Dynamic Field Theory

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Discrete “neurons”

- or activation variables: how do they arise? How do they sample sensory/motor spaces...
- no evidence that neural discreteness matters for behavior

Continuity in space

- hypothesis: behavior is embedded in continua
  - the space of possible behaviors, e.g. space of movements, percepts, timing structures
  - neuronal substrate is continuous (maps, broad tuning)
- (=> need to understand how categorical behavior may emerge from such continua)

Dynamical Field Theory: space

- in DFT, continuous spaces are dimension over which activation fields are defined
    - homologous to sensory surfaces, e.g., visual or auditory space (retinal, allocentric, ...)
    - homologous to motor surfaces, e.g., saccadic end-points or direction of movement of the end-effector in outer space
    - feature spaces, e.g., localized visual orientations, color, impedance, ...
    - abstract spaces, e.g., ordinal space, along which serial order is represented

example: motion perception

- single motion
- motion pattern

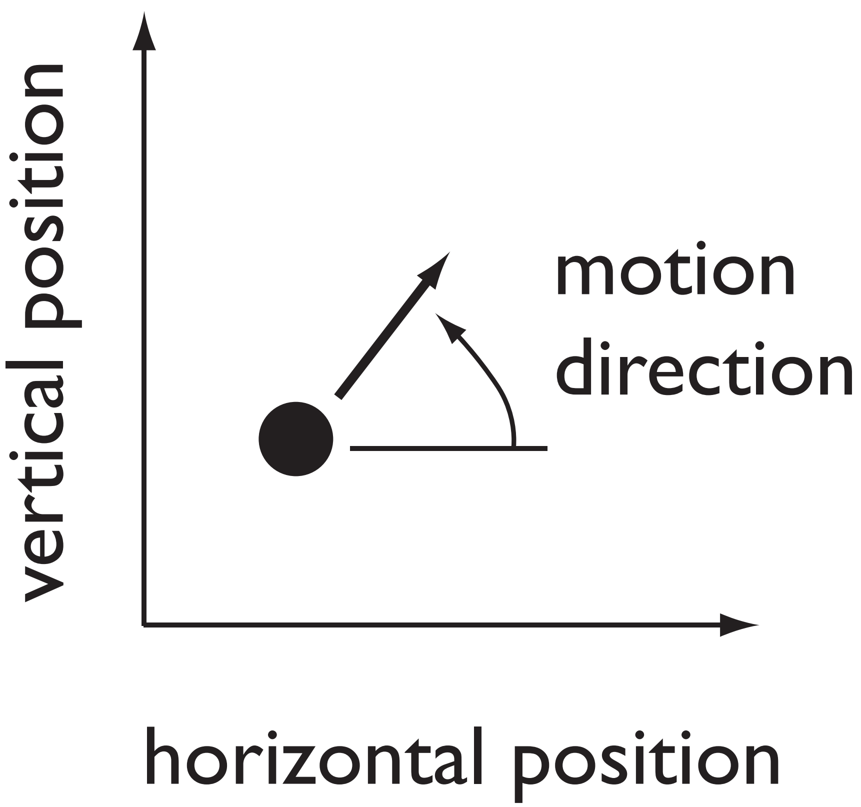
example: selection decisions in motion perception

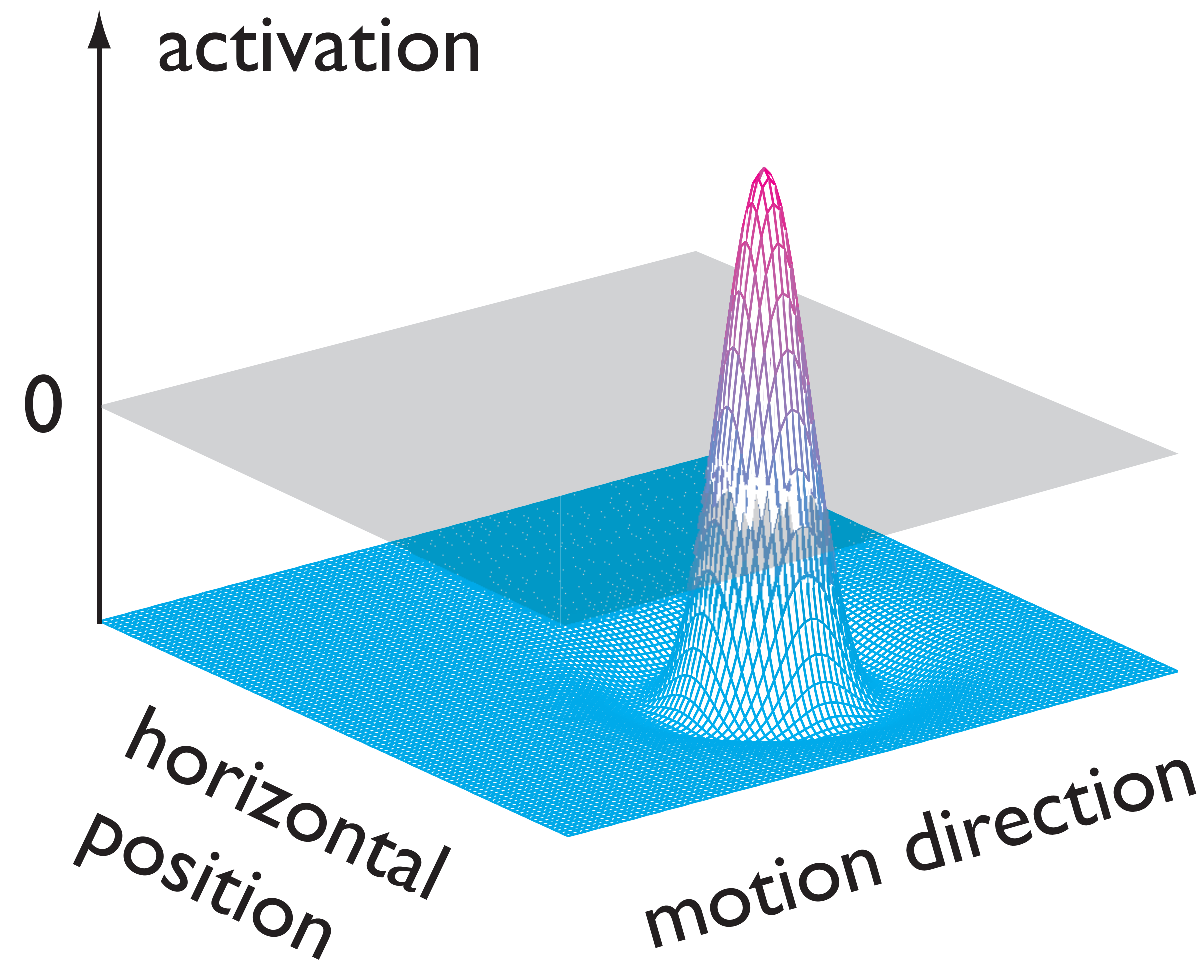
- motion pattern
  - why not diagonal motion?
  - or the other diagonal motion?

example: selection decisions in motion perception

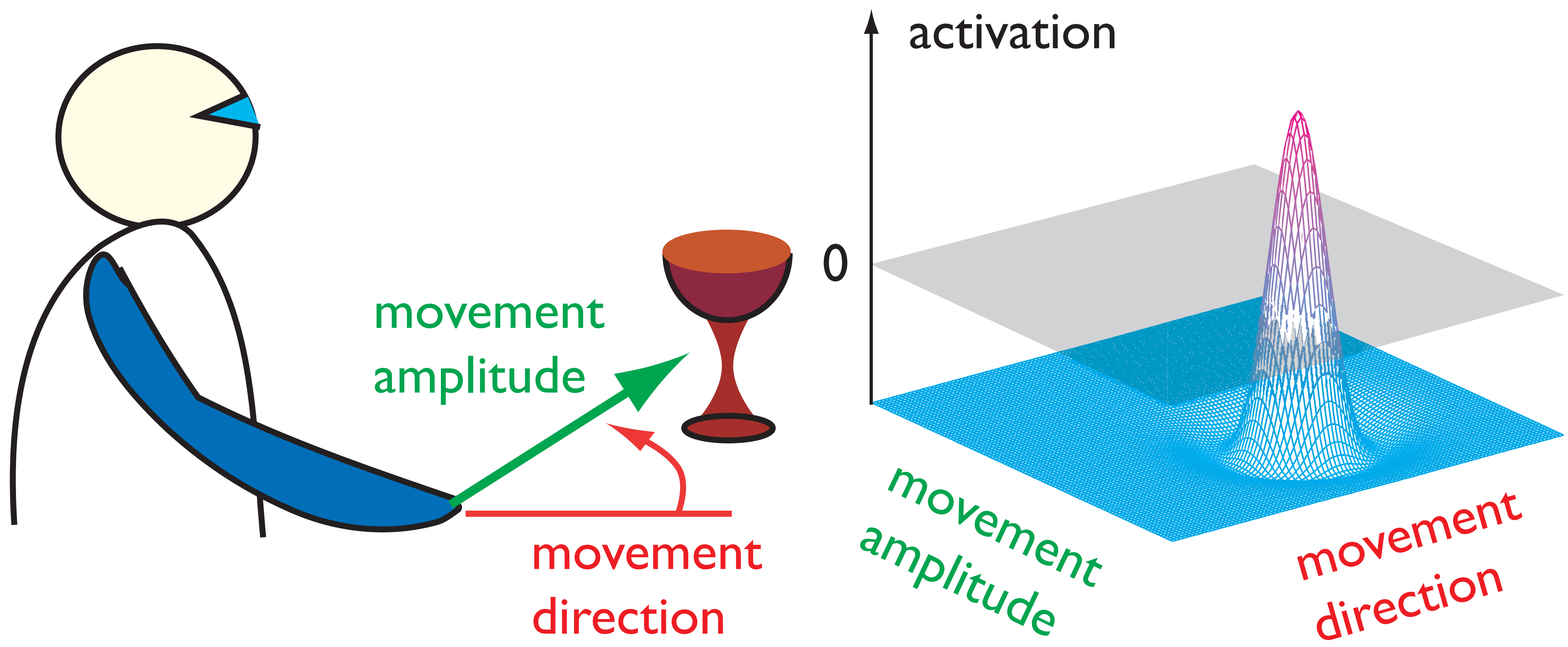
- is the alternative motion realized?
  - flat motion quartet
  - tall motion quartet
  - square motion quartet

space of possible percepts and activation field





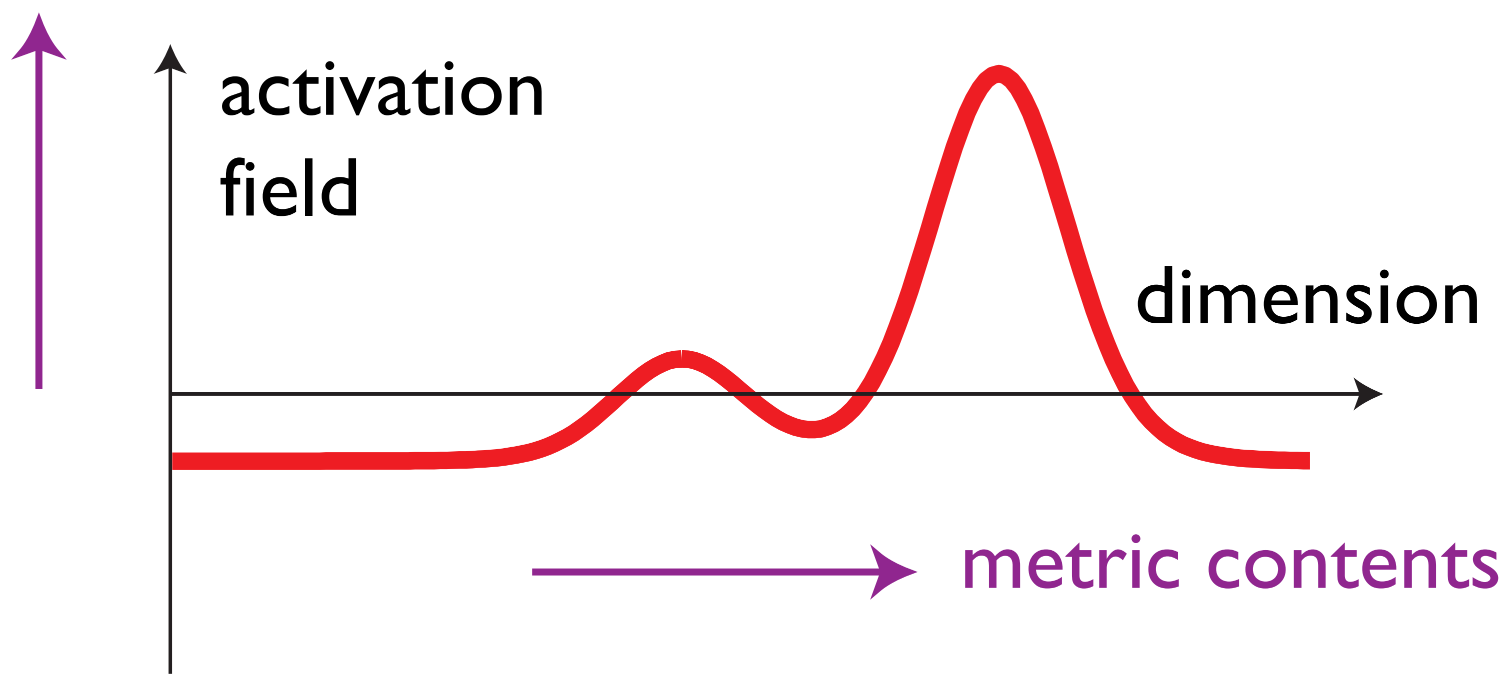
space of possible actions and activation field



Dynamical Field Theory: space

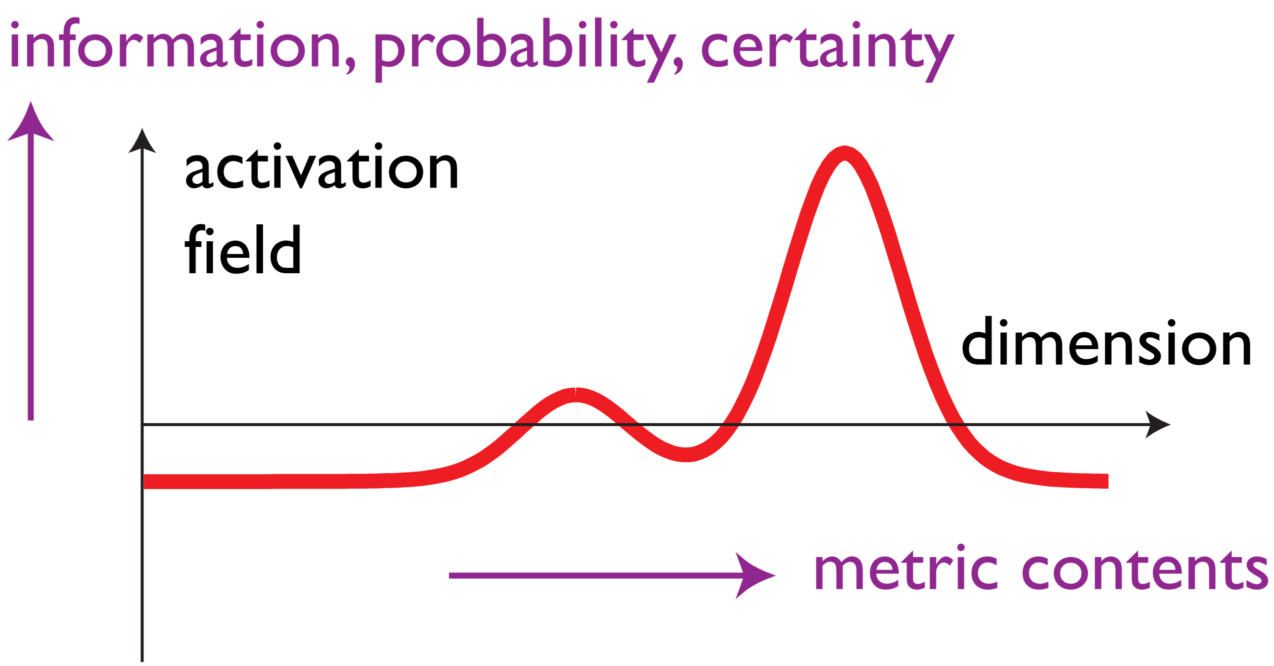
- fields: continuous activation variables defined over continuous spaces

information, probability, certainty

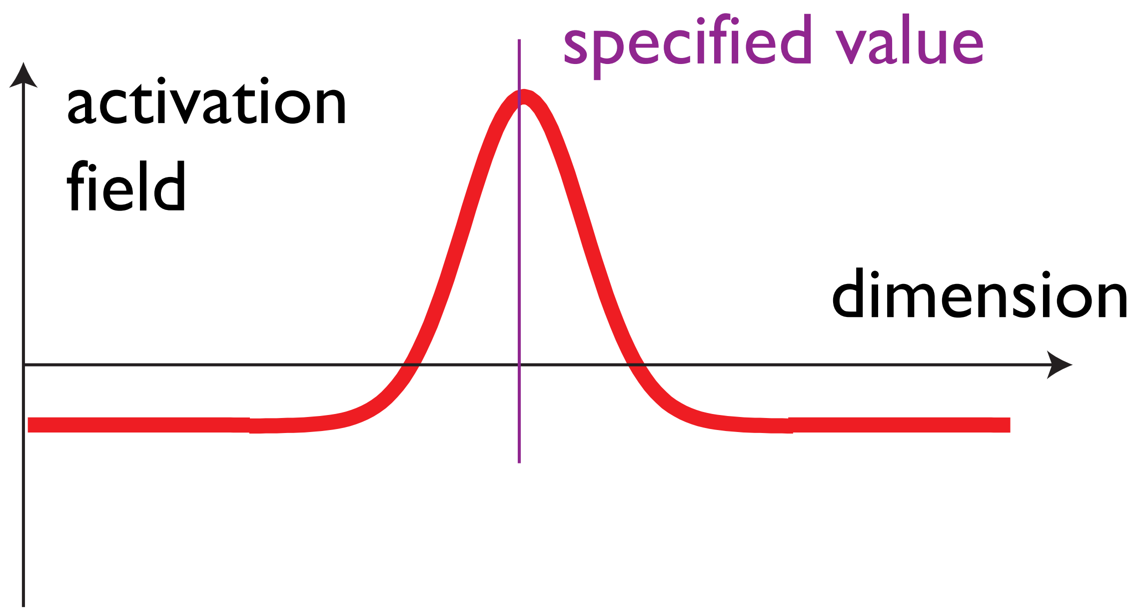


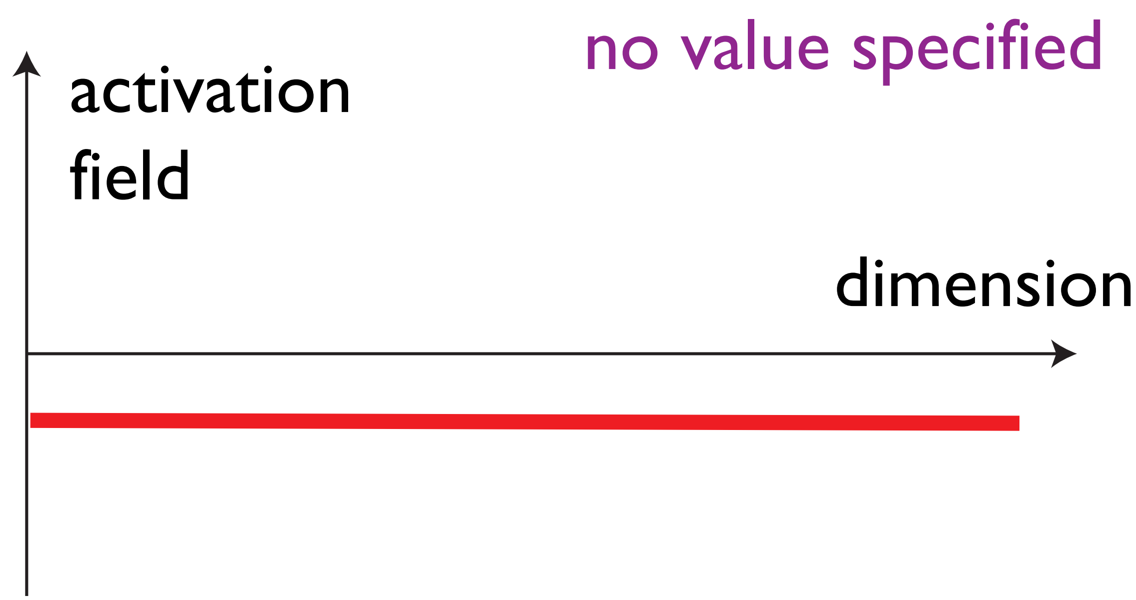
e.g., retinal space, movement parameters, feature dimensions, viewing parameters, ...

activation fields

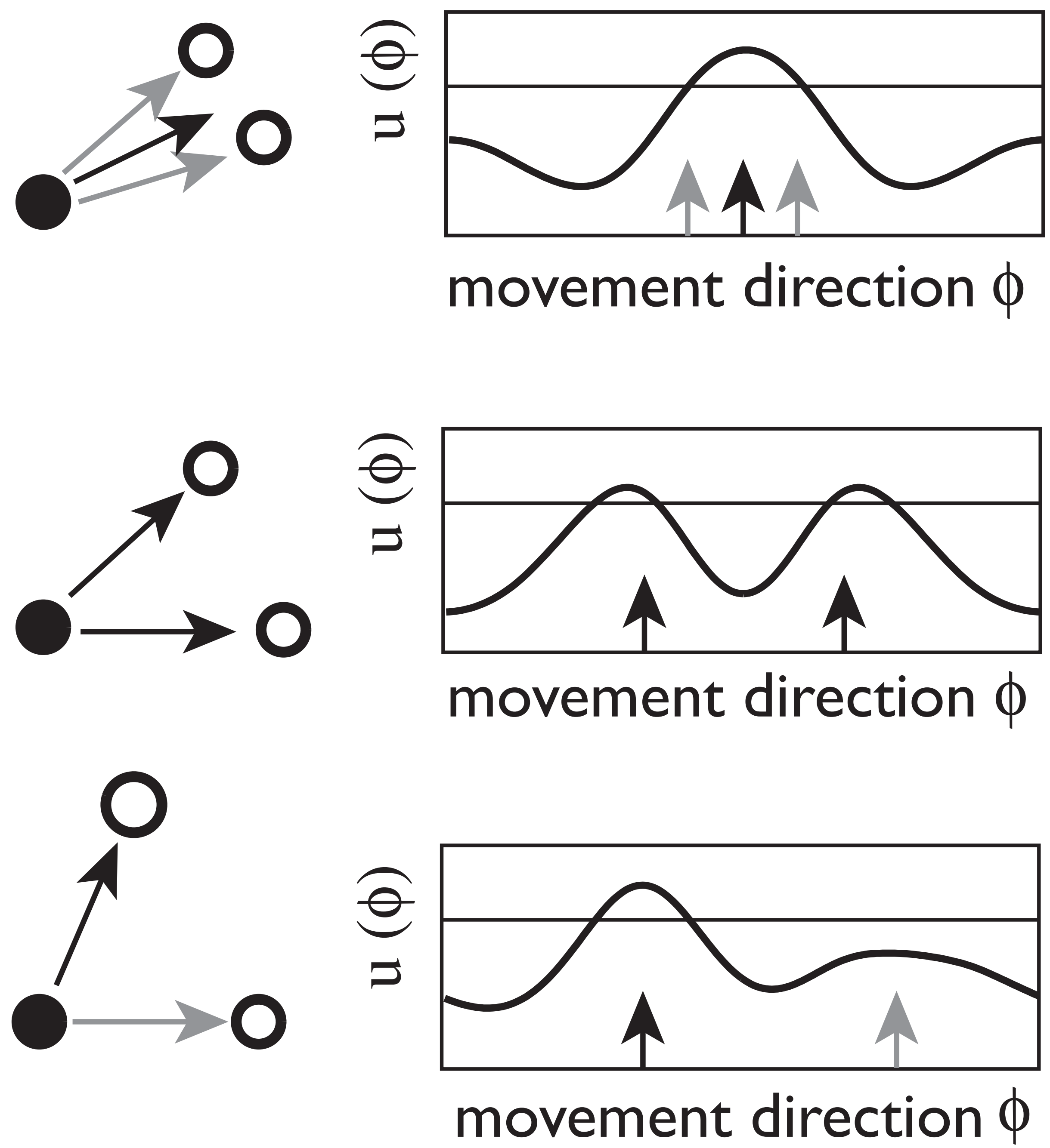


e.g., space, movement parameters, feature dimensions, viewing parameters, ...





representing different percepts

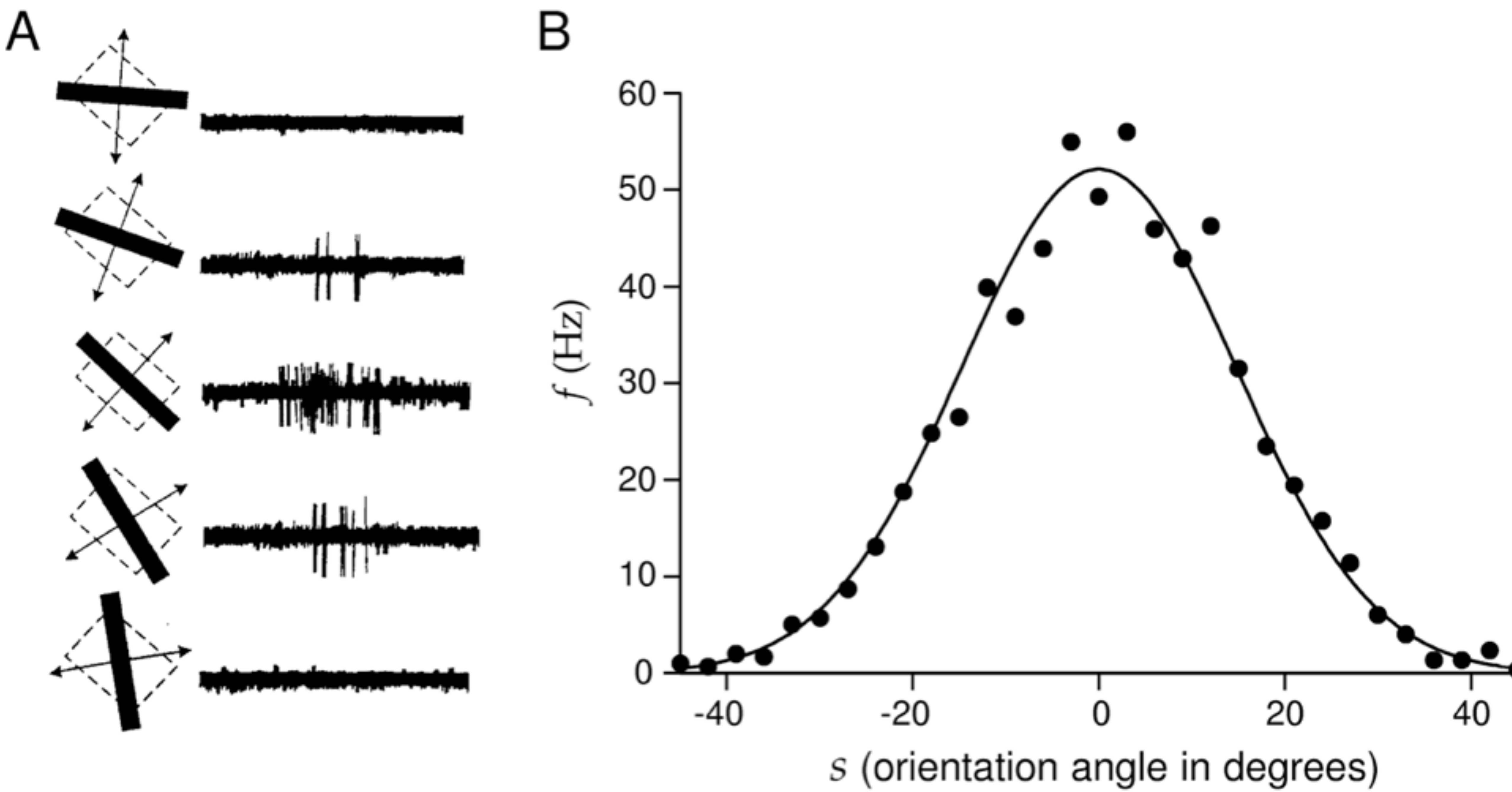


Link between DFT and neurophysiology

- What do neurons represent?

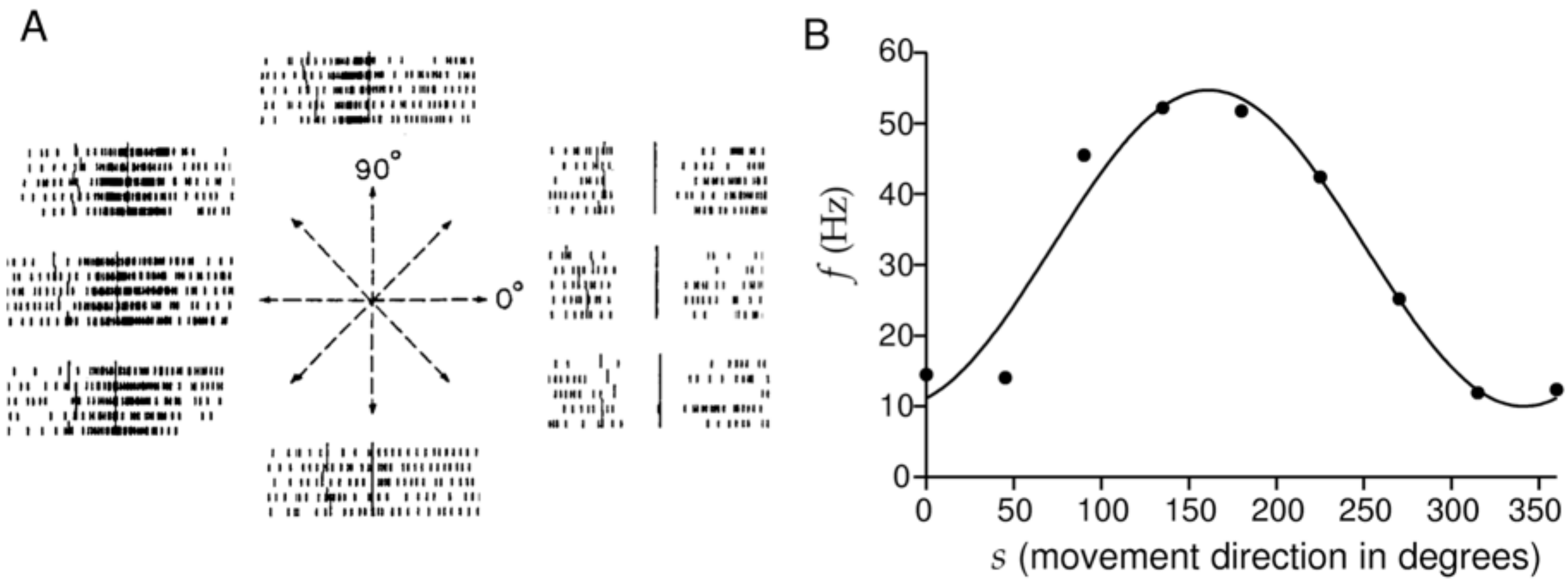
tuning curve

- example: primary visual cortex (monkey)



tuning curve

- example: primary motor cortex (monkey)

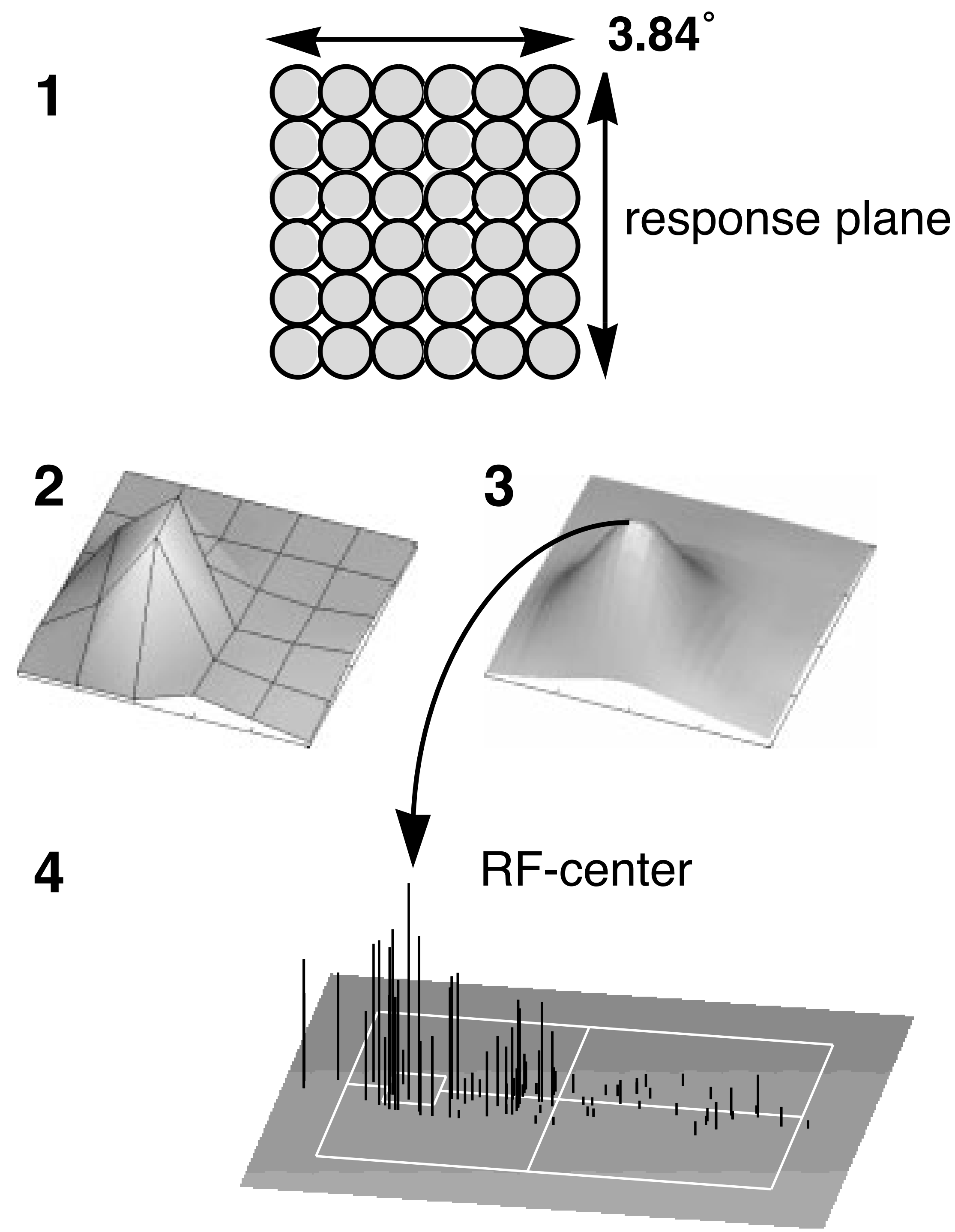


Link between DFT and neurophysiology

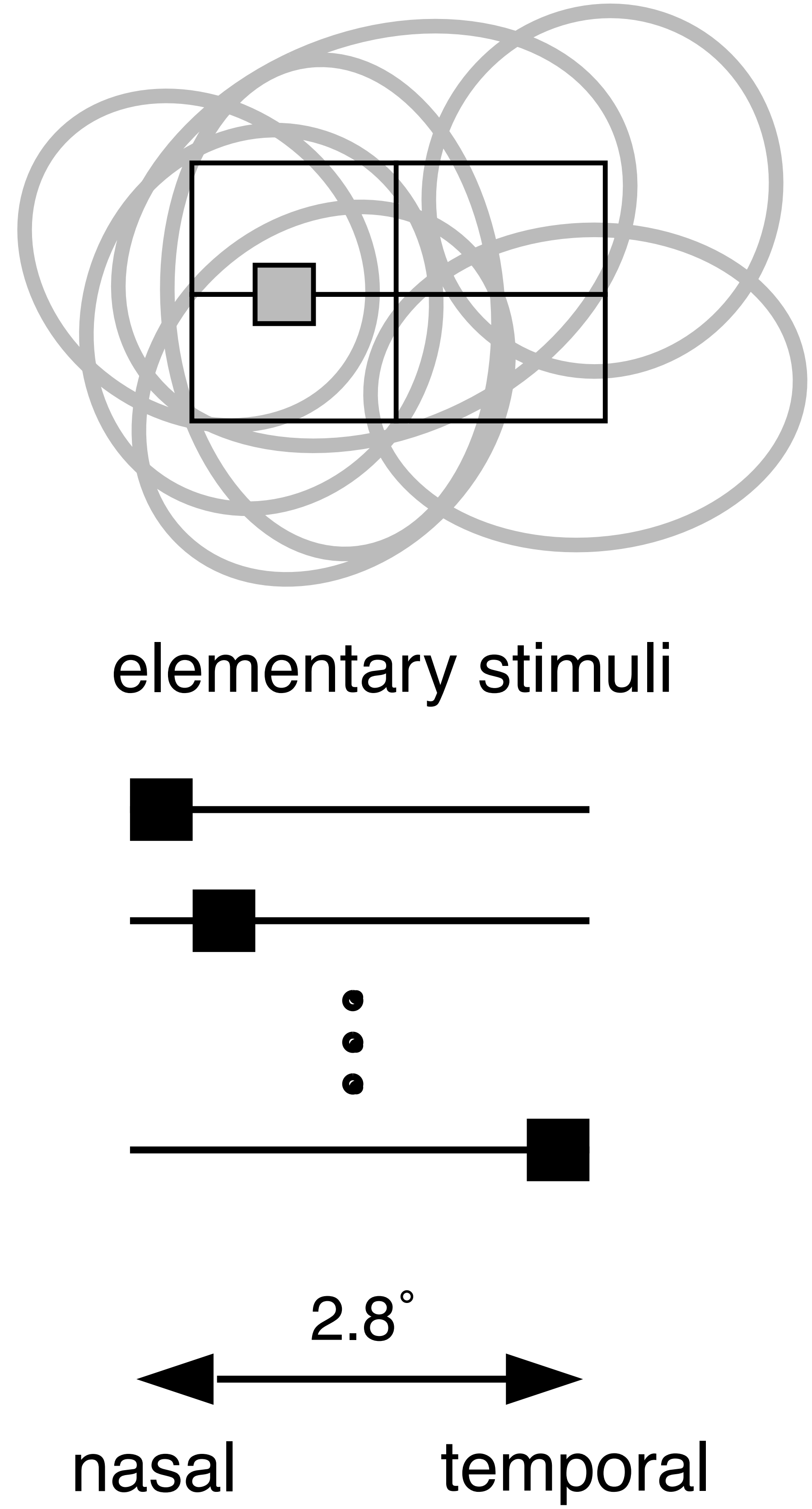
- Example 1: Jancke et al: A17 in the cat, population representation of retinal location

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

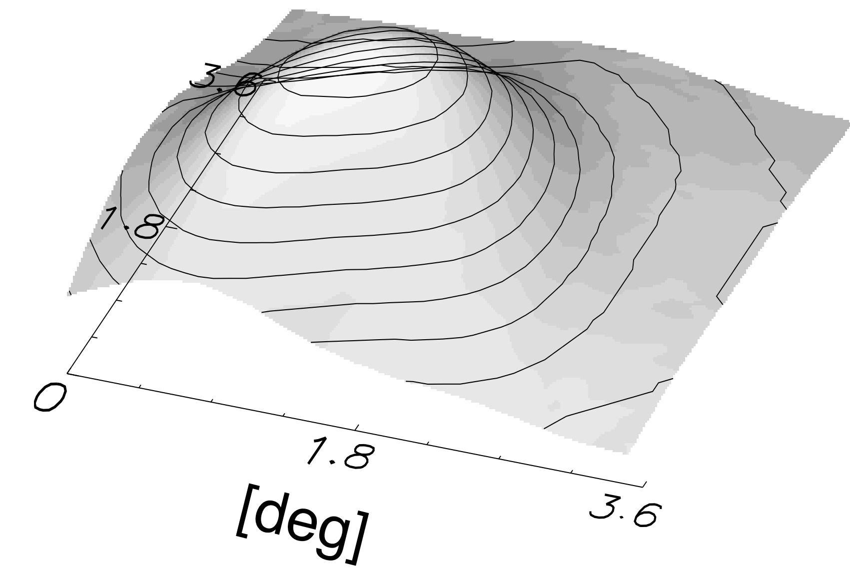
- determine RF profile for each cell
- it's center determines what that neuron codes for
- compute a distribution of population activation by superposing RF profiles weighted with current neural firing rate

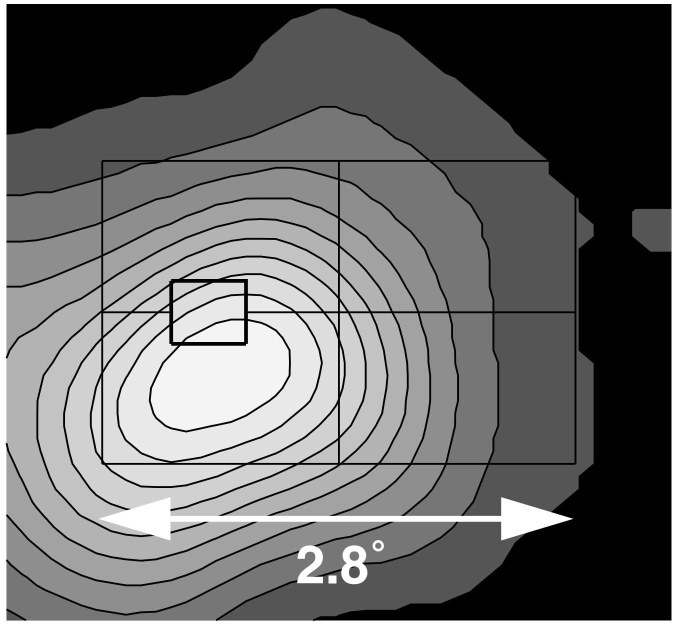


- The current response refers to a stimulus experienced by all neurons
- Reference condition: localized points of light

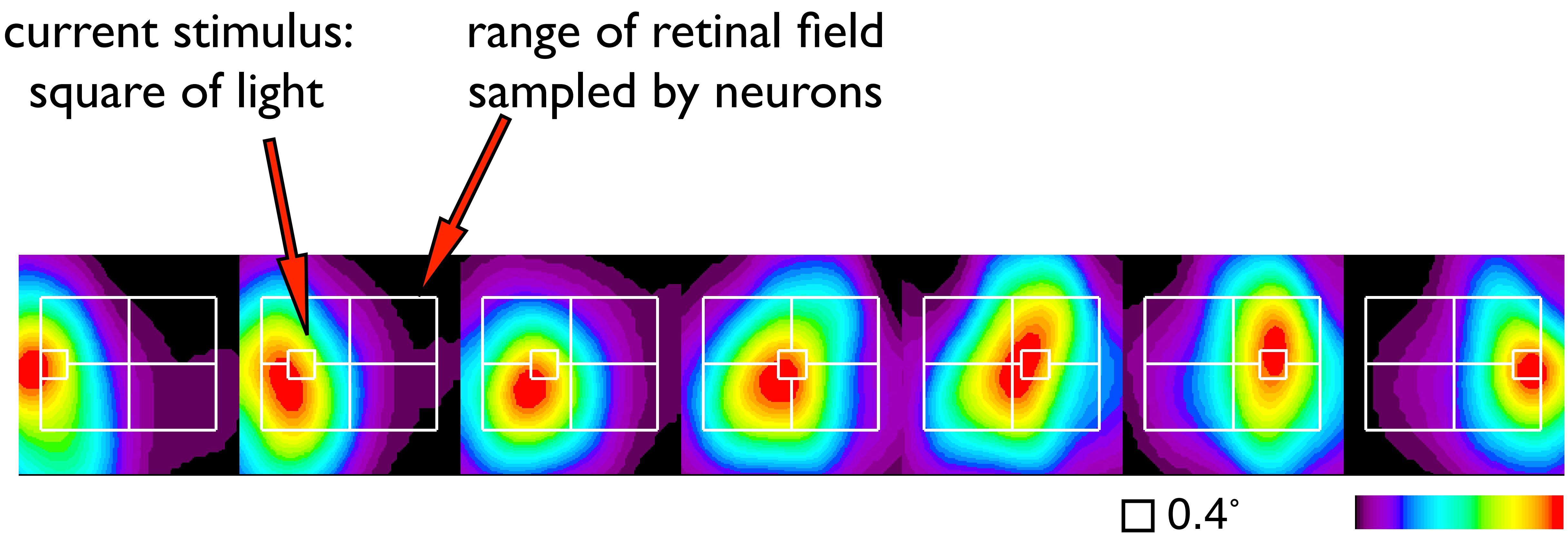


- result: population distribution of activation defined over retinal space = representation of visual location

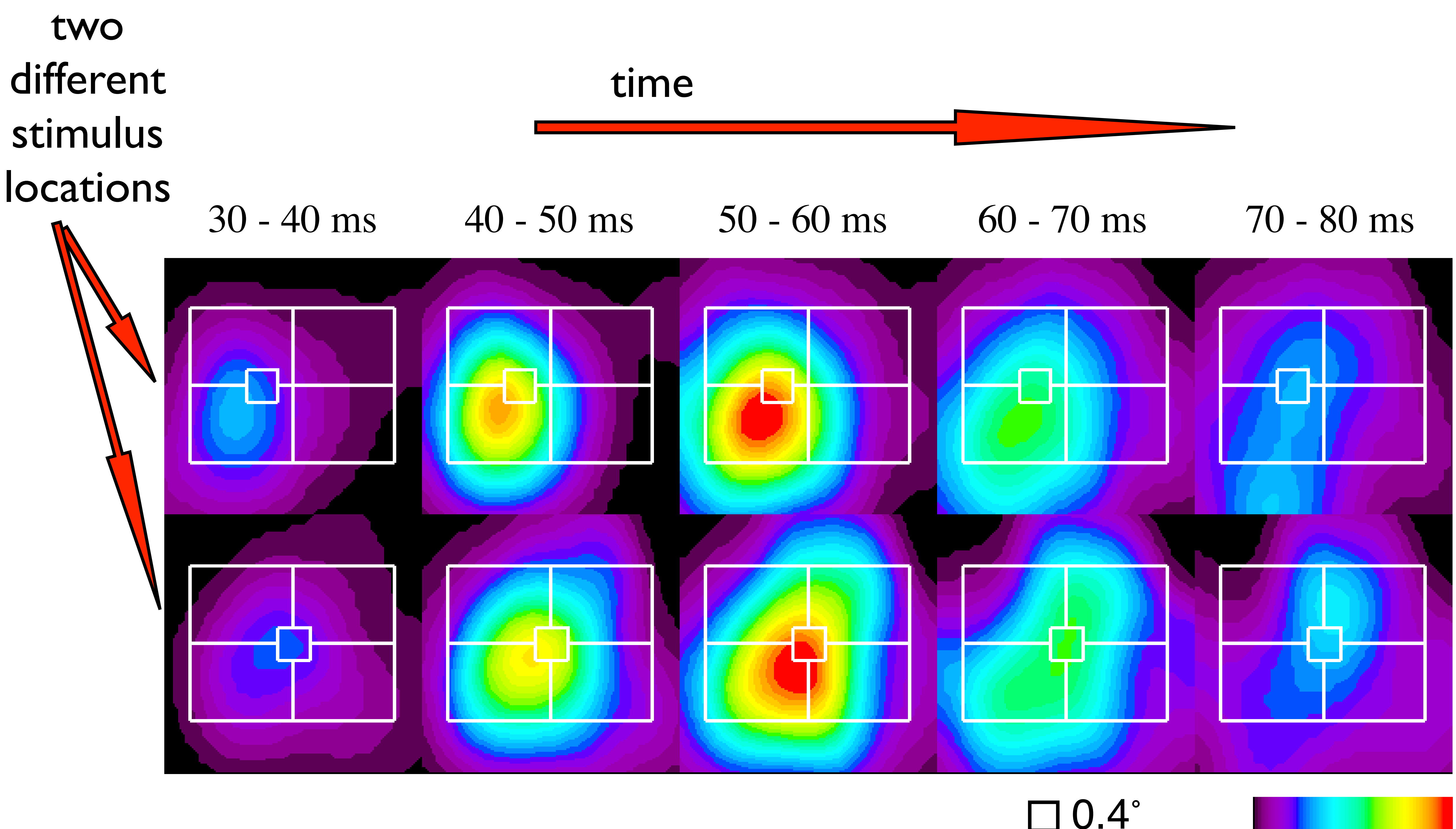




- => does a decent job estimating retinal position



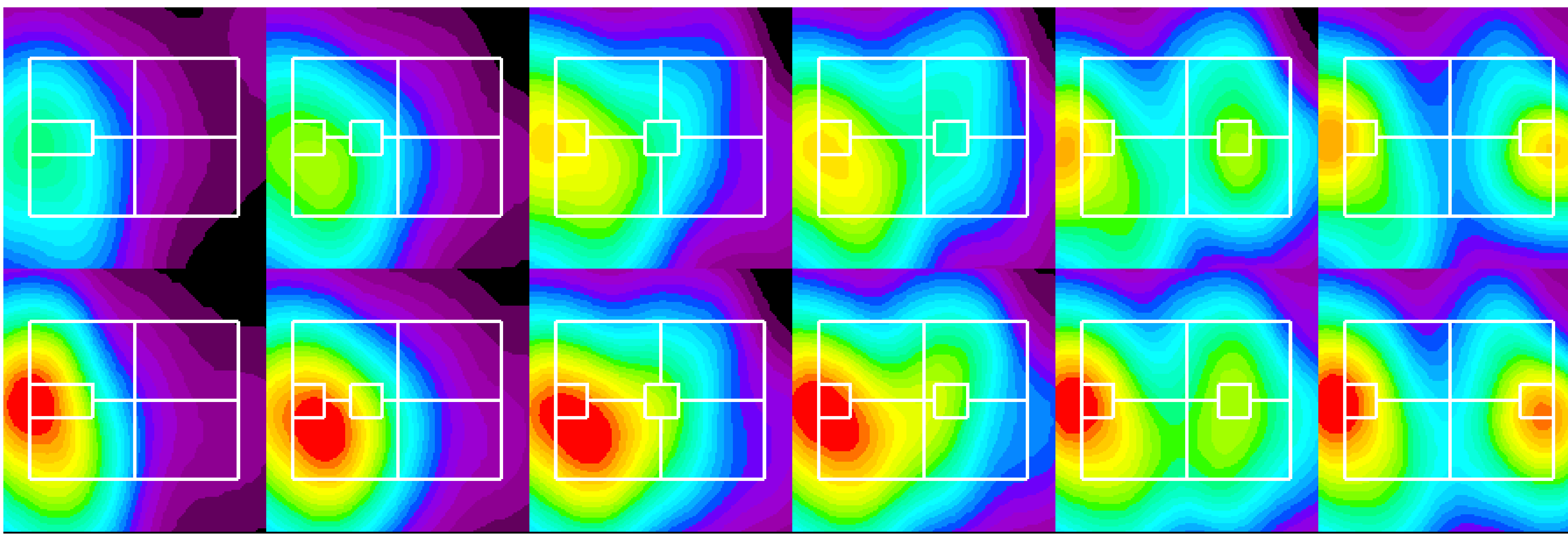
- Extrapolate measurement device to new conditions
- e.g., time resolved



- or when complex stimuli are presented (here: two spots of light)

response to composite stimuli

increasing distance between the two squares of light

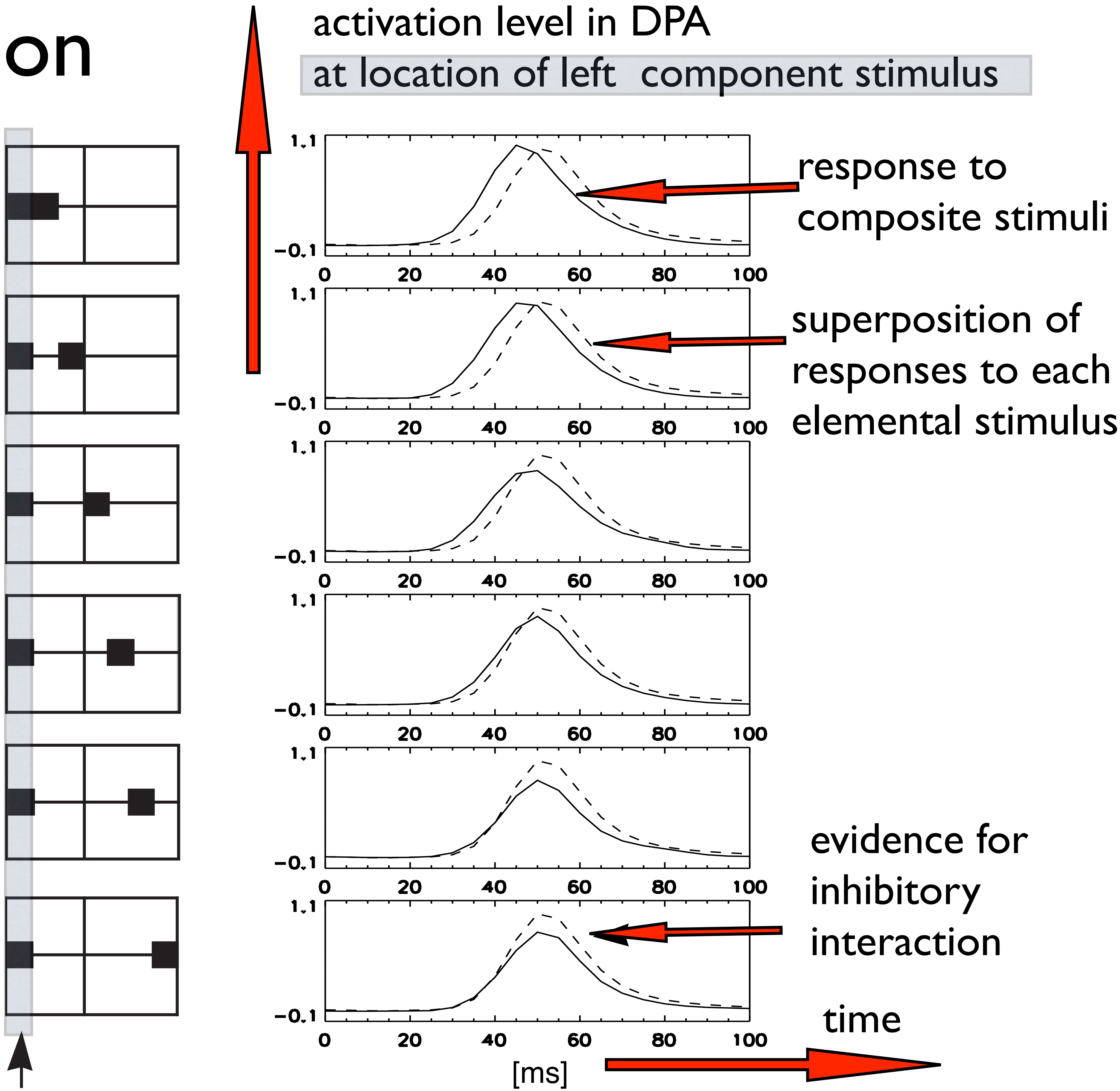


superposition of responses to each elemental stimulus

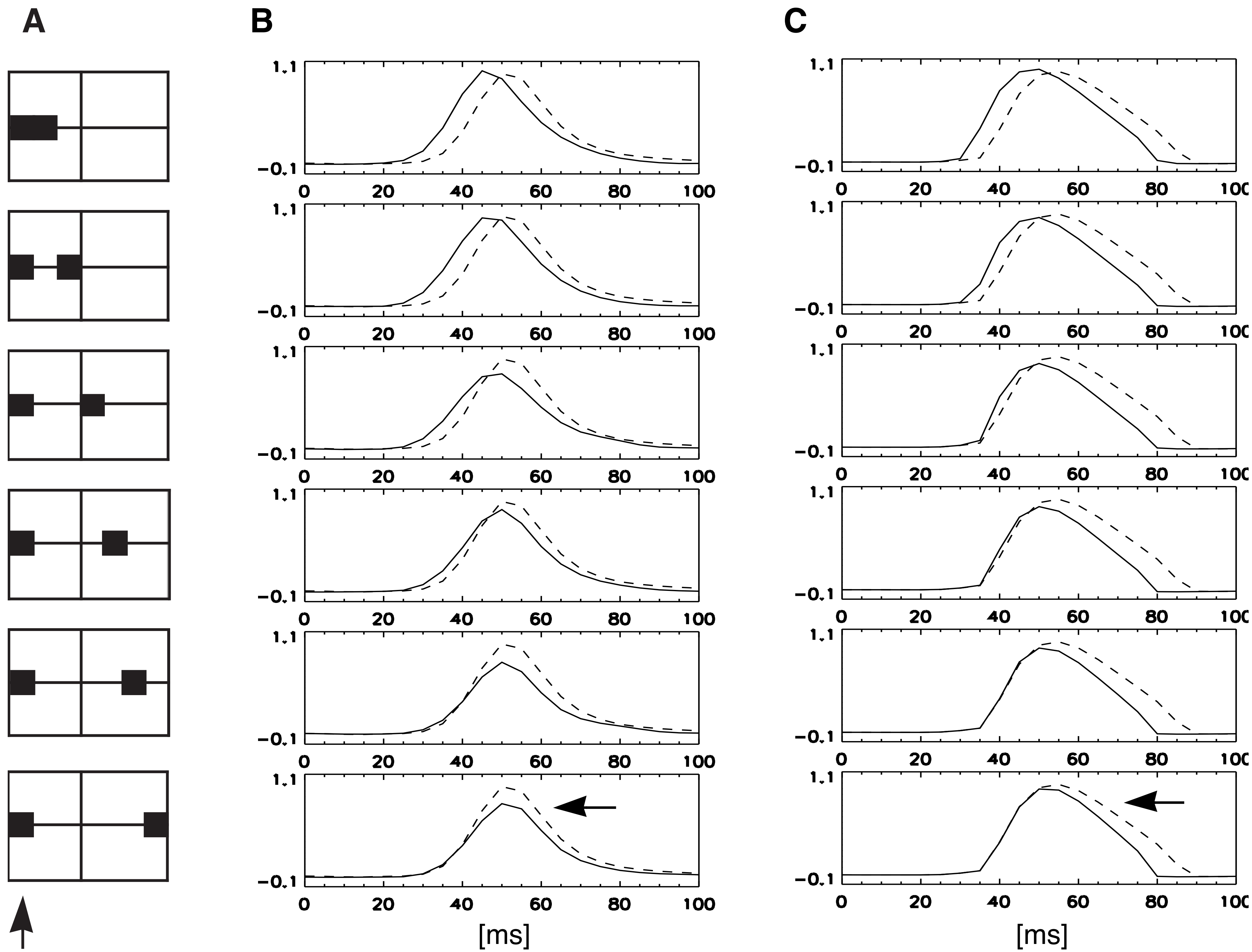
□ 0.4°

- by comparing DPA of composite stimuli to superposition of DPAs of the two elementary stimuil obtain evidence for interaction
  - early excitation
  - late inhibition

interaction

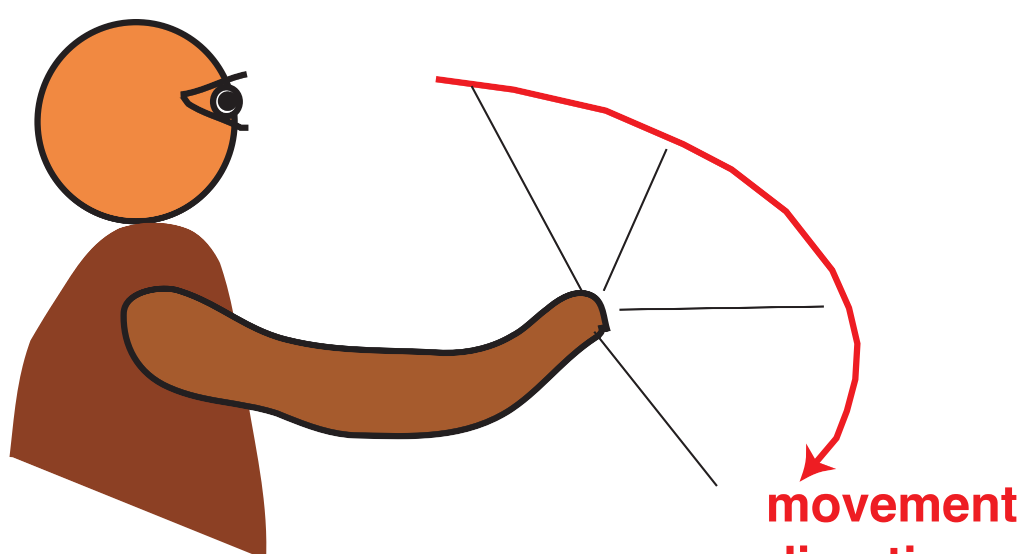


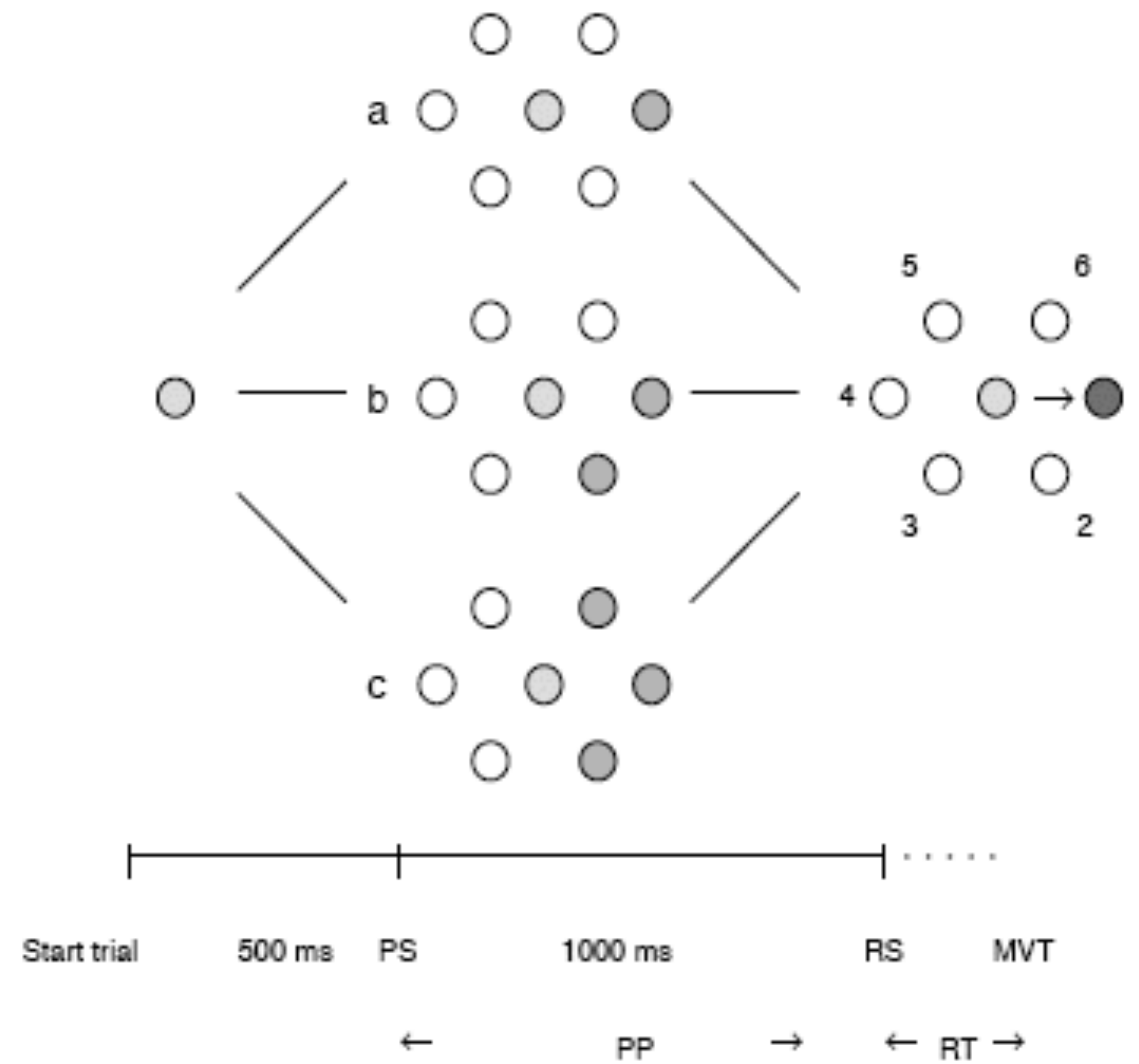
model by dynamic field:



stimulus experiment DFT model

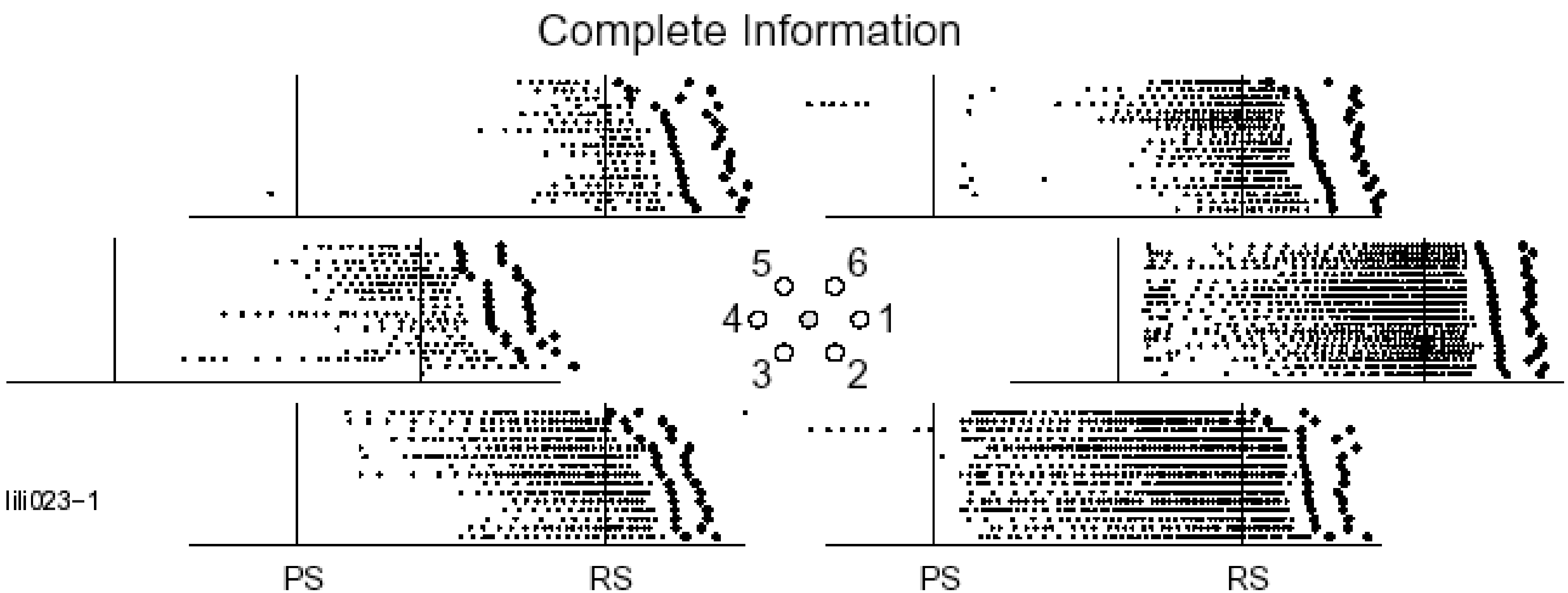
Neurophysiological grounding of DFT example: movement planning





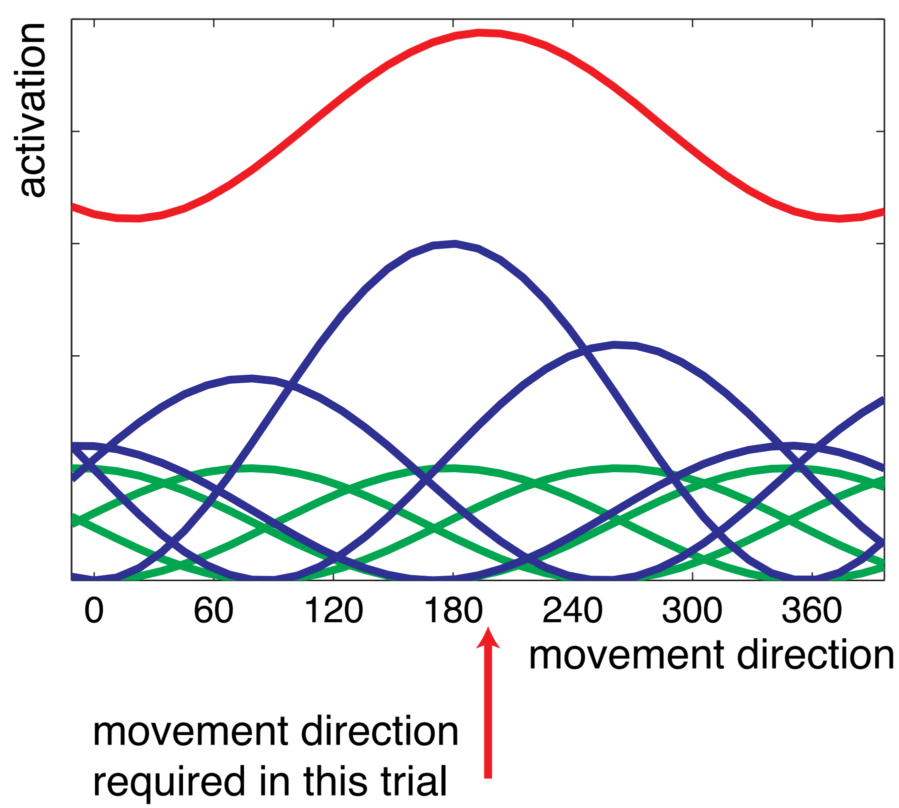
Bastian, Riehle, Schöner, 2003

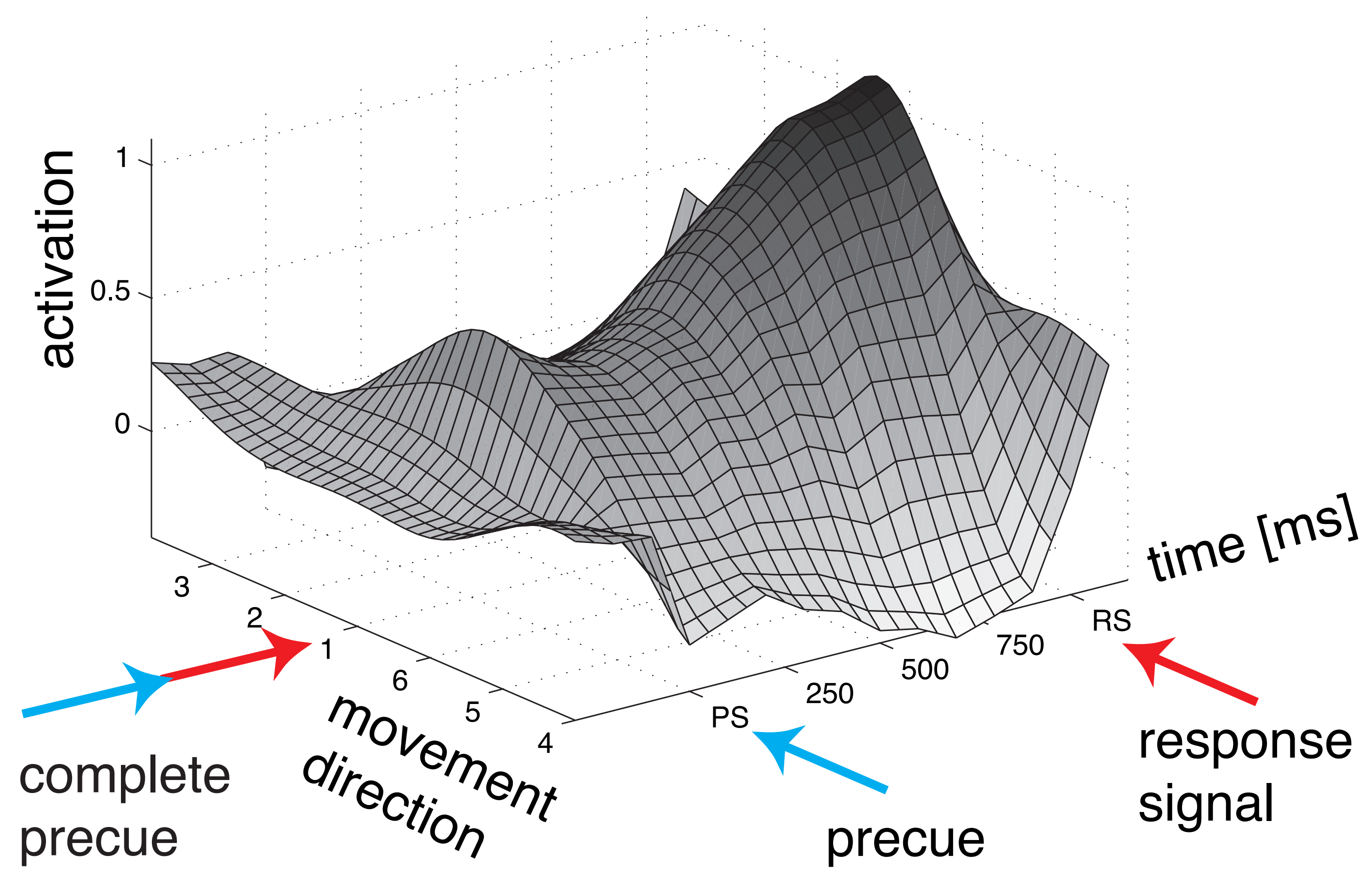
- tuning of cells in motor and premotor cortex to direction of end-effector movement path



Distribution of Population Activation (DPA)

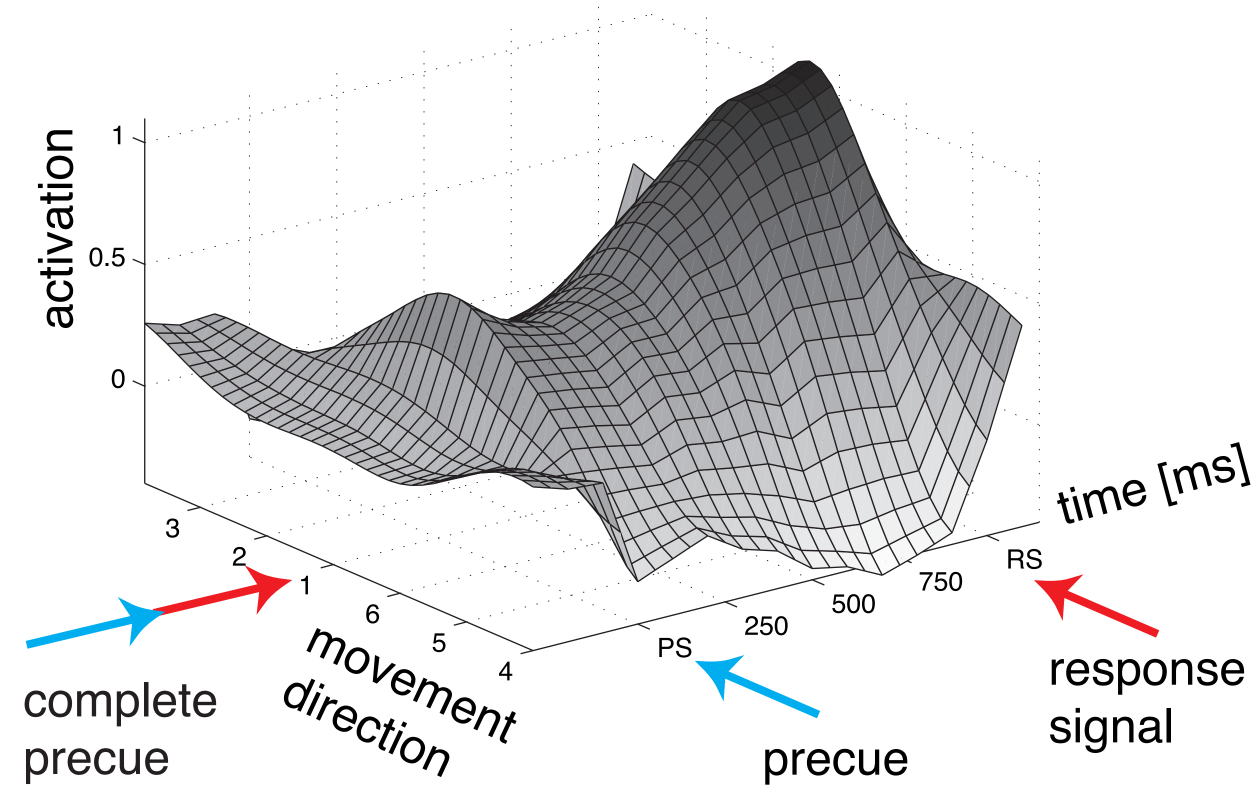
Distribution of population activation =
$\sum_{\text{neurons}}$ tuning curve * current firing rate

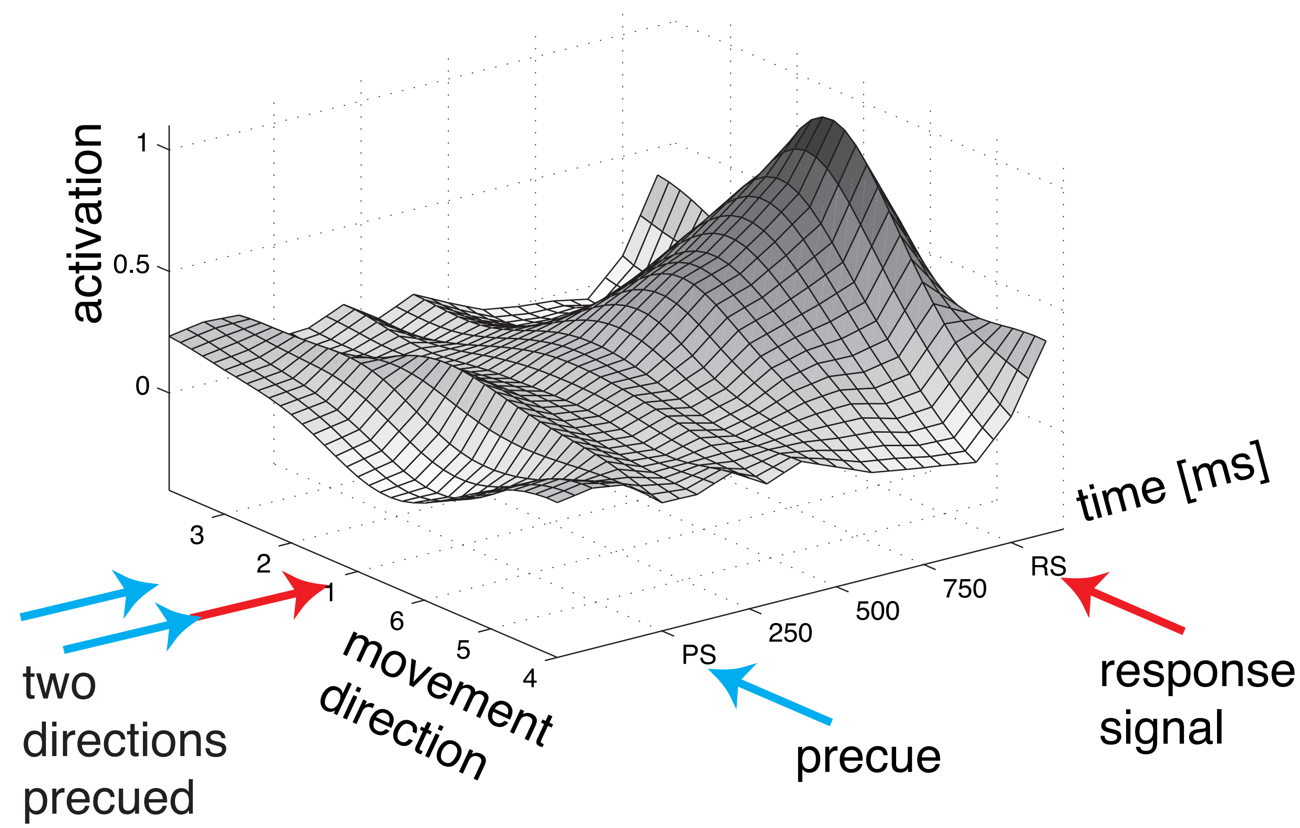




[Bastian, Riehle, Schöner, 2003]

- look at temporal evolution of DPA
- or DPAs in new conditions, here: DPA reflects prior information





Distributions of Population Activation are abstract

- neurons are not localized within DPA!
- cortical neurons really are sensitive to many dimensions
  - motor: arm configuration, force direction
  - visual: many feature dimensions such as spatial frequency, orientation, direction...
- => DPA is a projection from that high-dimensional space onto a single dimension