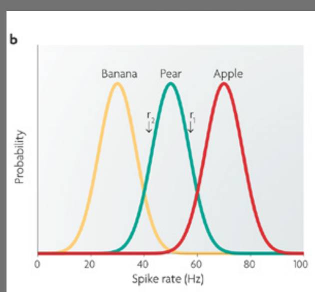
Shannon Entropy
$$H(S) = -\sum_s P(s)\log_2 P(s)$$

Joint Entropy
$$H(S,R) = -\sum_{s,r} P(s,r)\log_2 P(s,r)$$

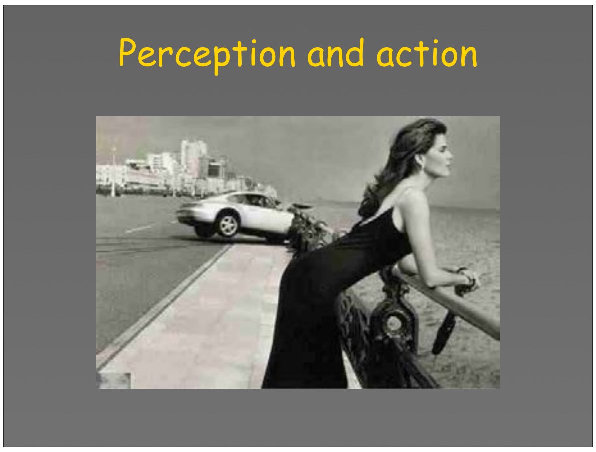
For independent distributions…
$$P(S,R) = P(S) \times P(R)$$
$$H(S,R) = H(S) + H(R)$$

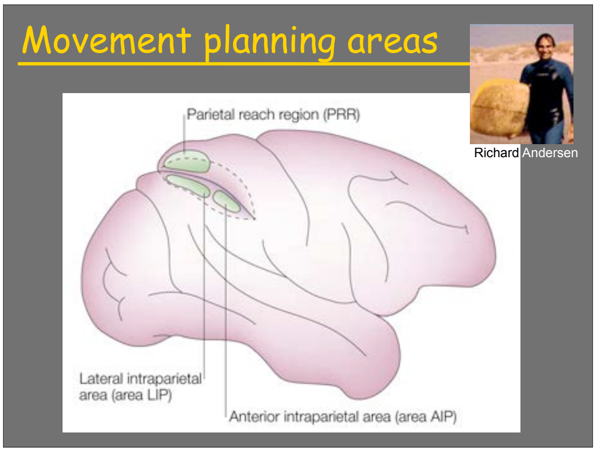
Mutual information
$$I(S,R) = H(S) + H(R) - H(S,R) = \sum_{s,r} P(s,r)\log_2 \frac{P(s,r)}{P(s) \times P(r)}$$

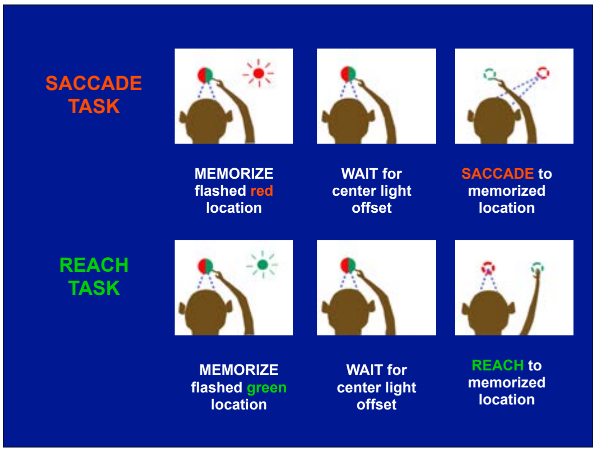
Decoding and Information theory

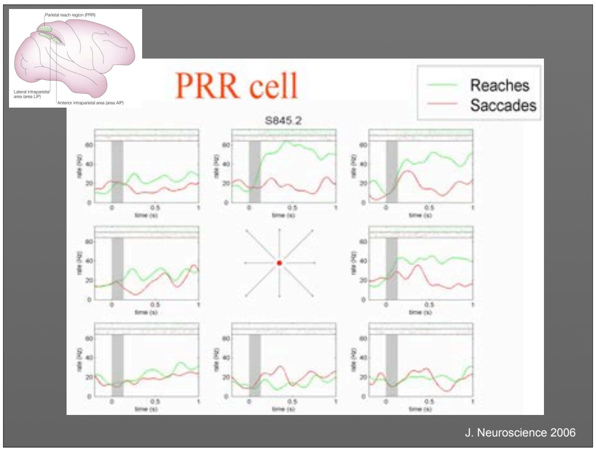


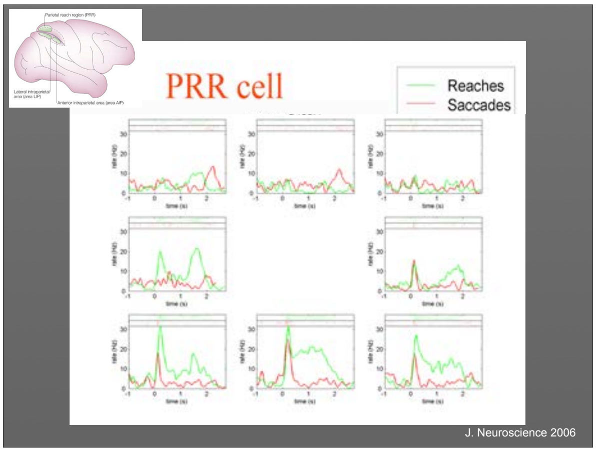
Nature Reviews Neuroscience 10: 173-185; 2009

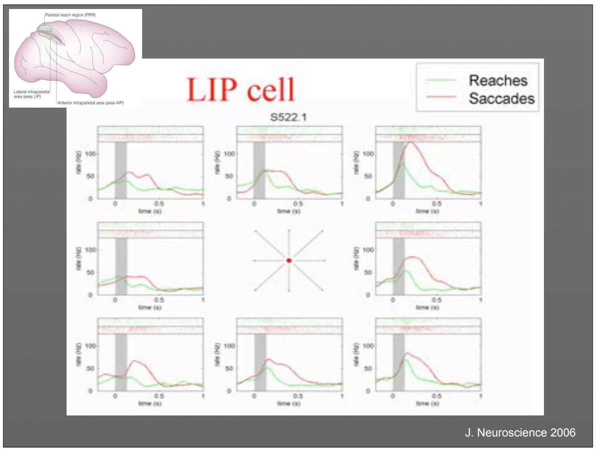

Perception and action


Movement planning areas
Richard Andersen
Parietal reach region (PRR)
Lateral intraparietal area (area LIP)
Anterior intraparietal area (area AIP)


SACCADE TASK
MEMORIZE flashed red location
WAIT for center light offset
SACCADE to memorized location
REACH TASK
MEMORIZE flashed green location
WAIT for center light offset
REACH to memorized location


PRR cell
Reaches
Saccades
S845.2
J. Neuroscience 2006


PRR cell
Reaches
Saccades
J. Neuroscience 2006

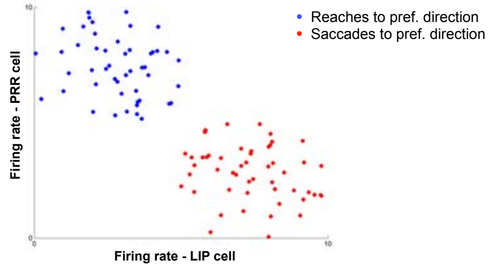

LIP cell
Reaches
Saccades
S522.1
J. Neuroscience 2006

Are reaches confused with saccades?

Is this an attention effect?

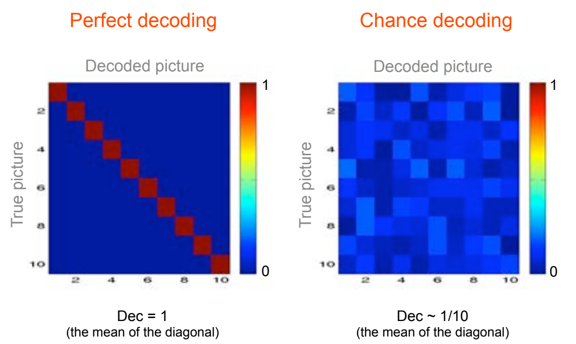
Can we predict movements?

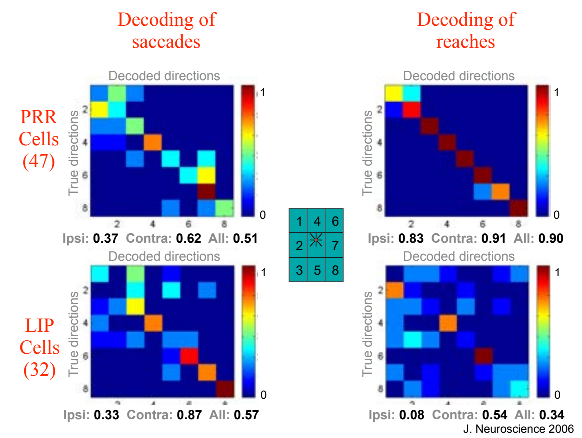
Nearest neighbors decoding



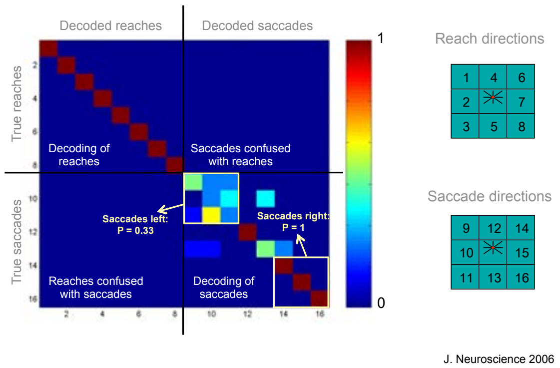
- Single-trial mean firing rates in delay period (150-750ms)
- 1st nearest neighbor
- All but 1 decoding (1 test trial at a time)

Decoding matrices

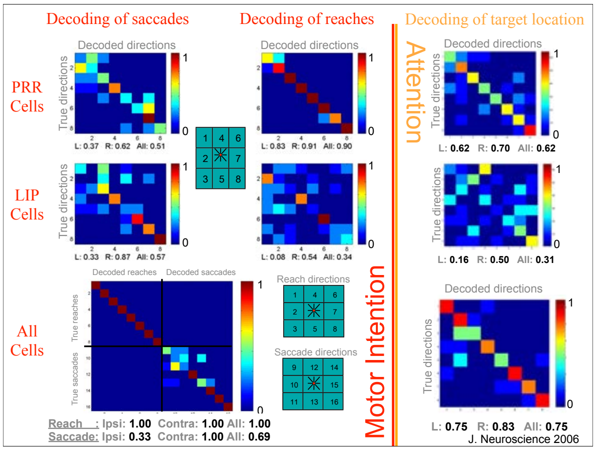




PRR (47cells) + LIP (32cells)



J. Neuroscience 2006



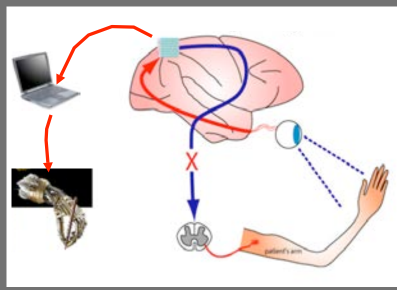
Interim Conclusions

- We can reliably decode saccade and reach intentions from posterior parietal lobe cells.
- Saccade intentions are better decoded from LIP cells and reach intentions from PRR cells.
- LIP cells code for the contralateral field and PRR cells for both hemifields.
- Results cannot be attributed to an attention effect.

There are two segregated (and interacting) areas, PRR and LIP coding for different movement intentions.

J. Neuroscience 2006

Neural Prosthesis

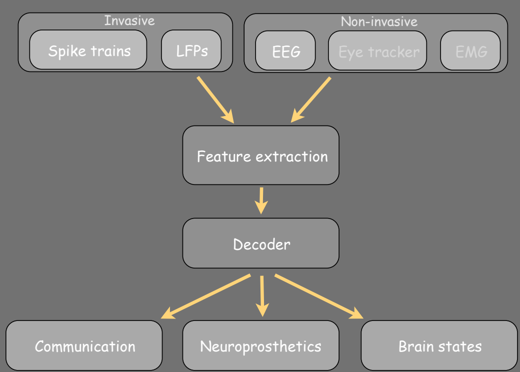


Adapted from www.vis.caltech.edu

From Andy Schwartz lab

From Richard Andersen's lab

BMI - Clinical application

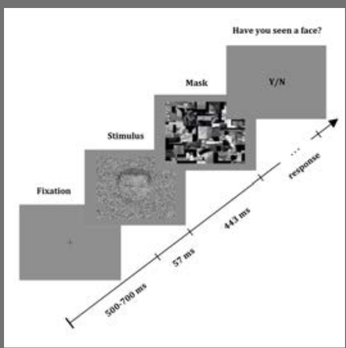


Guiding a robot arm with the gaze

Decoding EEG responses

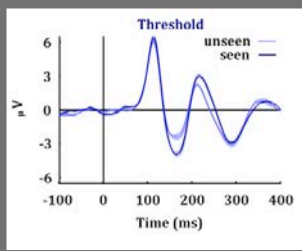
Joaquin Navajas

Face detection paradigm



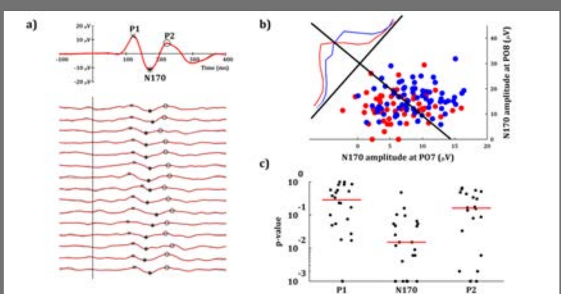
Navajas et al. J. Neuroscience 2013

N170



Navajas et al. J. Neuroscience 2013

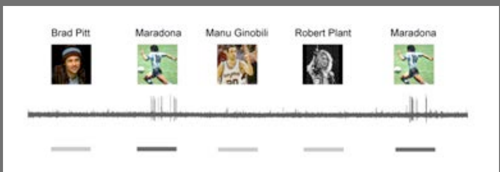
Single trial decoding

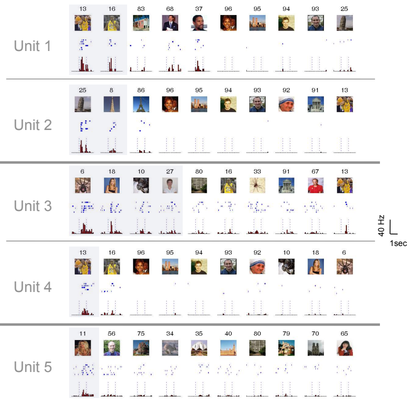


Navajas et al. J. Neuroscience 2013

Epilepsy surgery

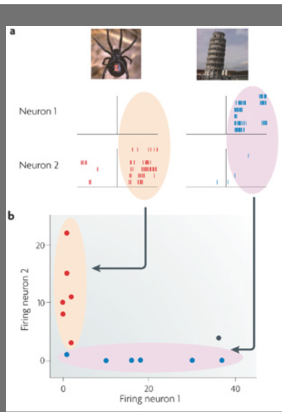
Recordings in the human MTL



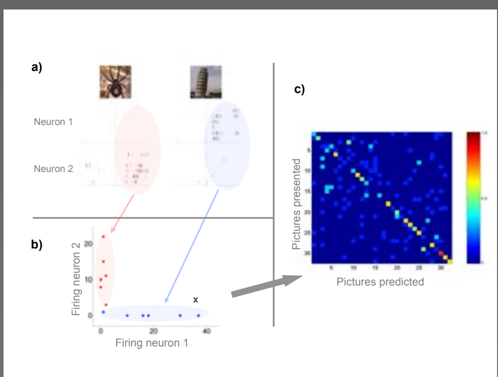


J. Neurophysiology, 2007

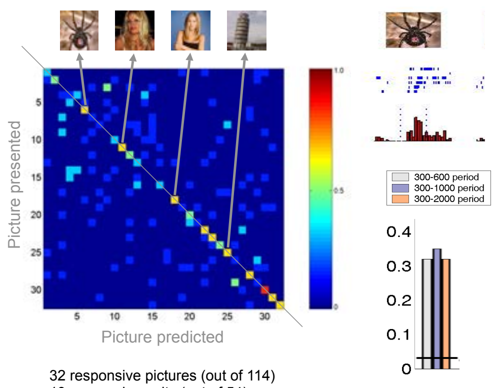
Can we tell each trial which picture was shown?



Nature Reviews Neuroscience, 2009



Nature Reviews Neuroscience, 2009

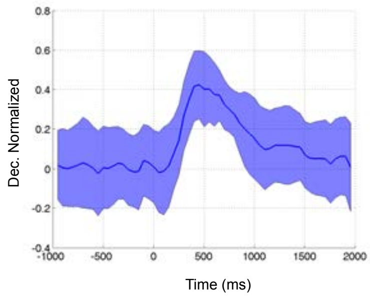


32 responsive pictures (out of 114)
19 responsive units (out of 54)

J. Neurophysiology, 2007

Time profile of decoding

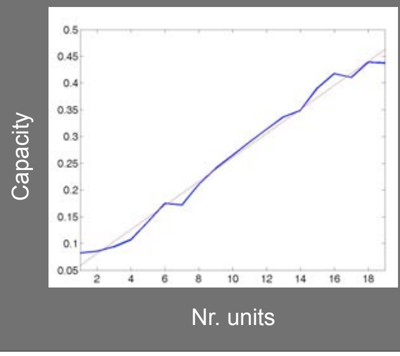
Dec. Normalized = (Dec. – chance) / (Dec. + chance)



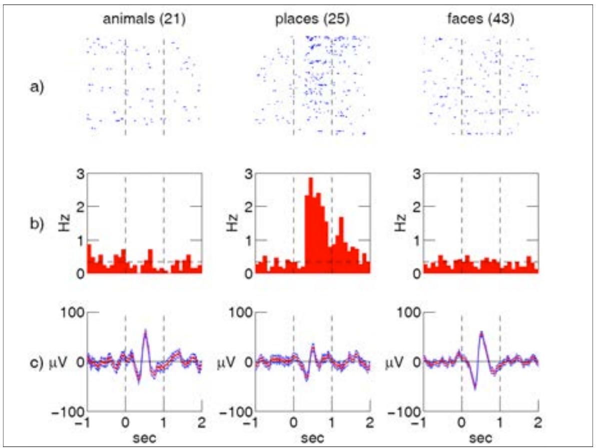
J. Neurophysiology, 2007

Capacity

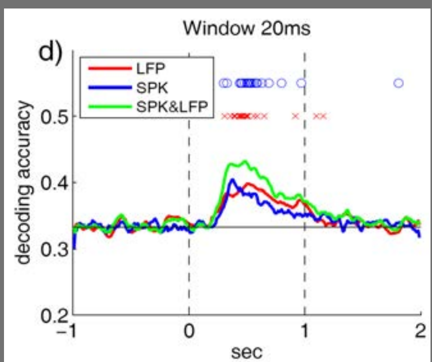
(Number of pictures decoded with >50% success)



What about local field potentials?



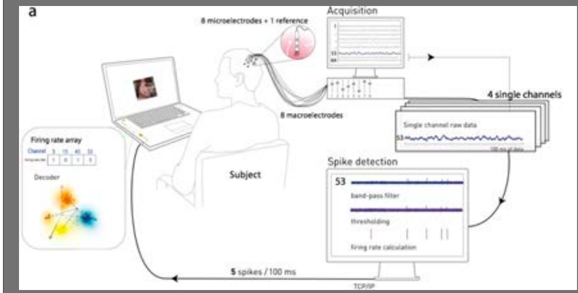
Decoding with spikes and LFPs



Kraskov et al, J.Cogn. Neurosci. 2007

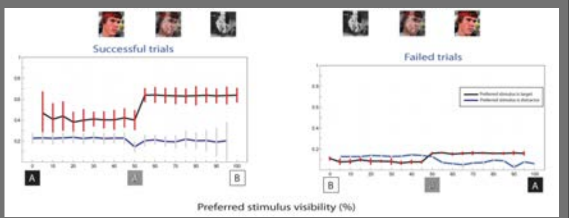
Though projection…

On-line voluntary control of single cell firing



Cerf, Thiruvengadam, Mormann, Kraskov, Quian Quiroga, Koch & Fried. Nature 2010

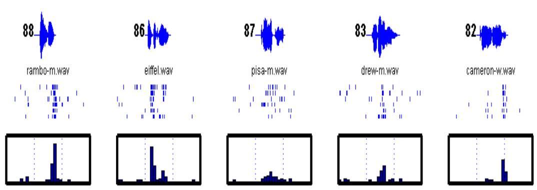
On-line voluntary control of single cell firing



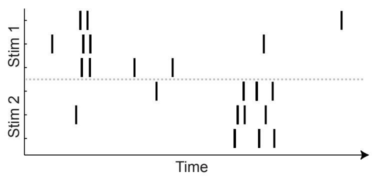
Cerf, Thiruvengadam, Mormann, Kraskov, Quian Quiroga, Koch & Fried. Nature 2010

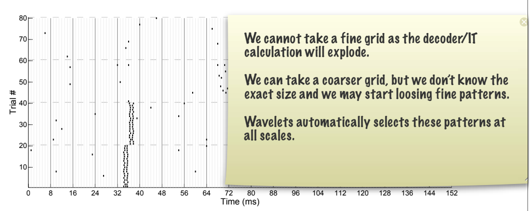
Information in time patterns

Vitor Lopes dos Santos



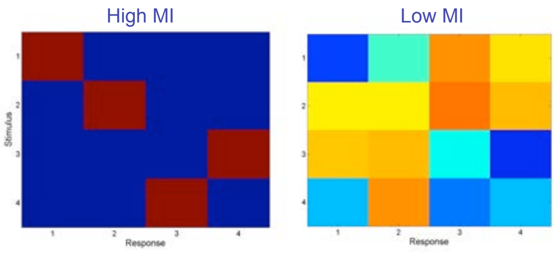
How can we quantify time patters?



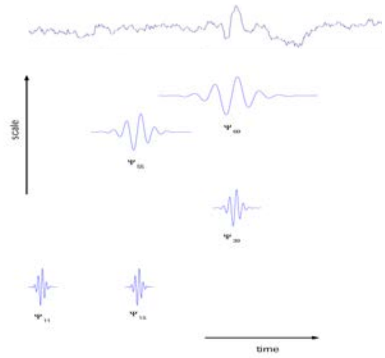


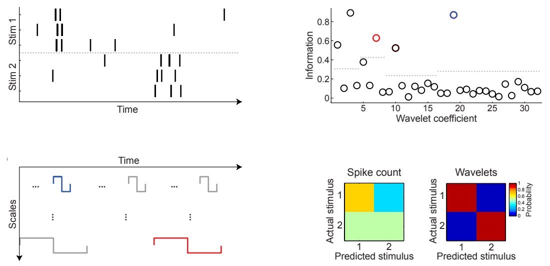
Mutual Information

$$I(S,R)=H(S)+H(R)-H(S,R)=\sum_{s,r}P(s,r)\log_2\frac{P(s,r)}{P(s)\times P(r)}$$



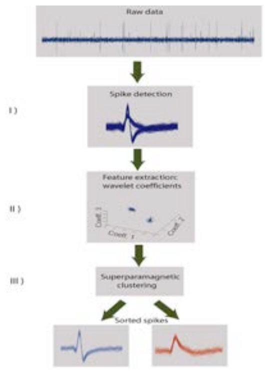
Wavelets



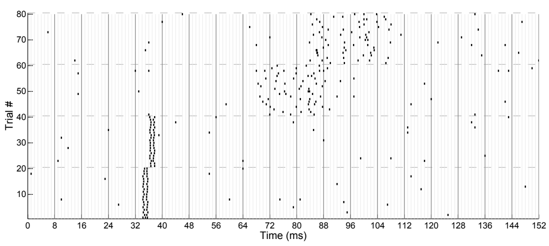


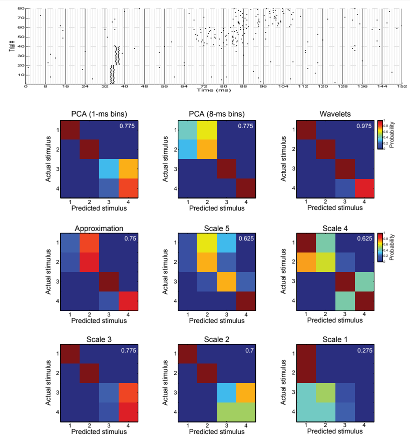
Selection of coefficients -> Mutual information

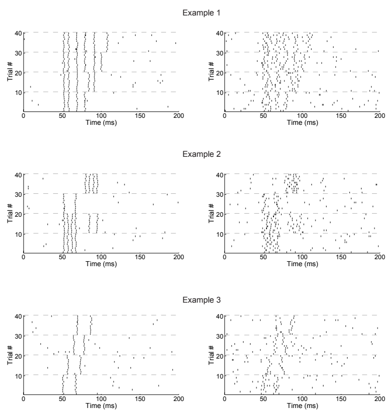
Spike sorting



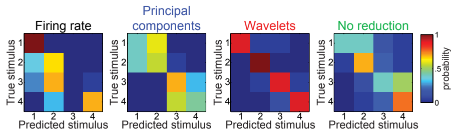
Multiple scale example

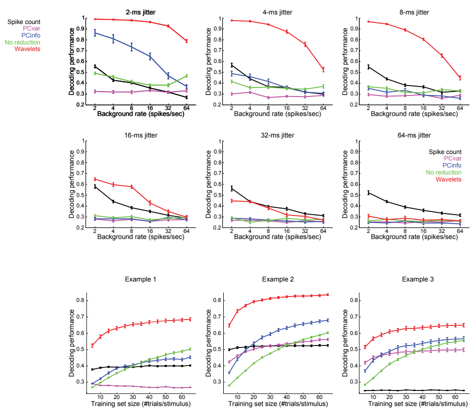




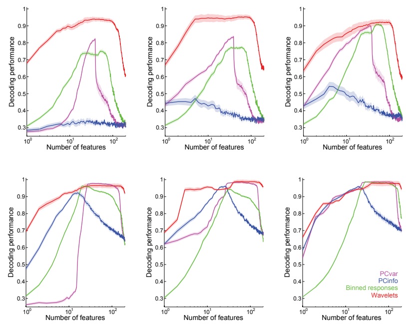


Performance quantification





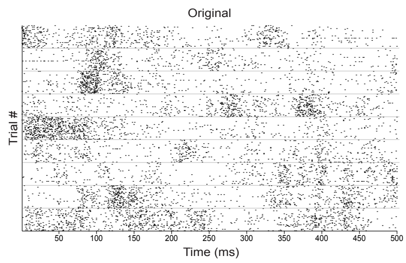
Dependence with nr. of features



Monkey auditory cortex

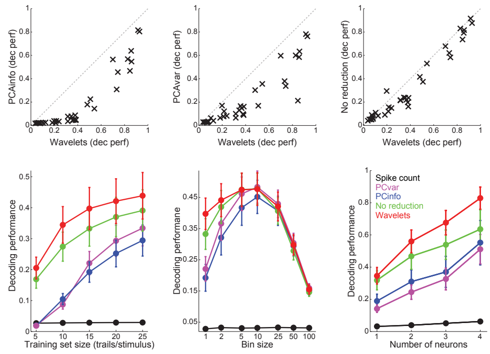
Data from Christoph Kayser

Kayser C, Logothetis NK, Panzeri S (2010) Millisecond encoding precision of auditory cortex neurons. Proceedings of the National Academy of Sciences of the United States of America 107: 16976- 16981.



- 46 neurons in 3 monkeys
- 50 repetitions of 30-40 sec sequences of pseudorandom tones
- We cut the sequence into 50 'stimuli' of 500ms each.

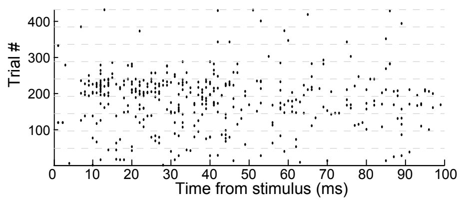
Performance with monkey data



Rat barrel cortex

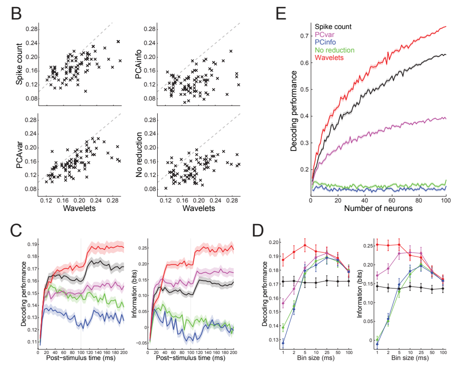
Data from Mathew Diamond

Panzeri S, Petersen RS, Schultz SR, Lebedev M, Diamond ME (2001) The role of spike timing in the coding of stimulus location in rat somatosensory cortex. Neuron 29: 769-777.



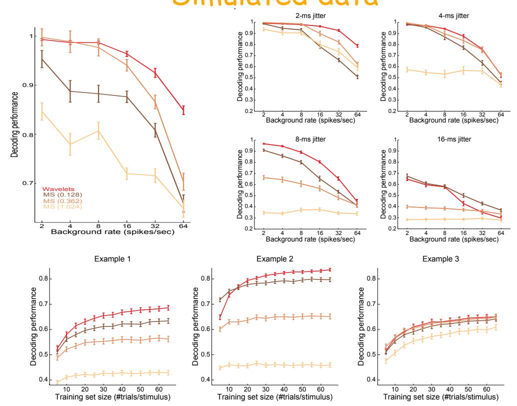
- 100 neurons in barrels C1-3, D1-3, E1-3
- 50 pulse stimulations of each corresponding whisker

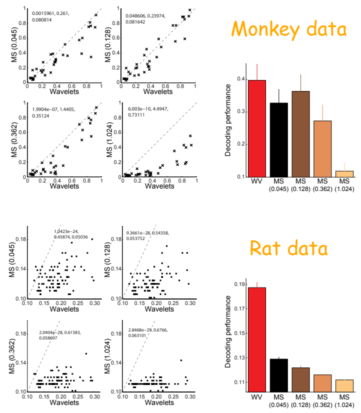
Performance with rat data



Victor and Purpura's method

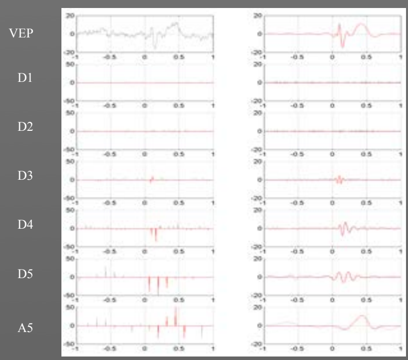
Simulated data



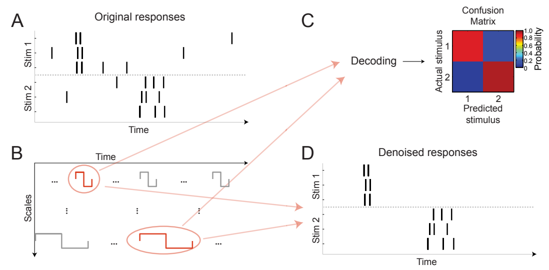


Denoising

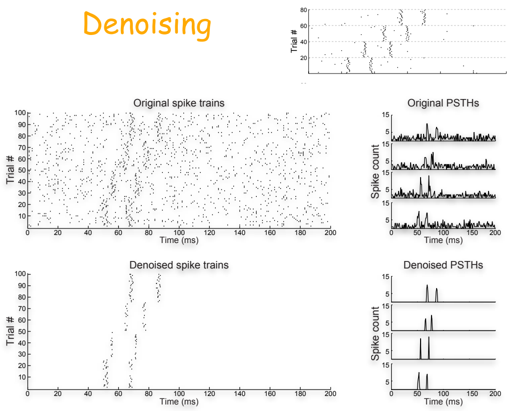
Denoising



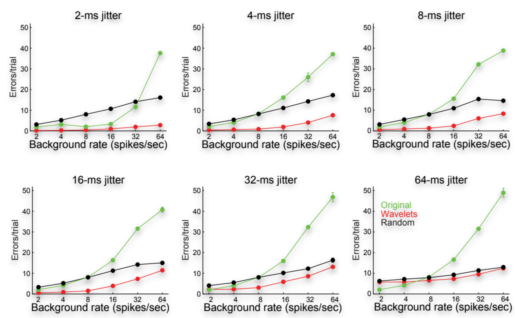
Physica D 145: 278-292 (2000)



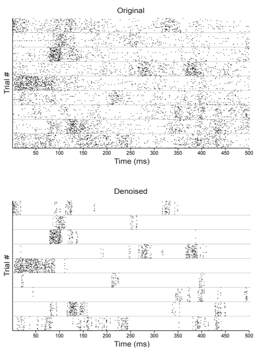
Denoising



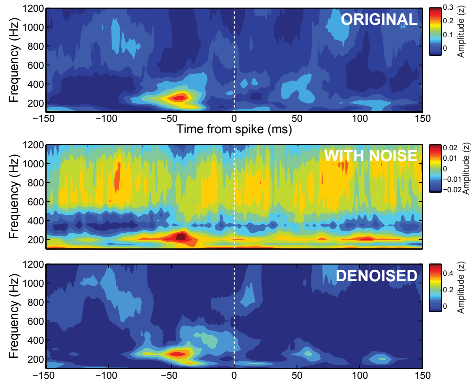
Denoising results



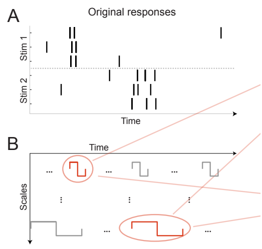
Monkey data

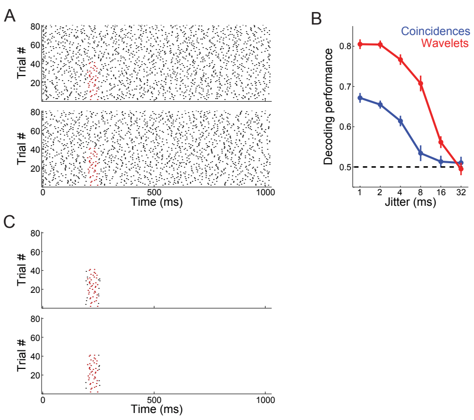


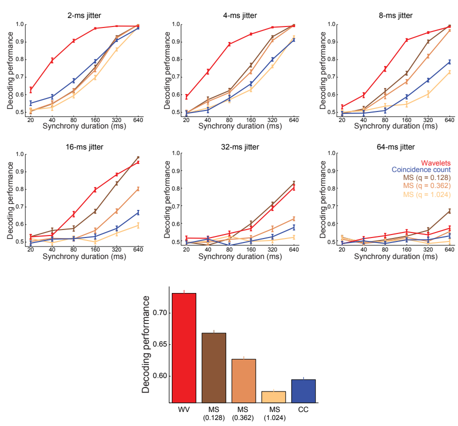
Reverse correlations



Correlations







Clase 5. Decodificación – Teoría de la información.

Extracting information from neural populations: Information theory and decoding approaches
Quian Quiroga R and Panzeri S.
Nature Reviews Neuroscience. 10: 173-185; 2009.

Extracting information in spike time patterns with wavelets and information Theory.
Vitor Lopes-dos-Santos , Stefano Panzeri , Christoph Kayser , Mathew E. Diamond, Rodrigo Quian Quiroga.
Journal of Neurophysiology, 113: 1015-1033, 2015.

Principles of Neural Coding
Rodrigo Quian Quiroga and Stefano Panzeri.
CRC Taylor and Francis; 2013.

Rieke, Warland, de Ruyter van Steveninck and Bialek. Spikes *(un clásico!)*