# Ultra-Rapid Scene Processing: Temporal Constraints and Neural Computation


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# Plan

- Ultra Rapid Processing of Natural Images
  - Certain key stimuli such as animals and faces can be detected in complex natural scenes in as little as 100 ms
- Biological plausible processing algorithms
  - Feed-forward models
  - Computation with a wave of spikes
    - Rank order coding
    - Spike Time Dependant Plasticity
- A mechanism for unsupervised learning of frequently occuring visual patterns

# Ultra Rapid Scene Processing

**Speed of processing in the human visual system**

**Simon Thorpe, Denis Fize & Catherine Marlot**

Centre de Recherche Cerveau & Cognition, UMR 5549, 31062 Toulouse, France

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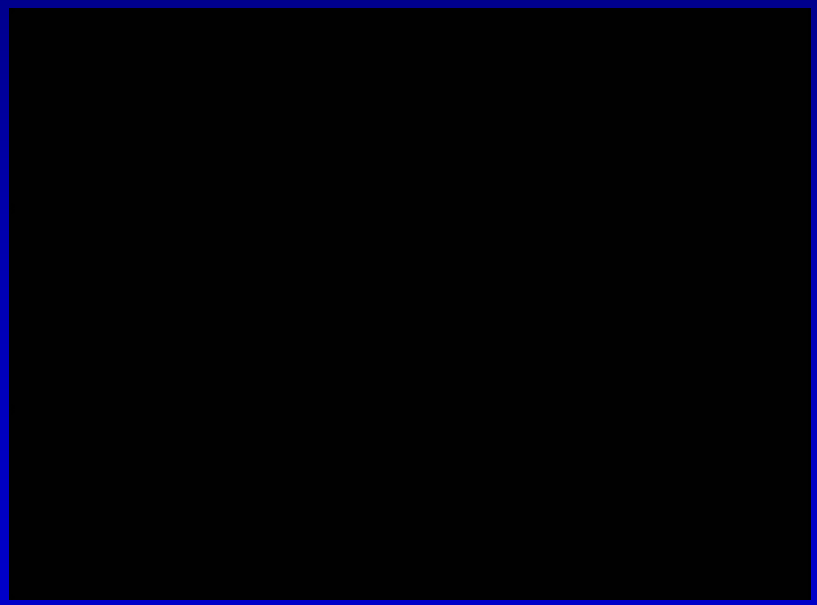
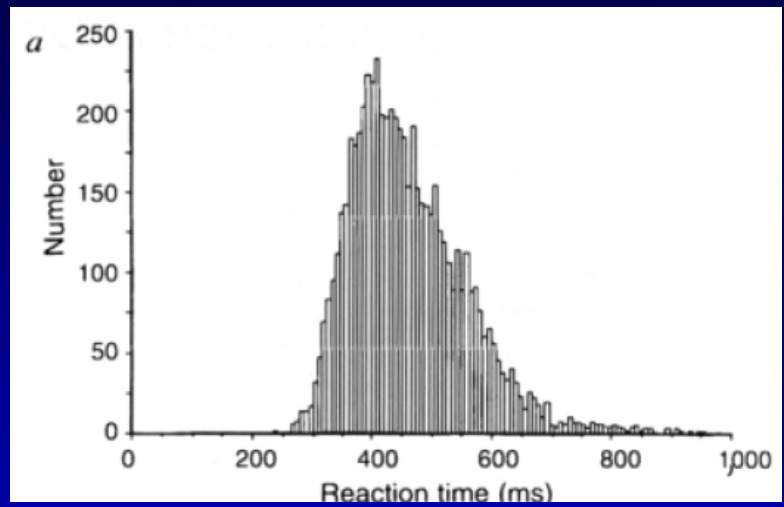
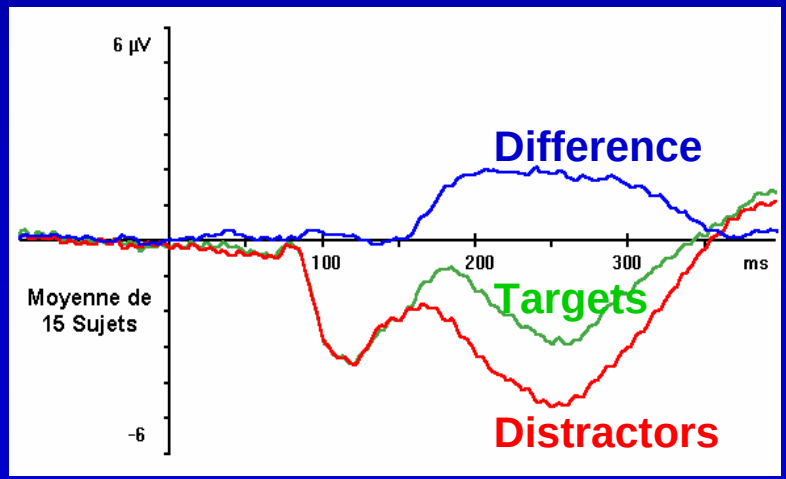


Scene Processing in 150 ms

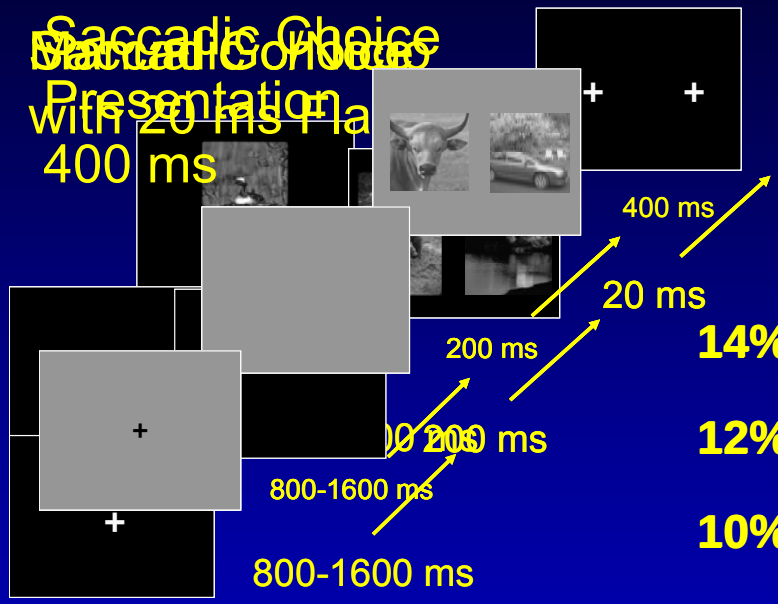
## Behavioural Reaction Times

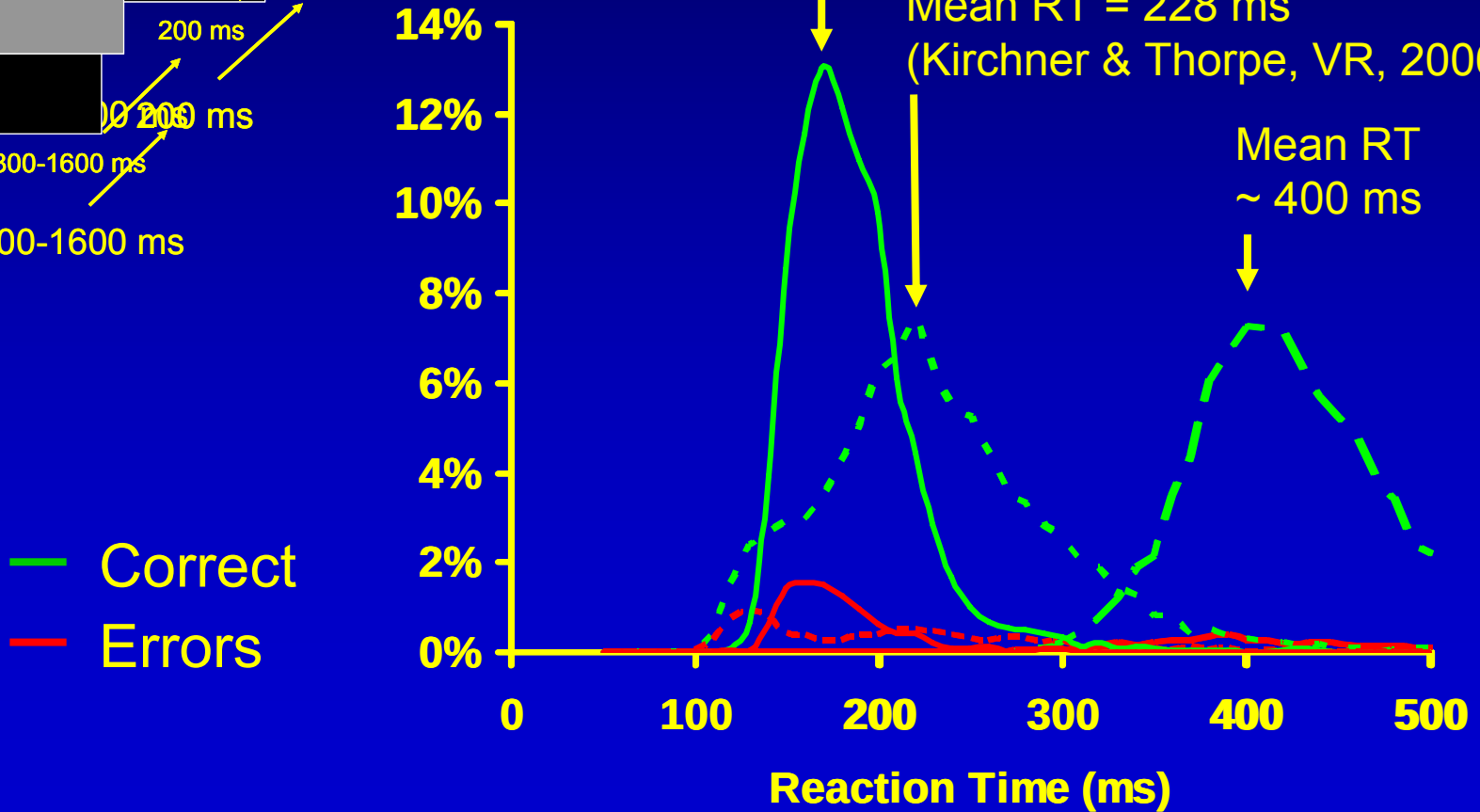



## Event Related Potentials

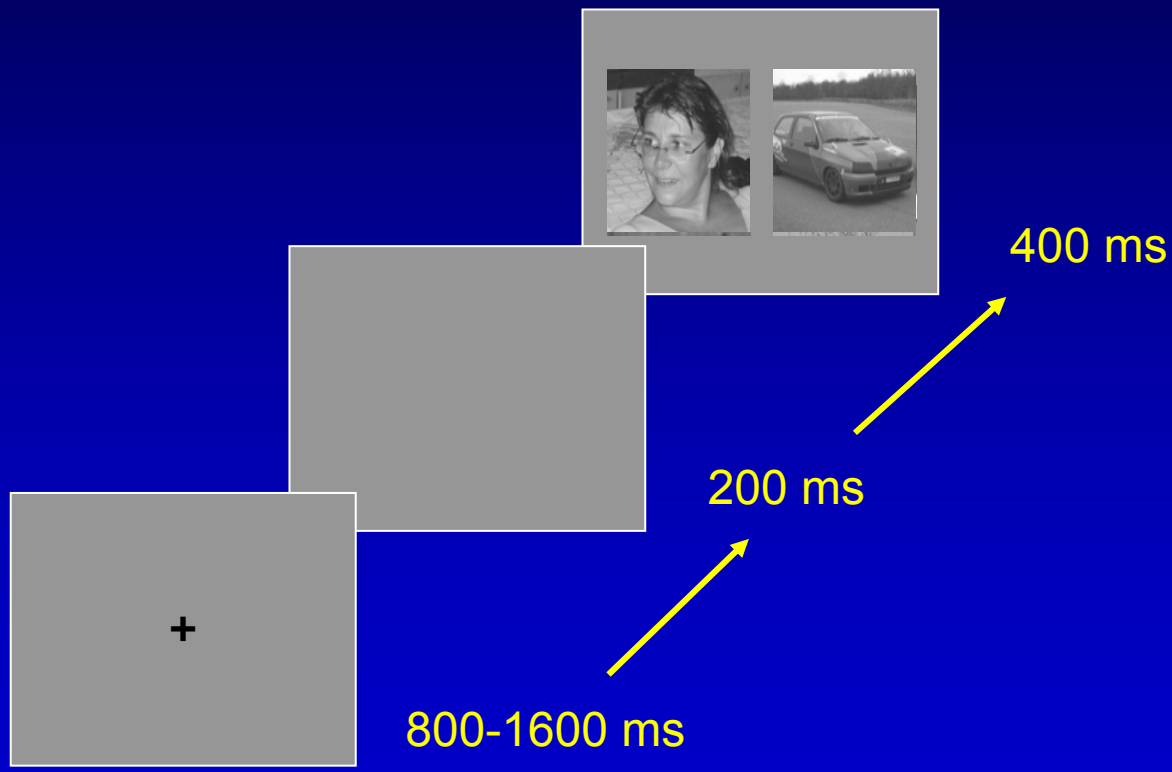


# Rapid Animal Categorisation Tasks



# Ultra-Rapid Detection of Human Faces



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116

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RAIL MOTOR Nº 34

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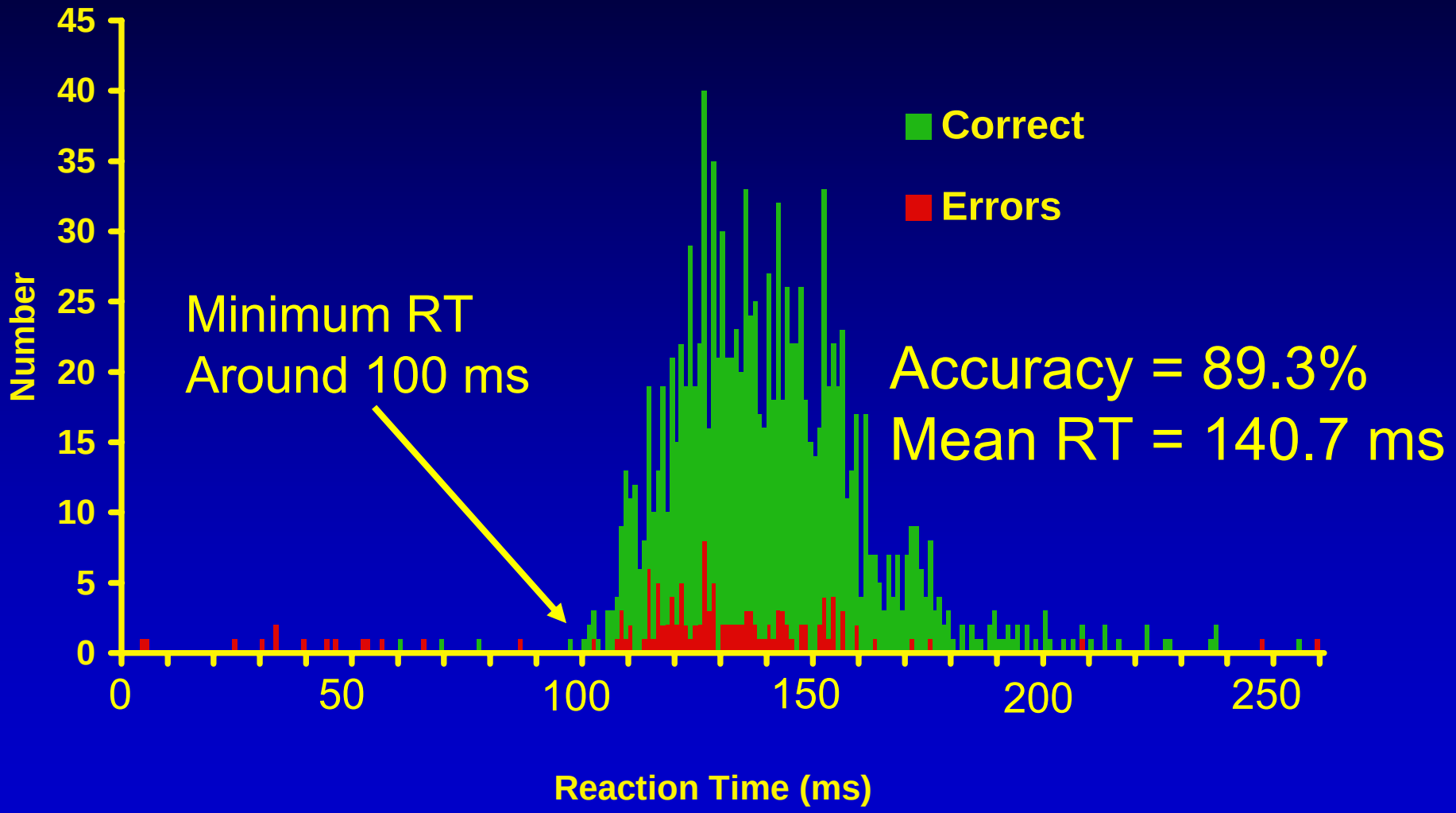
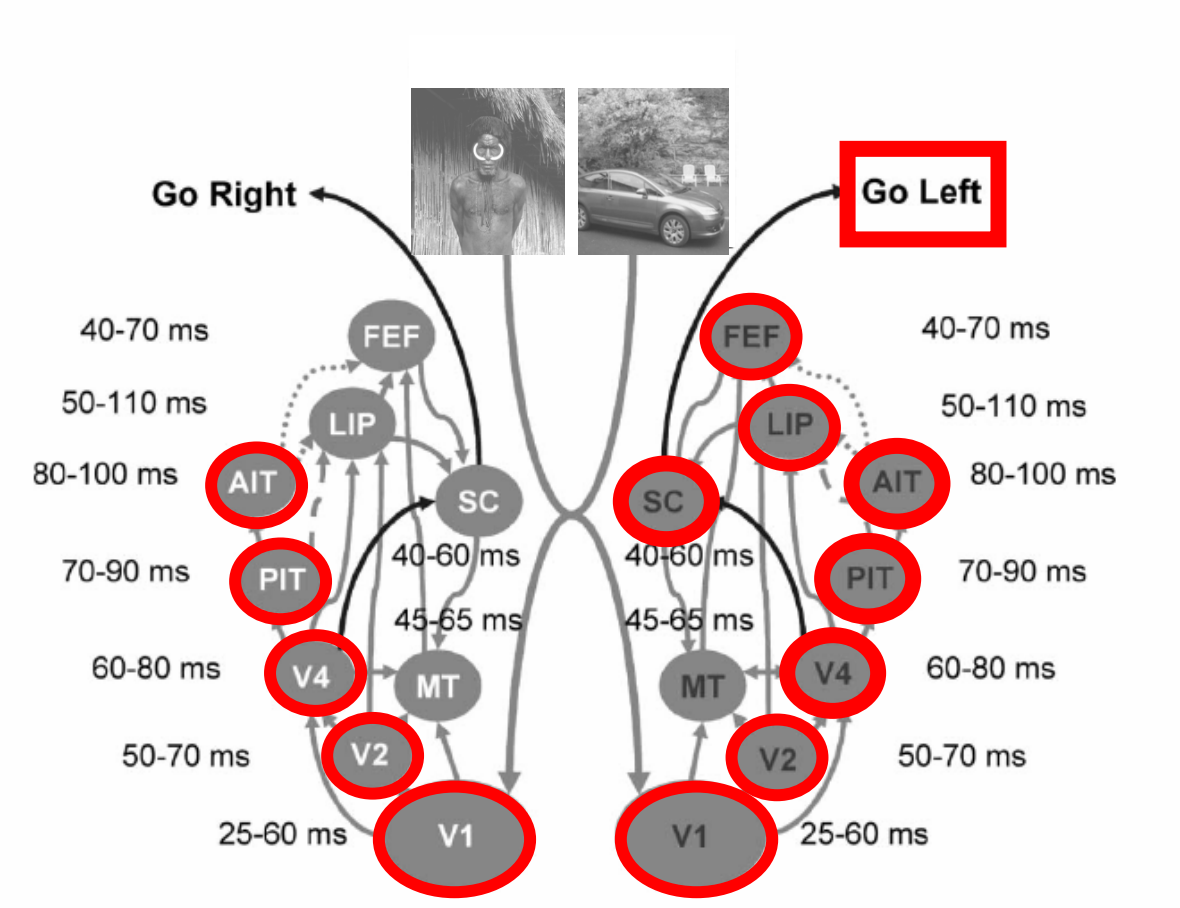
# Results for 8 subjects



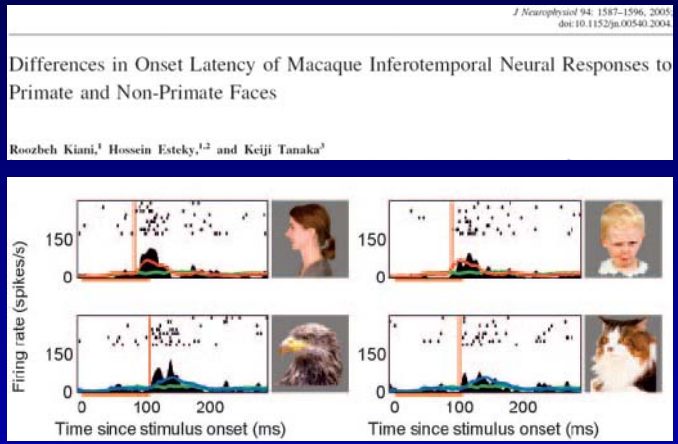
# Fast trials for one subject

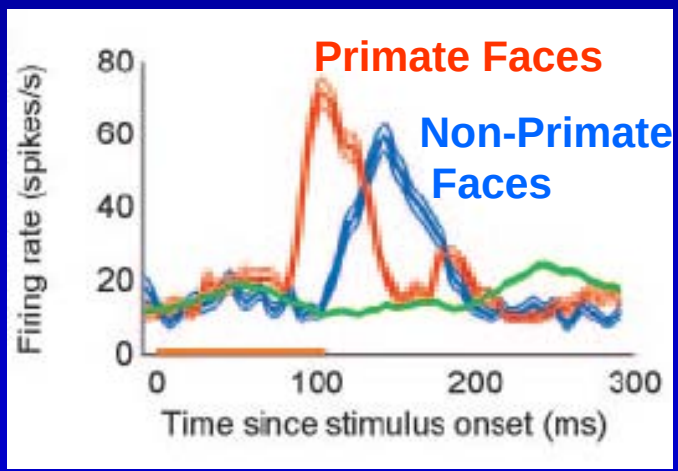

- All trials with RTs of ≤ 122 ms
- Correct on 22/24 (91.6%)

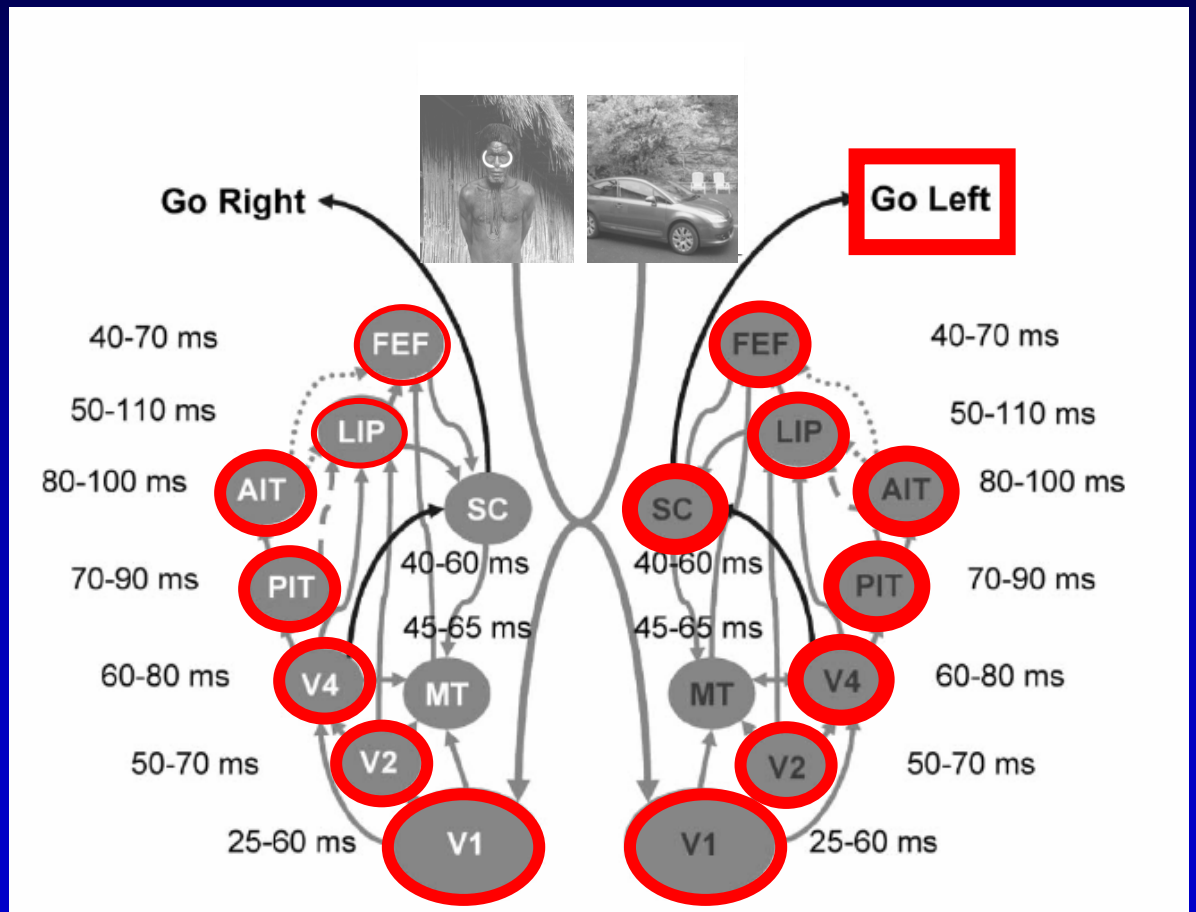
# What Pathways are Involved?



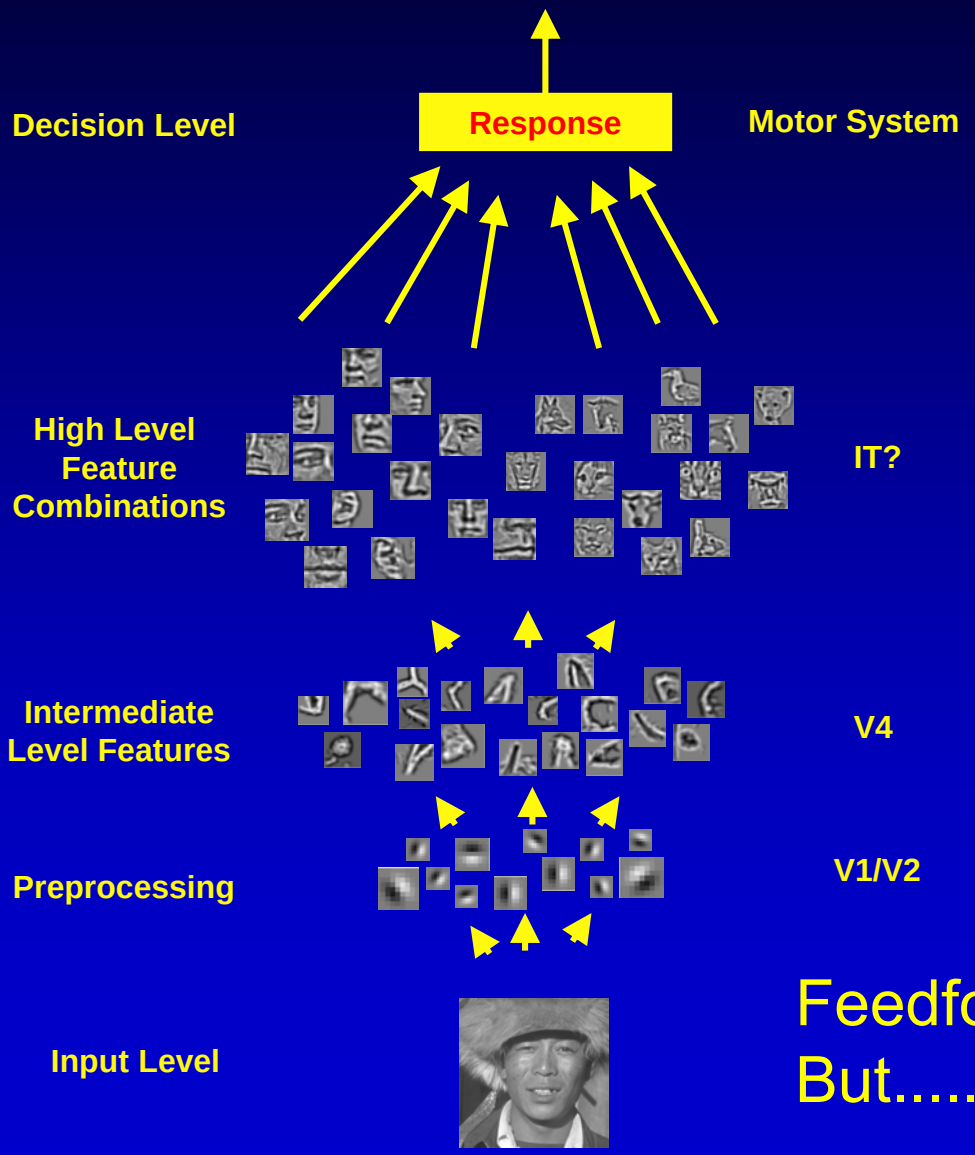
# A temporal saliency effect?



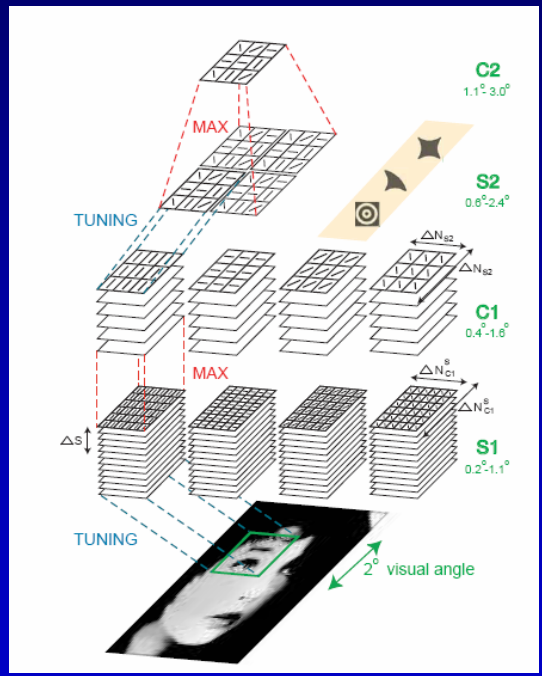
# What could be the mechanism?




**A feedforward architecture accounts for rapid categorization**

Thomas Serre*†‡§, Aude Oliva‡, and Tomaso Poggio*†‡

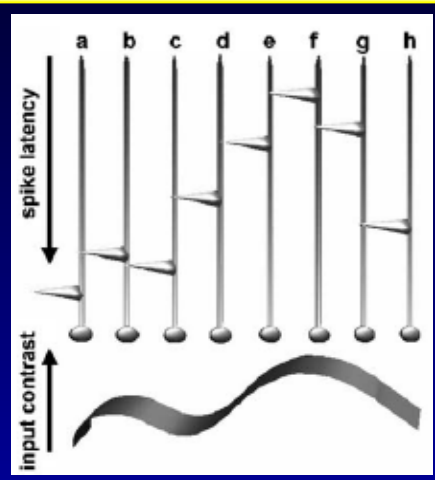
6424–6429 | PNAS | April 10, 2007 | vol. 104 | no. 15




Feedforward architectures are enough, But.....

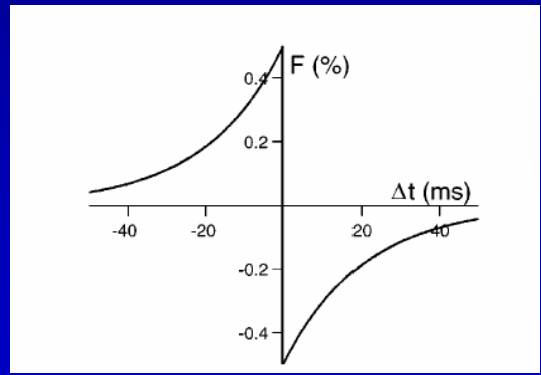
# The Temporal Coding Option

## Two Key Ideas




- Coding with a wave of spikes
  - The most strongly activated neurons fire first

- Spike Time Dependent Plasticity
  - With repeated exposure, high weights will concentrate on the inputs that fire first

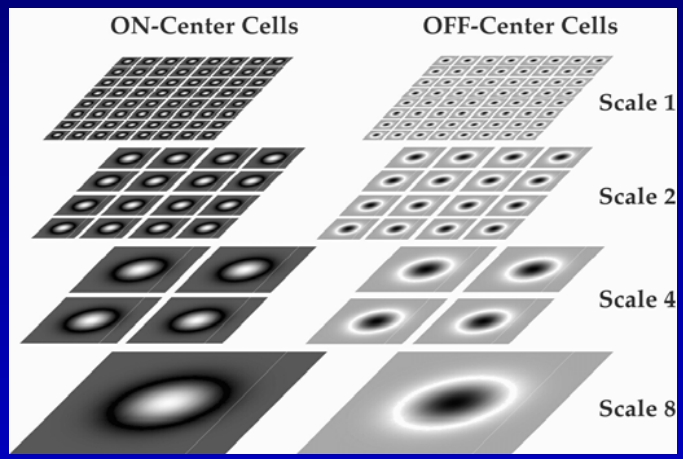



**Song, Miller & Abbott, 2000**

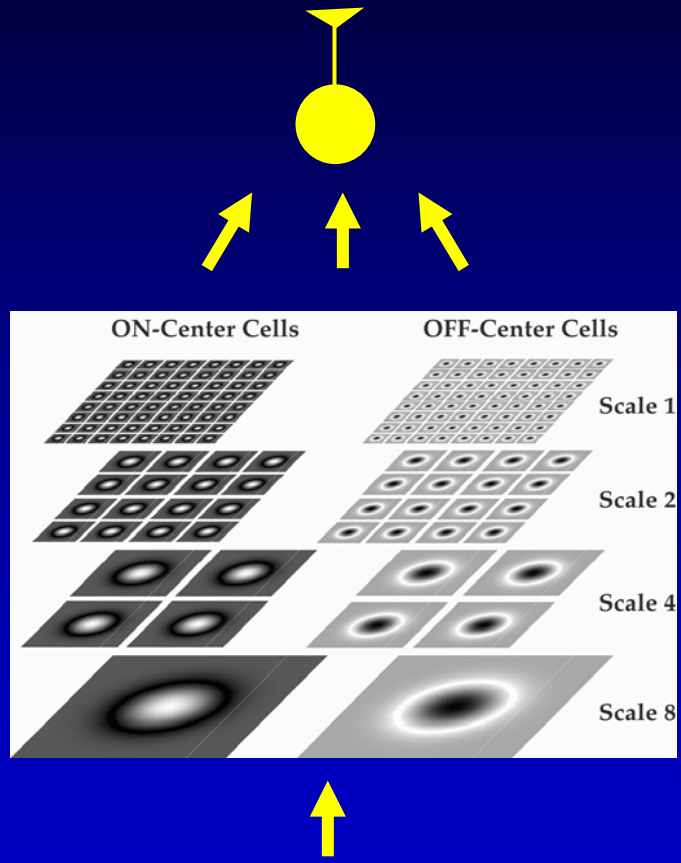
# Rank Based Coding

1% of the population active is enough for recognition !

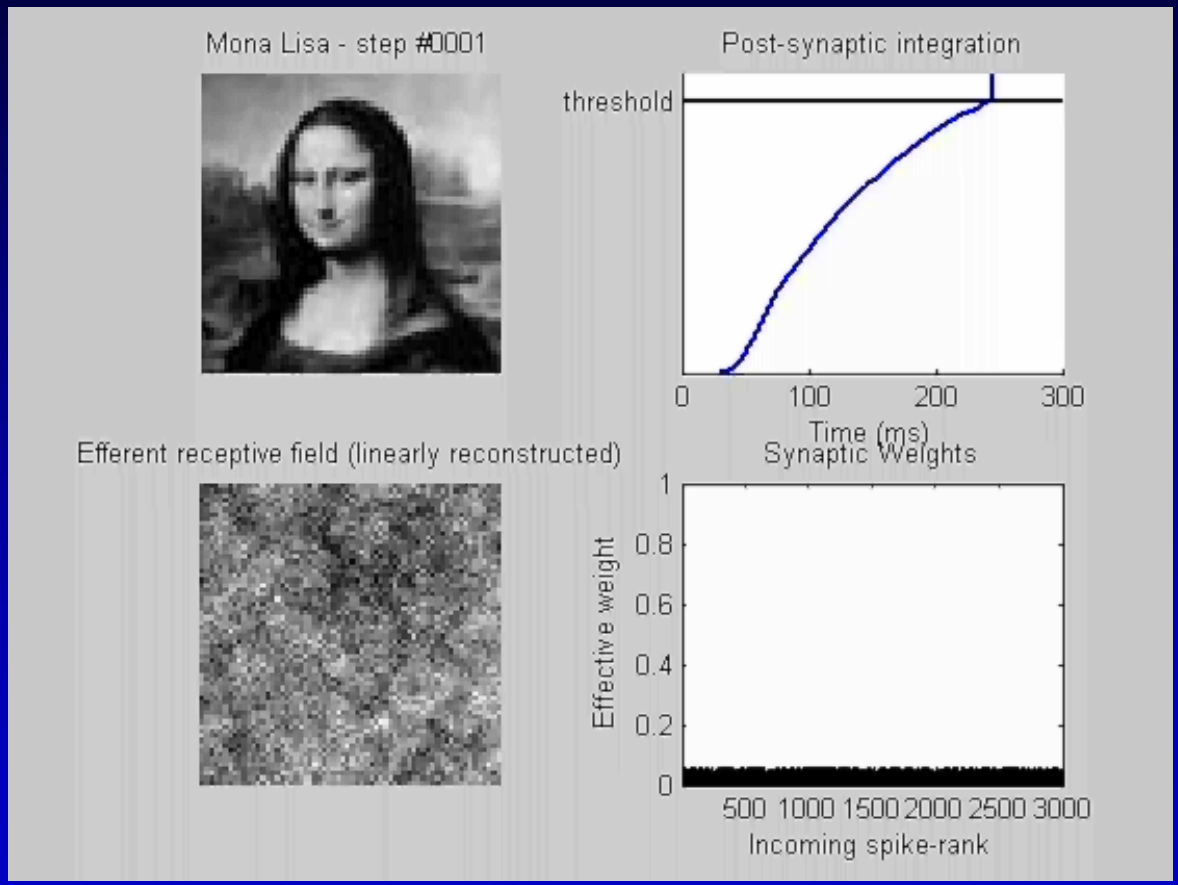
(VanRullen & Thorpe, 2001)




# Rank Based coding with STDP



# STDP Based Learning

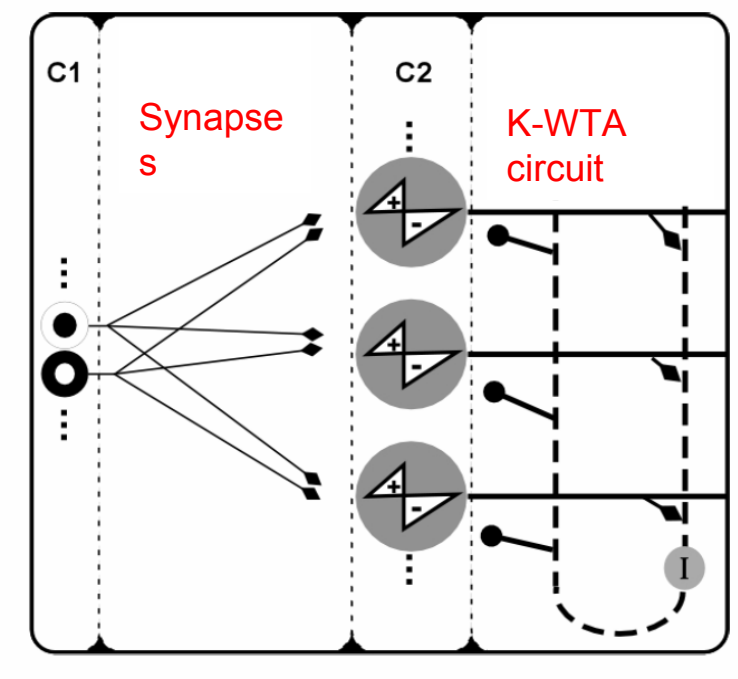



With Rank-based coding and STDP, neurones naturally

(a) become selective to repeatedly presented stimuli

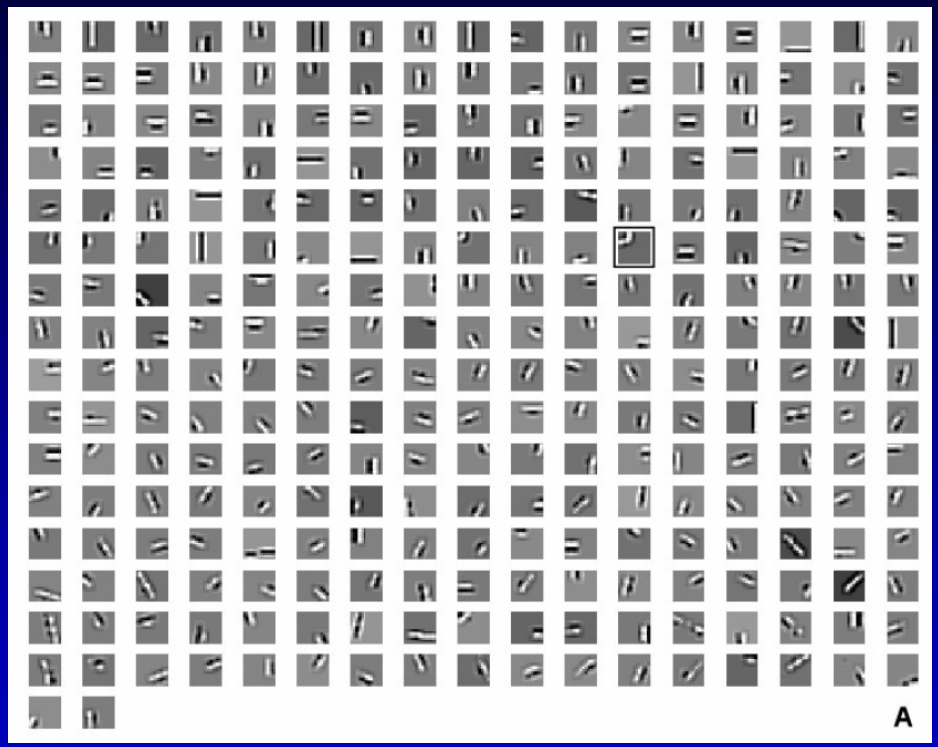
(b) respond more and more quickly

# STDP with a population of output cells

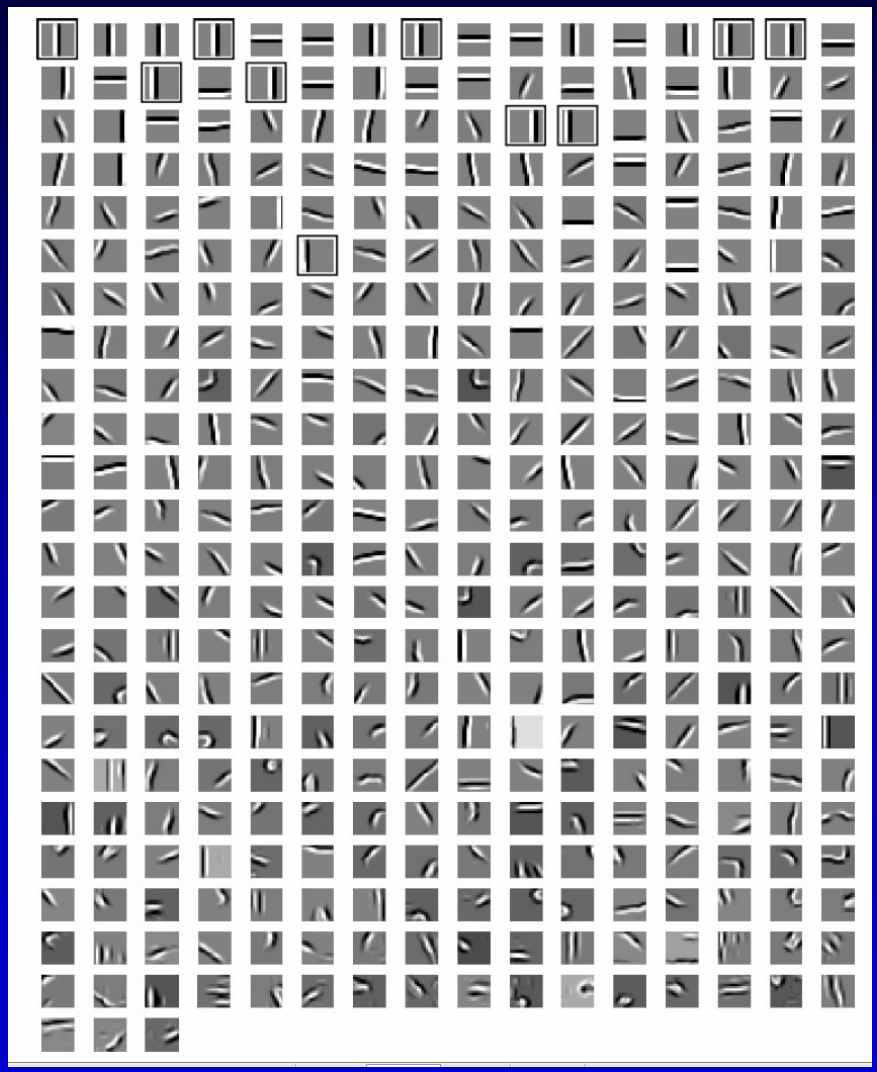



Neurons compete to grab parts of feature space

# STDP Learning with Natural Images




First layer training



Second layer training

# Learning Objects

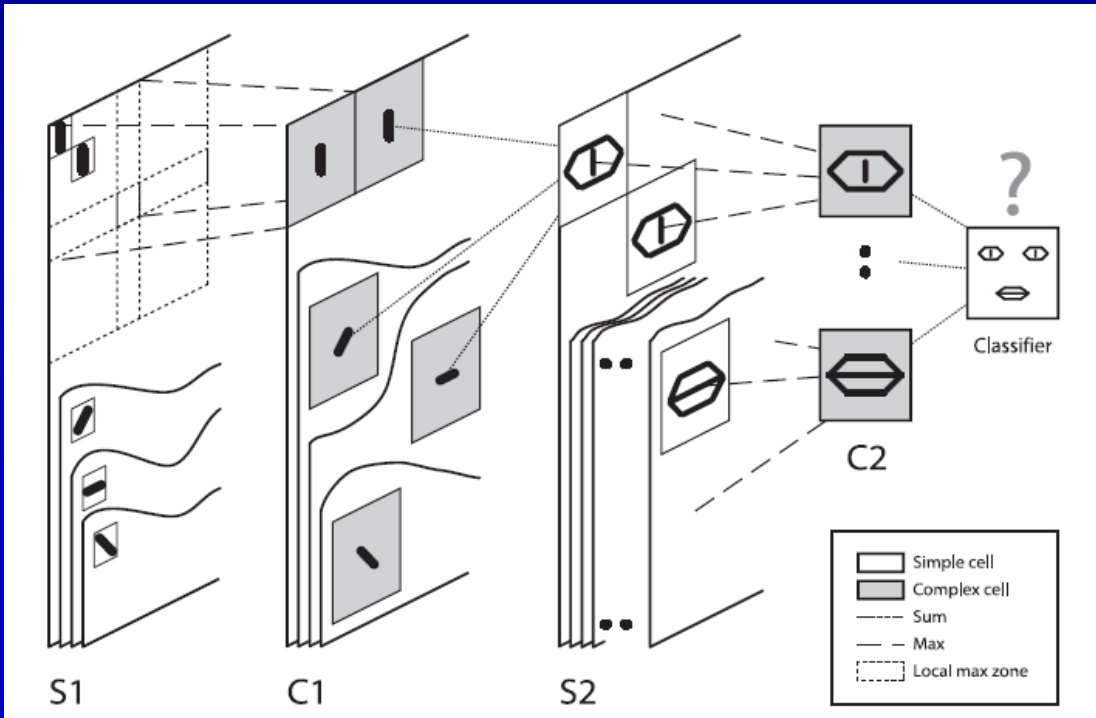
OPEN ACCESS Freely available online

PLoS COMPUTATIONAL BIOLOGY

## Unsupervised Learning of Visual Features through Spike Timing Dependent Plasticity

**Timothée Masquelier**[1,2*], **Simon J. Thorpe**[1,2]

1 Centre de Recherche Cerveau et Cognition, Centre National de la Recherche Scientifique, Université Paul Sabatier, Faculté de Médecine de Rangueil, Toulouse, France, 2 SpikeNet Technology SARL, Labege, France



# Scene Processing Conclusions 1

Temporal constraints have got even worse!

- Key visual patterns such as faces can be detected in roughly 100 ms

Strong evidence for very rapid feedforward mechanisms

- Serre, Oliva & Poggio (2007)

Processing using Spikes

- The most strongly activated neurons fire first
- Any flashed image will generate a wave of spikes
- STDP will systematically concentrate high synaptic weights on the earliest firing inputs

An unsupervised mechanism that guarantees short latency and reliable responses to frequently occuring input patterns

# Scene Processing Conclusions 2

Any natural image is likely to contain at least some visual patterns that can be detected with a feedforward pass

Processing time varies depending on the visual pattern

- Fastest for faces (100 ms)
- Fast for animals (120 ms)
- Somewhat slower for other stimuli (140-180 ms)

The fastest processing will occur for the most important frequently occuring visual patterns

The feedforward pass can then be used to guide feedback mechanisms for other important operations

- Figure-ground segregation
- Accurate localisation

# Thanks!

Holle Kirchner

Sébastien Crouzet

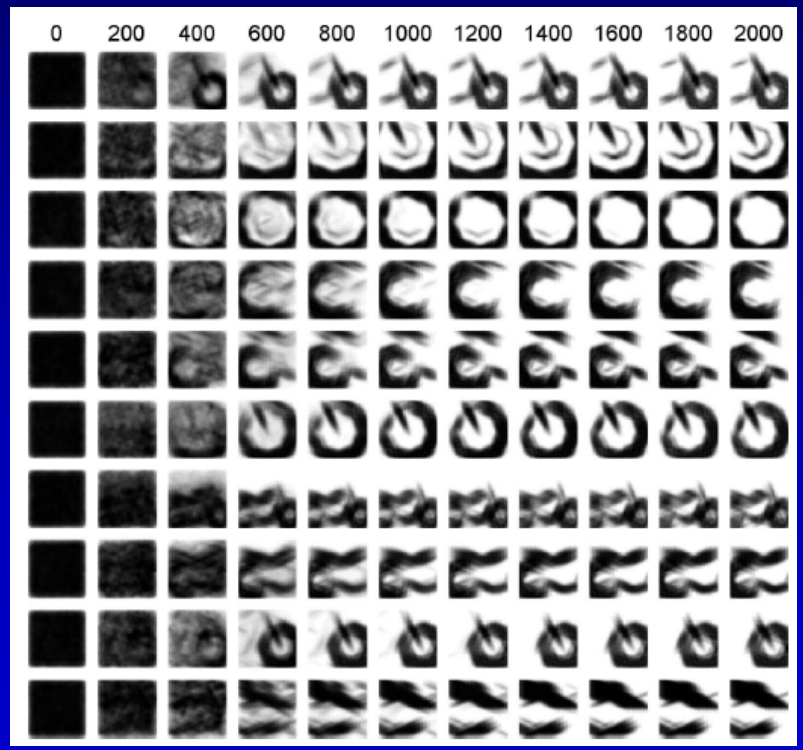
Rudy Guyonneau

Tim Masquelier

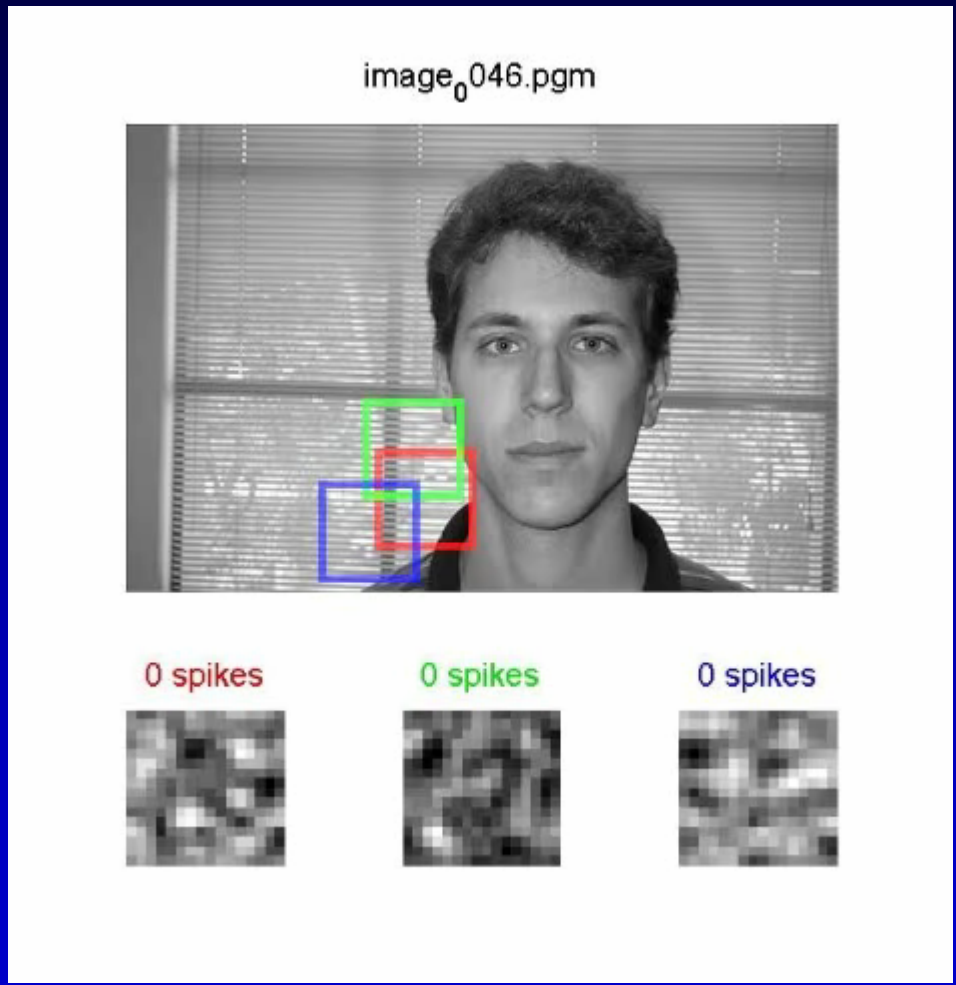
# Unsupervised learning

## Faces


## Motorcyles

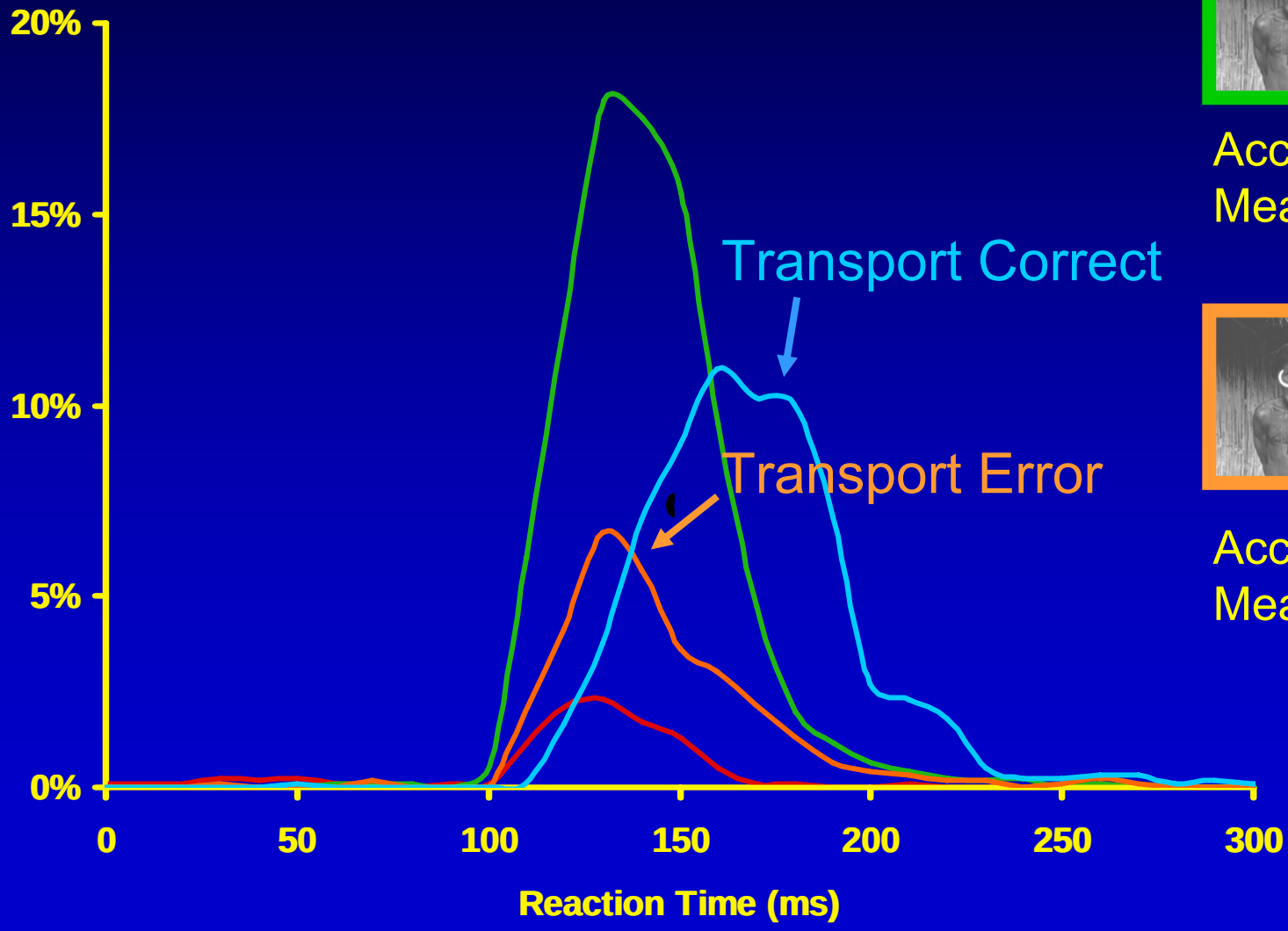


# Developping Face Selective Cells



# Inversion?

## Transport versus Human




Accuracy = 89.3%
Mean RT = 140.7 ms

Accuracy = 69.0%
Mean RT = 169 ms