Dynamic Field Theory Part 1: continuous spaces and activation fields

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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

- continuous motion
- apparent motion
- motion pattern

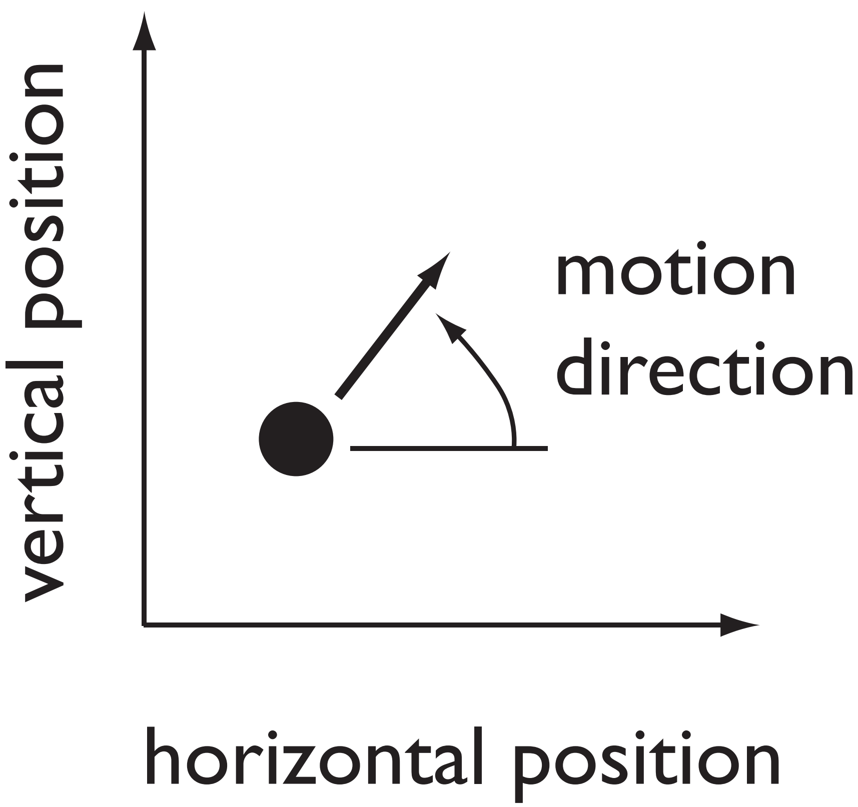
example: selection decisions in motion perception

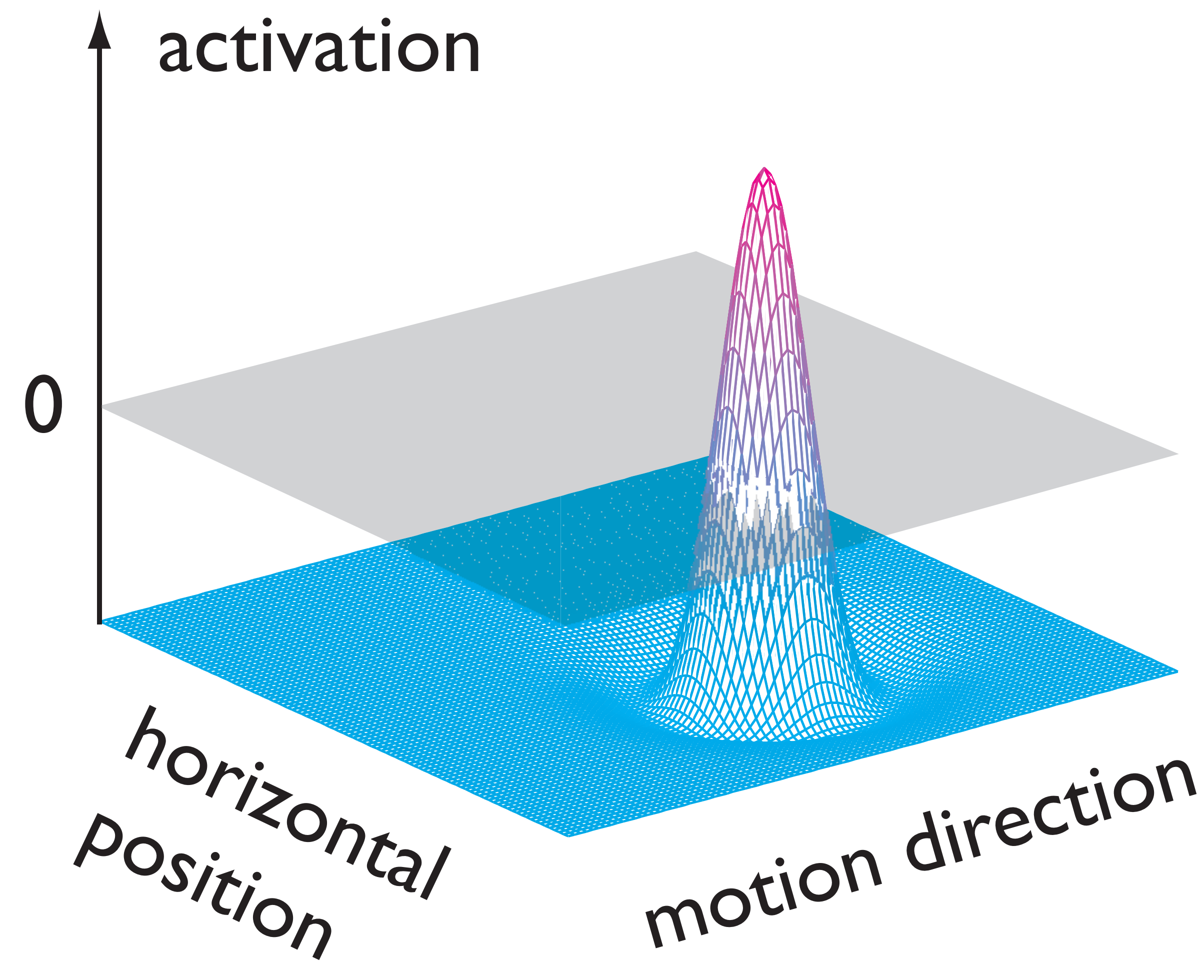
- motion pattern
  - why not diagonal motion?
  - or the other diagonal motion?
  - => motion pattern perception involves selection decision

example: selection decisions in motion perception

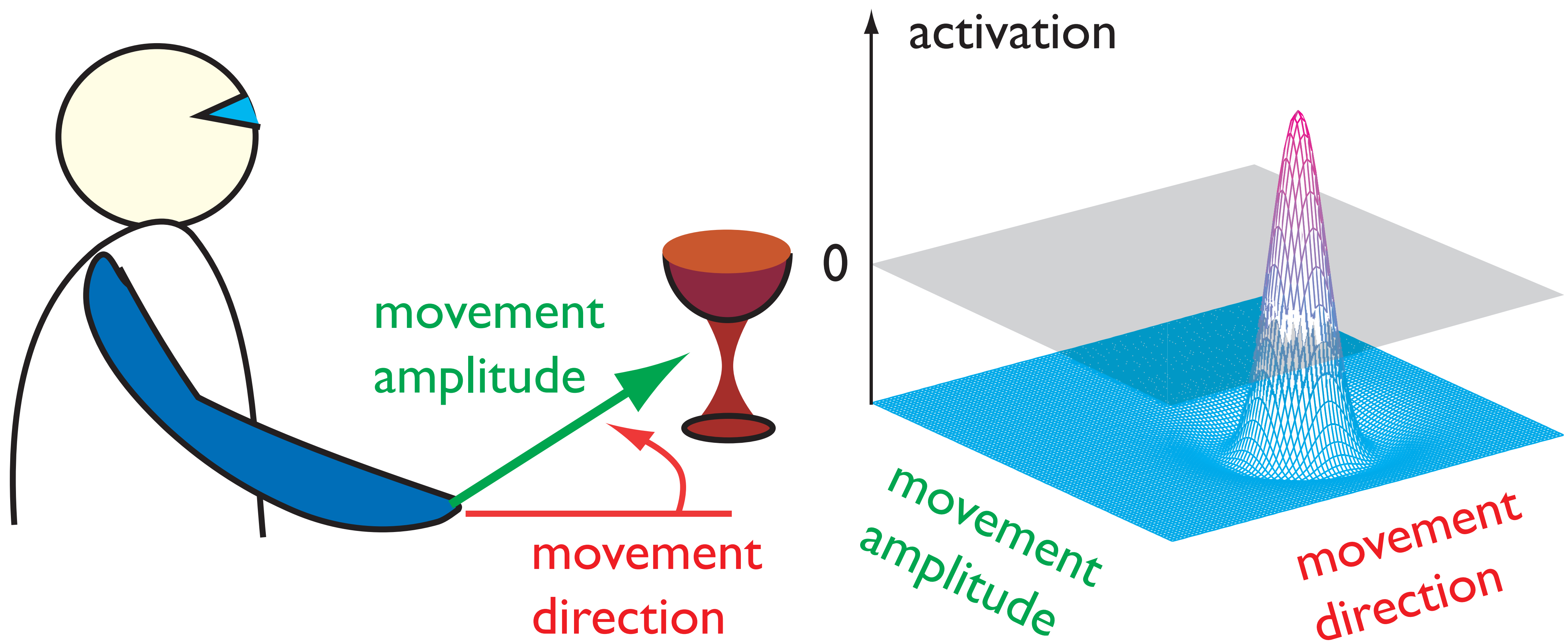
- can the alternative motion pattern be realized?
  - flat motion quartet
  - tall motion quartet
  - square motion quartet

space of possible percepts and activation field



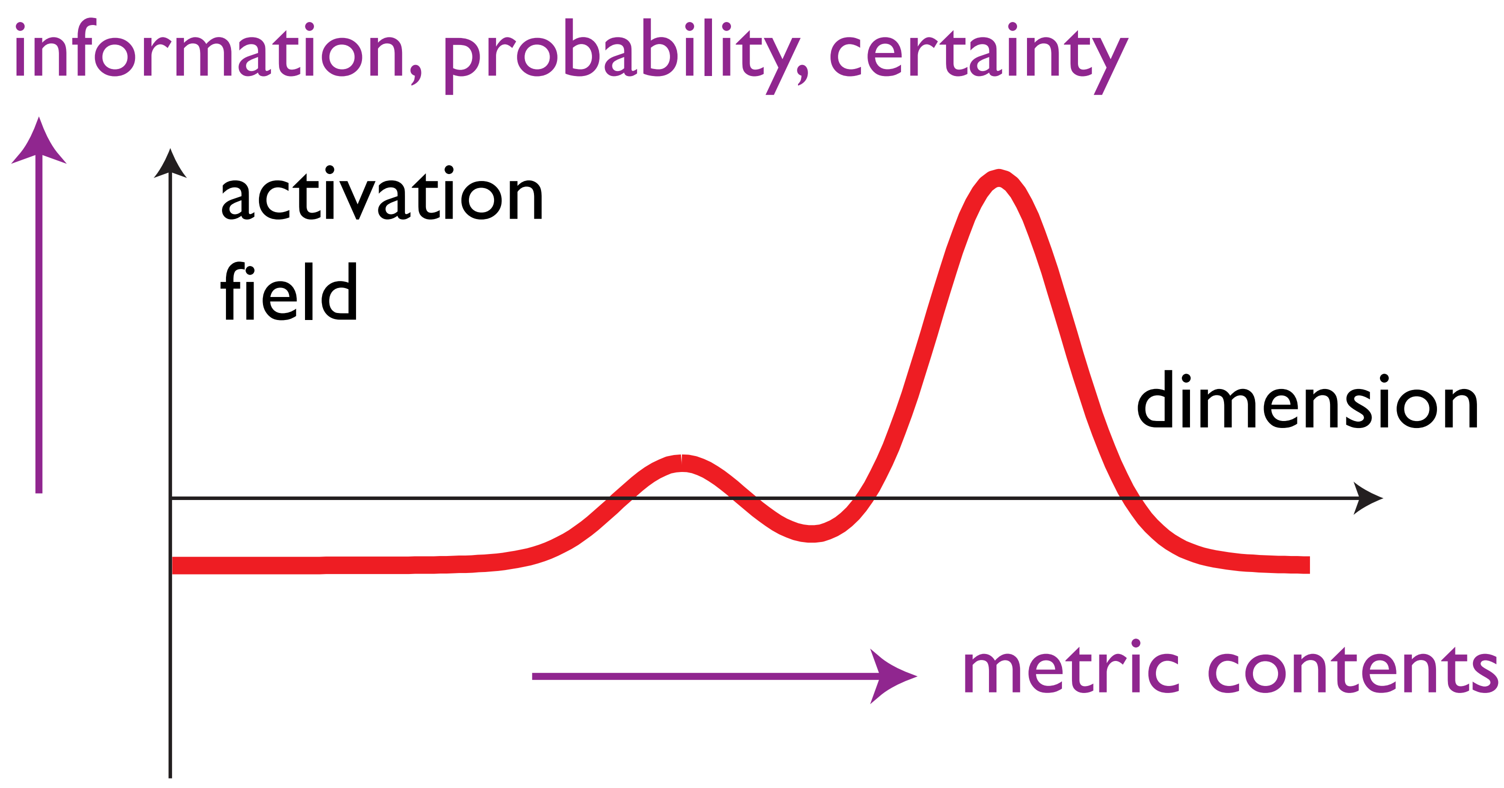


space of possible actions and activation field



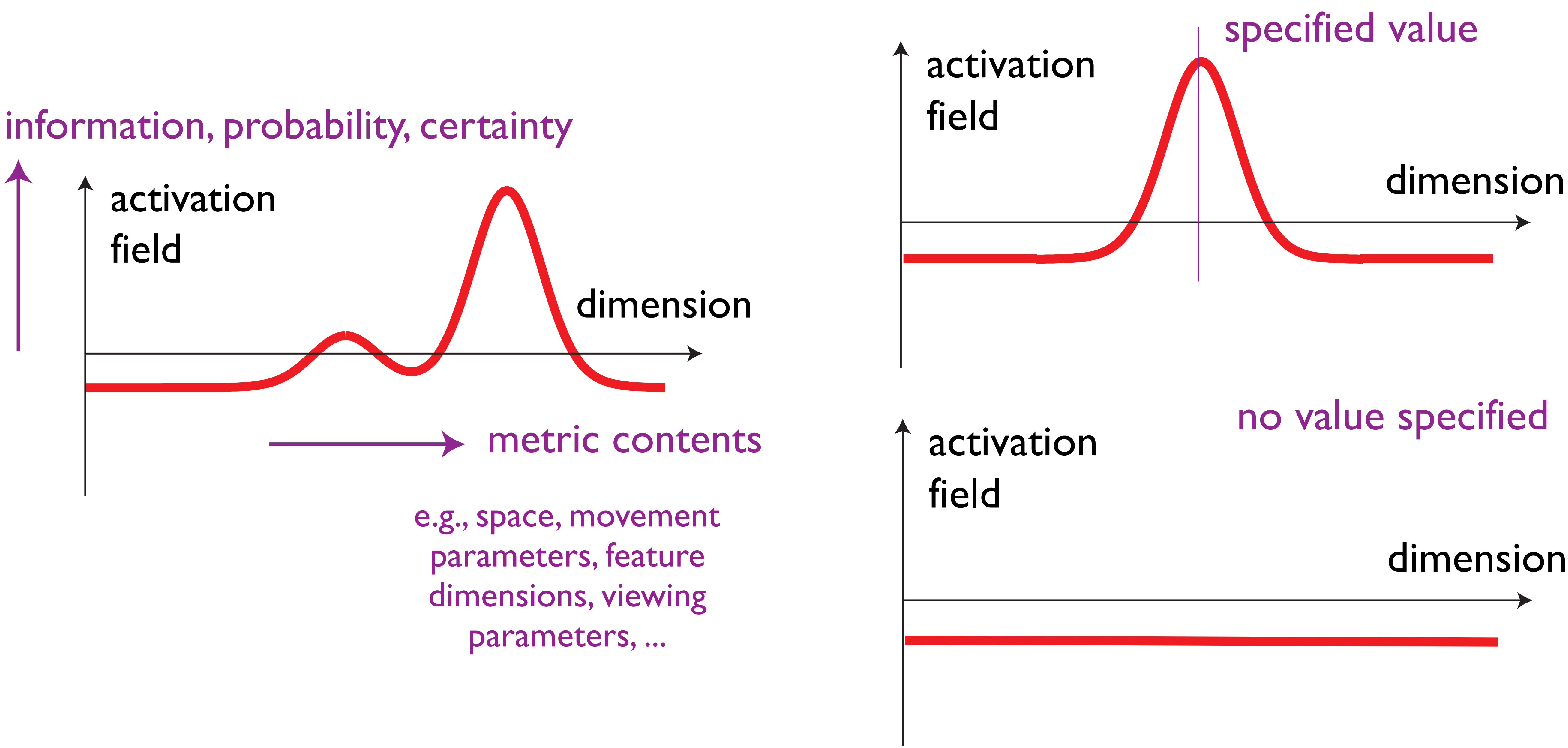
Dynamical Field Theory: space

- fields: continuous activation variables defined over continuous spaces

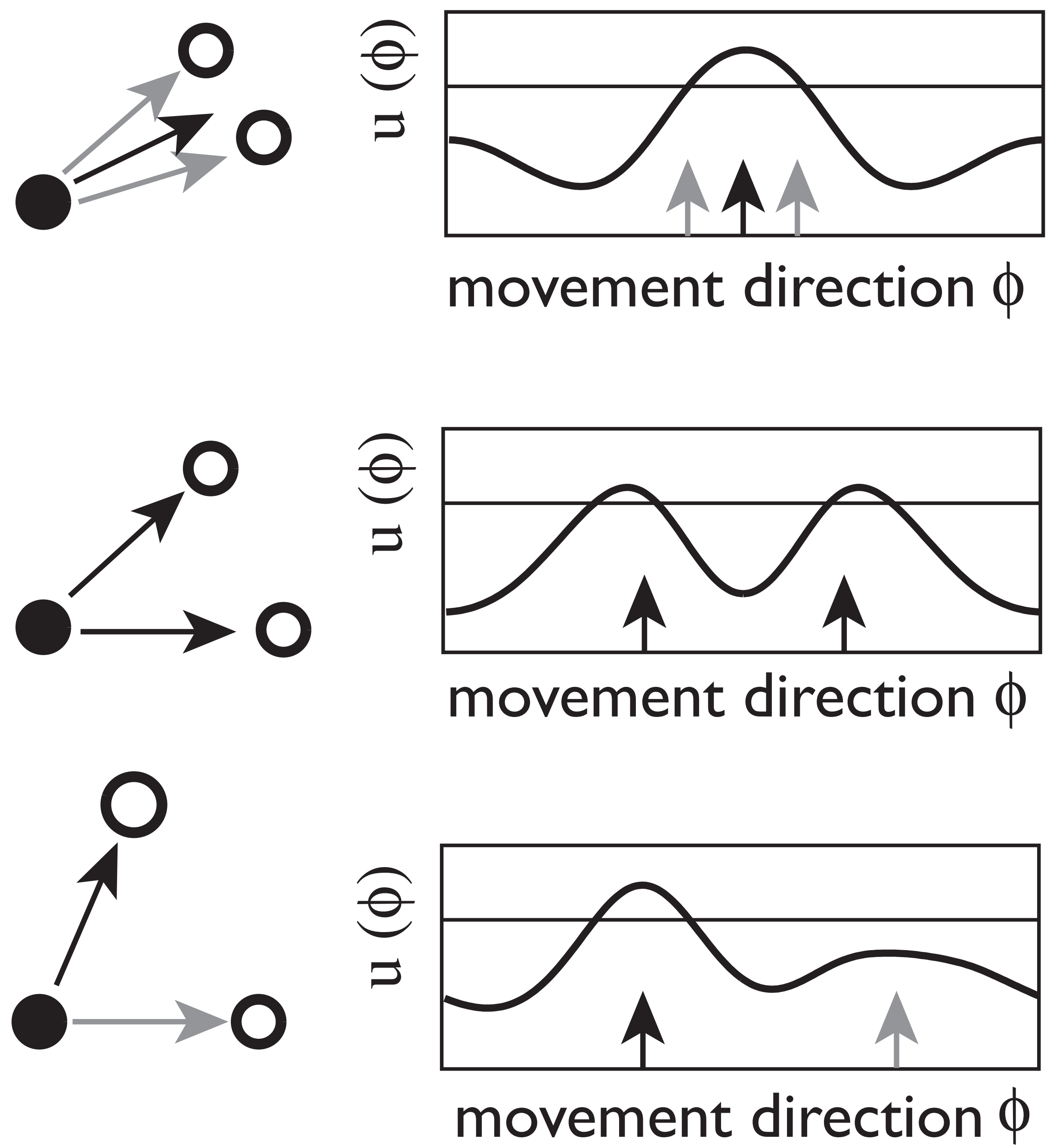


e.g., retinal space, movement parameters, feature dimensions, viewing parameters, ...

activation fields



representing different percepts

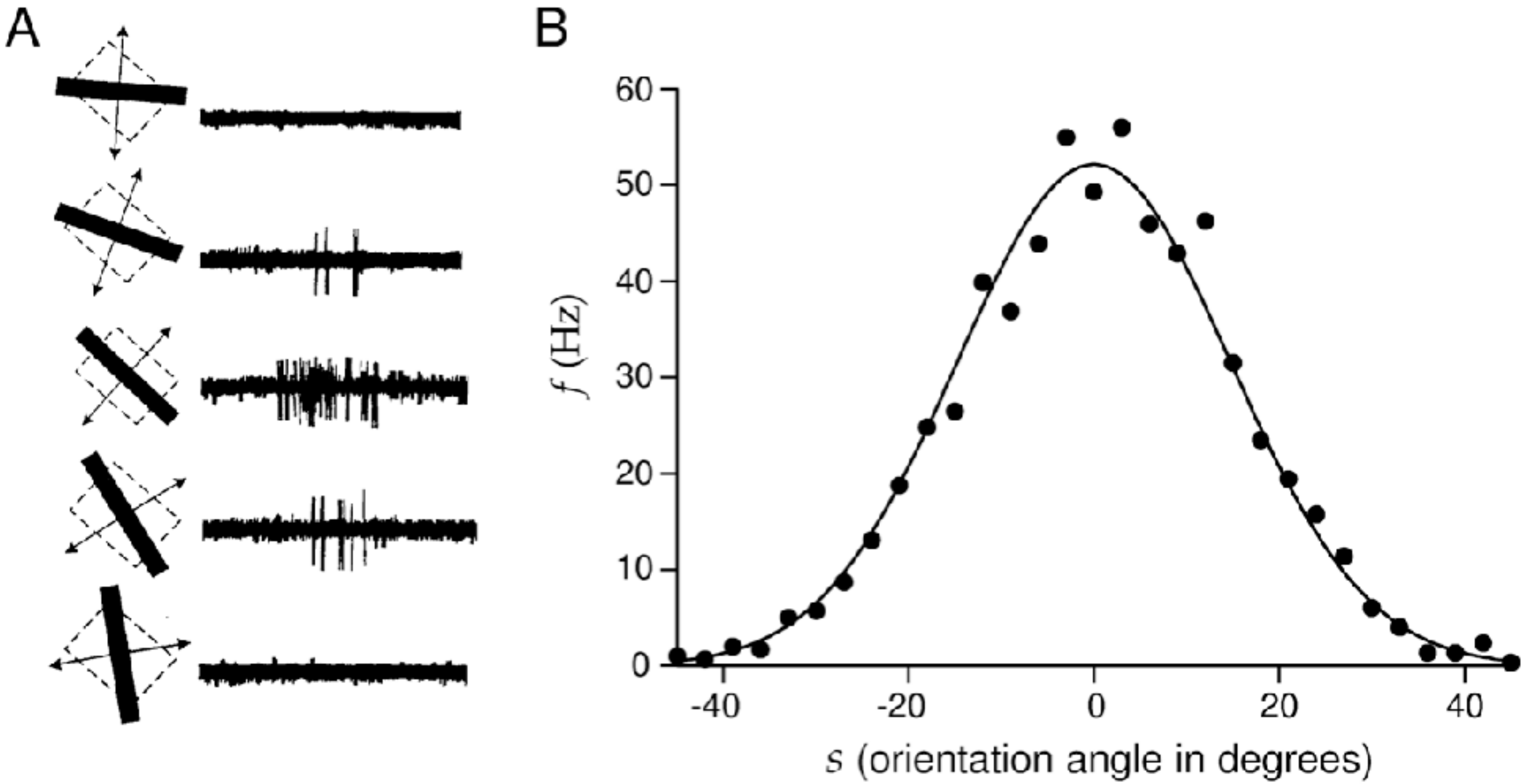


Link between DFT and neurophysiology

- What do neurons represent?

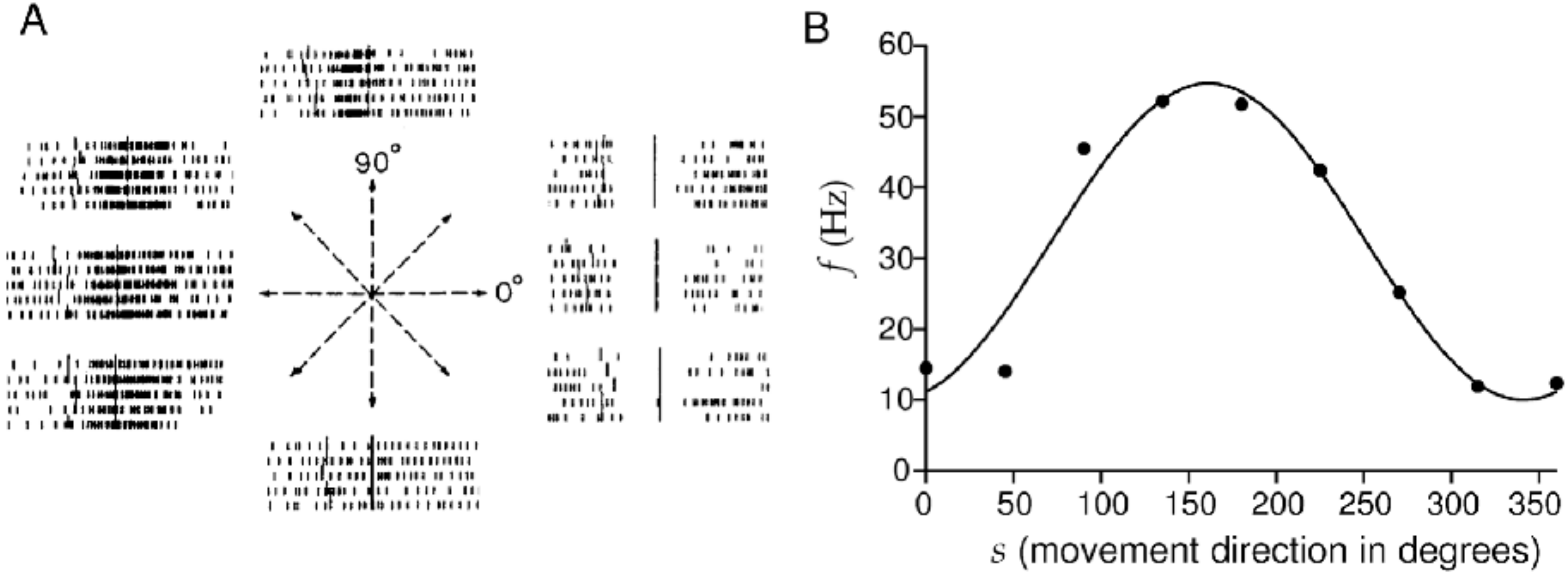
tuning curve

- example: primary visual cortex (monkey)



tuning curve

- example: primary motor cortex (monkey)

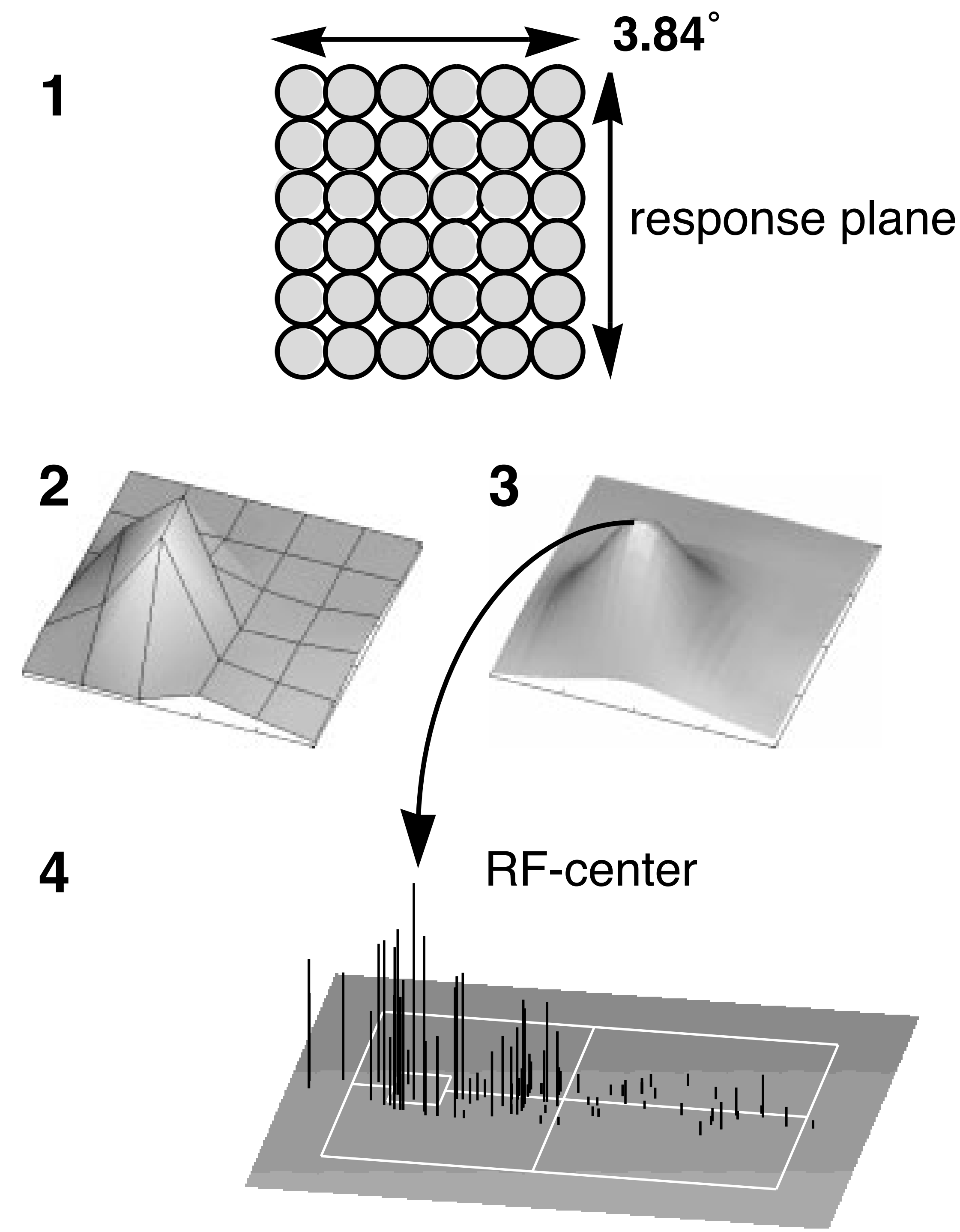


Link between DFT and neurophysiology

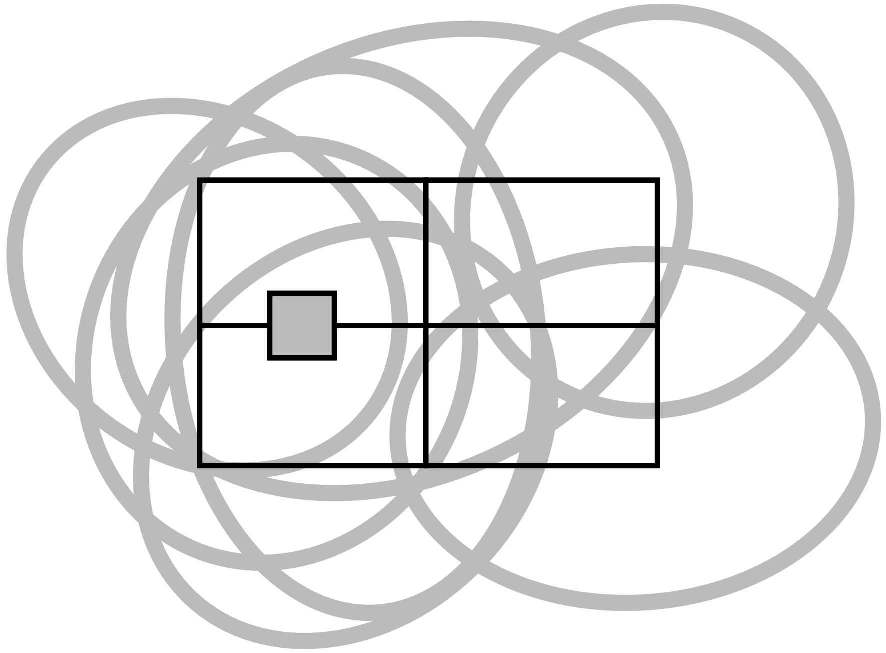
- Example 1: Jancke et al: A17 in the cat, population representation of retinal location

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

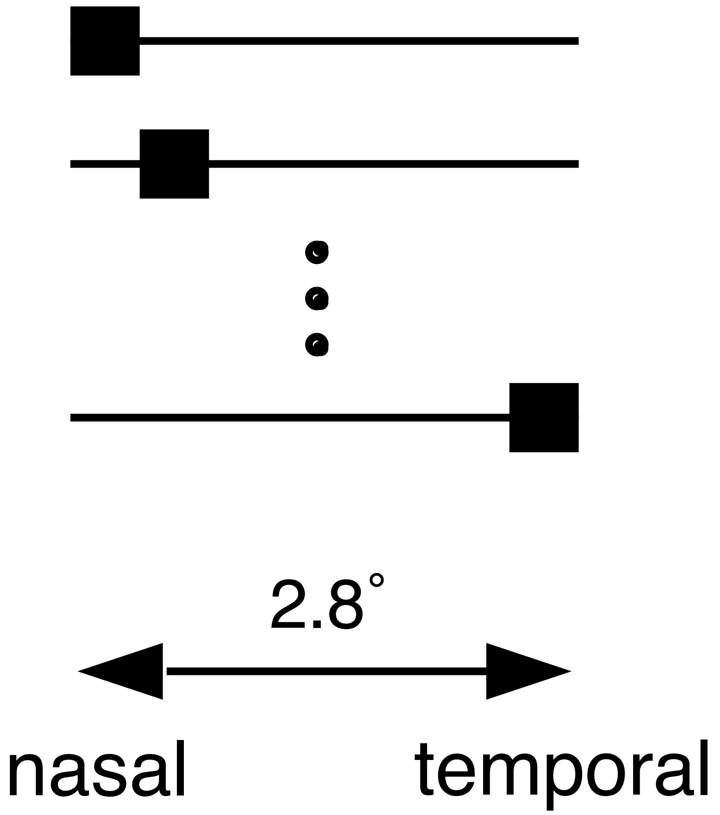
- determine RF profile for each cell
- it's center determines what that neuron codes for
- compute a distribution of population activation by superposing RF profiles weighted with current neural firing rate



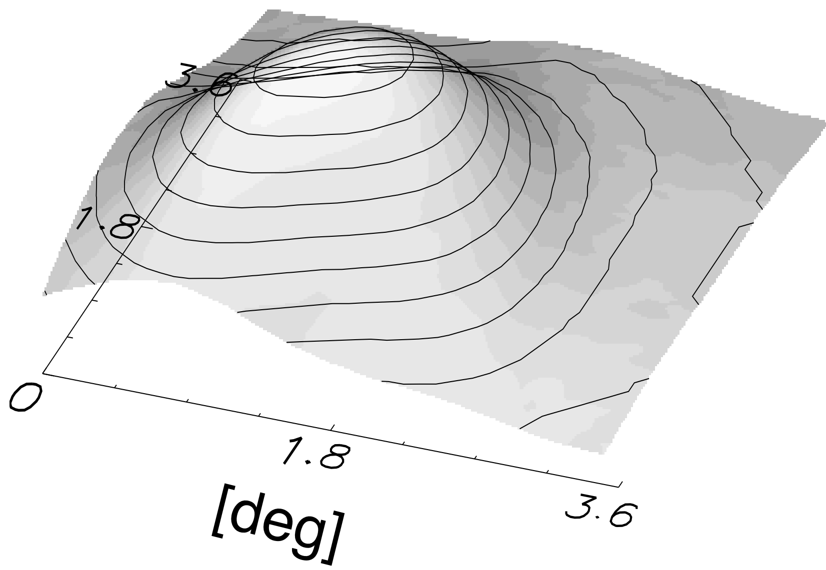
- The current response refers to a stimulus experienced by all neurons
- Reference condition: localized points of light

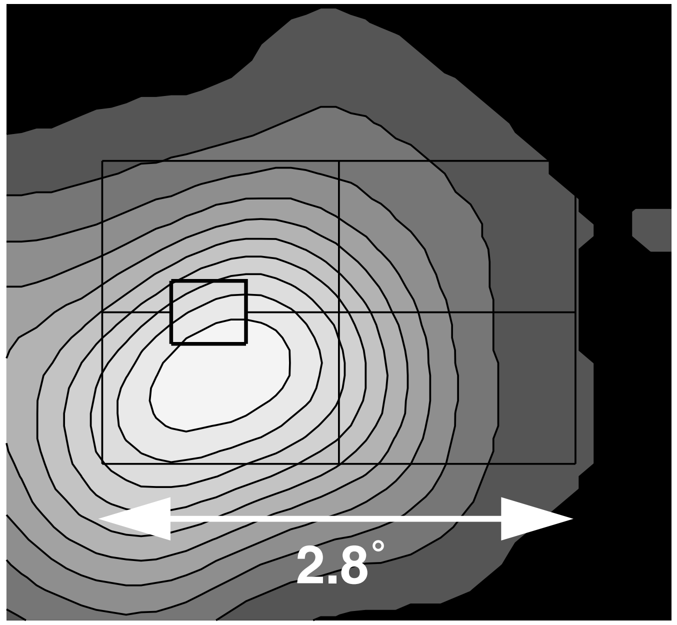


elementary stimuli

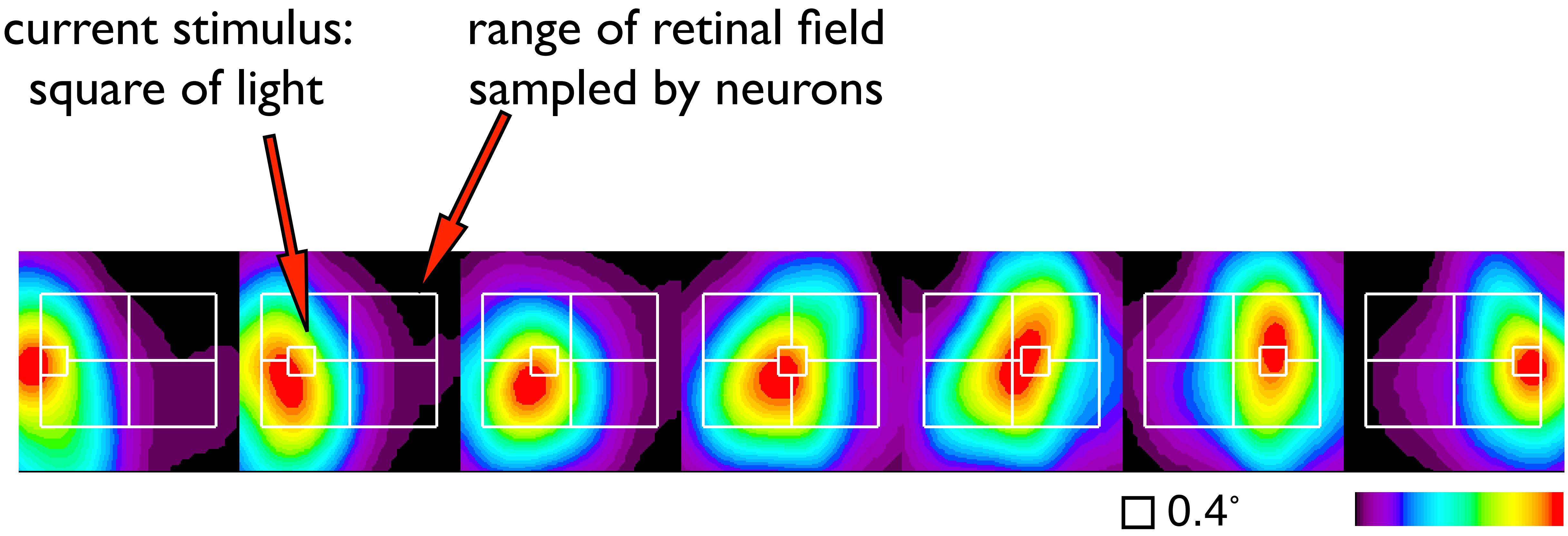


- result: population distribution of activation defined over retinal space = representation of visual location

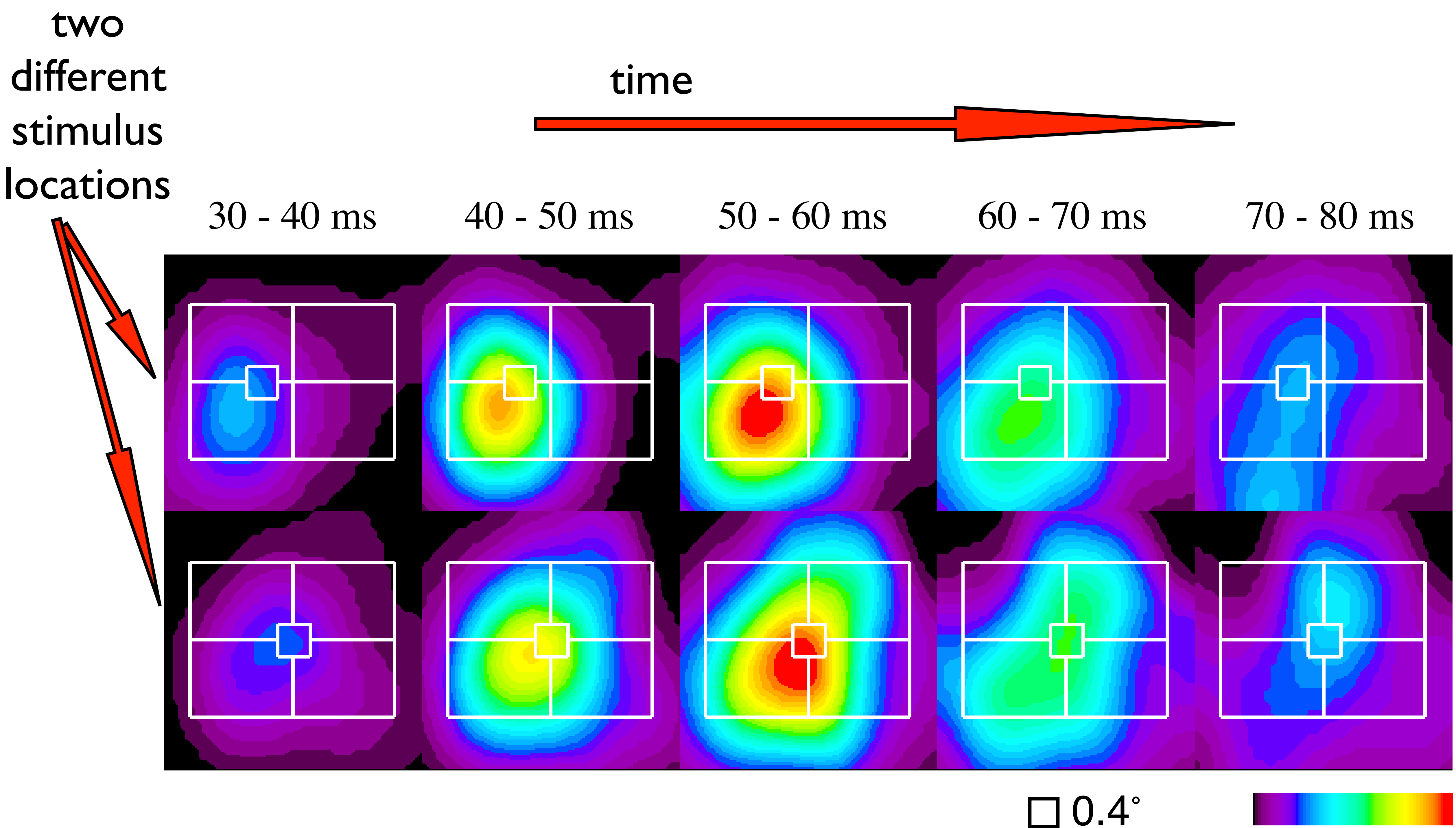




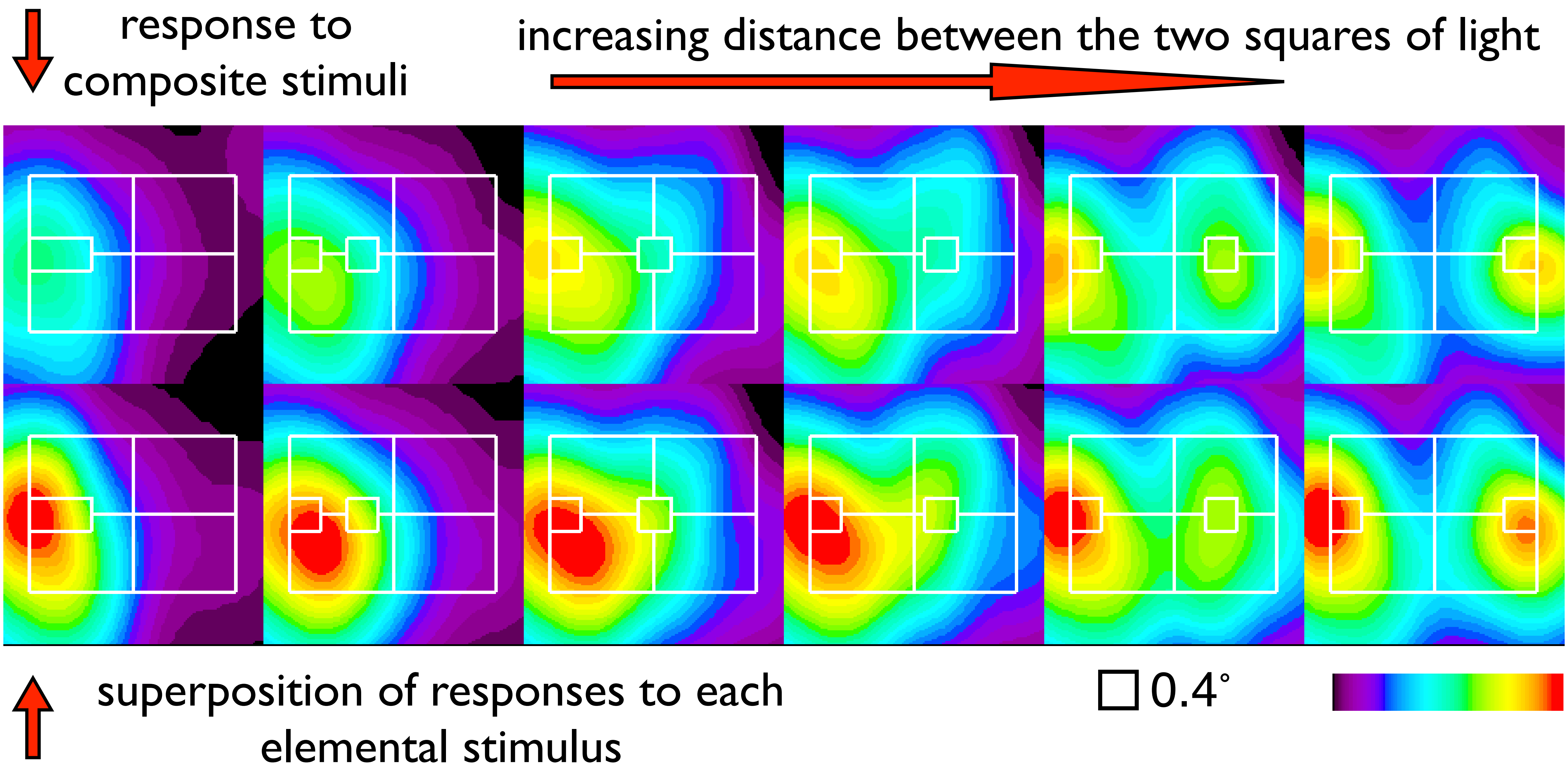
- => does a decent job estimating retinal position



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

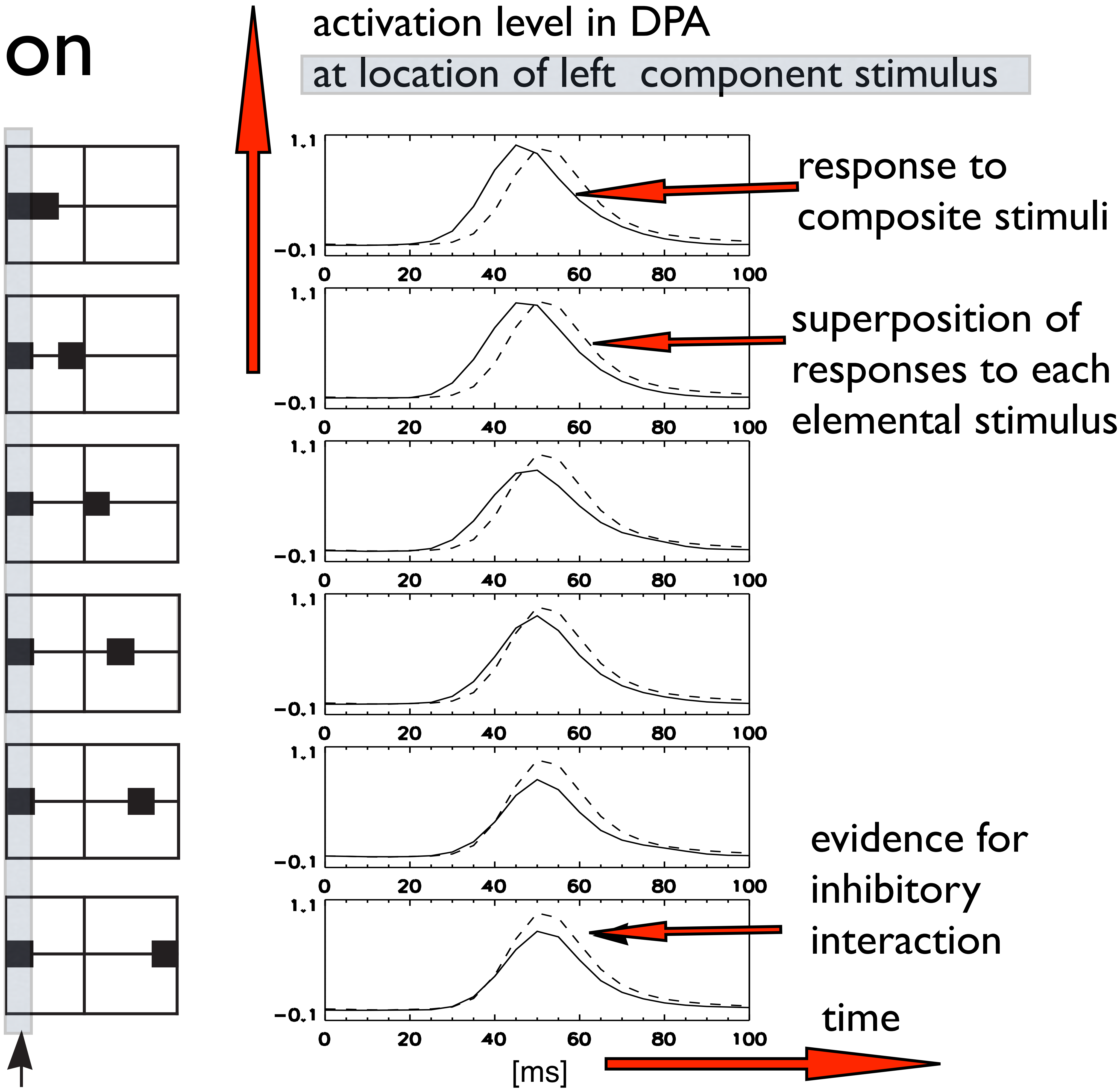


- or when complex stimuli are presented (here: two spots of light)

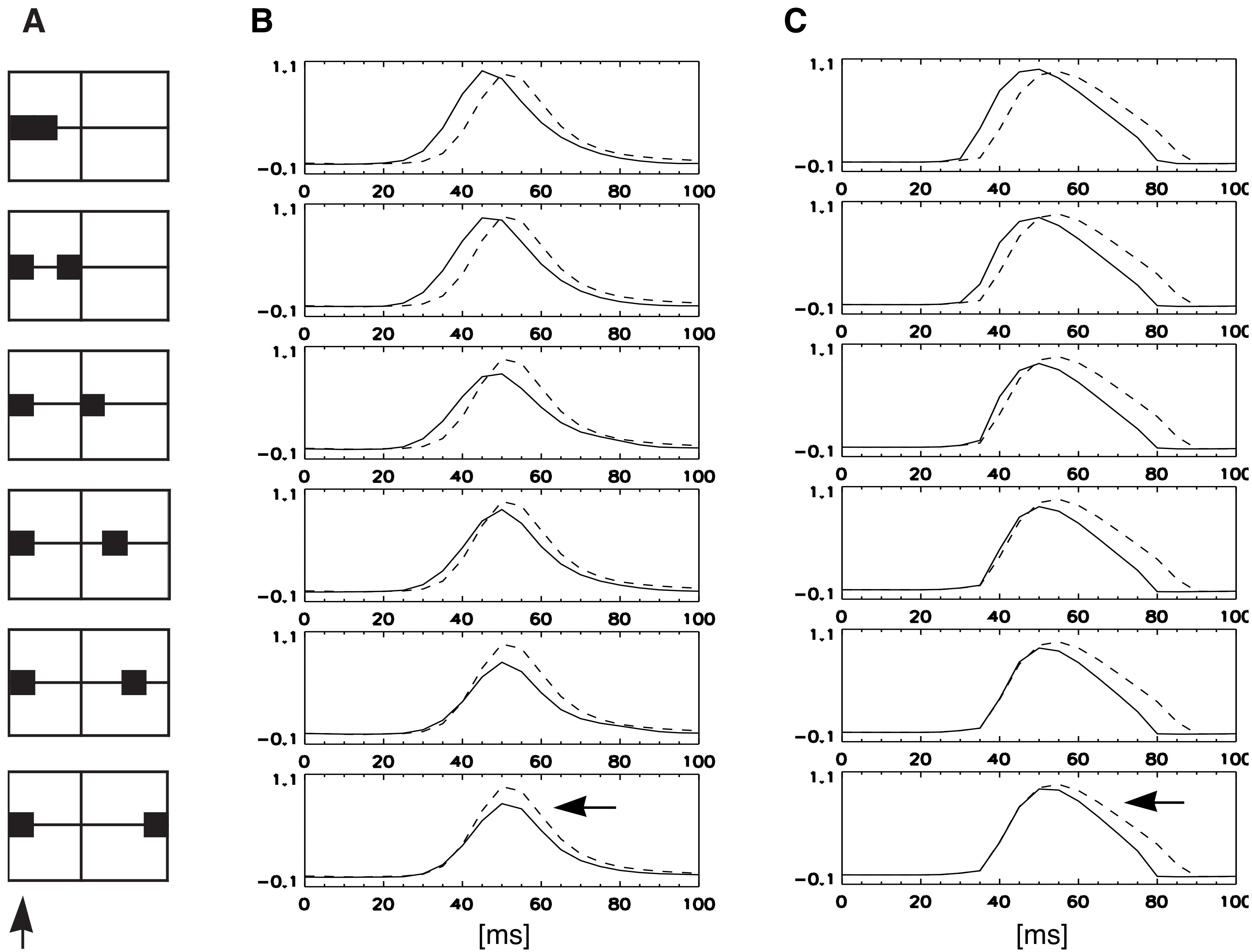


- by comparing DPA of composite stimuli to superposition of DPAs of the two elementary stimuil obtain evidence for interaction
  - early excitation
  - late inhibition

interaction

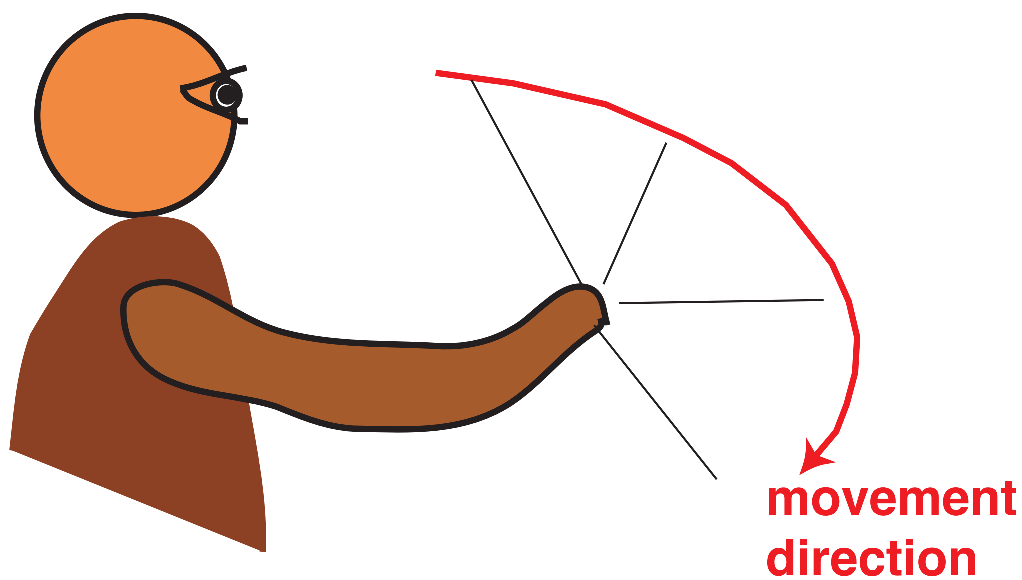


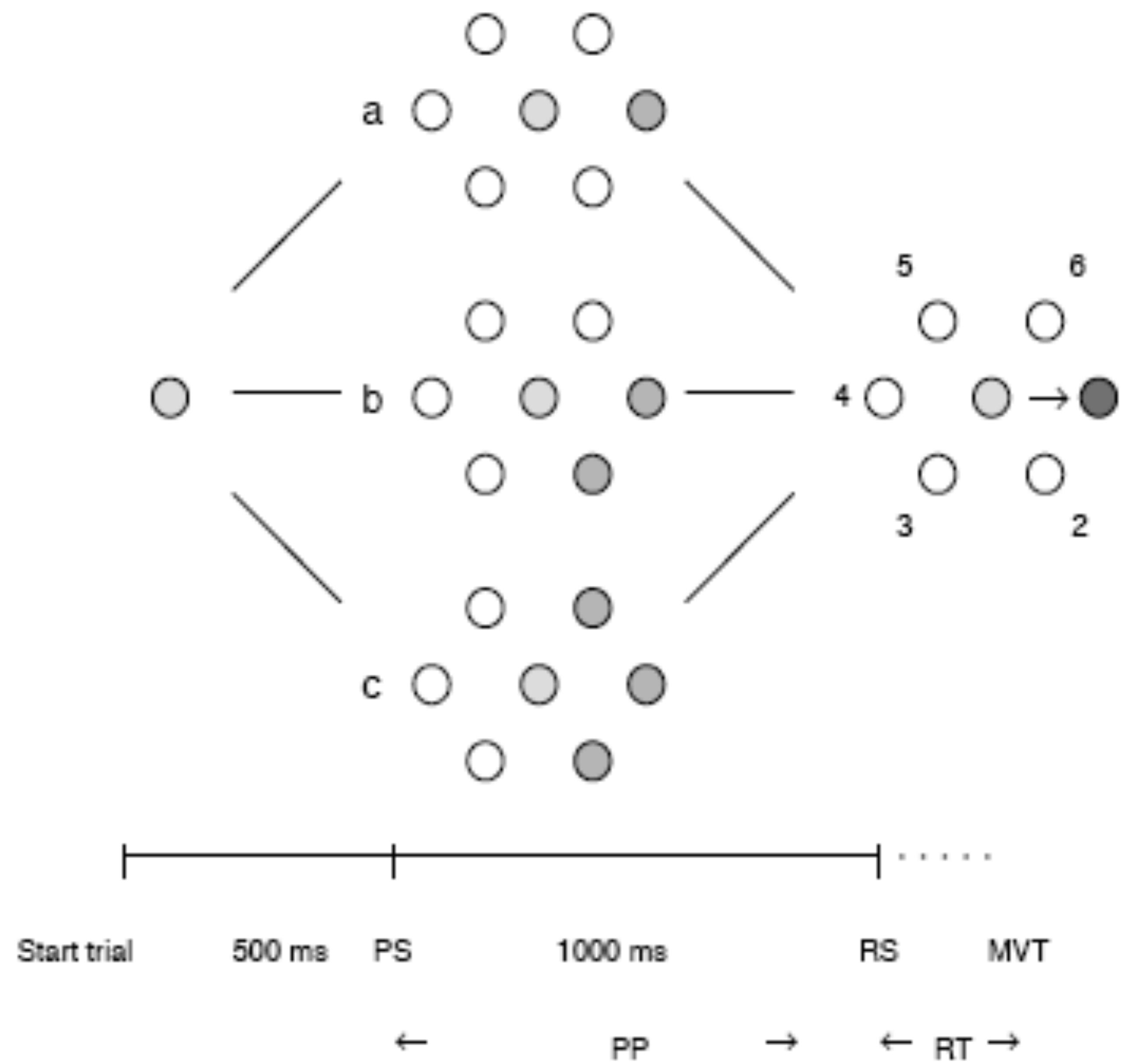
model by dynamic field:



stimulus experiment DFT model

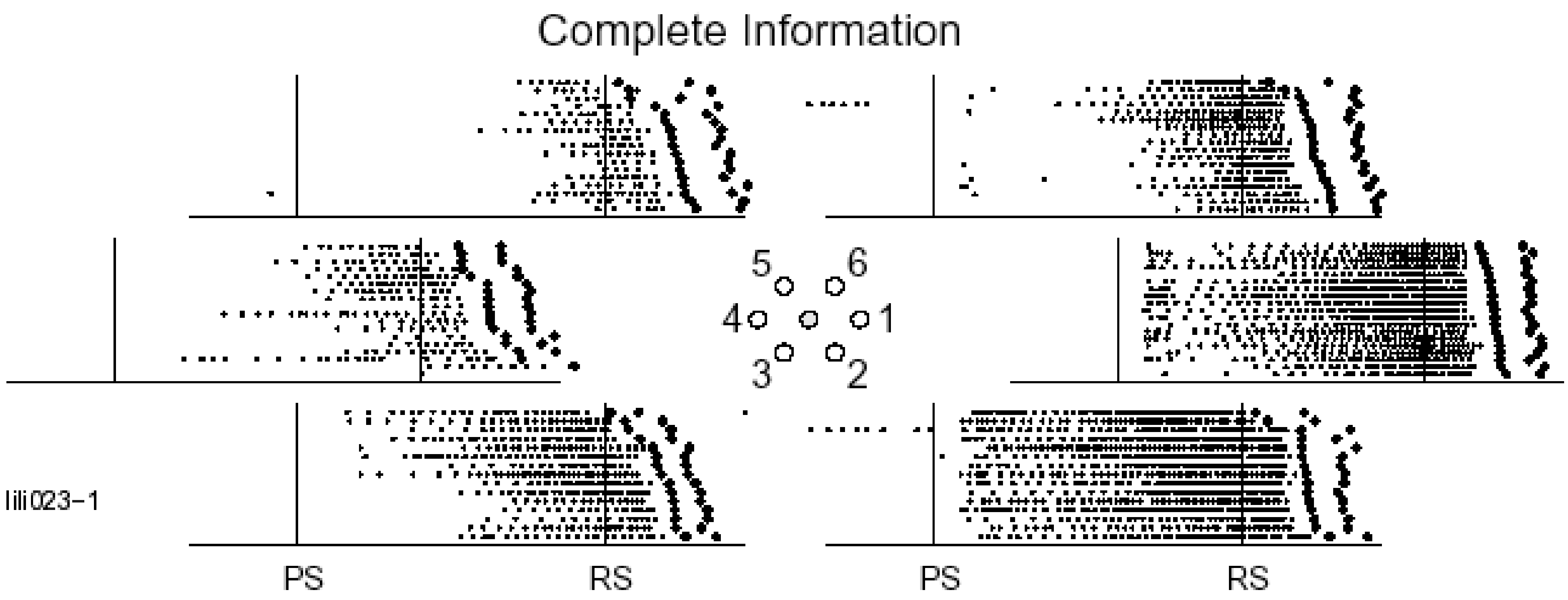
Neurophysiological grounding of DFT example: movement planning





Bastian, Riehle, Schöner, 2003

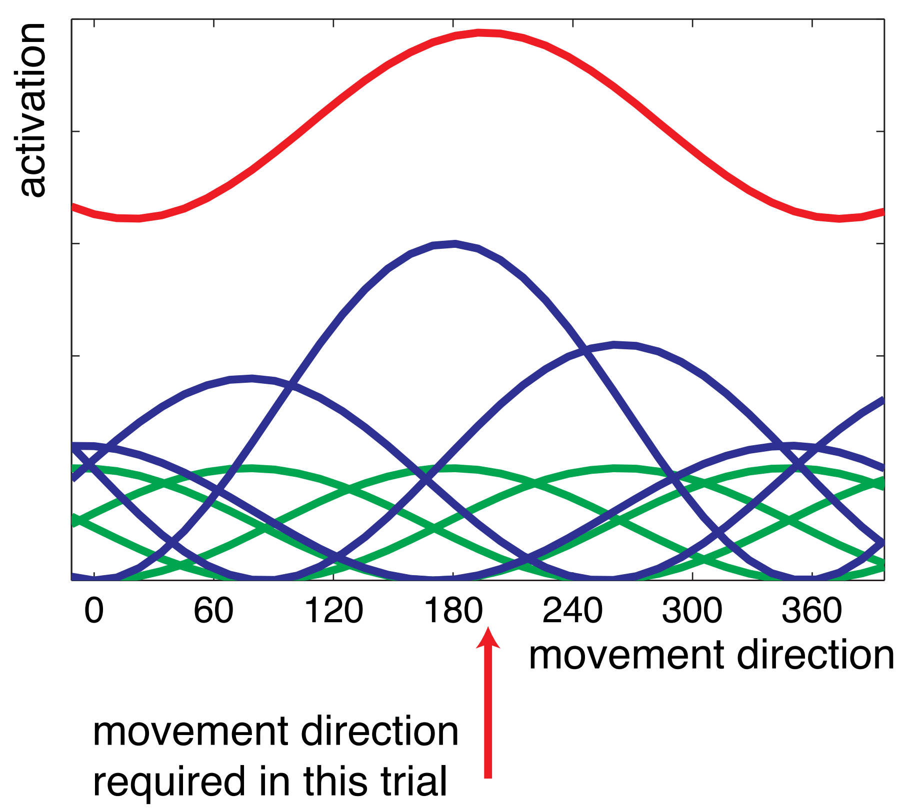
- tuning of cells in motor and premotor cortex to direction of end-effector movement path

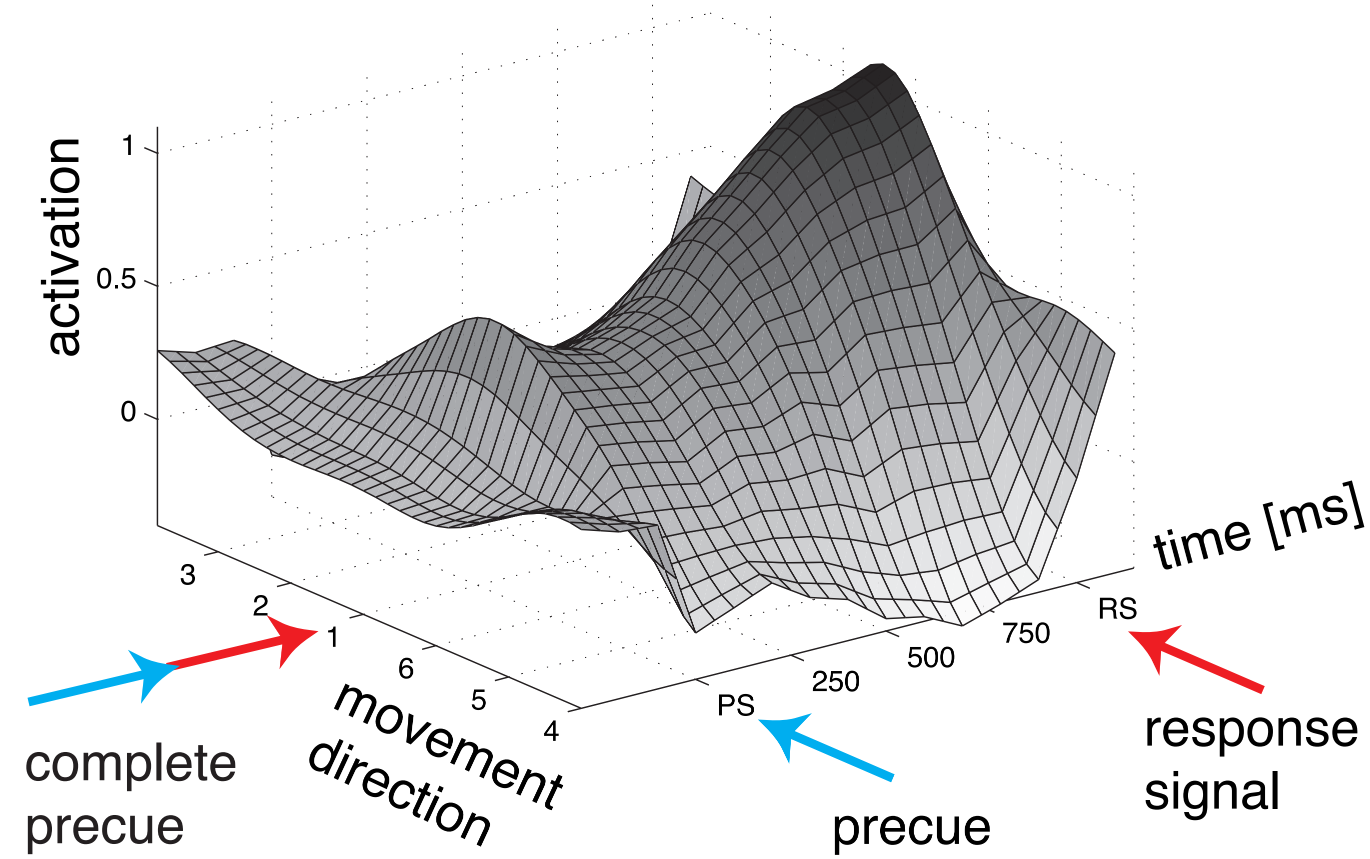


Distribution of Population Activation (DPA)

Distribution of population activation =

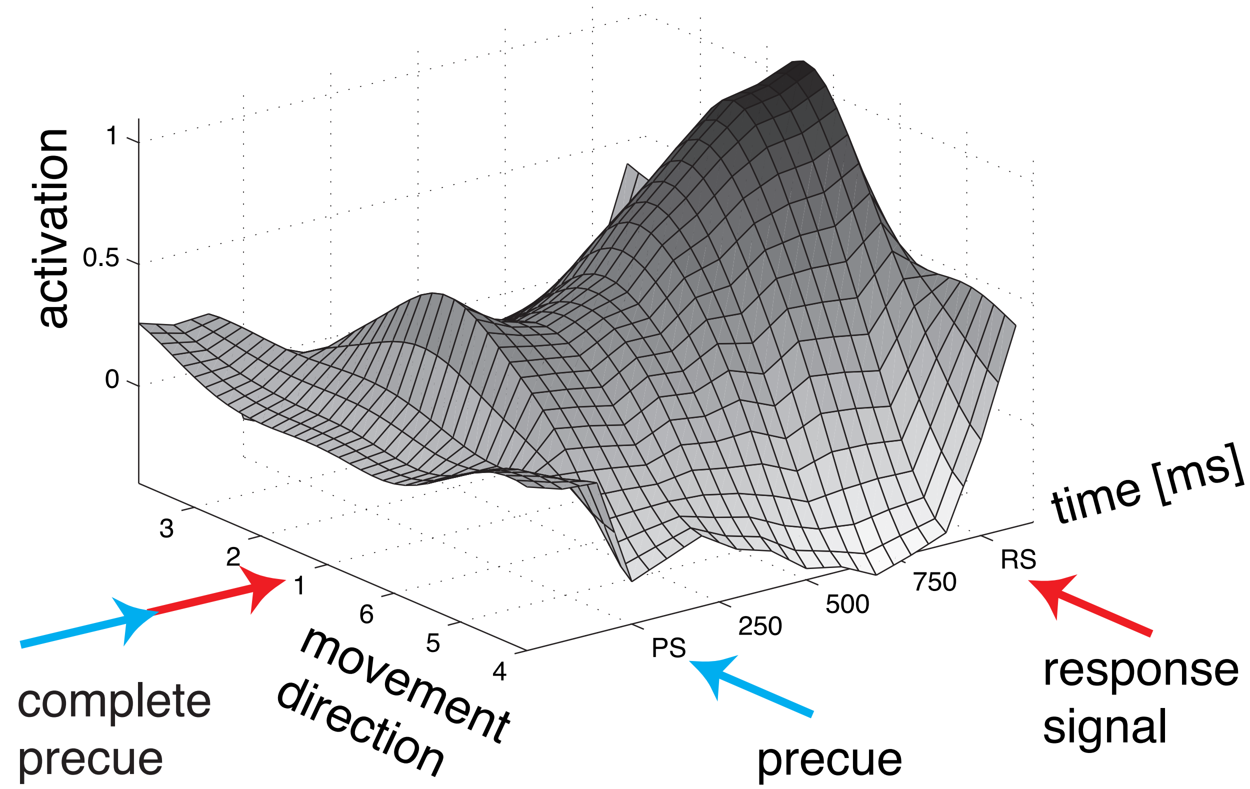
$\sum_{\text{neurons}}$ tuning curve * current firing rate

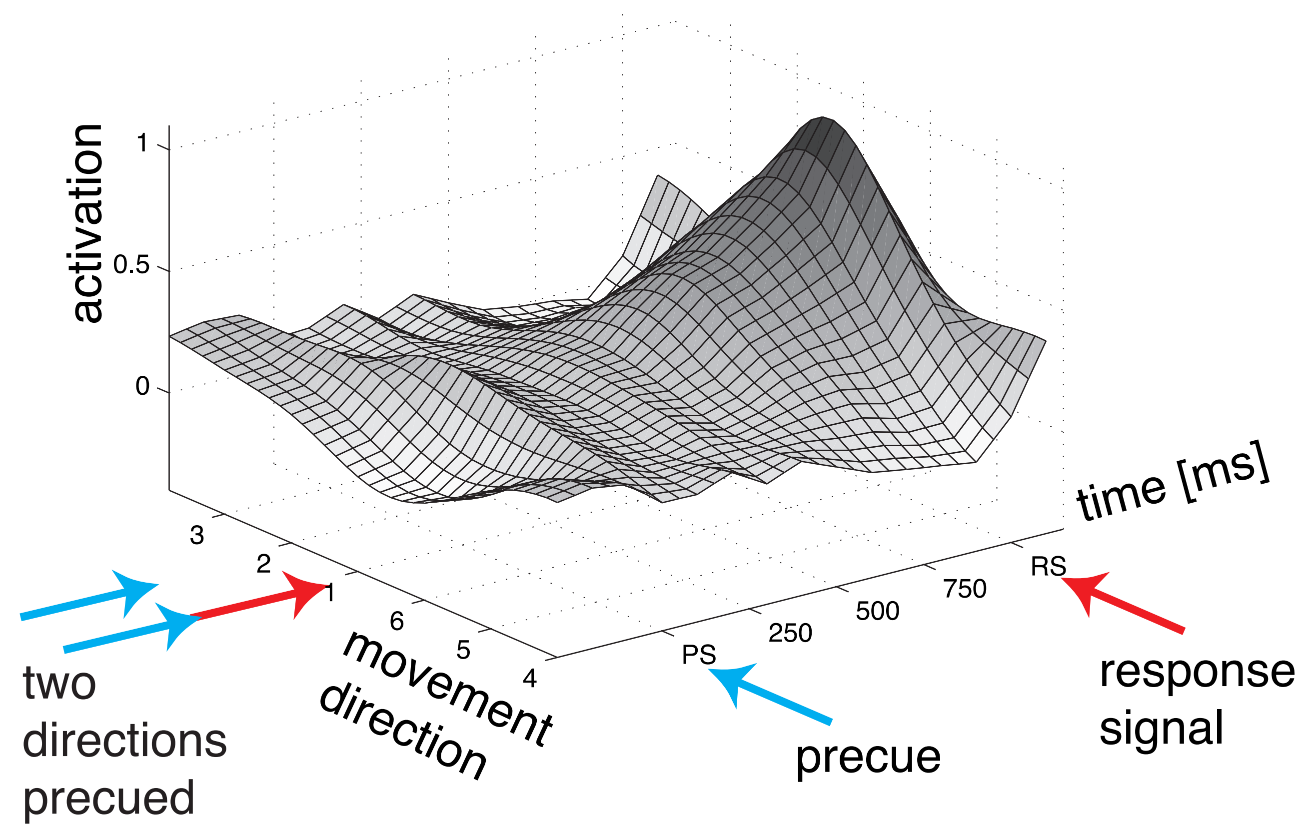




[Bastian, Riehle, Schöner, 2003]

- 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

… back to the activation fields

- how do we arrange that a field is "defined" over the appropriate dimension?
- => by its input/output connectivity…