Neural foundation of DFT

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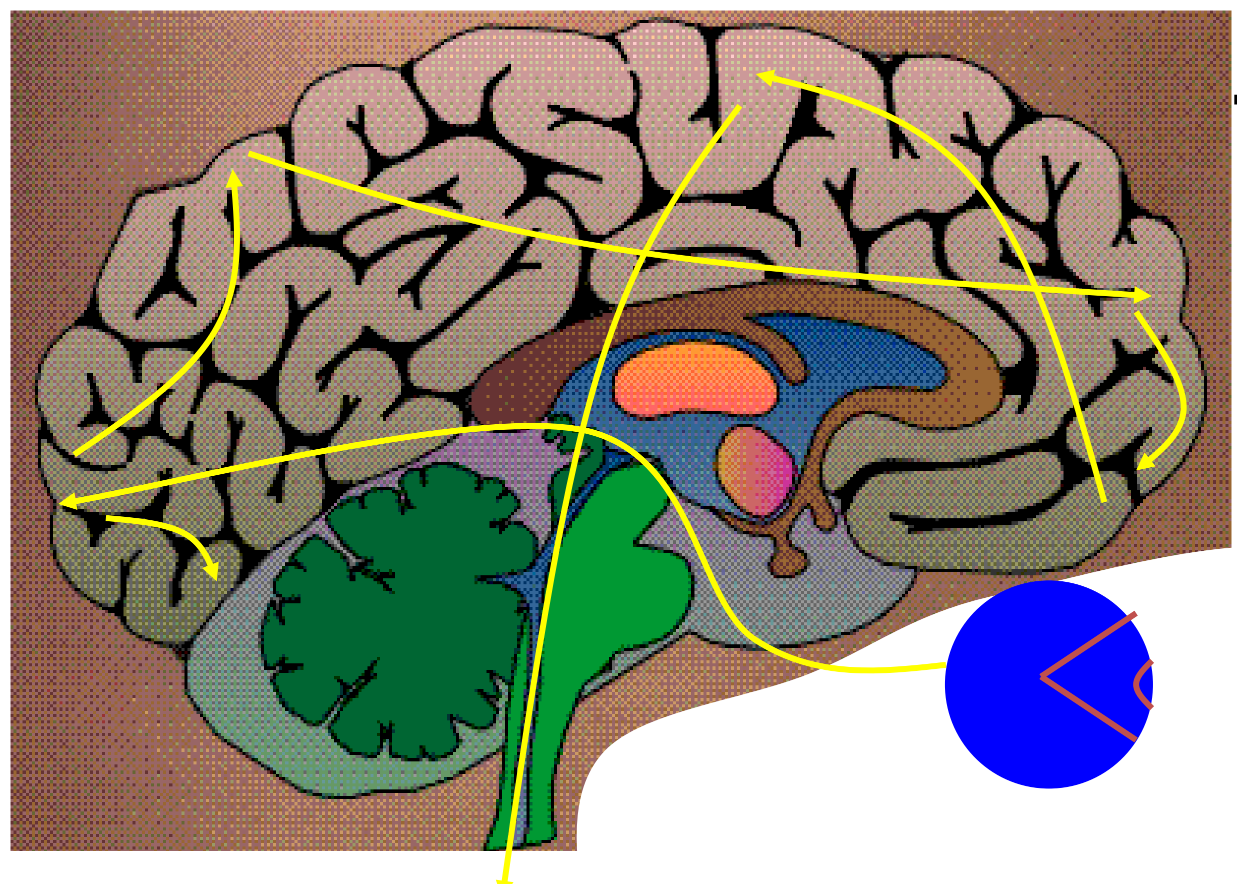
Functional analysis of the brain

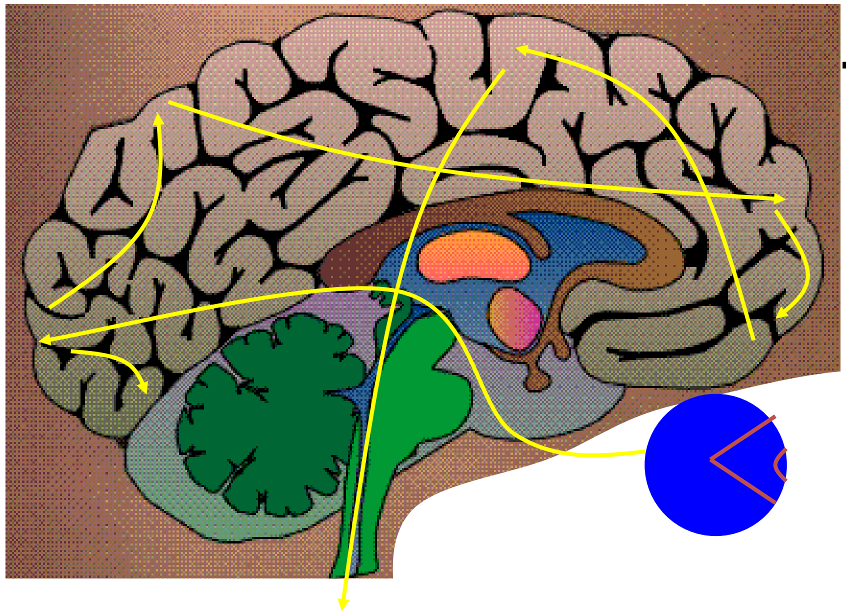


[Tresilian, 2012]

Functional analysis of the brain: how?

- vary conditions "outside" the brain: stimulus, motor task, cognitive task and relate to neural activity: coding/ decoding, cognitive neuroscience

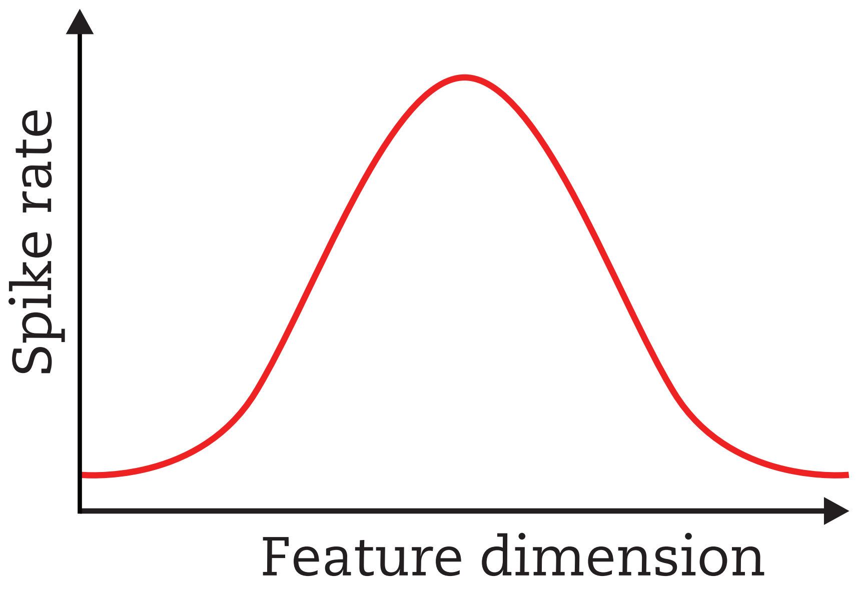
- or the reverse: vary neural substrate (lesioning, optogenetics, etc) and observe what happens to behavior/ competence: neuropsychology



[Tresilian, 2012]

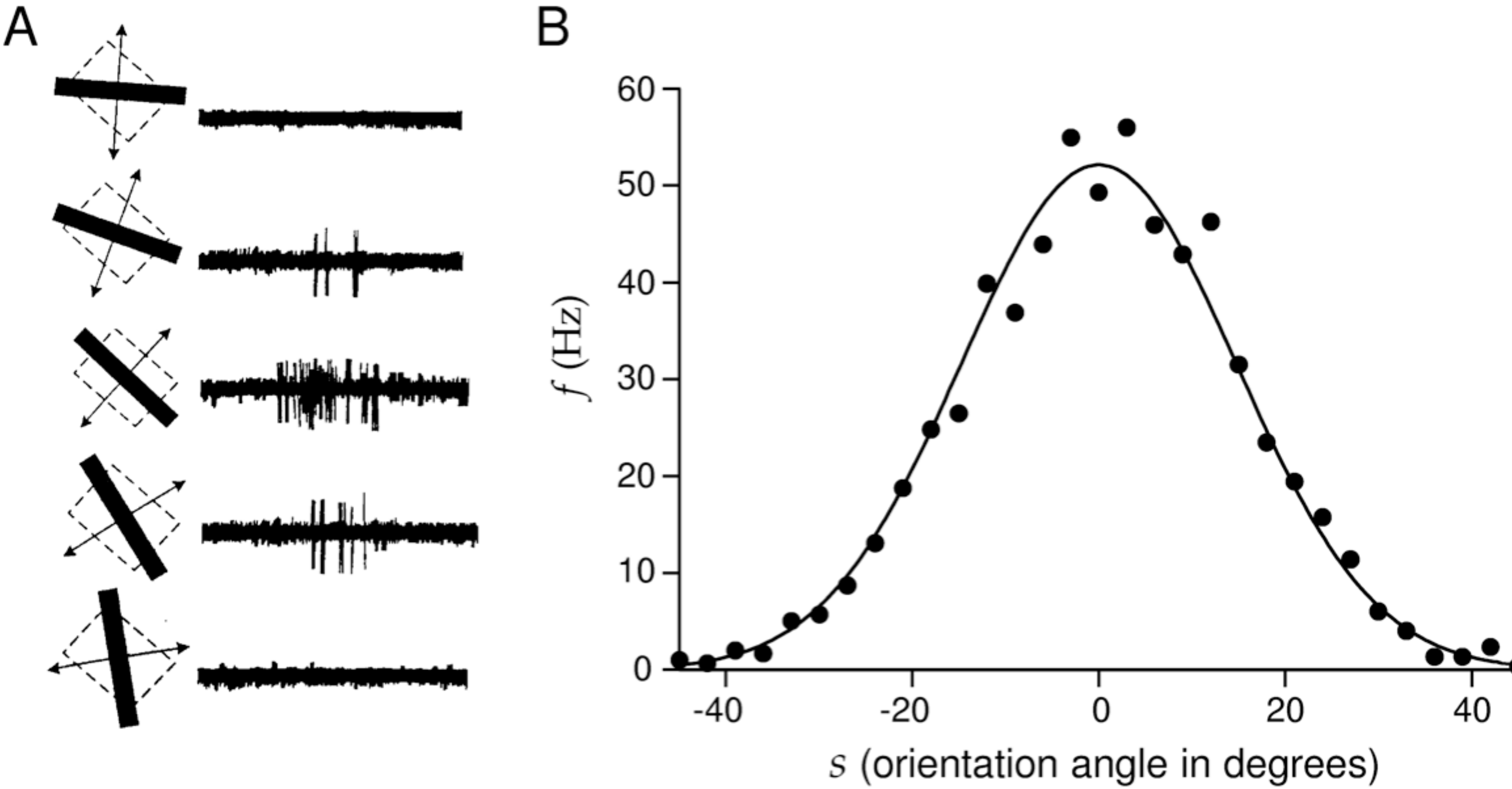
Coding/decoding at neural level

- Tuning curves: neural activity (e.g. .spike rate) as a function of stimulus/task parameter



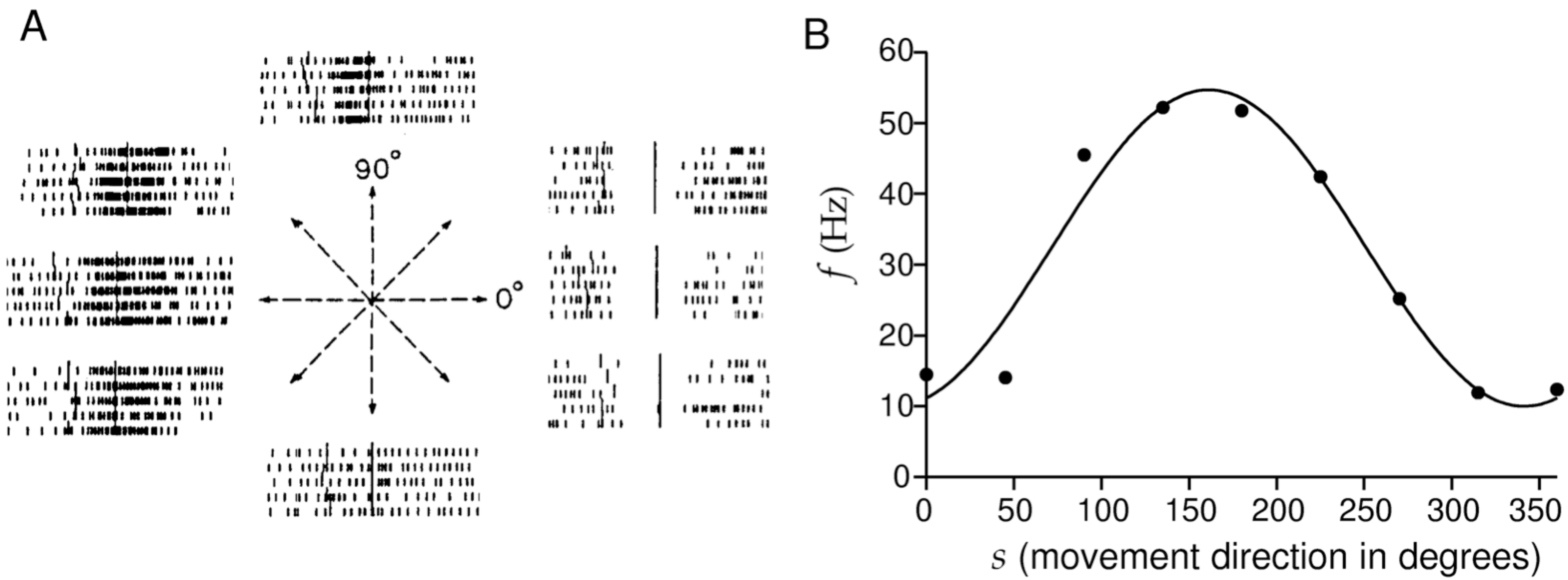
[Chapter 3 of DFT book]

Example tuning curve in primary visual cortex (monkey)



[Hubel, Wiesel, 1962]

Example: tuning curve in primary motor cortex (monkey)

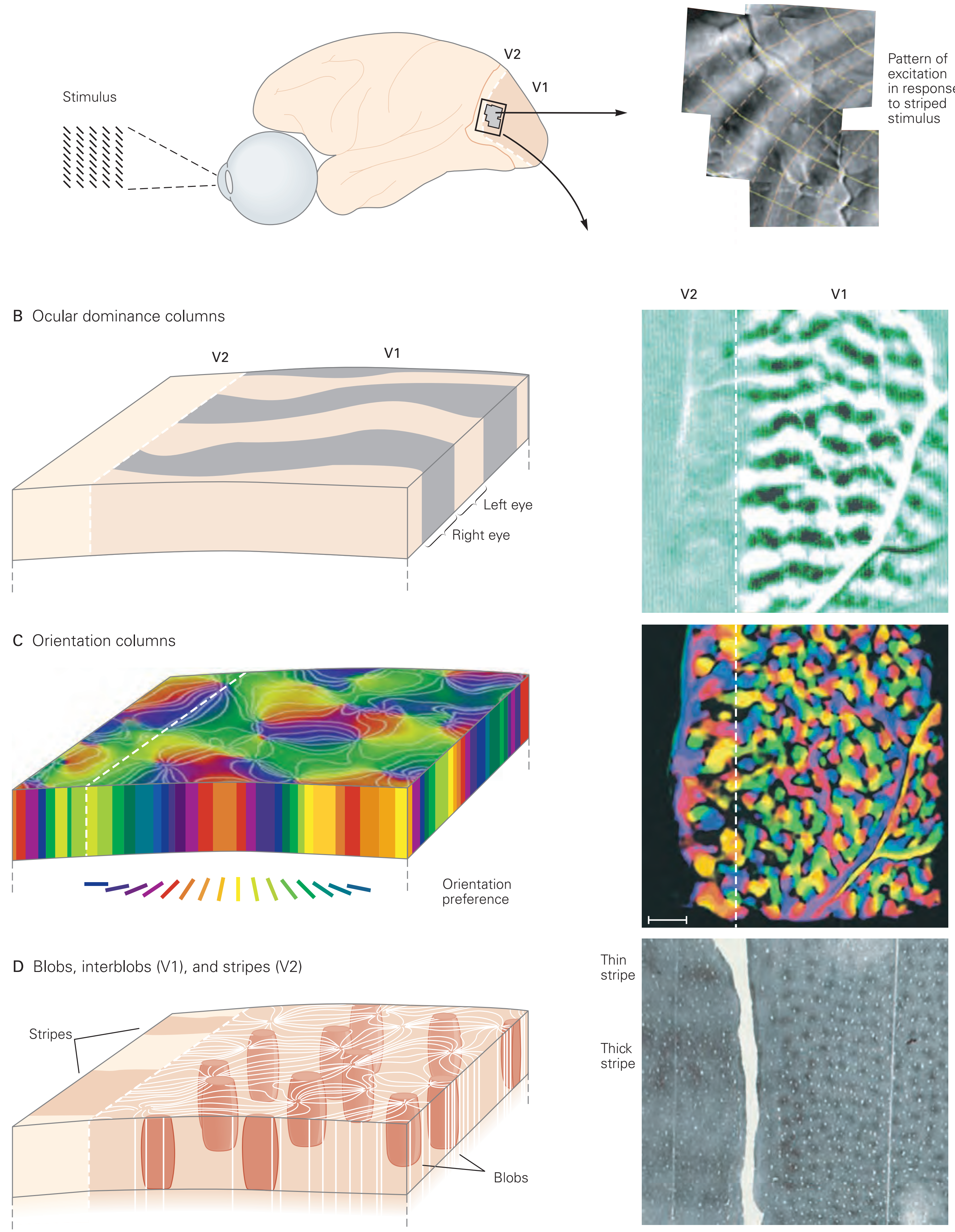


[Georgopoulos, Schwartz, Kalaska, 1986]

Neural maps

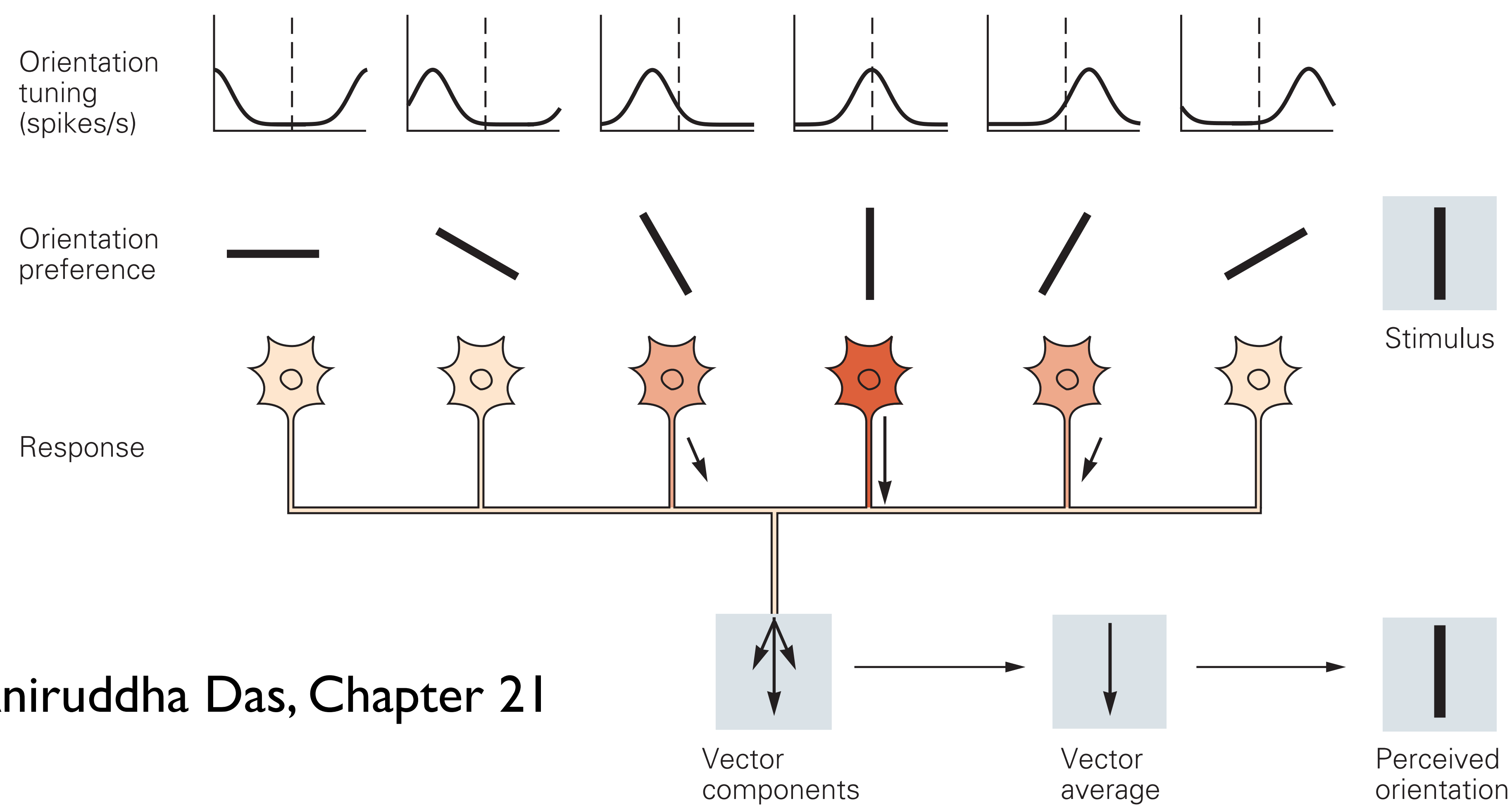
- tuning curves studied systematically across the cortical surface
- => feature maps
- topography

[Charles D. Gilbert, Aniruddha Das, Chapter 21 of Kandel et al 2021]



Population code

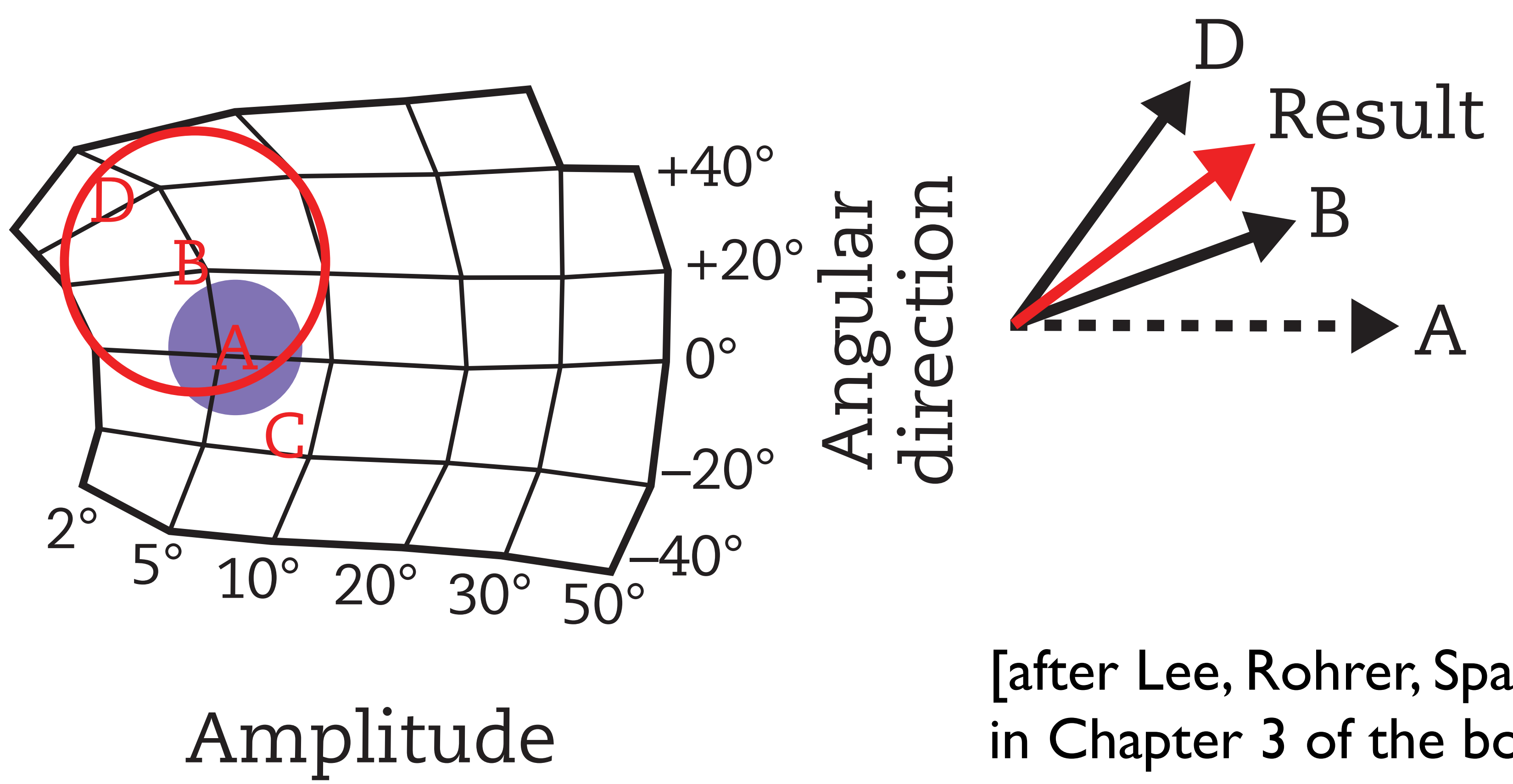
- notion that all activated neurons contribute to feature representation according to their tuning curves



[Charles D. Gilbert, Aniruddha Das, Chapter 21 of Kandel et al 2021]

Experimental evidence for population representations

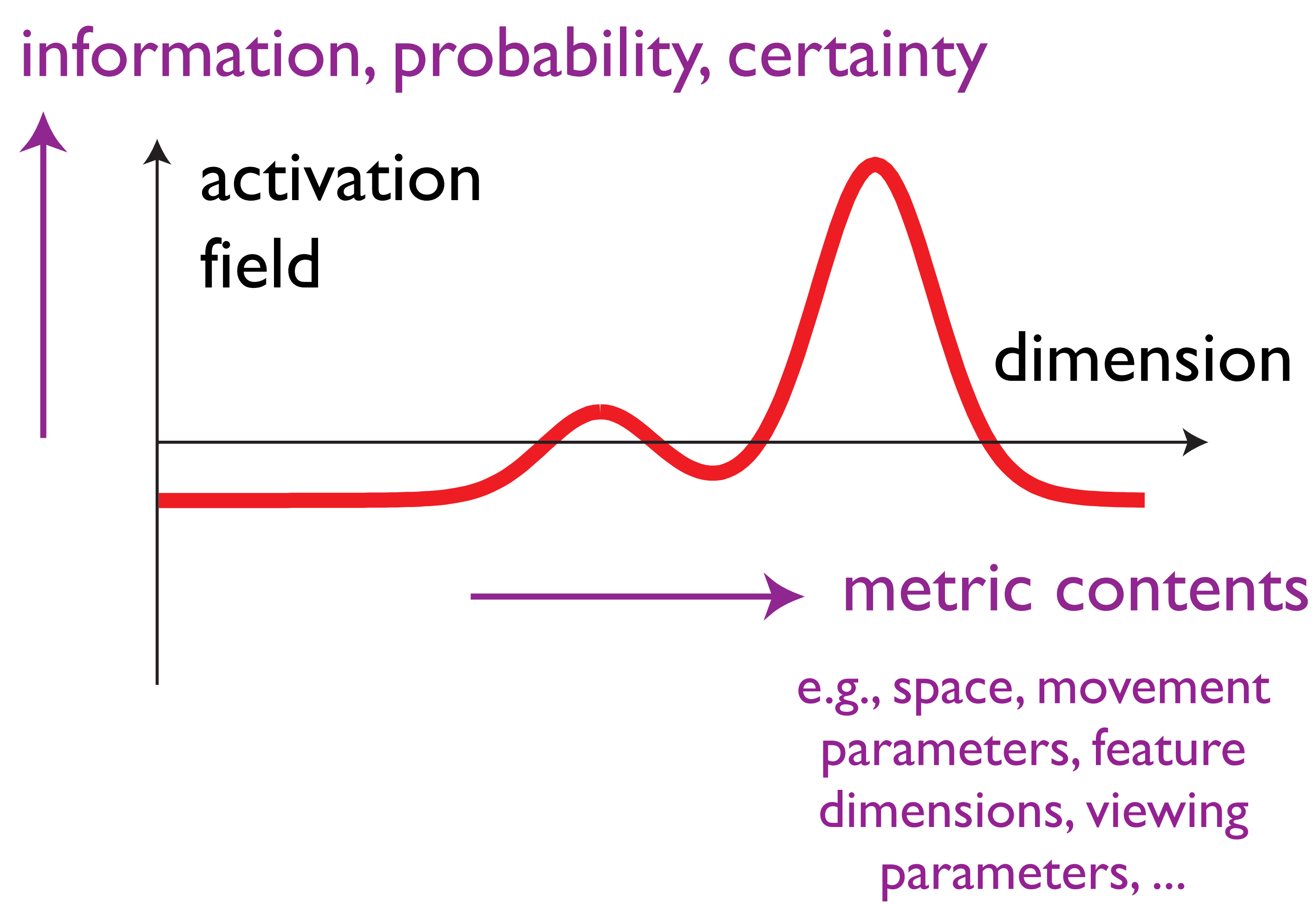
- Lee, Rohrer, Sparks: use the topographic map of saccadic endpoint in superior colliculus
- to reversibly deactivate portions of the population: observe predicted deviations of saccadic endpoints



[after Lee, Rohrer, Sparks: Nature (1988) in Chapter 3 of the book]

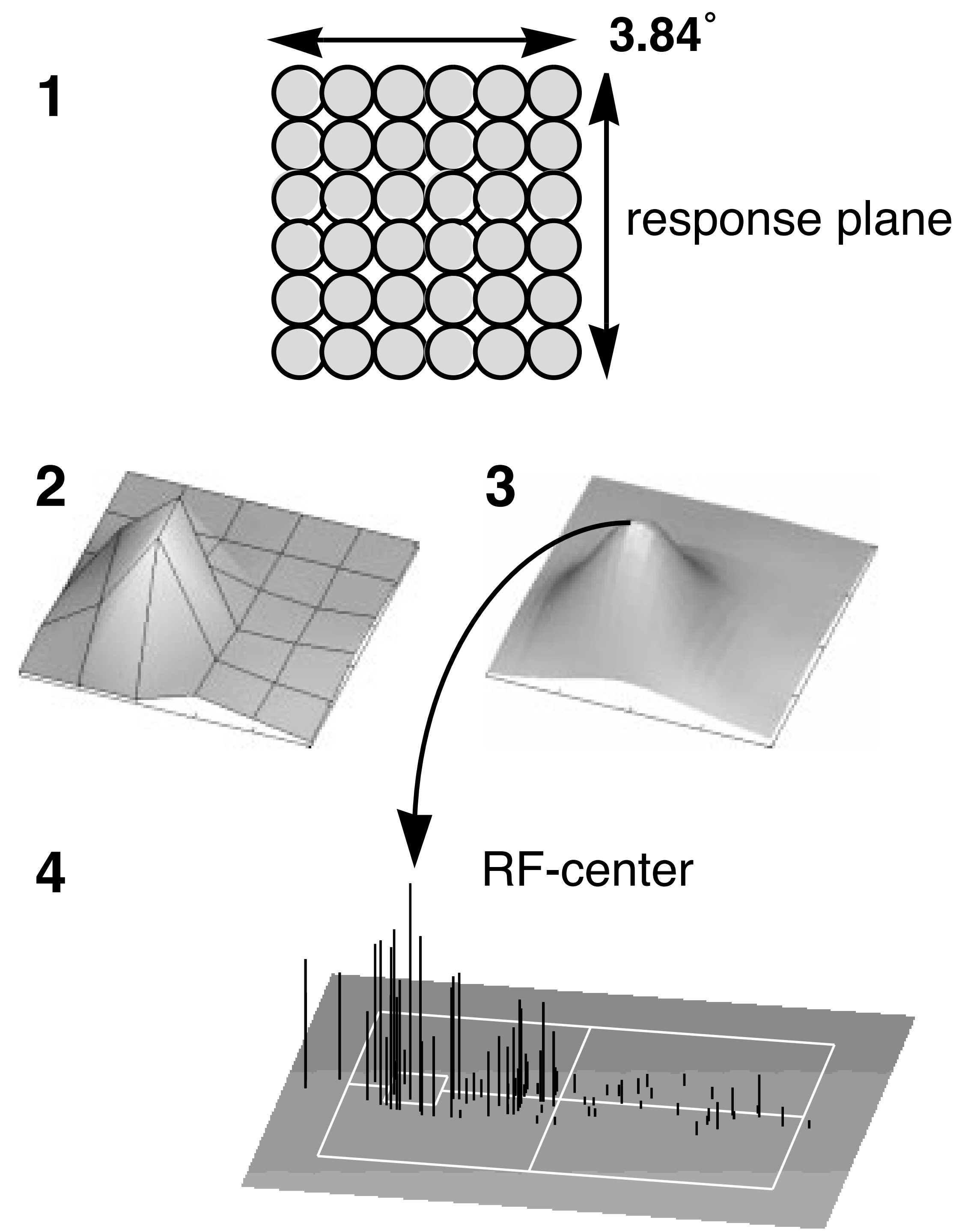
Neural grounding of DFT

- neural fields as activation patterns defined over feature dimensions
- rather than over the cortical surface as for neural maps



Neural grounding of DFT: sensory

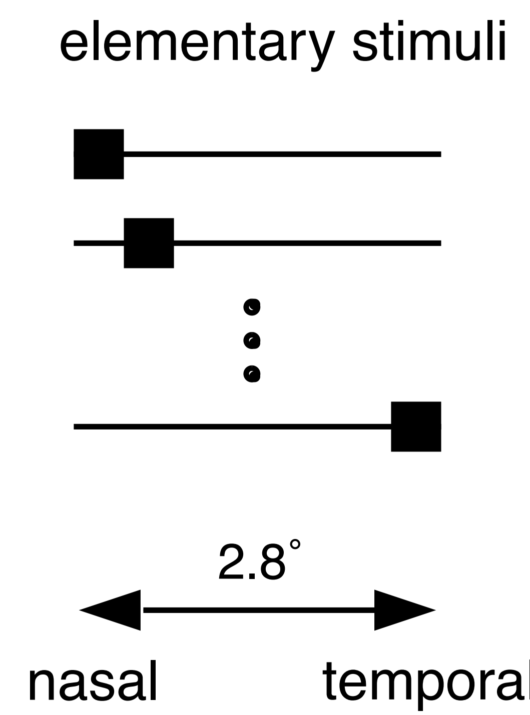
- Example: primary visual cortex A17 in the cat
- determine tuning to retinal location for each cell
- superpose tuning curves weighted by current firing rate: distribution of population activation DPA representing retinal location

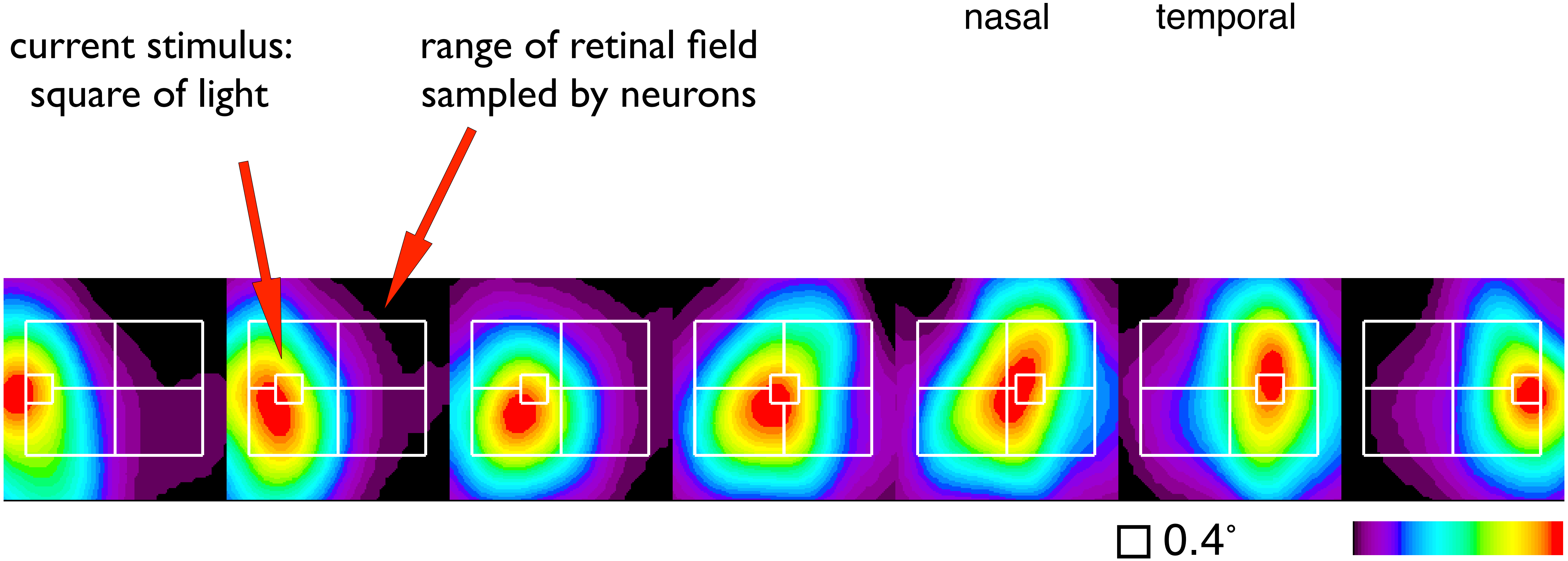


[Jancke, Erlhagen, Dinse, Akhavan, Giese, Steinhage, Schöner JNsci 19:9016 (99)]

Neural grounding of DFT: sensory

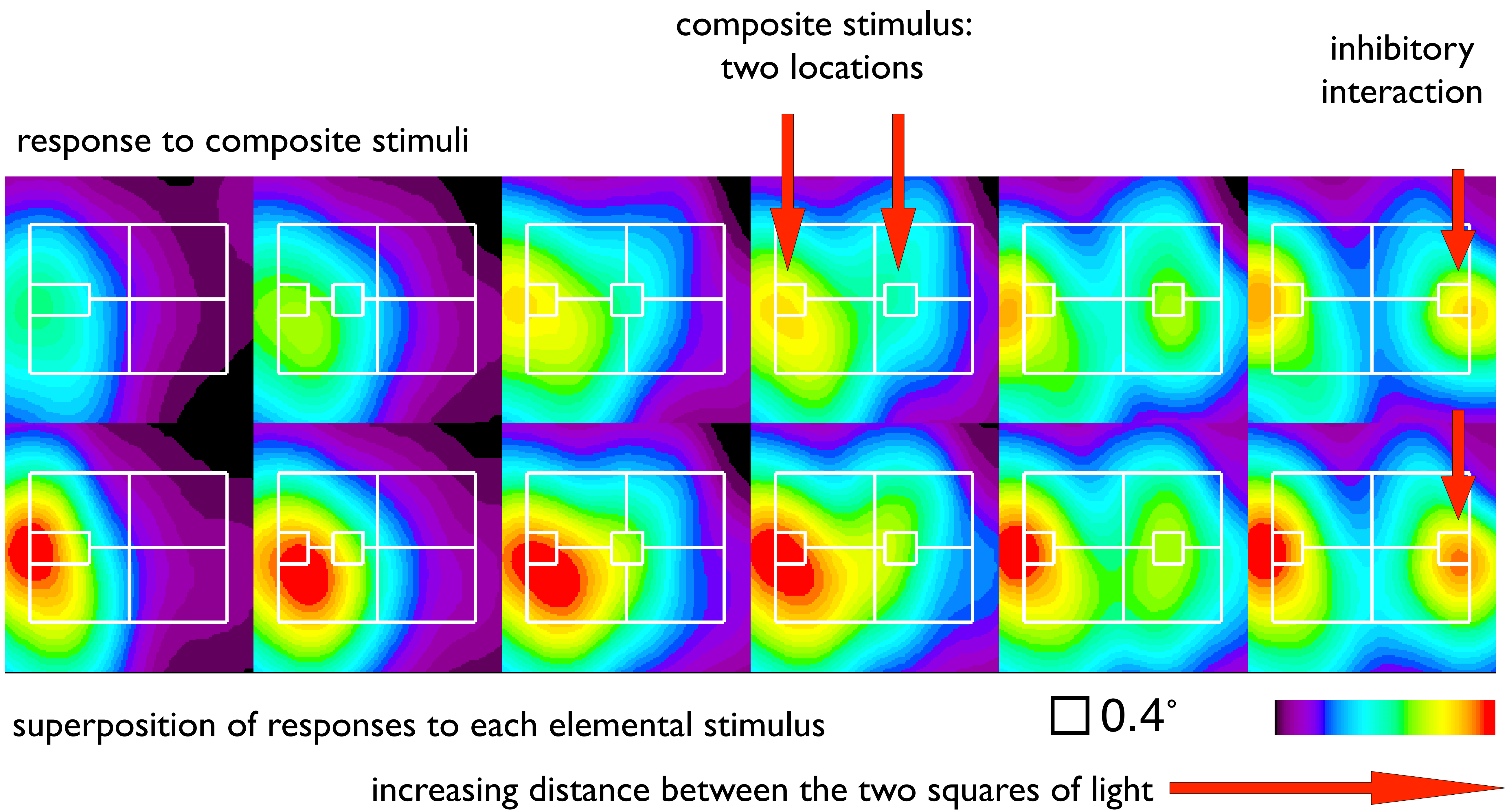
- DPA of stimuli presented to all neurons





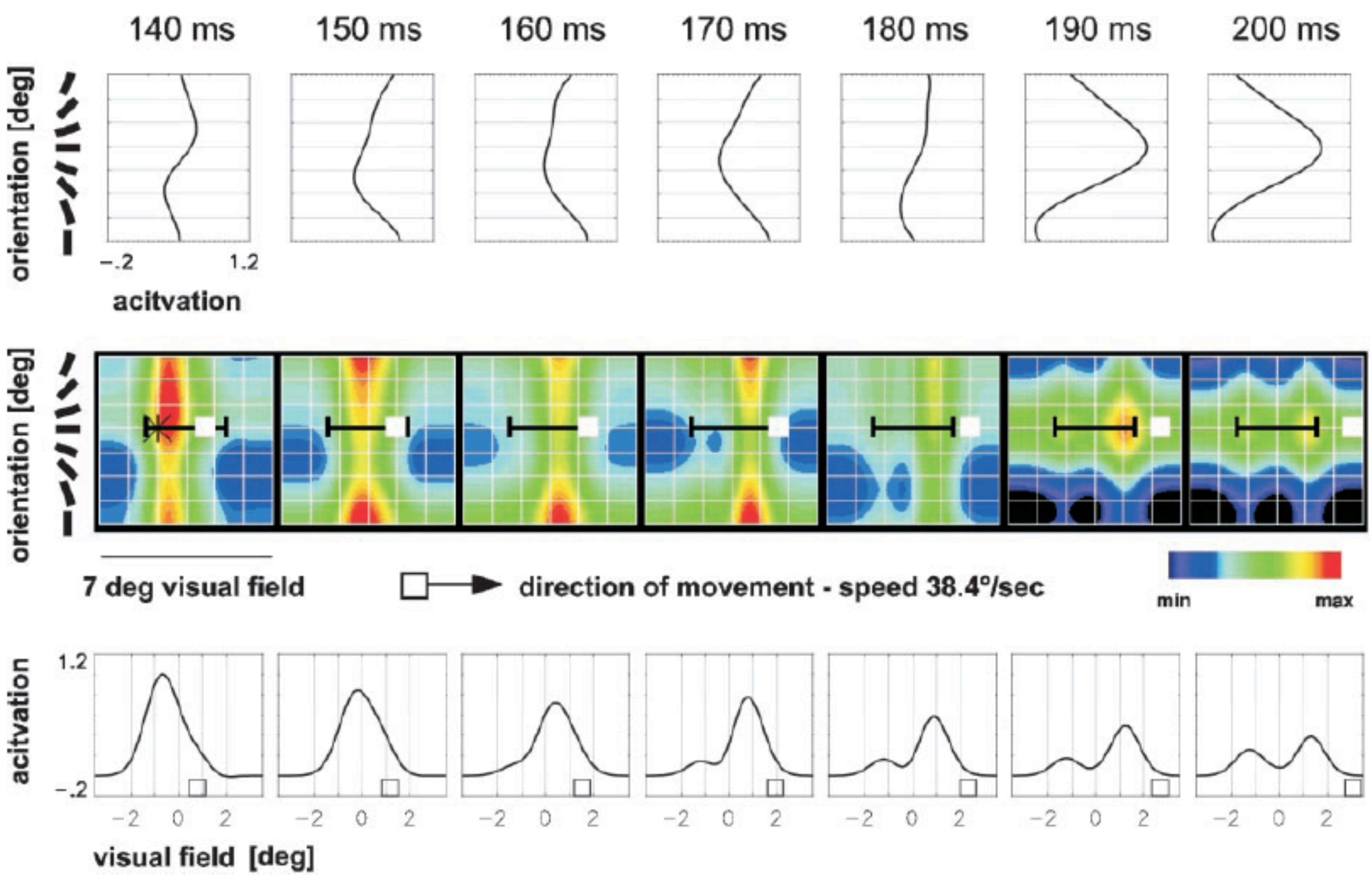
Neural grounding of DFT: sensory

- => observe interaction in DPA



Neural grounding of DFT: sensory

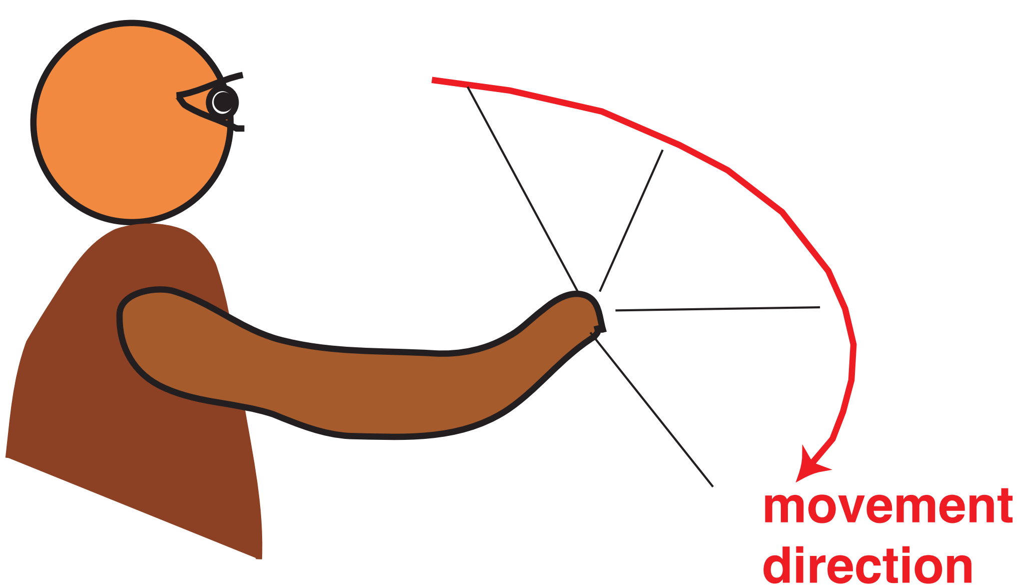
- DPA of orientation and (1D) retinal location

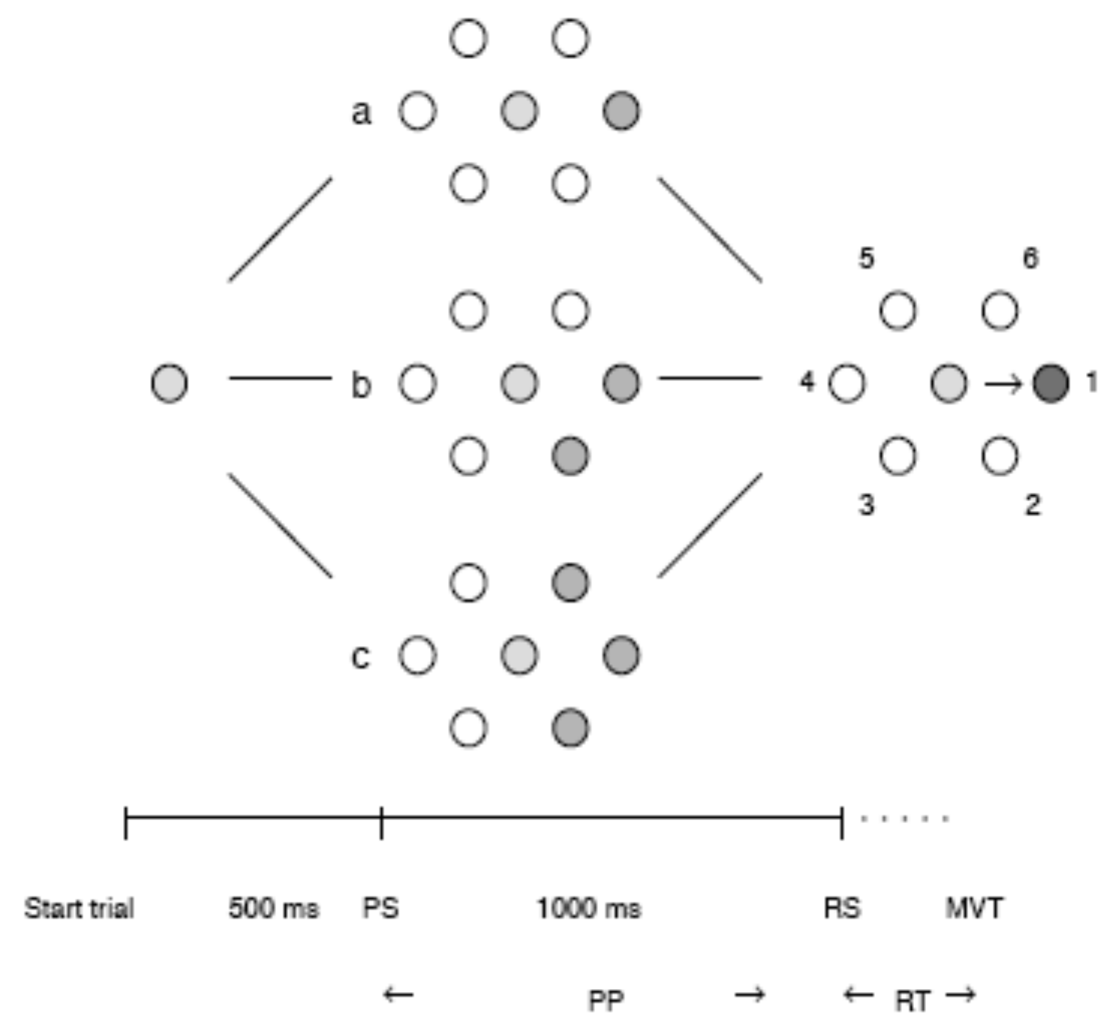


[Jancke, JNeursci (2000)]

Neural grounding of DFT: motor

- Example 2: primary motor cortex (M1)
- DPA of movement direction of the hand

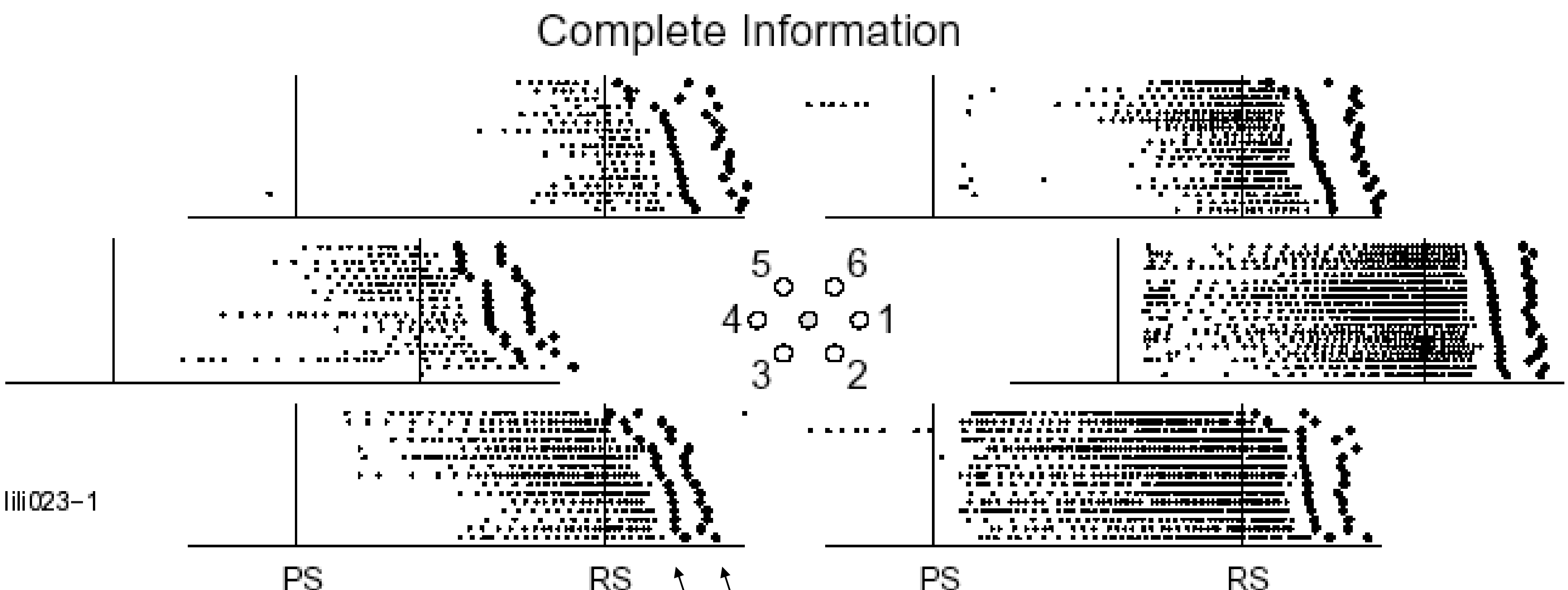




[Bastian, Riehle, Schöner, Europ J Neurosci 2003]

Neural grounding of DFT: motor

- tuning to movement direction
- trials aligned by go signals, ordered by reaction time



hand lands on target

hand lifts off start button

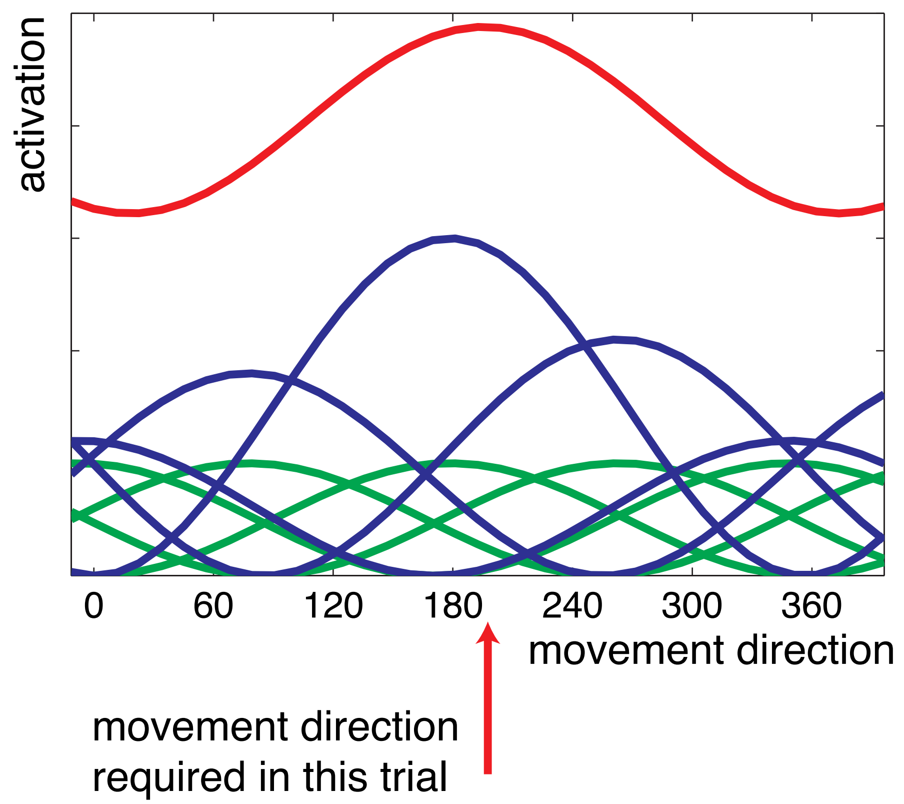
trials aligned by go signal
ordered by RT

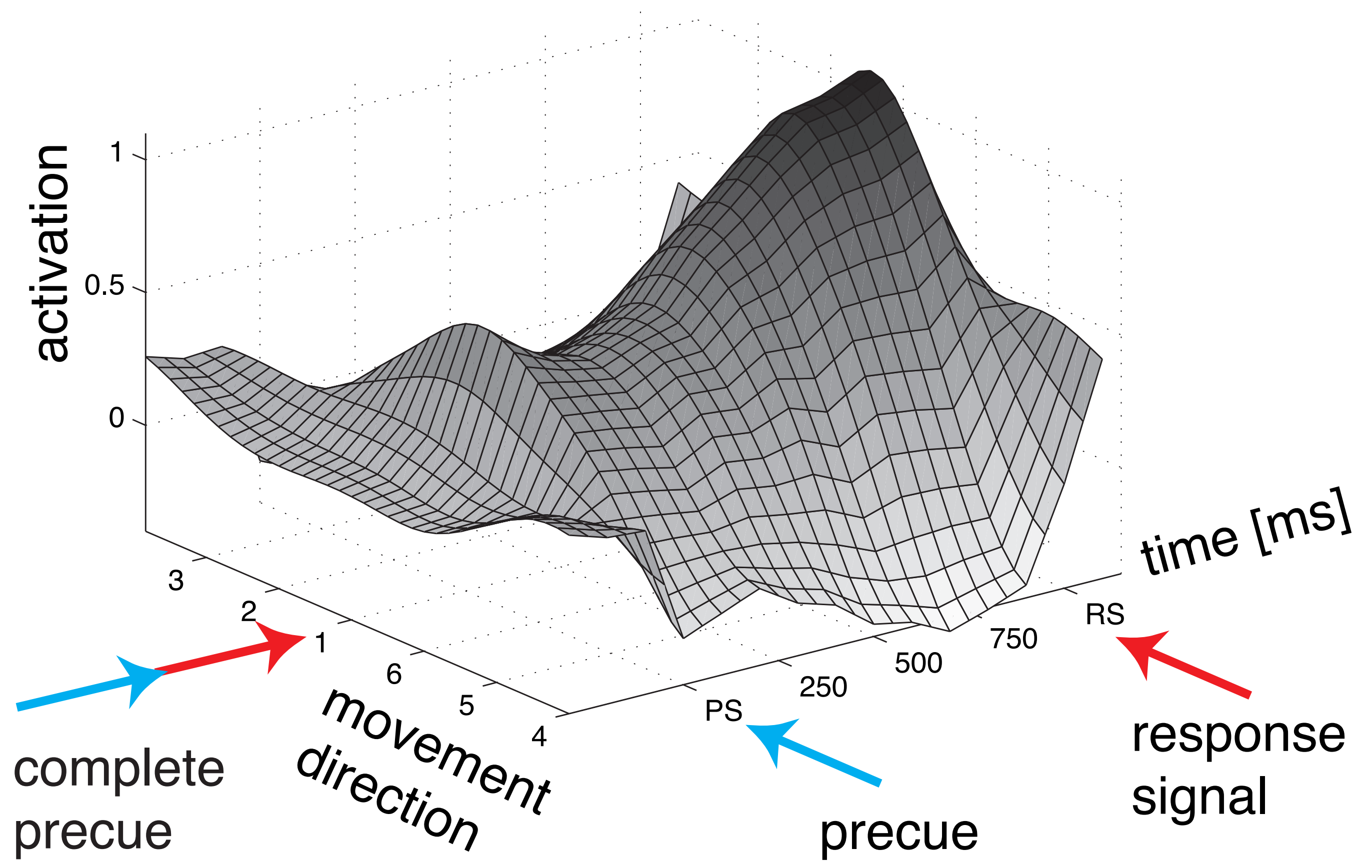
[Bastian, et al J Europ J Neurosci 2003]

Neural grounding of DFT: motor

Distribution of population activation =

$\sum_{\text{neurons}}$ tuning curve * current firing rate

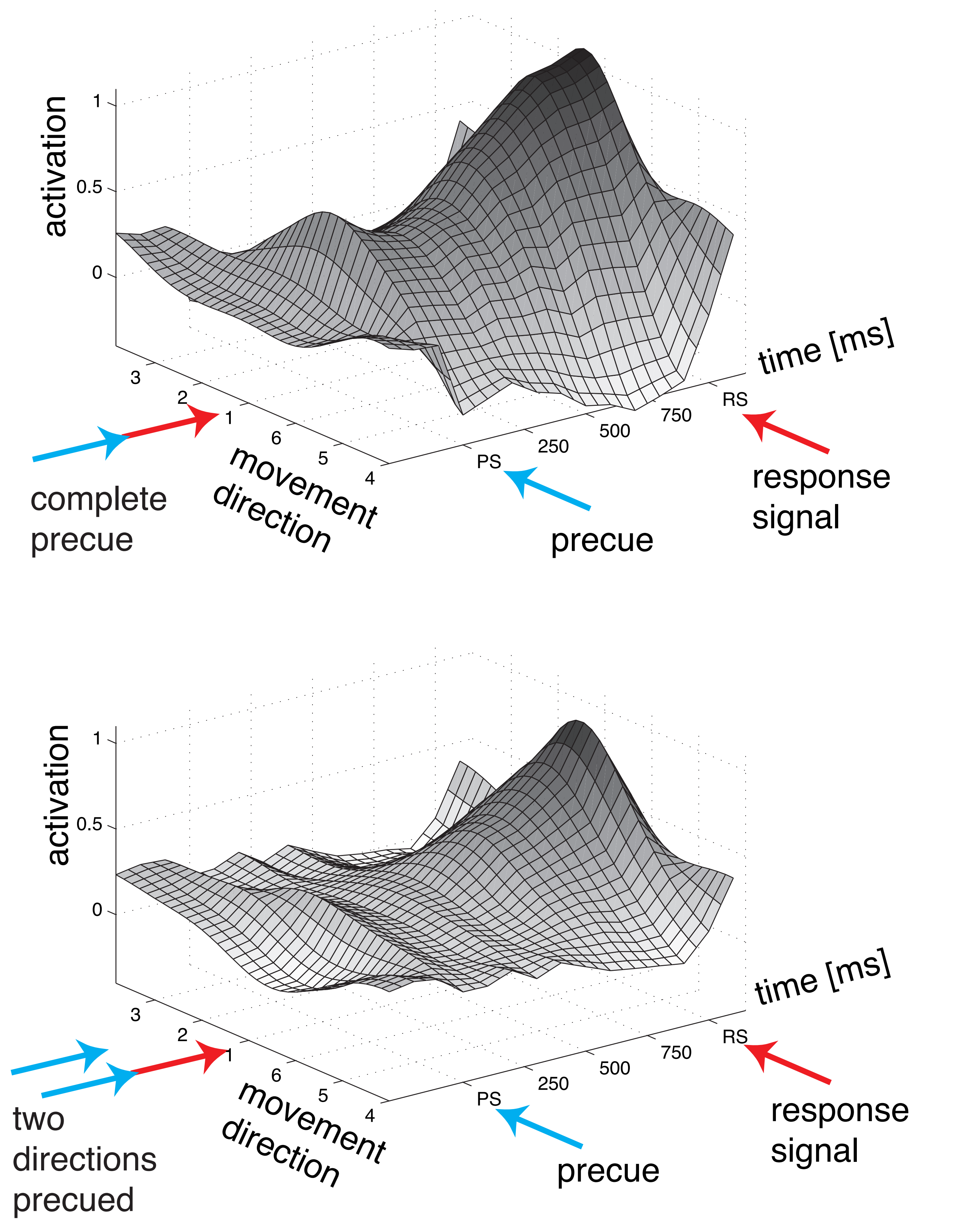




[Bastian, et al J Europ J Neurosci 2003]

Neural grounding of DFT: motor

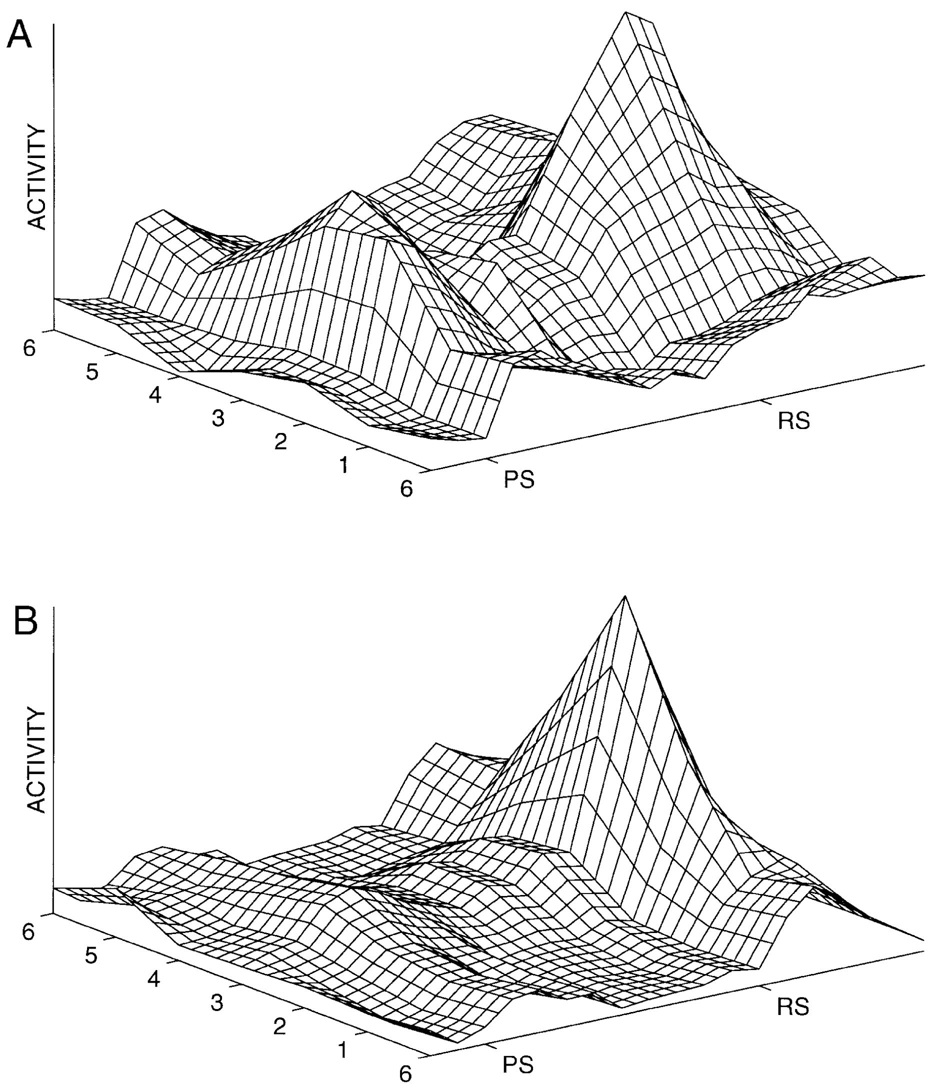
- evolution in time
- prior information



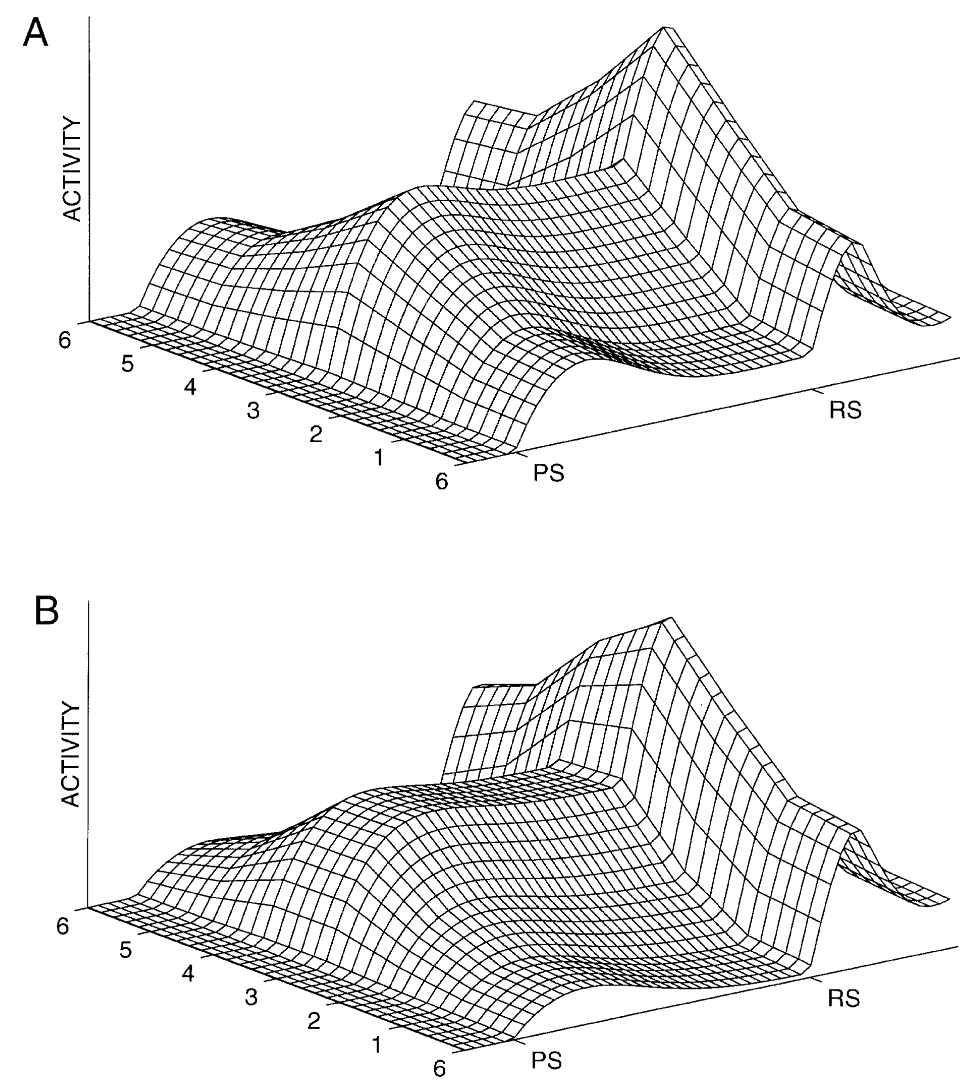
[Bastian, et al J Europ J Neurosci 2003]

Neural grounding of DFT: motor

DPA



DFT

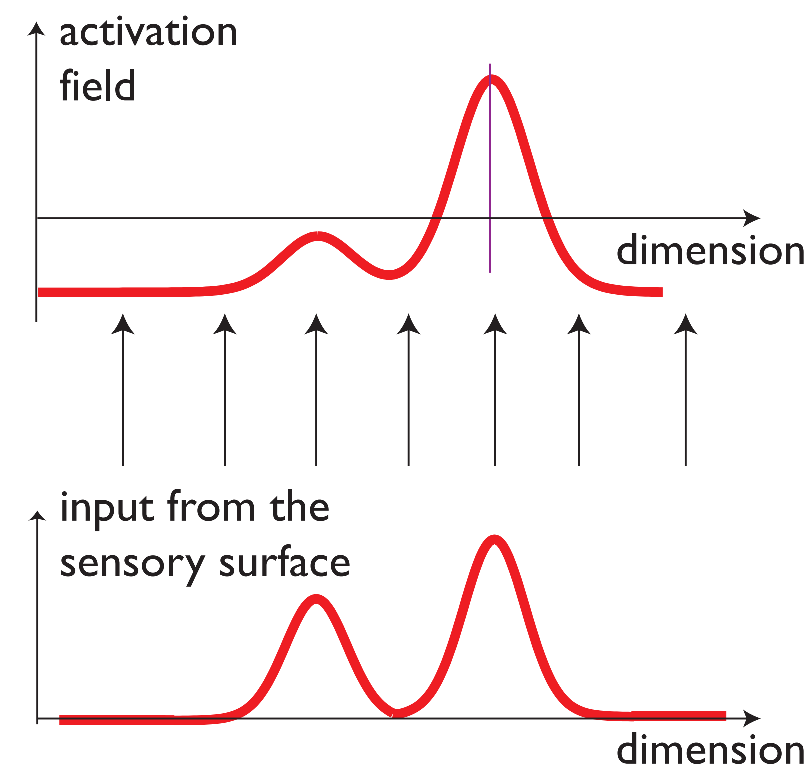


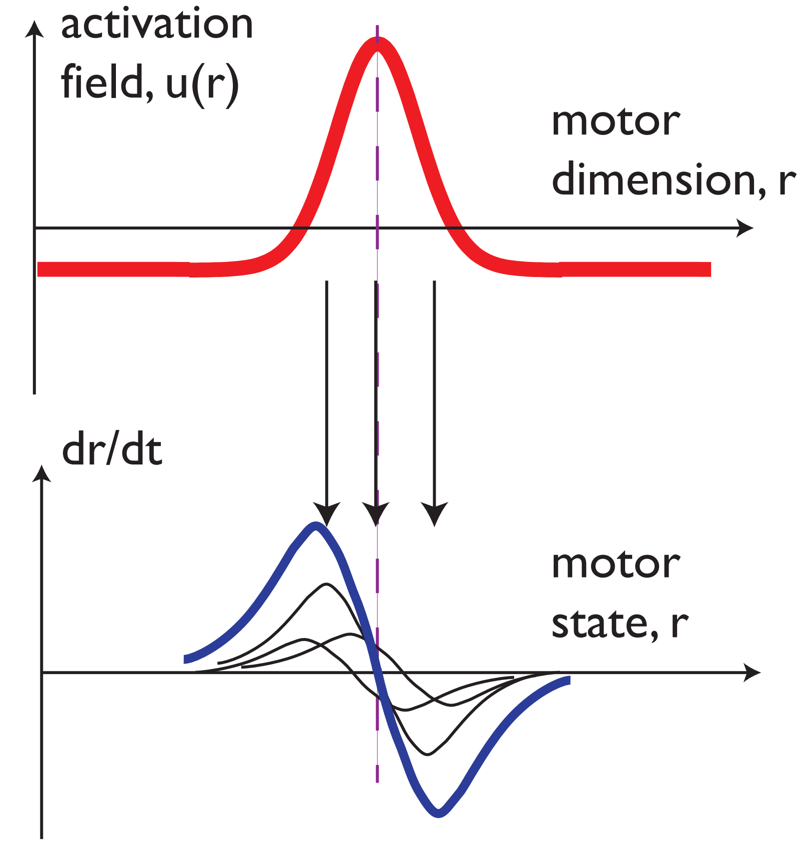
[Bastian, Riehle, Erlhagen, Schöner, 98]

Distributions of Population Activation as the neural grounding of dynamic neural fields

- neurons are not localized within a DPA!
- => neural fields abstract from the cortical surface and sampling by discrete neurons

… back to DFT





- field dimensions reflect the input/output connectivity from which the tuning of neurons derives