University of Waterloo

How to build a brain

Applications

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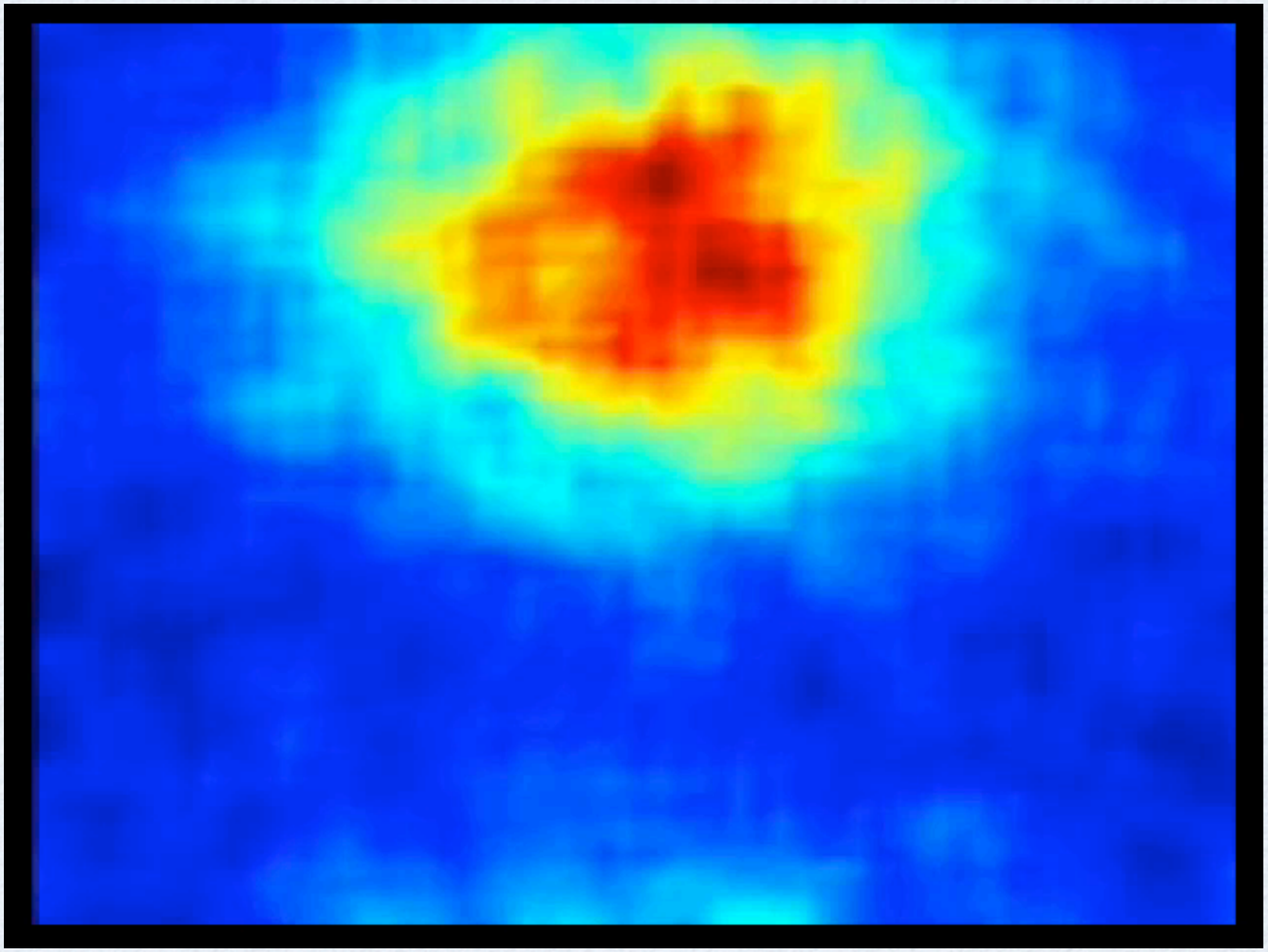
Other applications

- Motor
  - Zebrafish swimming and escape (Kuo and Eliasmith (2005) Bio. Cyber.); arm control; eye position control;
- Sensory
  - Vestibular system (Eliasmith et al. (2002) Neurocomp.); auditory localization; parietal cortex/hemineglect; rodent navigation (Conkiln & Eliasmith, 2005, J. Comp Neuro)
- Cognitive
  - Working memory dynamics (Singh & Eliasmith (2006) J. Neuro.); emotional effects on decisions (loss aversion); linguistic inference
- Theoretical
  - Controlled attractor dynamics (line, circle, plane, cyclic, chaotic) (Eliasmith (2005) Neural Comp.); pattern generation and temporal bases; neural differentiation
  - Negative weights problem: Biologically realistic weight distributions for arbitrary networks (Parisien & Eliasmith (forthcoming))

- All together: Biologically realistic models that *explains behaviour*



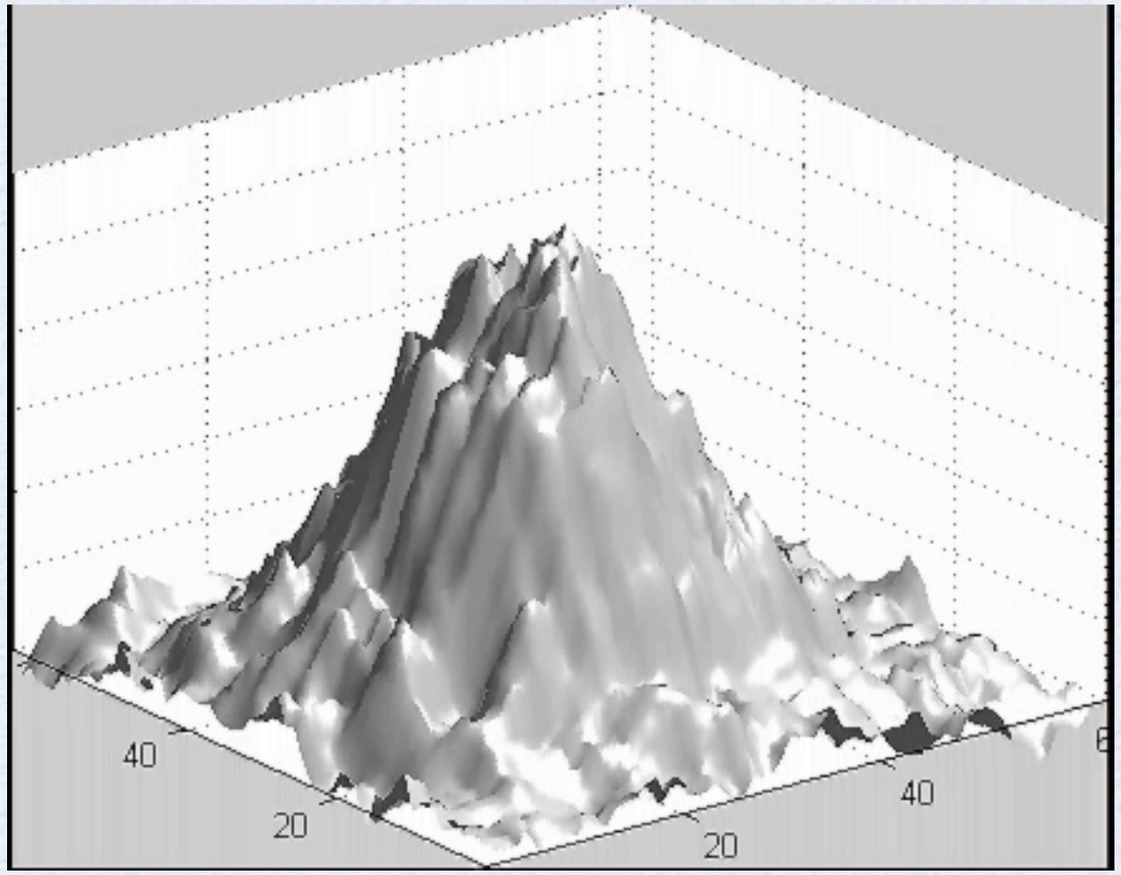
- this model: 11% error with 4000 cells
- best previous model: 100% error with 300 000 cells

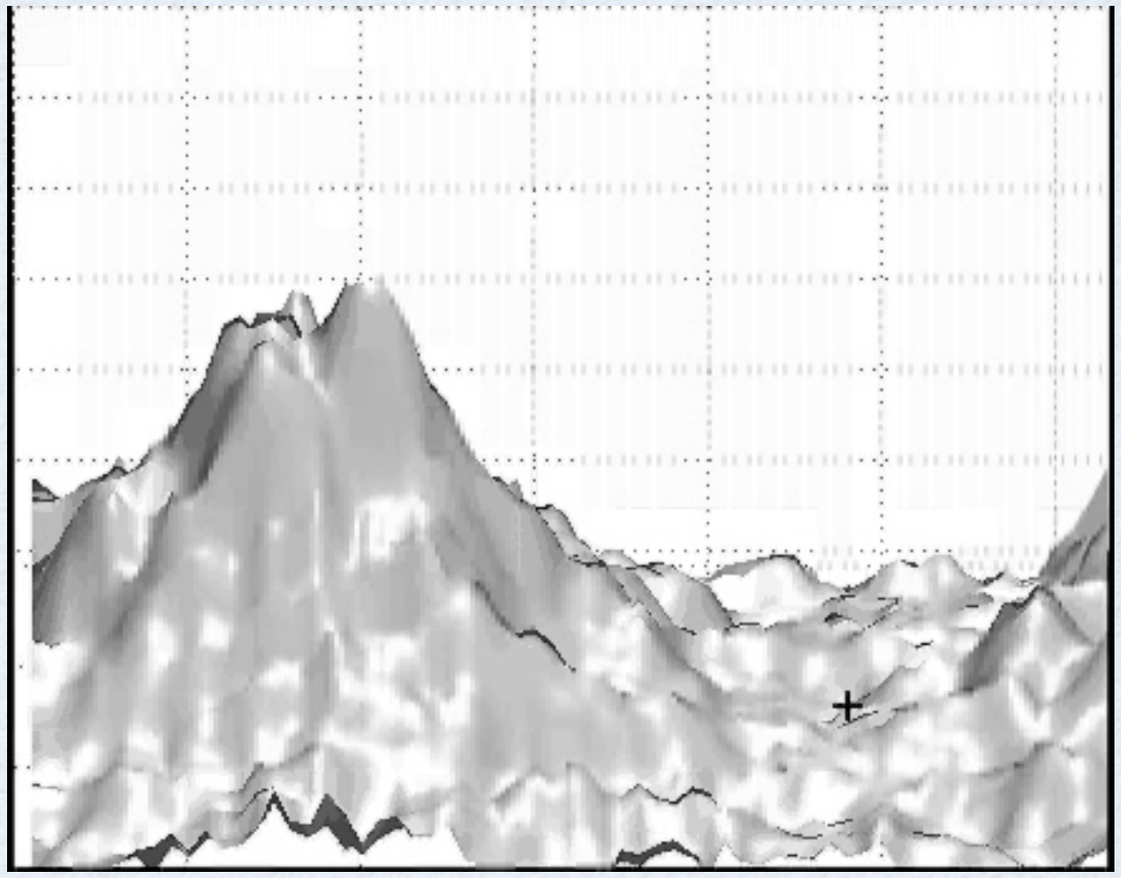
Model accounts for:

- Tuning curves in different environments
- Velocity sensitivity of neuron tuning
- Theta dependent phase precession and amplitude
- Weak visual input gives smooth acceleration
- Strong visual input gives rapid displacement

Model Predicts:

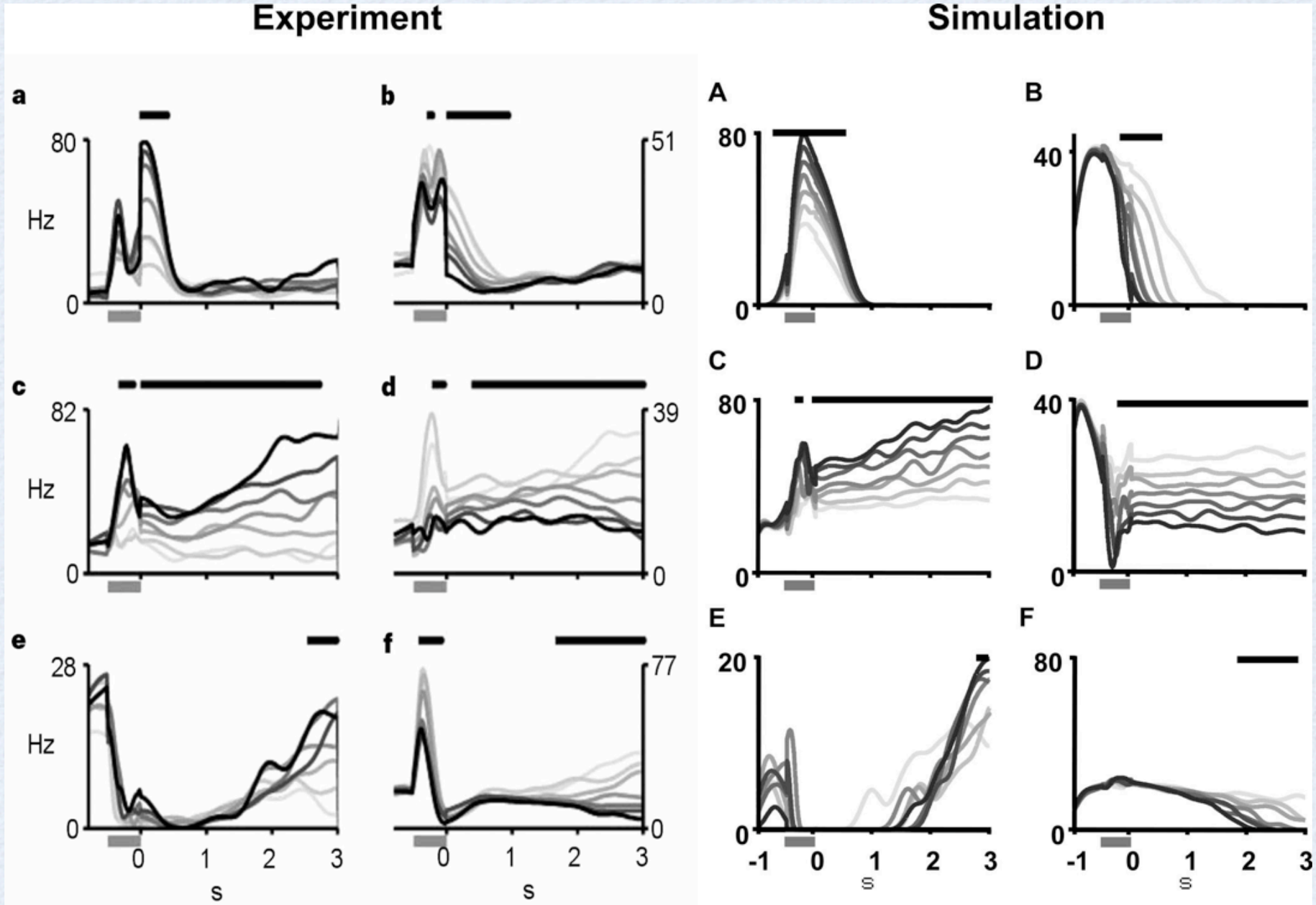
- Identically coupled velocity and direction sensitivity across environments
- Head-direction independent accuracy



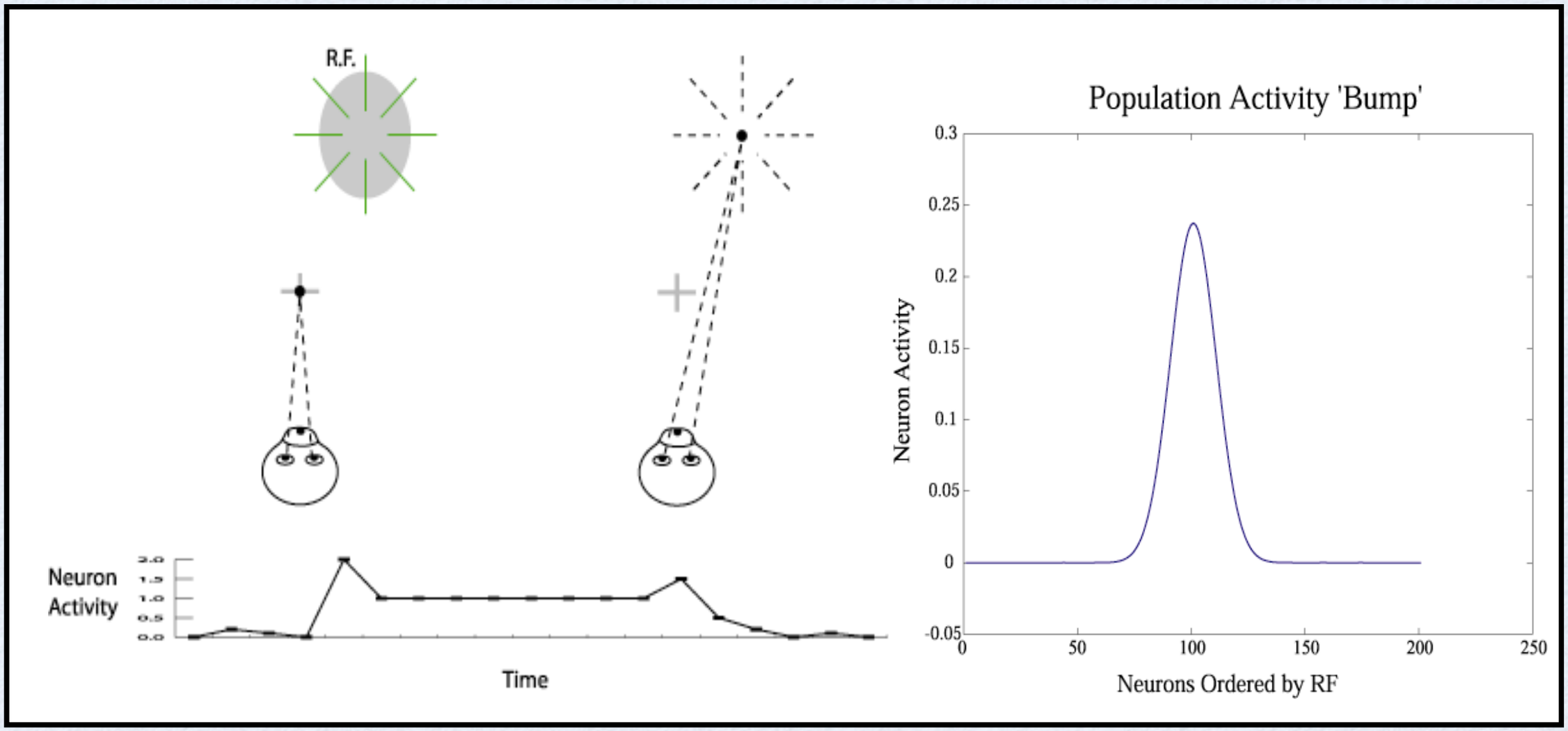


Working memory

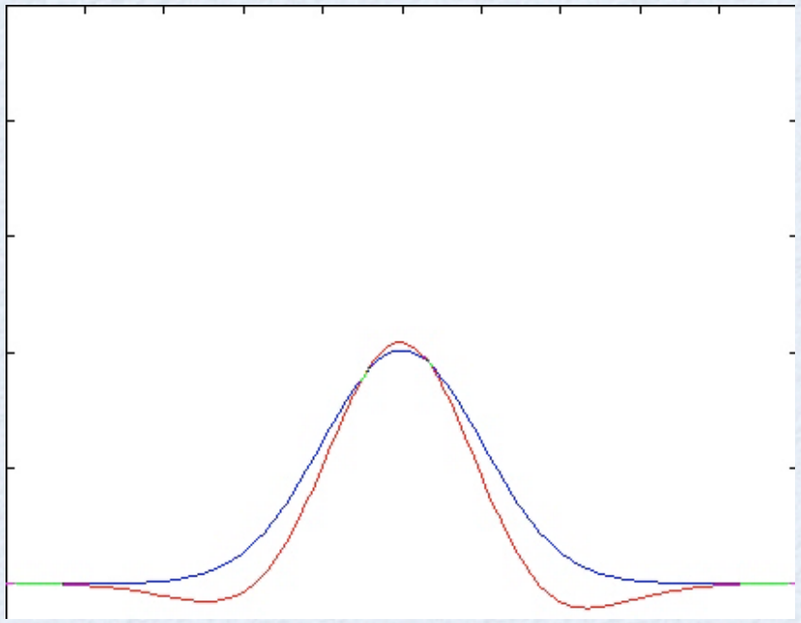
- Parametric working memory (Singh & Eliasmith (2006) J. Neuro.)

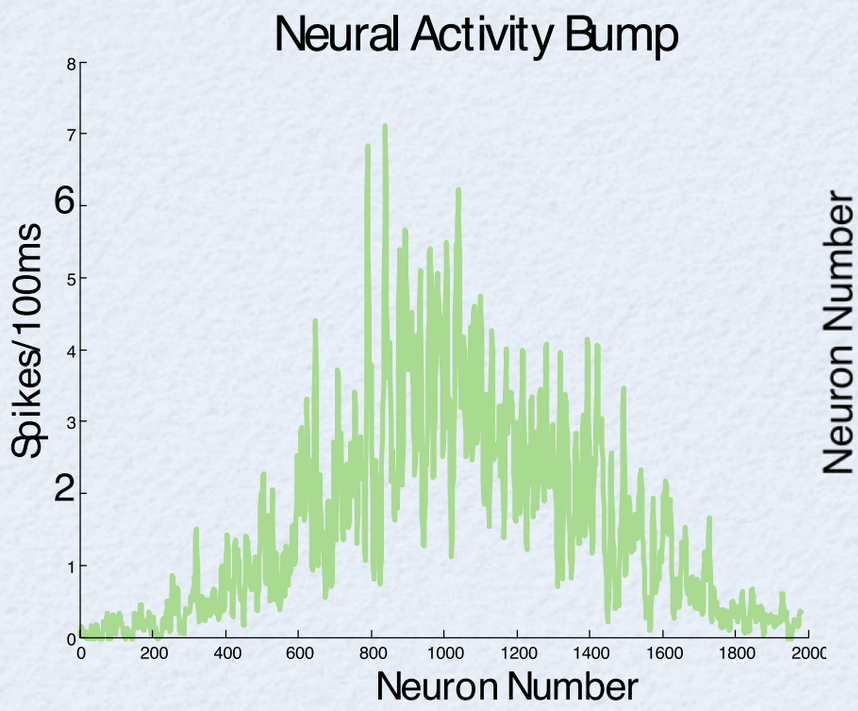


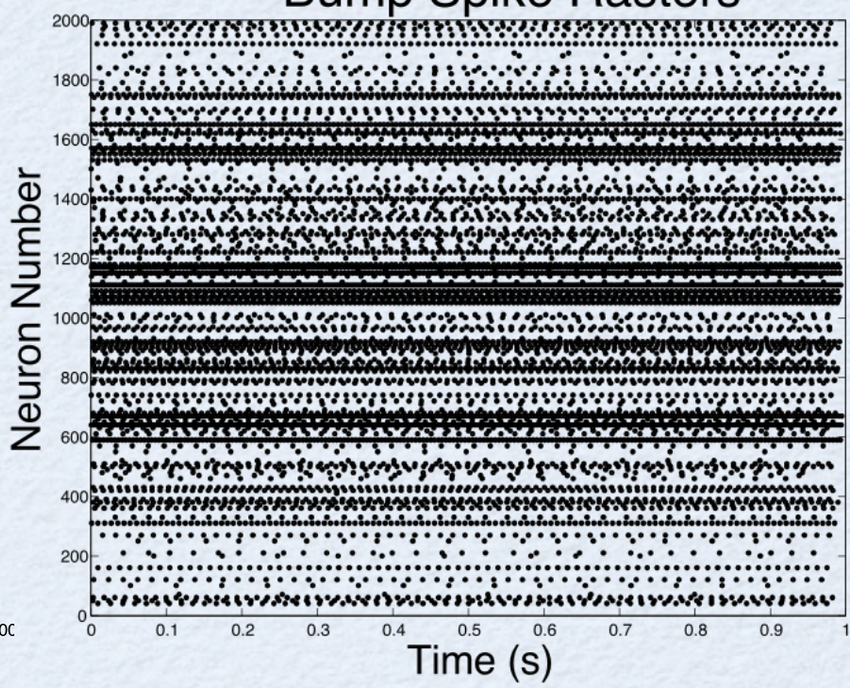
Visual working memory

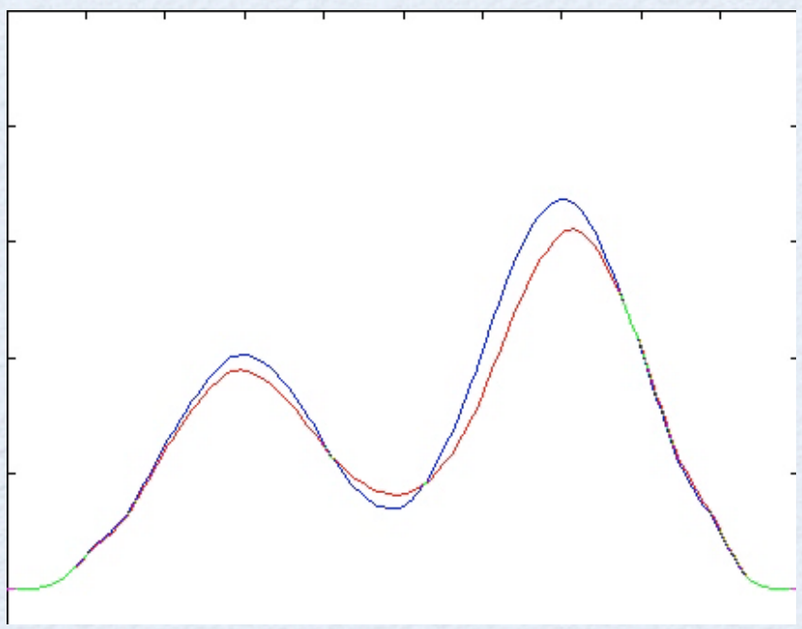


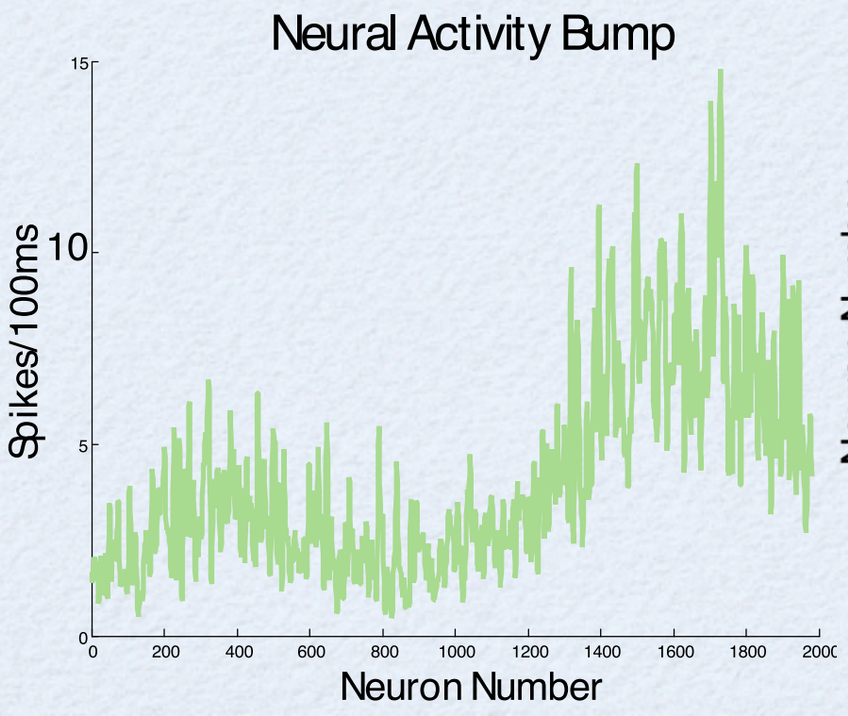
Working memory

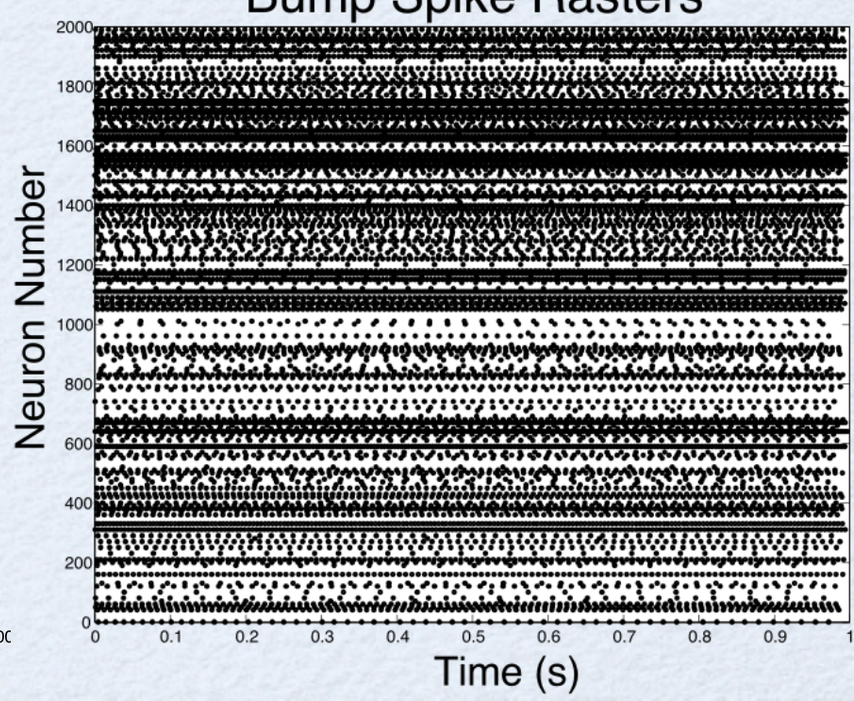




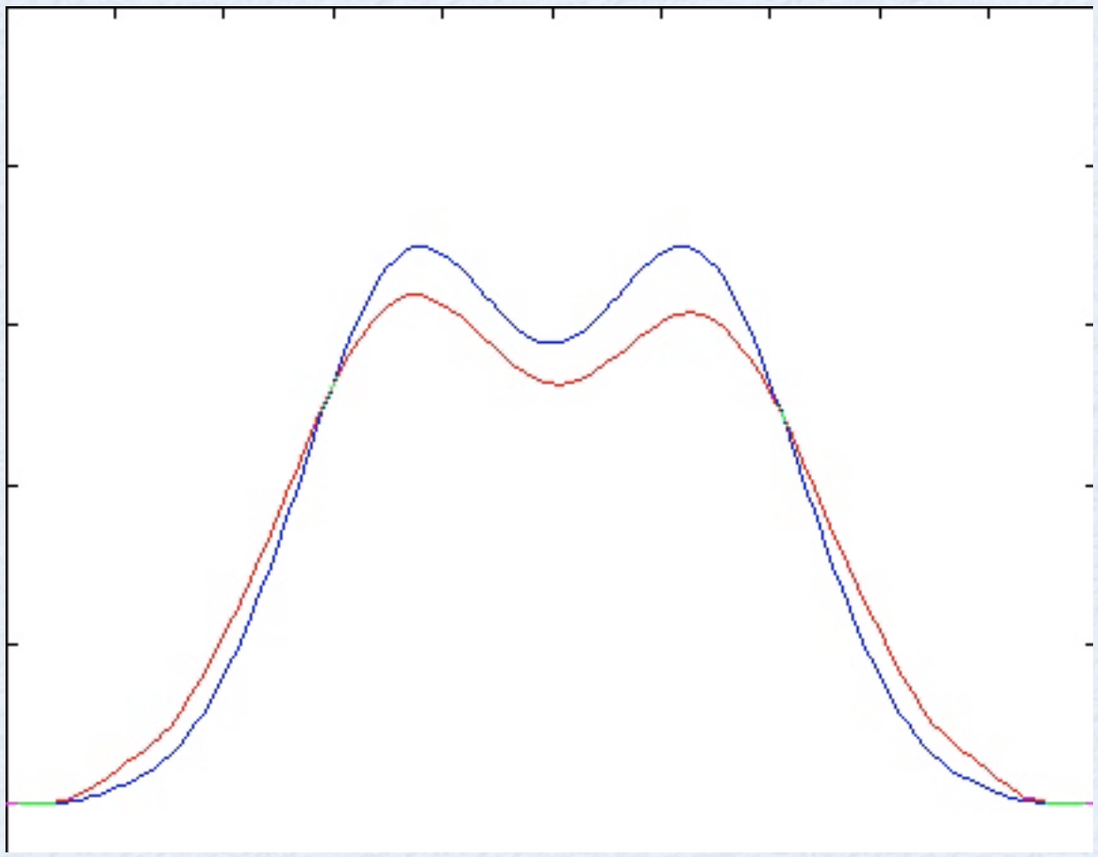




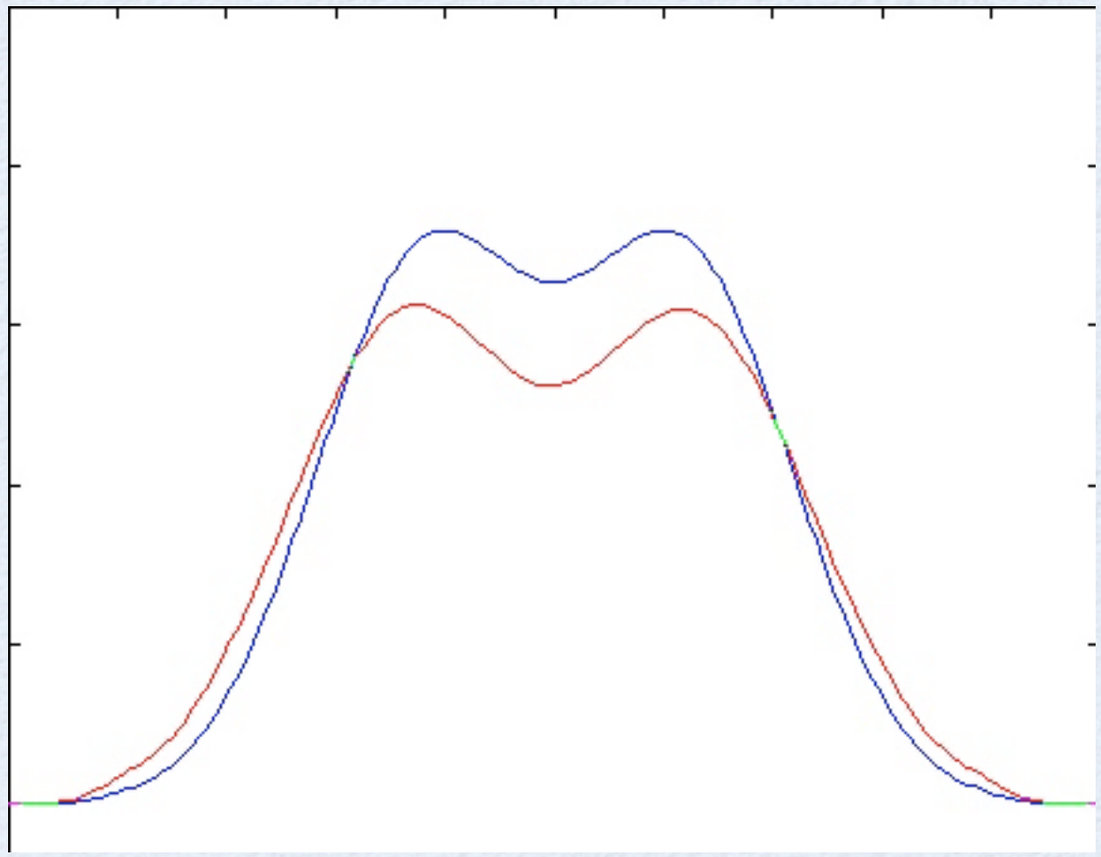




Working memory

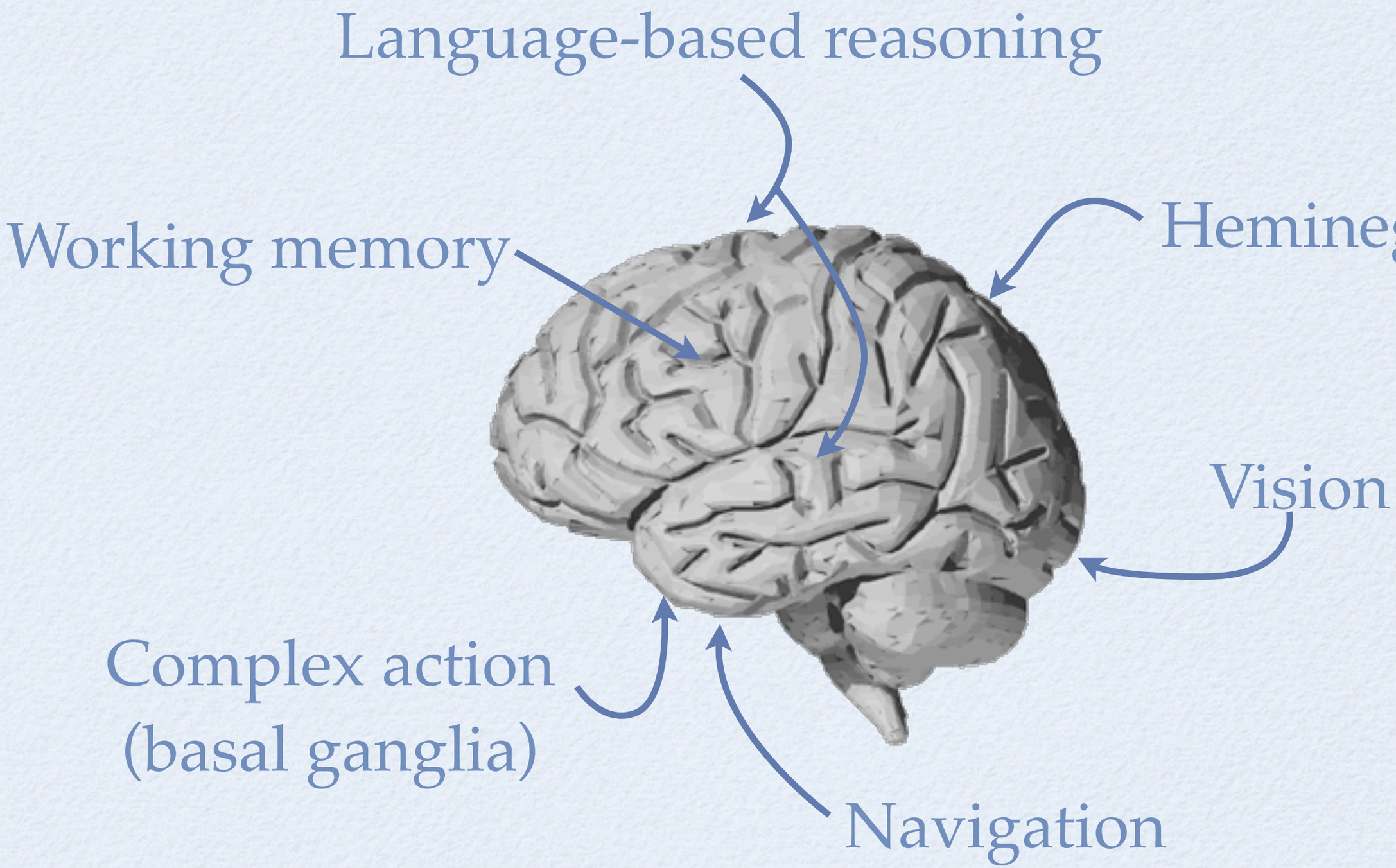


Forgetting

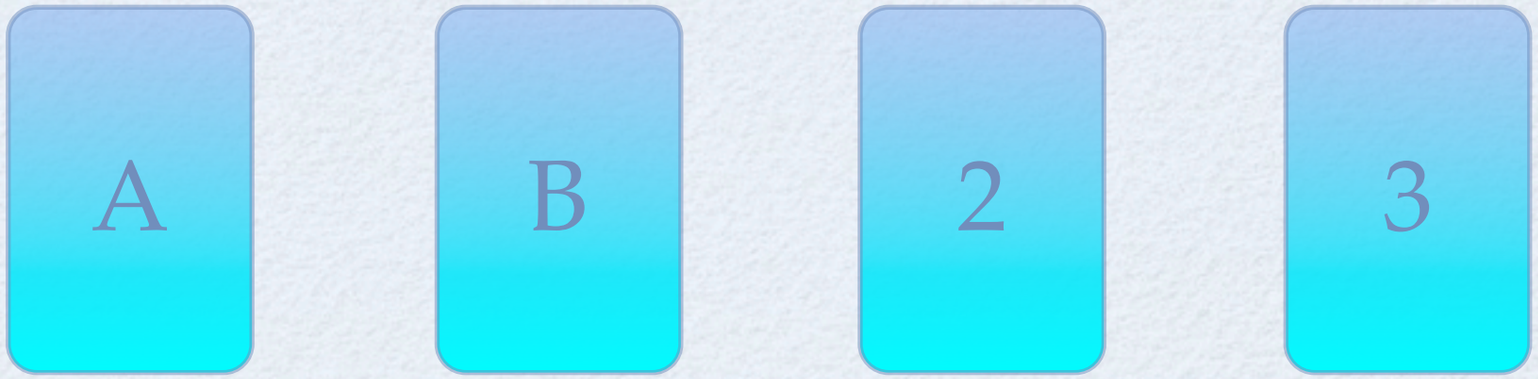


Blending

Applications

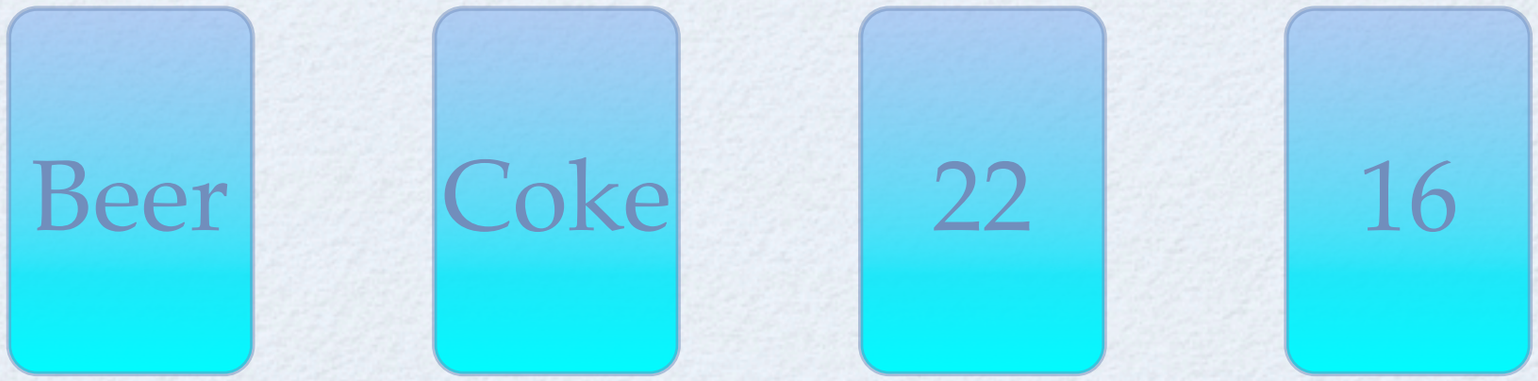


- Abstract Rule
  - If there is a vowel on one side
    then there is an even number on the other.



30%

- Social Rule
  - If someone is drinking alcohol
    then they are over 21.

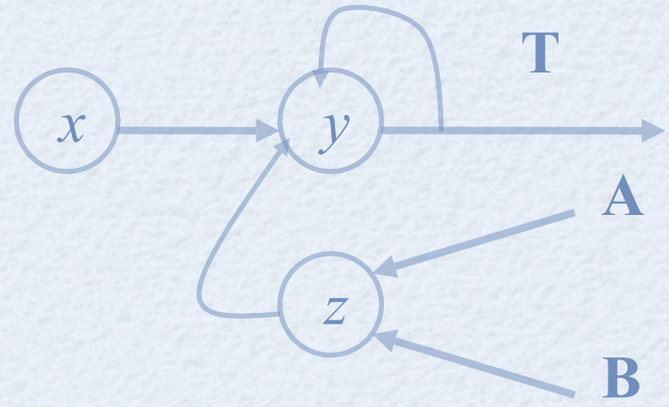


90%

Learning transformations

- Learning HRR transformations

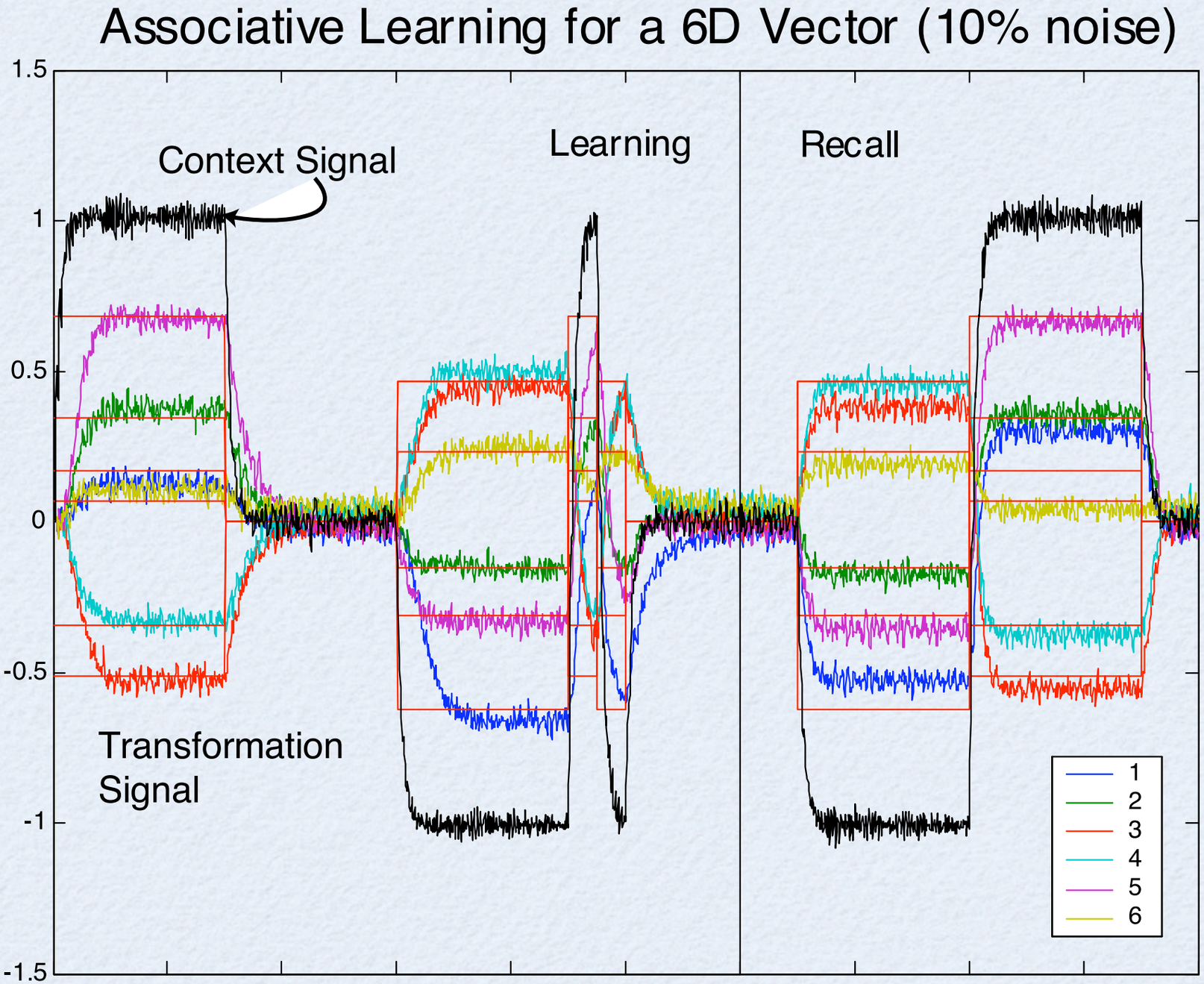
$$\mathbf{T}_{i+1} = \mathbf{T}_i - \epsilon_i(\mathbf{T}_i - \mathbf{A}_i \oplus \mathbf{B}_i)$$

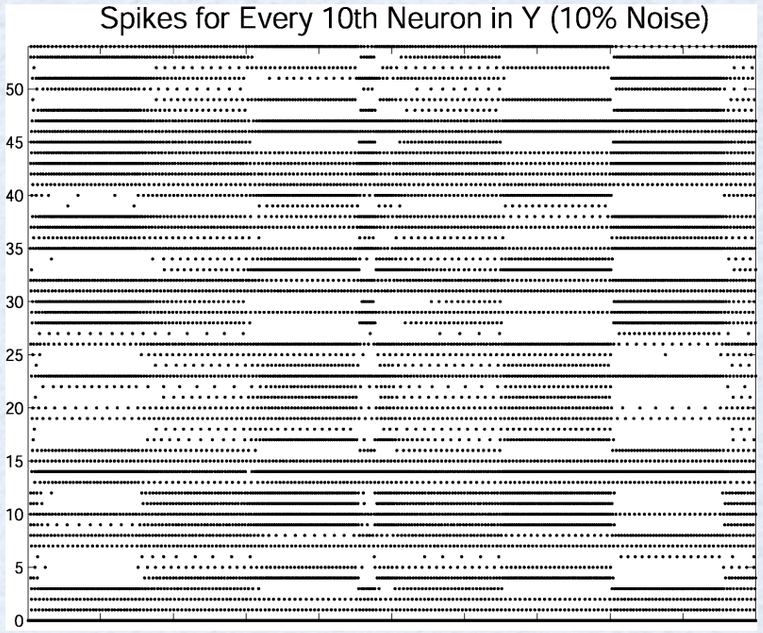


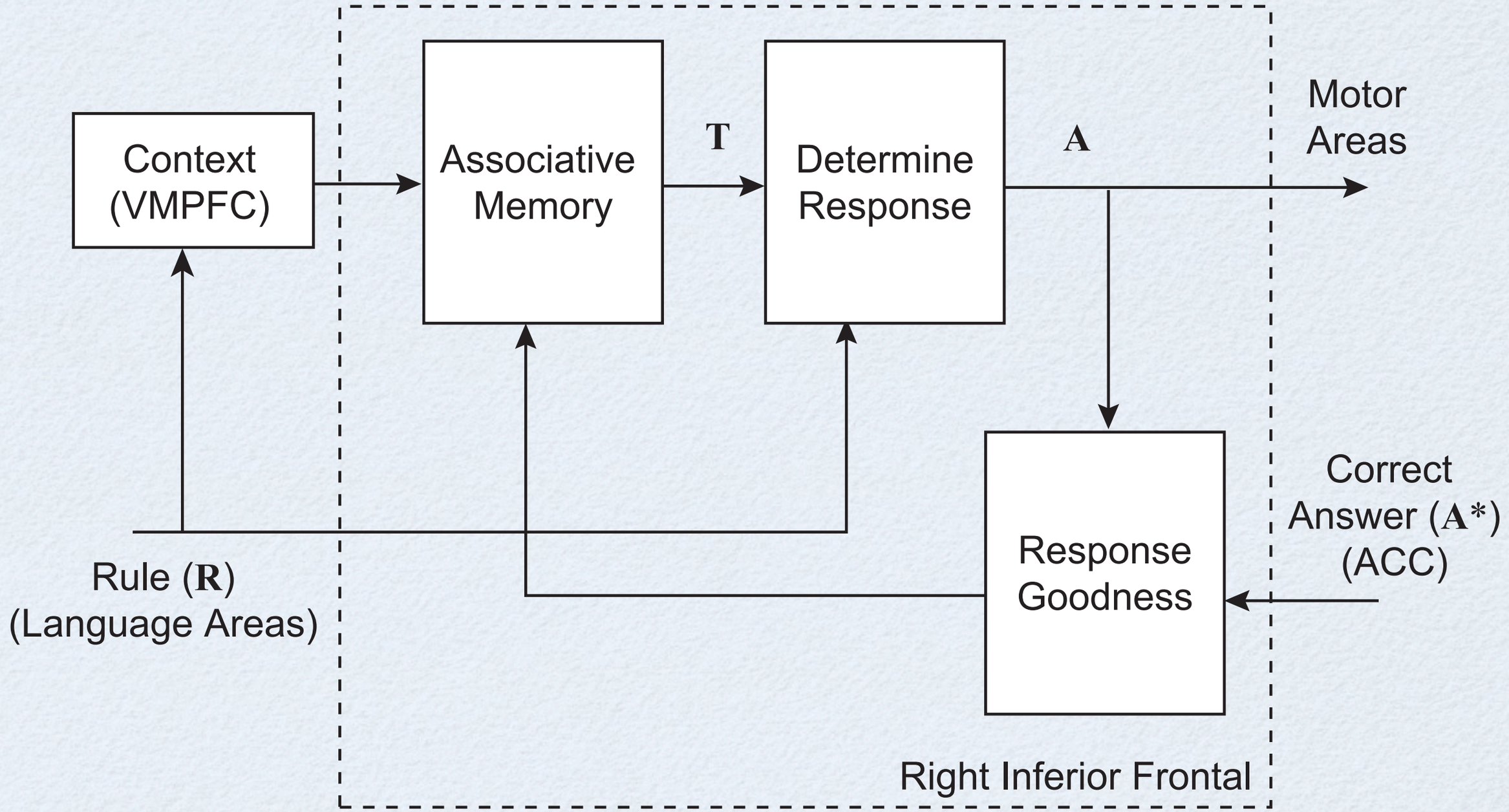
- Learning contextual neural transformations

$$\Delta w_{jl} = \kappa \frac{\delta E}{\delta \omega_{jl}} = \frac{\kappa}{\alpha_j \left\| \tilde{\phi}_j \right\|} \left[\sum_k \omega_{jk} z_k - \sum_{j'} \omega_{j'j} y_j \right] (y_j > 0) x_l$$

Learning results






Context
(VMPFC)
Associative
Memory
T
Determine
Response
A
Motor
Areas
Rule (R)
(Language Areas)
Response
Goodness
Correct
Answer (A*)
(ACC)
Right Inferior Frontal

vowel: 0.72
even: 0.48
drinkalcohol: 0.85
not_over21: 0.73
vowel: 0.67
even: 0.43
drinkalcohol: 0.85
not_over21: 0.71
abstract
social
abstract
social
Possible Responses
Similarity to
Neuron Number
100
90
80
70
60
50
30
20
10
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
50
100
150
200
250
300
350
400
Time
Learning on
Learning off
0
1
2
3
4
5
6
Time (s)

Other theoretical results

- Respecting 'Dale's principle'
- Arbitrary attractor dynamics (line, ring, plane, chaotic, etc.)
- Complex single cell dynamics (adaptation, bursting, etc.)
- Statistical inference
- Pattern generators
- Neural differentiators