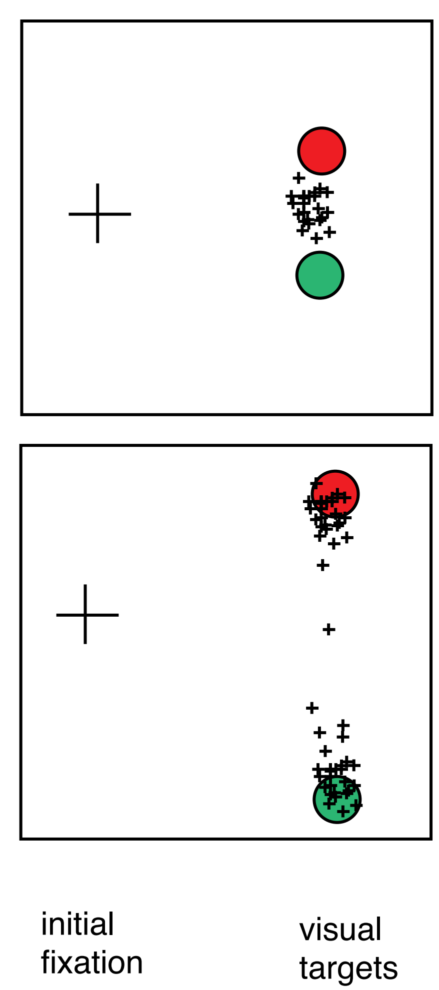
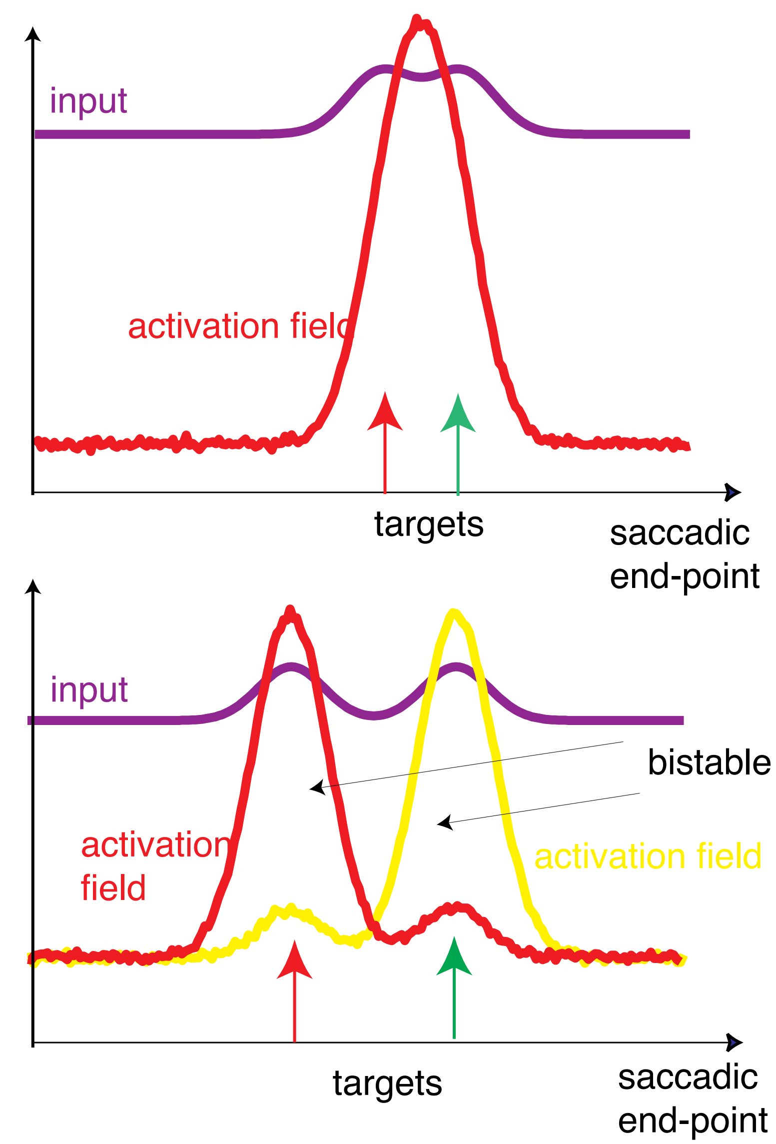
Dynamic Field Theory: Selection Decisions

Gregor Schöner
gregor.schoener@ini.rub.de

Recall from last lecture ...

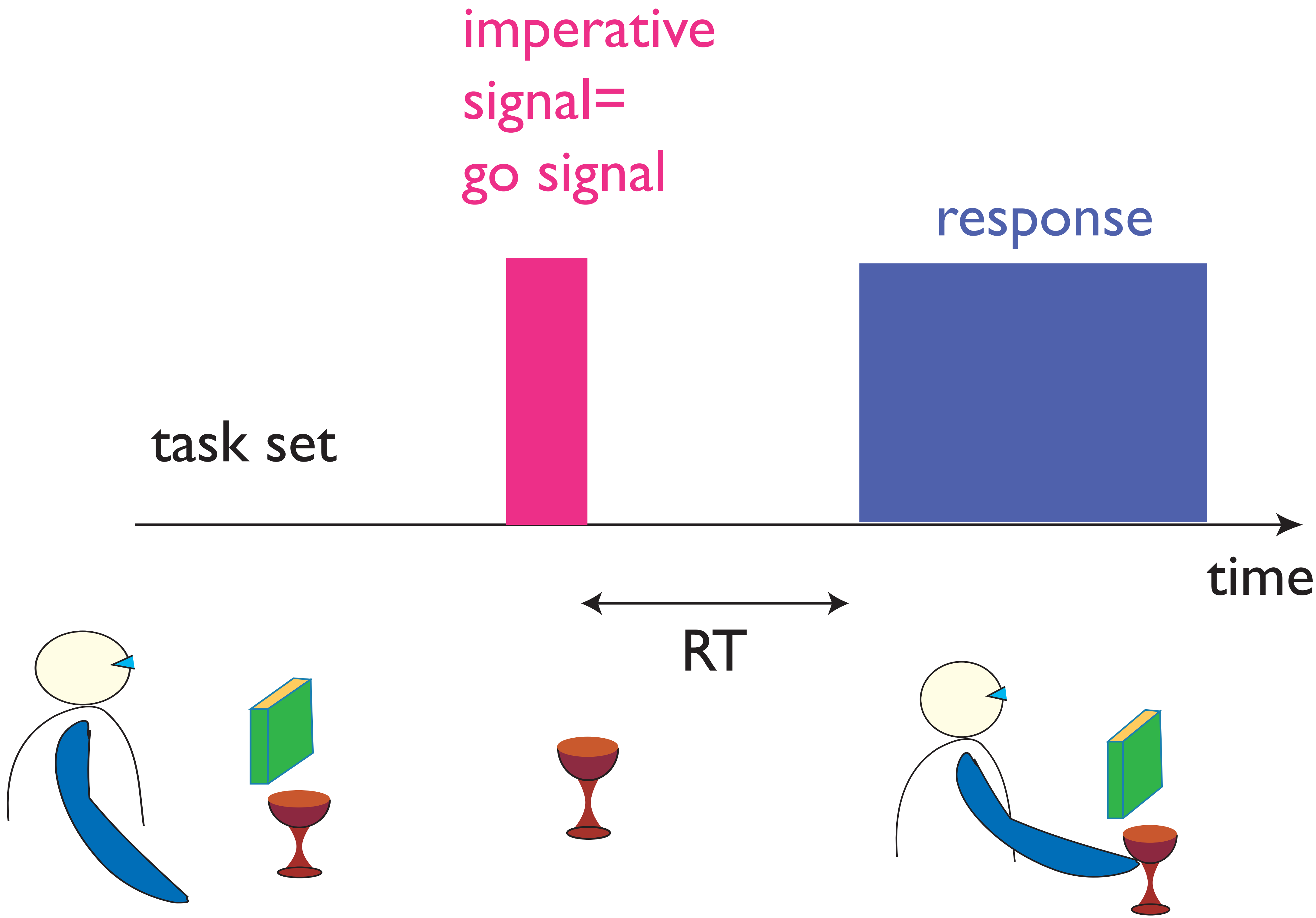


[after: Ottes et al., Vis. Res. 25:825 (85)]



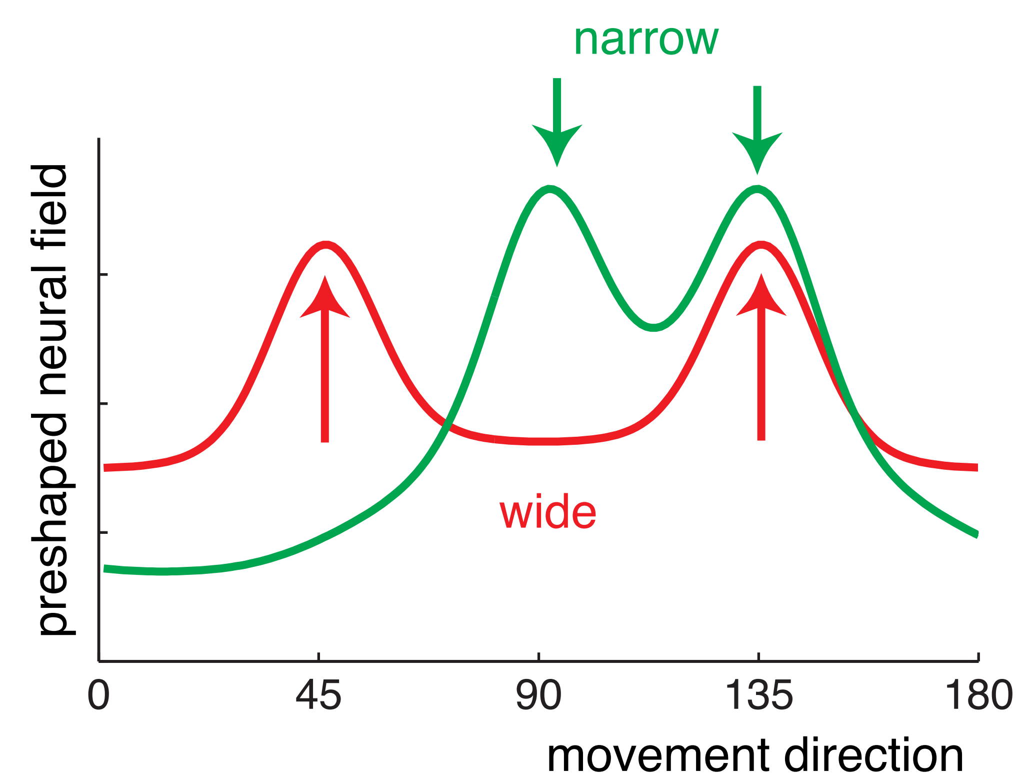
[after Kopecz, Schöner: Biol Cybern 73:49 (95)]

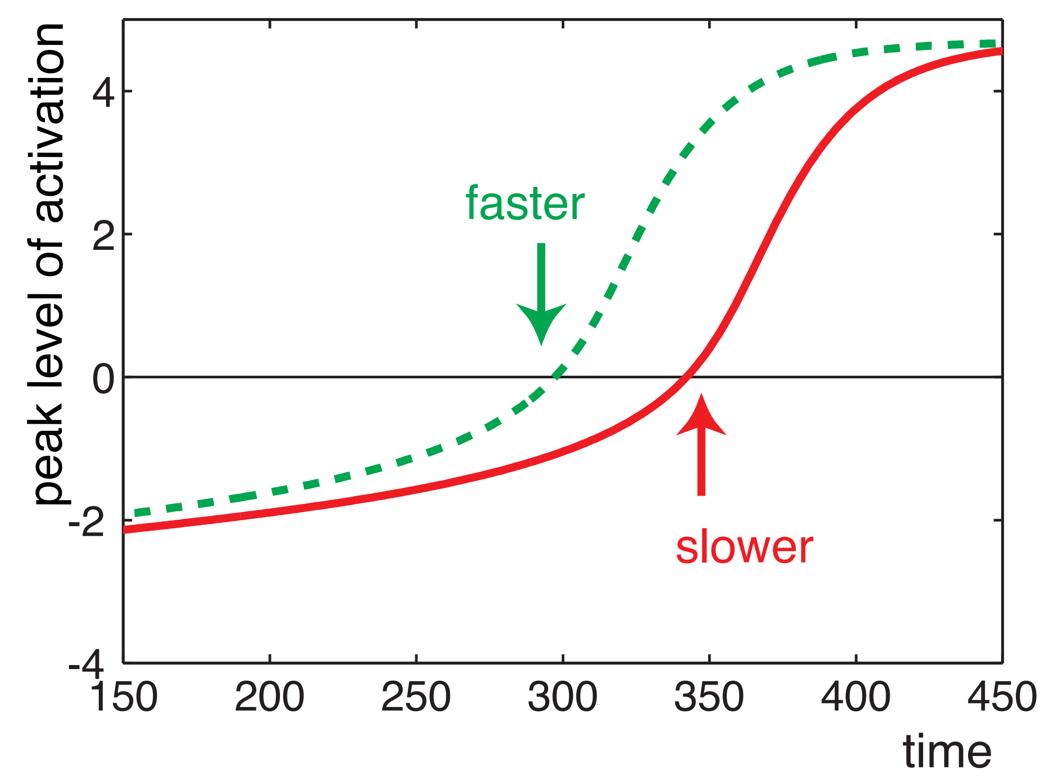
reaction time (RT) paradigm



metric effect

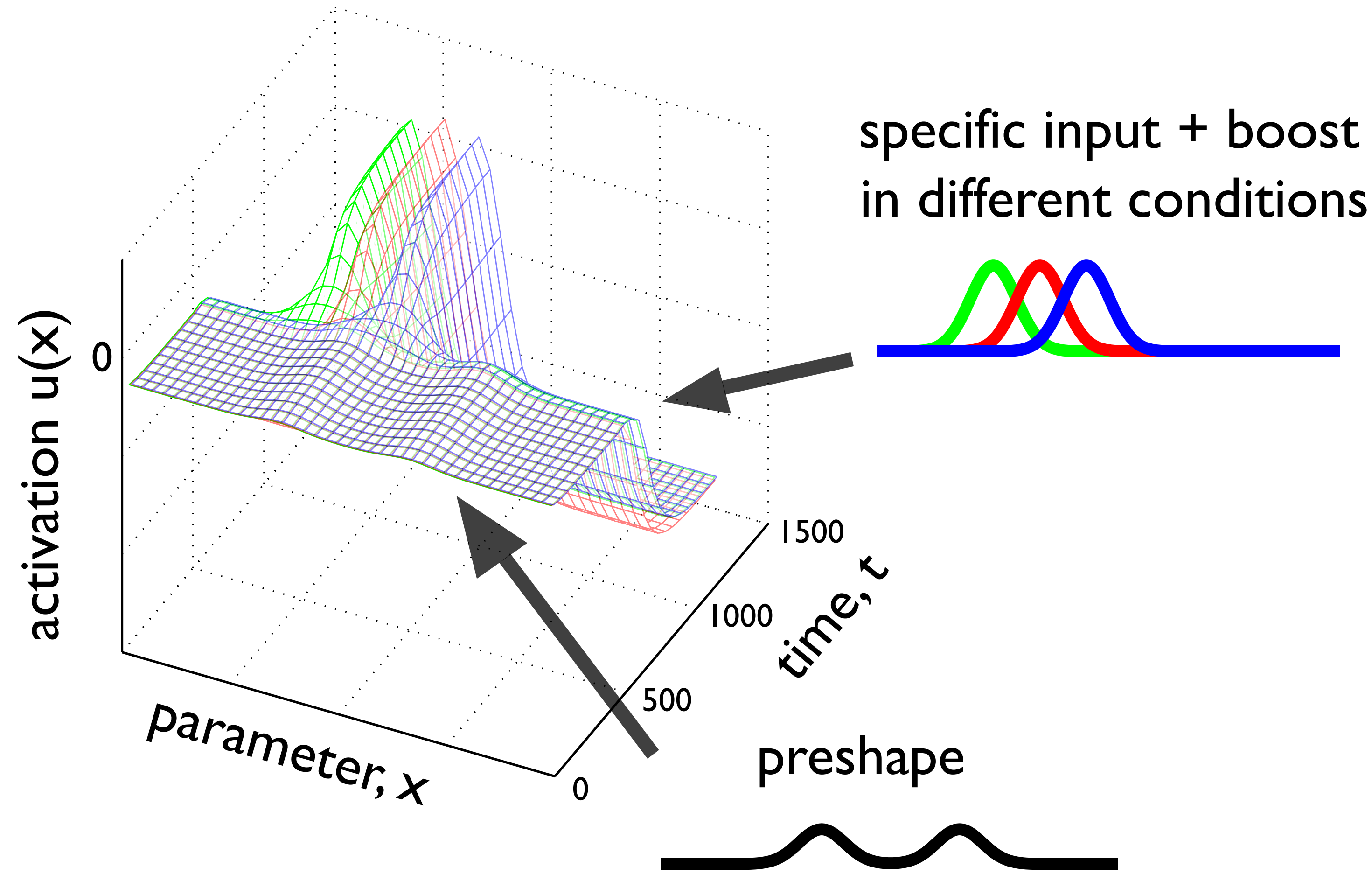
- predict faster response times for metrically close than for metrically far choices



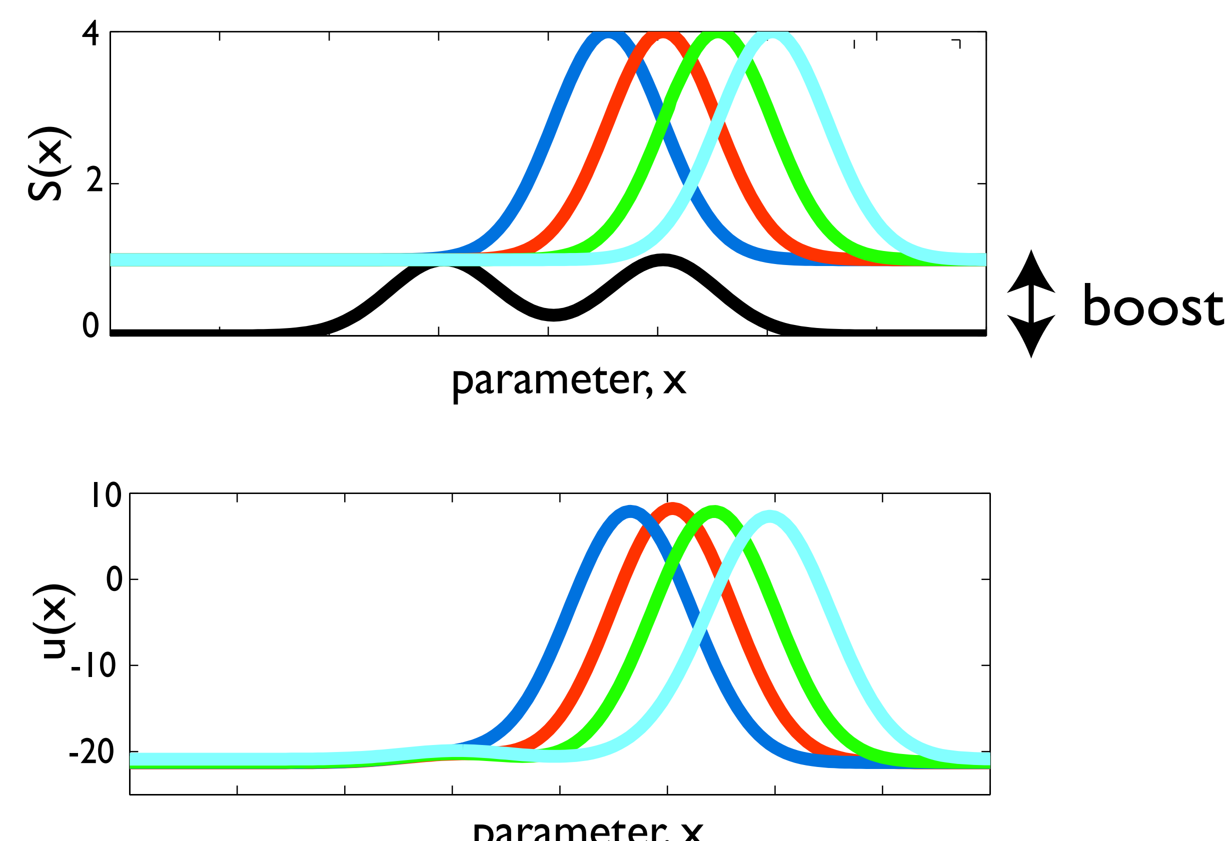


[from Schöner, Kopecz, Erlhagen, 1997]

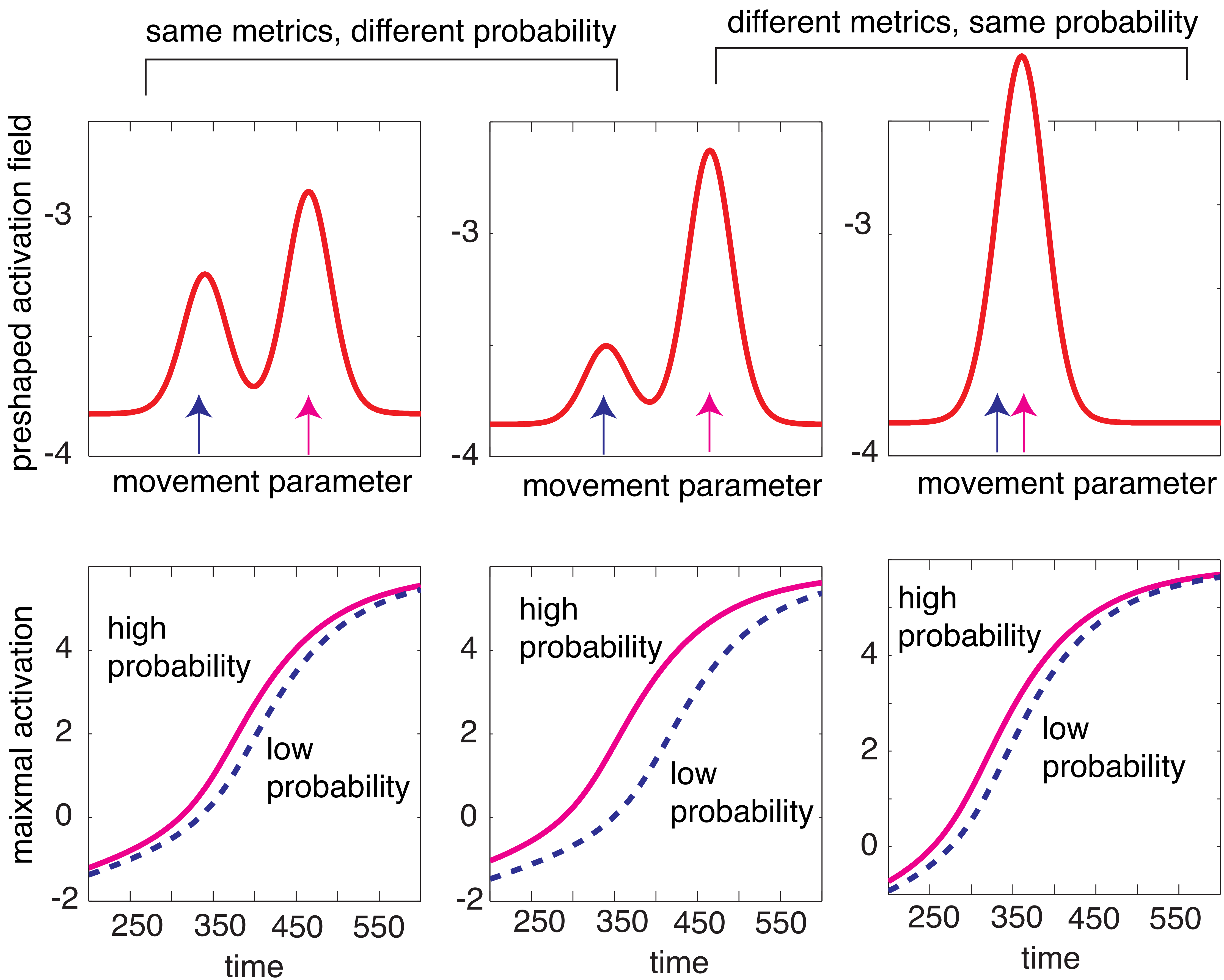
weak preshape in selection



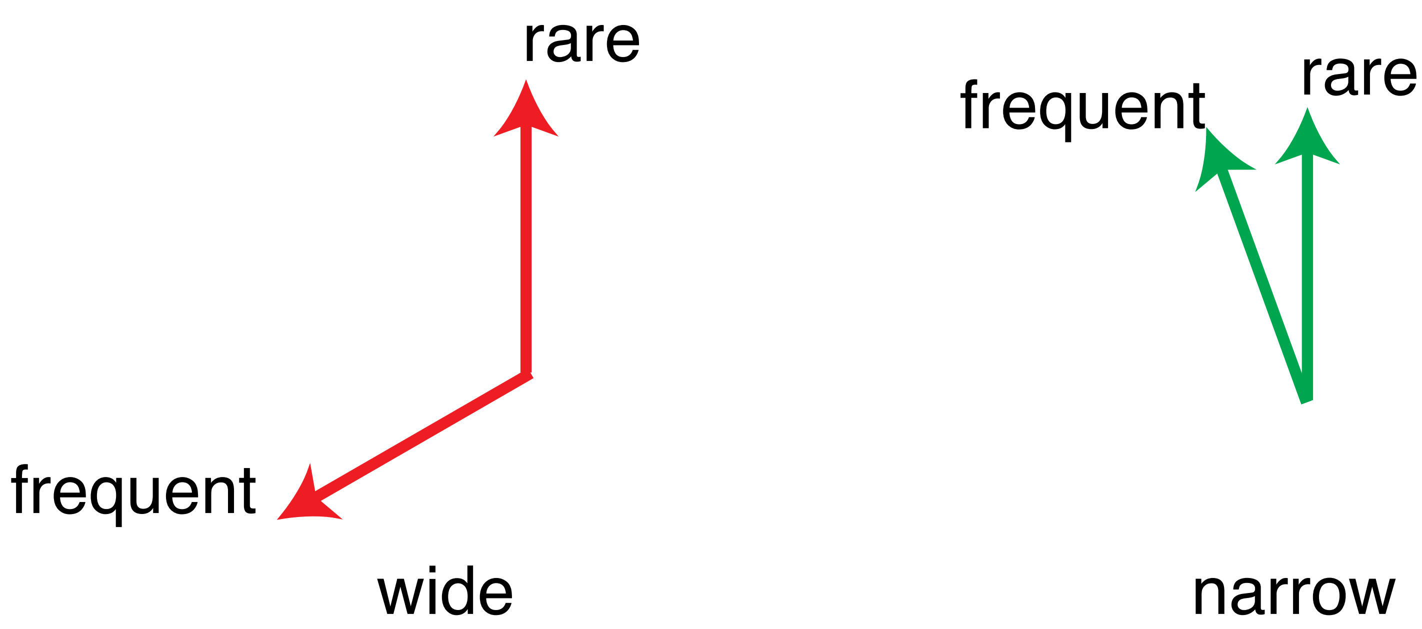
- specific (imperative) input dominates and drives detection instability

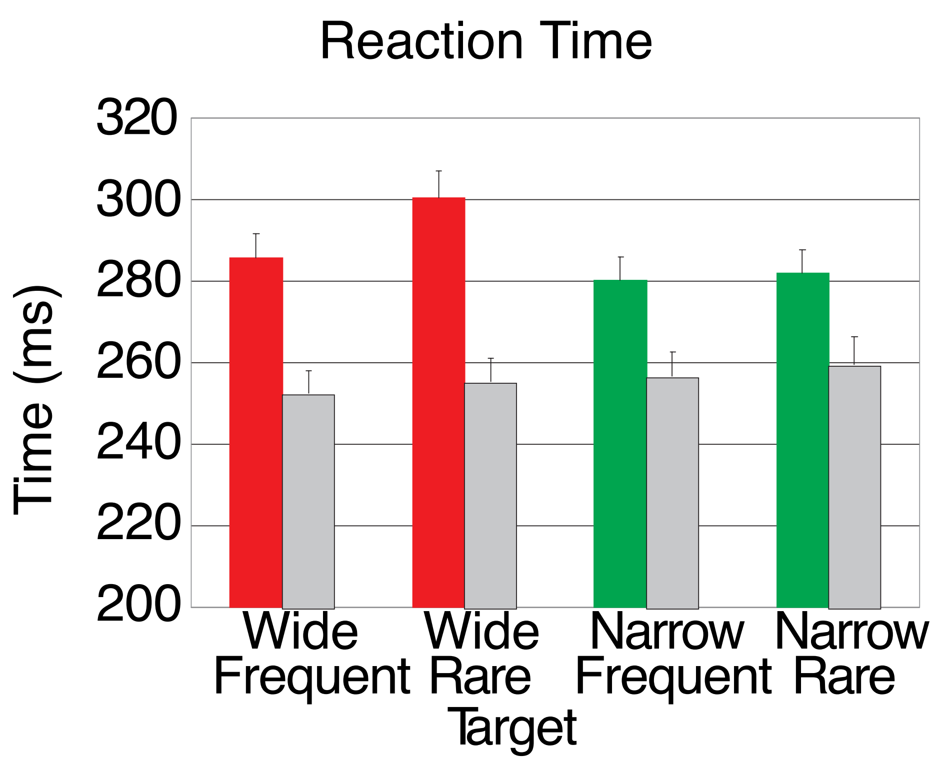


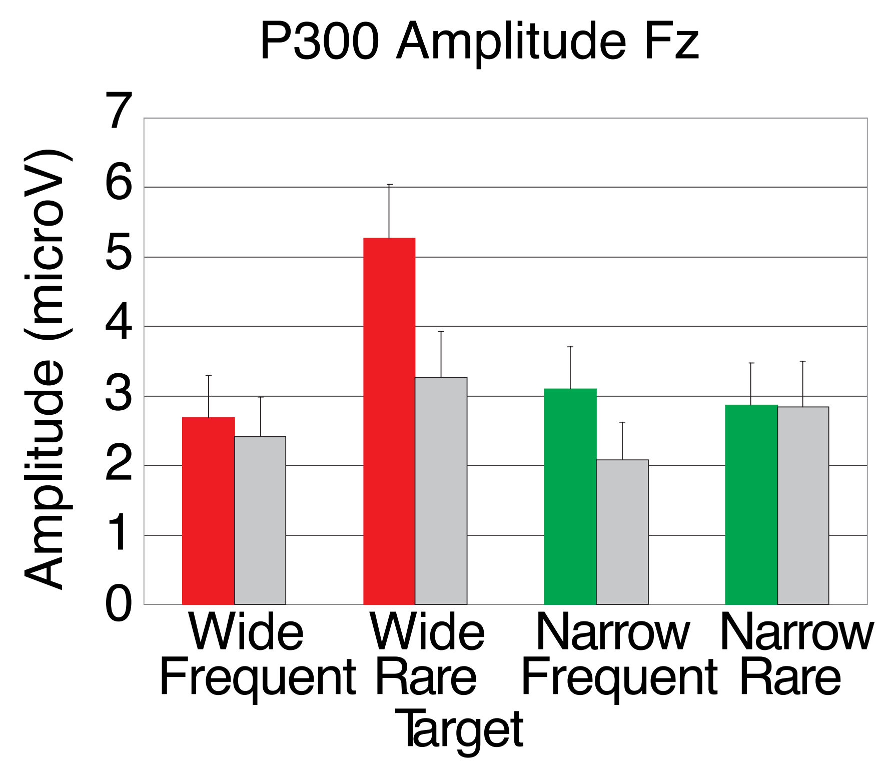
[Wilimzig, Schöner, 2006]



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

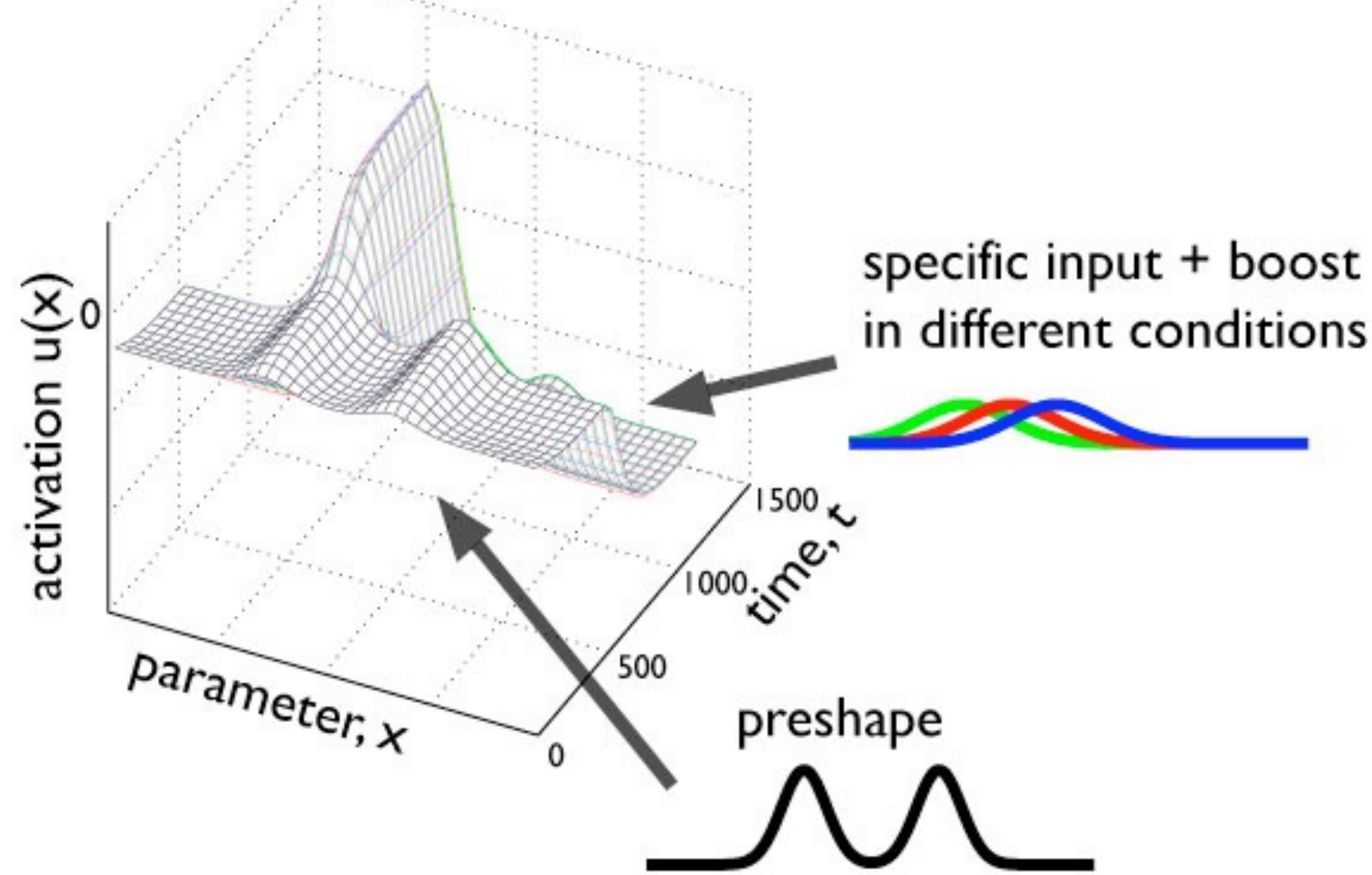




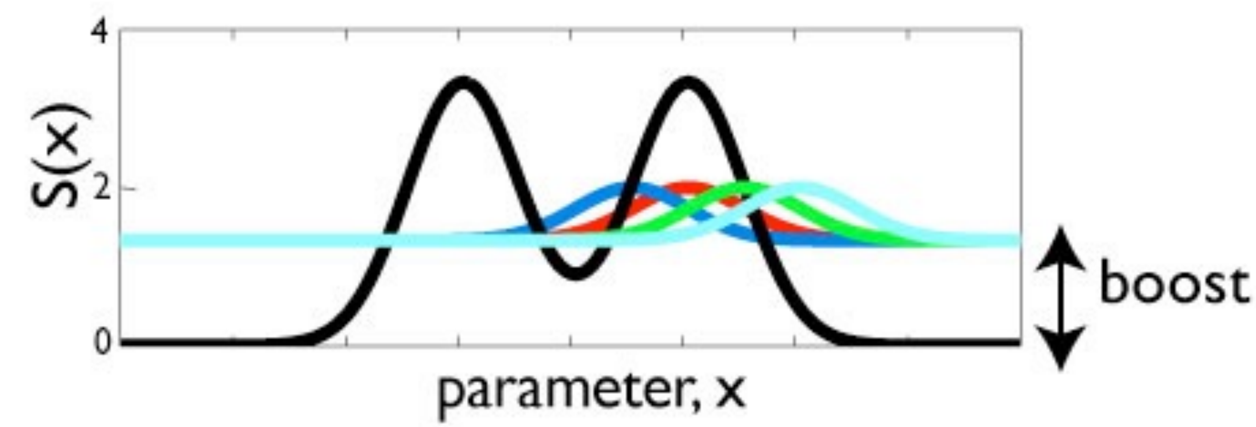


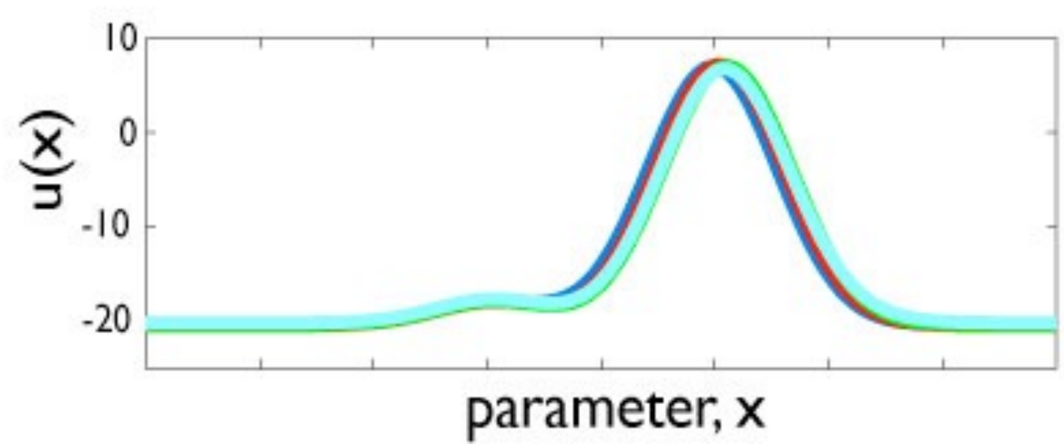
[from McDowell, Jeka, Schöner, Hatfield, 2002]

this supports categorical behavior



- when preshape dominates

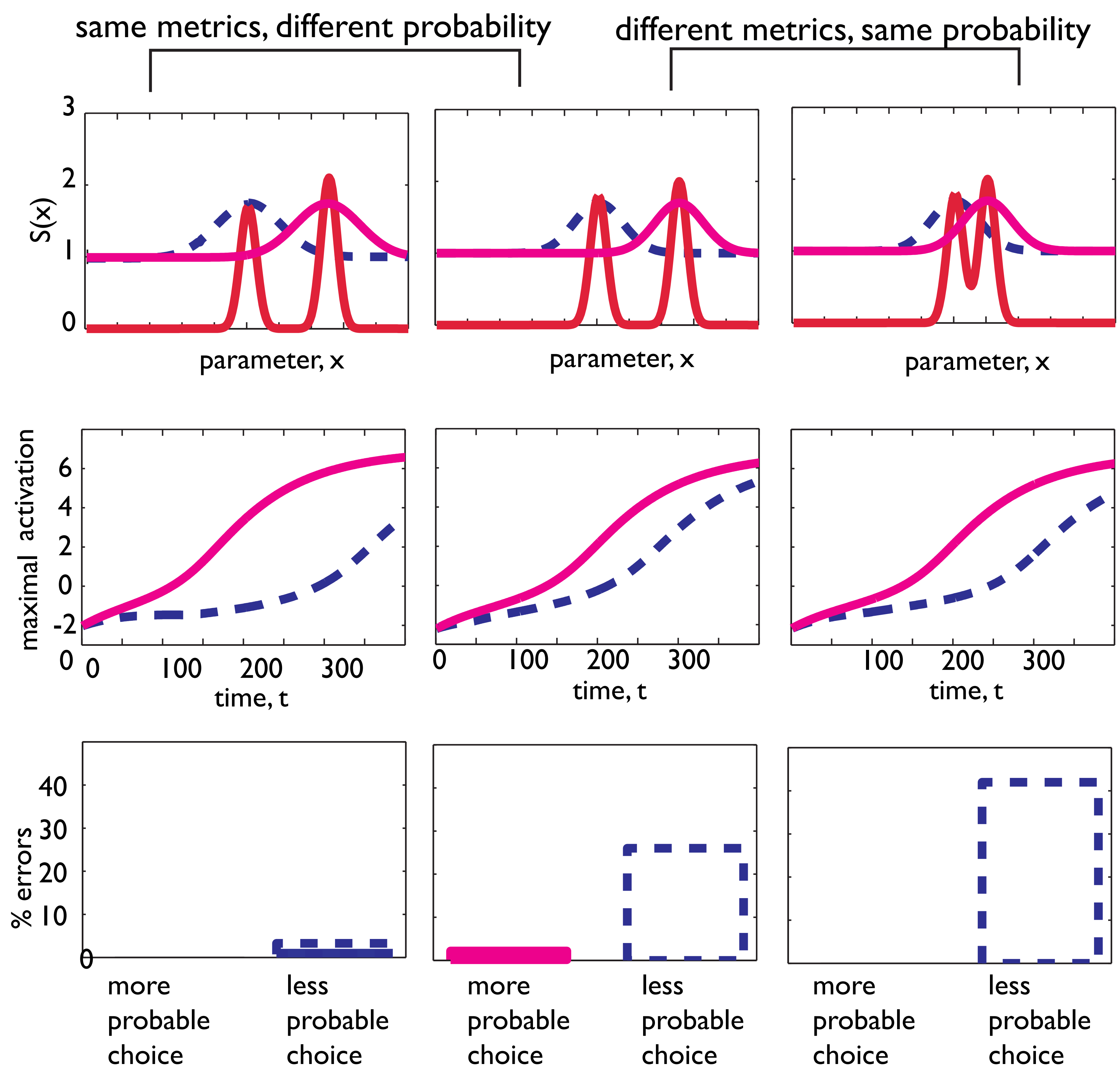




[Wilimzig, Schöner, 2006]

interaction metrics-probability

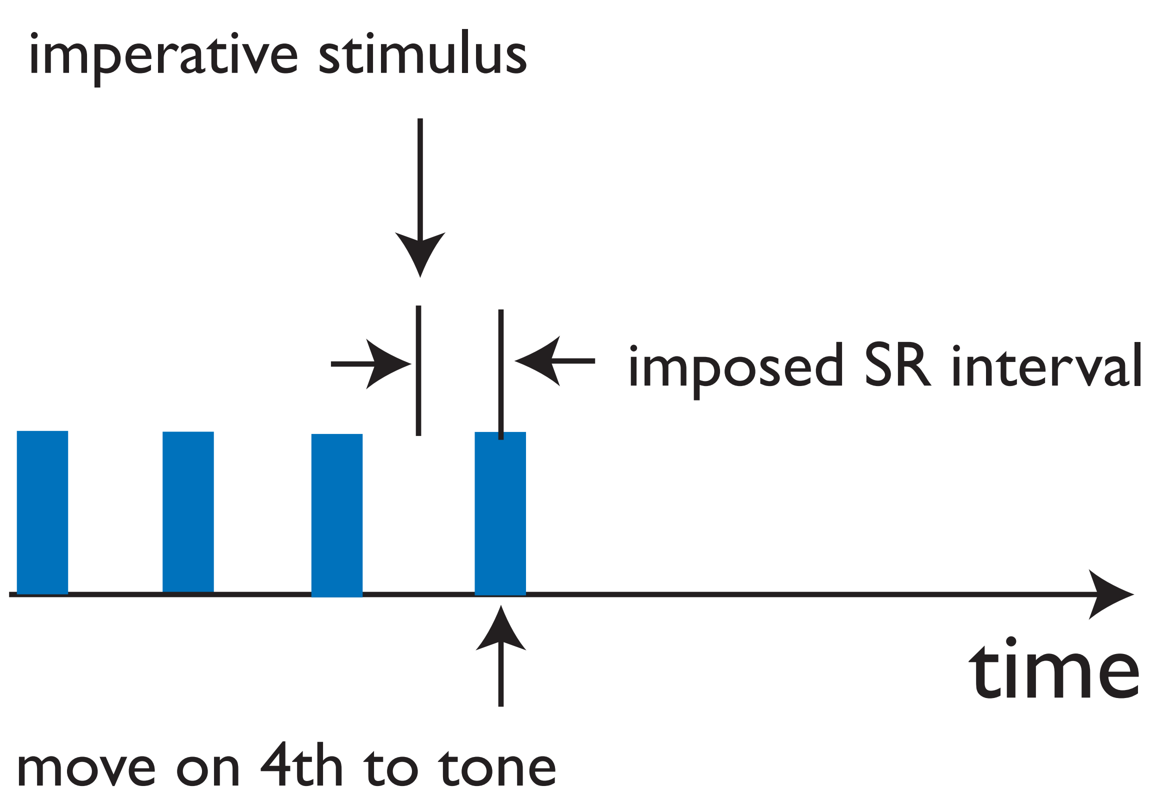
- opposite to that predicted for input-driven detection instabilities:
- metrically close choices show larger effect of probability



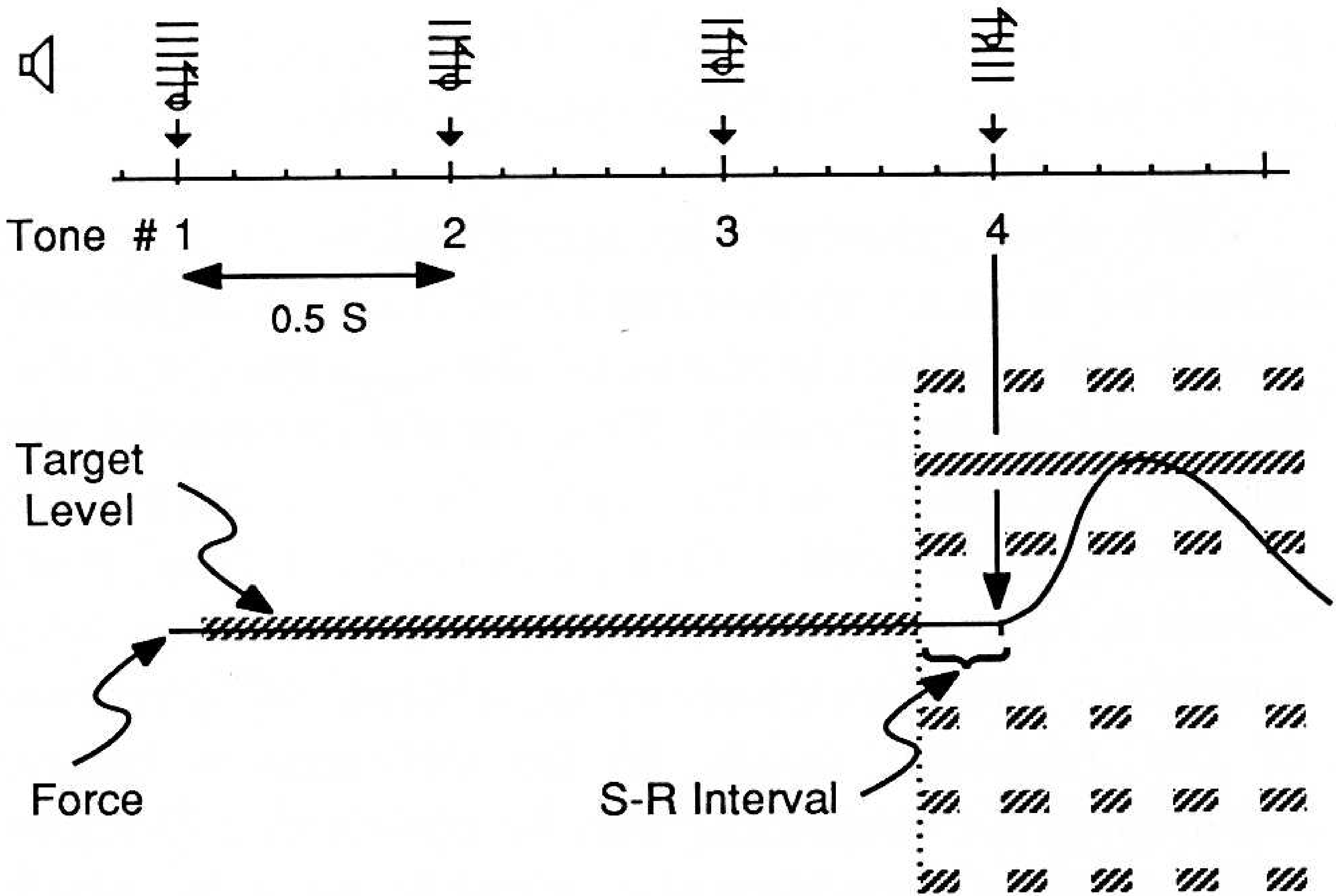
Wilimzig, Schöner, 2006

Behavioral evidence for the graded and continuous evolution of decision

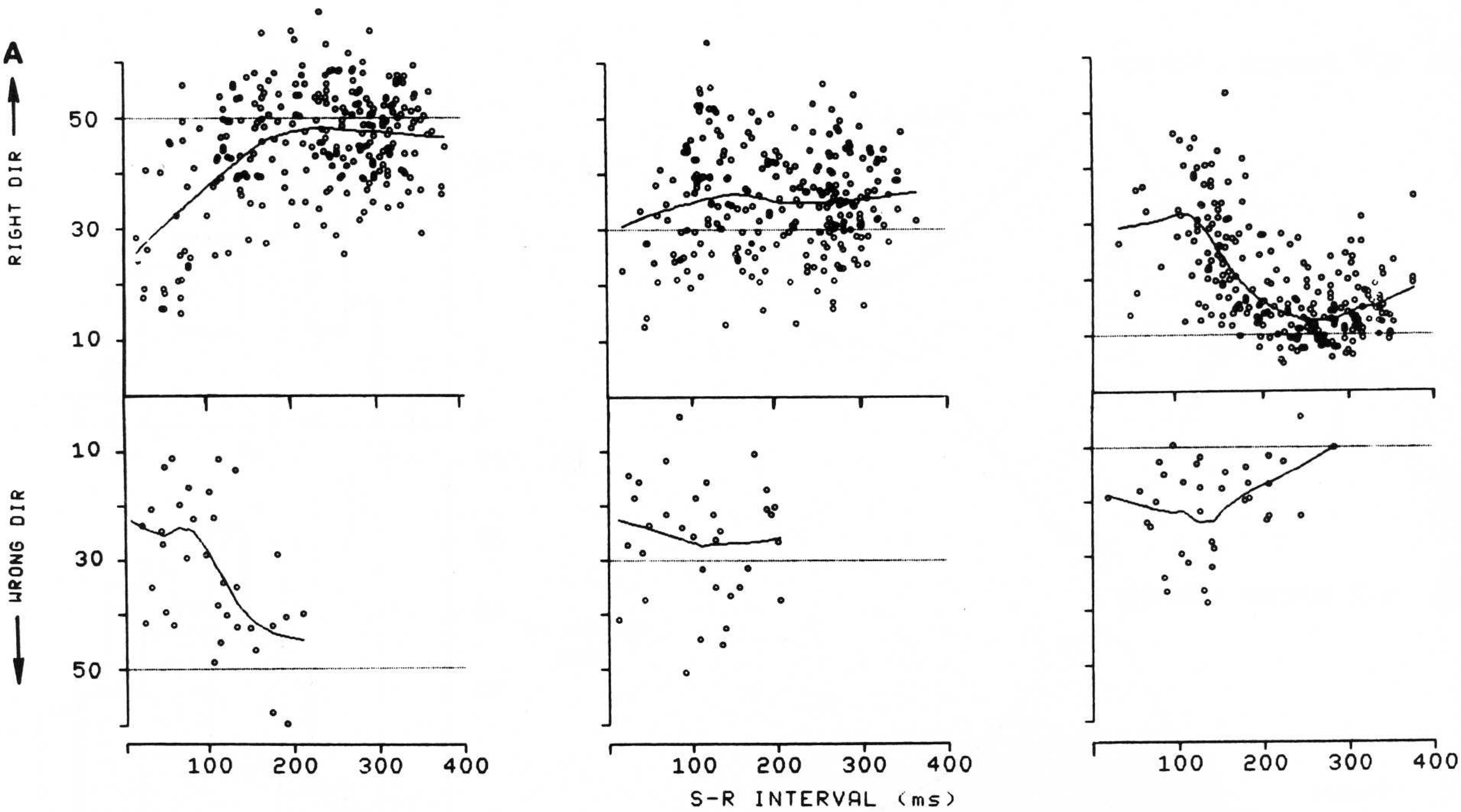
timed movement
initiation paradigm



[Ghez and colleagues, 1988 to 1990's]

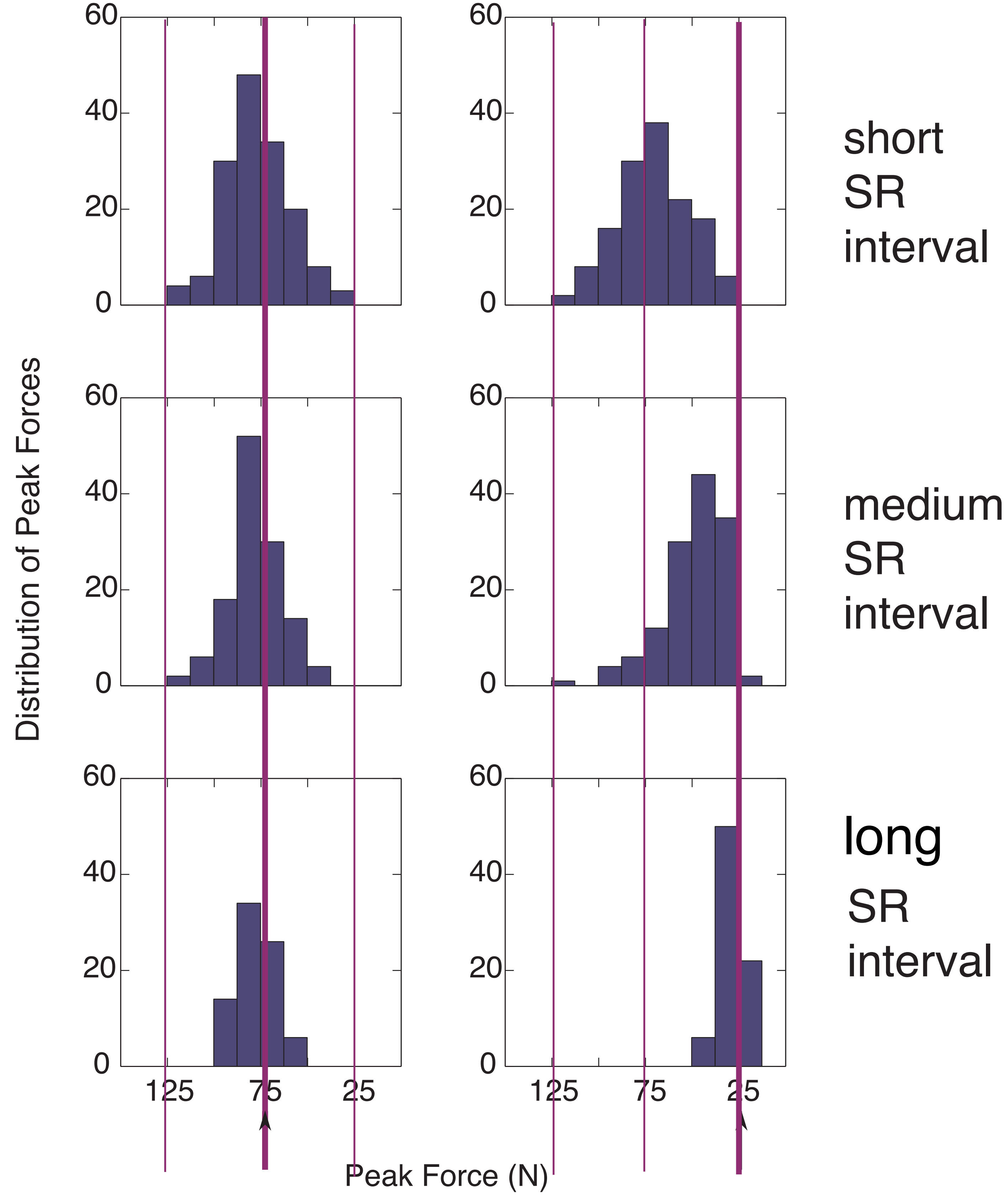


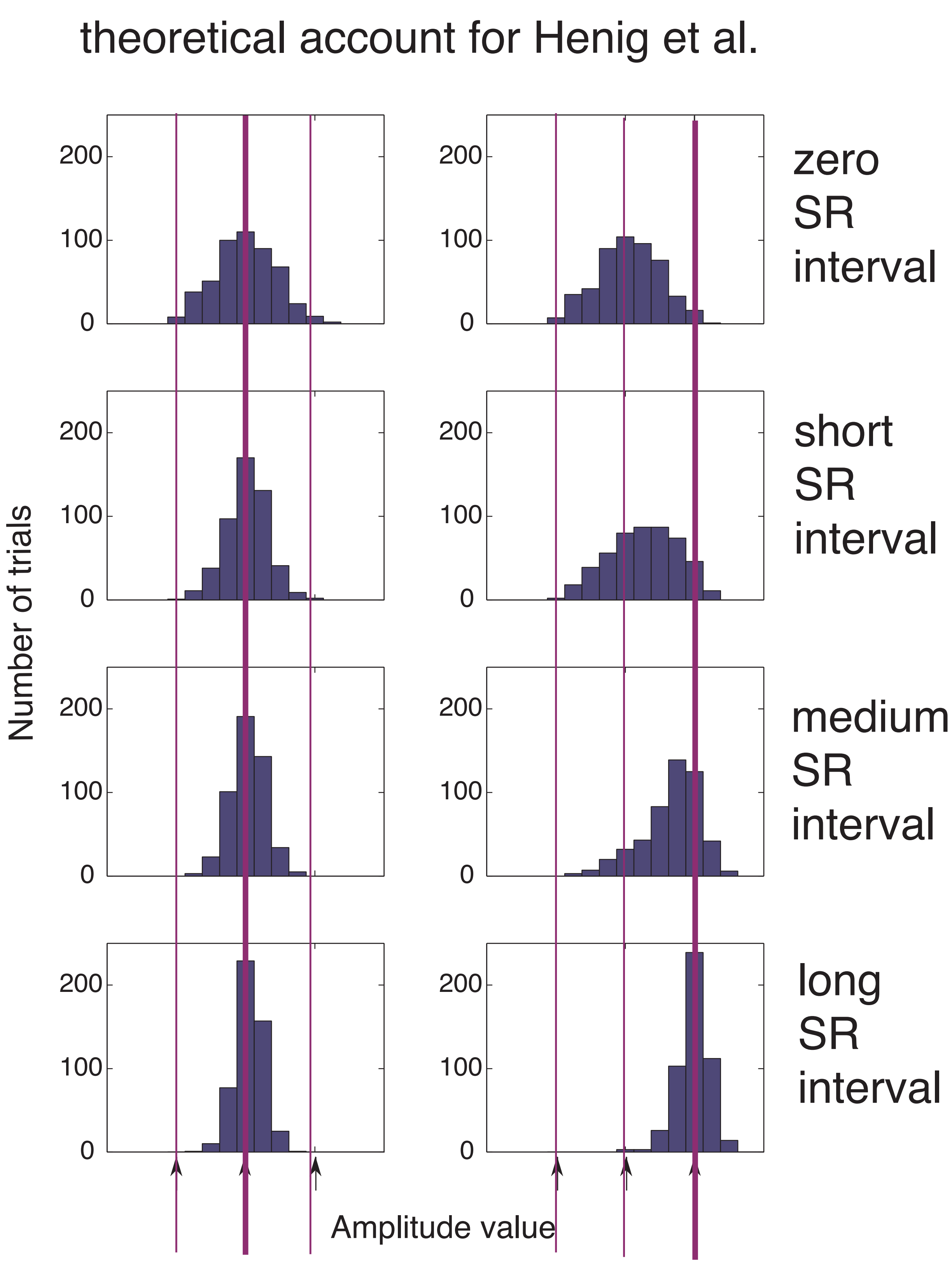
[Favilla et al. 1989]

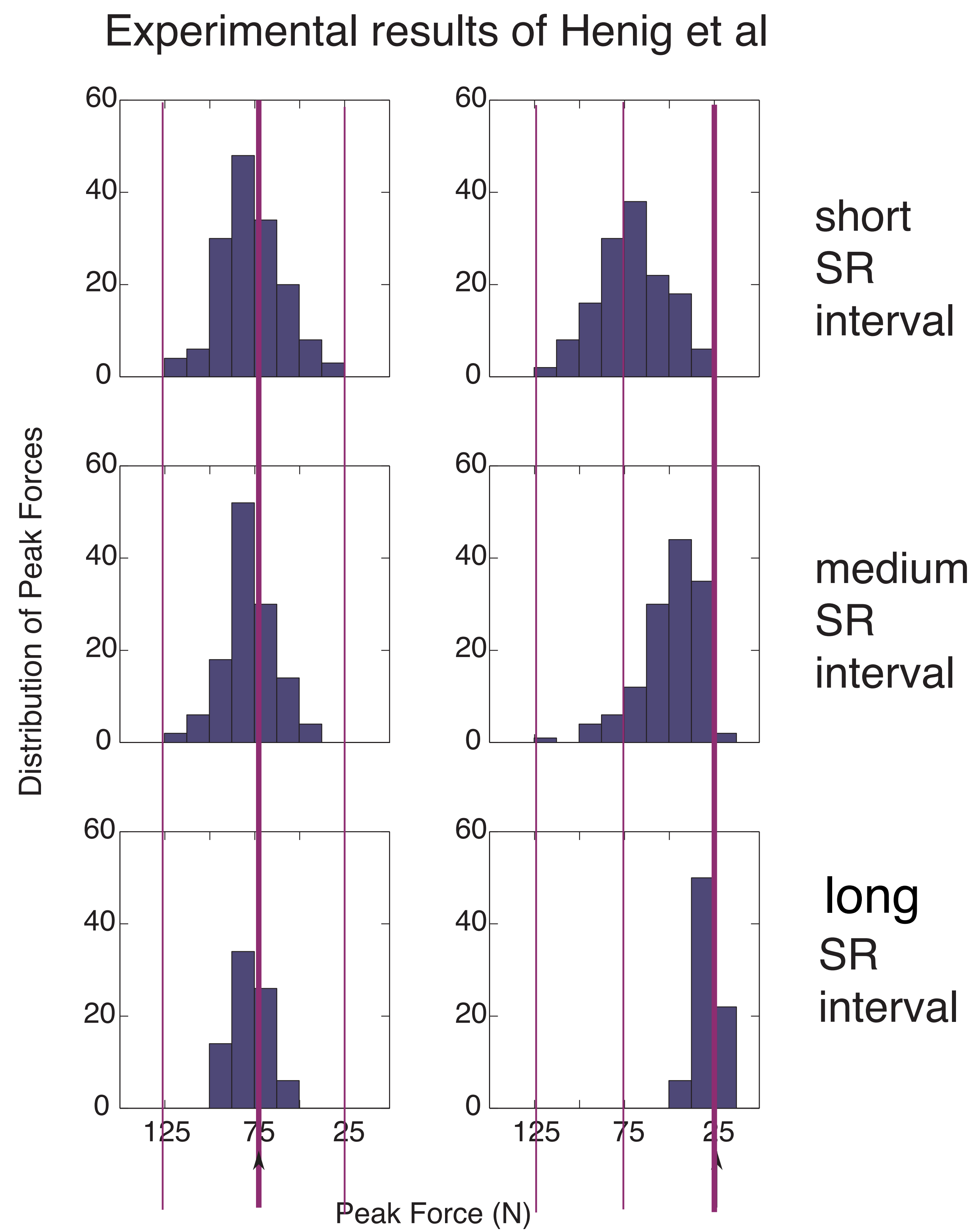


[Favilla et al. 1989]

Experimental results of Henig et al



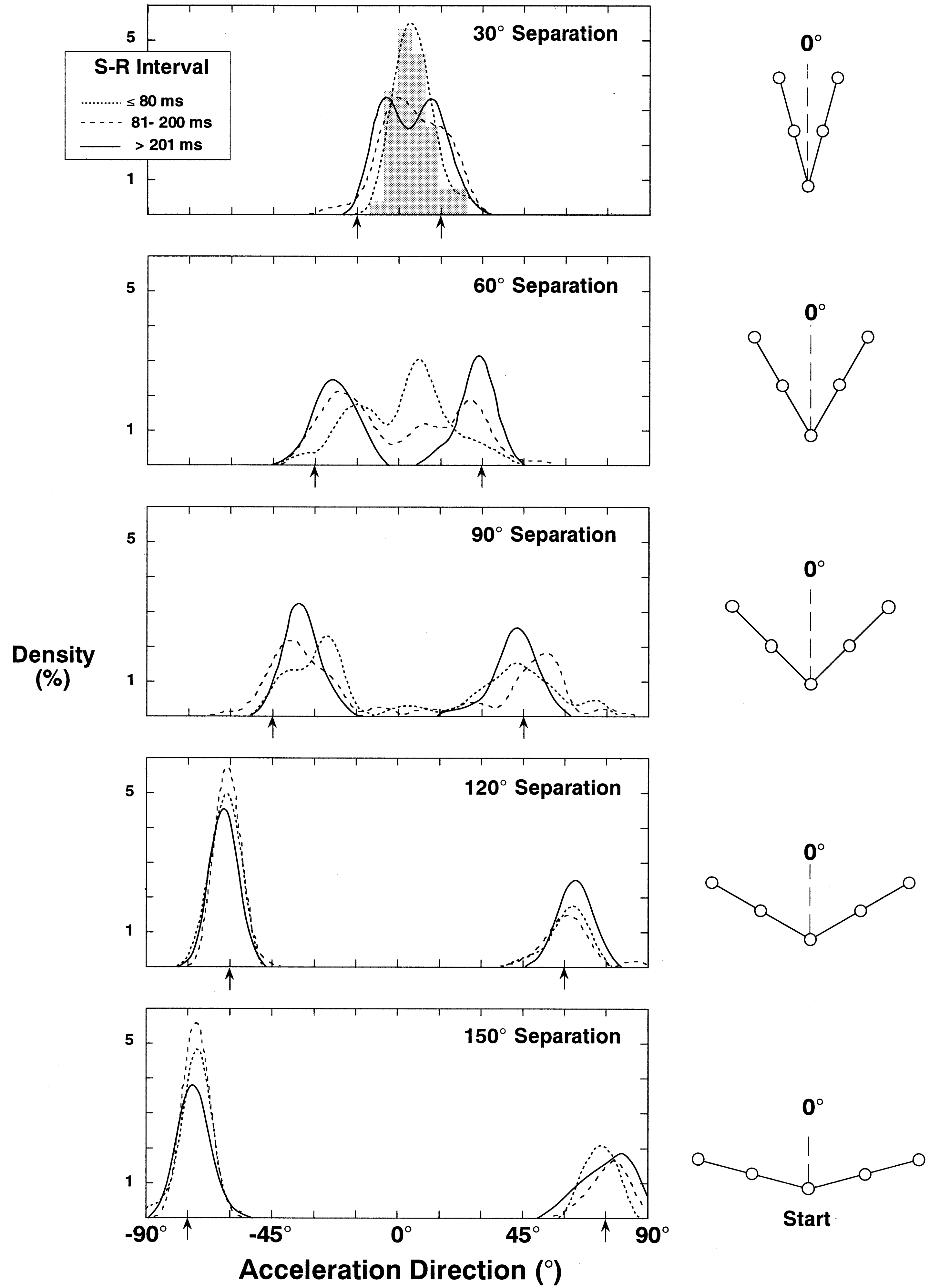




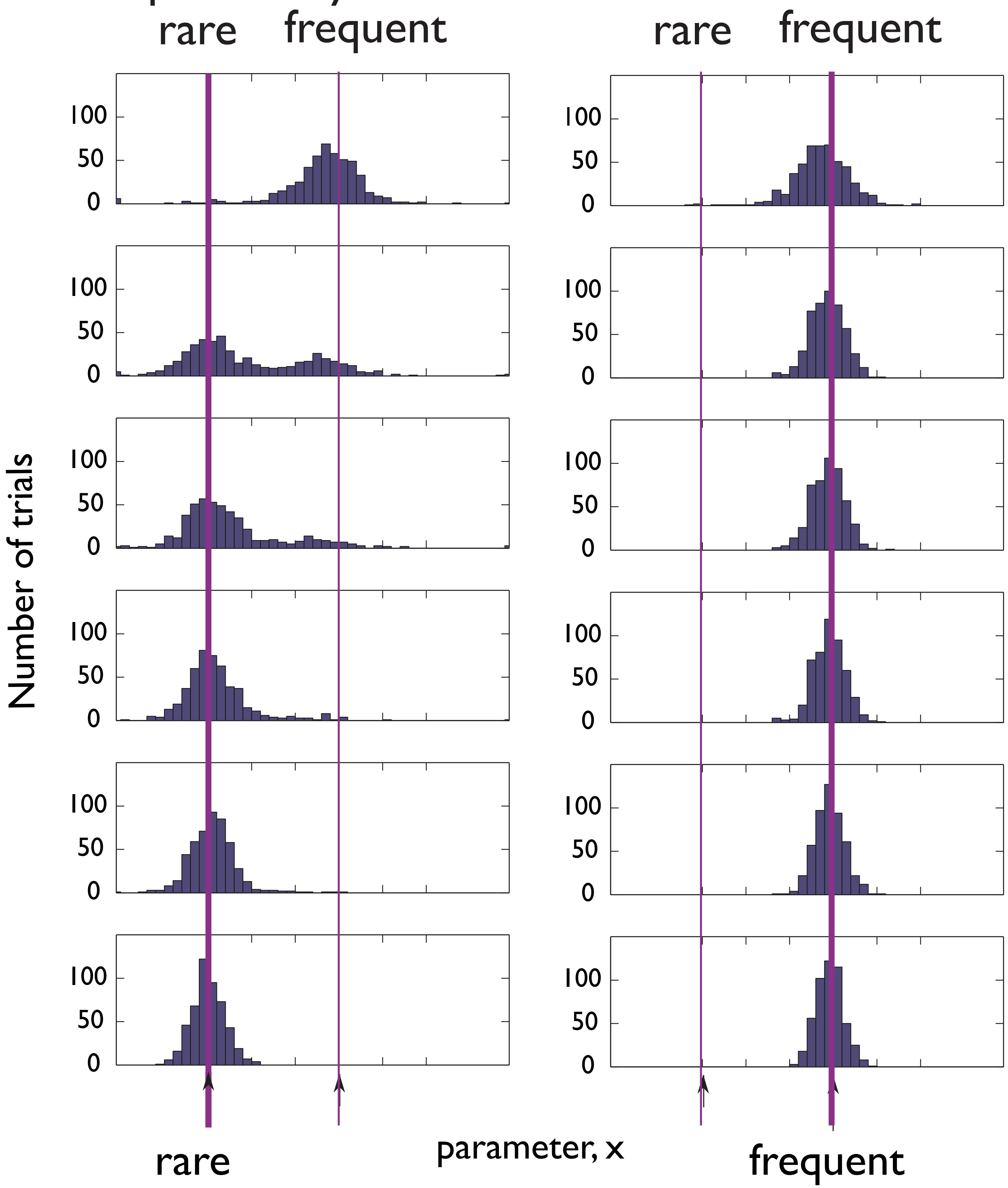
[Erlhagen, Schöner. 2002, Psychological Review 109, 545–572 (2002)]

- infer width of preshape peaks in field

[Ghez et al 1997]



probability in timed movement initiation

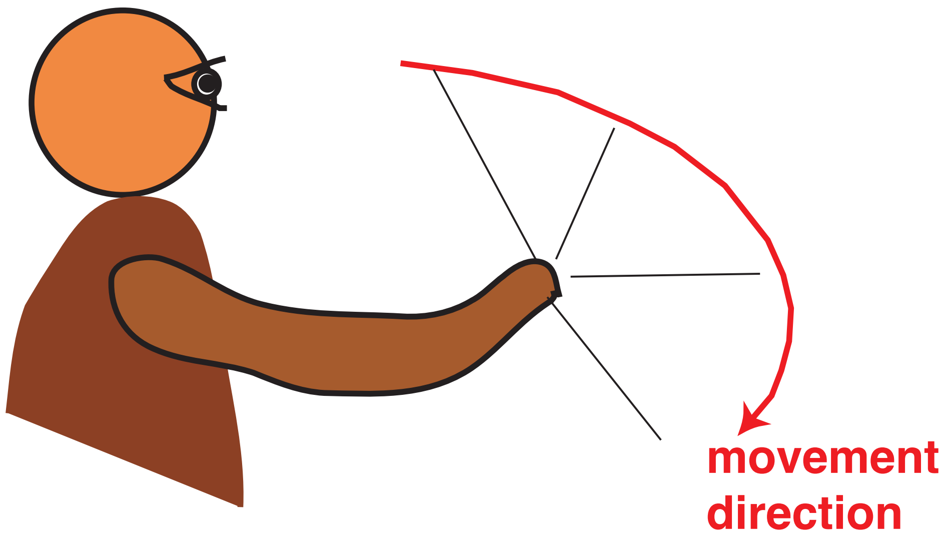


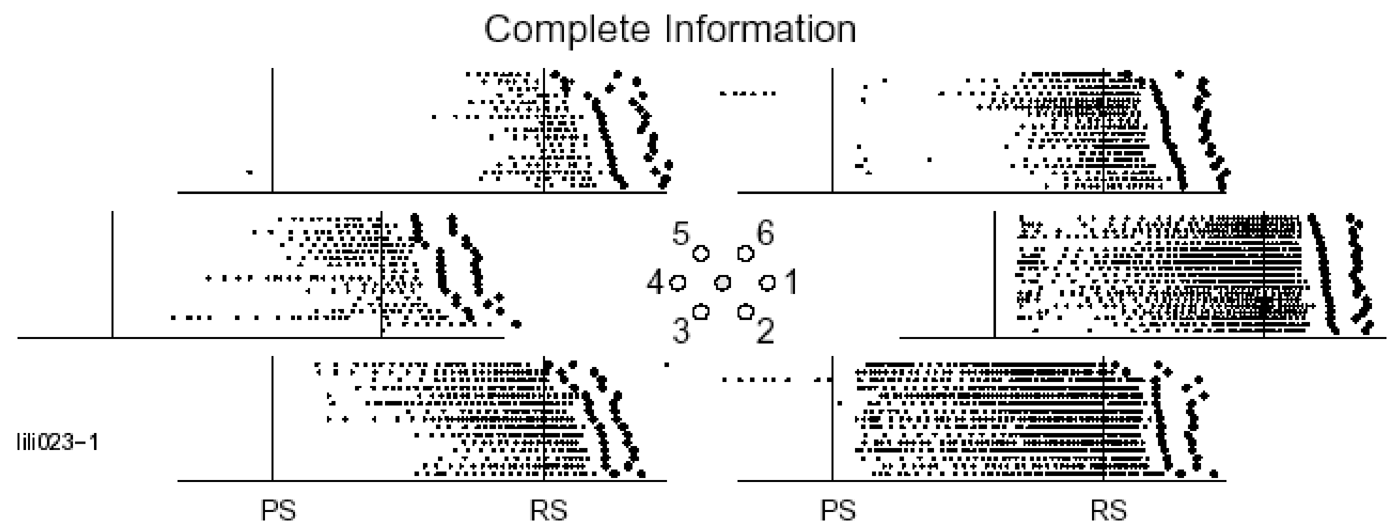
short SR interval:
observe preshape

long SR interval:
observe stimulus-defined
movement plan

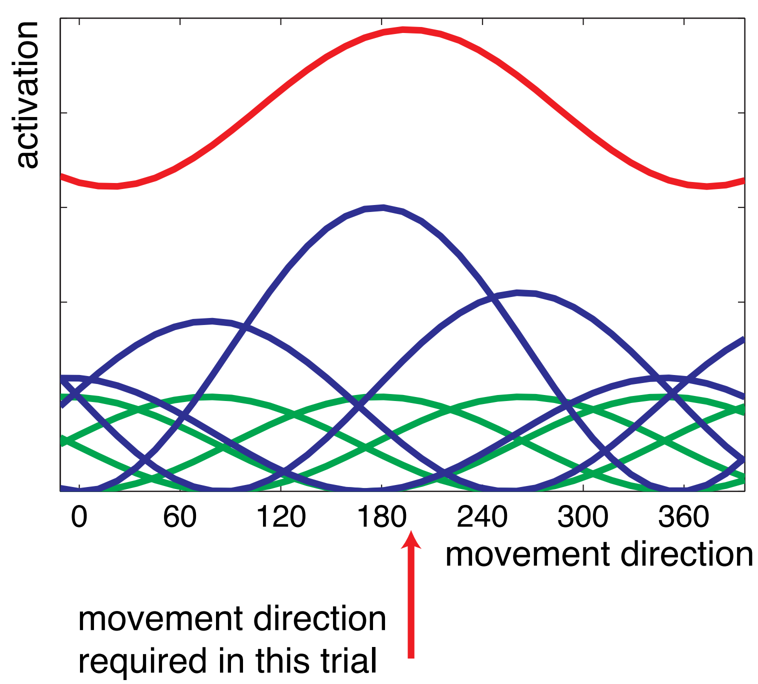
Ghez et al, 1997

Neural evidence for preshape

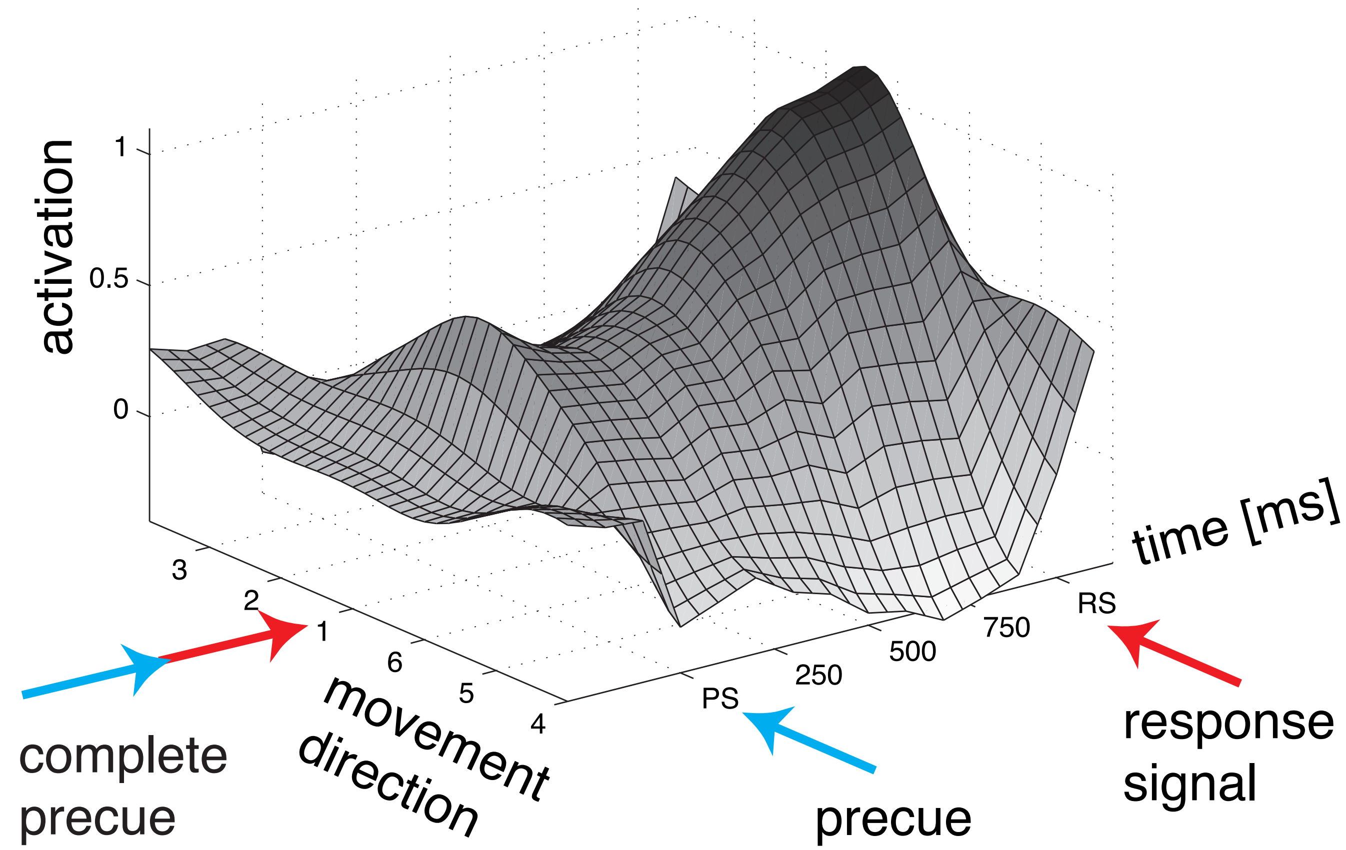




Distribution of population activation = $\sum_{\text{neurons}}$ tuning curve * current firing rate

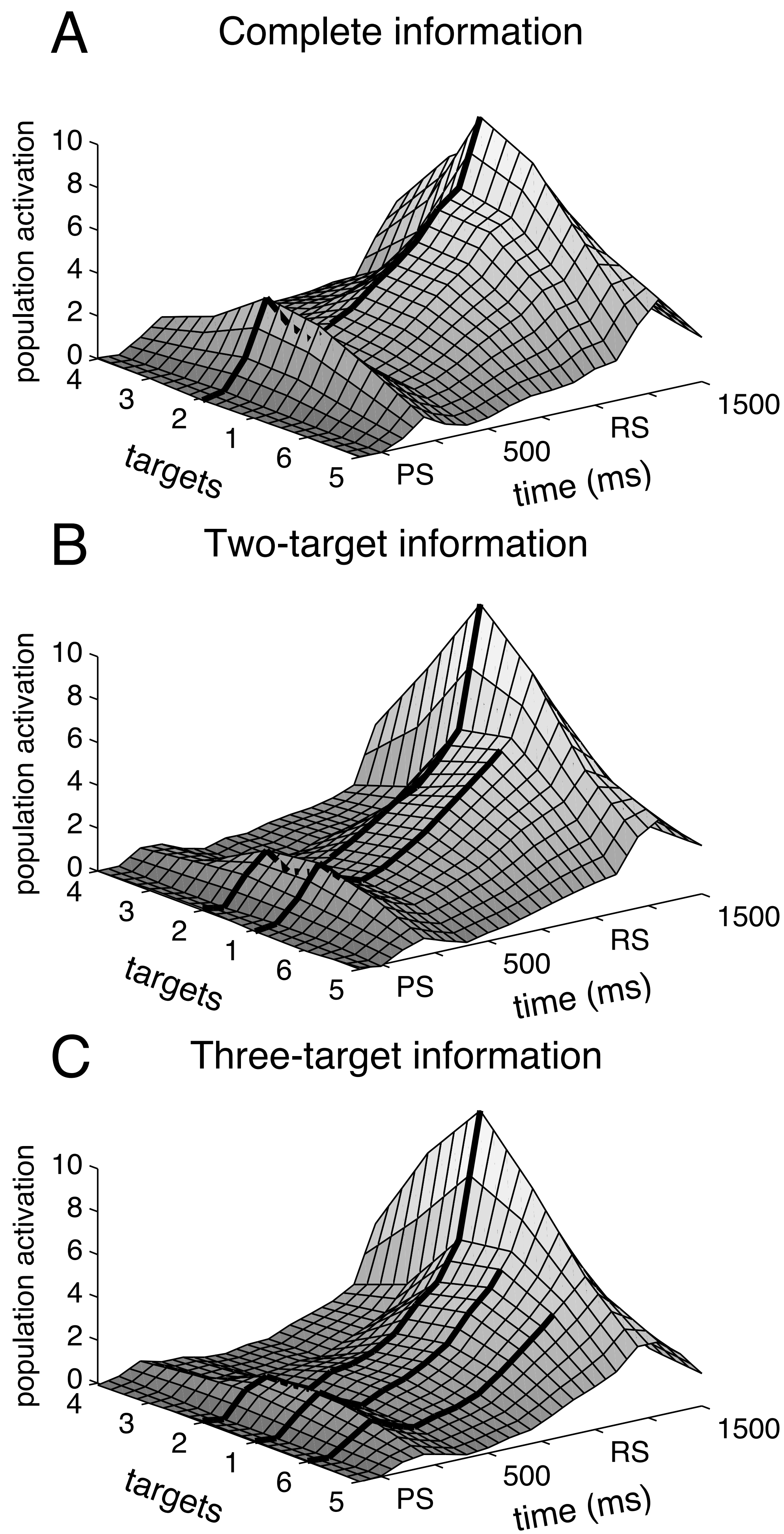


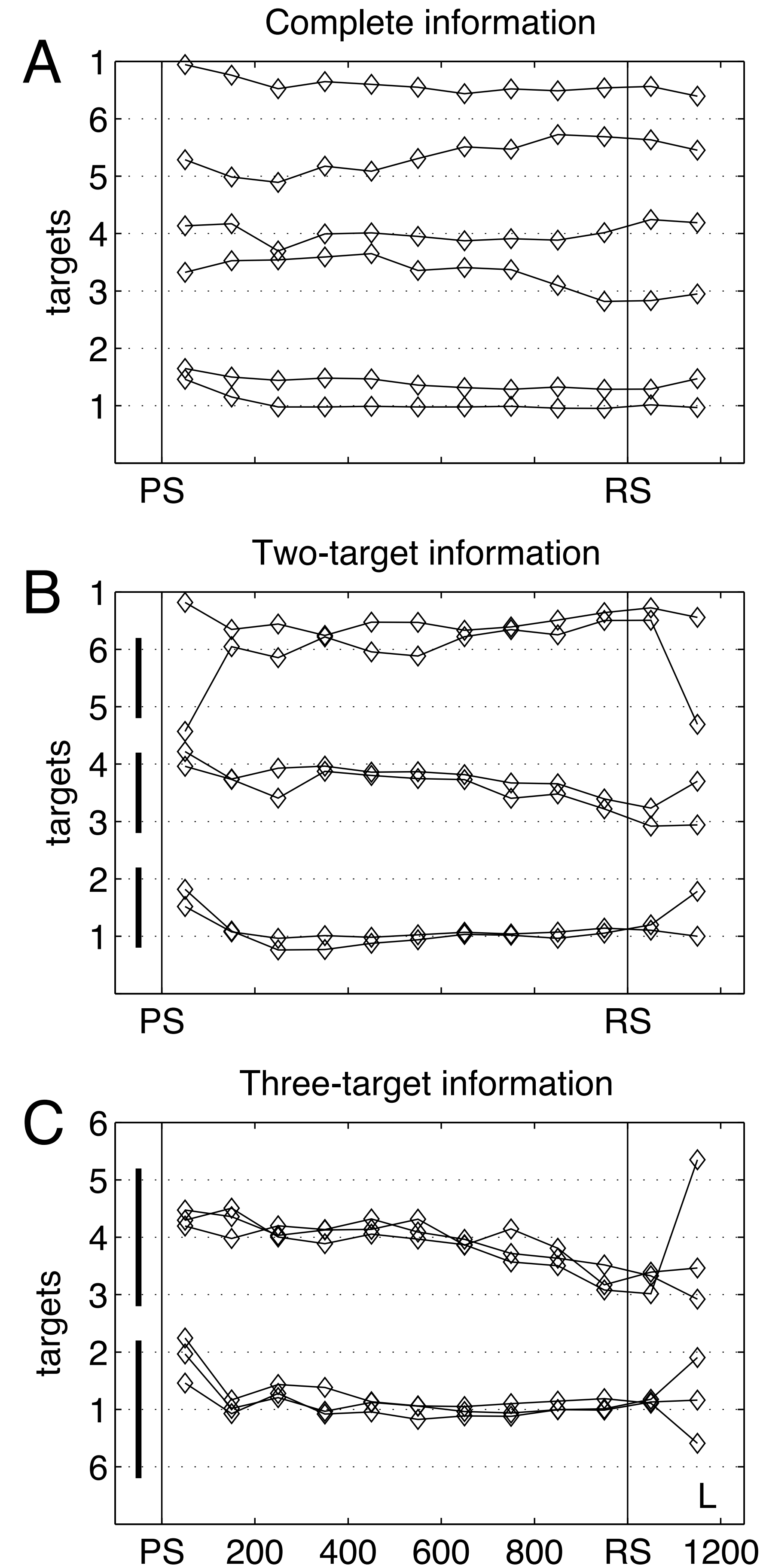
[after Bastian, Riehle, Schöner, submitted]



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

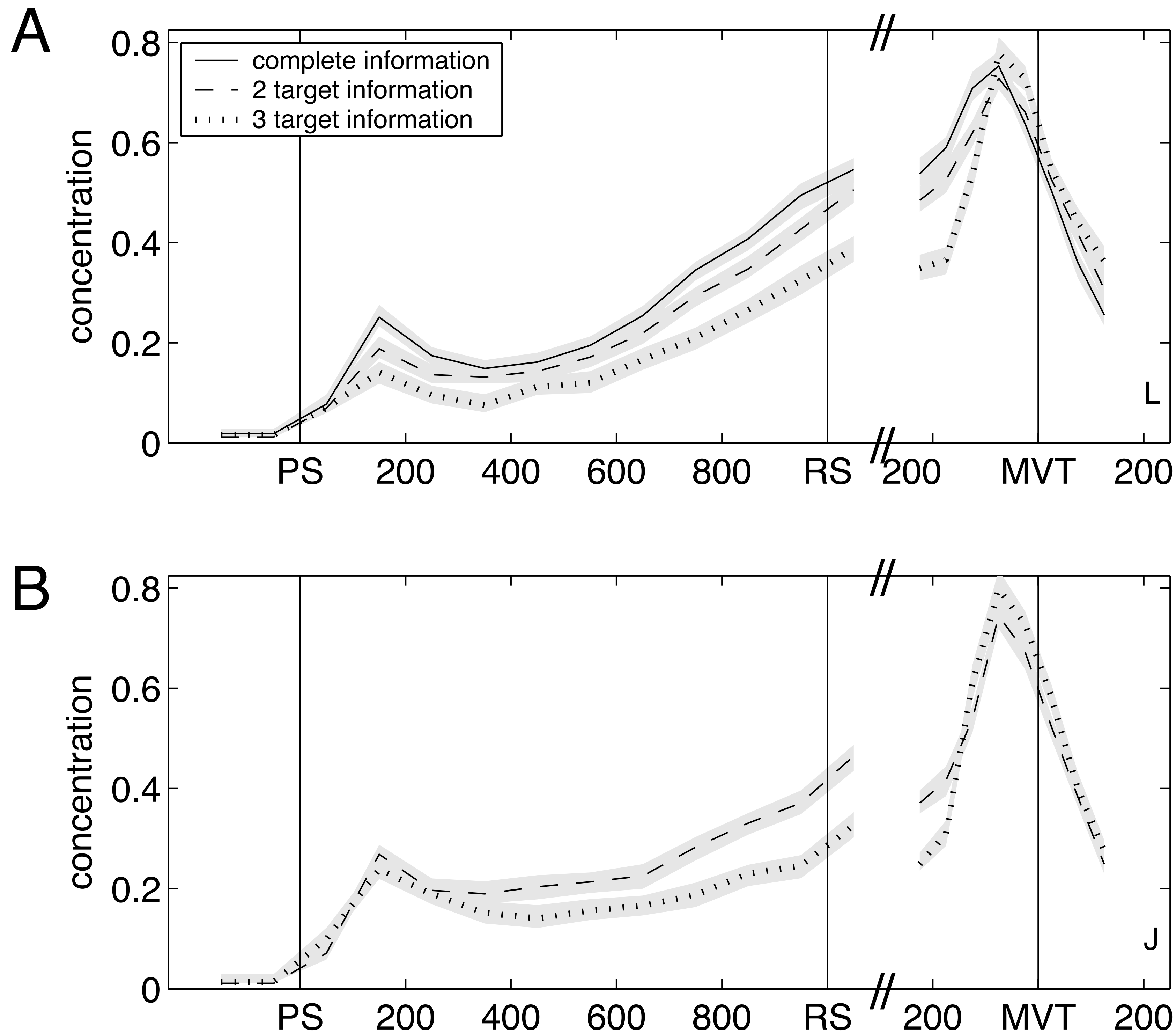
- DPA reflects prior information





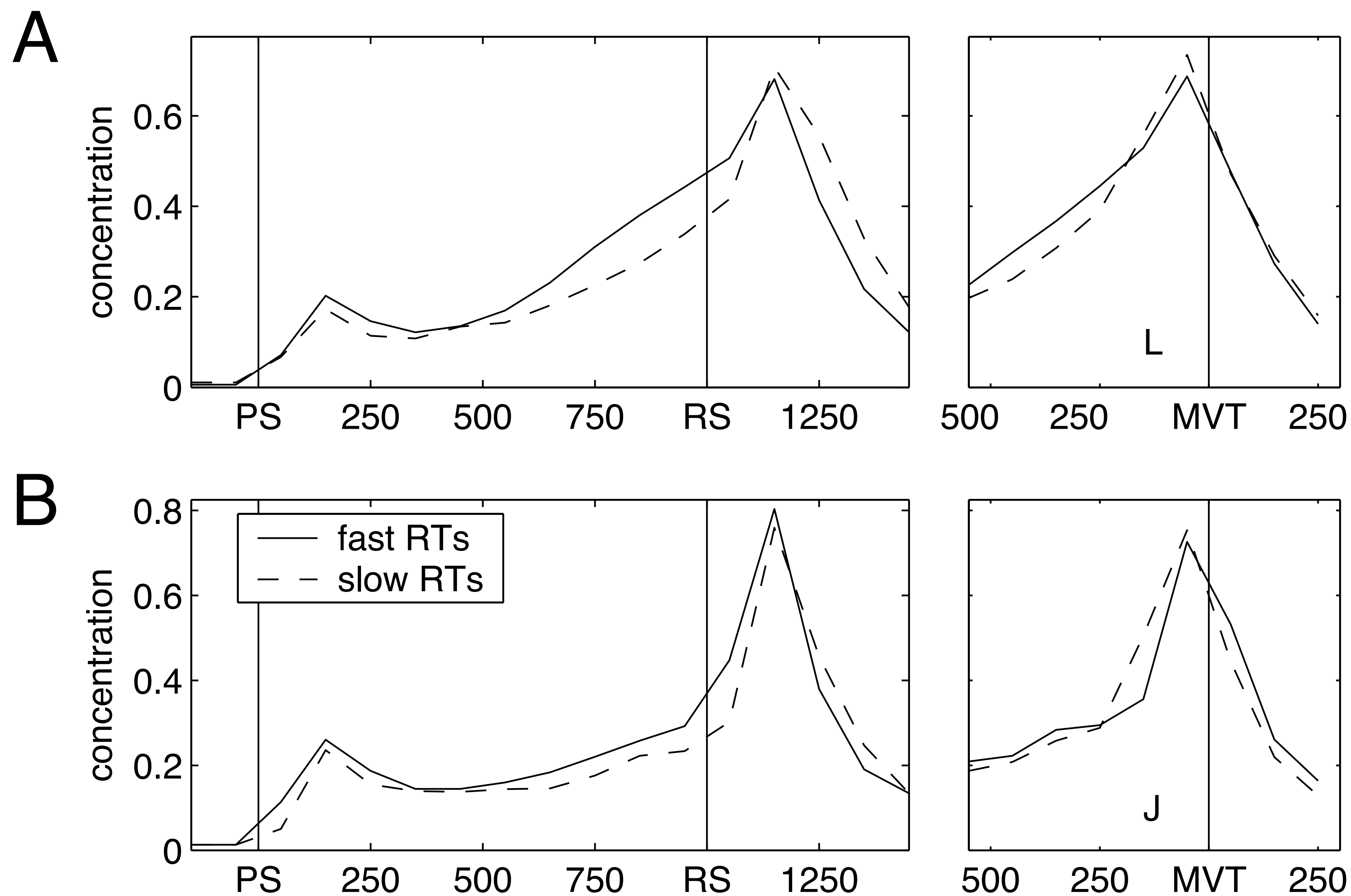
[Bastian, Schöner, Riehle 2003]

- DPA reflects prior information



[Bastian, Schöner, Riehle 2003]

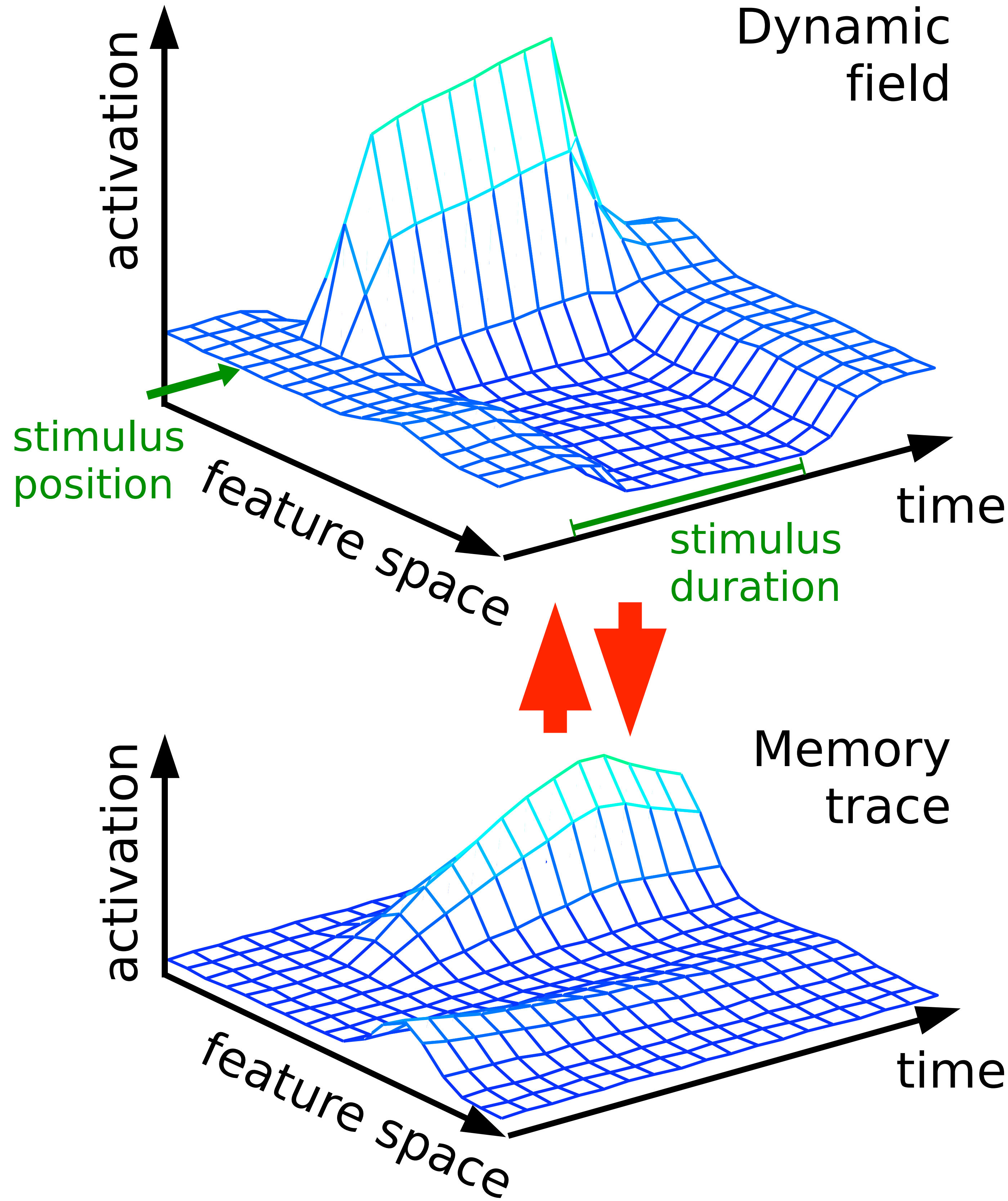
- preshape correlates with RT



[Bastian, Schöner, Riehle 2003]

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..



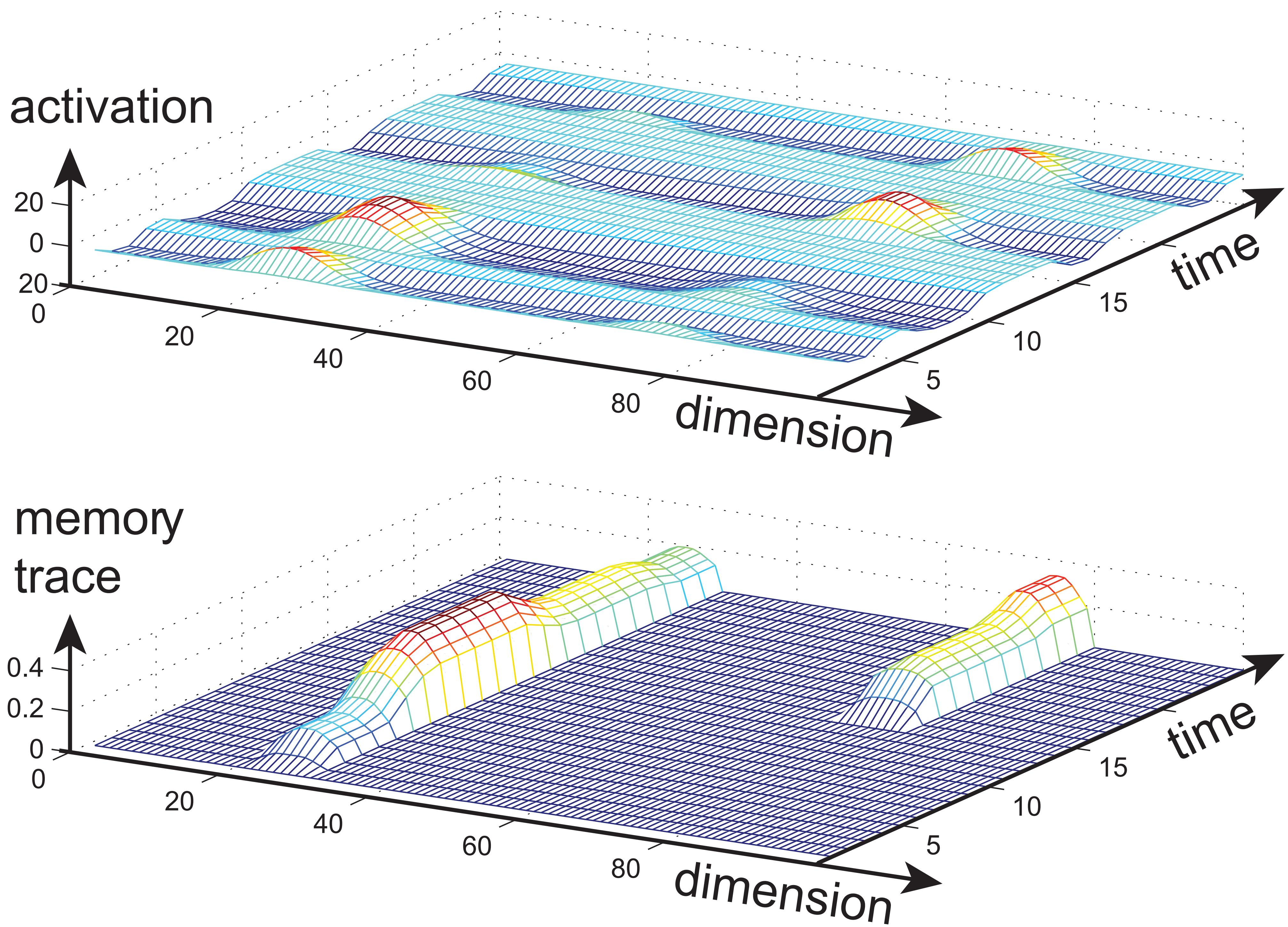
mathematics of the memory trace

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

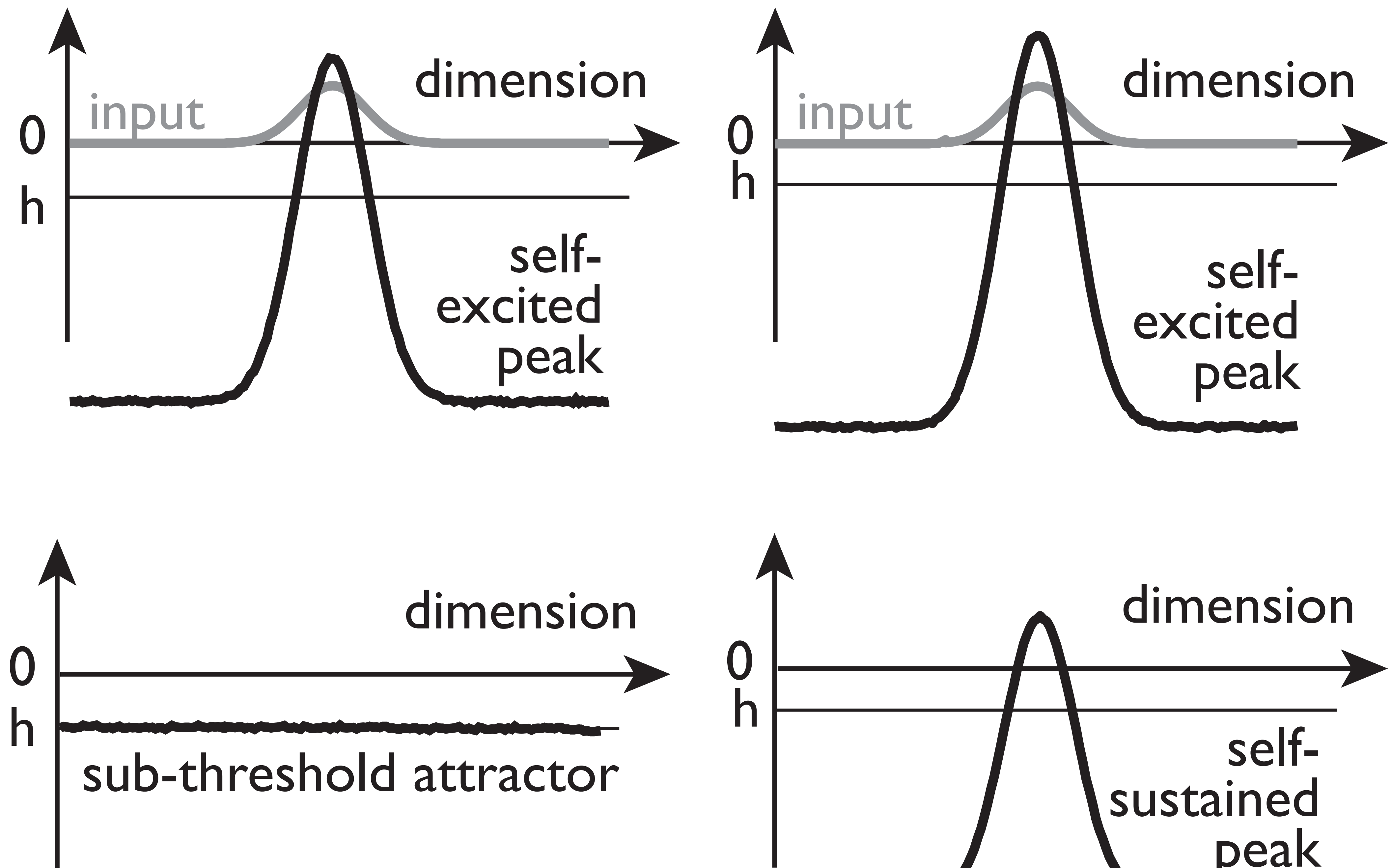
$$\begin{aligned}
\tau_{\text{mem}} \; \dot{u}_{\text{mem}}(x,t) &= -u_{\text{mem}}(x,t) \\
&+ \int dx' \; w_{\text{mem}}(x-x')\sigma(u(x',t))
\end{aligned}$$

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

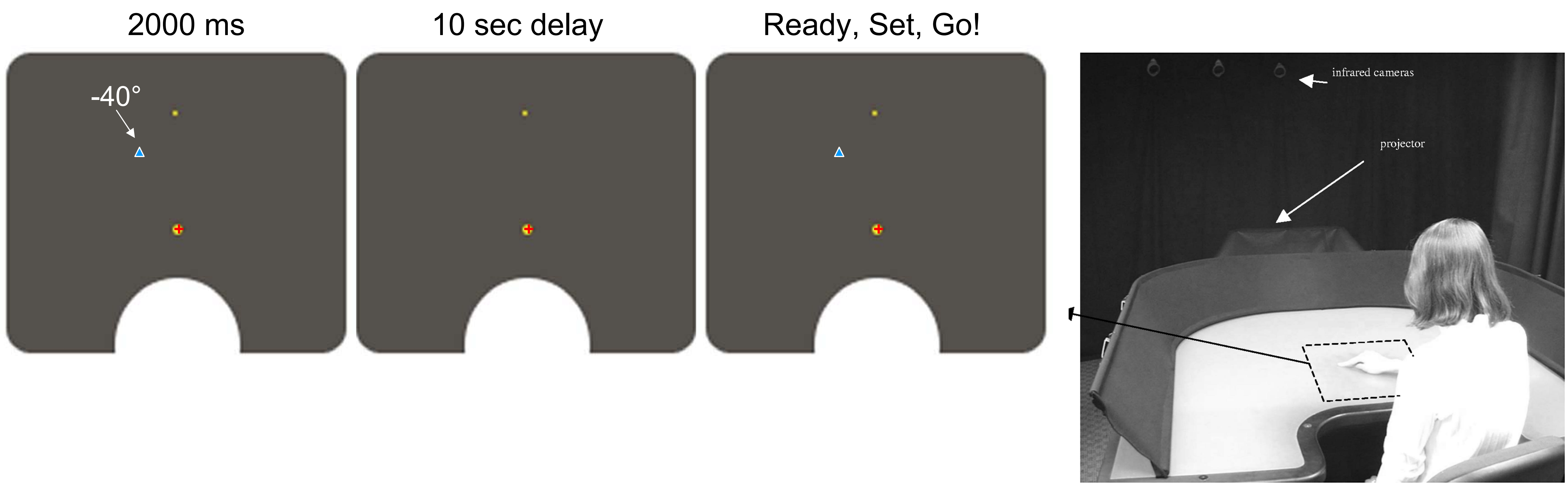
memory trace reflects history of decisions formation



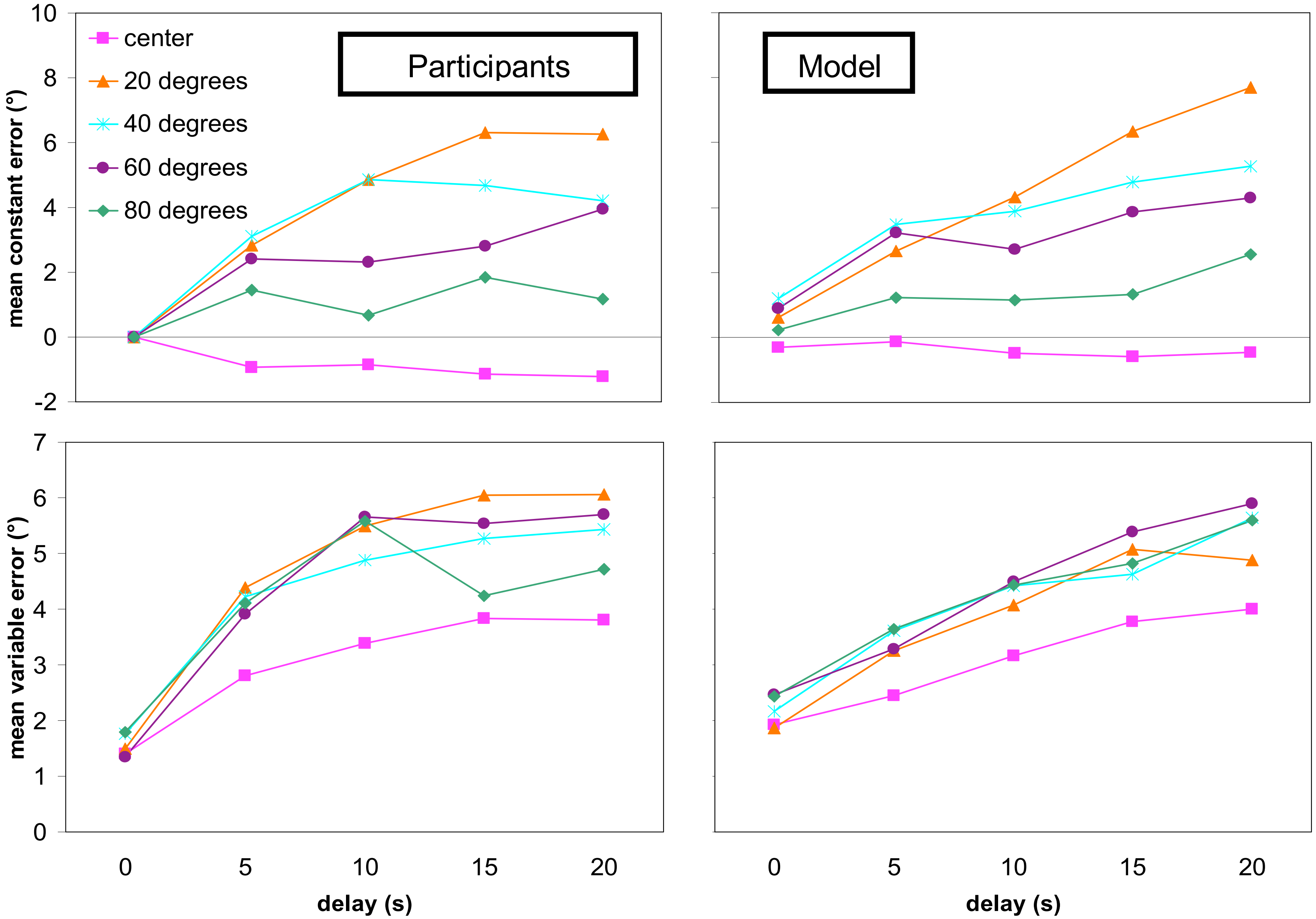
Memory instability



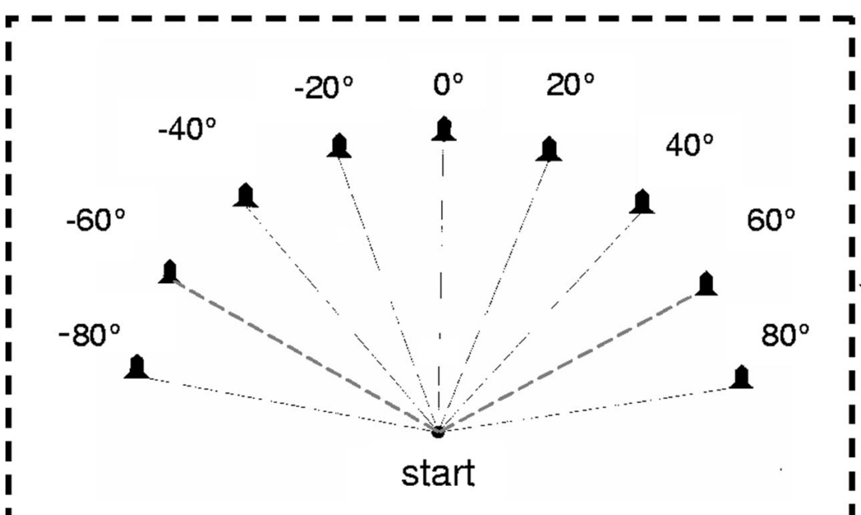
“space ship” task probing spatial working memory

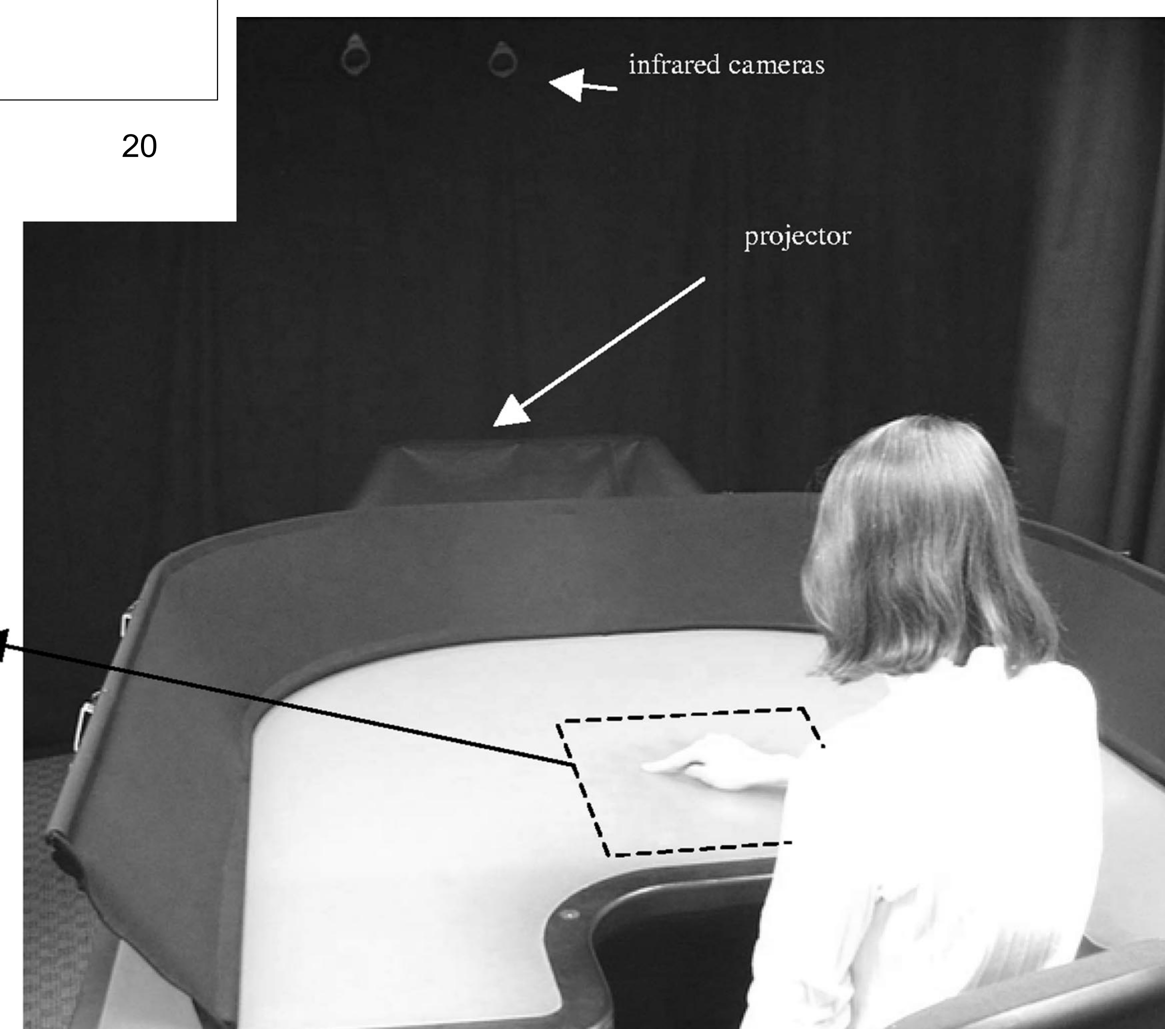


[Schutte, Spencer, JEP:HPP 2009]



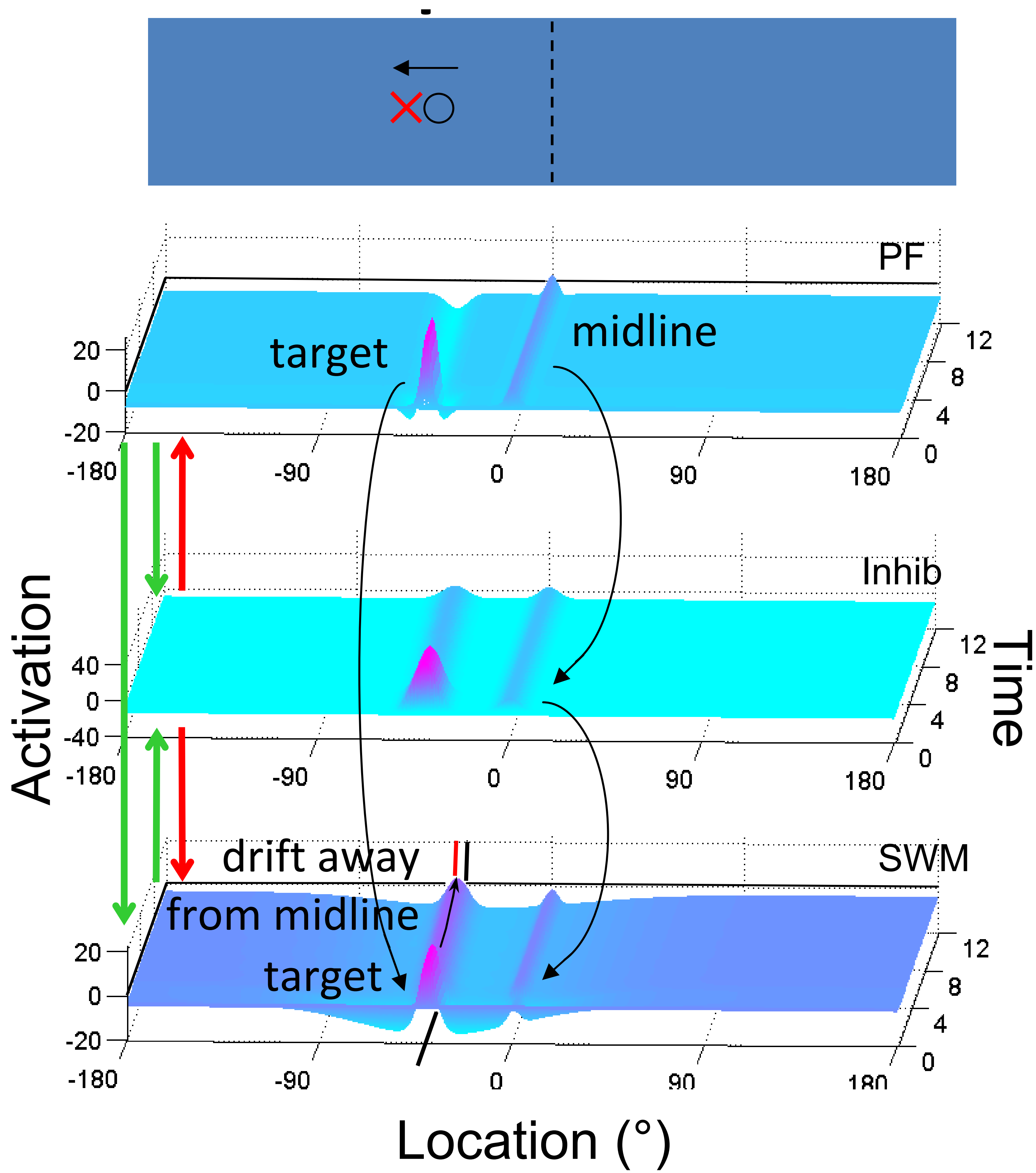
repulsion from mid-line





[Spencer, Schöner, 2006]

- DFT account of repulsion: inhibitory interaction with peak representing landmark

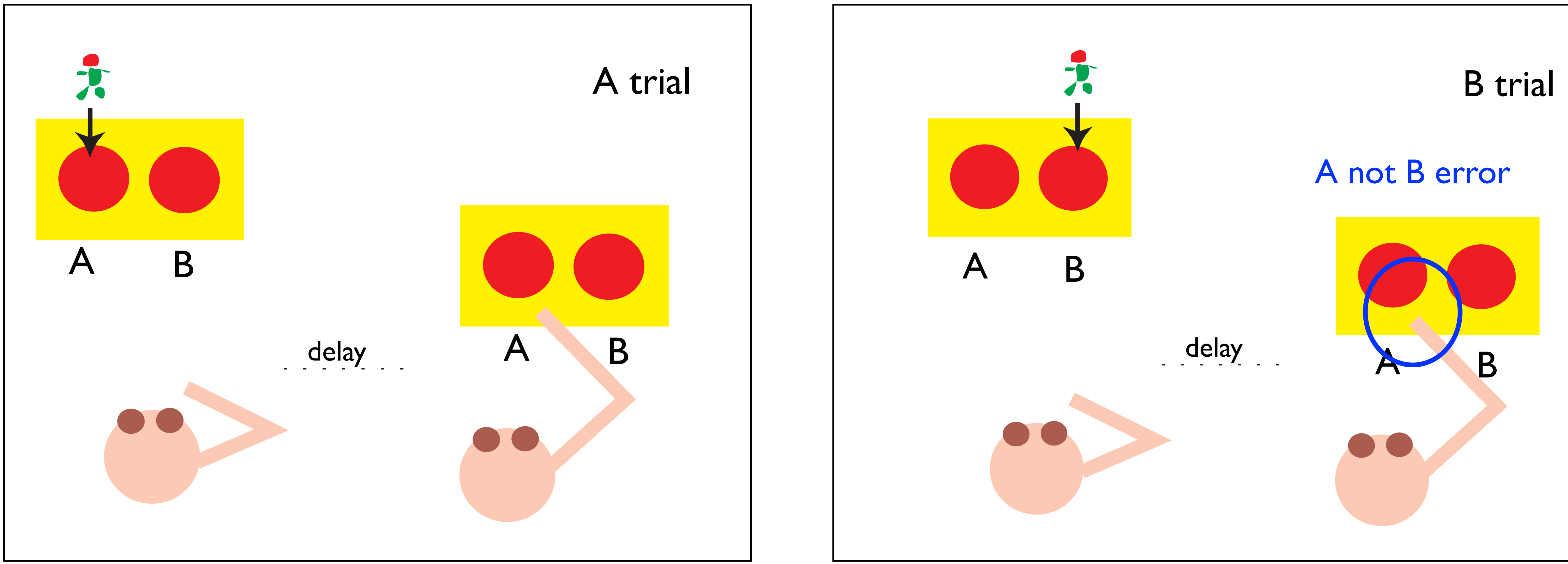


[Simmering, Schutte, Spencer: Brain Research, 2007]

Working memory as sustained peaks

- implies metric drift of WM, which is a marginally stable state (one direction in which it is not asymptotically stable)
- => empirically real..

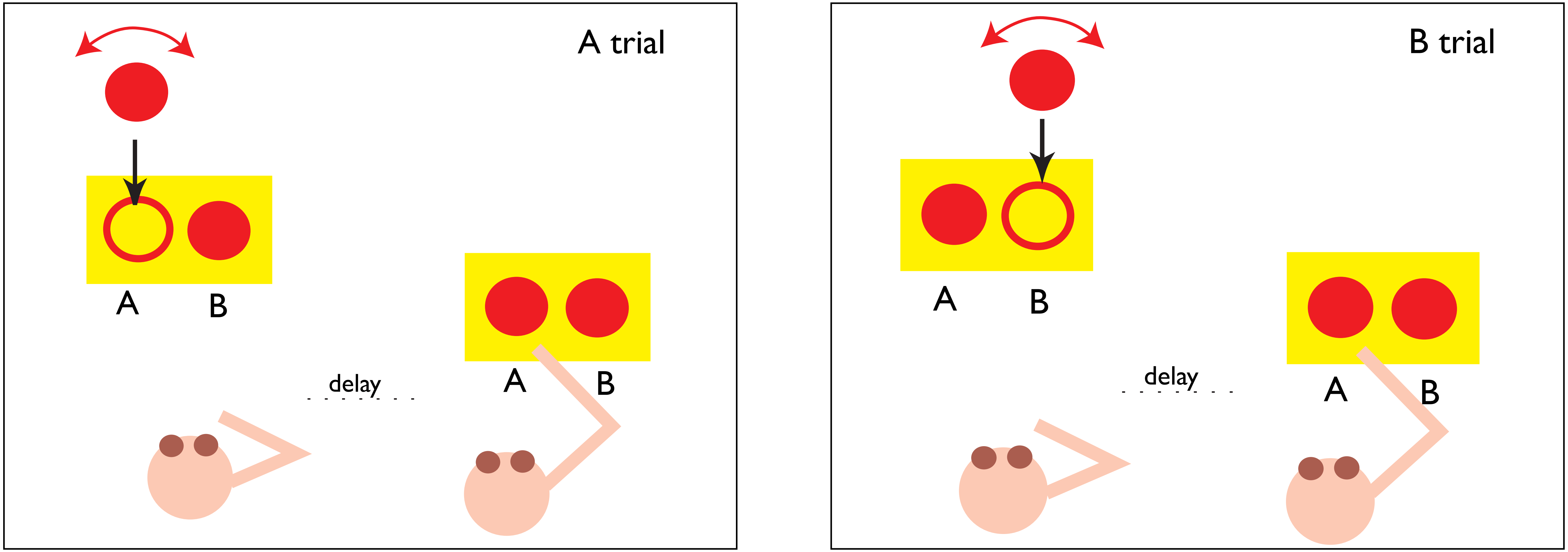
Piaget's A not B paradigm: "out-of-sight -- out of mind"



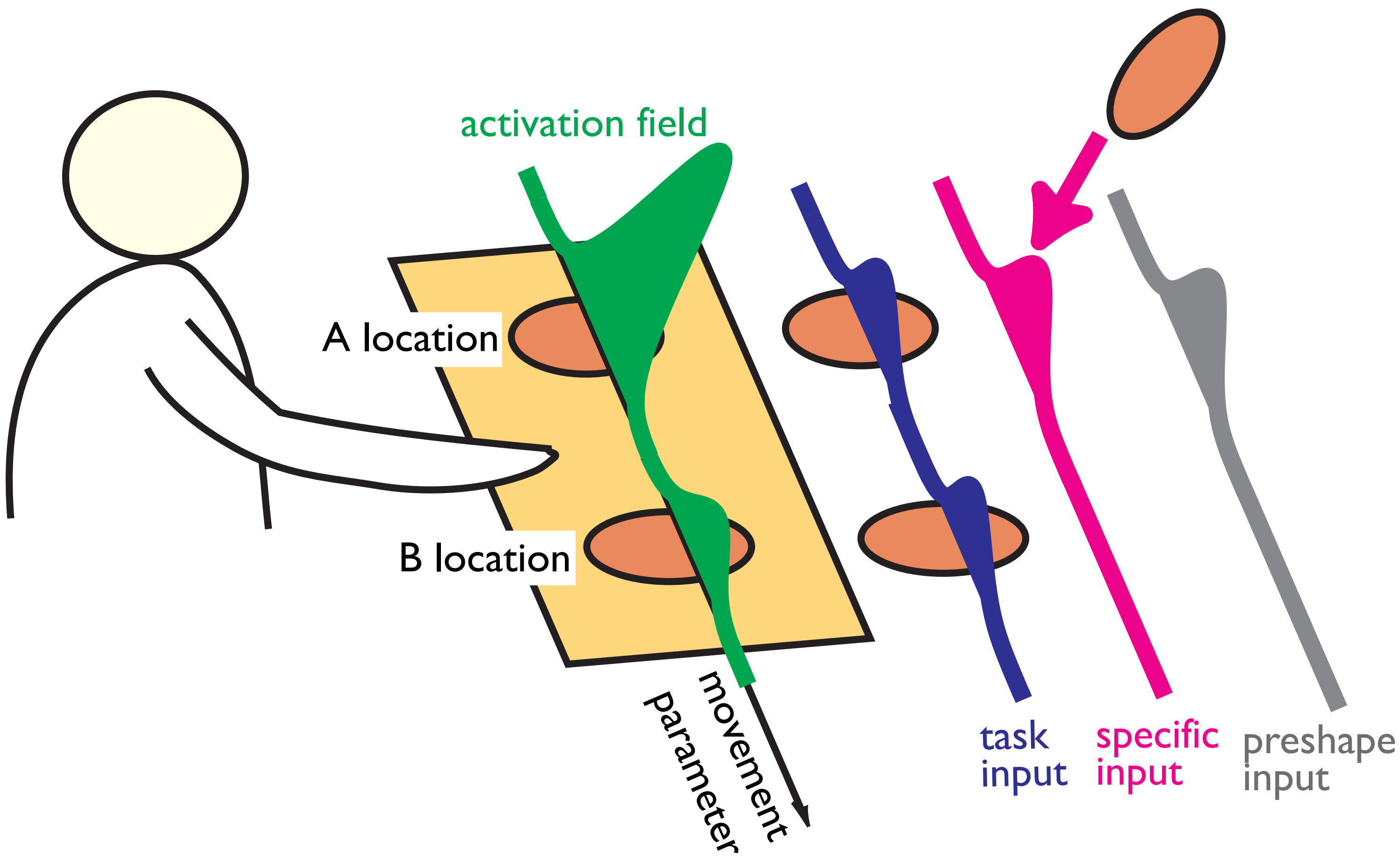
Toyless variant of A not B task

[Smith, Thelen et al.: Psychological Review (1999)]

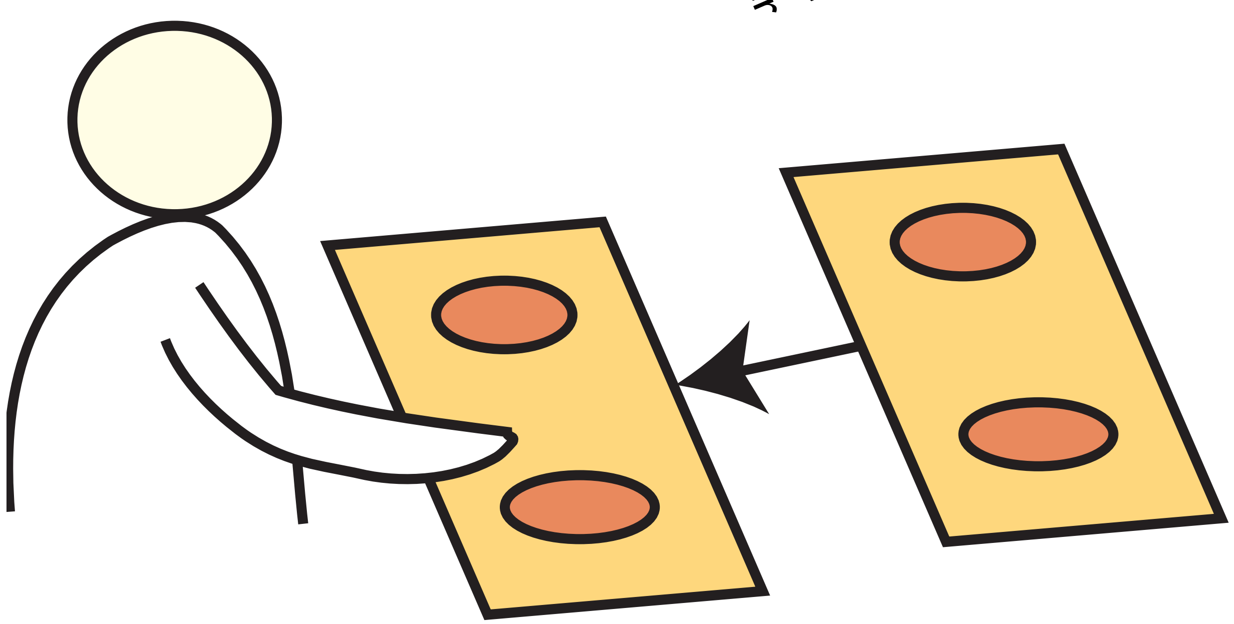
Toyless variant of A not B task reveals that A not B is essentially a decision task!



[Smith, Thelen et al.: Psychological Review (1999)]



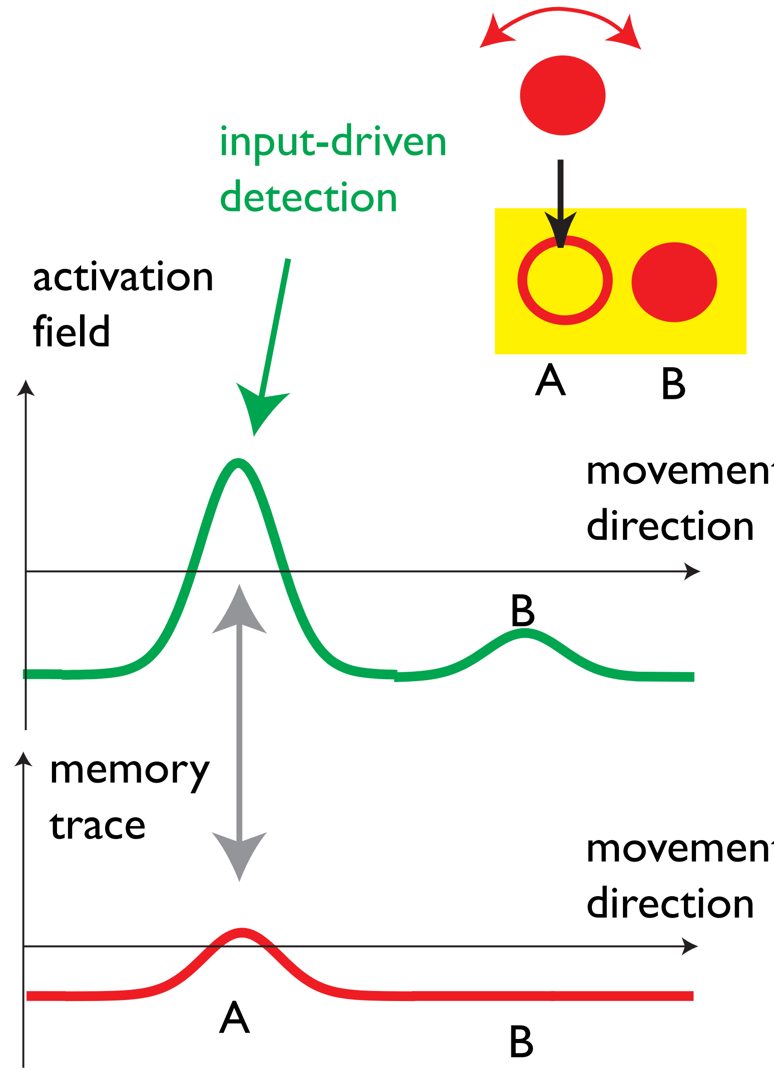
[Thelen, et al., BBS (2001)]



[Dineva, Schöner, Dev. Science 2007]

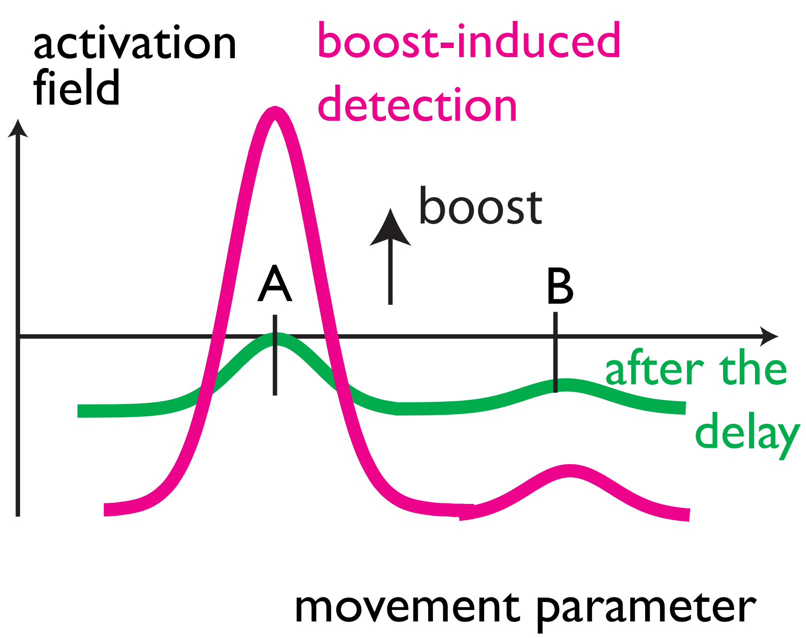
Instabilities

- detection: forming and initiating a movement goal
- selection: making sensori-motor decisions
- (learning: memory trace)
- boost-driven detection: initiating the action
- memory instability: old infants sustain during the delay, young infants do not



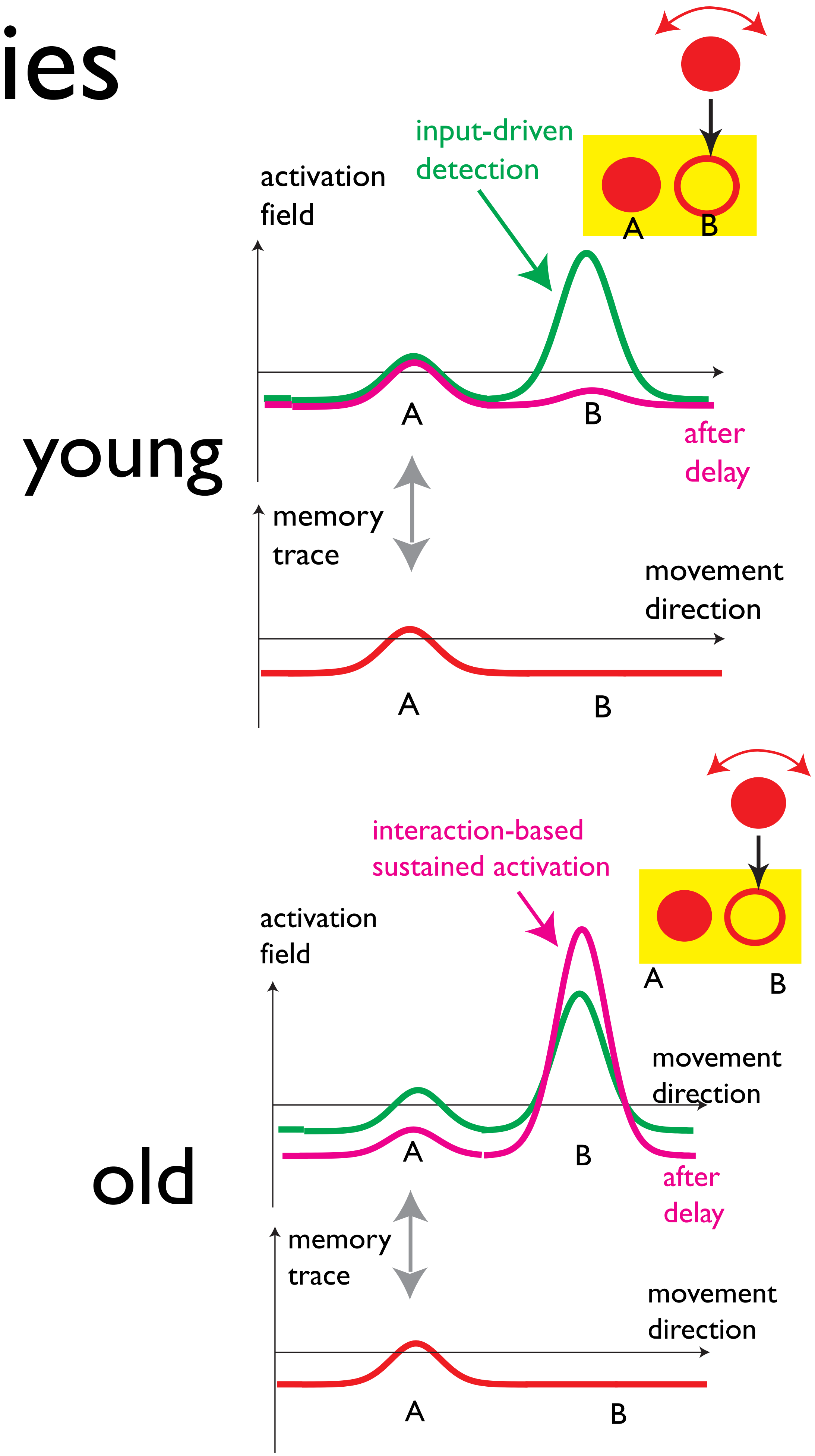
Instabilities

- detection: forming and initiating a movement goal
- selection: making sensori-motor decisions
- (learning: memory trace)
- boost-driven detection: initiating the action
- memory instability: old infants sustain during the delay, young infants do not

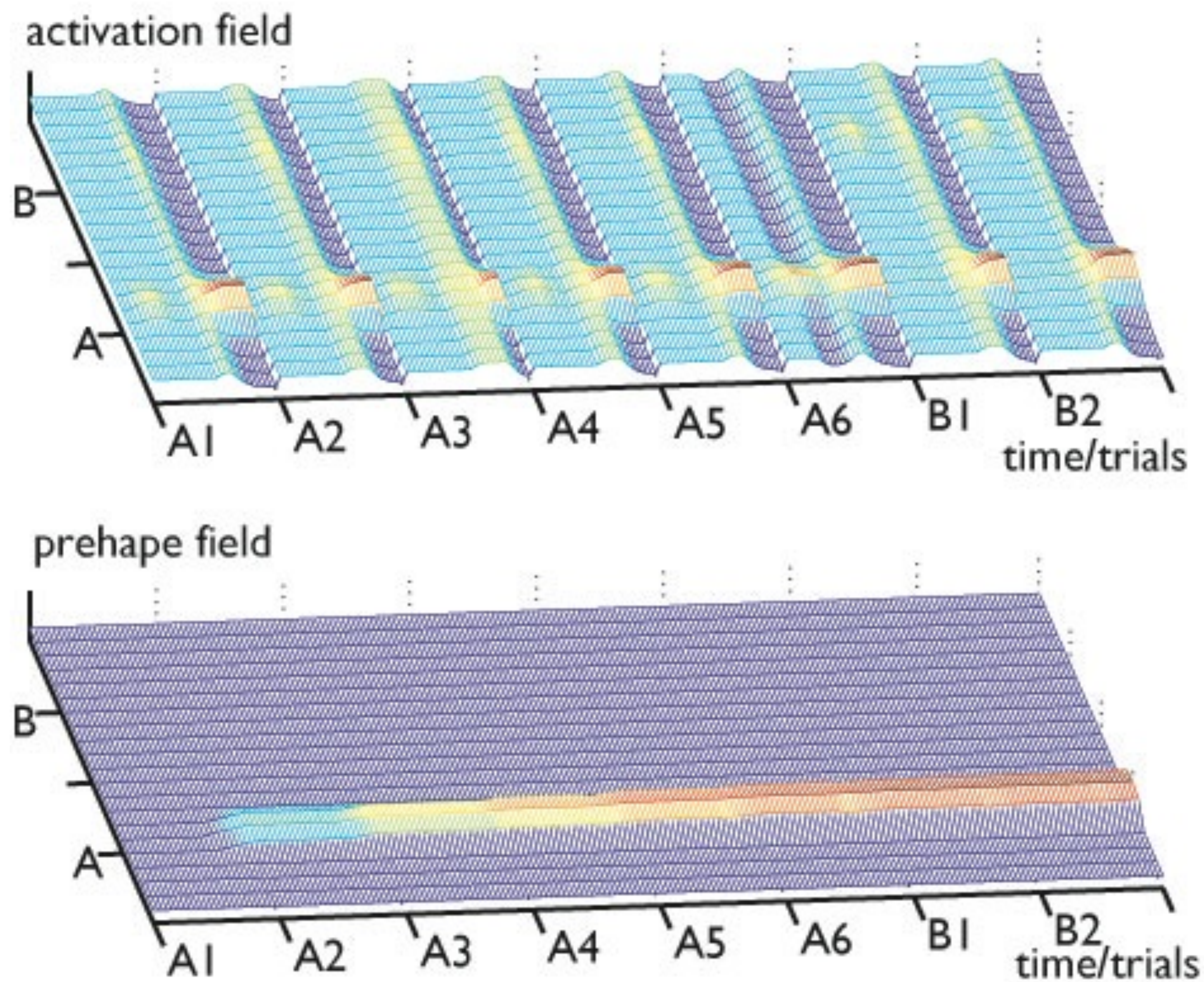


Instabilities

- detection: forming and initiating a movement goal
- selection: making sensori-motor decisions
- (learning: memory trace)
- boost-driven detection: initiating the action
- memory instability: old infants sustain during the delay, young infants do not

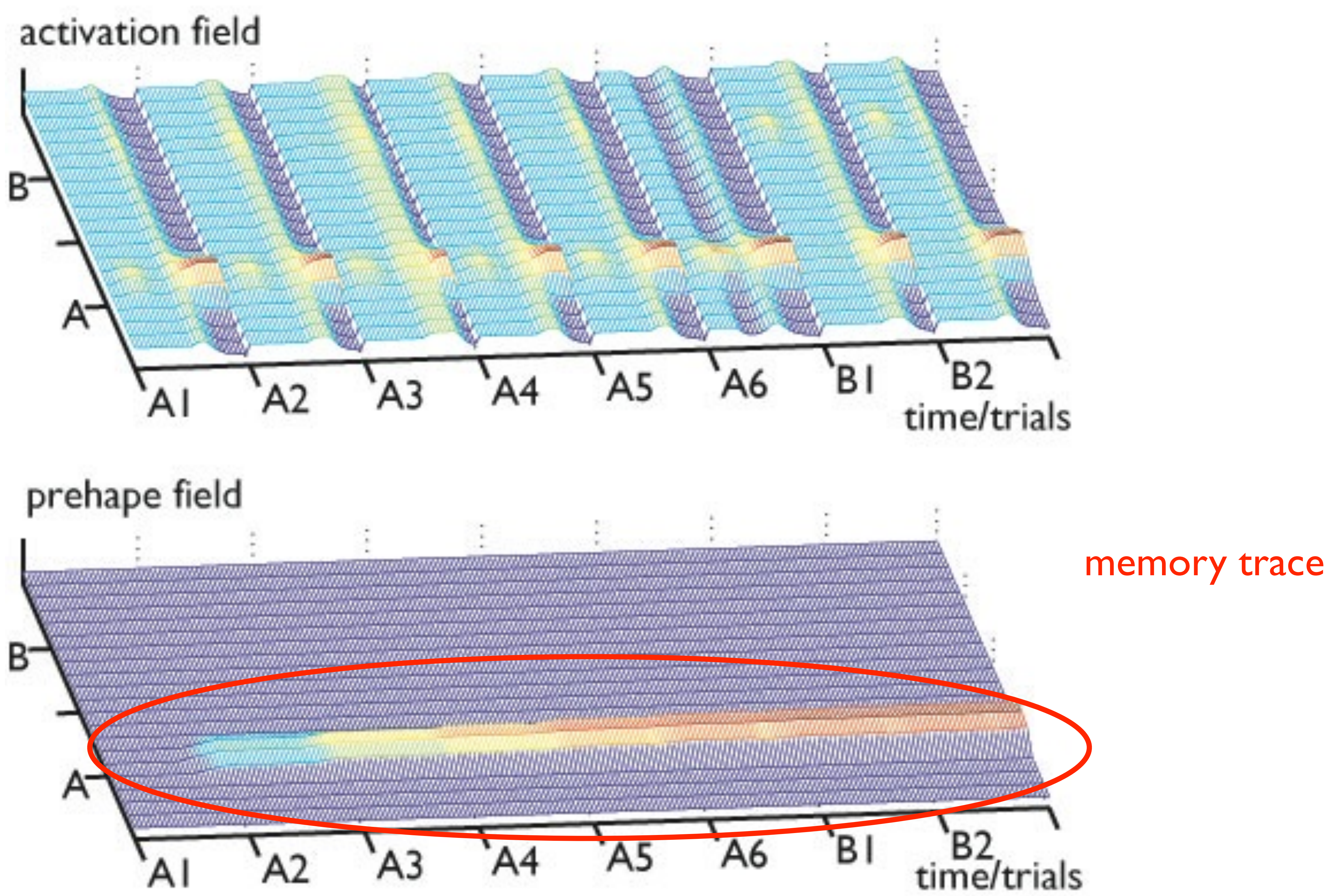


DFT of infant perseverative reaching



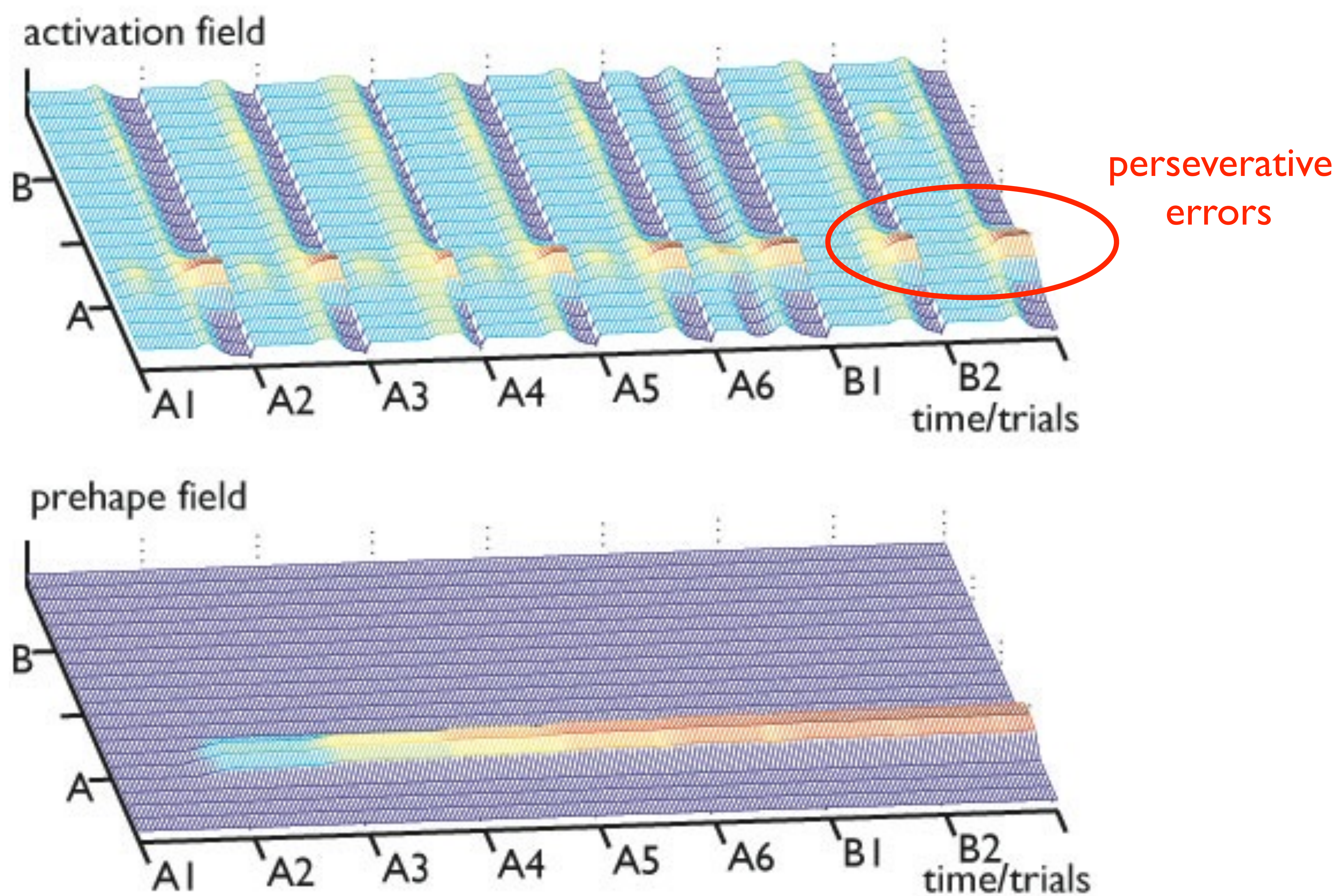
[Dinveva, Schöner, Dev. Science 2007]

DFT of infant perseverative reaching



[Dinveva, Schöner, Dev. Science 2007]

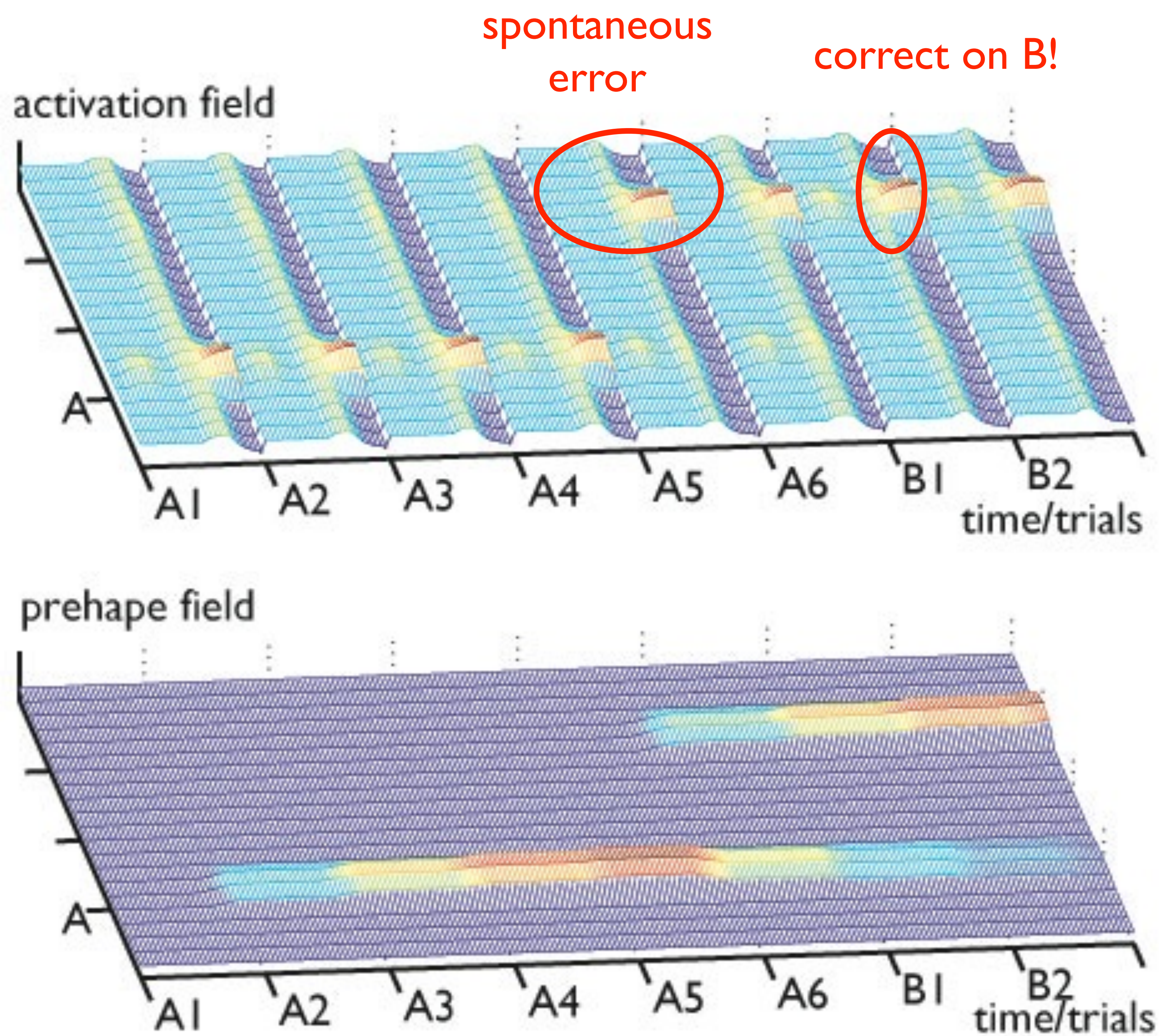
DFT of infant perseverative reaching



[Dinveva, Schöner, Dev. Science 2007]

DFT of infant perseverative reaching

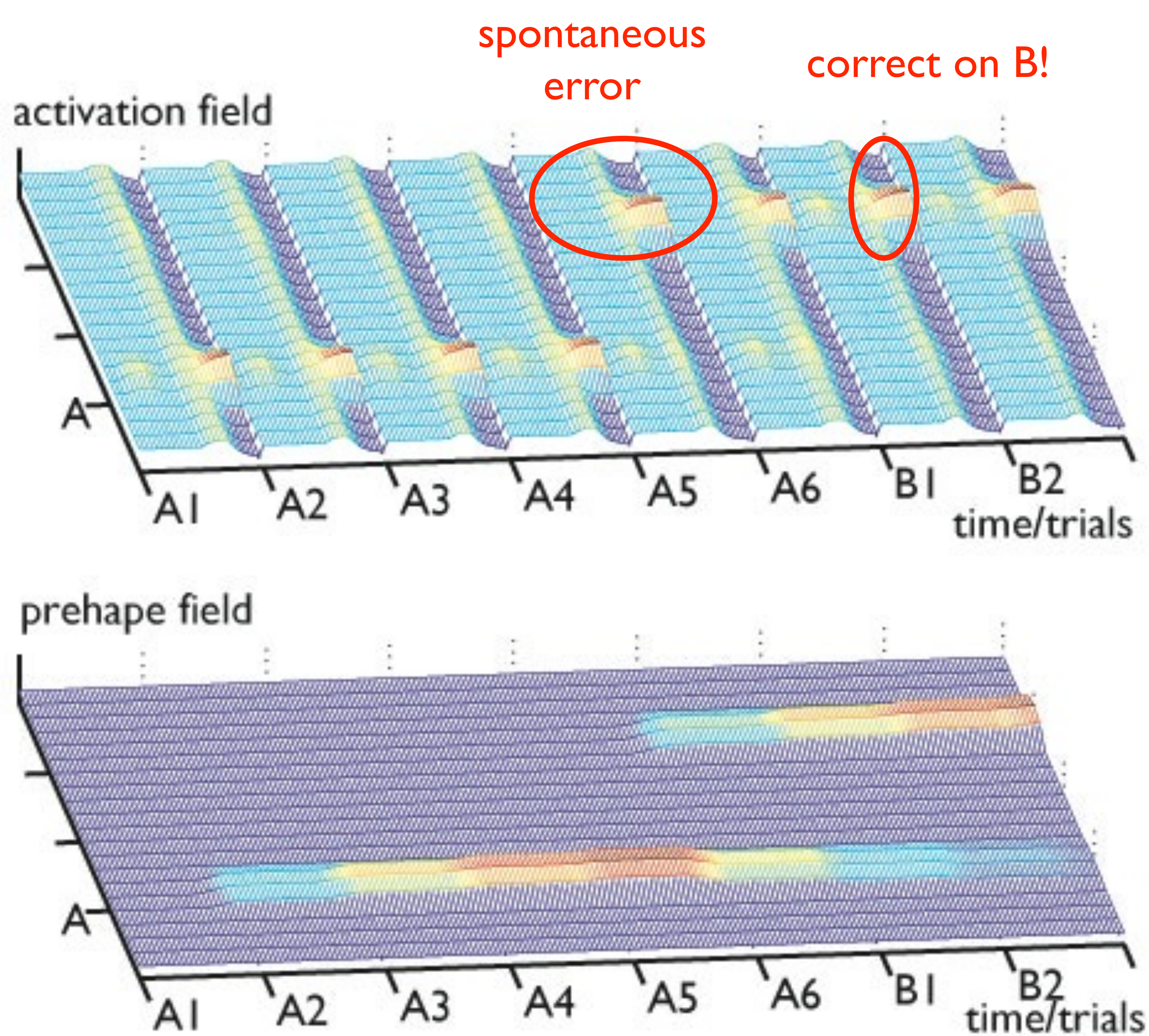
- in spotaneous errors, activation arises at B on an A trial
- which leads to correct reaching on B trial



[Dinveva, Schöner, Dev. Science 2007]

DFT of infant perseverative reaching

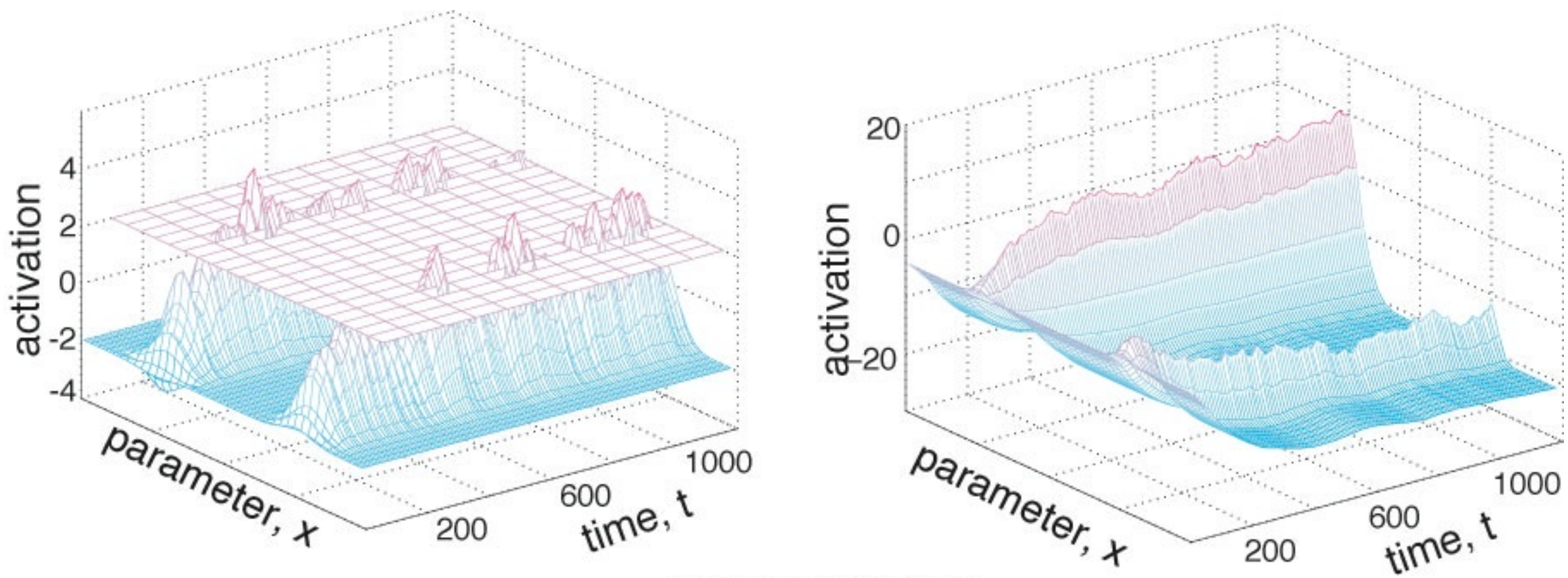
- that is because reaches to B on A trials leave memory trace at B



[Dinveva, Schöner, Dev. Science 2007]

DFT is a neural process model

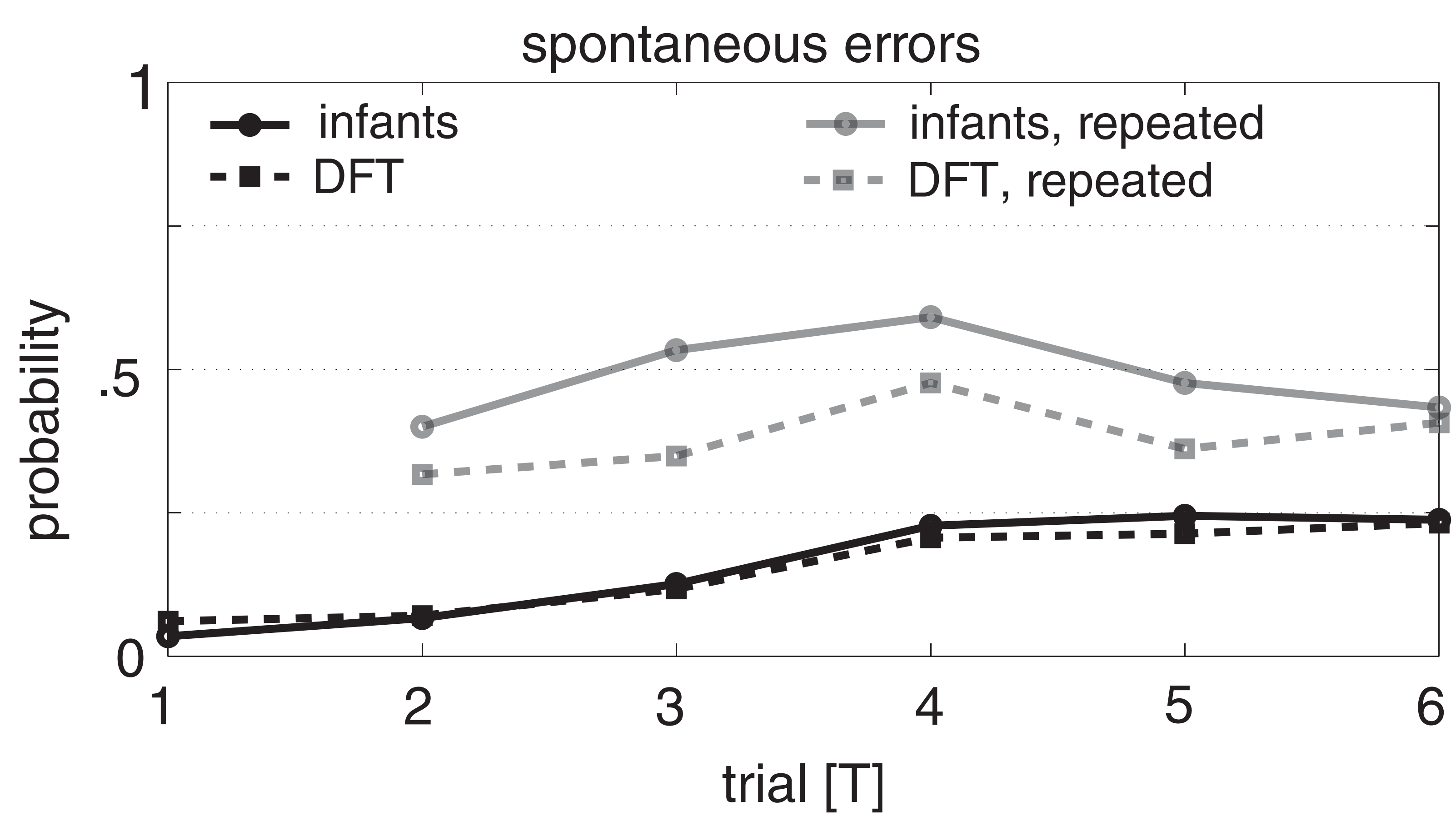
- that makes the decisions in each individual trial, by amplifying small differences into a macroscopic stable state
- and that's how decisions leave traces, have consequences



[Wilimzig, Schöner, 2006]

Decisions have consequences

- a spontaneous error doubles probability to make the spontaneous error again



[Dineva, Schöner: Connection Science 2018]

Conclusions

- 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

The conceptual framework of DFT