

Dynamic Field Theory

Part 4:

the memory trace and preshape

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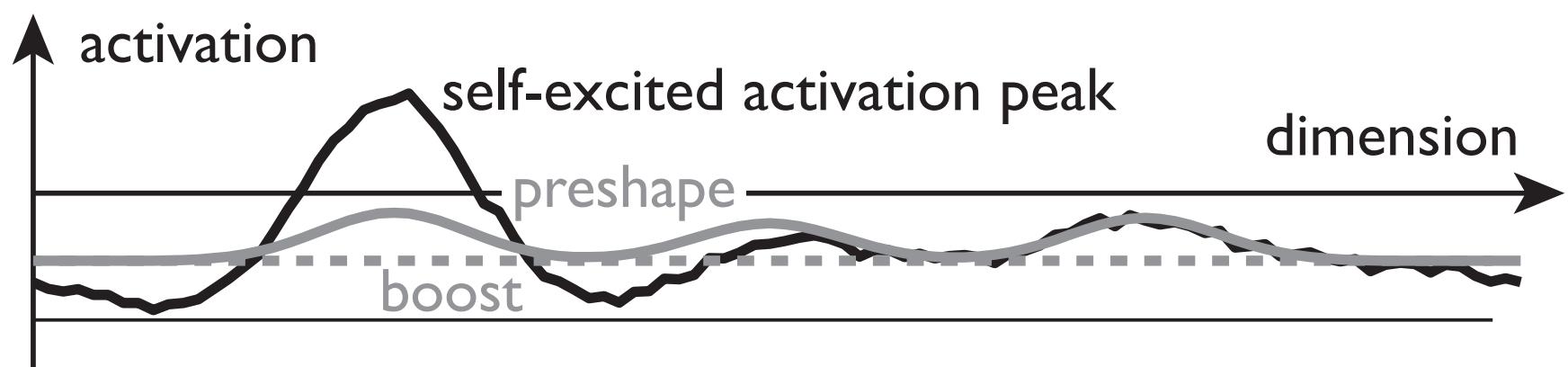
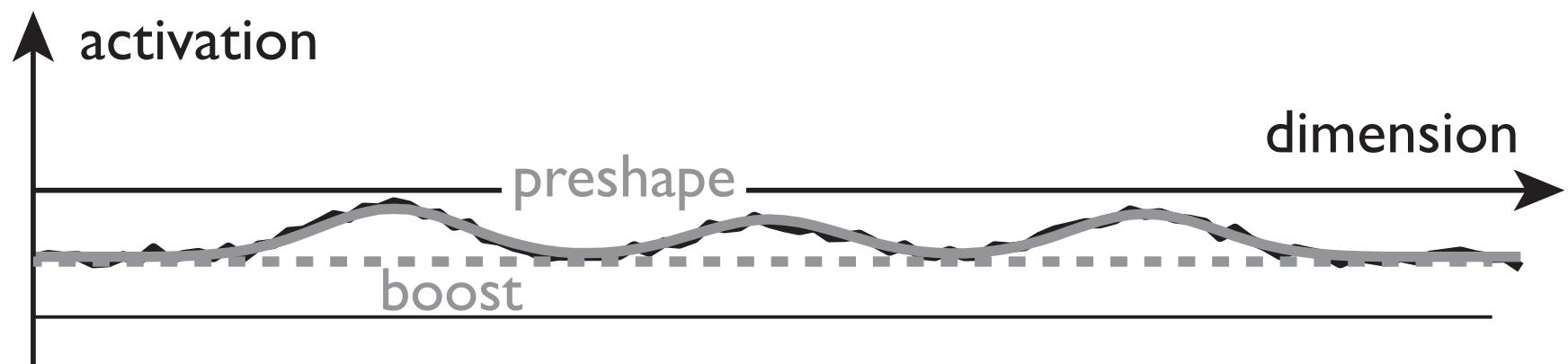
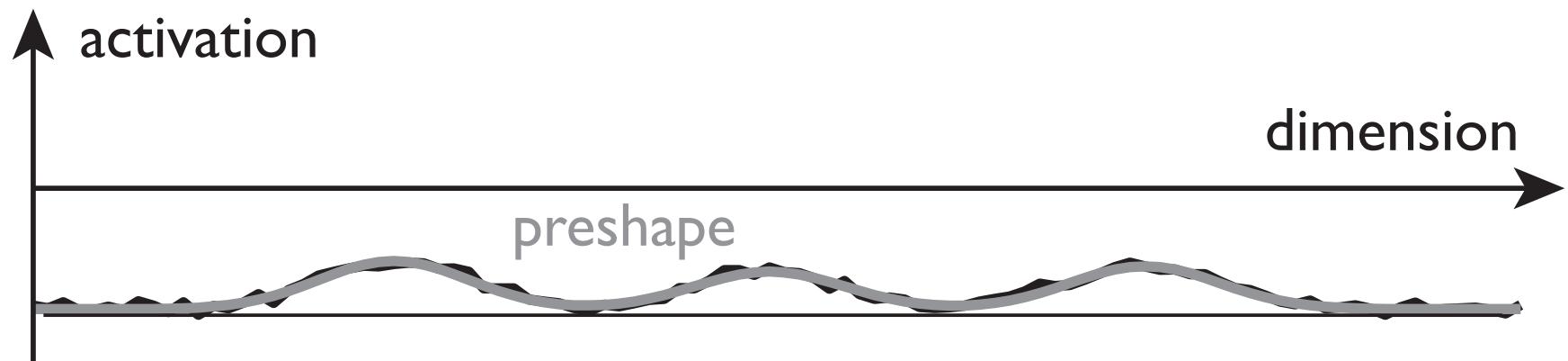
Summary/recall

- action, perception, and embodied cognition takes place in continuous spaces. peaks = units of representation are attractors of the neural dynamics
- neural fields link neural representations to these continua
- stable activation peaks are the units of neural representation
- peaks arise and disappear through instabilities through which elementary cognitive functions (e.g. detection, selection, memory) emerge

Summary/recall

- inhomogeneities in the field may be amplified into peaks through the (boost-driven) detection instability

boost-induced detection instability

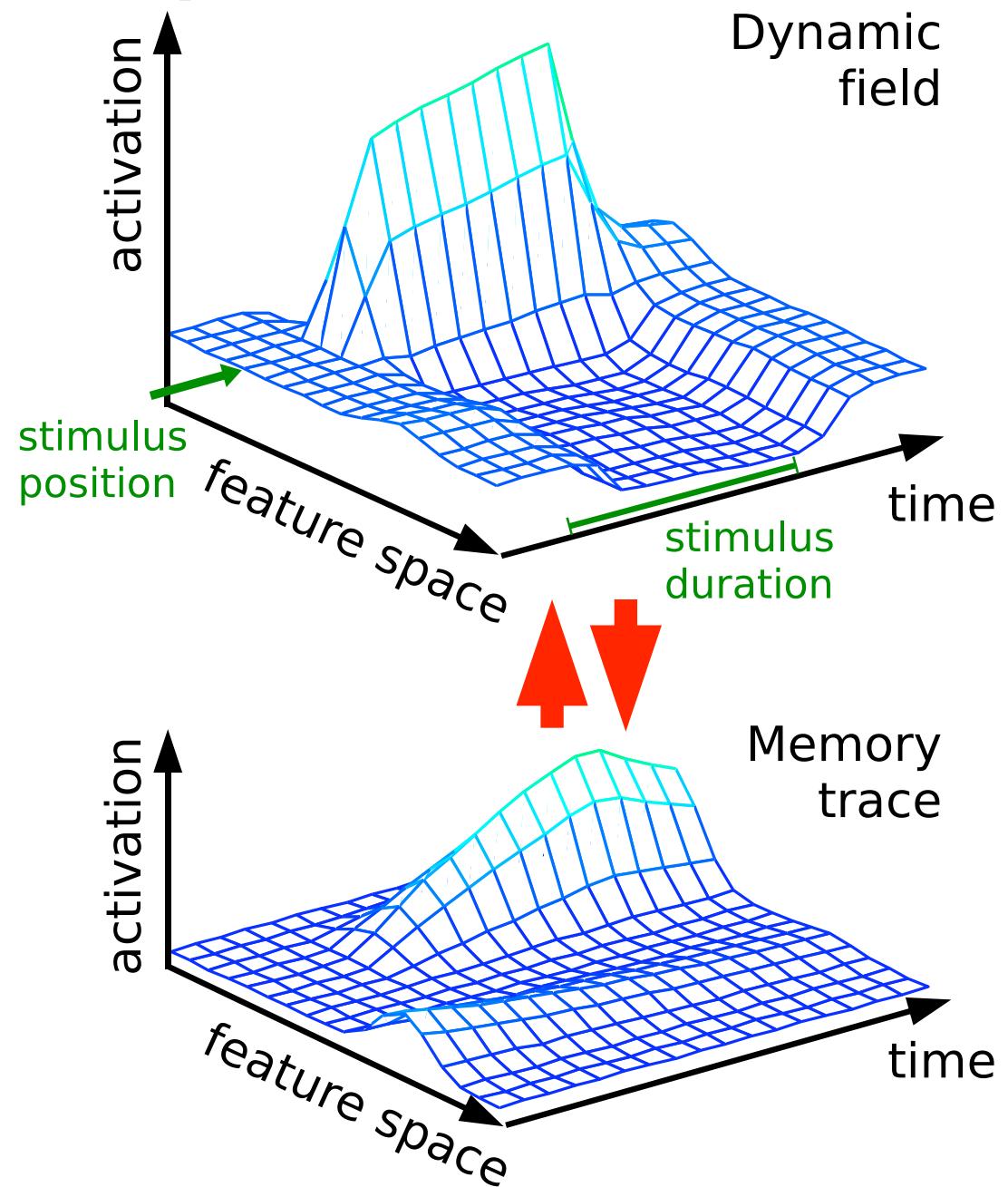


... emergence of categories?

■ if we understand, how such inhomogeneities come about, we understand the emergence of categories...

the memory trace

- inhomogeneities from simplest from the memory trace
- ~ habit formation (?)
William James: habit formation as the simplest form of learning
- habituation: the memory trace for inhibition..



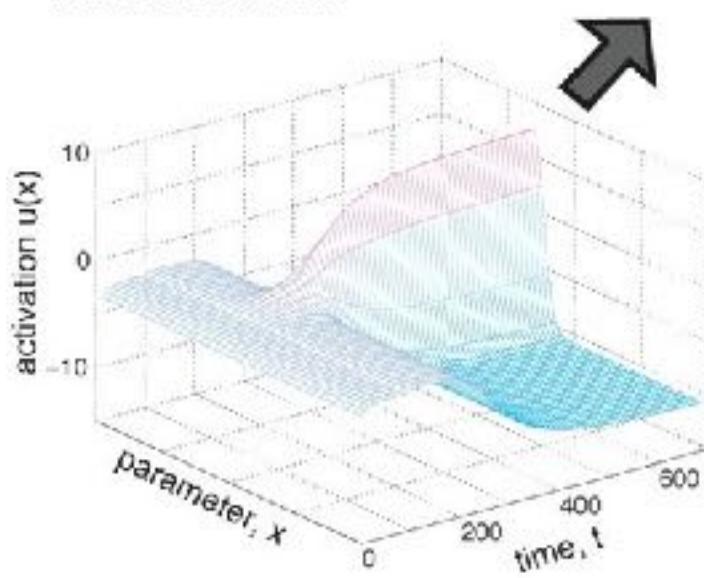
mathematics of the memory trace

$$\begin{aligned}\tau \dot{u}(x, t) &= -u(x, t) + h + S(x, t) + u_{\text{mem}}(x, t) \\ &\quad + \int dx' w(x - x') \sigma(u(x'))\end{aligned}$$

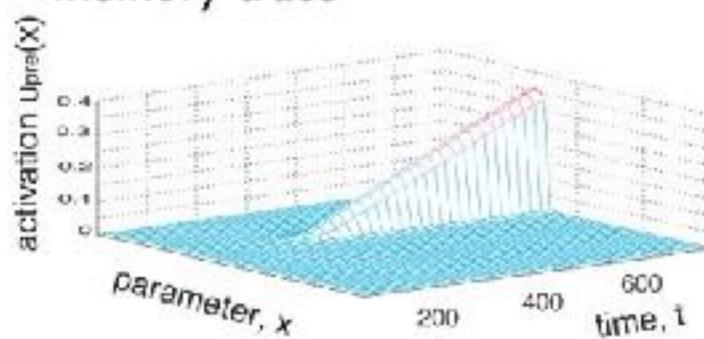
$$\begin{aligned}\tau_{\text{mem}} \dot{u}_{\text{mem}}(x, t) &= -u_{\text{mem}}(x, t) \\ &\quad + \int dx' w_{\text{mem}}(x - x') \sigma(u(x', t))\end{aligned}$$

- memory trace only evolves while activation is excited
- potentially different growth and decay rates

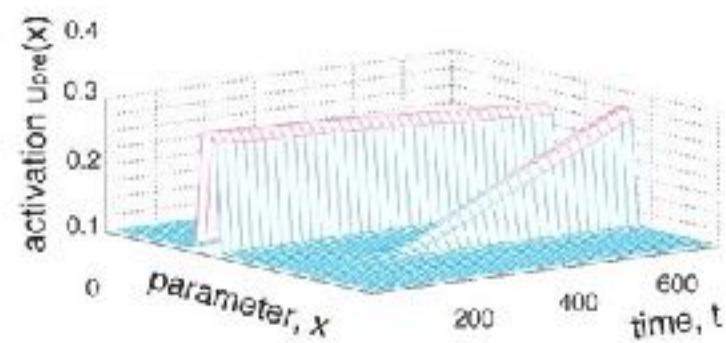
fast activation field



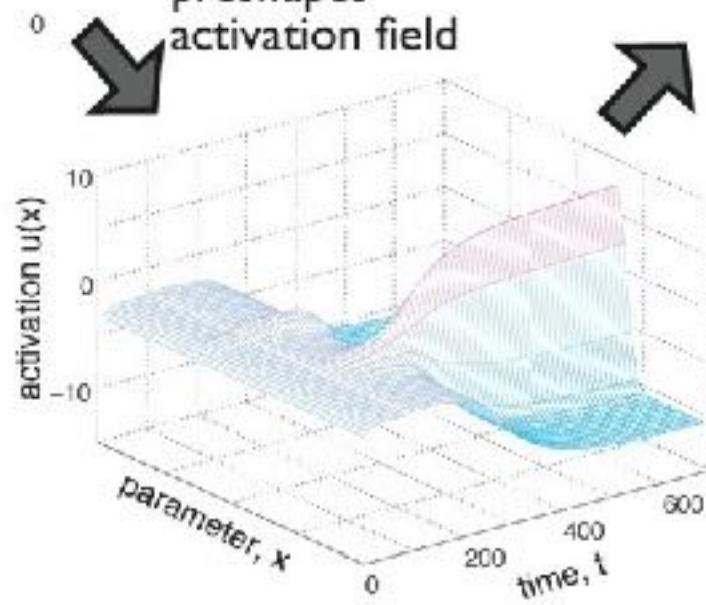
slow memory trace



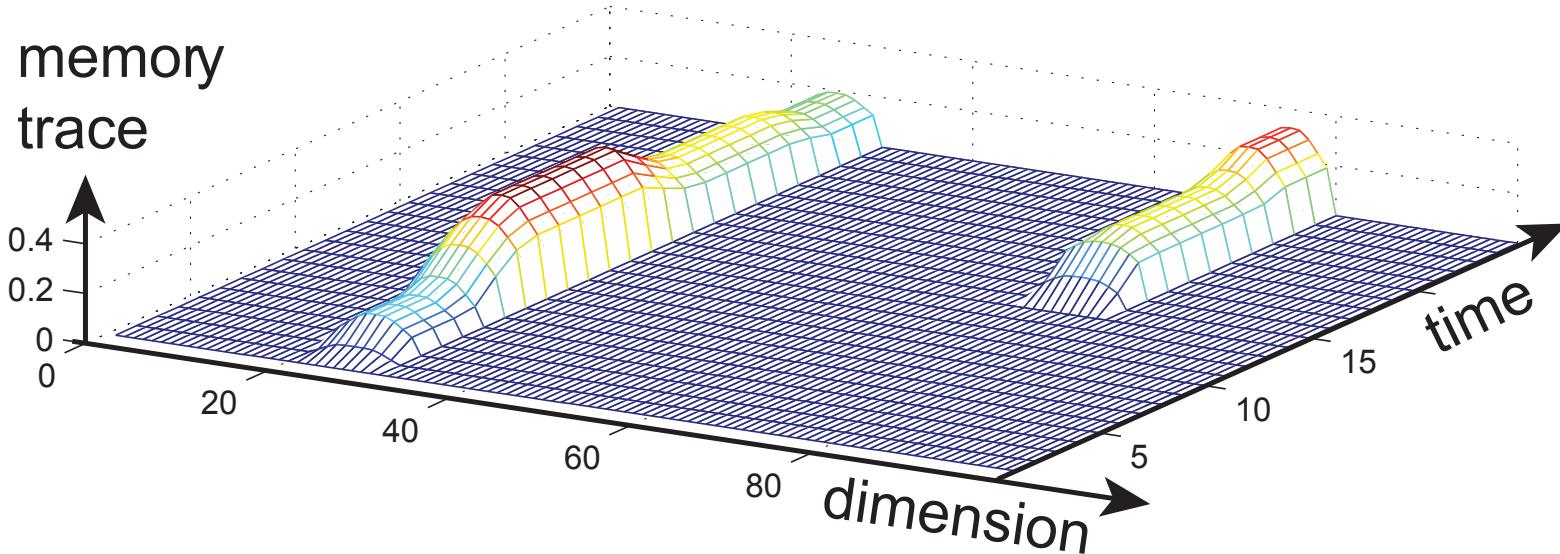
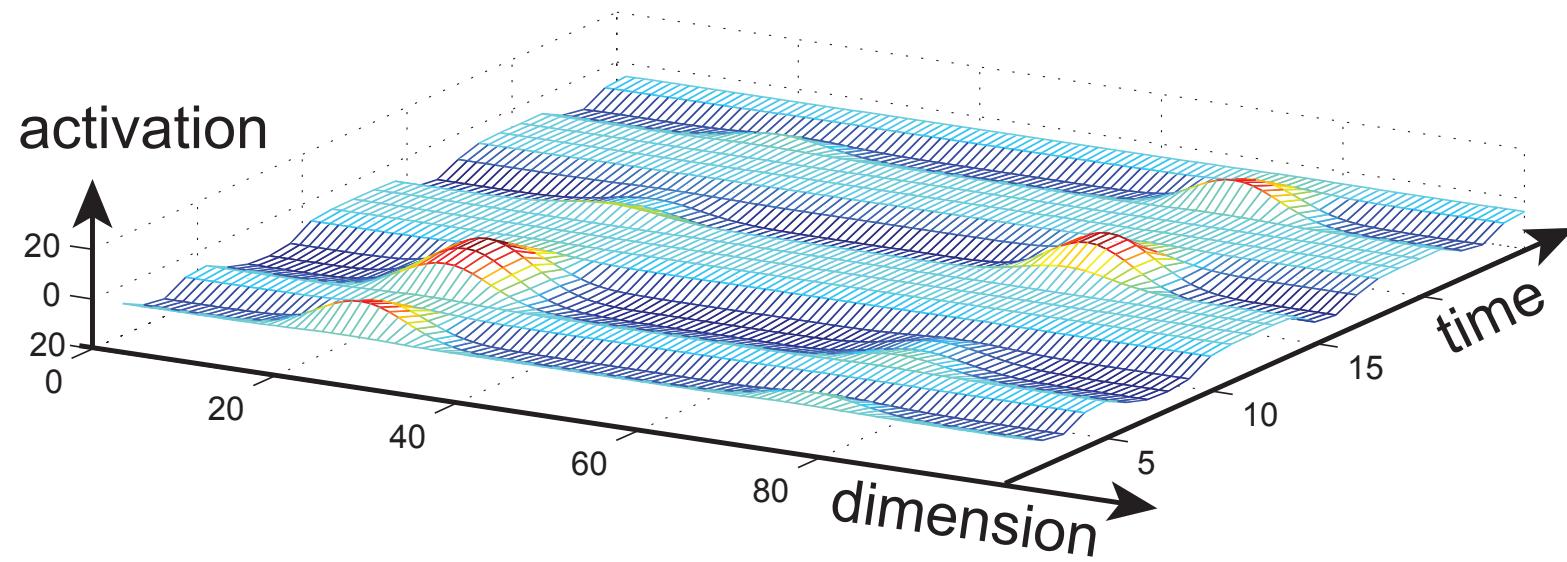
memory trace



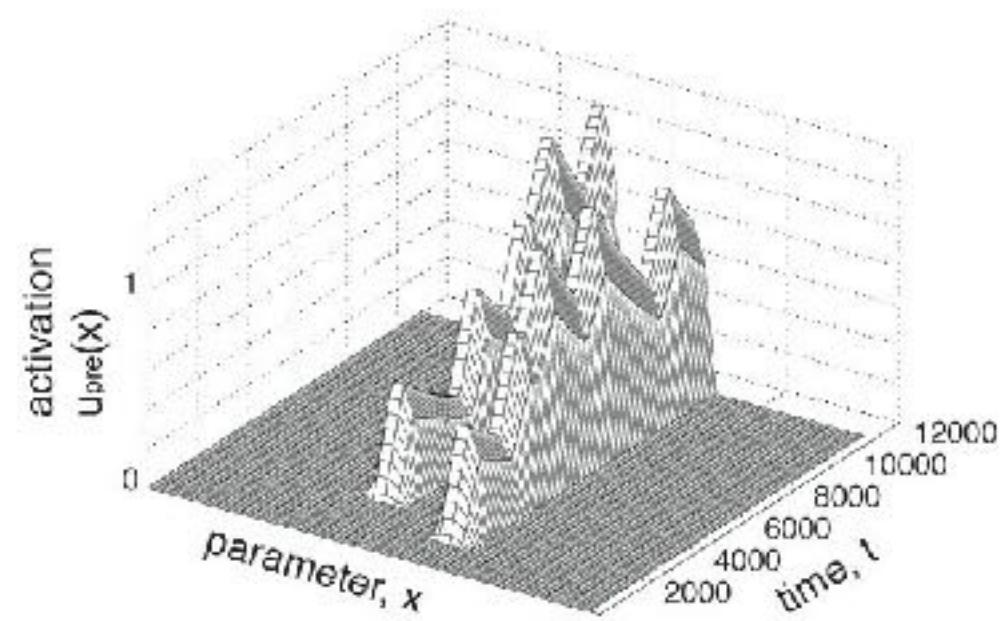
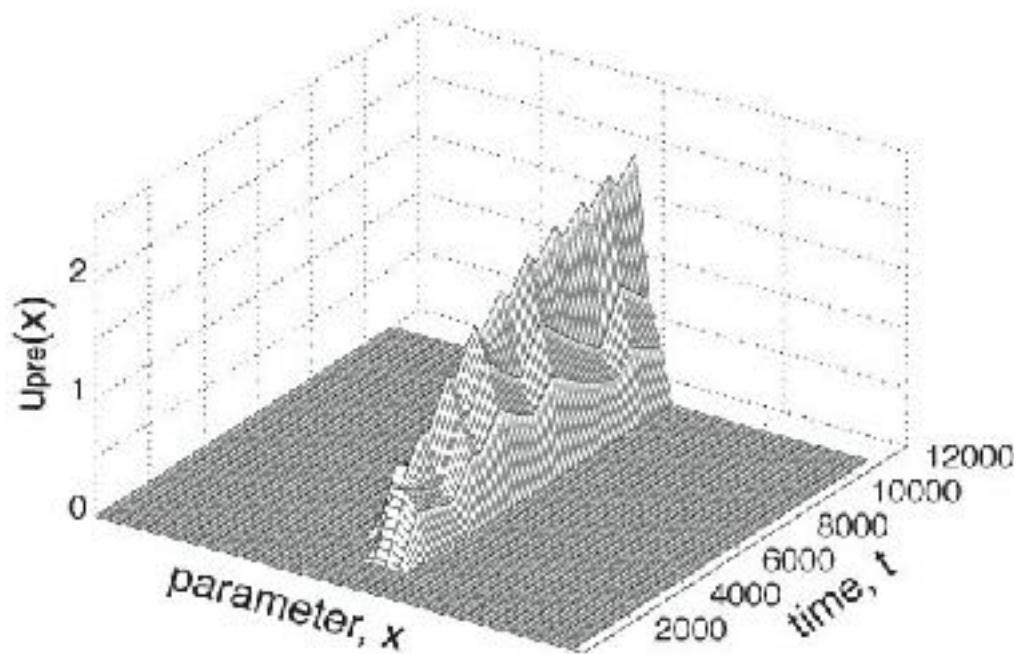
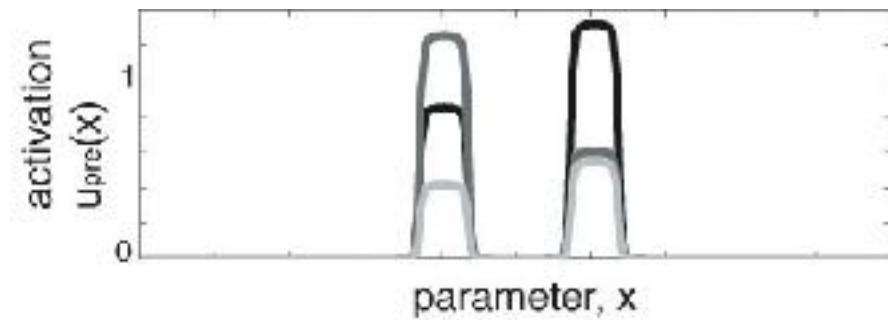
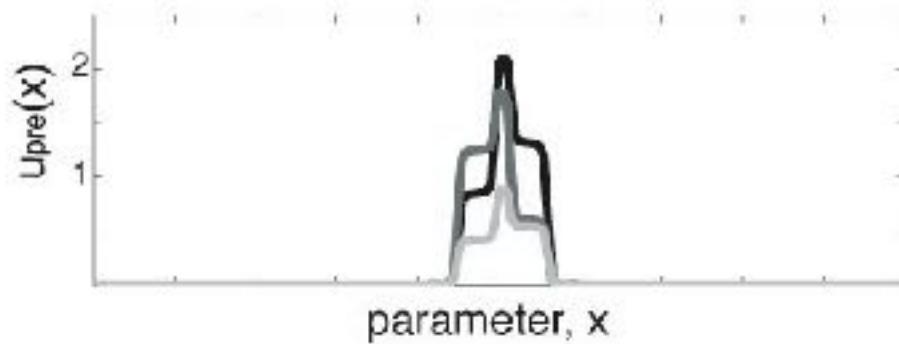
preshapes
activation field



memory trace reflects history of decisions formation



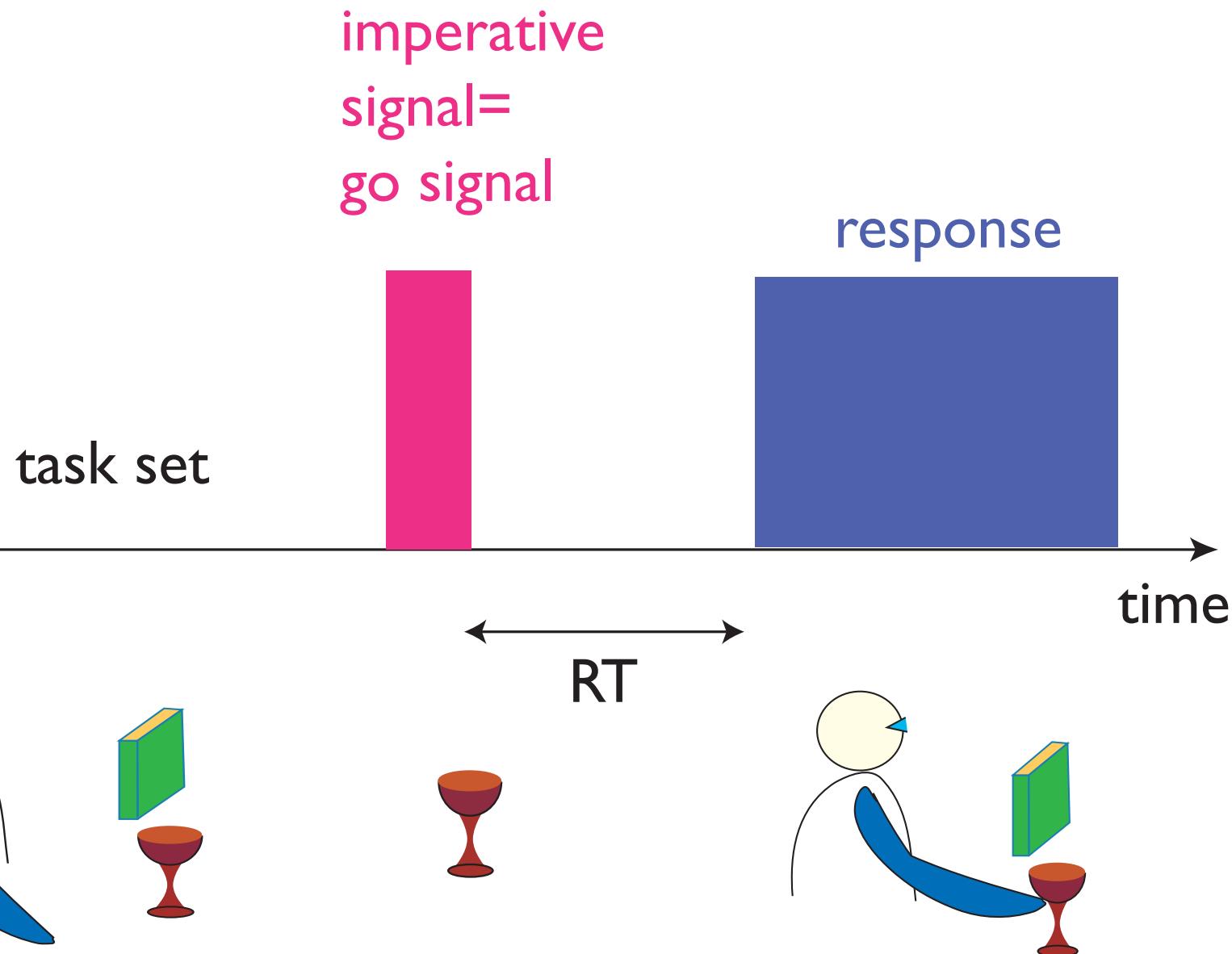
categories may emerge ...



preshape

- is a decisive concept, it turns out, in how selection decisions are studied in the laboratory

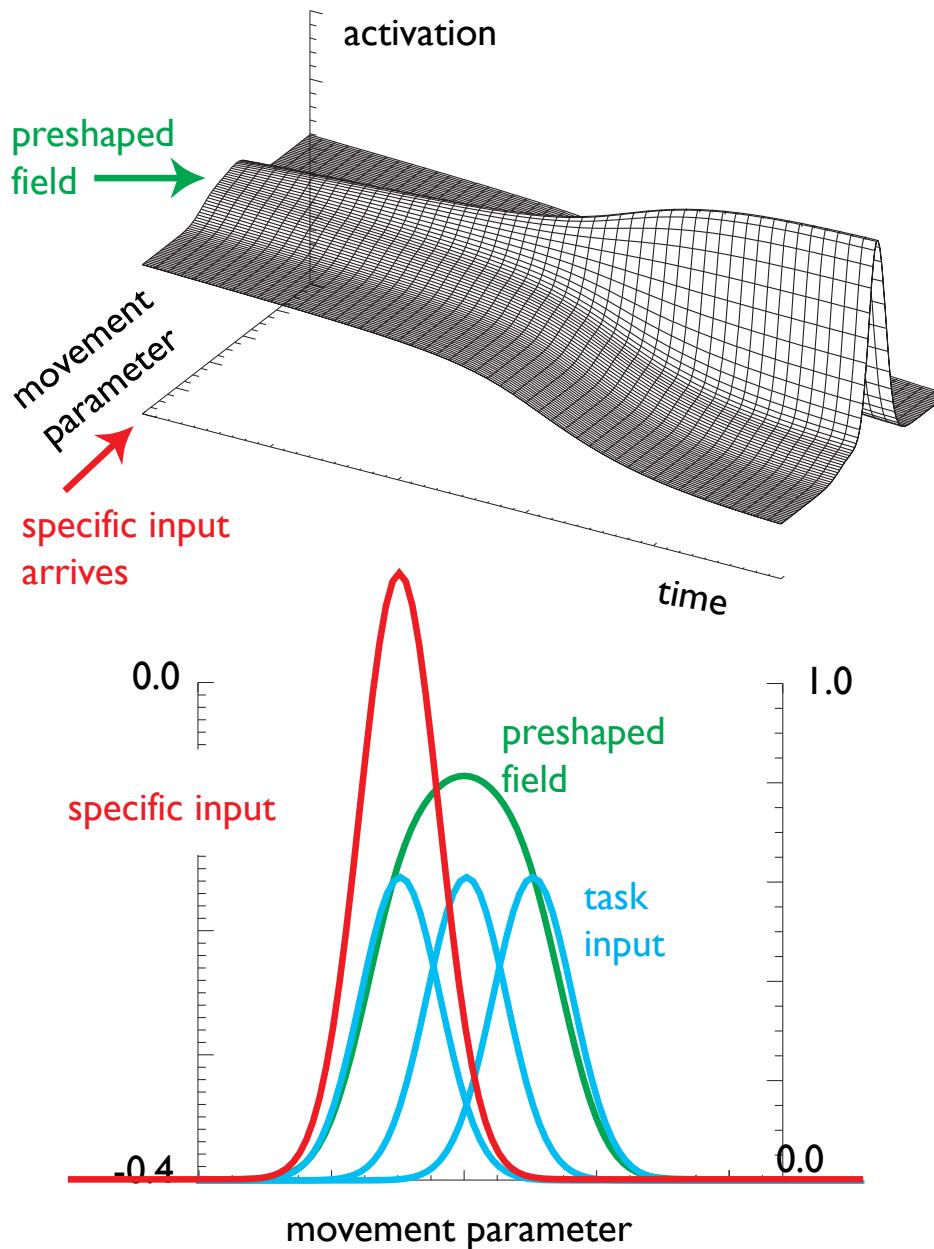
reaction time (RT) paradigm



the task set

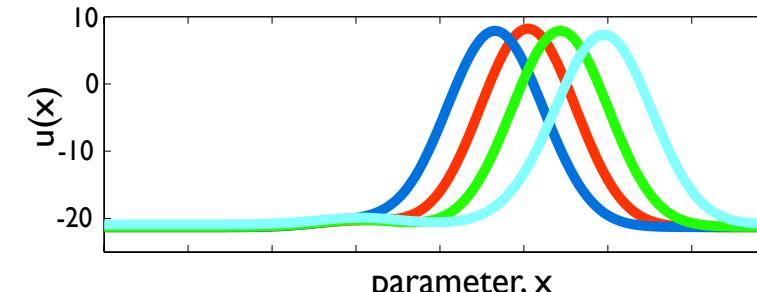
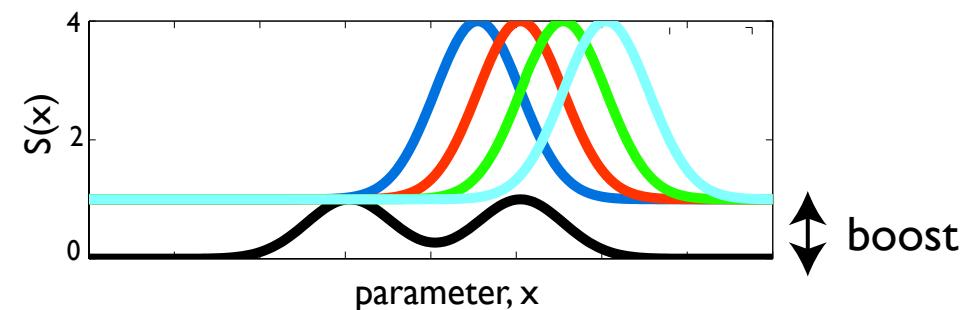
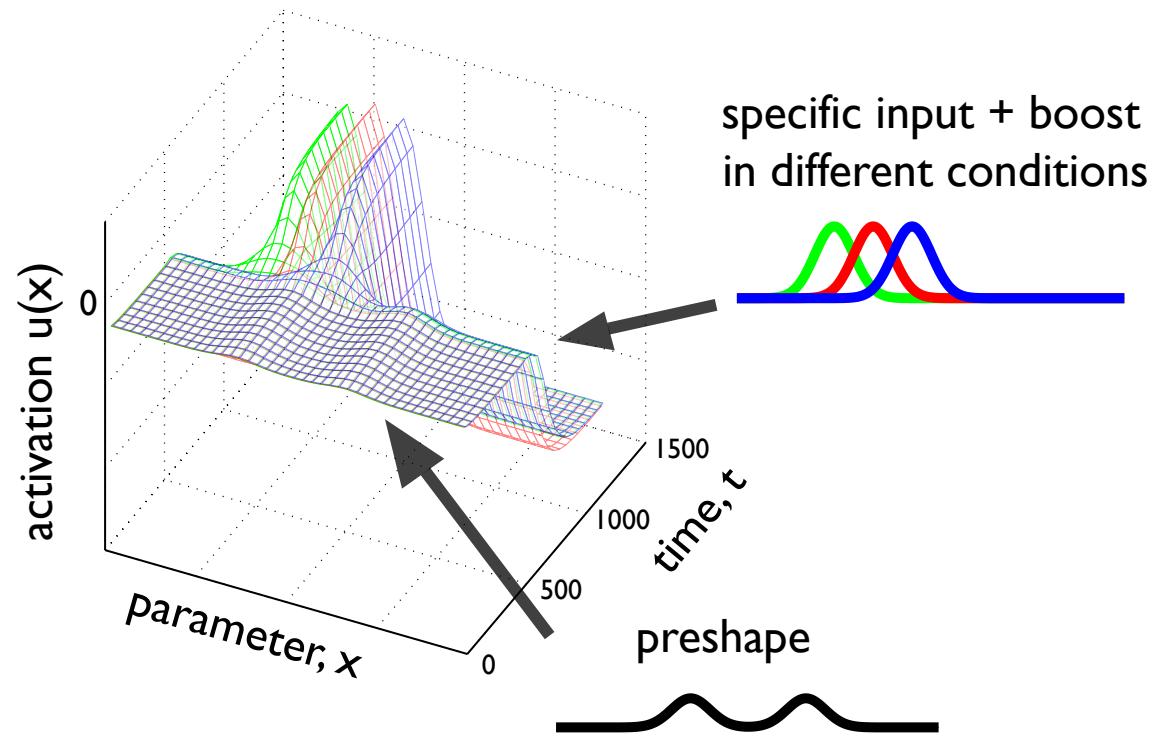
- is the critical factor in such studies of selection:
which perceptual/action alternative/choices are
available...
 - e.g., how many choices
 - e.g., how likely is each choice
 - e.g., how “easy” are the choices to recognize/perform
- because the task set is known to the participant
prior to the presentation of the imperative signal,
one may think of the task set as a “preshaping” of
the underlying representation (pre=before the
decision)

DFT: preshape



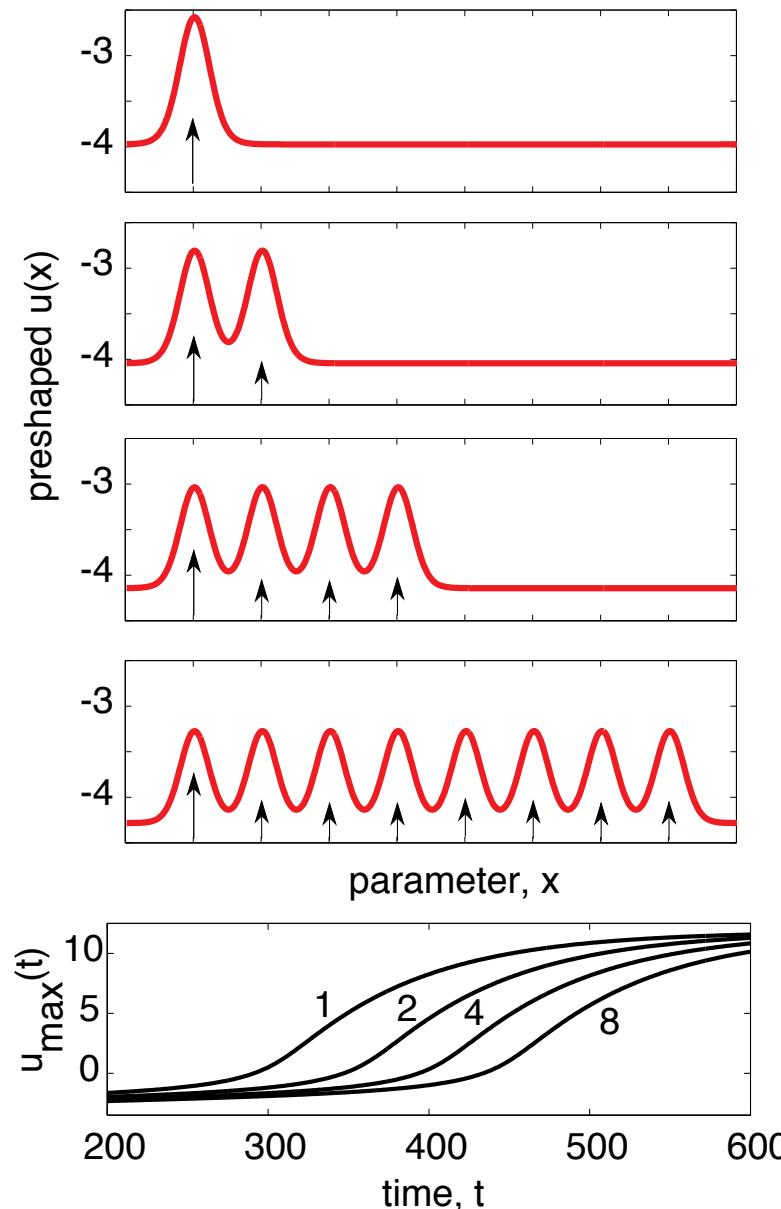
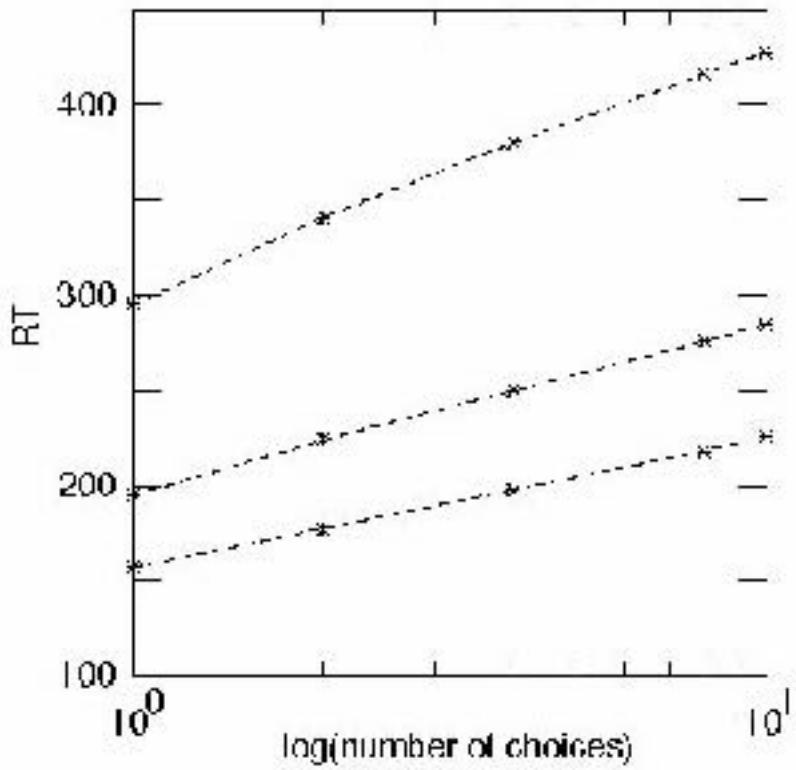
weak preshape in selection

- specific (imperative) input dominates and drives detection instability



using preshape to account for classical RT data

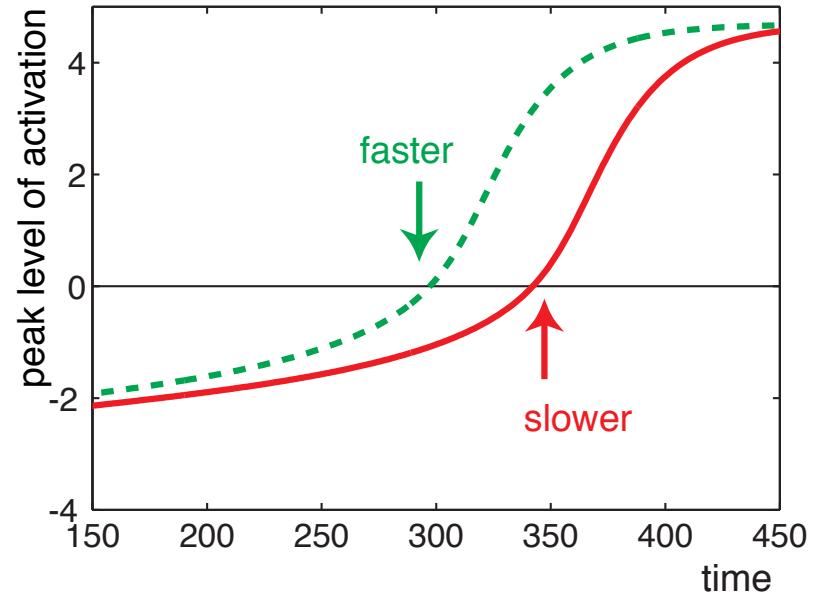
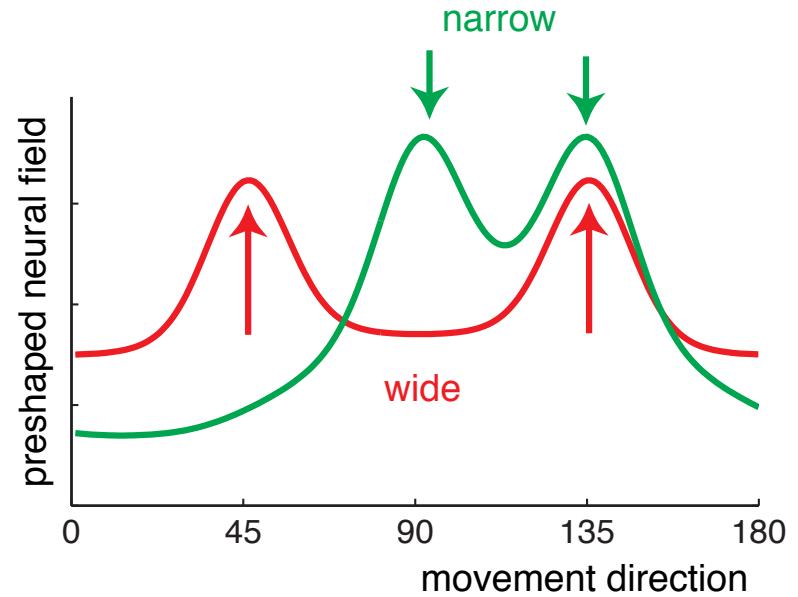
- Hick's law: RT increases with the number of choices



[Erlhagen, Schöner, Psych Rev 2002]

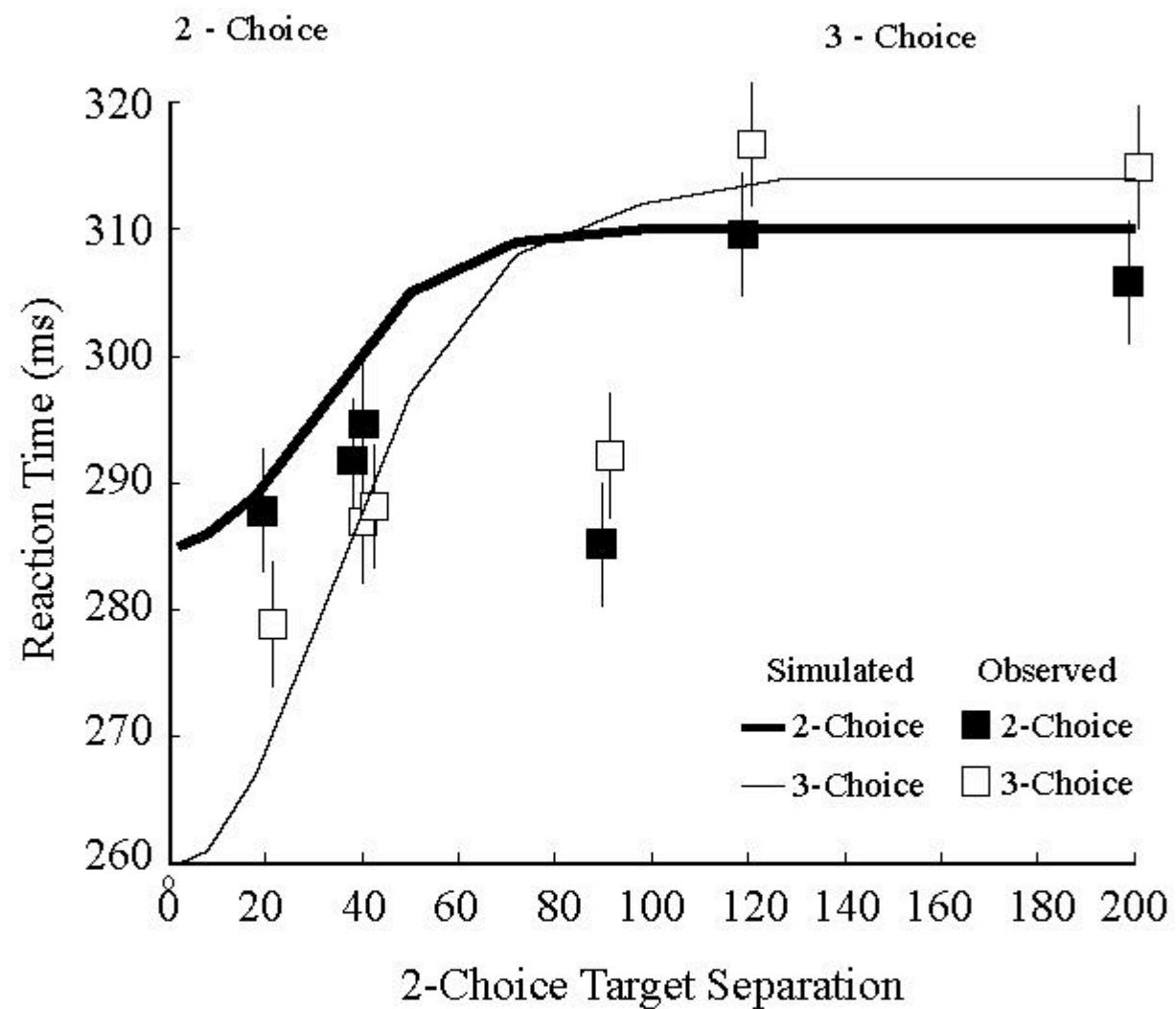
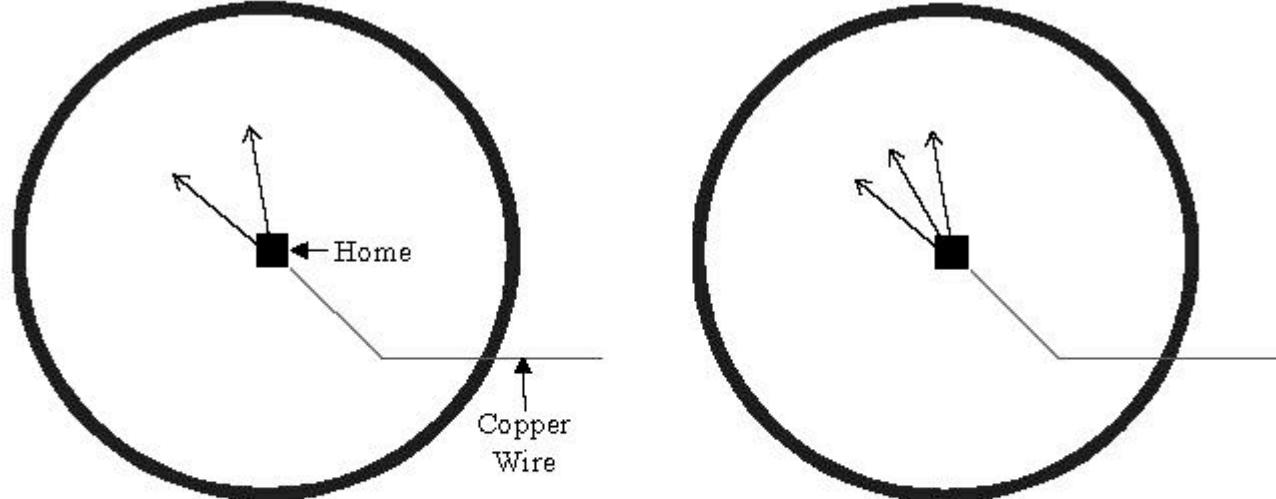
metric effect

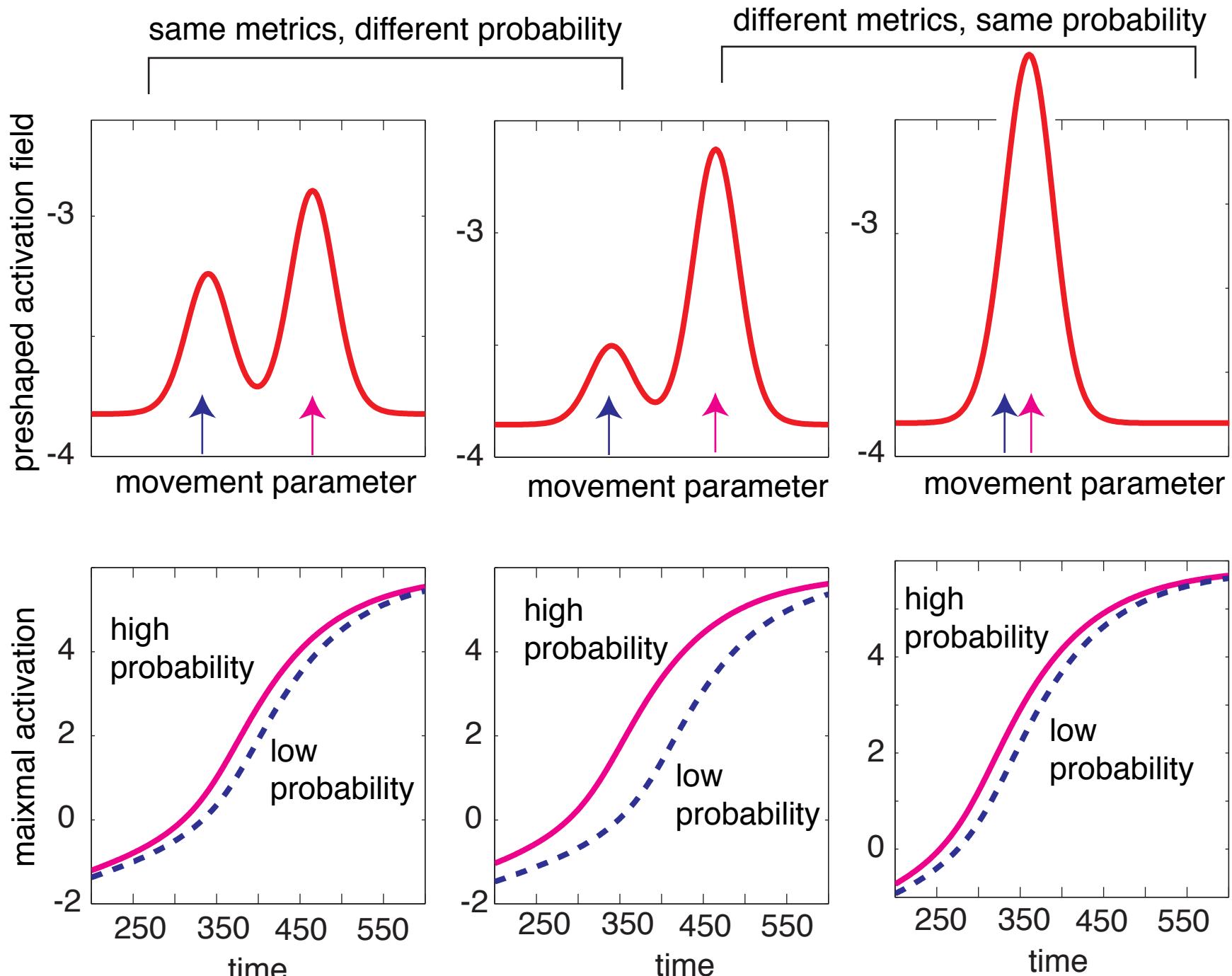
- predict faster response times for metrically close than for metrically far choices



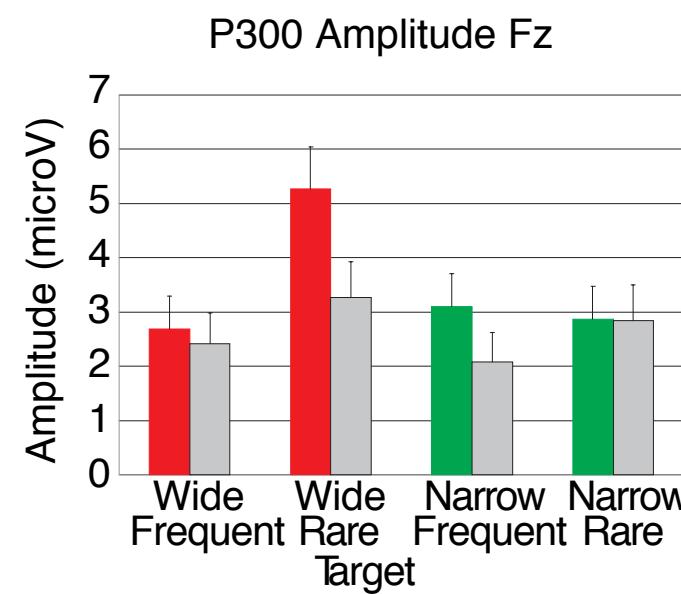
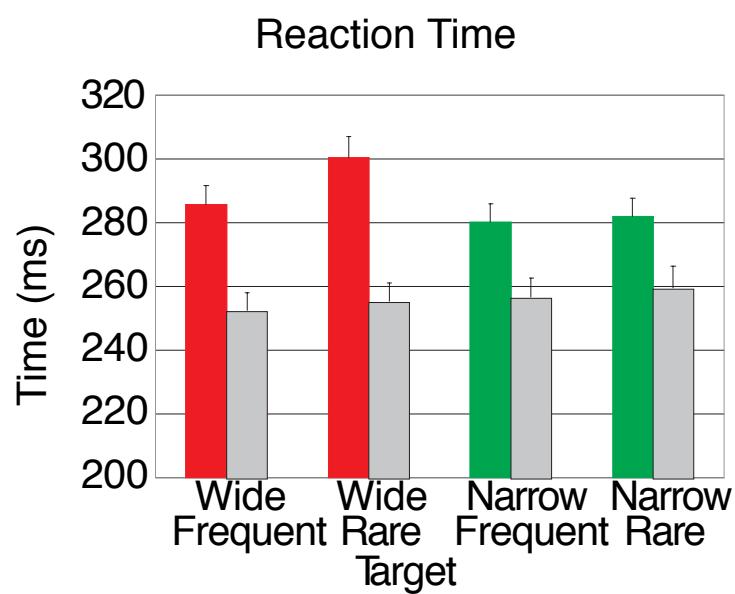
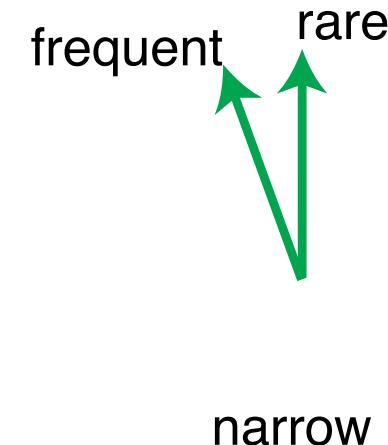
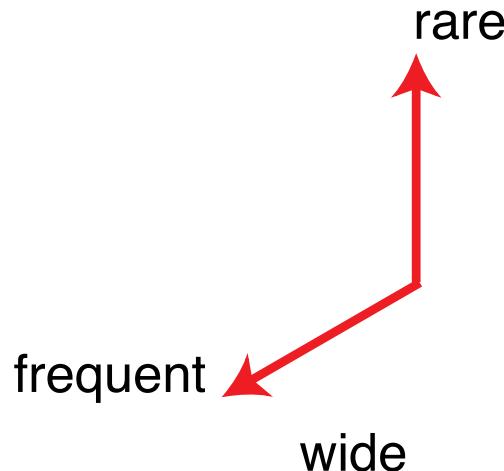
[from Schöner, Kopecz, Erhagen, 1997]

experiment: metric effect



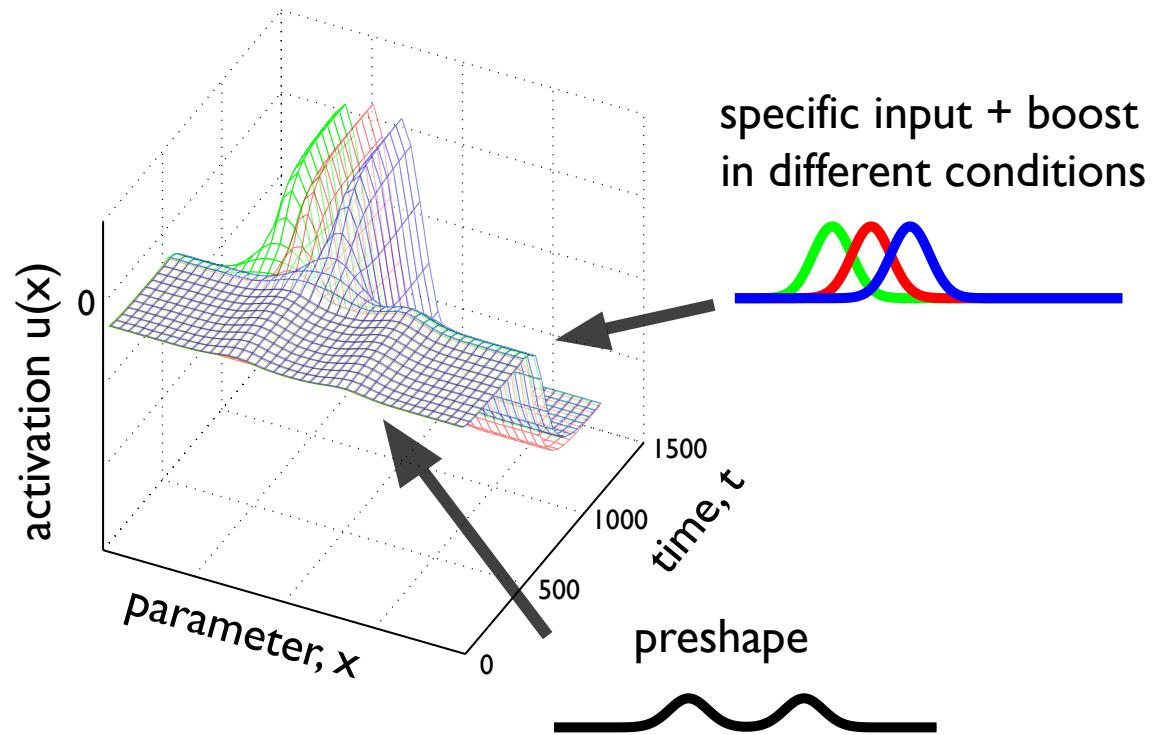


[from Erhagen, Schöner: Psych. Rev. 2002]

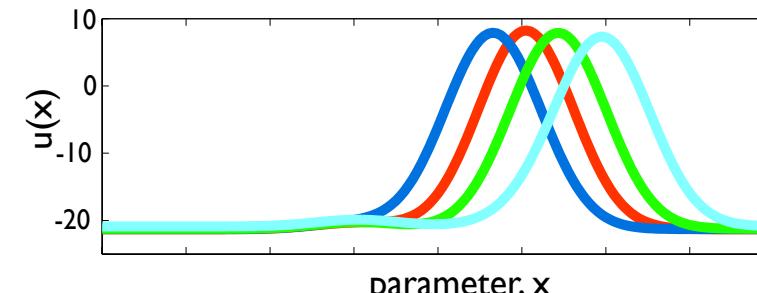
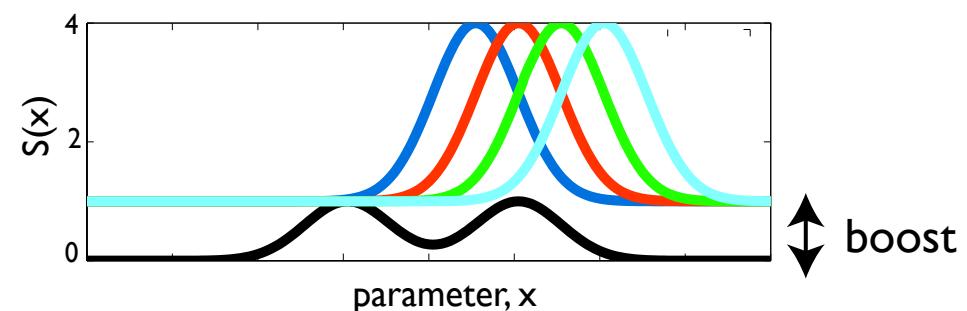


[from McDowell, Jeka, Schöner, Hatfield, 2002]

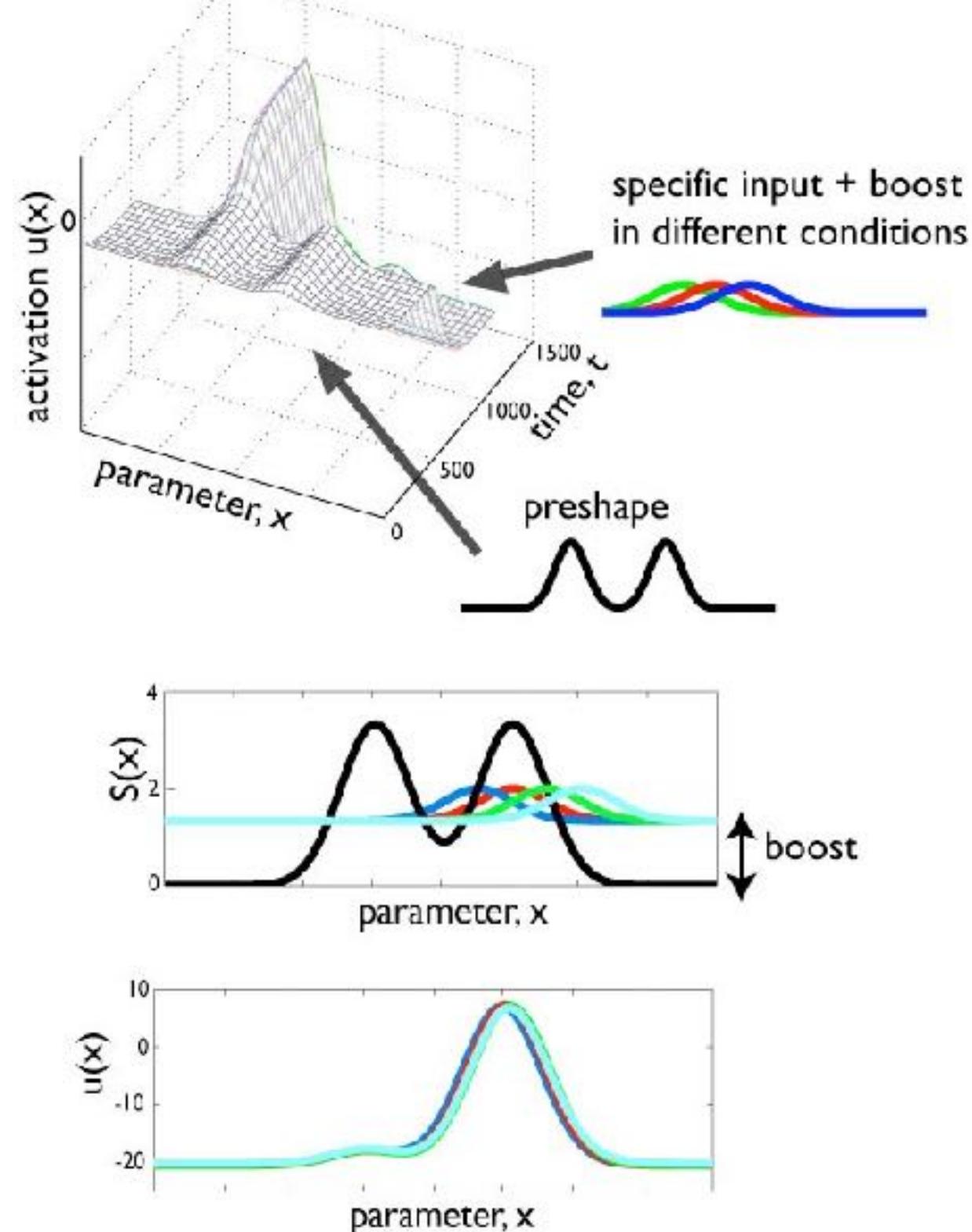
this was: weak
preshape
relative to the
imperative
stimulus



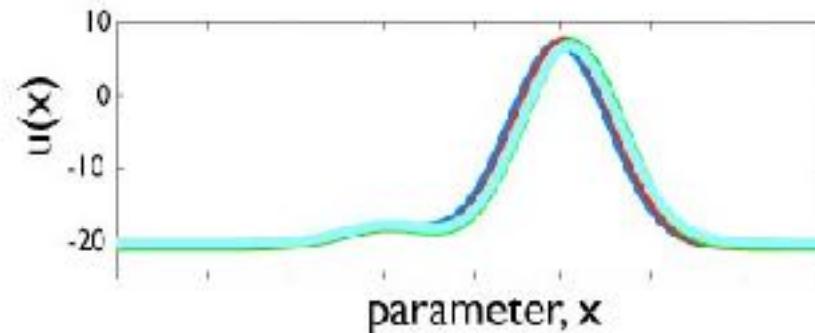
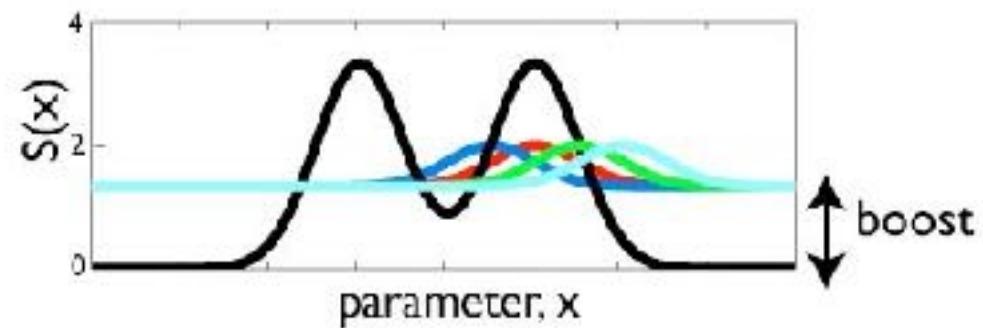
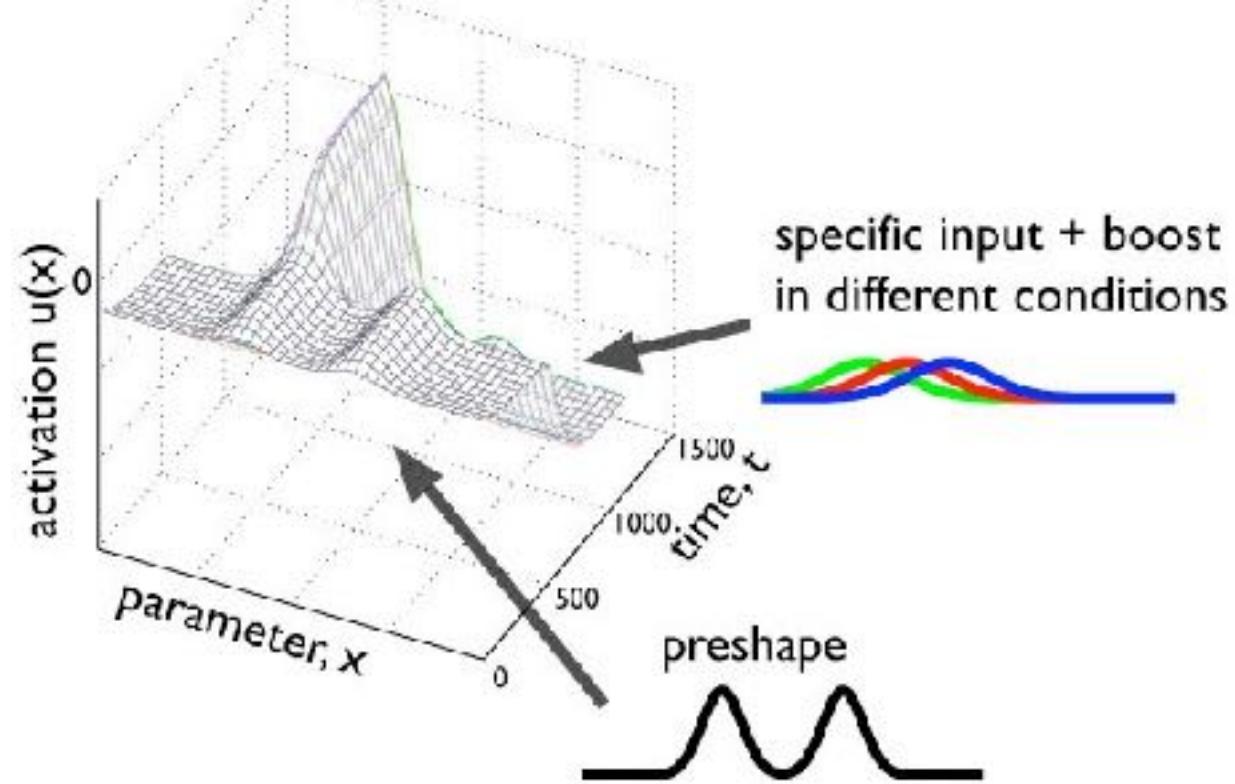
- specific (imperative) input dominates and drives detection instability



strong preshape
relative to the
imperative
stimulus

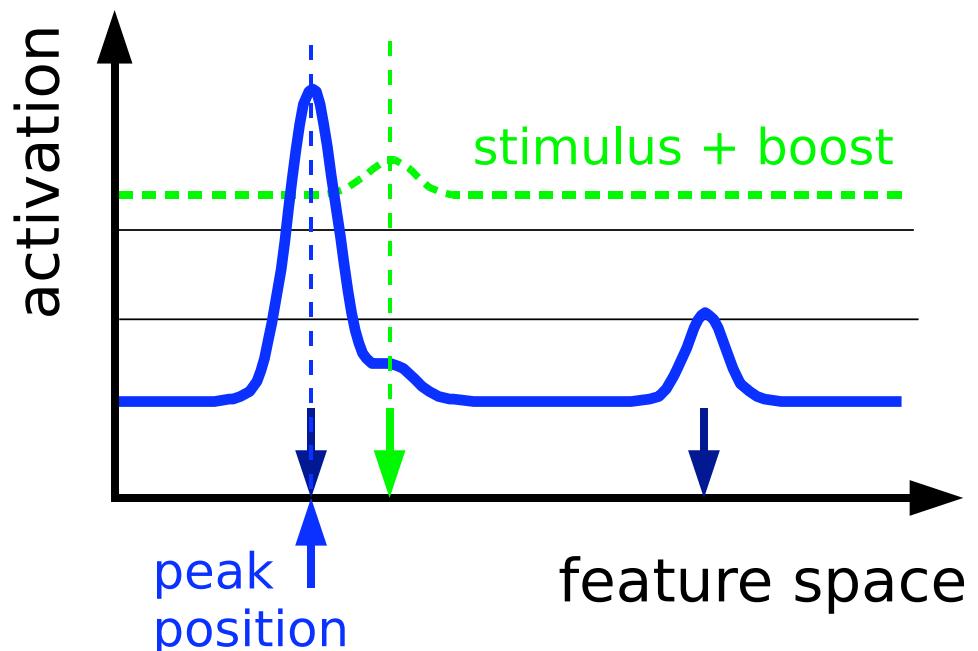
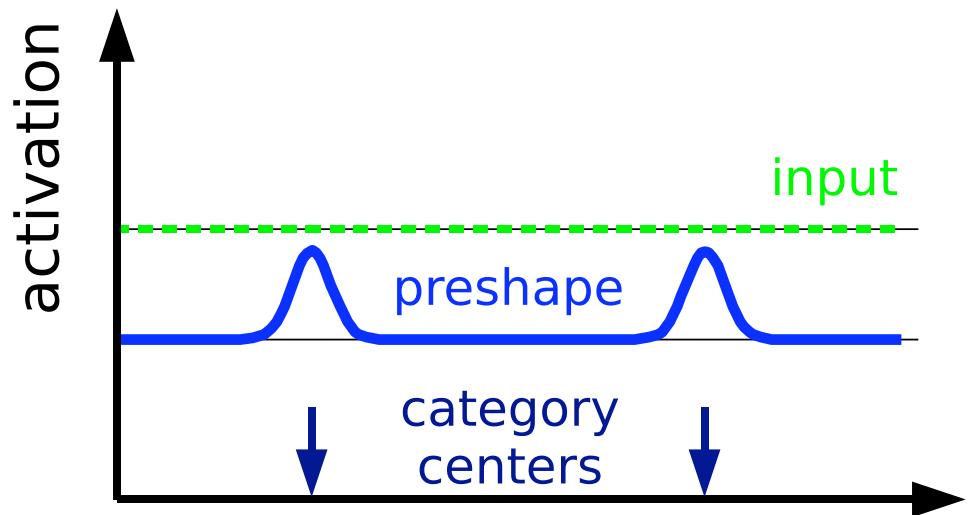


■ => field responds categorically



categorical responding

■ based on categorical
memory trace and
boost-driven detection
instability

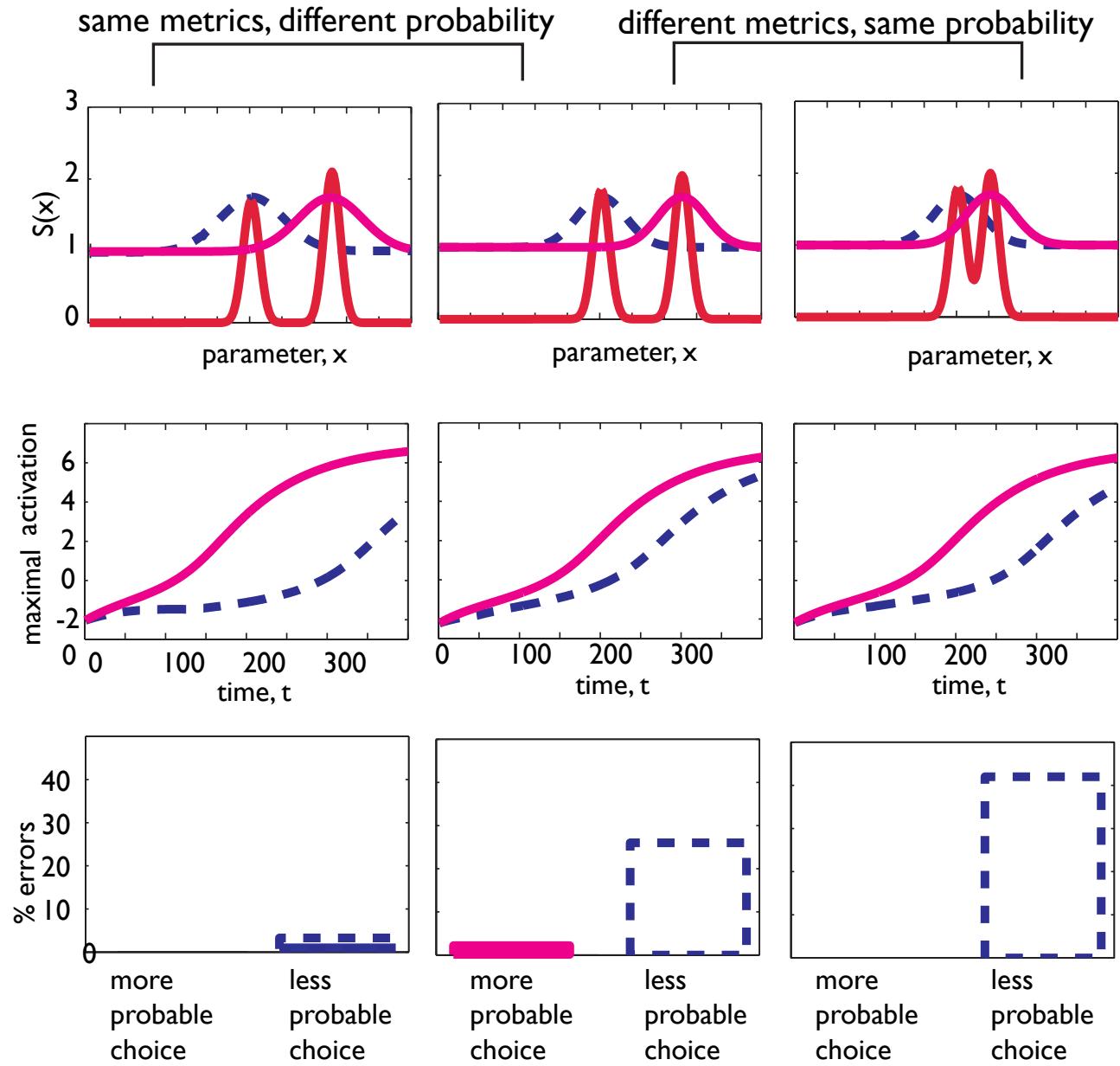


distance effect

- common in categorical tasks... e.g., decide which of two sticks is longer => RT is larger when sticks are more similar in length (1930s')

interaction metrics-probability

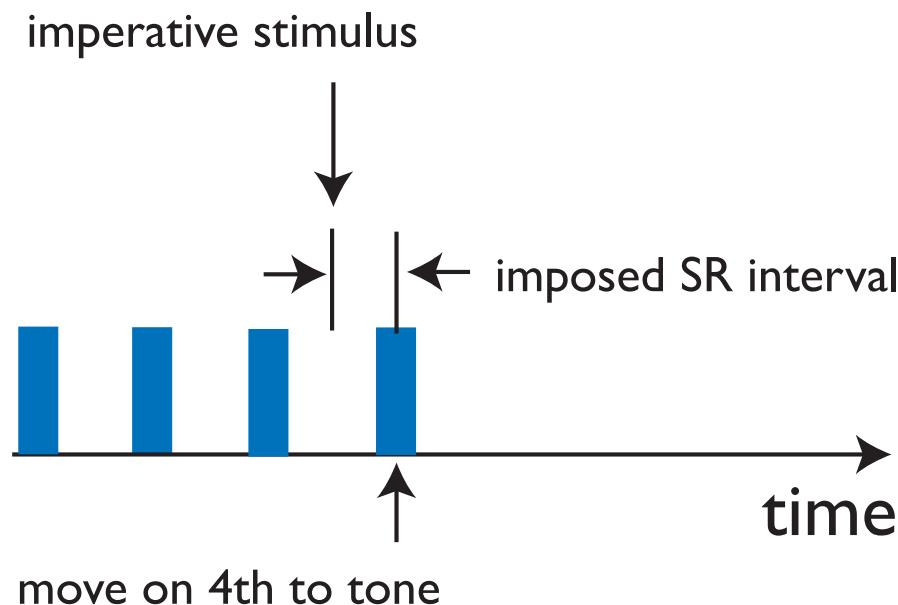
- opposite to that predicted for input-driven detection instabilities:
- metrically close choices show larger effect of probability



Behavioral evidence for preshape

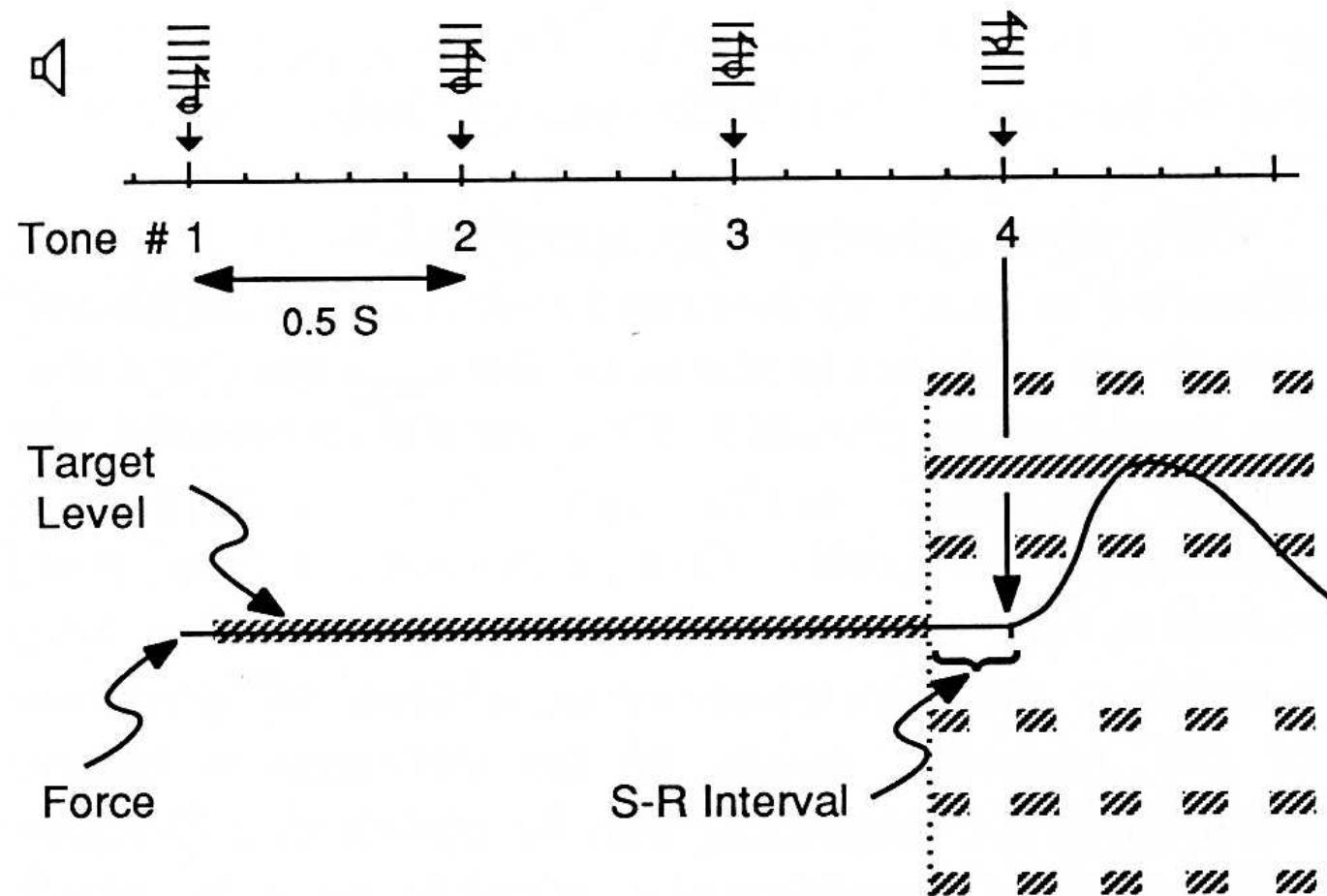
- movement preparation is graded and continuous in time starting out from preshaped representations

timed movement
initiation paradigm

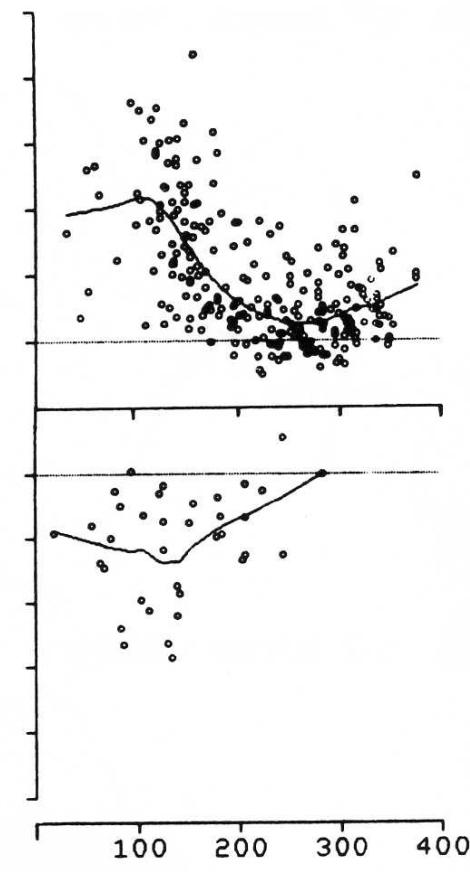
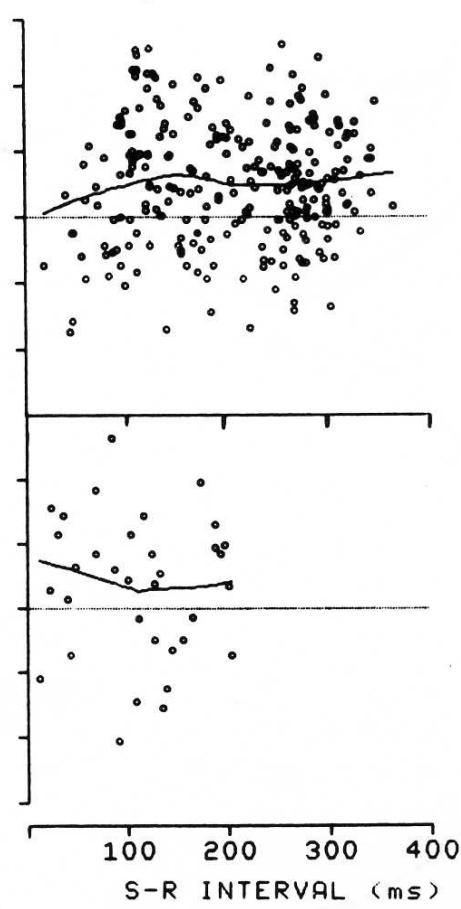
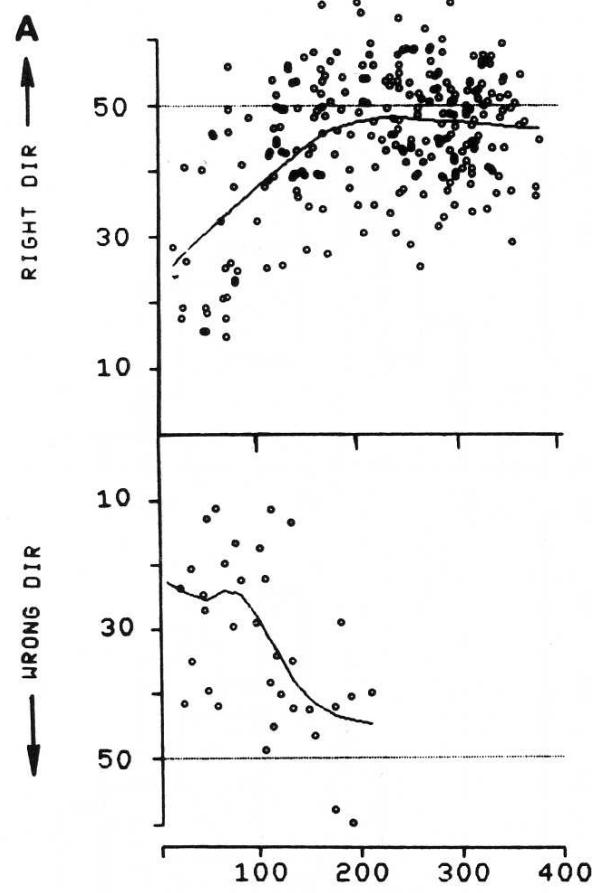


[Ghez and colleagues, 1988 to 1990's]

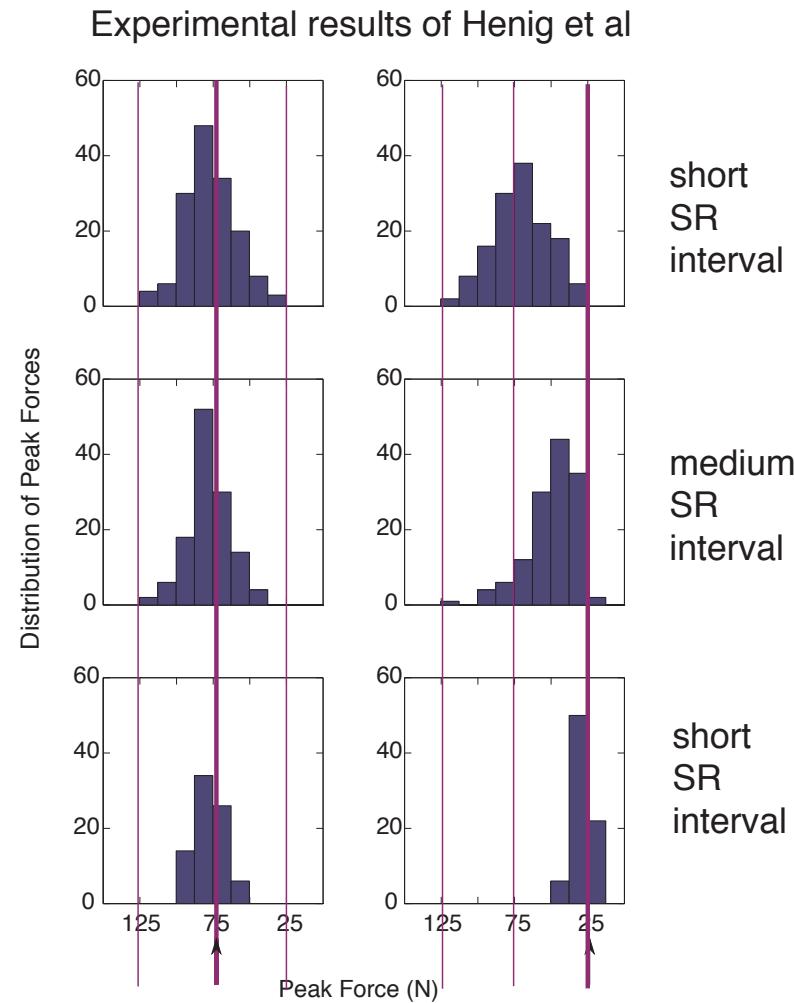
Behavioral evidence for preshape



[Favilla et al. 1989]



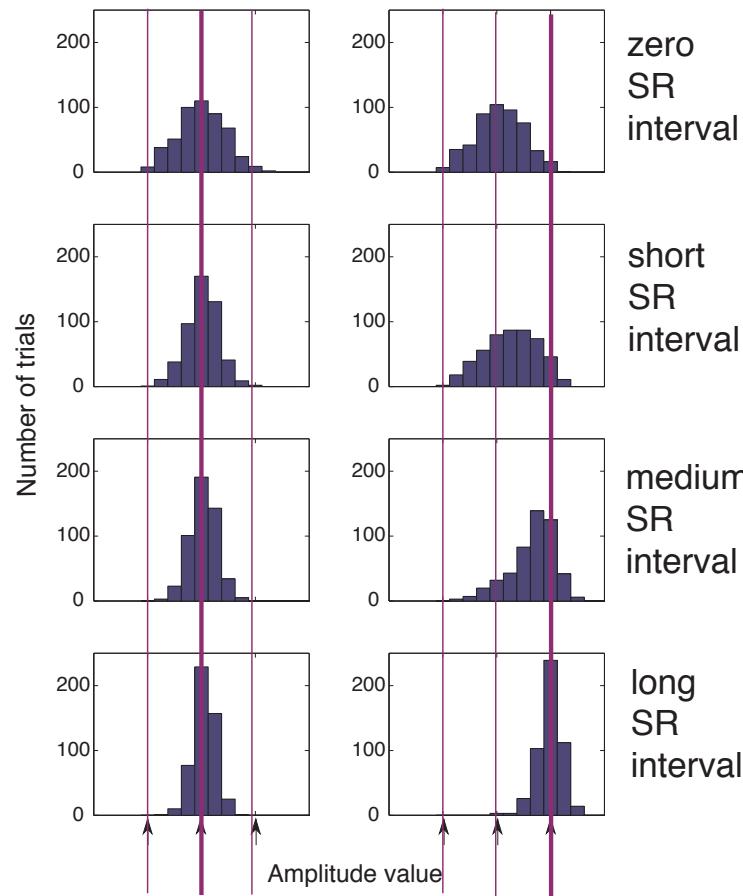
Behavioral evidence for preshape



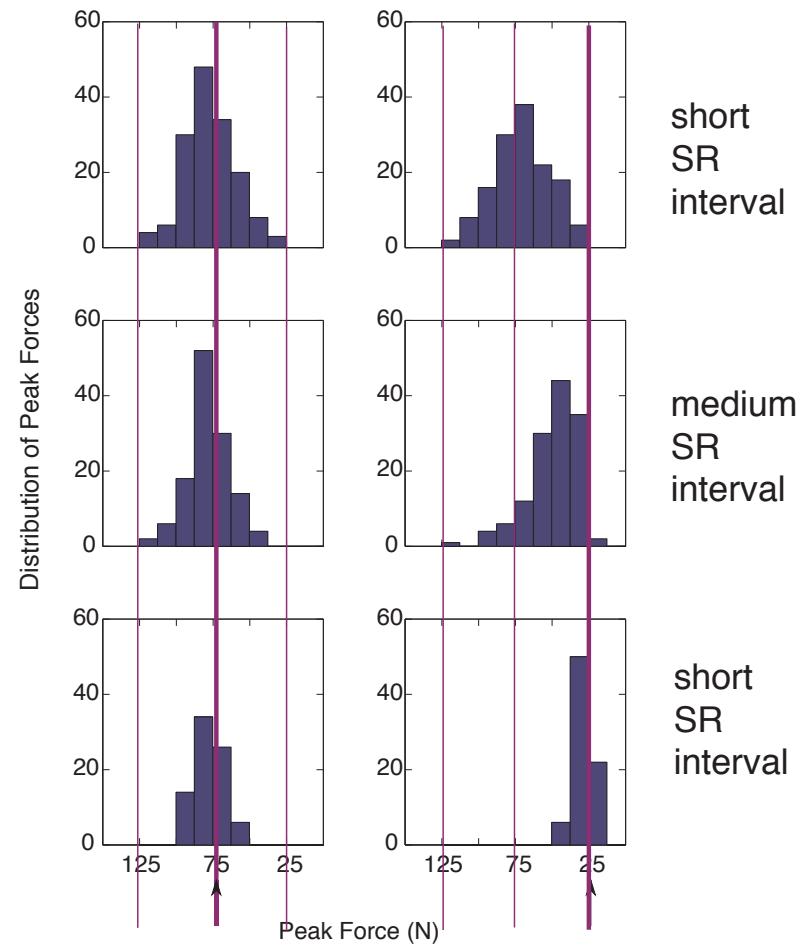
Dynamic Field Theory (DFT)

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

theoretical account for Henig et al.

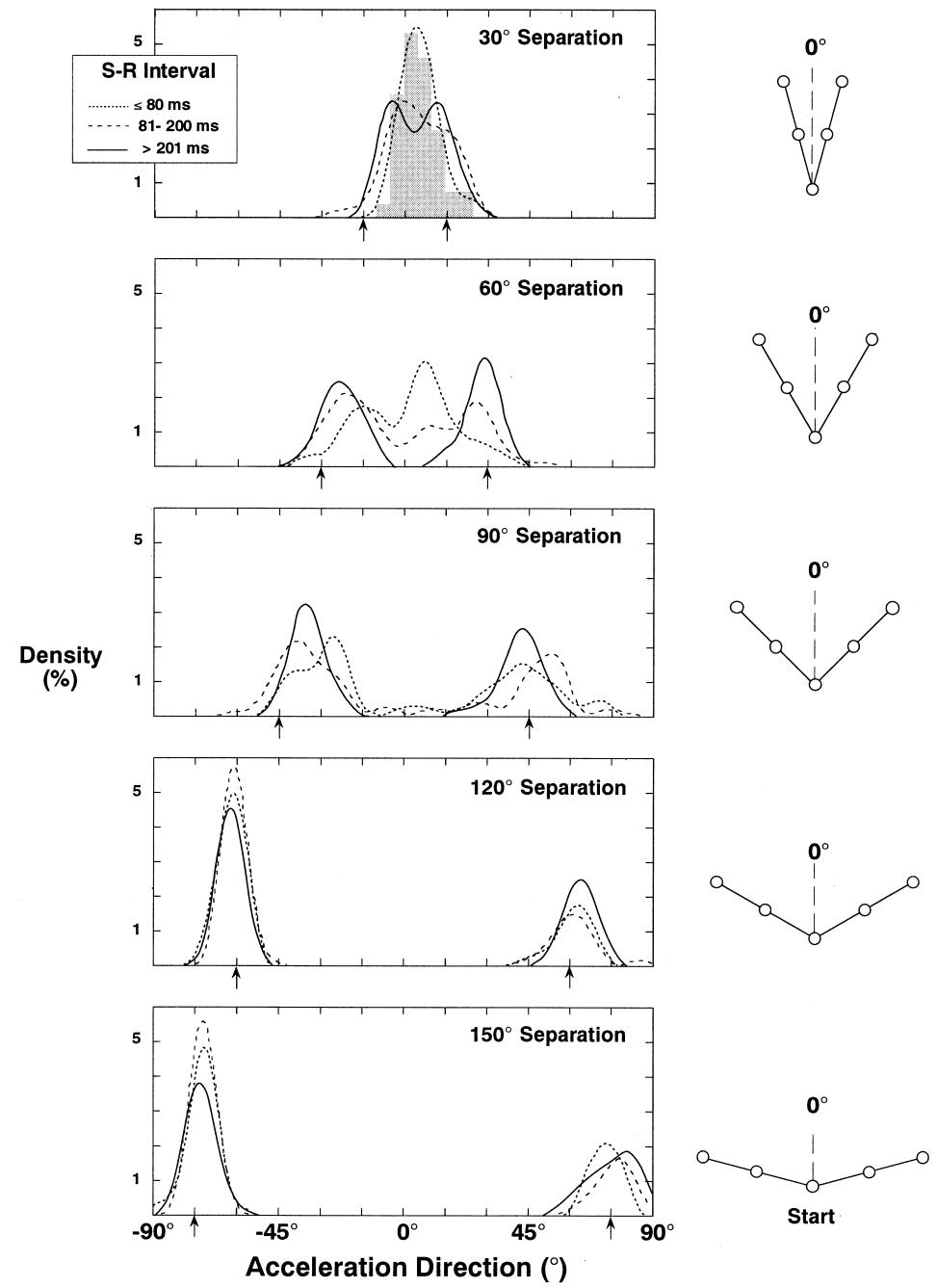


Experimental results of Henig et al



behavioral evidence for preshape

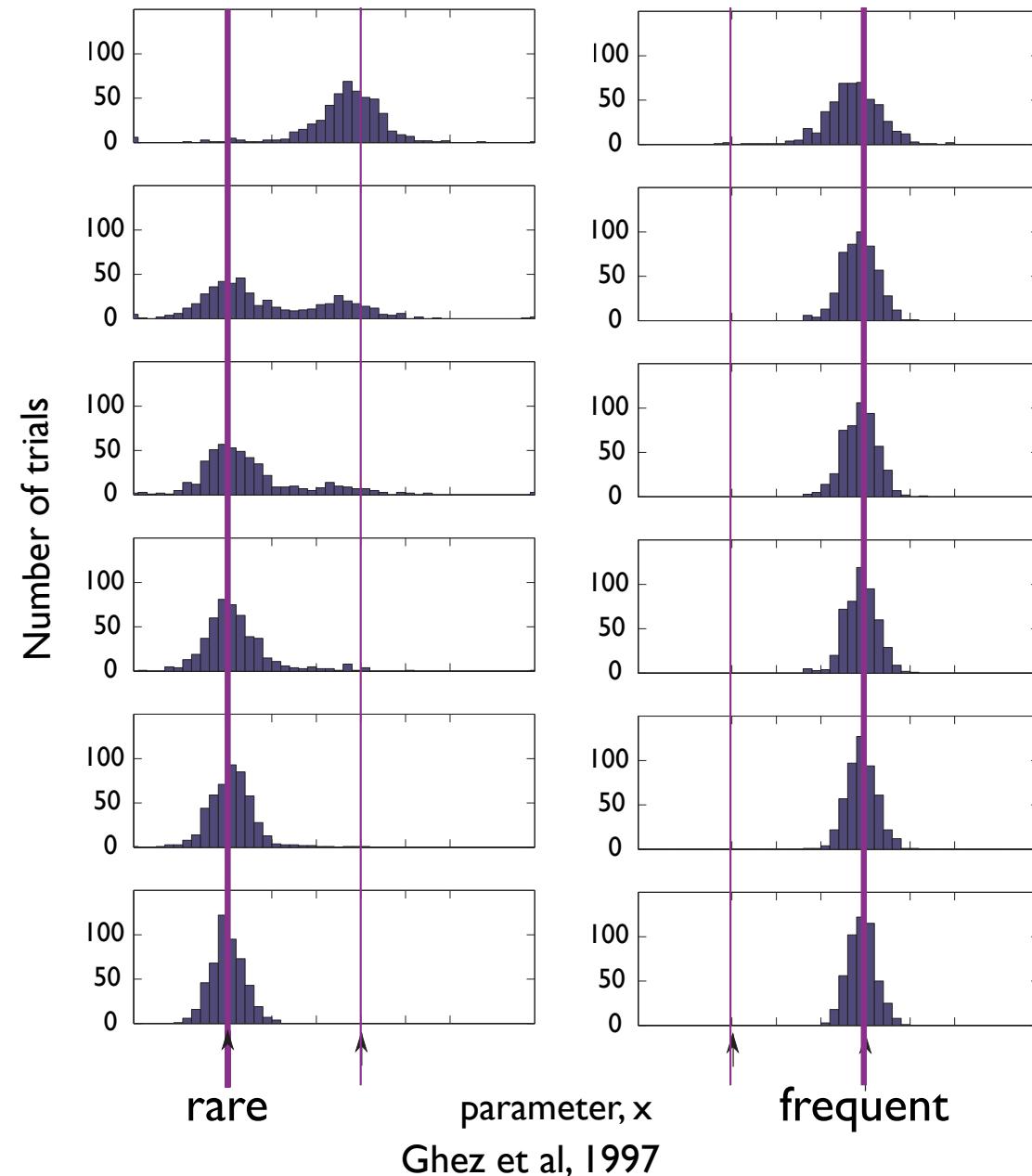
■ infer width of preshape peaks in field



[Ghez et al 1997]

behavioral evidence for preshape

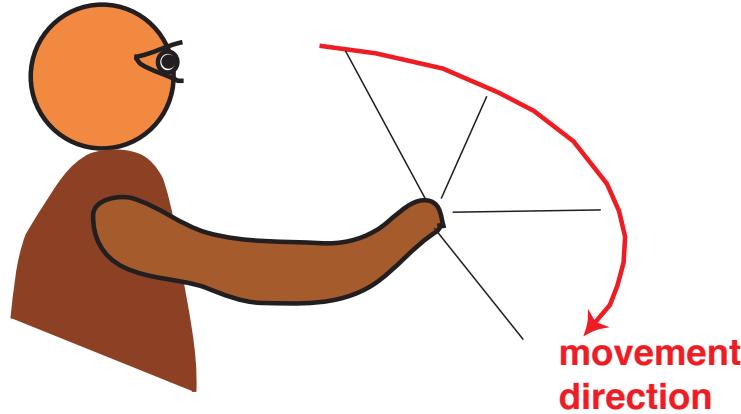
probability in timed movement initiation
rare frequent



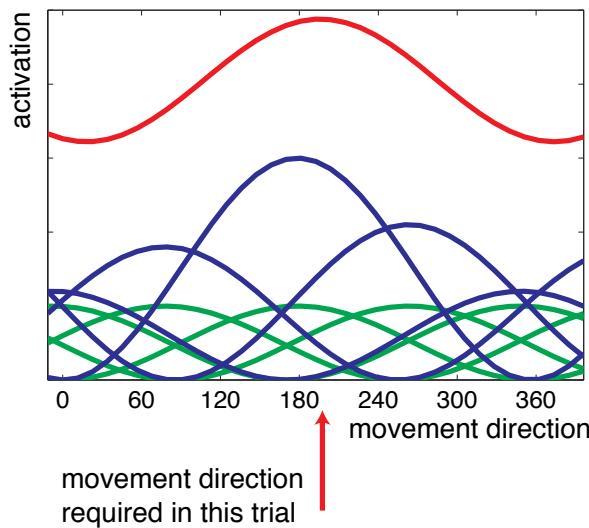
short SR interval:
observe preshape

long SR interval:
observe stimulus-defined
movement plan

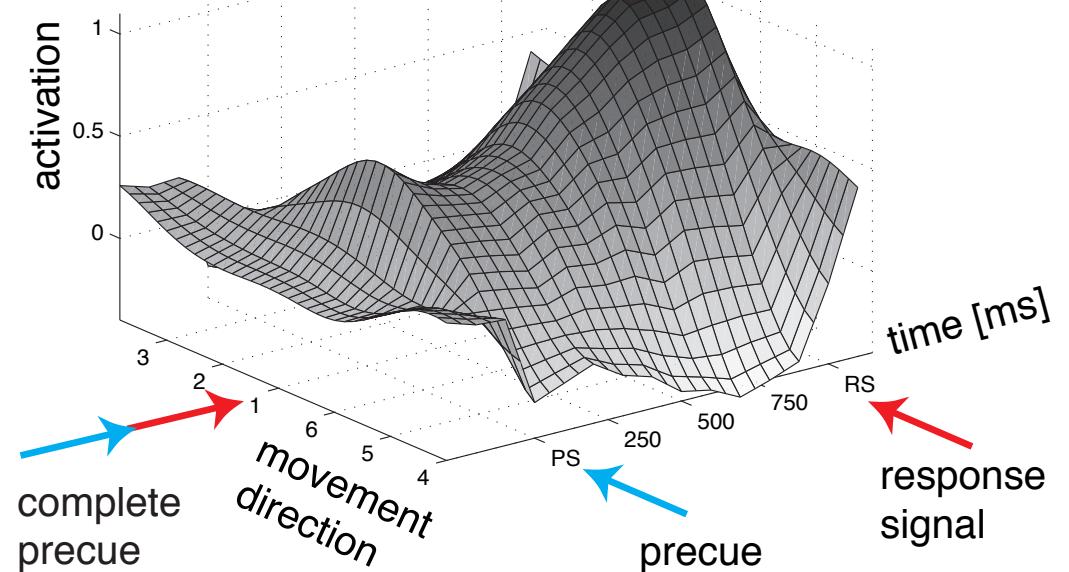
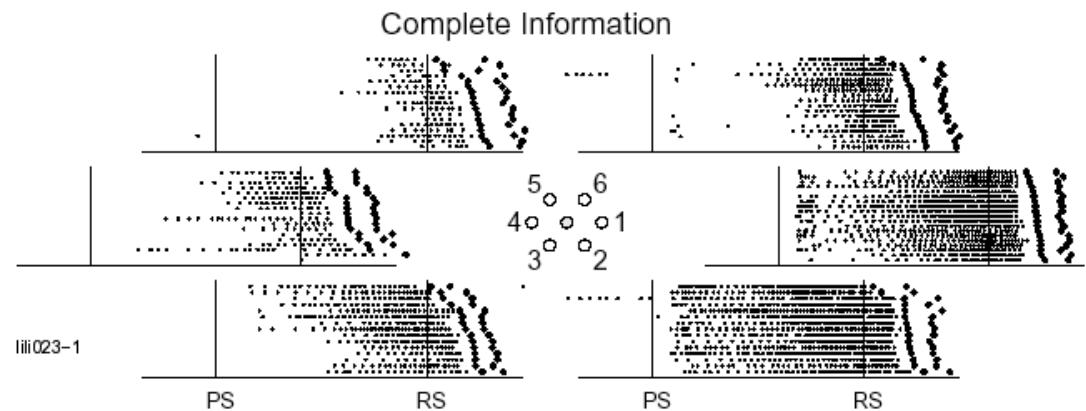
Neural evidence for preshape



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

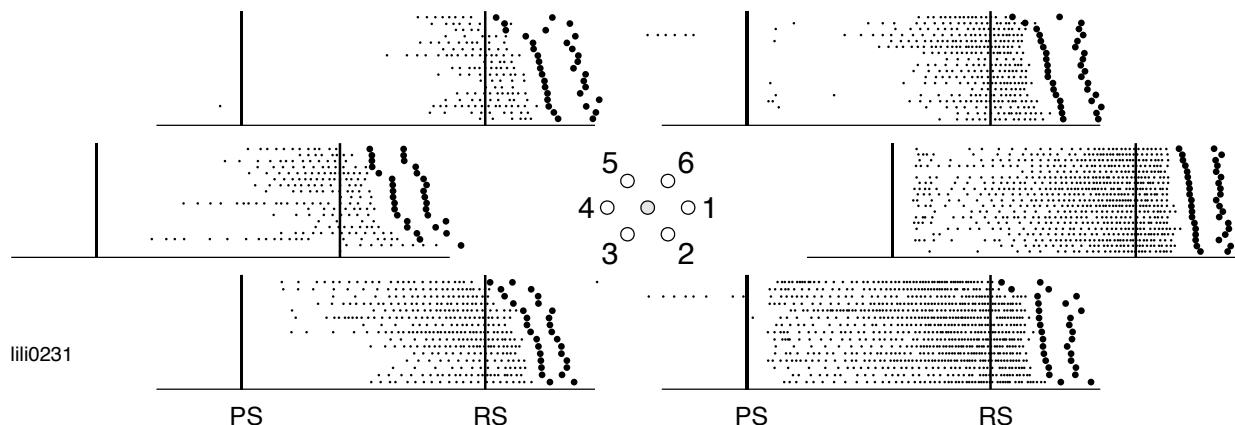


[after Bastian, Riehle, Schöner, submitted]

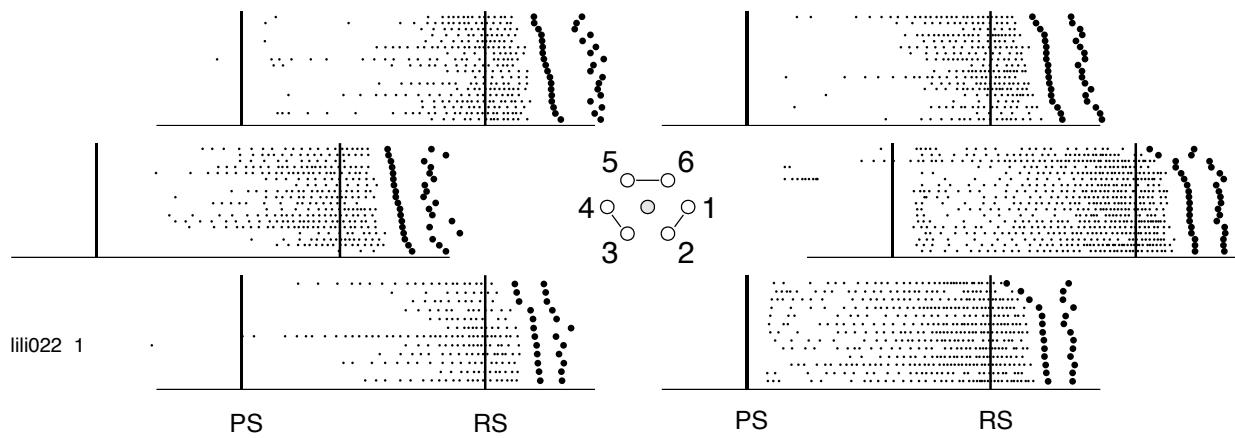


[Bastian, Riehle, Schöner: Europ J Neurosci 18: 2047 (2003)]

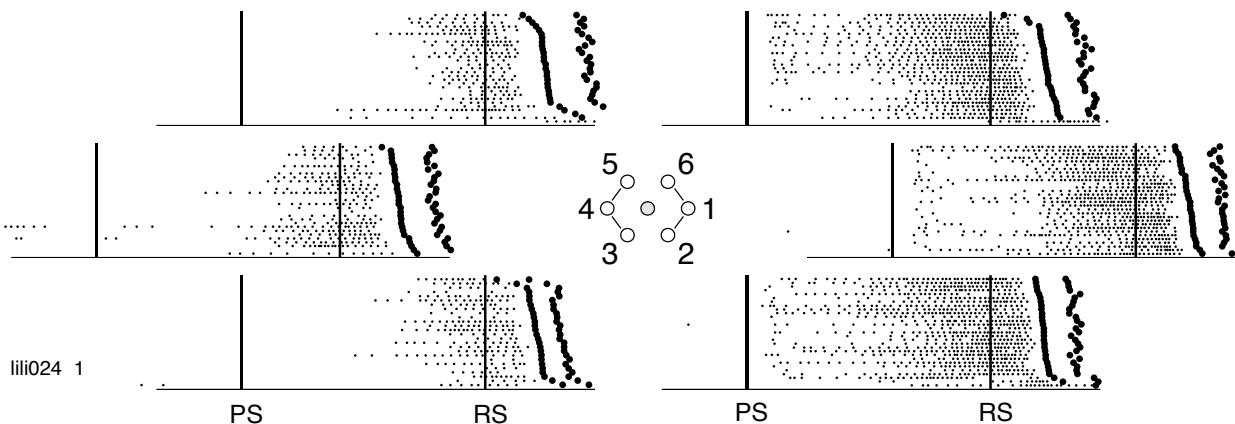
Complete Information



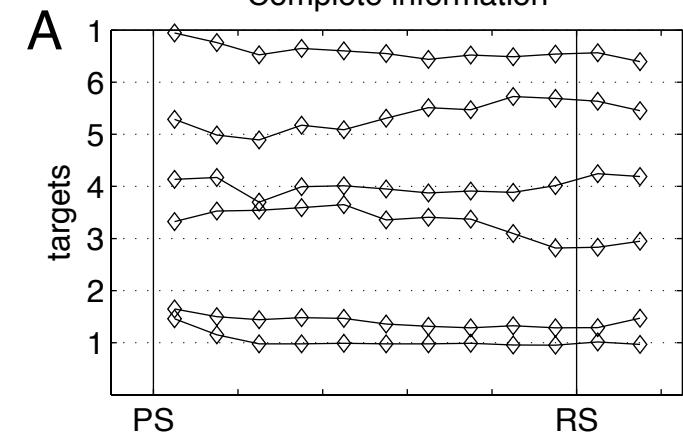
Two-target Information



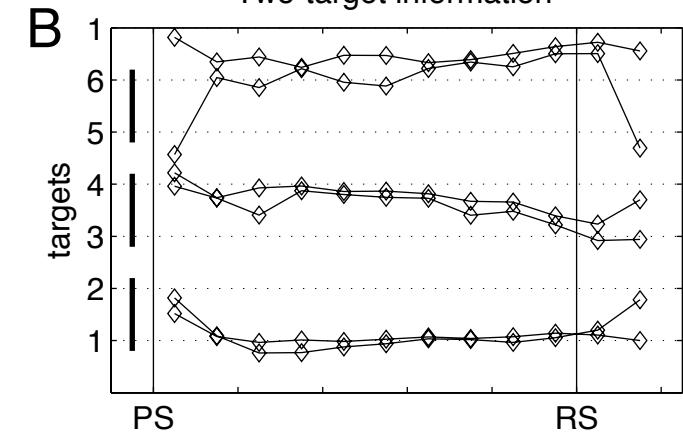
Three-target Information



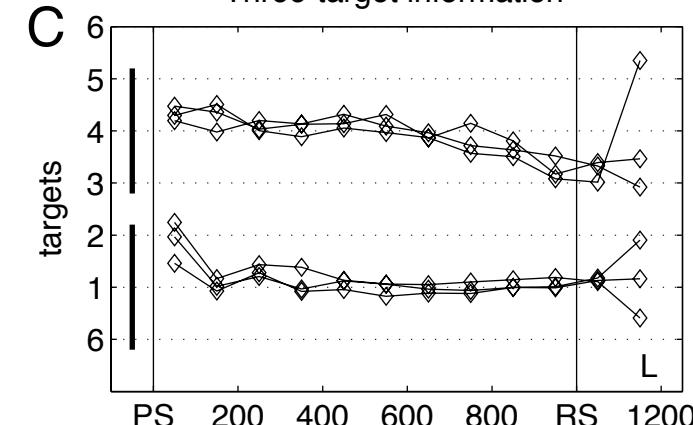
Complete information



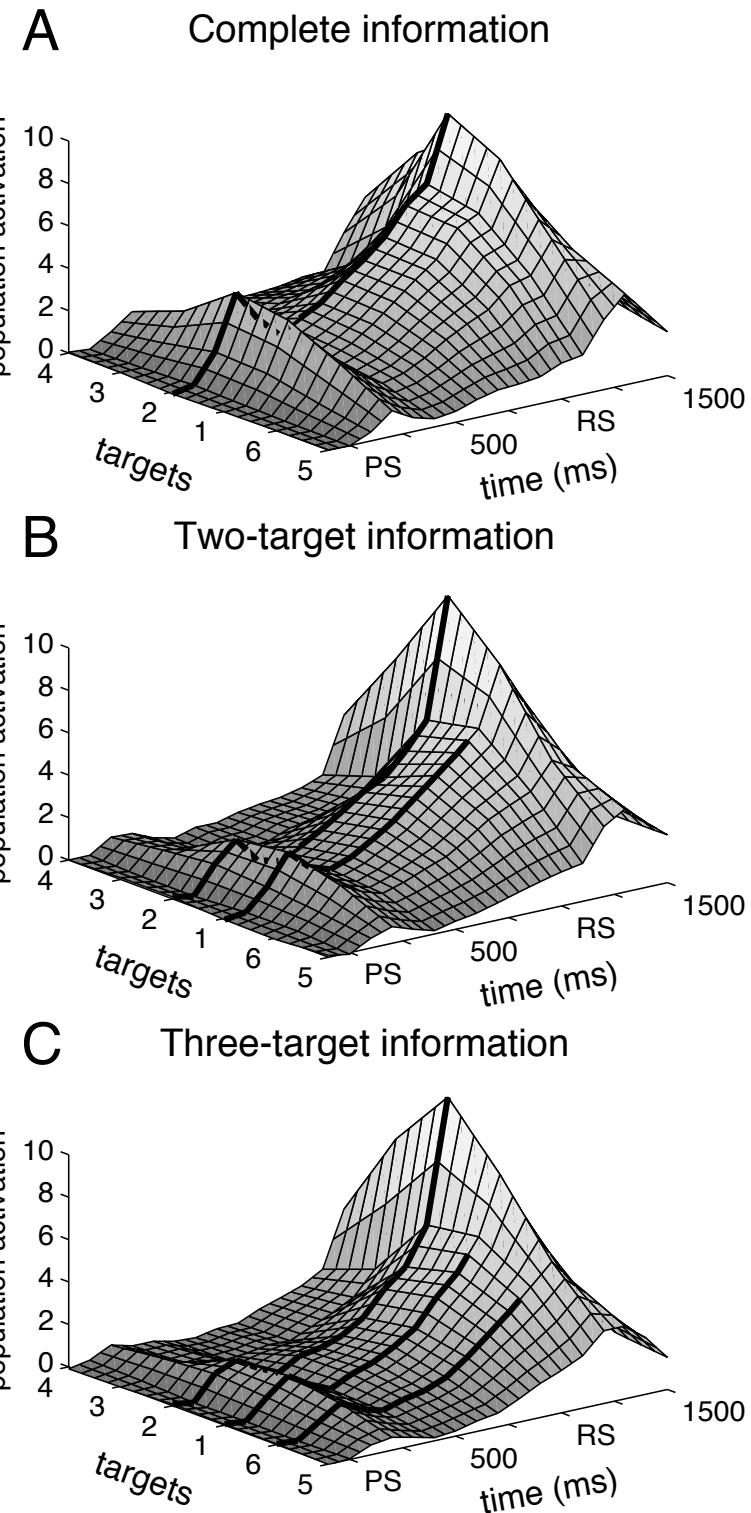
Two-target information



Three-target information

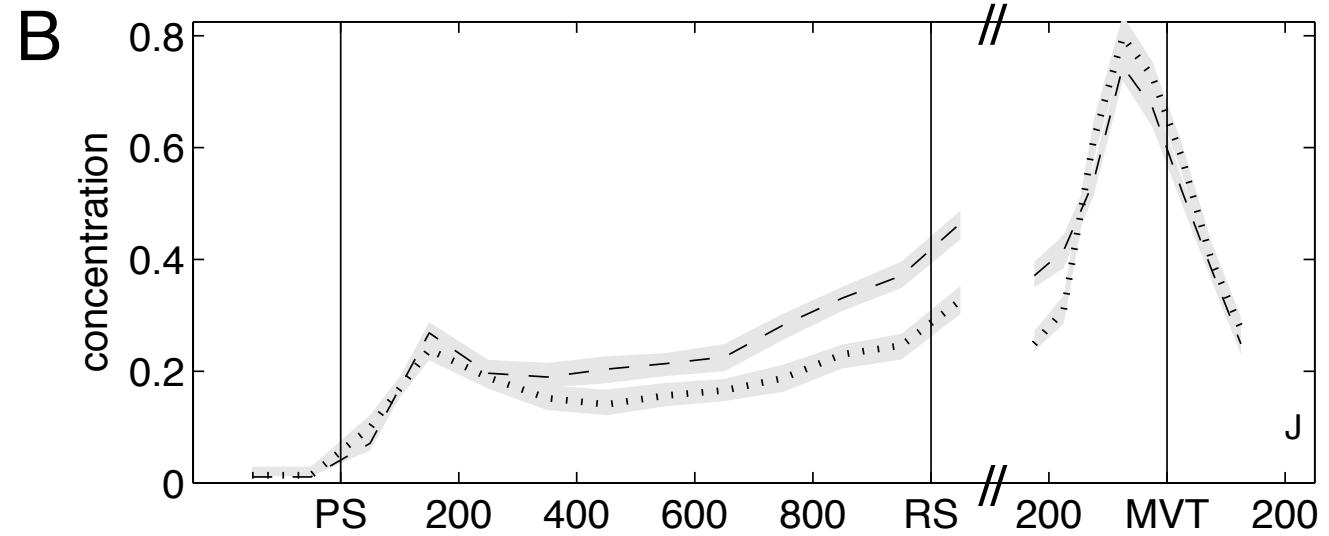
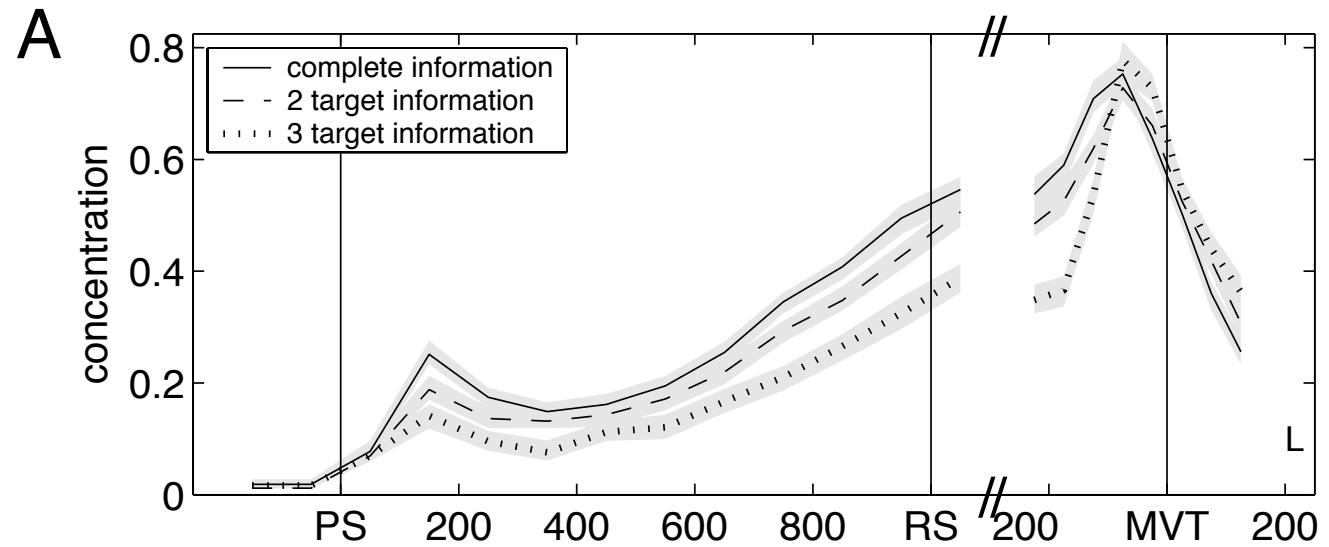


DPA reflects prior information



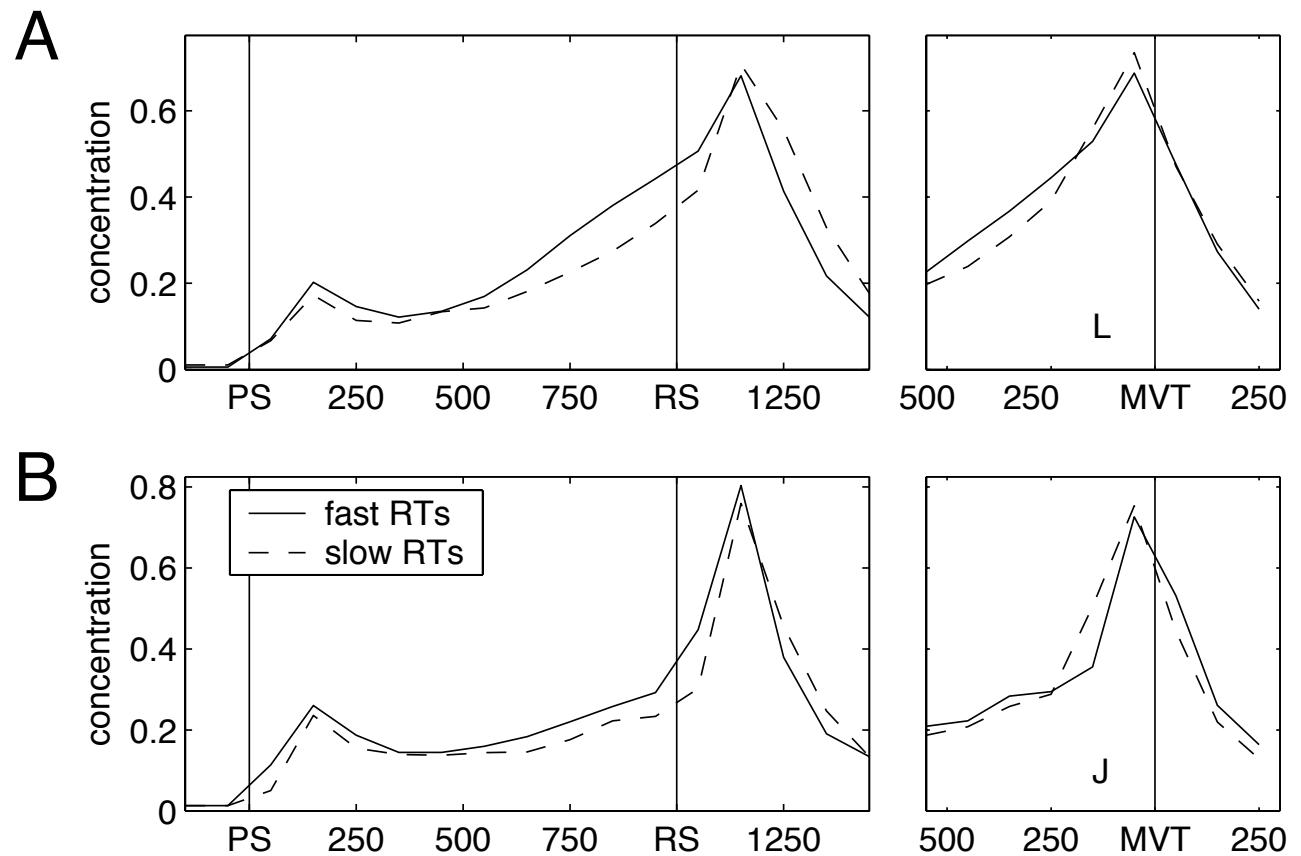
[Bastian, Schöner, Riehle 2003]

DPA reflects prior information



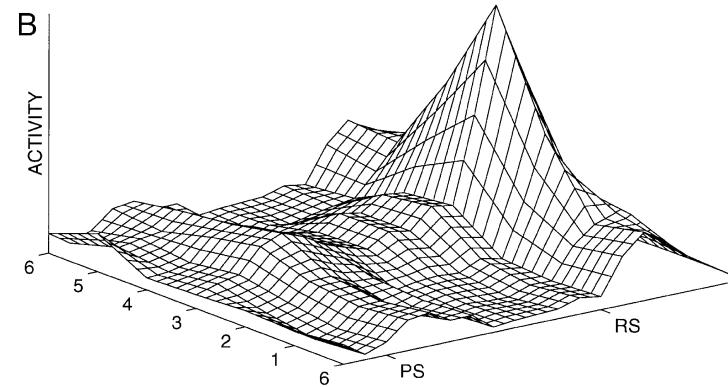
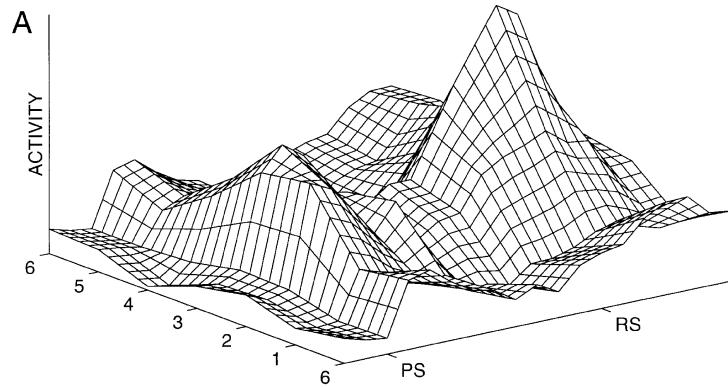
[Bastian, Schöner, Riehle 2003]

 preshape
correlates with RT

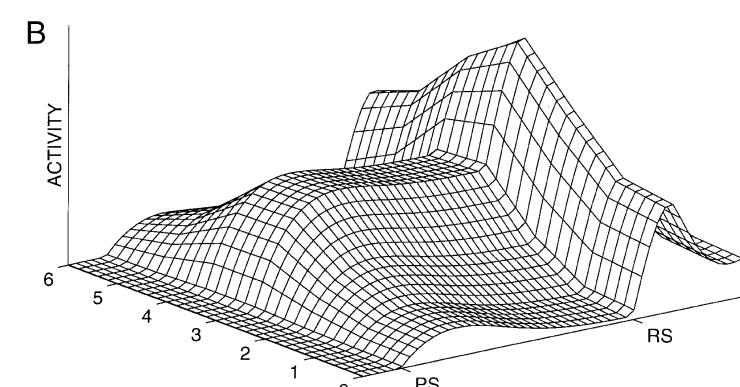
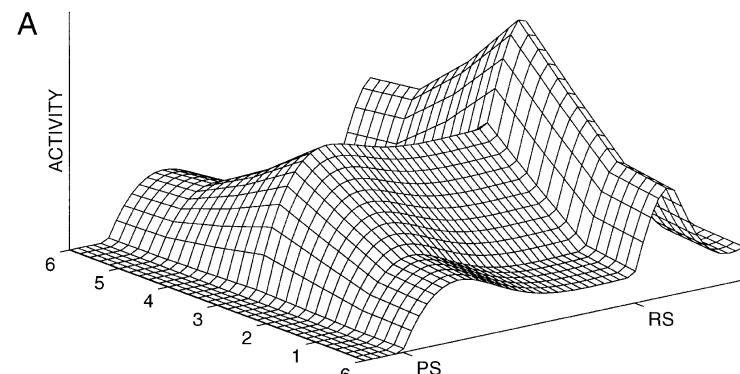


[Bastian, Schöner, Riehle 2003]

DPA experiment



DFT model



[Bastian, Riehle, Erhagen, Schöner, 98]