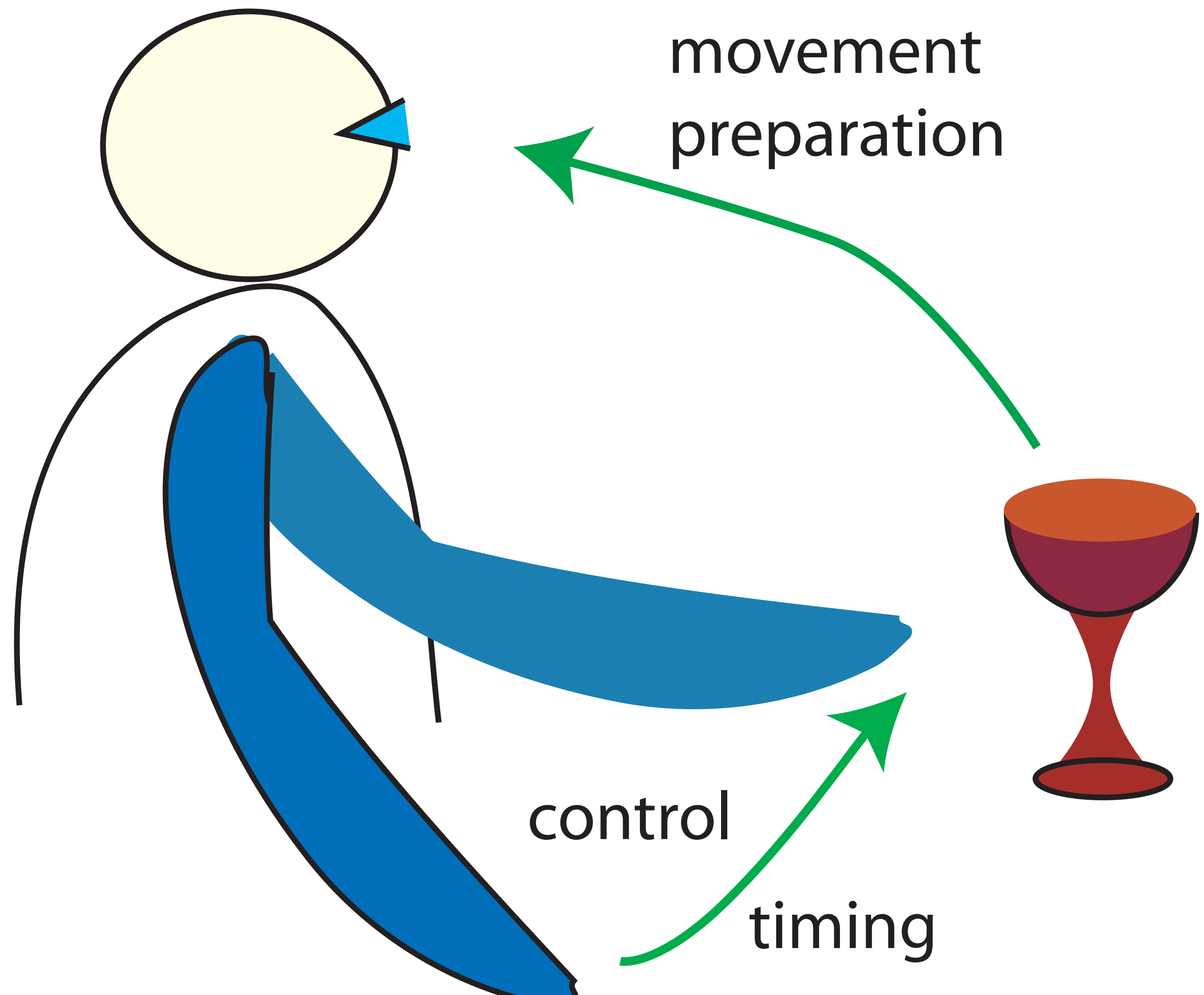
# Dynamic Field Theory: behavioral signatures

Gregor Schöner

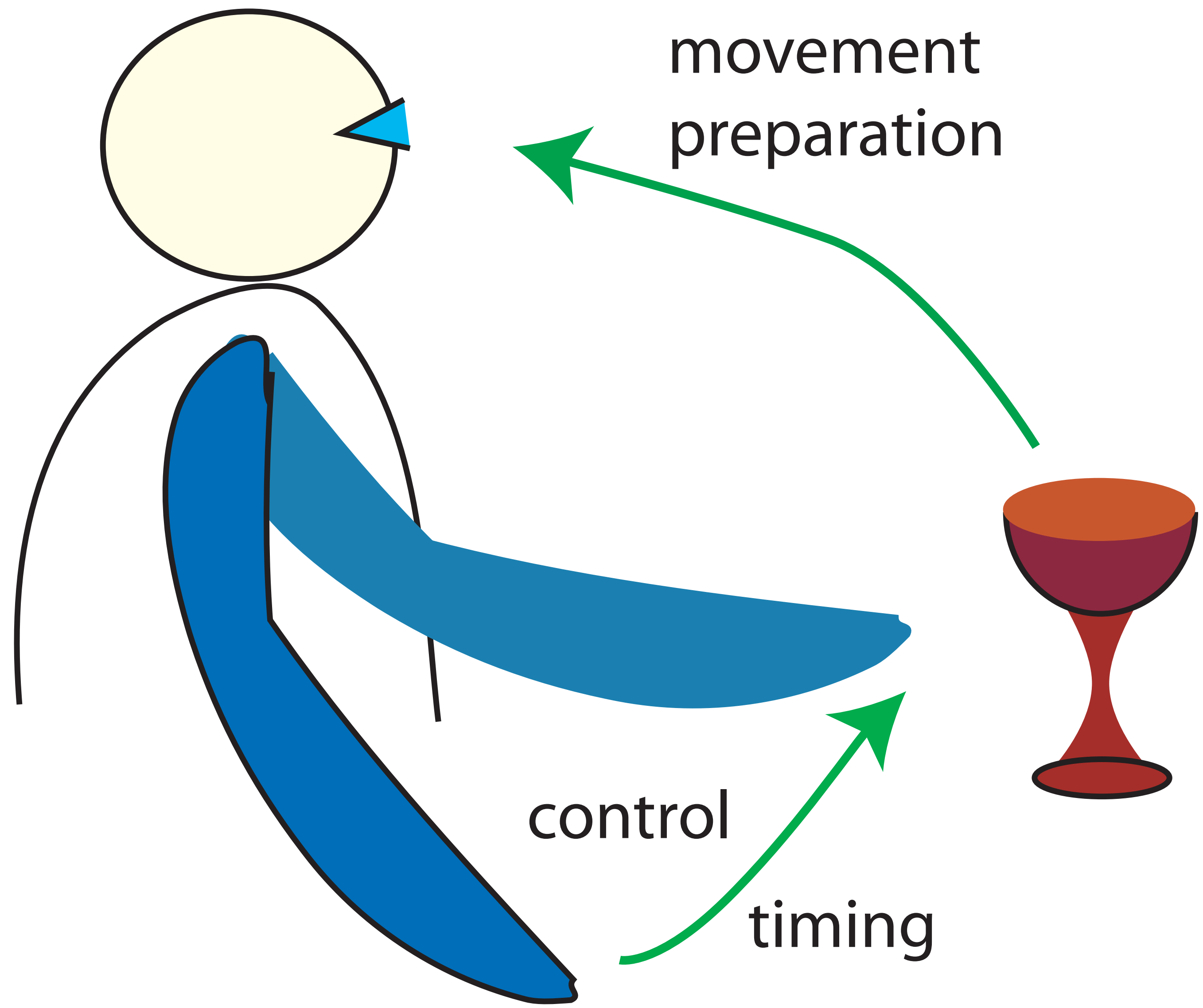
# What is entailed in generating an object-oriented movement?

- scene and object perception
- movement preparation
- movement initiation and termination
- movement timing and coordination
- motor control
- degree of freedom problem
- => spans perception, cognition and control



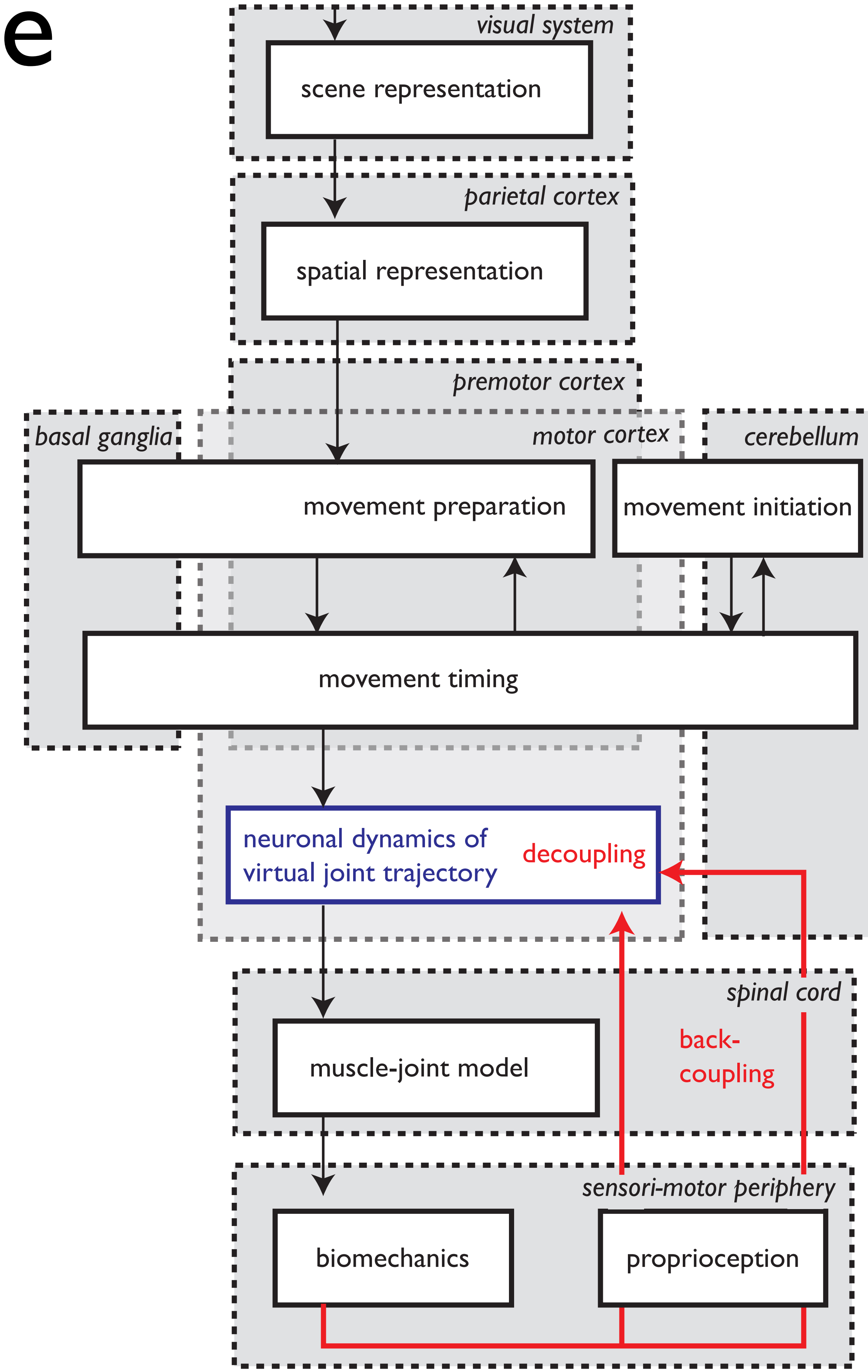
# What is entailed in generating an object-oriented movement?

- it is difficult to isolate any individual process
- => this is why movement is so hard to study
- => this is why it is critical to understand integration



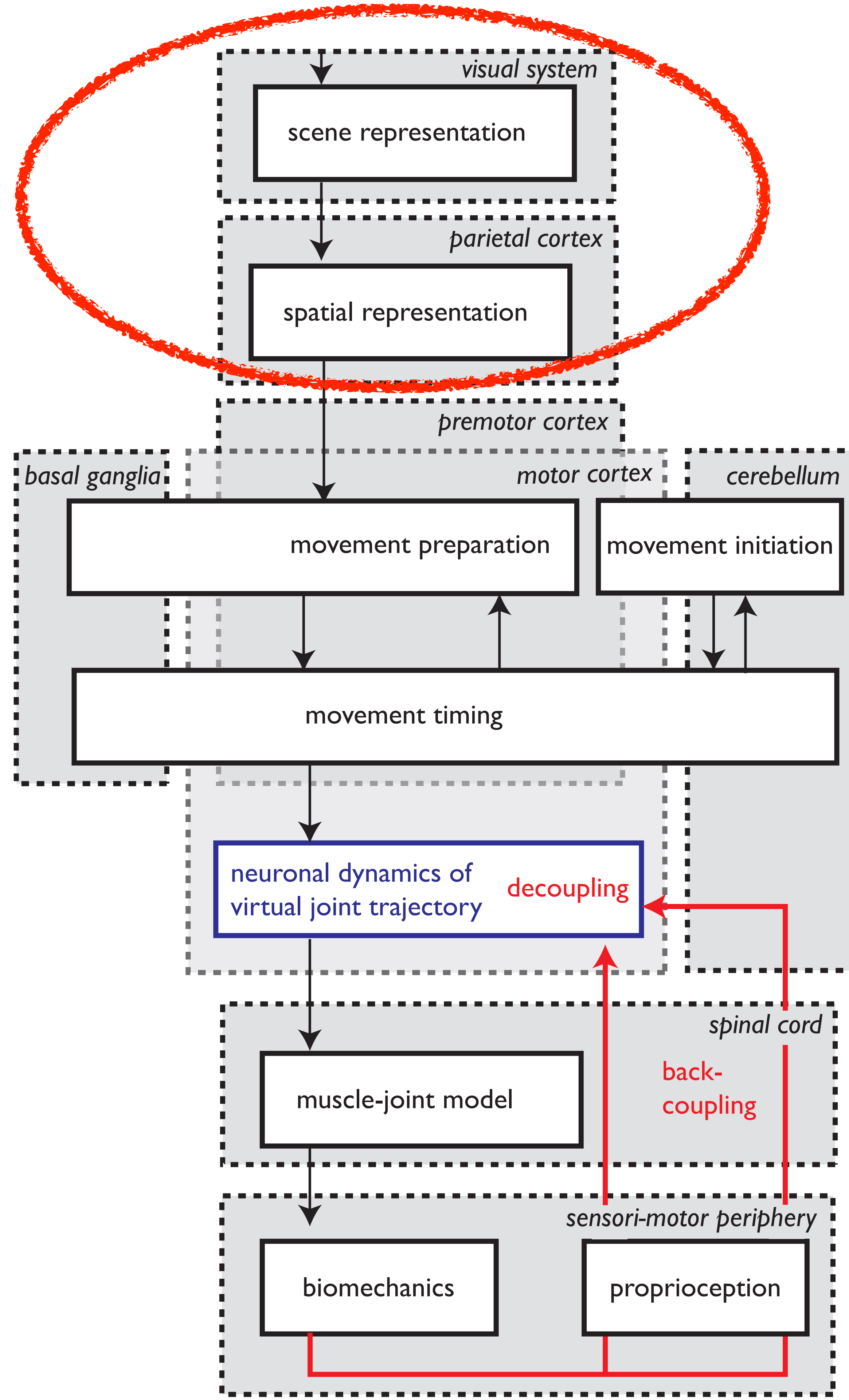
# plan for the rest of the course

- take you through the component process
- and discuss theoretical concepts relevant at each level
- point to open problems




[Martin, Scholz, Schöner. *Neural Computation* 21, 1371–1414 (2009)]

# 1) Scene representation




[Martin, Scholz, Schöner. *Neural Computation* 21, 1371–1414 (2009)]

# Scene representation

- Human movement is planned based on perception that is specific to movement
  - e.g., blind sight
- and is largely about where objects are in space and object pose
  - supported by gaze

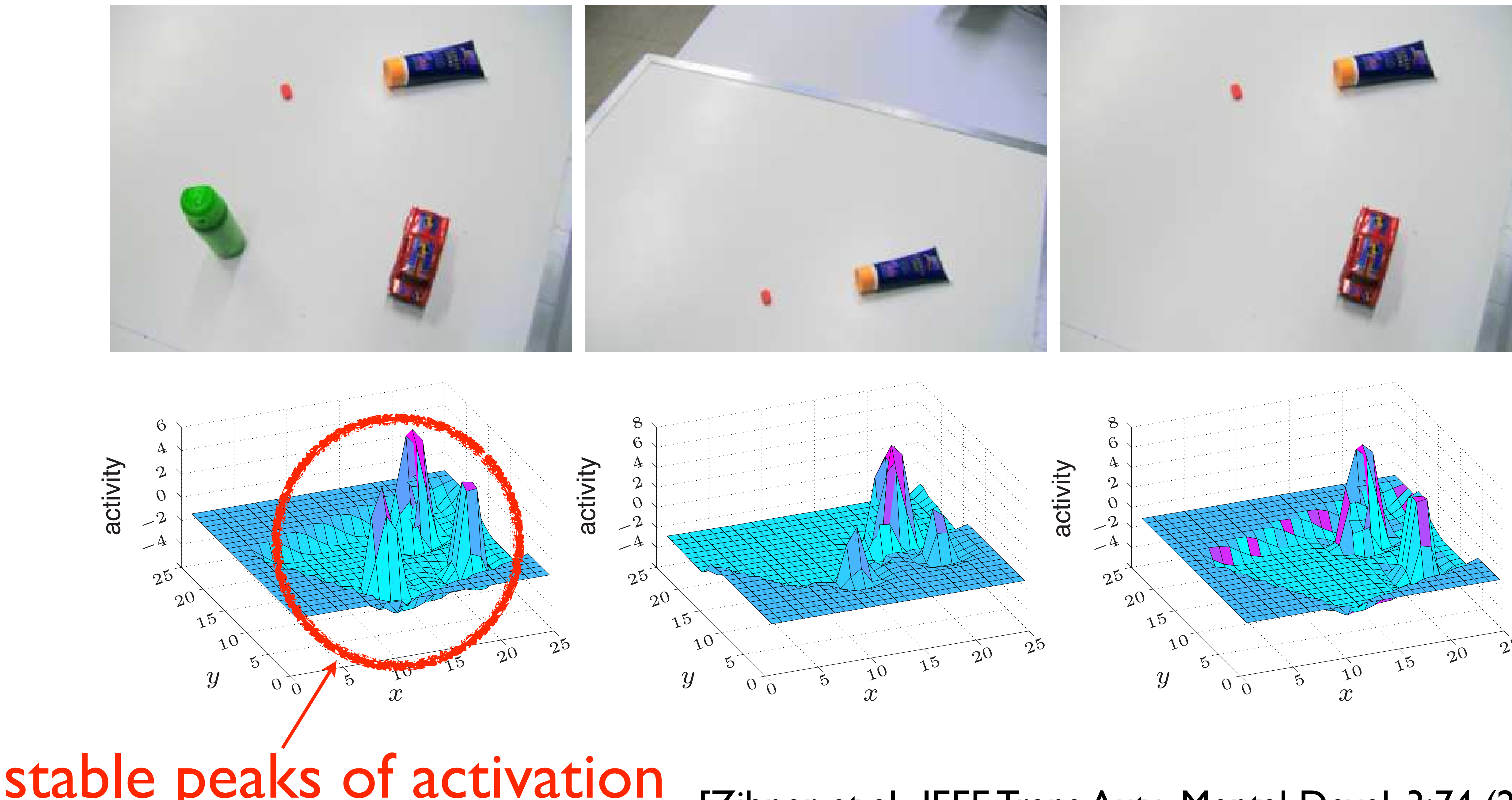
# Scene representation

- human scene perception is about space, in scene centered coordinates, but linked to gaze and body frame
- scene perception is driven from working memory and has limited capacity

[Schneegans et al., J Vision 2014]

# Theoretical concepts

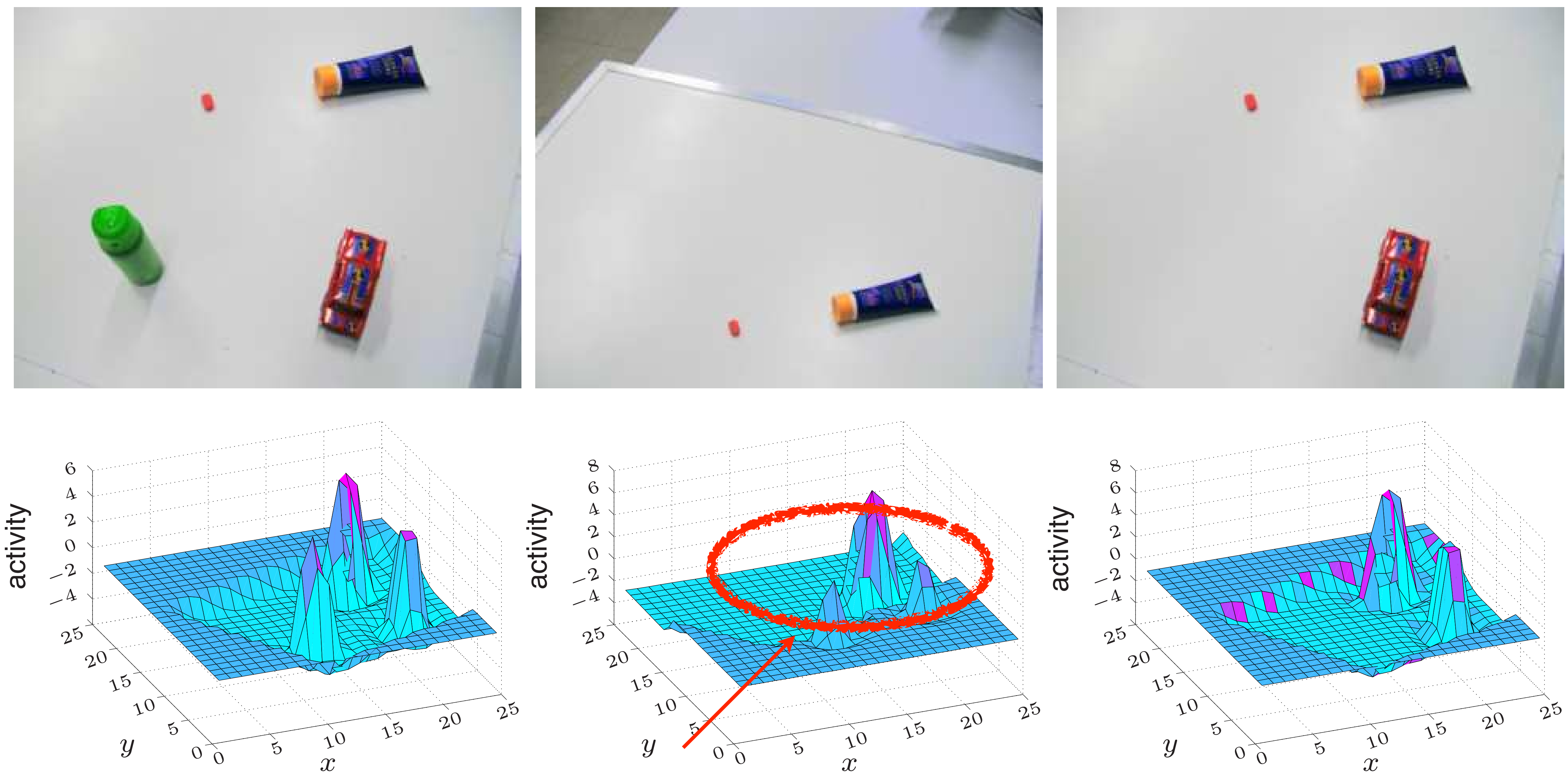
- visual scene representation is based on neural fields in visual and feature space




[Zibner et al., IEEE Trans Auto Mental Devel. 3:74 (2011)]

# Theoretical concepts

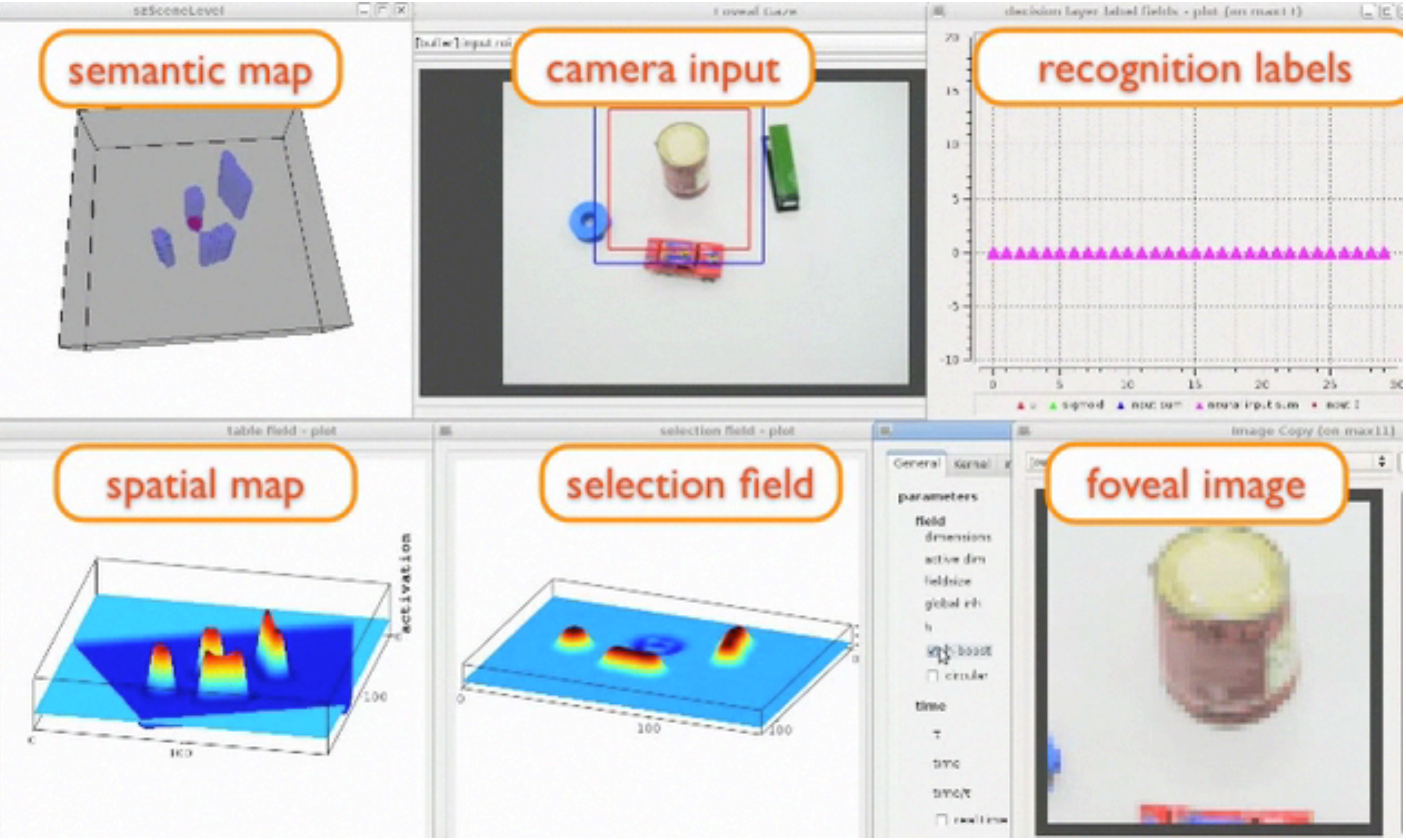
- visual scene representation is based on neural fields in visual and feature space




sustained peaks of activation: working memory

[Zibner et al., IEEE Trans Auto Mental Devel. 3:74 (2011)]

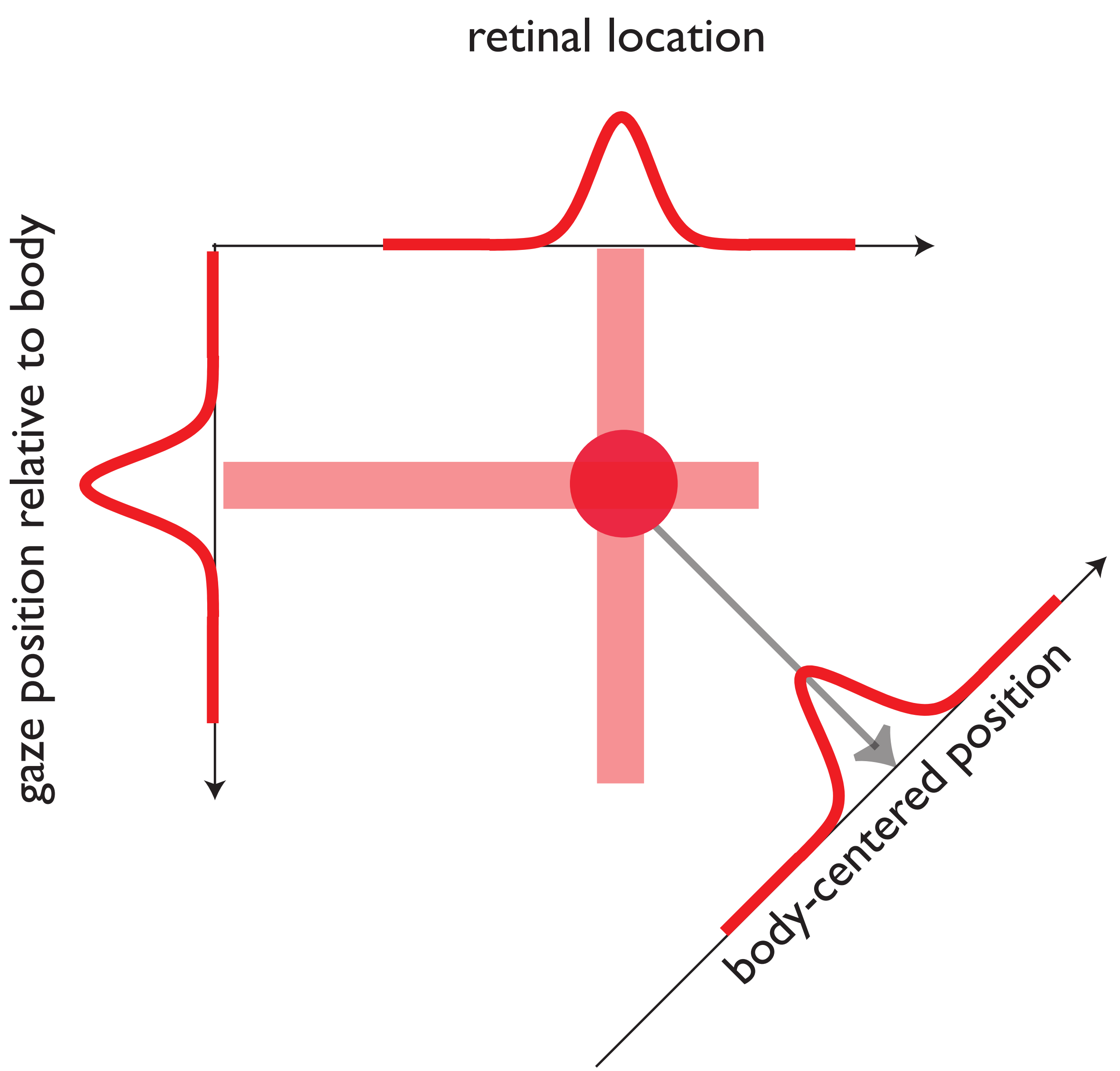
# Robotic demonstration

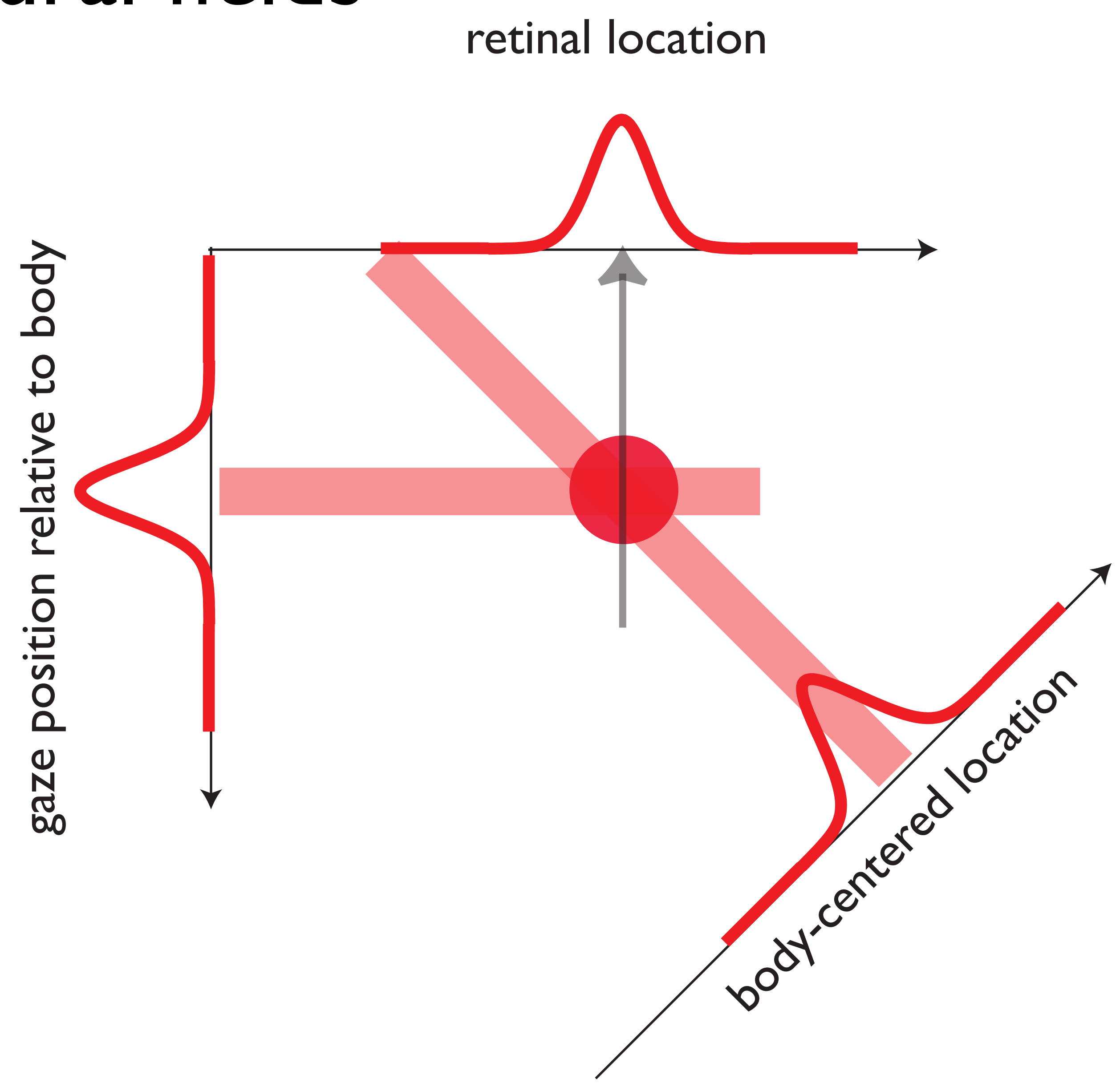



[Zibner, Faubel, ICDL 2011]

# Coordinate transformations

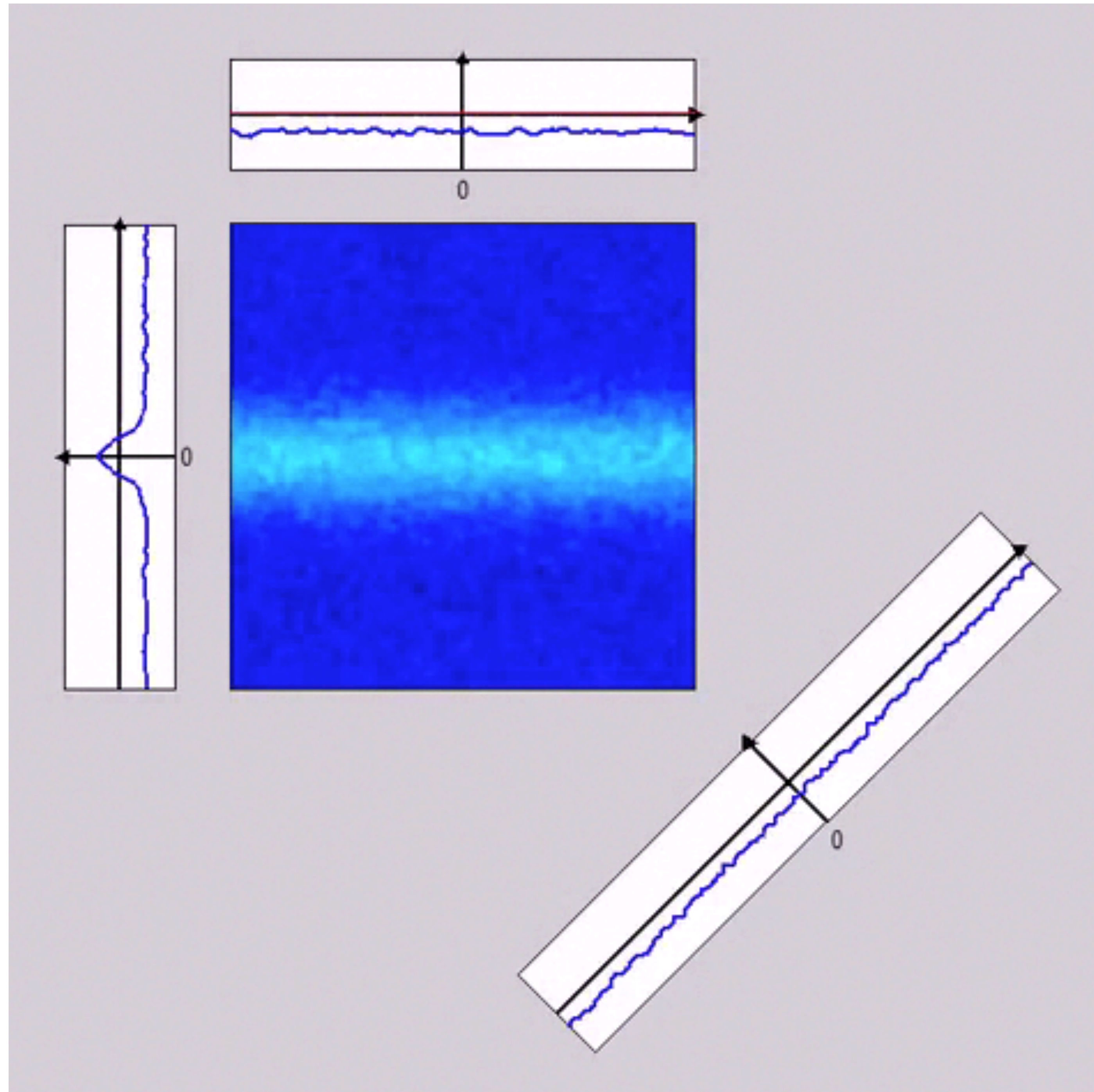
- are critical to make scenes representations useful for movement
- emerge from dynamic neural fields



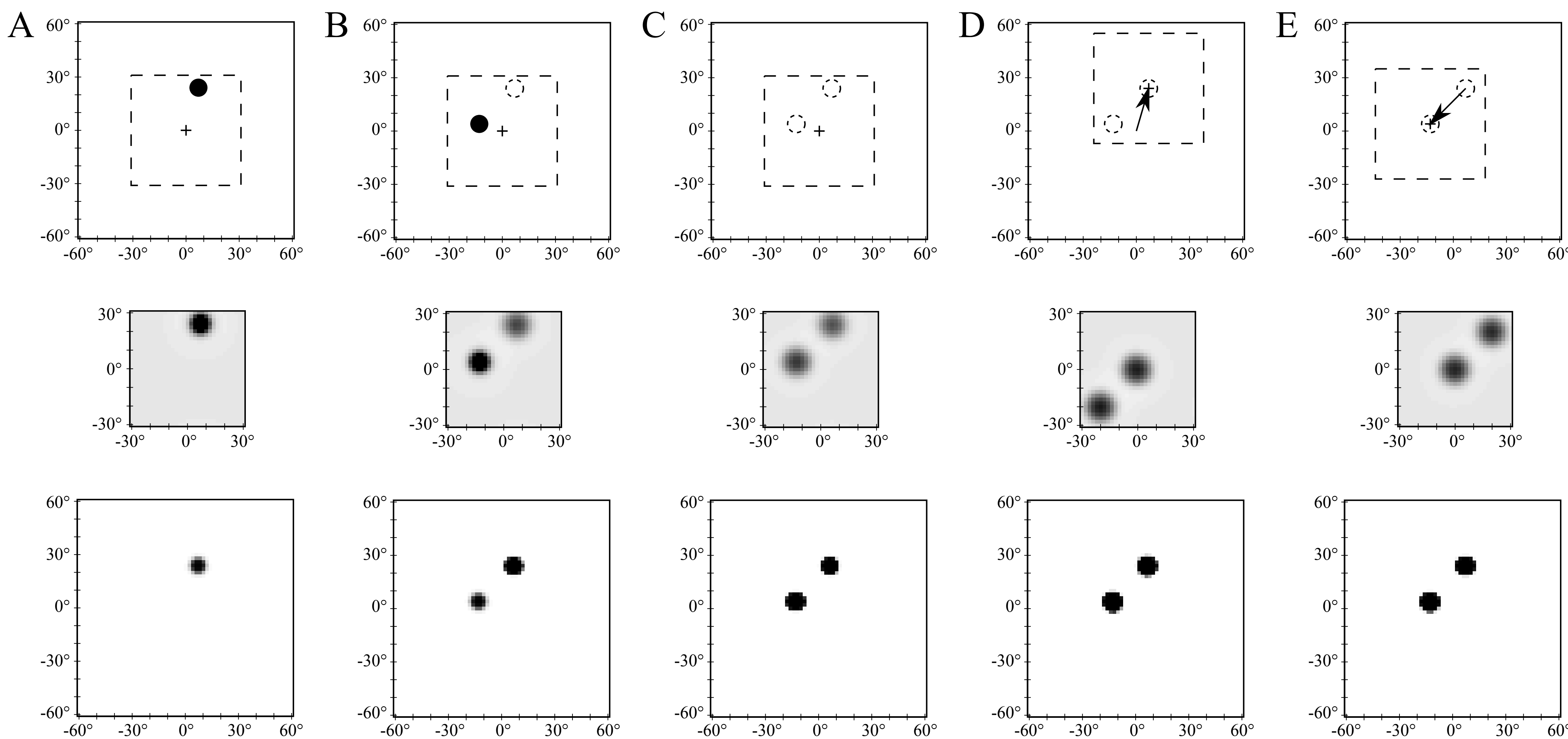
# Coordinate transformations

- example: predict retinal location following gaze shift




[Schneegans, Schöner, Biol Cybern 2012]

# DFT account for how to keep track of visual targets across saccades



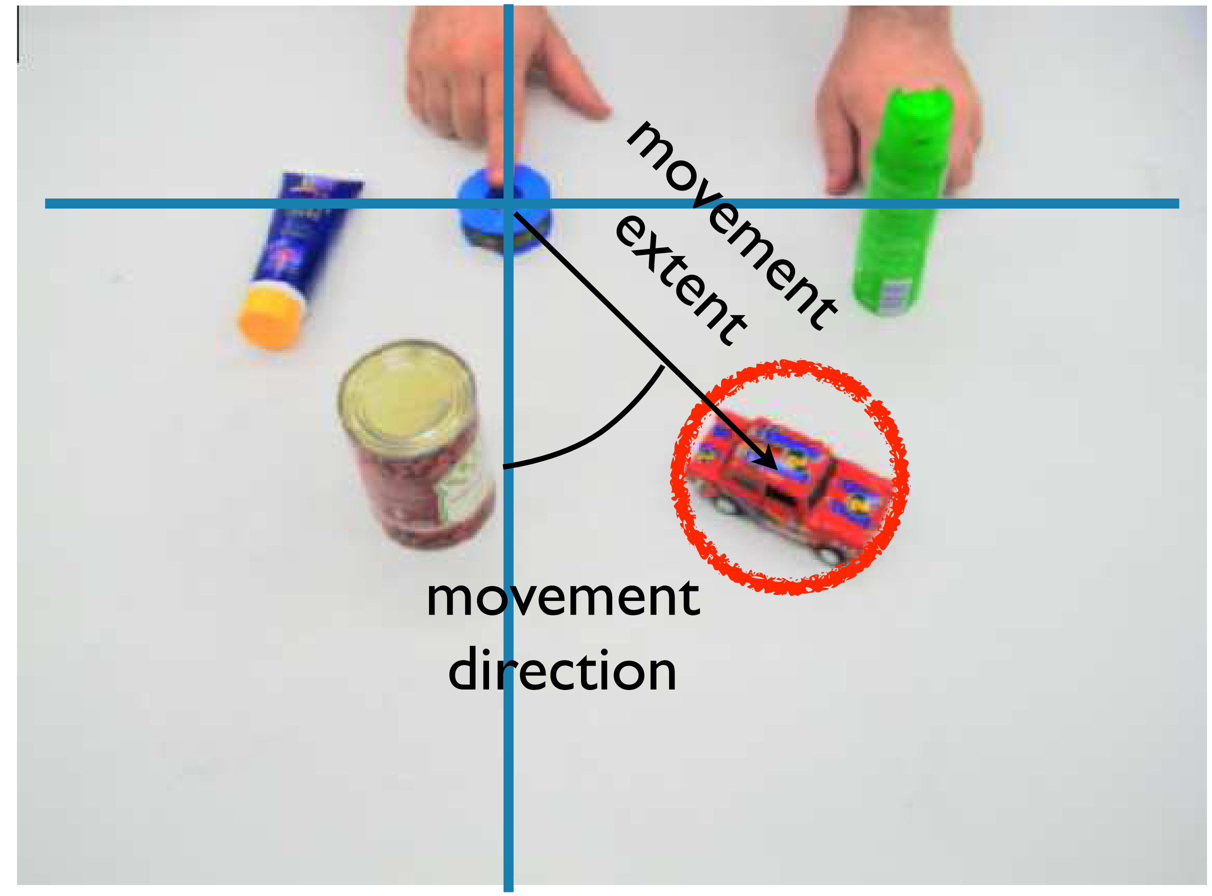

[Schneegans, Schöner, Biol Cybern 2012]

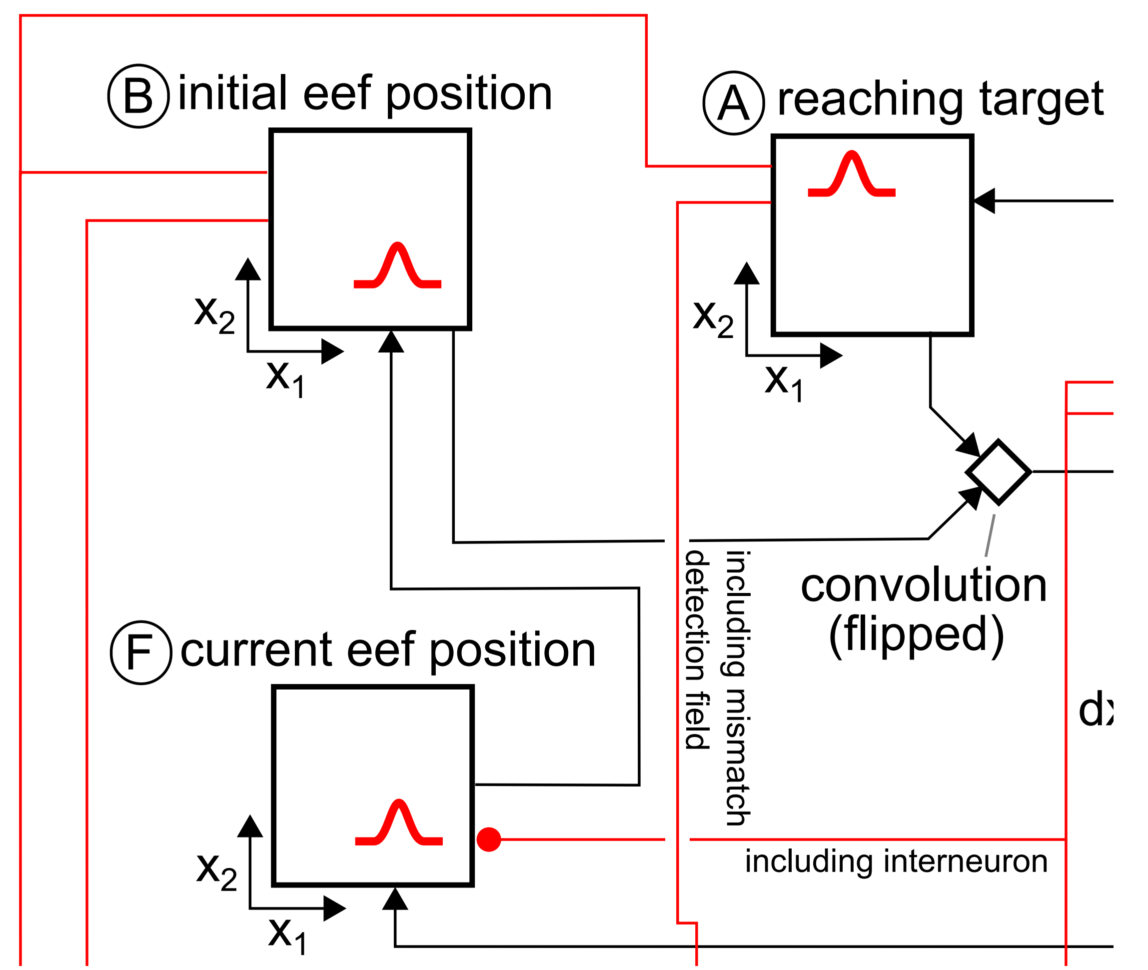
# Lessons

- neural representation of visual space with attentional selection and on-line updating provides information about movement targets
- coordinate transforms enable invariance across fixations

# Robotic demonstration

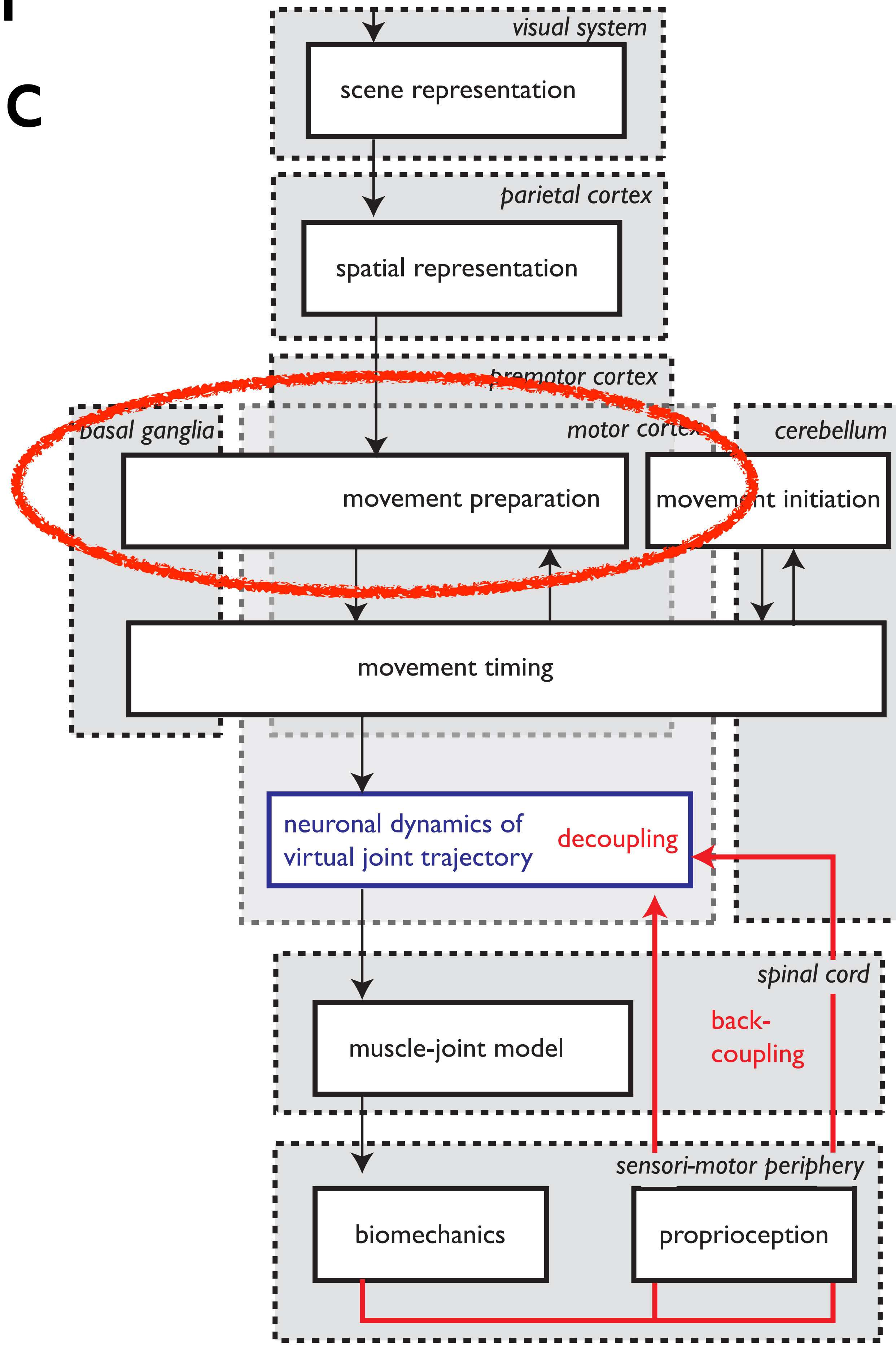
- hypothesis: movement parameters result from the visual representation of a reaching target, transformed into a frame that is centered on the initial position of the hand
- which is updated intermittently




[Zibner, Tekülve, Schöner, ICDL 2015]

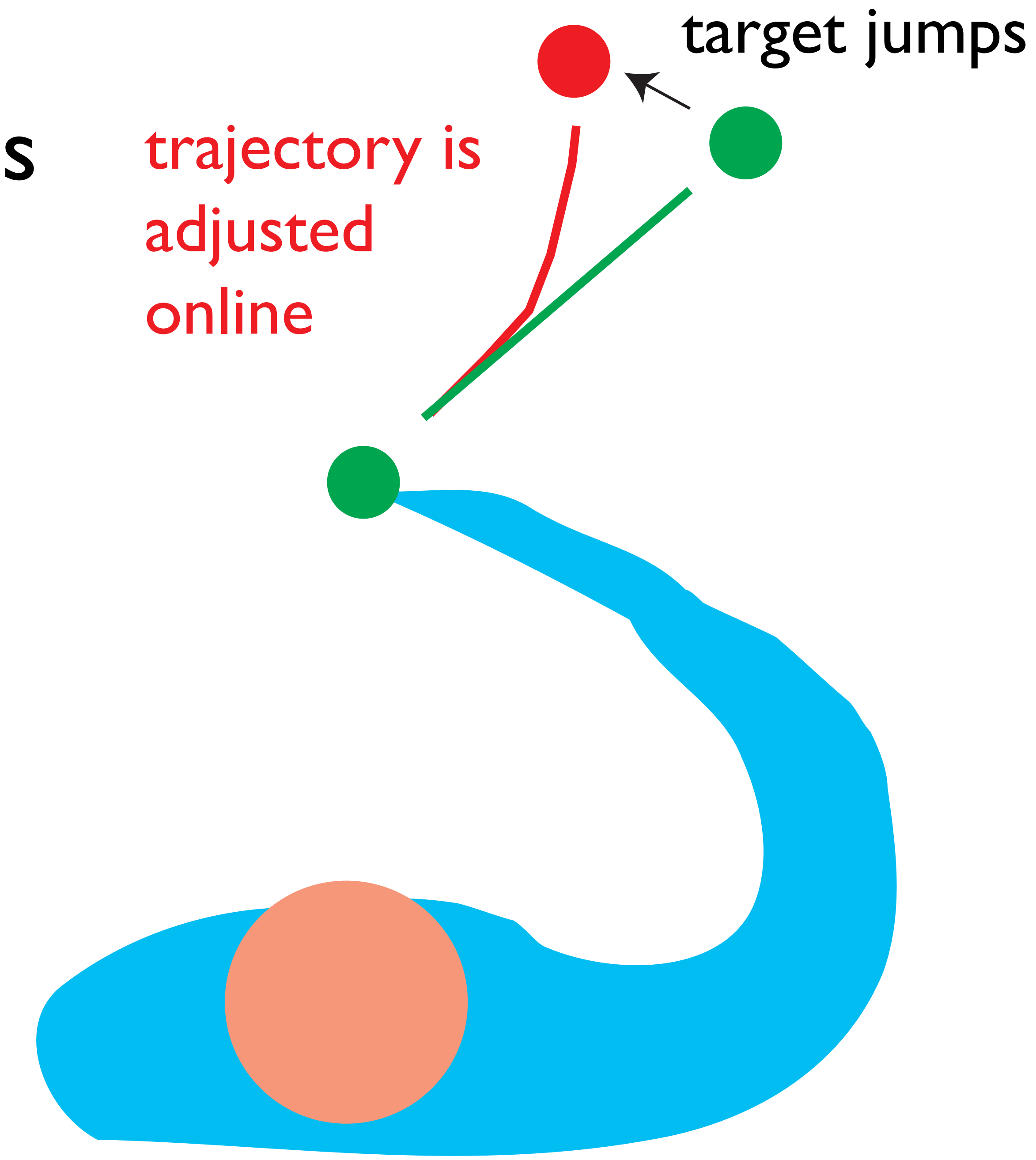
# 2) Movement planning in spatial terms as a dynamic process




[Martin, Scholz, Schöner. *Neural Computation* 21, 1371–1414 (2009)]

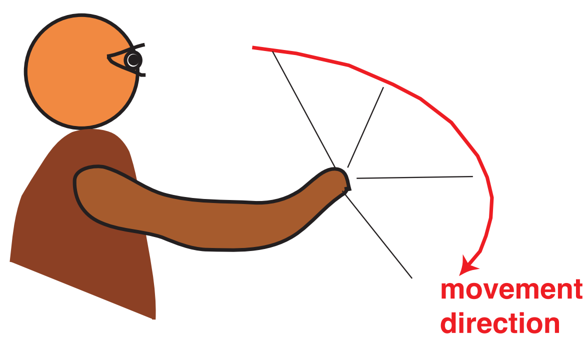
# Movement preparation

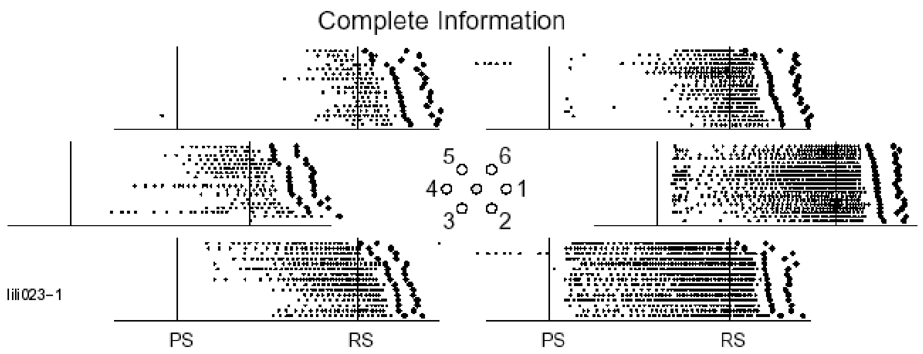
- movement is planned before it is initiated
- movement plans are about the hand's movement in space
- movement plans evolve continuously in time



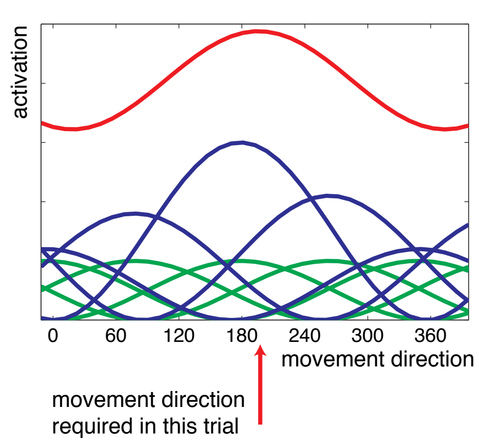

[Erlhagen, Schöner, Psych Rev 2002]

# Neural basis of movement preparation

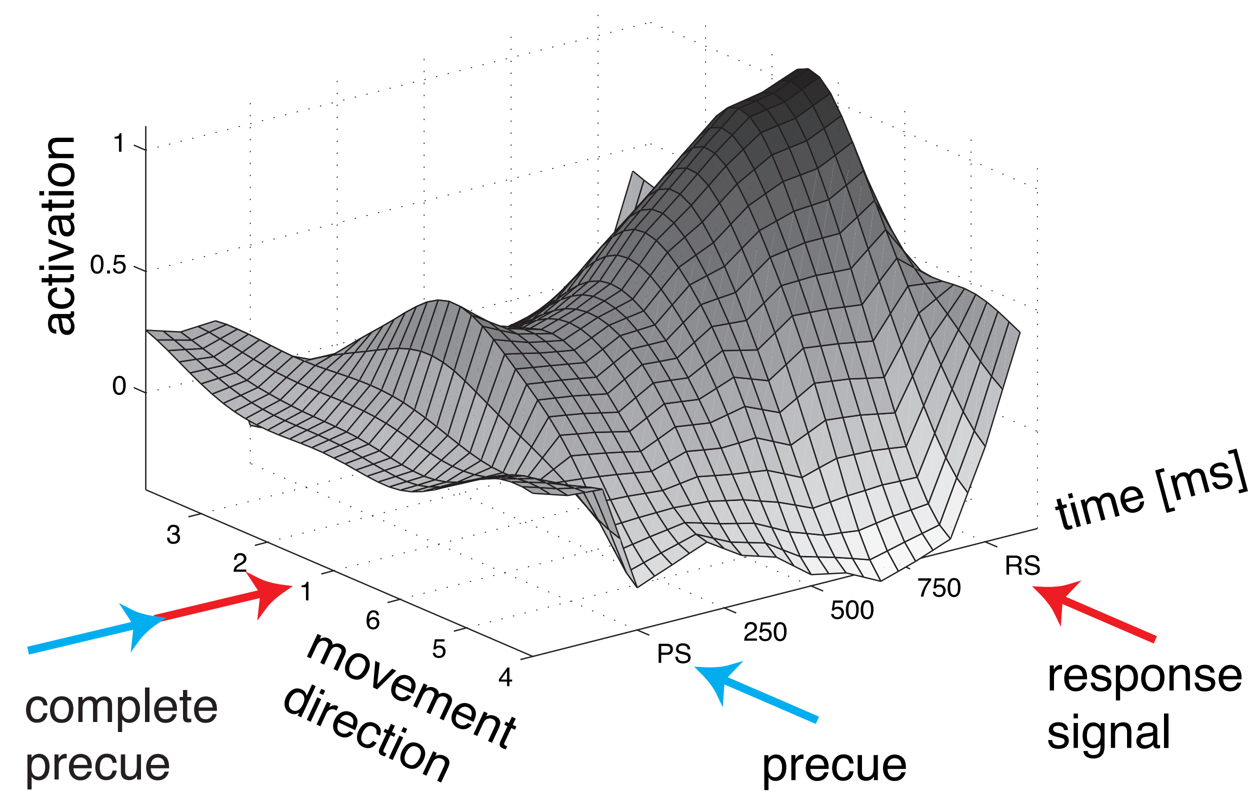



Distribution of population activation =
$\sum_{\text{neurons}}$ tuning curve * current firing rate



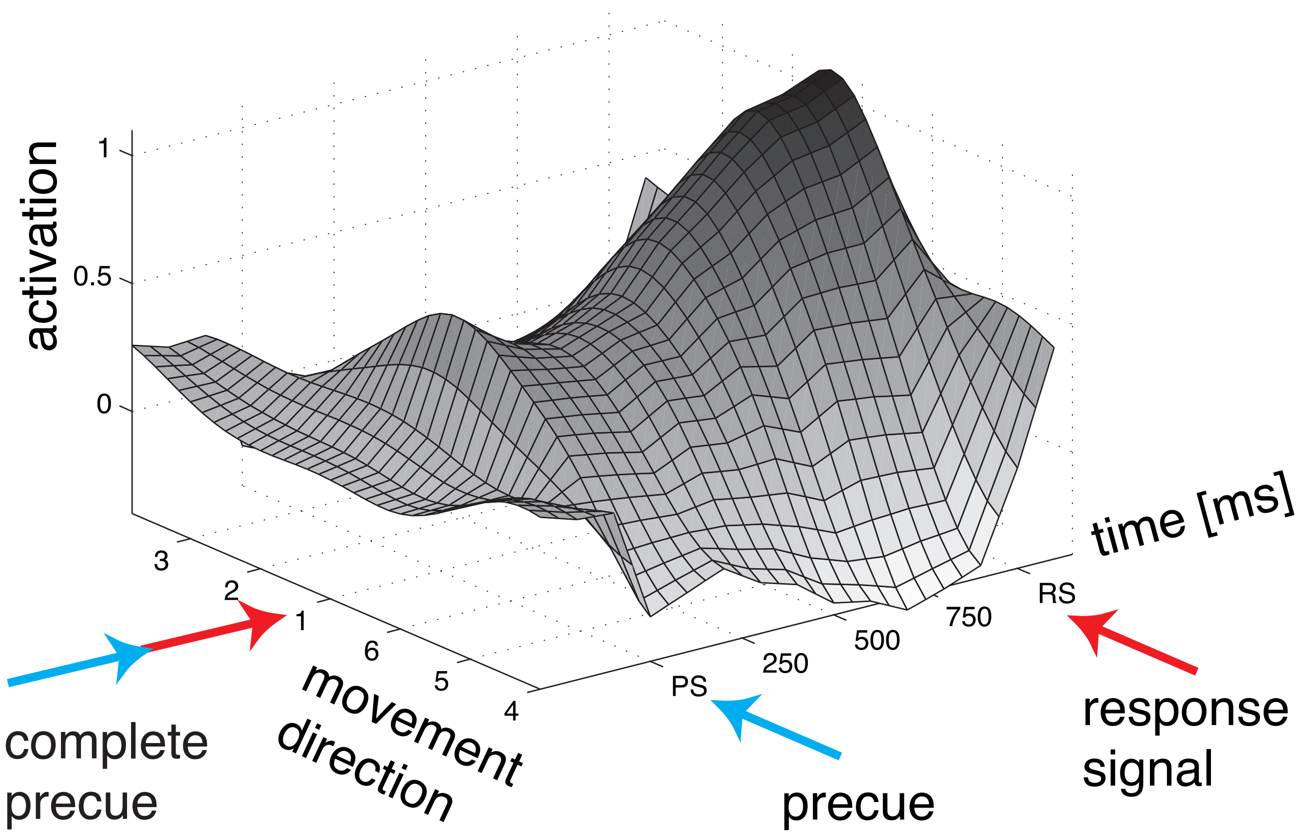

[after Bastian, Riehle, Schöner, submitted]



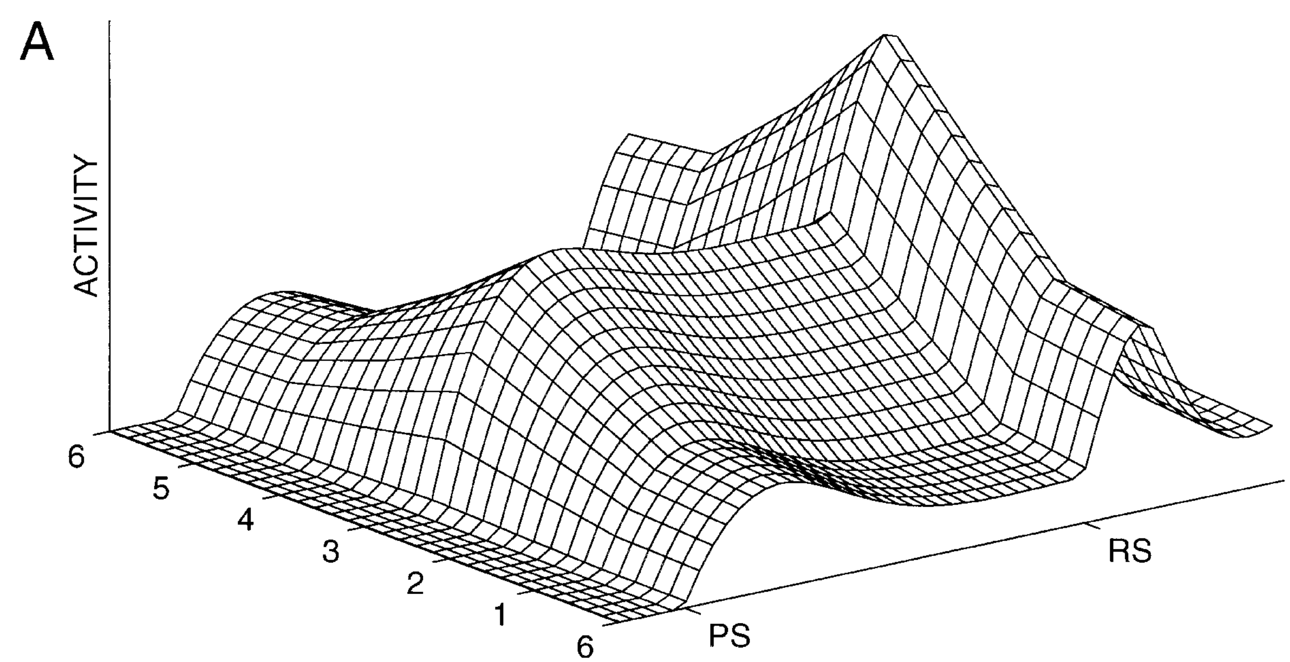

Bastian, Riehle, Schöner, European Journal of Neuroscience, Vol. 18, 2047-2058 (2003)

# Theoretical concept: dynamic fields

experiment




theory

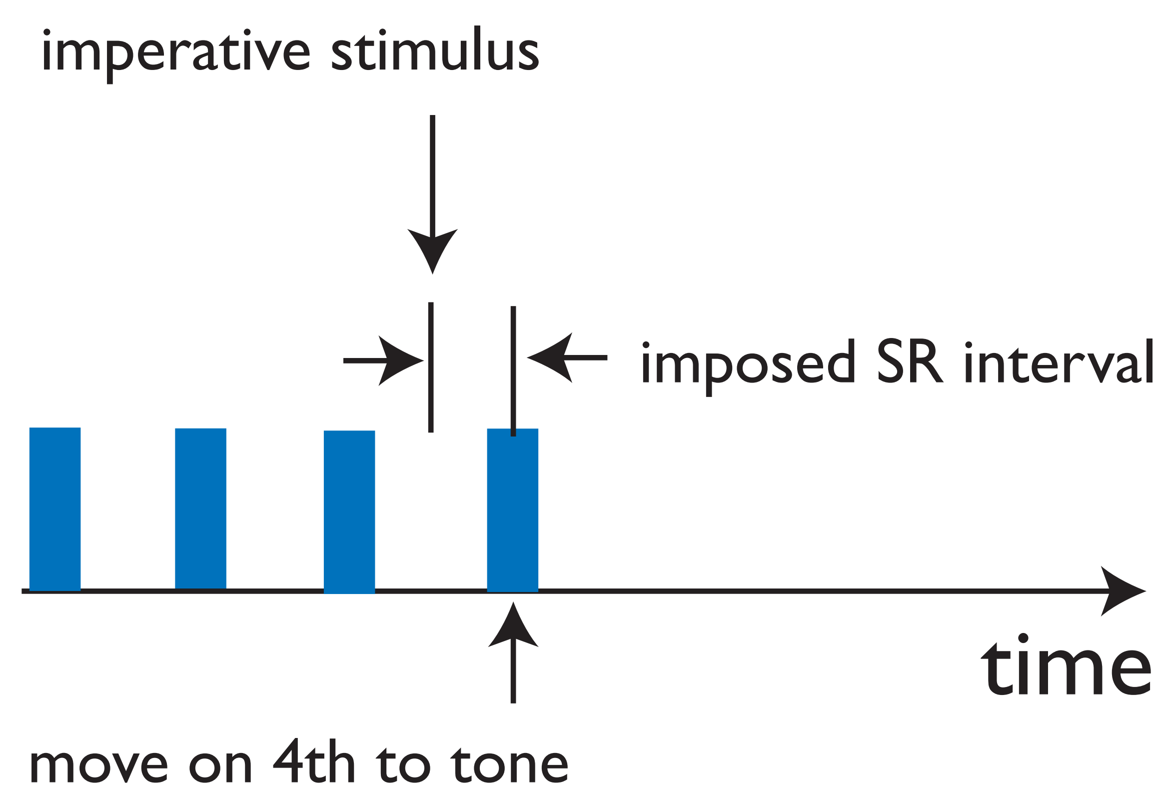



[Bastian, Riehle, Erlhagen Schöner, Neuroreports 9:315 (1998)]

# Movement plans evolve continuously in time

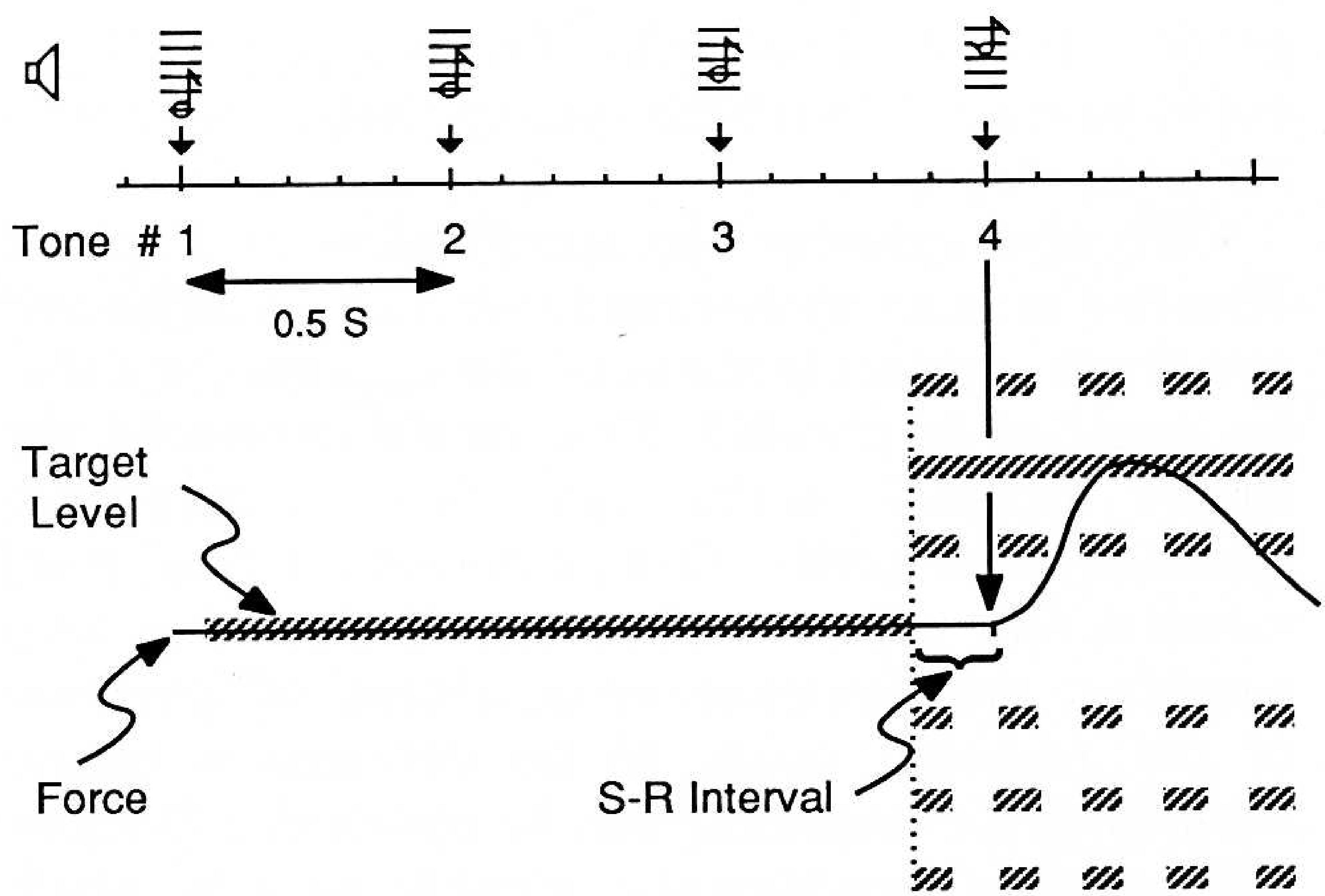
- movement preparation is graded and continuous in time starting out from preshaped representations

timed movement
initiation paradigm

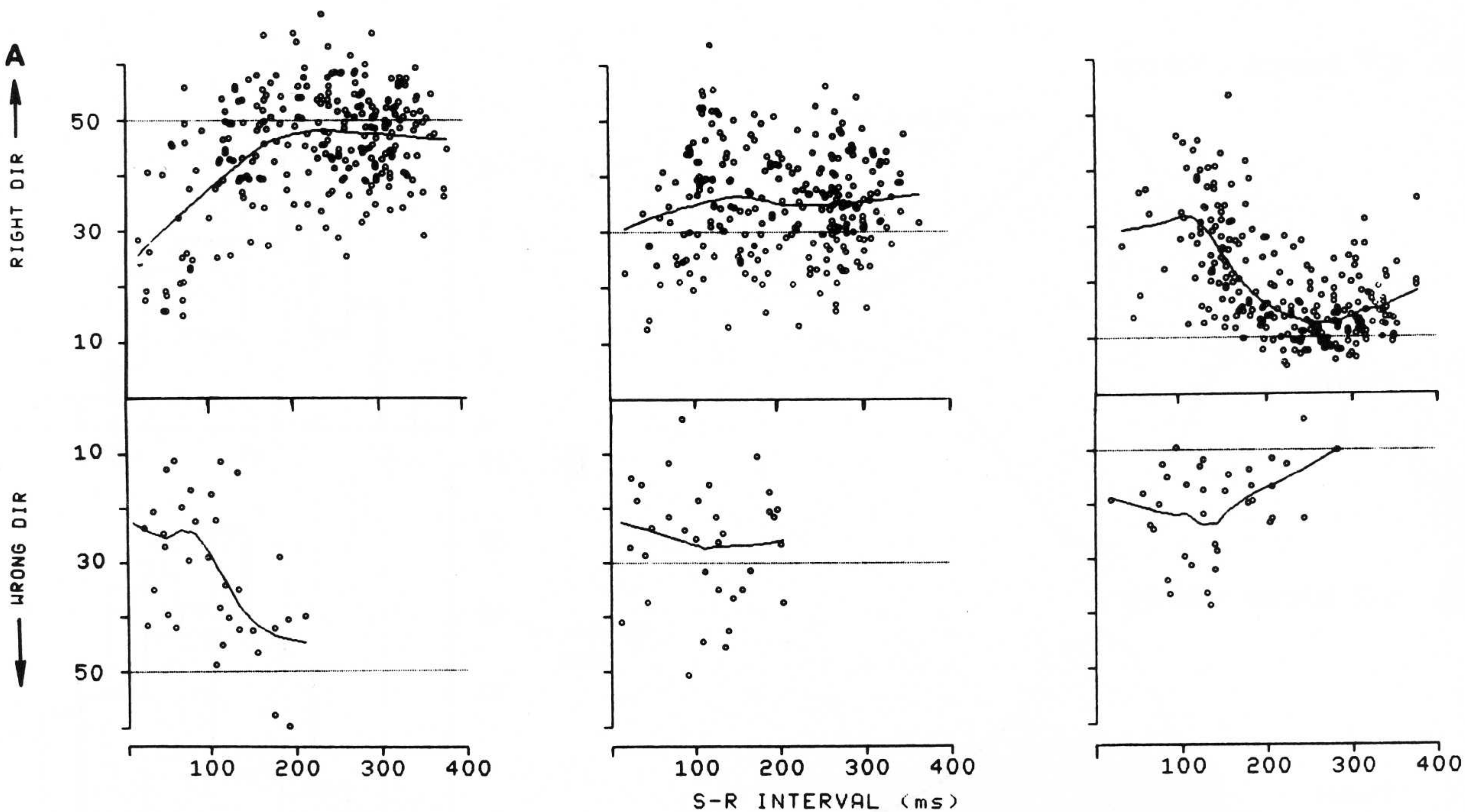



[Ghez and colleagues, 1988 to 1990’s]

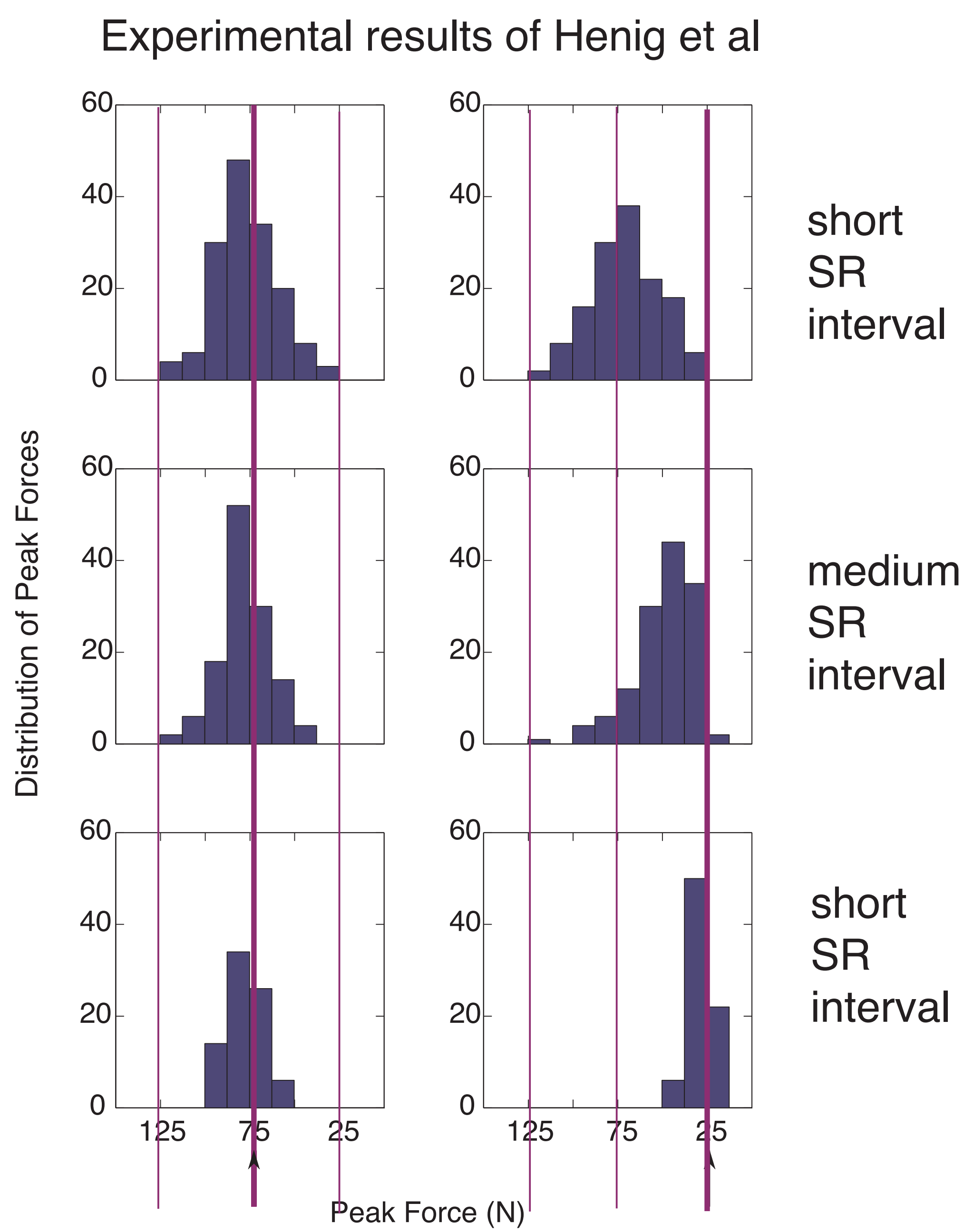
# Behavioral evidence for preshape




[Favilla et al. 1989]


A
RIGHT DIR
WRONG DIR
50
30
10
10
30
50
100
200
300
400
S-R INTERVAL (ms)

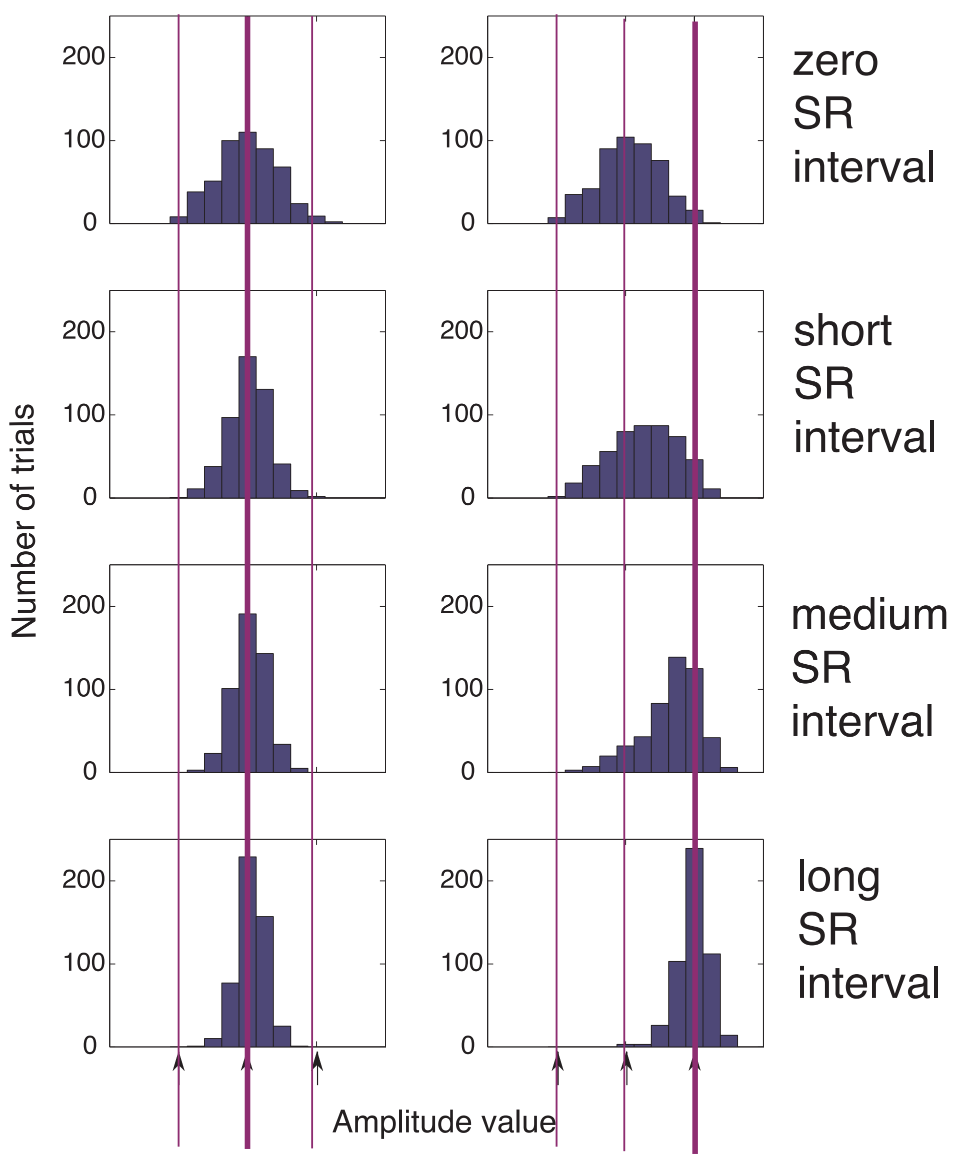
# Behavioral evidence for preshape



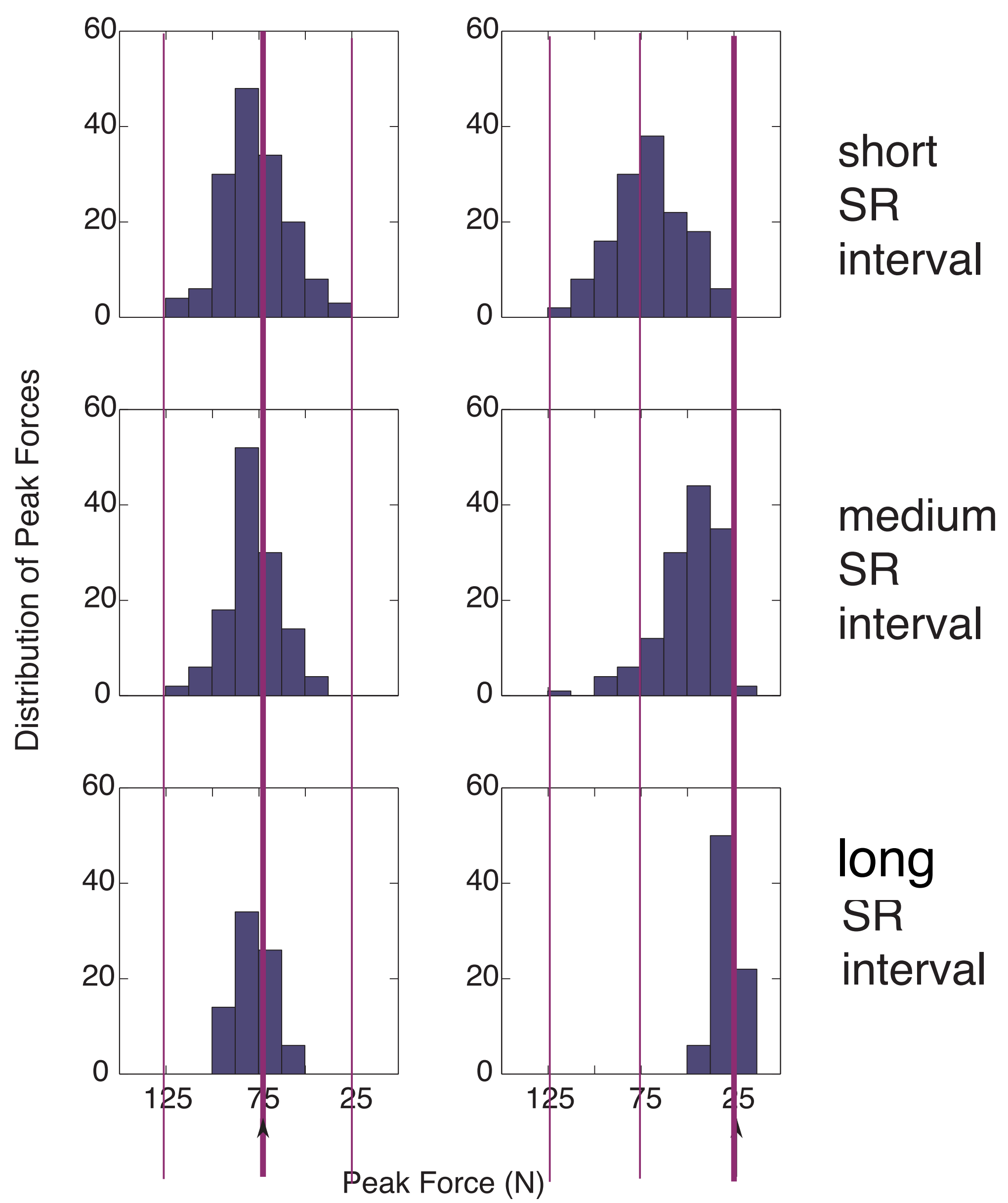
# Dynamic Field Theory (DFT)

- theoretical account: movement parameters are represented in dynamic neural activation fields

theoretical account for Henig et al.



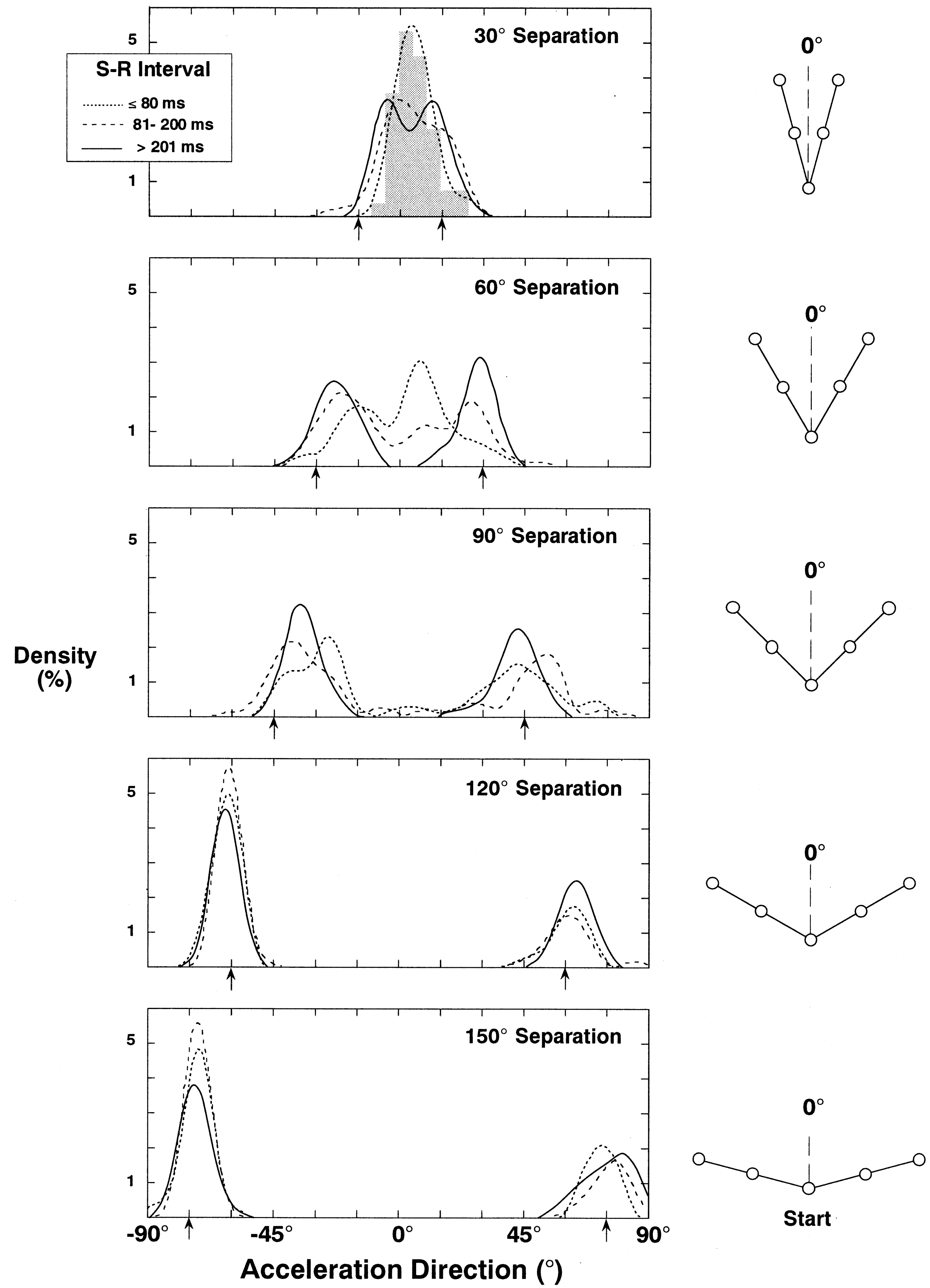

Experimental results of Henig et al




[Erlhagen, Schöner. 2002, Psychological Review 109, 545–572 (2002)]

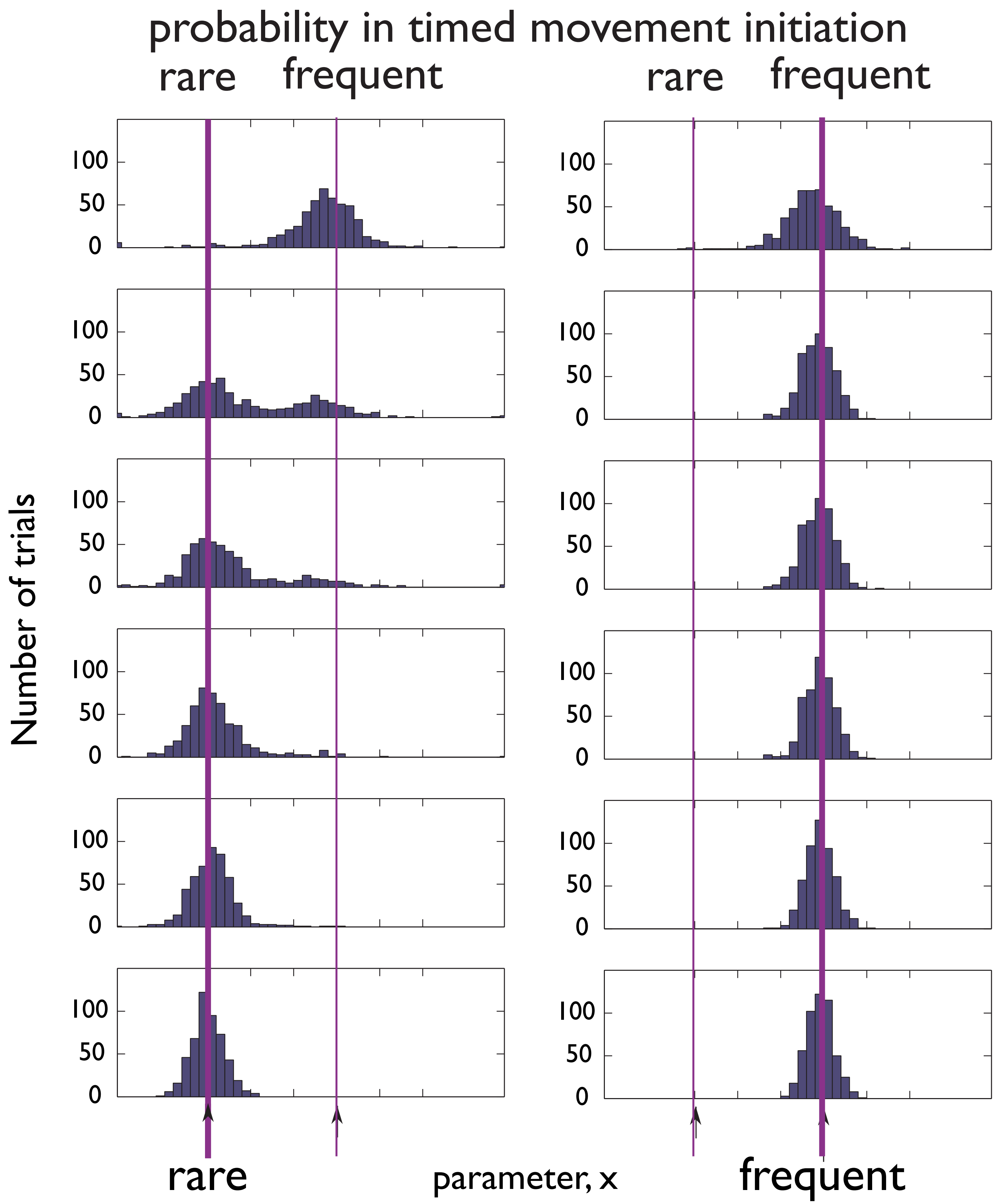
# behavioral evidence for preshape

- infer width of preshape peaks in field




[Ghez et al 1997]

# behavioral evidence for preshape

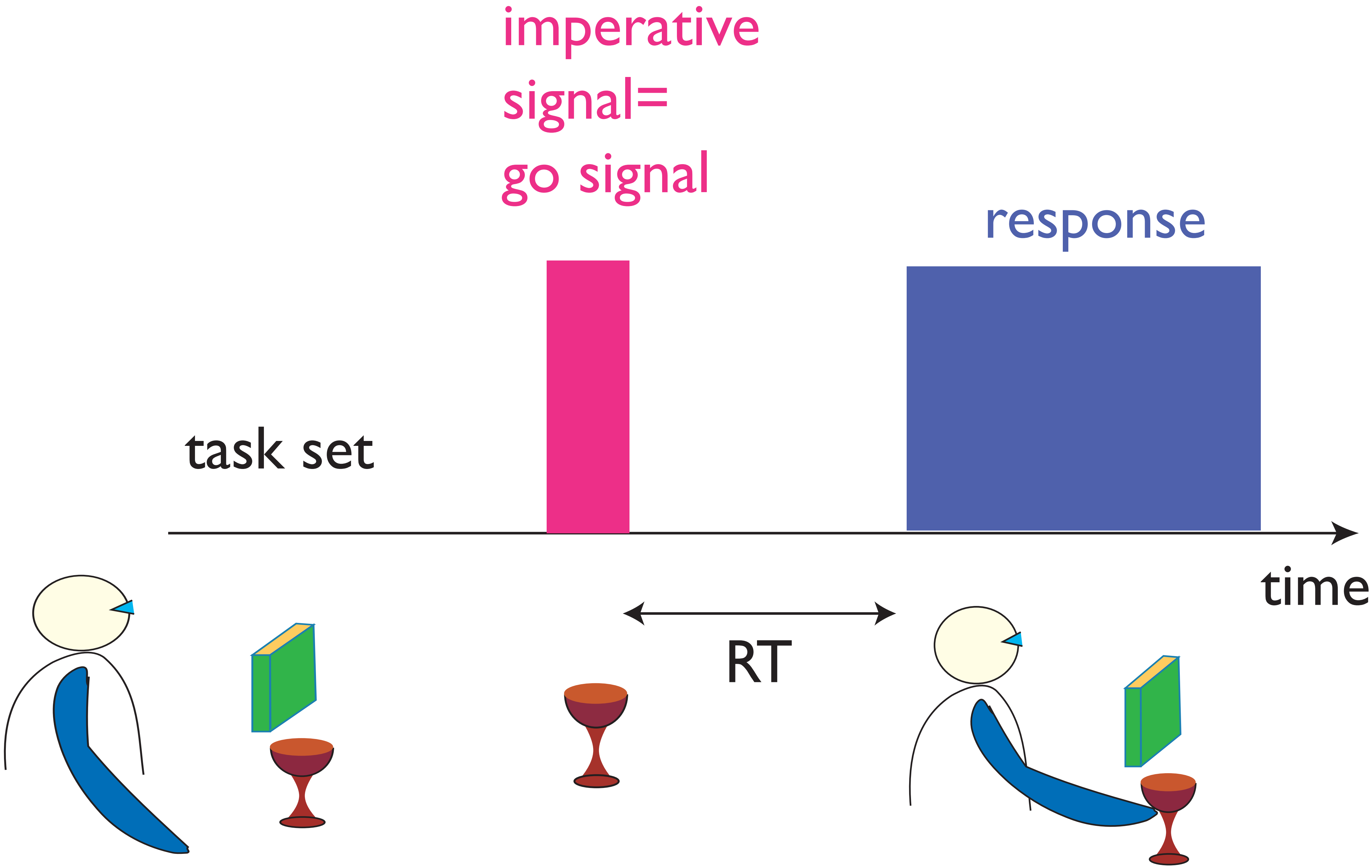


Ghez et al, 1997

short SR interval: observe preshape

long SR interval: observe stimulus-defined movement plan

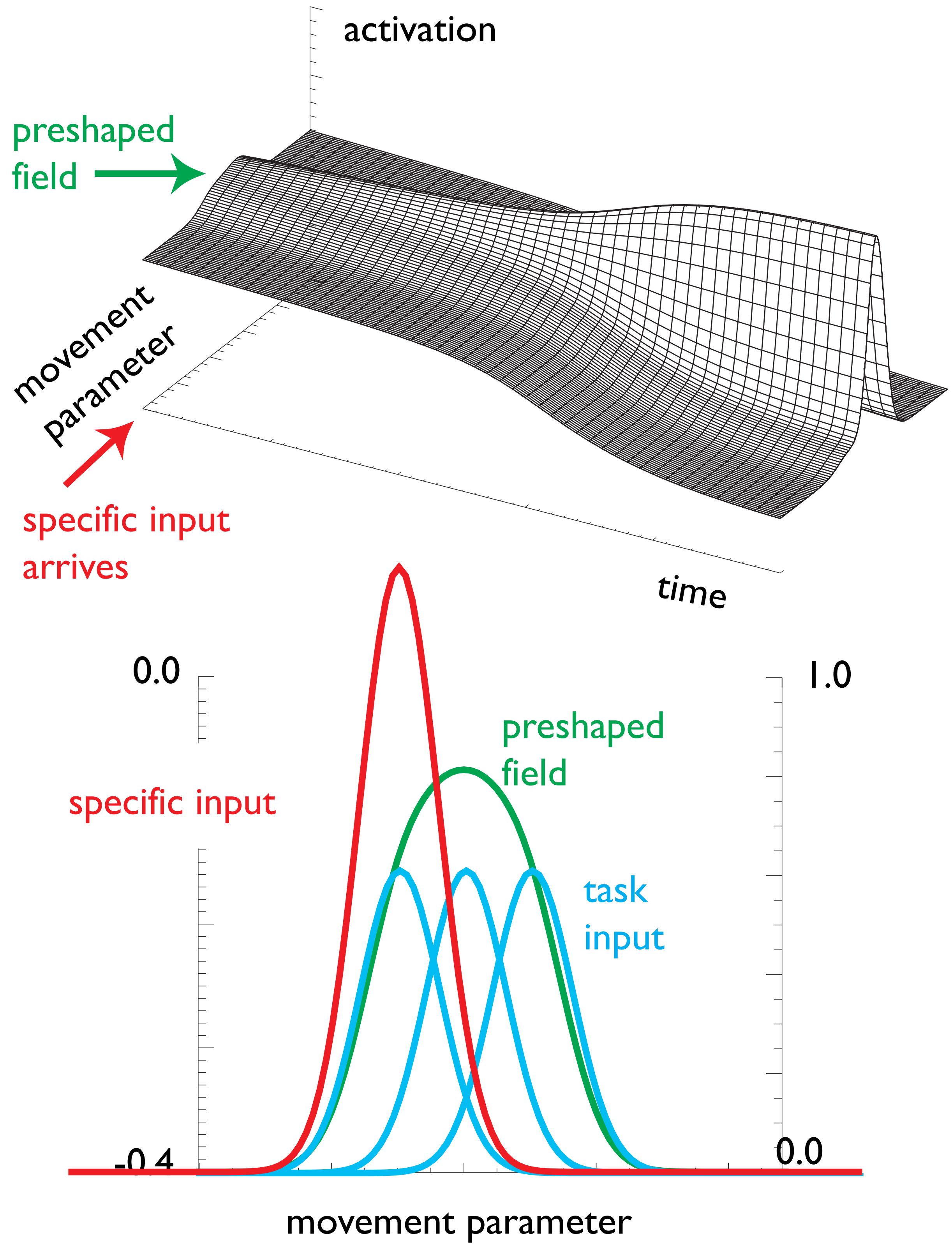
# Studying movement preparation in the reaction time (RT) paradigm



# task set

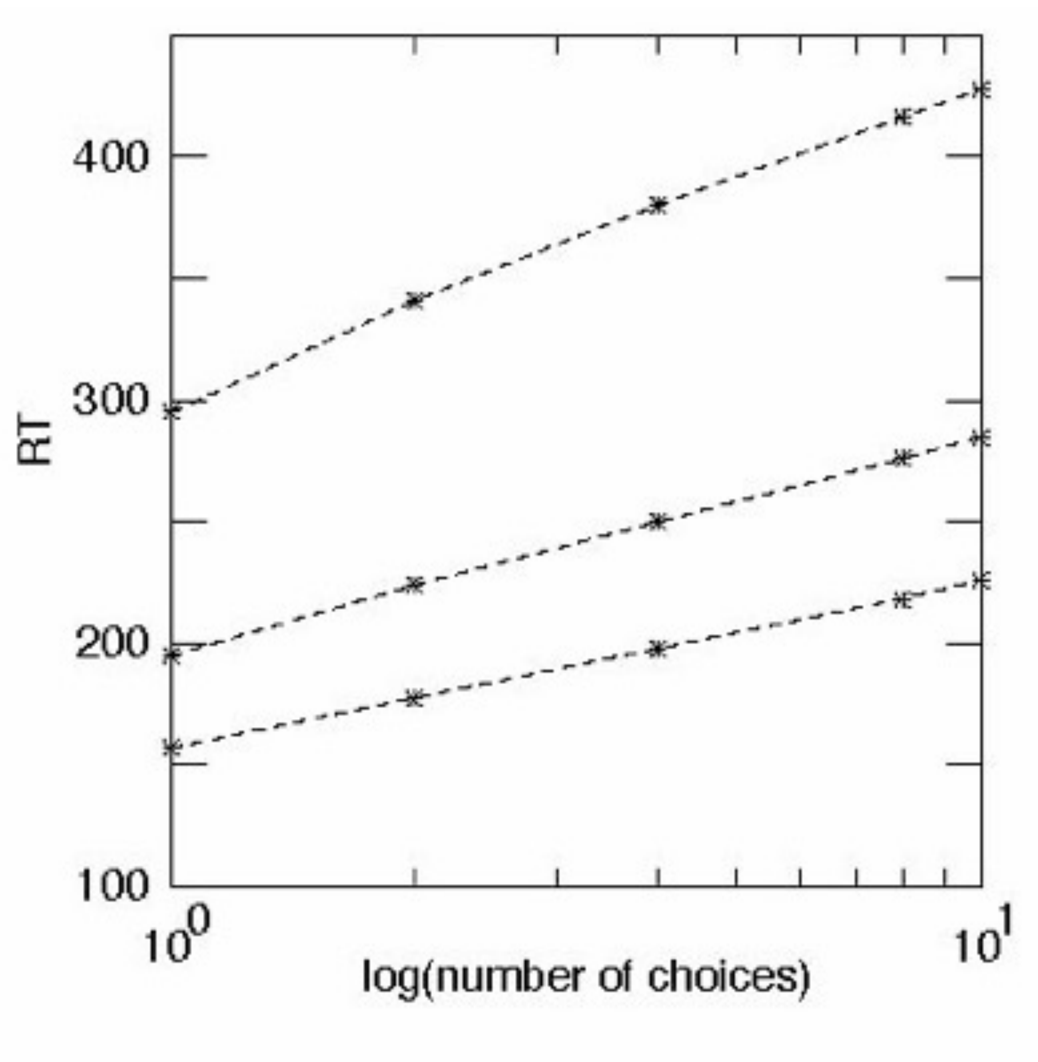
- that is the critical factor in most studies of selection!
  - for example, the classical Hick law, that the number of choices affects RT, is based on the task set specifying a number of choices
- (although the form in which the imperative signal is given is varied as well... )
- how do neuronal representations reflect the task set?

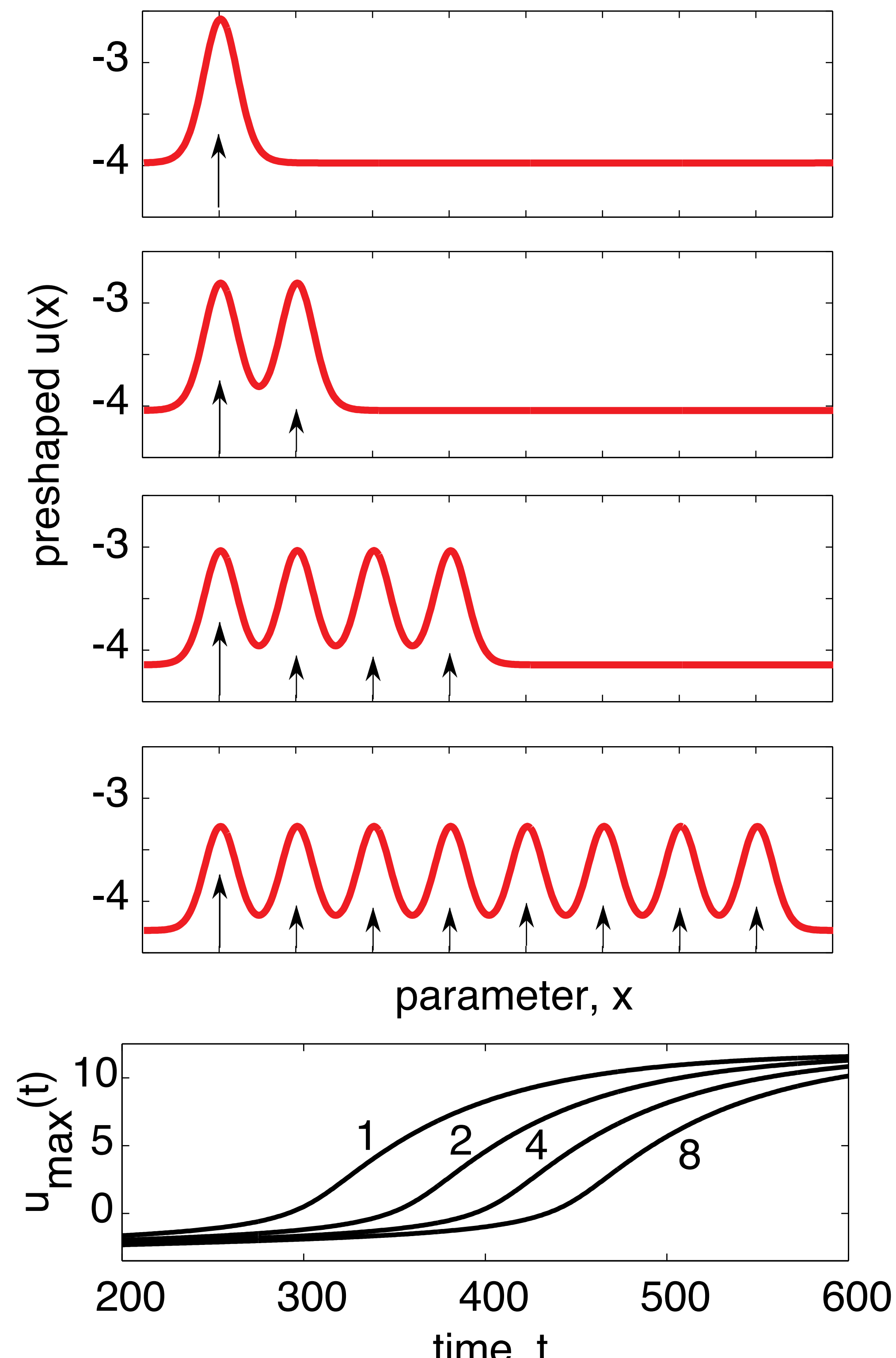
# notion of preshape



# using preshape to account for classical RT data

- Hick's law: RT increases with the number of choices

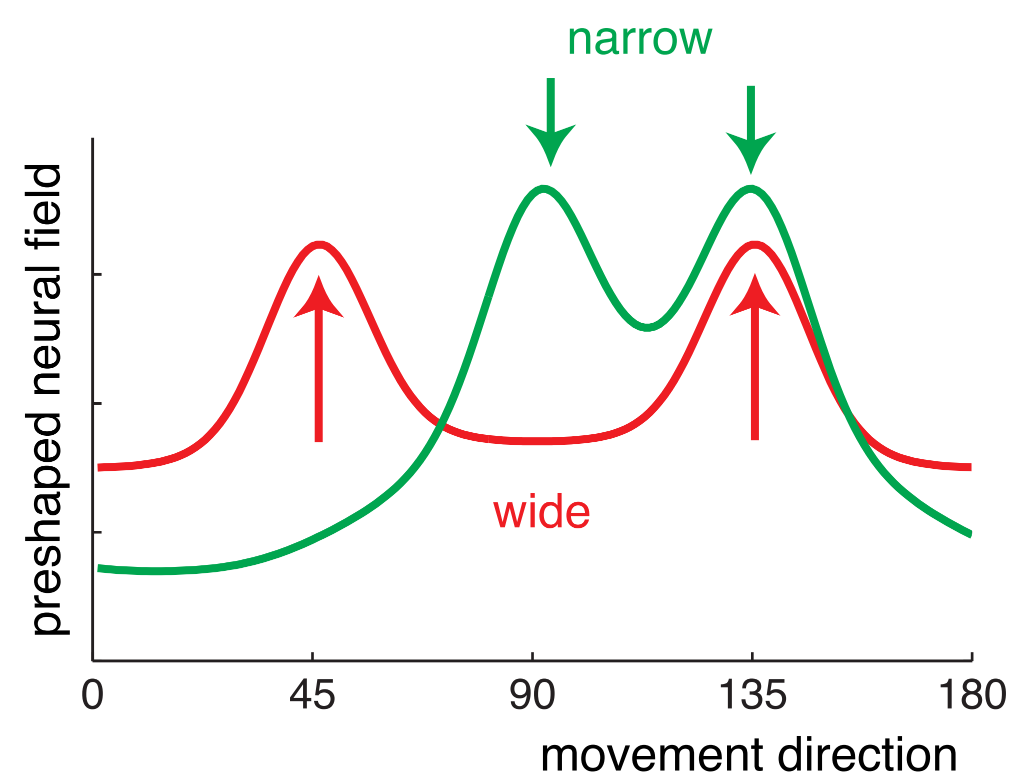


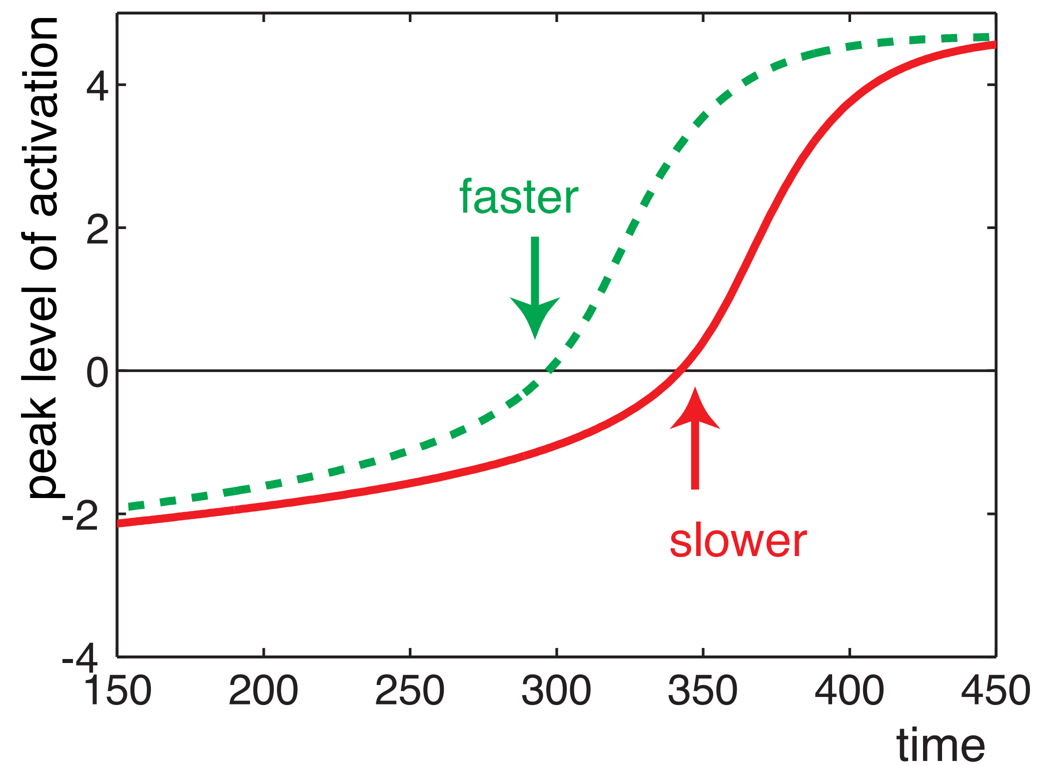




[Erlhagen, Schöner, Psych Rev 2002]

# metric effect

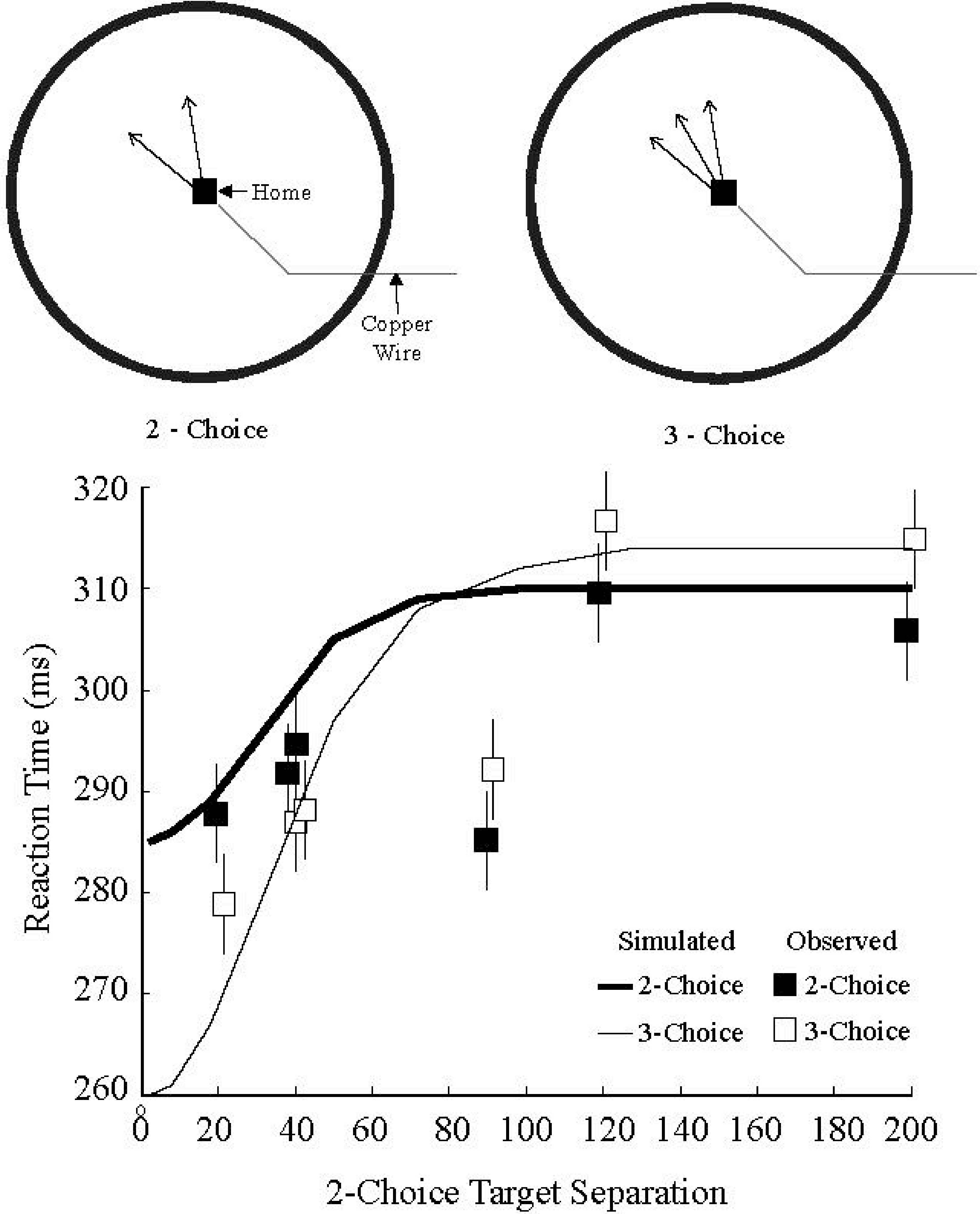
- predict faster response times for metrically close than for metrically far choices



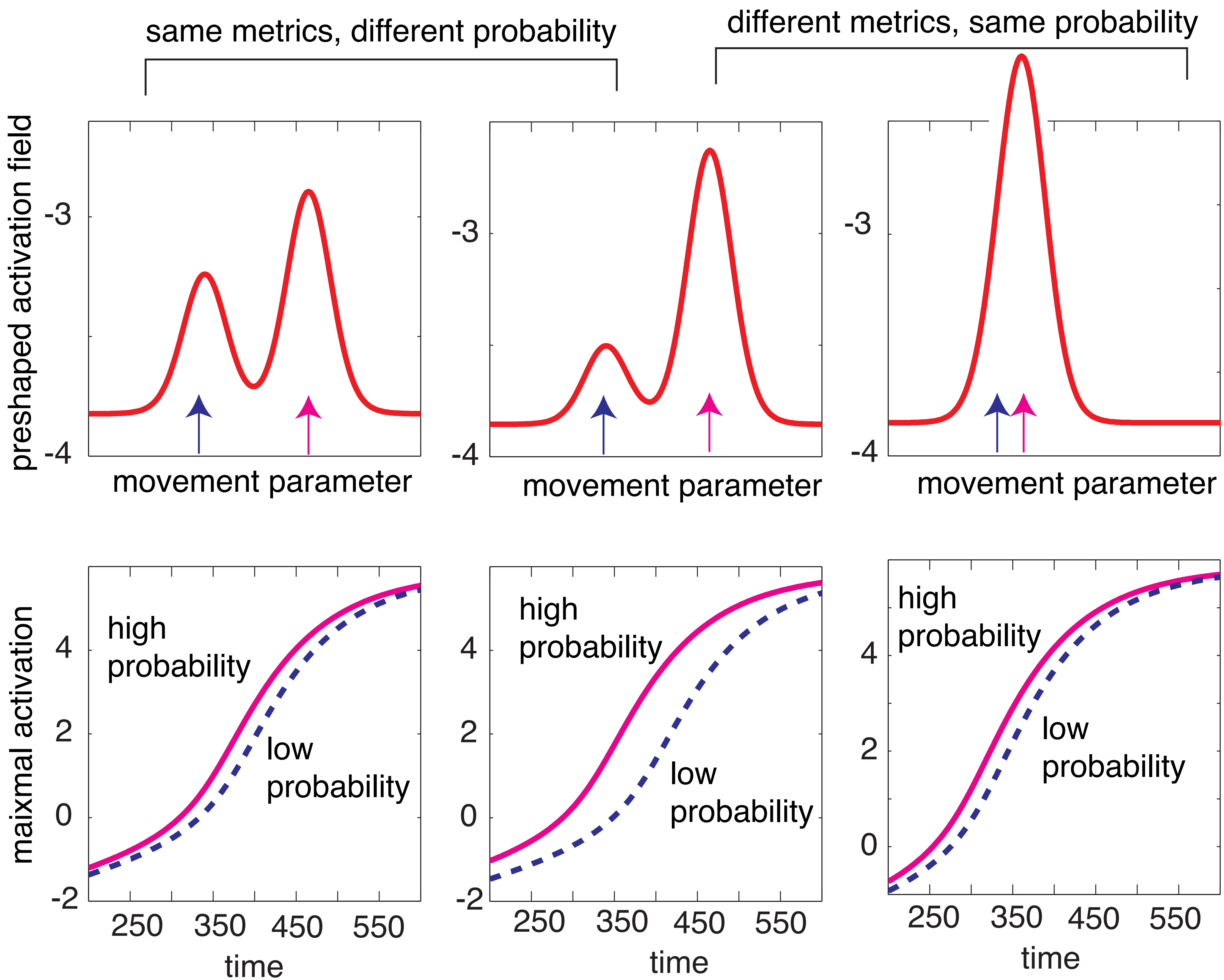




[from Schöner, Kopecz, Erlhagen, 1997]

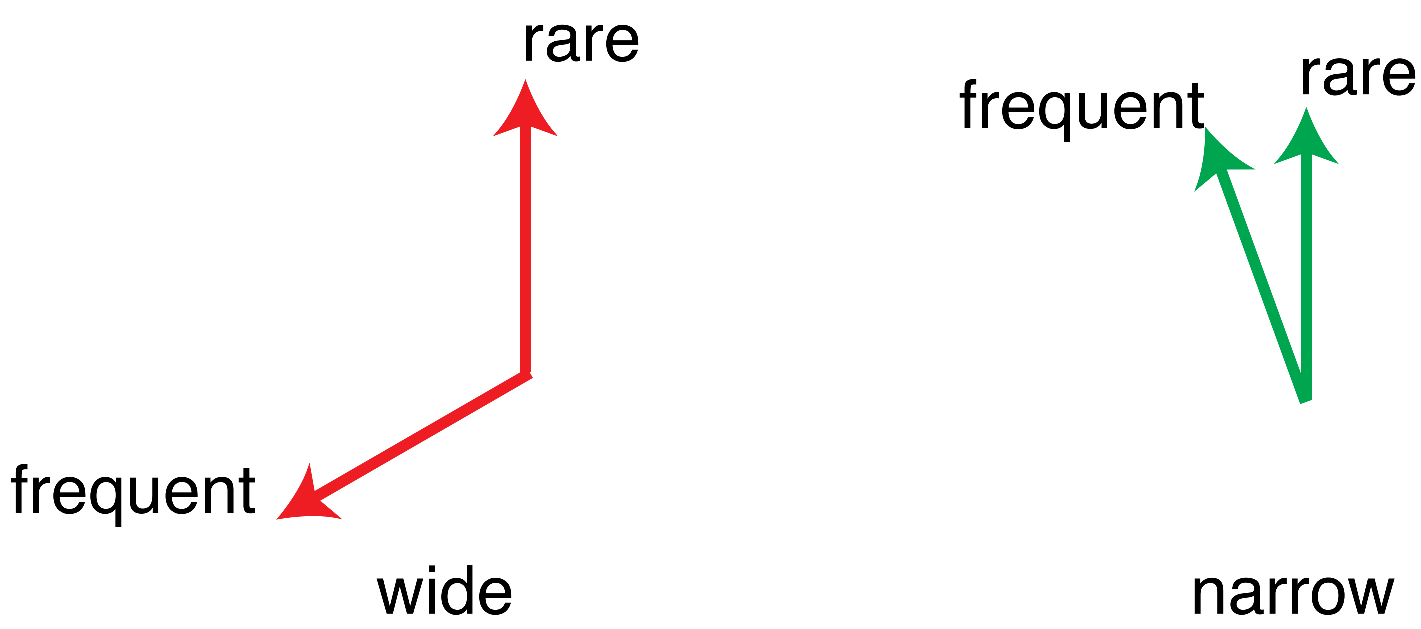
# experiment: metric effect

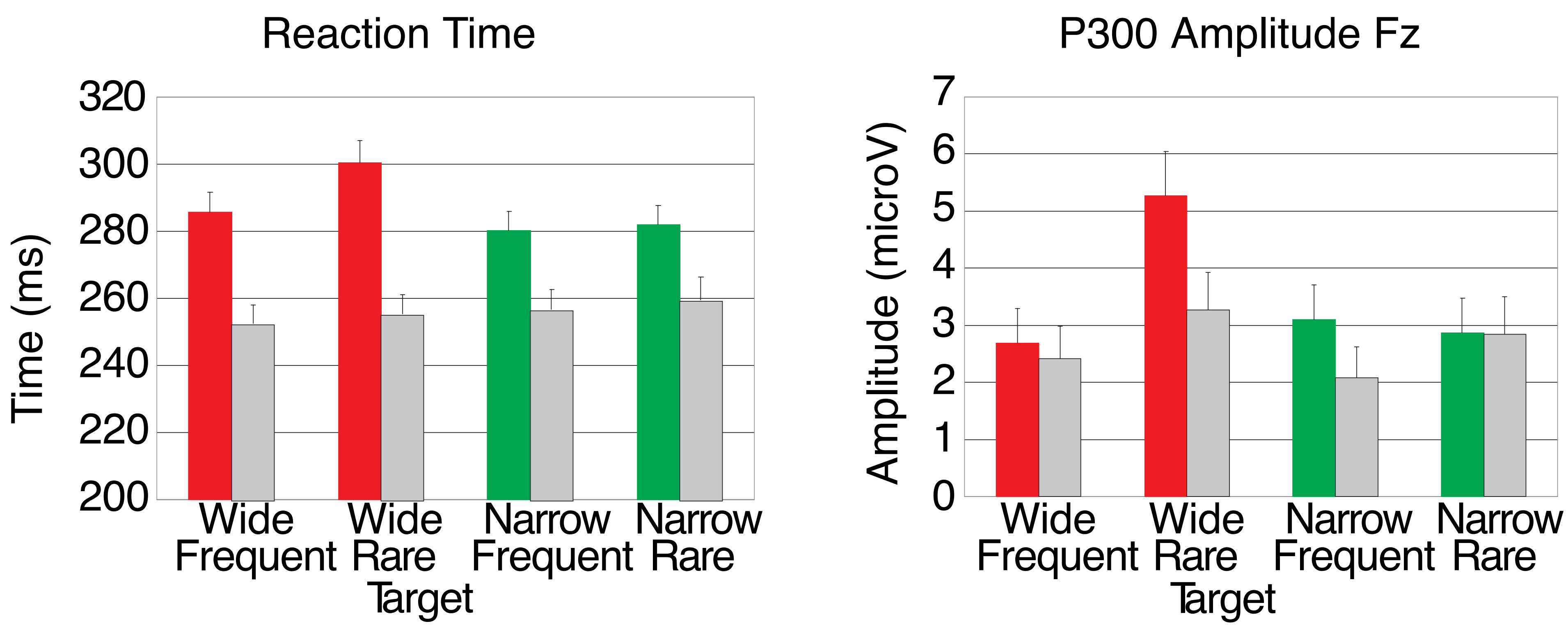



[McDowell, Jeka, Schöner ]




[from Erlhagen, Schöner: Psych. Rev. 2002]




[from McDowell, Jeka, Schöner, Hatfield, 2002]