Dynamic Field Theory: Selection decisions

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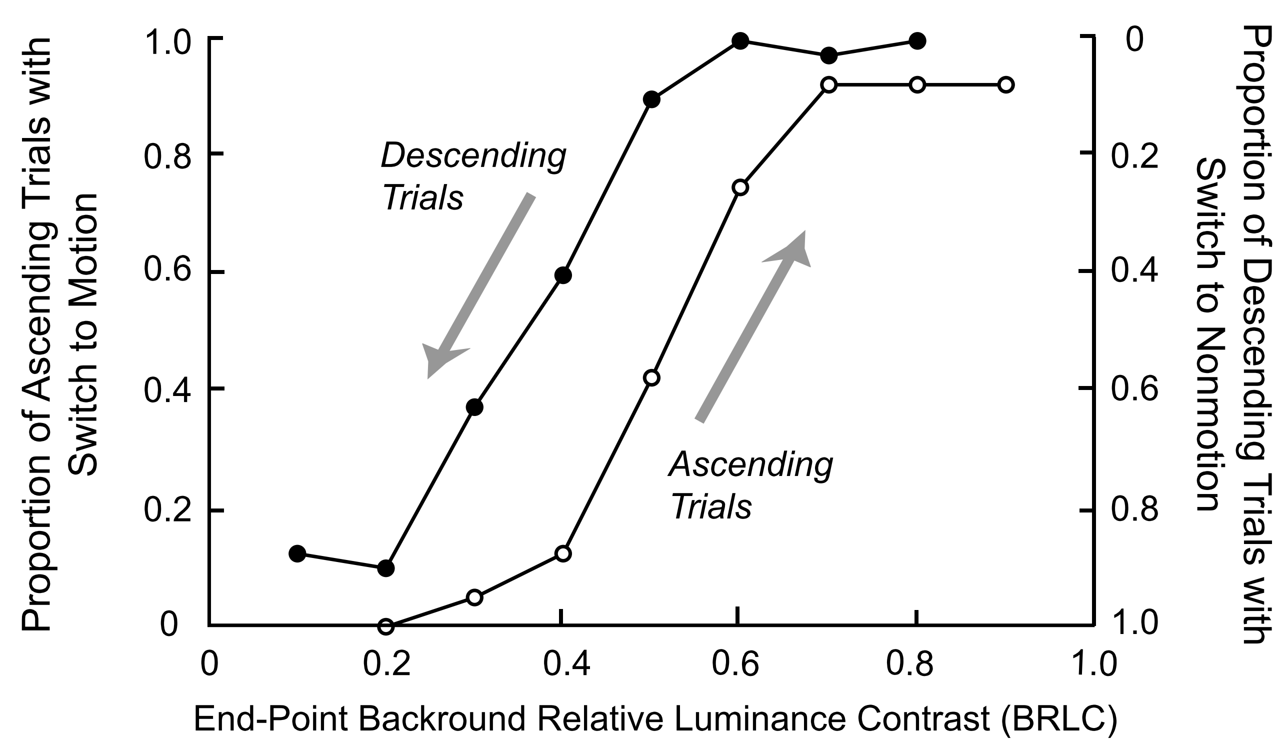
Recall from last lecture …

- Attractor states in neural dynamic fields and their instabilities
  - self-stabilized peaks vs. sub-threshold activation patterns
  - detection and reverse detection instability
  - selection
  - working memory
  - boos-driven detection…

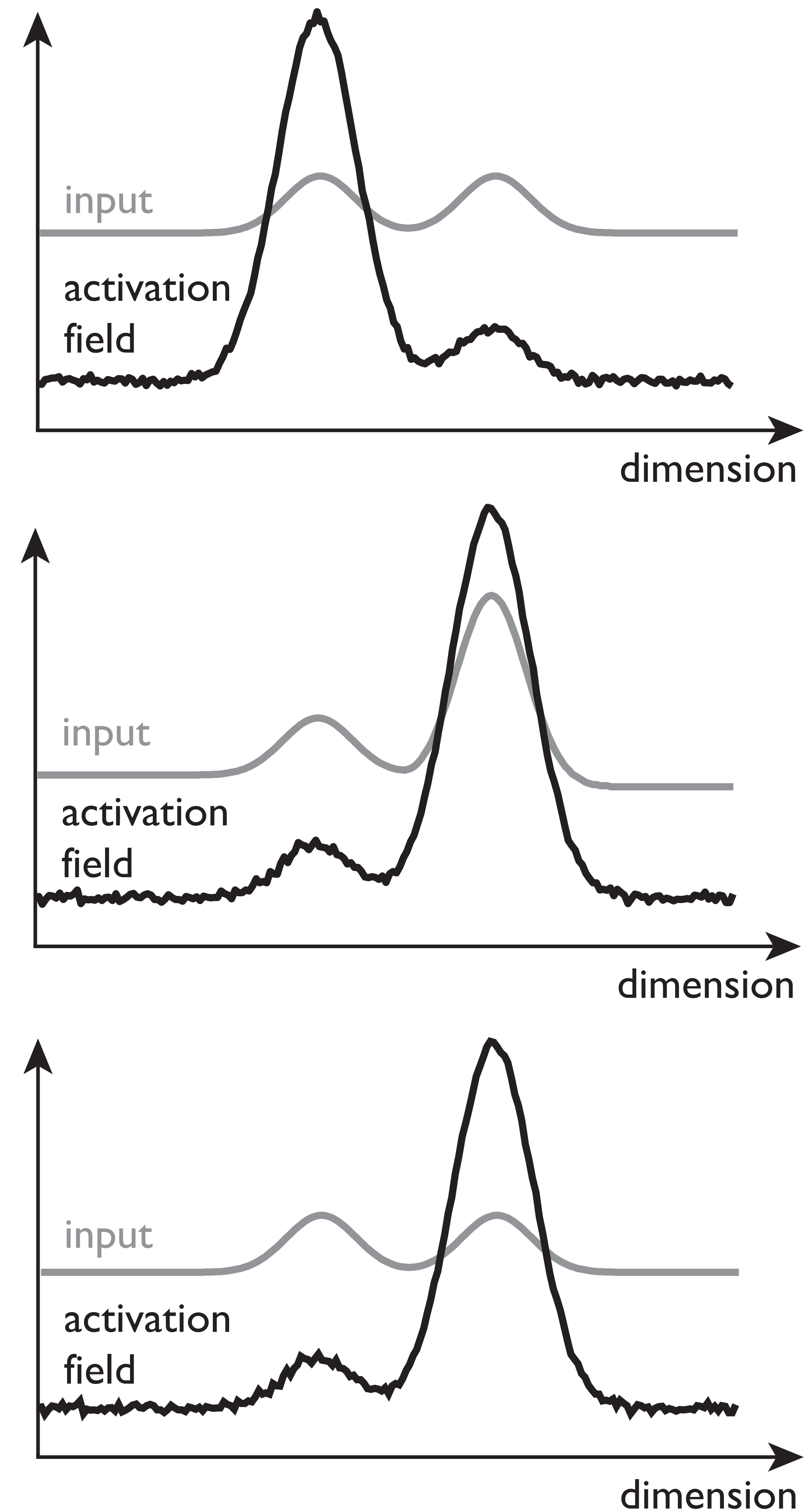
Detection instability

- just responding to input is a "decision" in which the "off" state becomes unstable and the system goes to the alternate "on" state
- that detection decision is self-stabilized… bistable regime..
- critical for the emergence of "events" at discrete times
- evidence for the detection instability from perceptual hysteresis

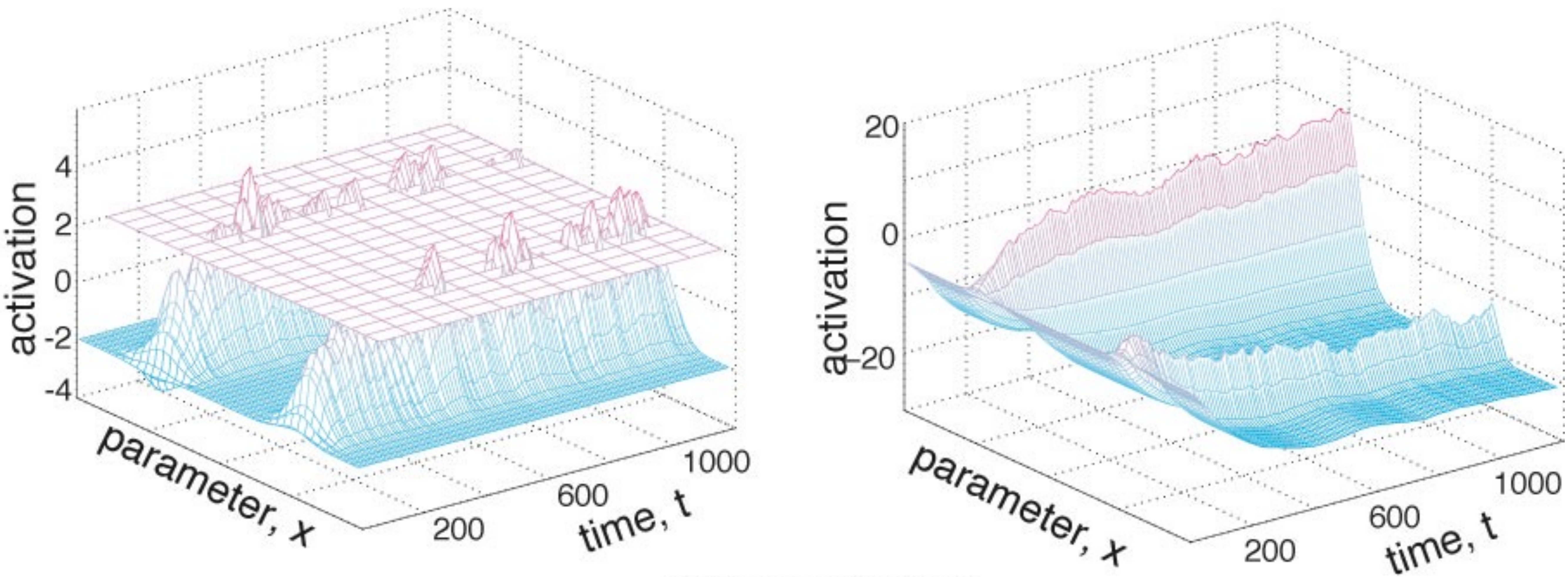
H. S. Hock, G. Schöner / Seeing and Perceiving 23 (2010) 173–195



selection instability



stabilizing selection decisions



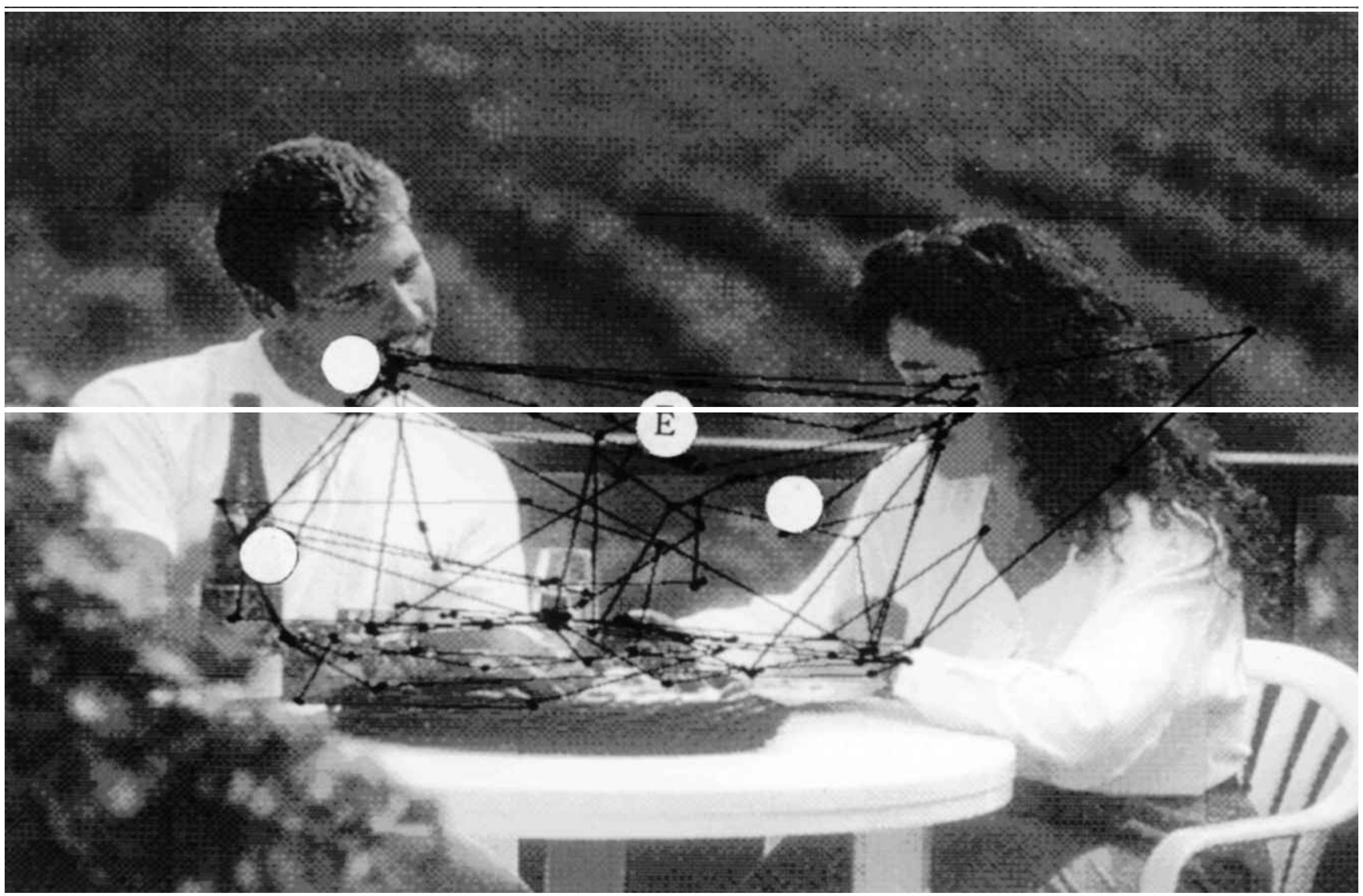
[Wilimzig, Schöner, 2006]

behavioral signatures of selection decisions

- in most experimental situations, the correct selection decision is cued by an *imperative signal* leaving no actual freedom of choice to the participant (only the freedom of *error*)
- when performance approaches chance level, this approximates *free choice*
- reasons are experimental (uncertainty, strategies…)
- (task set plays a major role … to be discussed later)

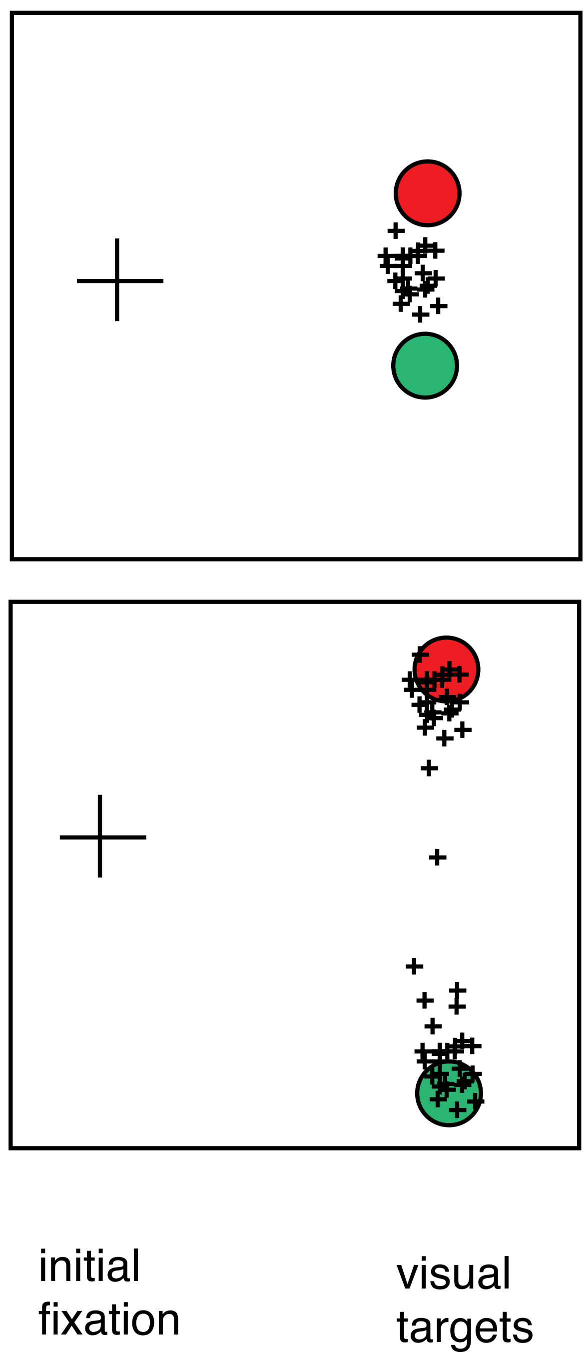
choice without imperative signal

- selecting a new saccadic location

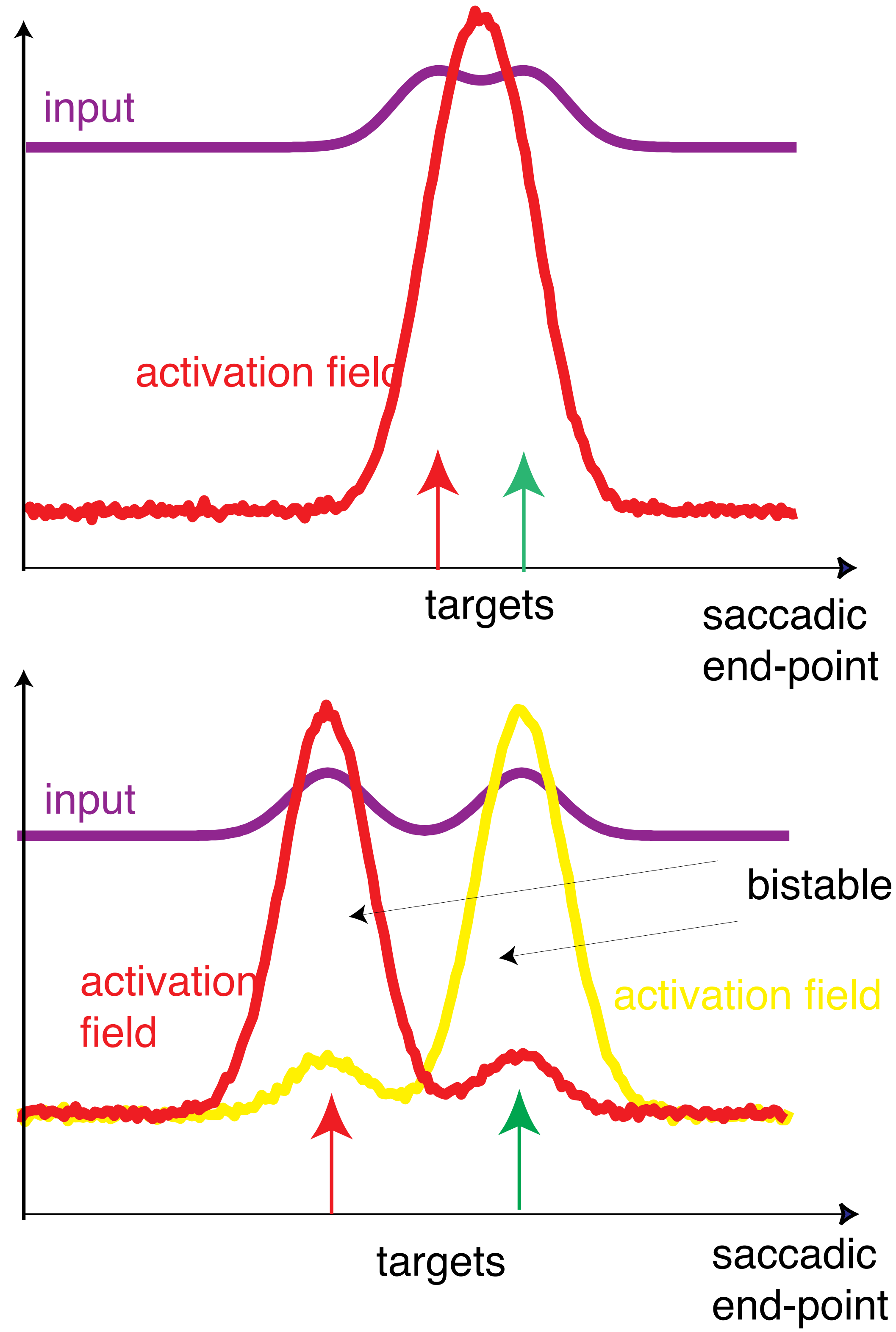


[O'Reagan et al., 2000]

saccadic selection



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



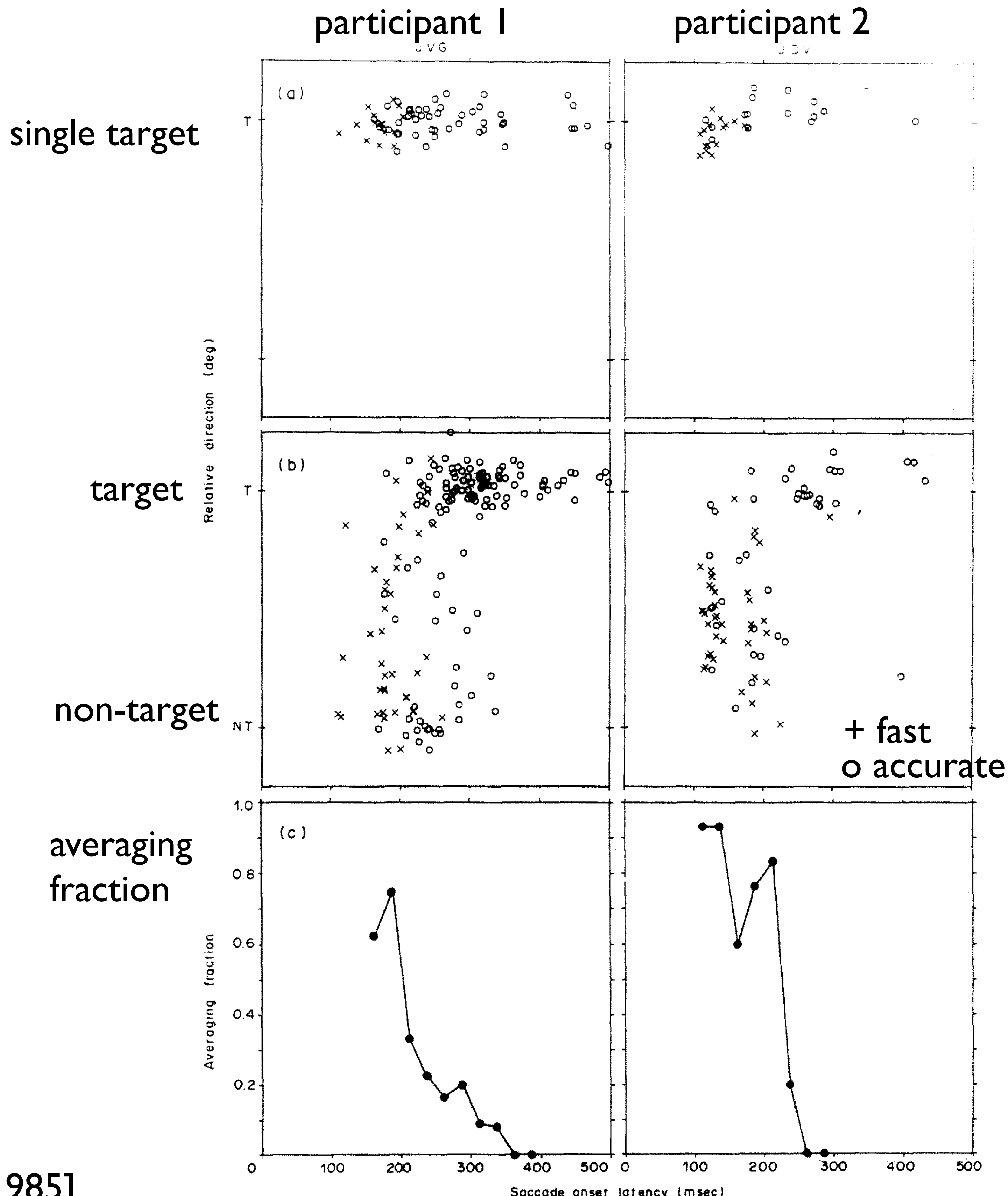
[after Kopecz, Schöner: Biol Cybern 73:49 (95)]

saccadic selection

- in reduced visual environment, selections become relatively reproducible…
- selection decisions depend on metrics of visual stimuli
  - averaging vs. selection

saccadic selection

- time course of saccadic selection:
- transition from averaging to selection



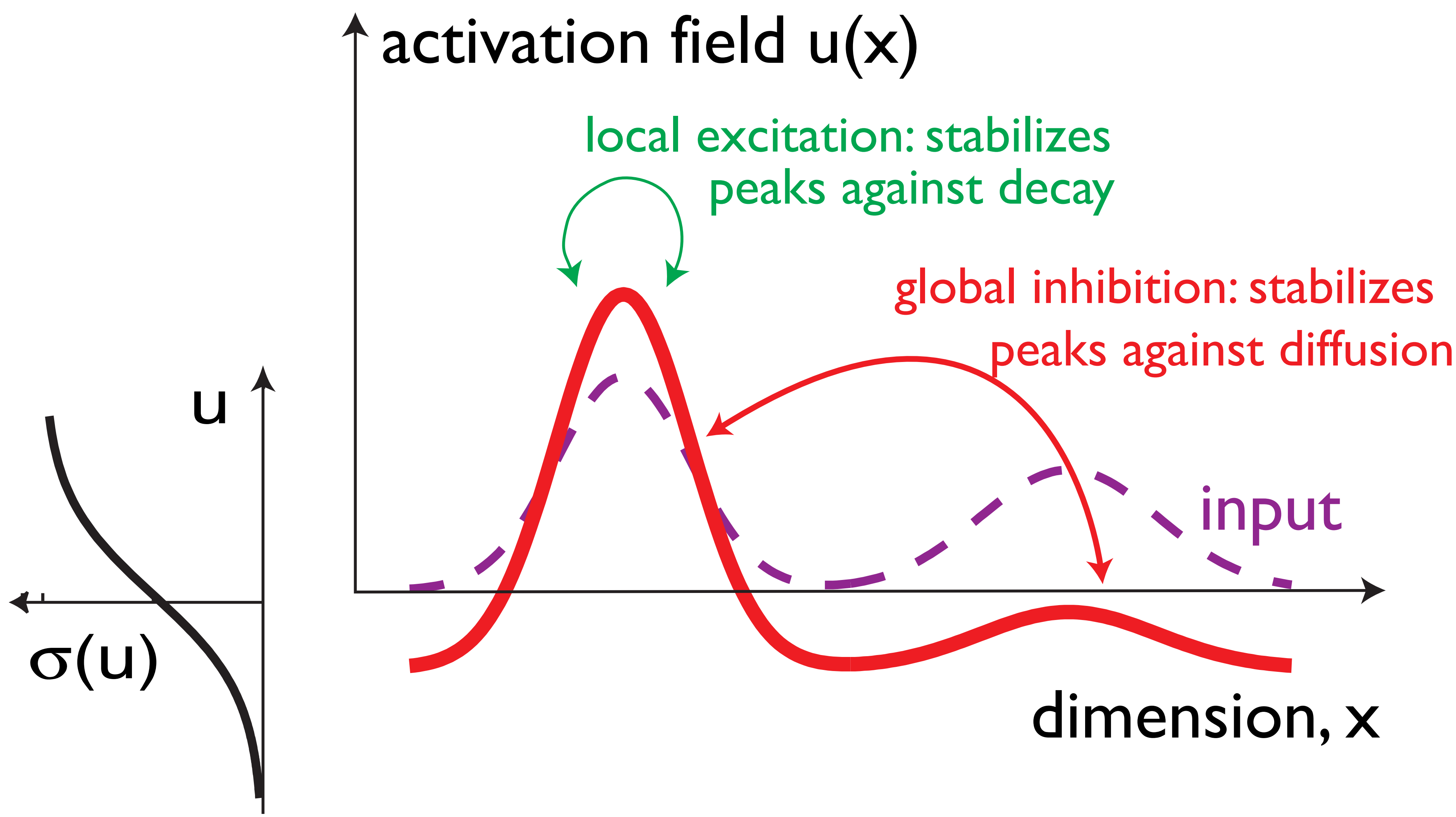
[Ottes, Van Gisbergen, Eggermont, 1985]

saccadic selection

- understanding the time course of selection requires a re-examination of the theory

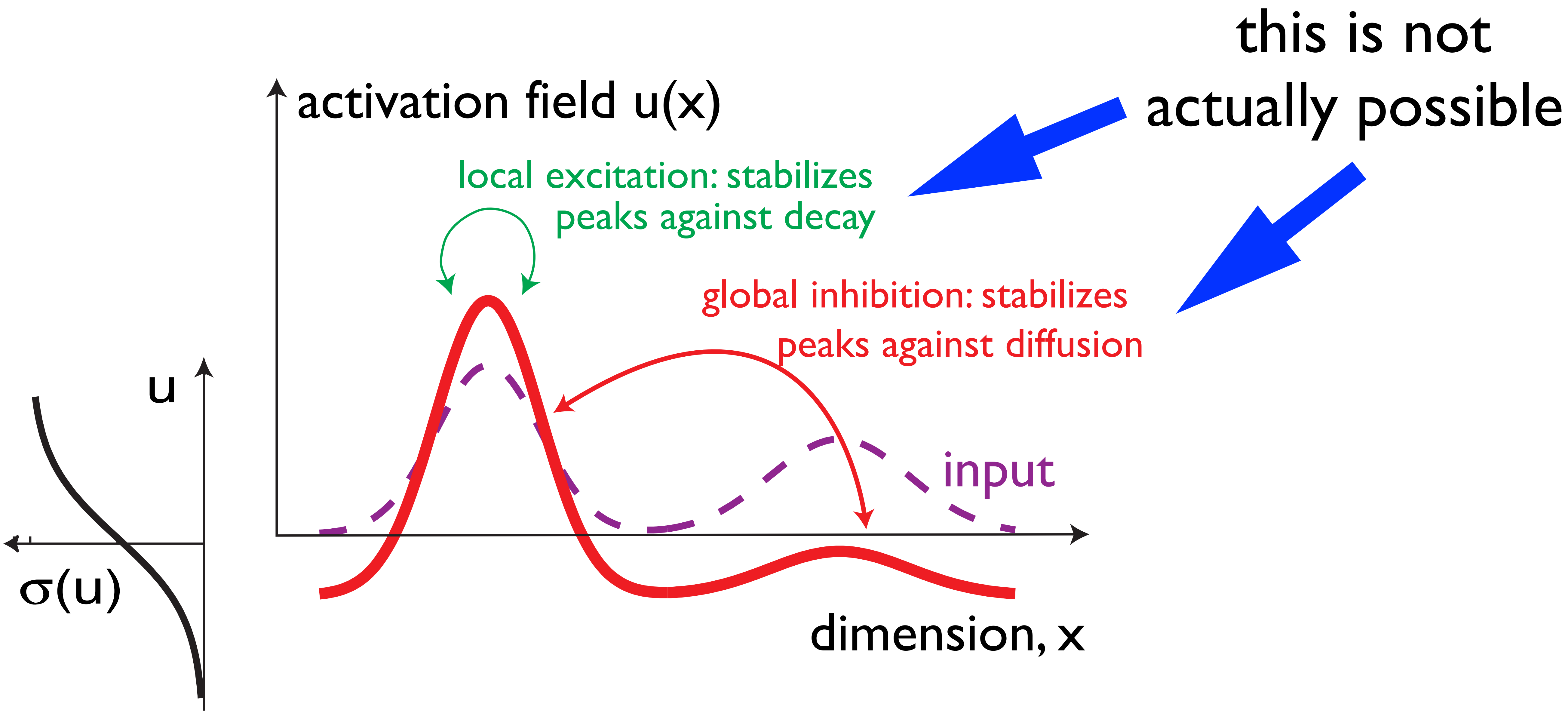
… so far we assumed

- that a single population of activation variable mediates both the excitatory and the inhibitory coupling required to make peaks attractors



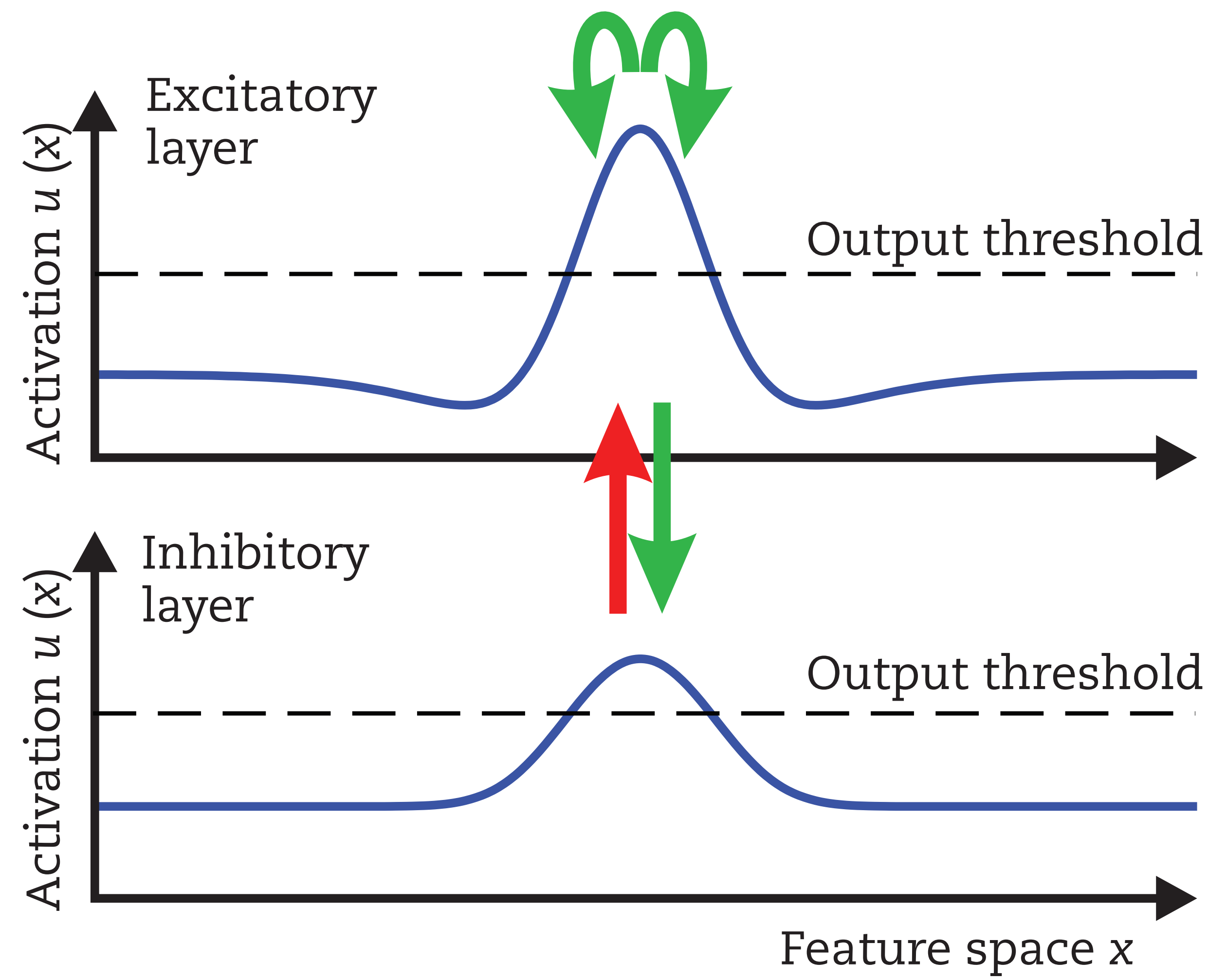
But: Dale's law

- says: every neuron forms with its axon only one type of synapse on the neurons it projects onto
- and that is either excitatory or inhibitory



2 layer neural fields

- inhibitory coupling is mediated by inhibitory interneurons that
  - are excited by the excitatory layer
  - and in turn inhibit the inhibitory layer



[chapter 3 of the book]

2 layer Amari fields

$$\tau_u \dot{u}(x,t) = -u(x,t) + h_u + s(x,t) + \int k_{uu}(x-x')g(u(x',t))dx' - \int k_{uv}(x-x')g(v(x',t))dx'$$

$$\tau_v \dot{v}(x,t) = -v(x,t) + h_v + \int k_{vu}(x-x')g(u(x',t))dx'$$

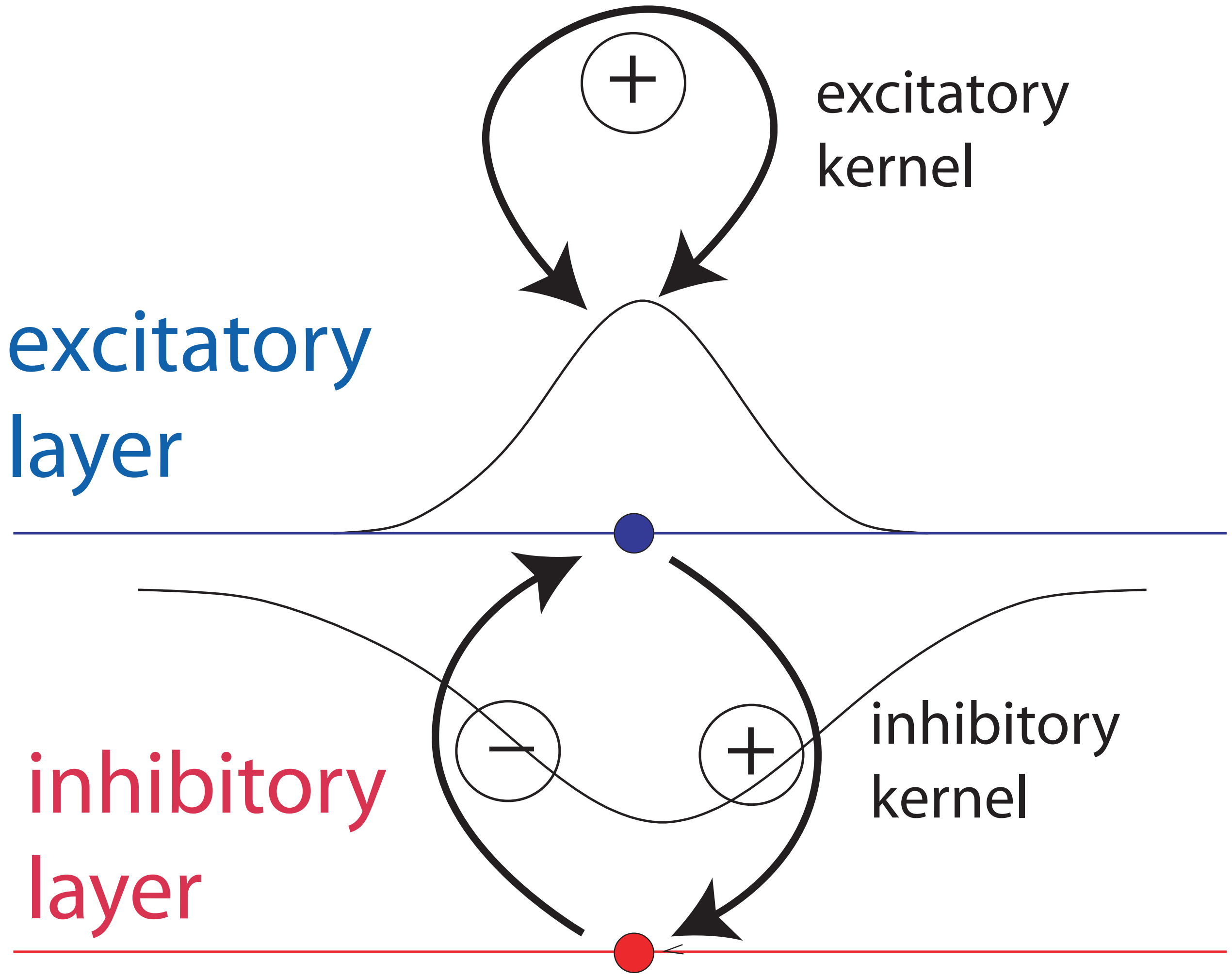
with projection kernels

$$k_{uu}(x-x') = c_{uu} \cdot \exp\left(-\frac{(x-x')^2}{2\sigma_{uu}^2}\right)$$

simulation

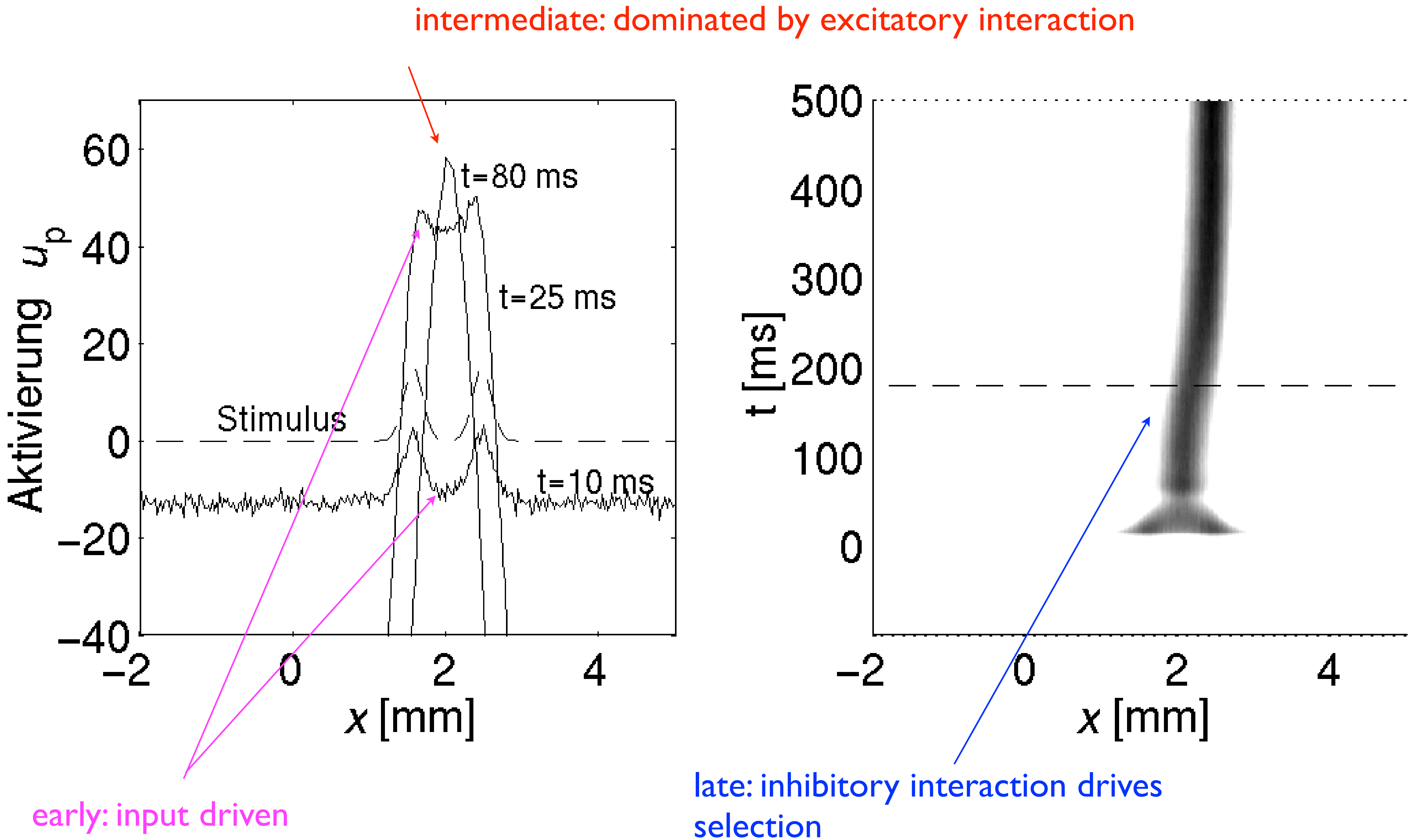
Implications

- the fact that inhibition arises only after excitation has been induced has observable consequences in the time course of decision making:
  - initially input-dominated
  - early excitatory interaction
  - late inhibitory interaction



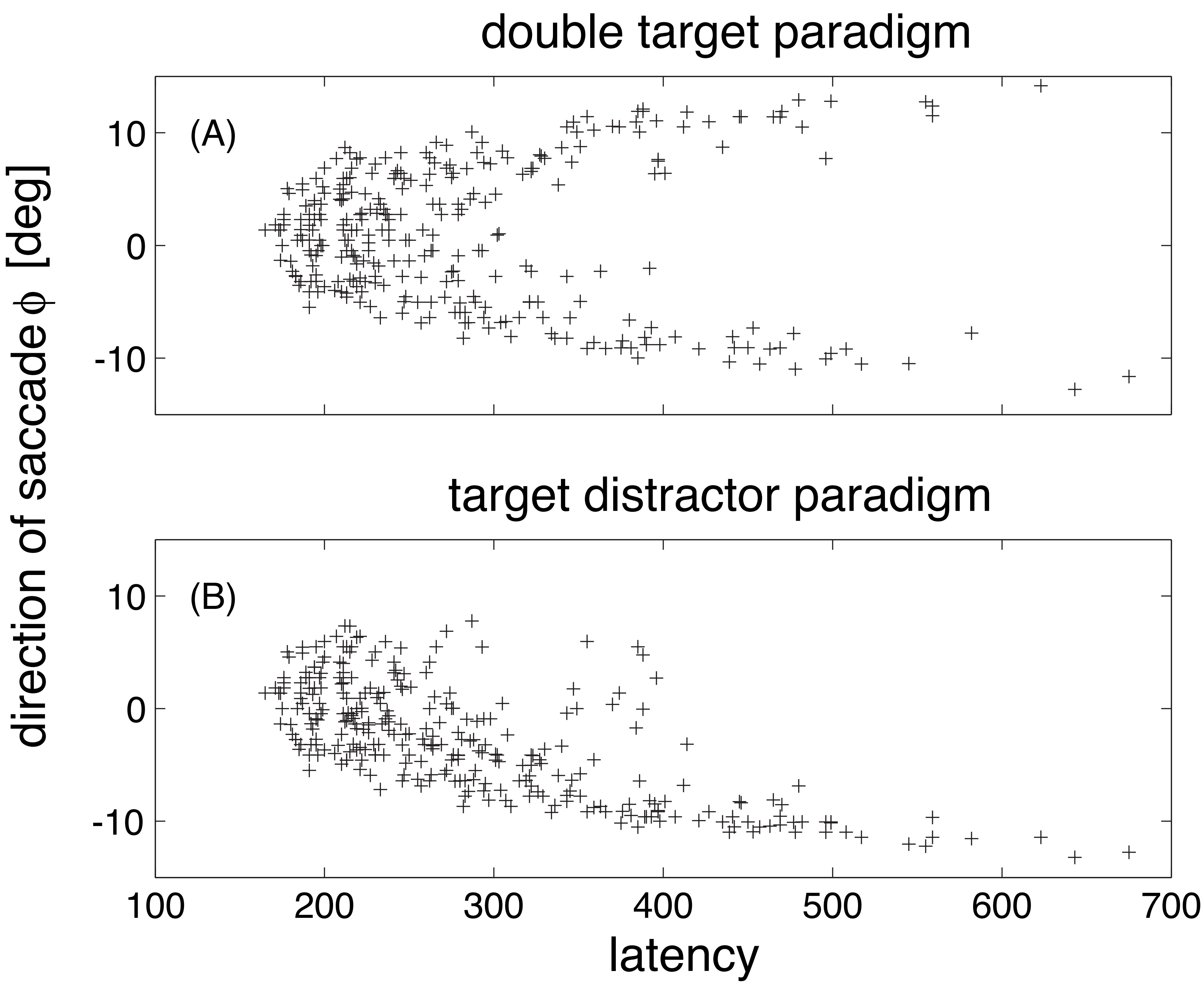
[figure: Wilimzig, Schneider, Schöner, Neural Networks, 2006]

time course of selection



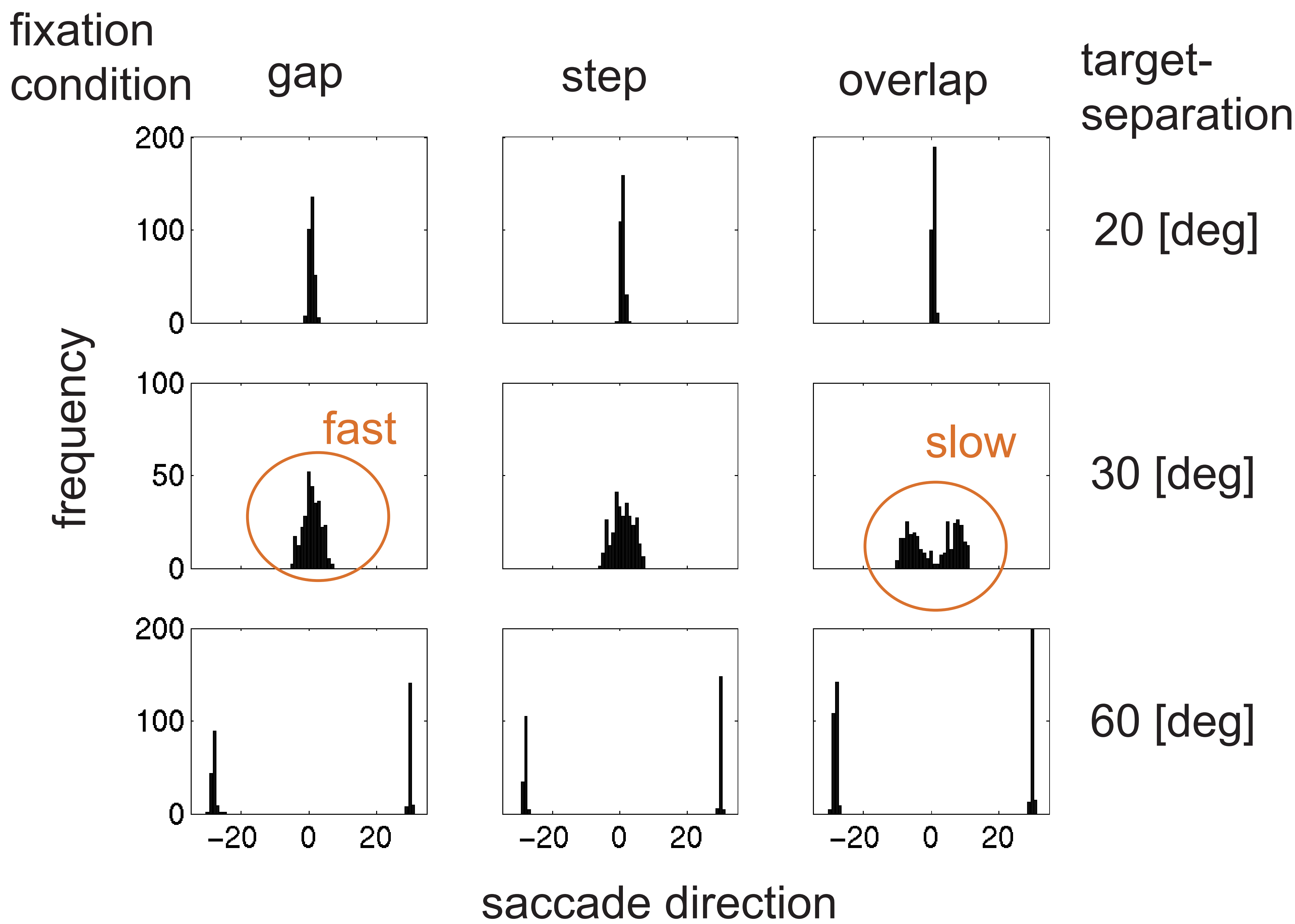
[figure: Wilimzig, Schneider, Schöner, Neural Networks, 2006]

=> early fusion, late selection



[figure: Wilimzig, Schneider, Schöner, Neural Networks, 2006]

fixation and selection



[figure: Wilimzig, Schneider, Schöner, Neural Networks, 2006]

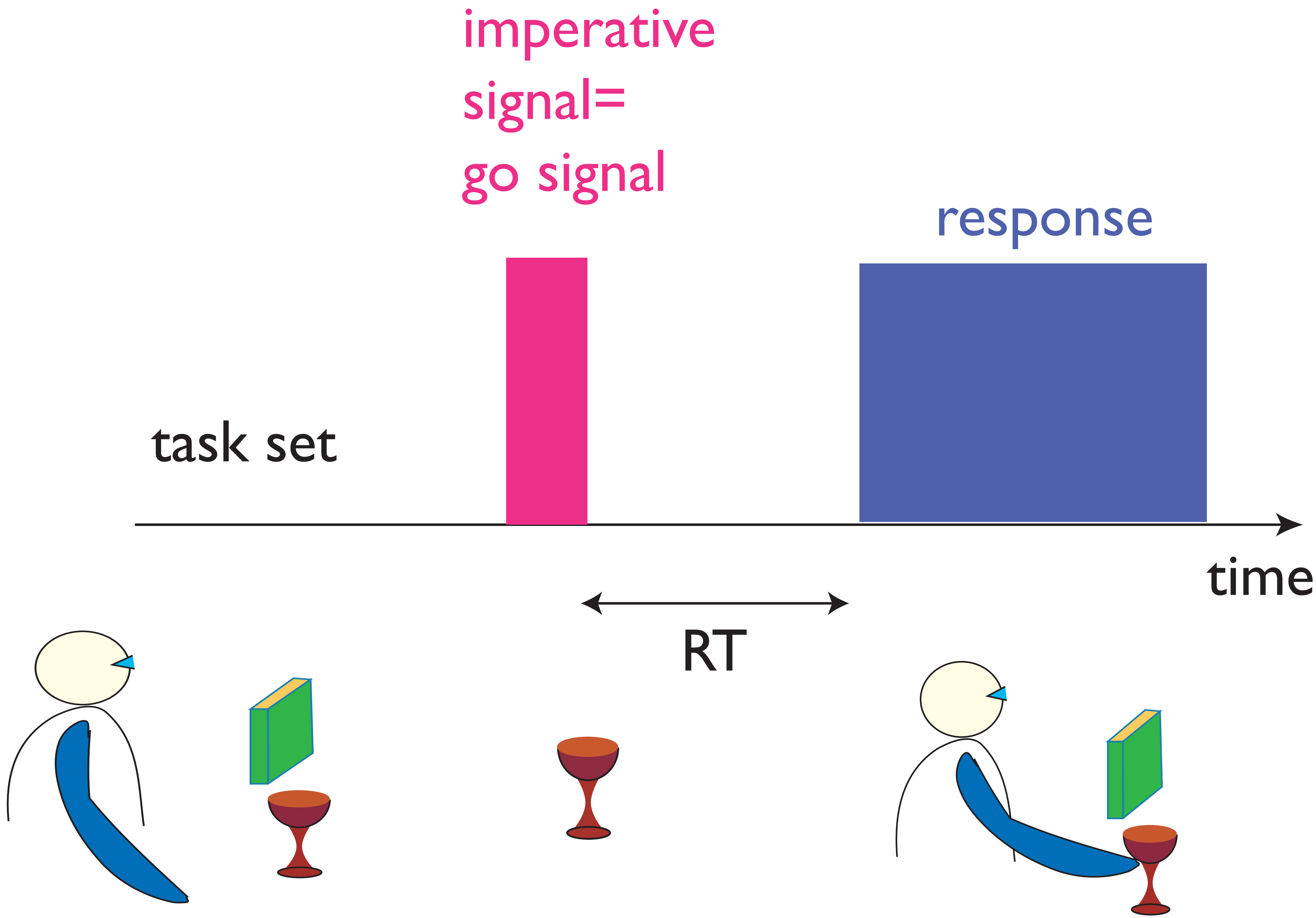
2 layer fields afford oscillations

- => simulation
- (oscillatory states for enhanced coupling among fields)
- (generic nature of oscillations)

studying selection decisions in the laboratory

- using an imperative signal...

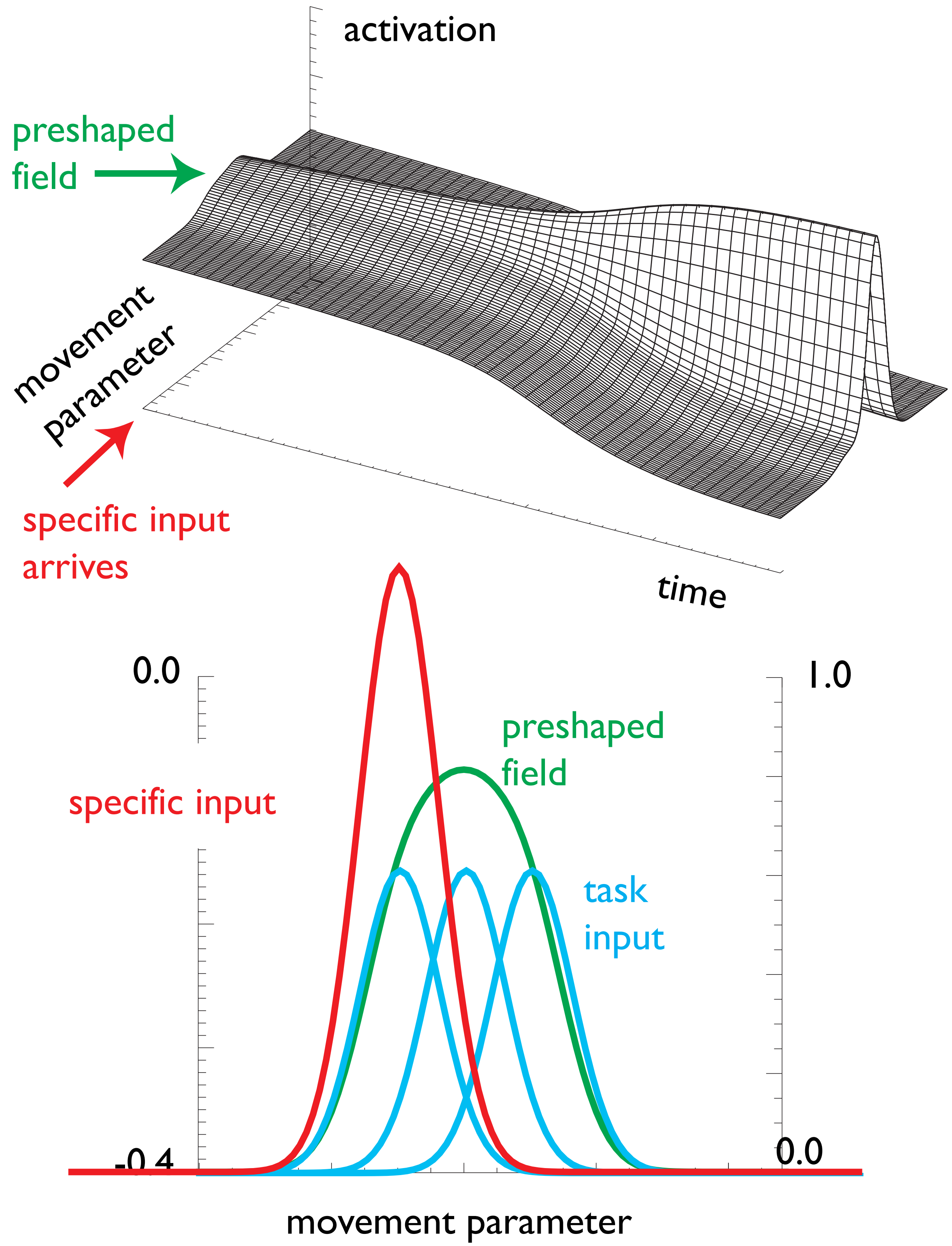
reaction time (RT) paradigm



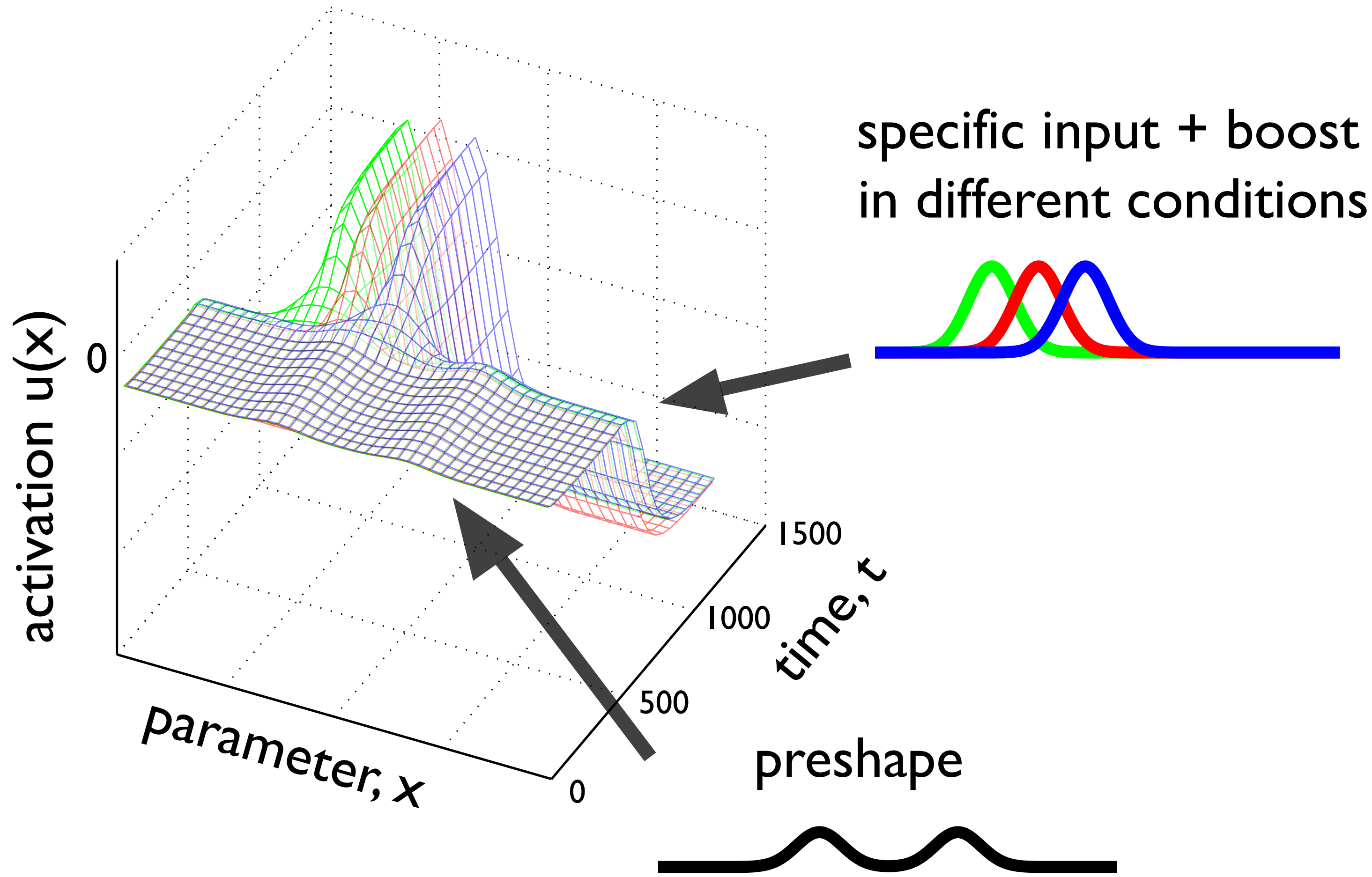
the task set

- 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)

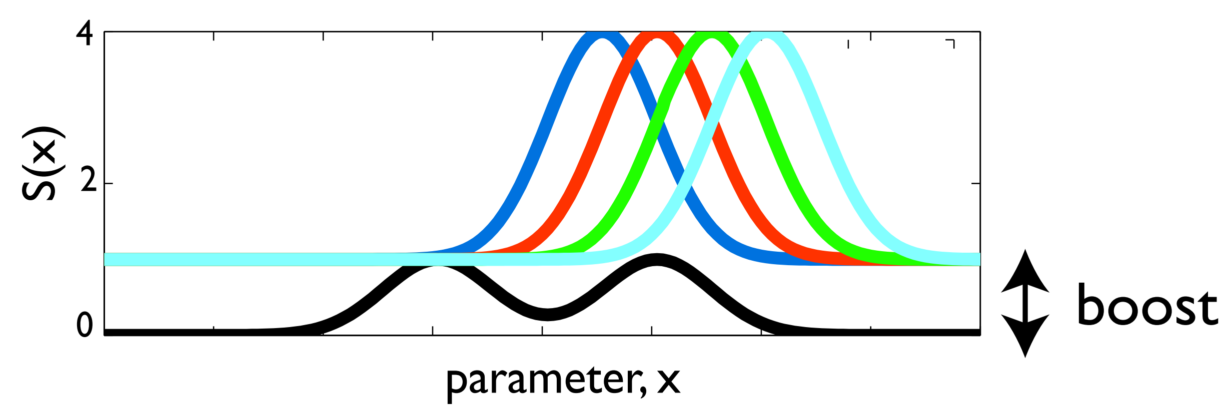
notion of preshape

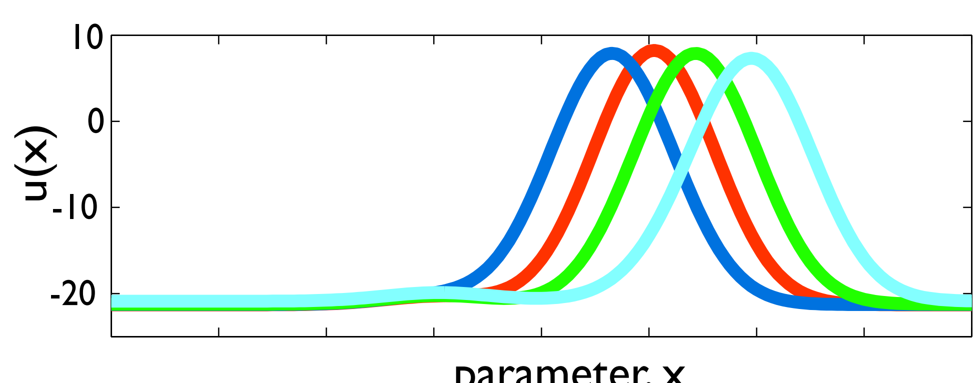


weak preshape in selection



- specific (imperative) input dominates and drives detection instability

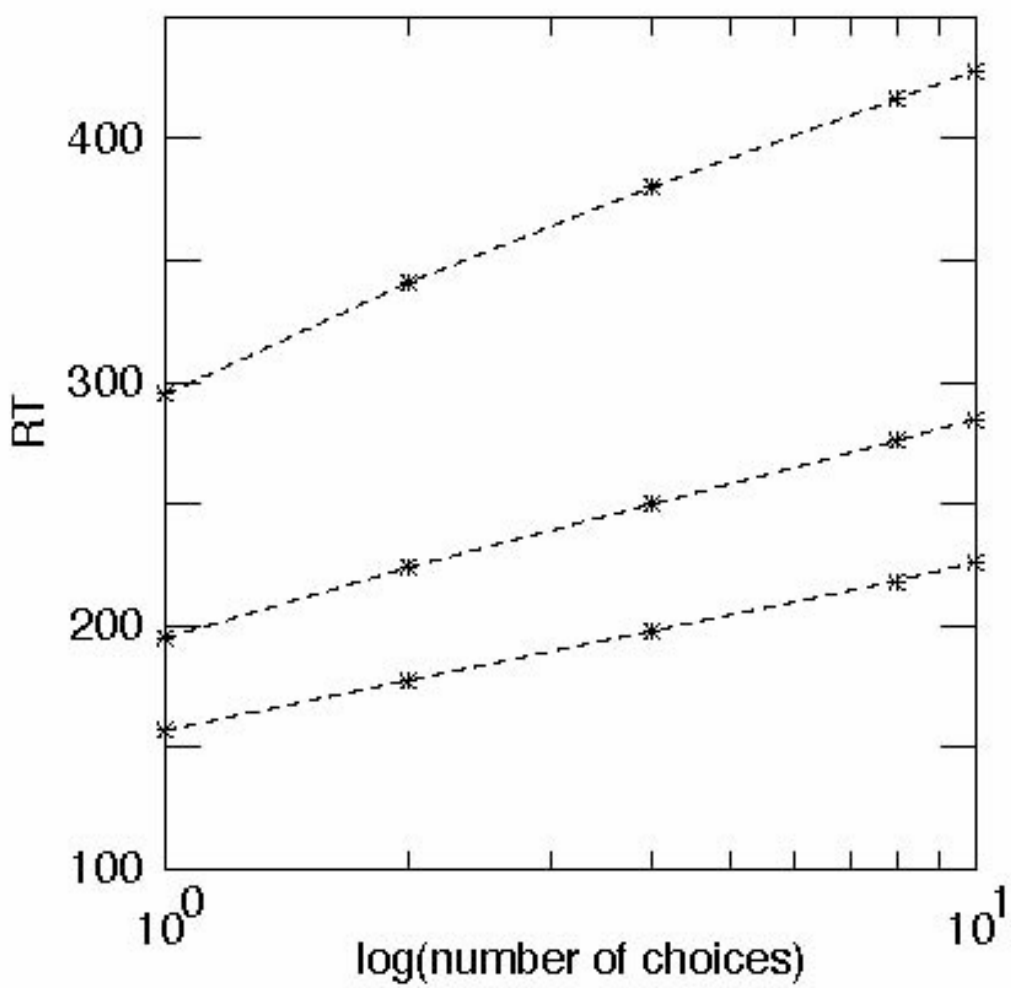


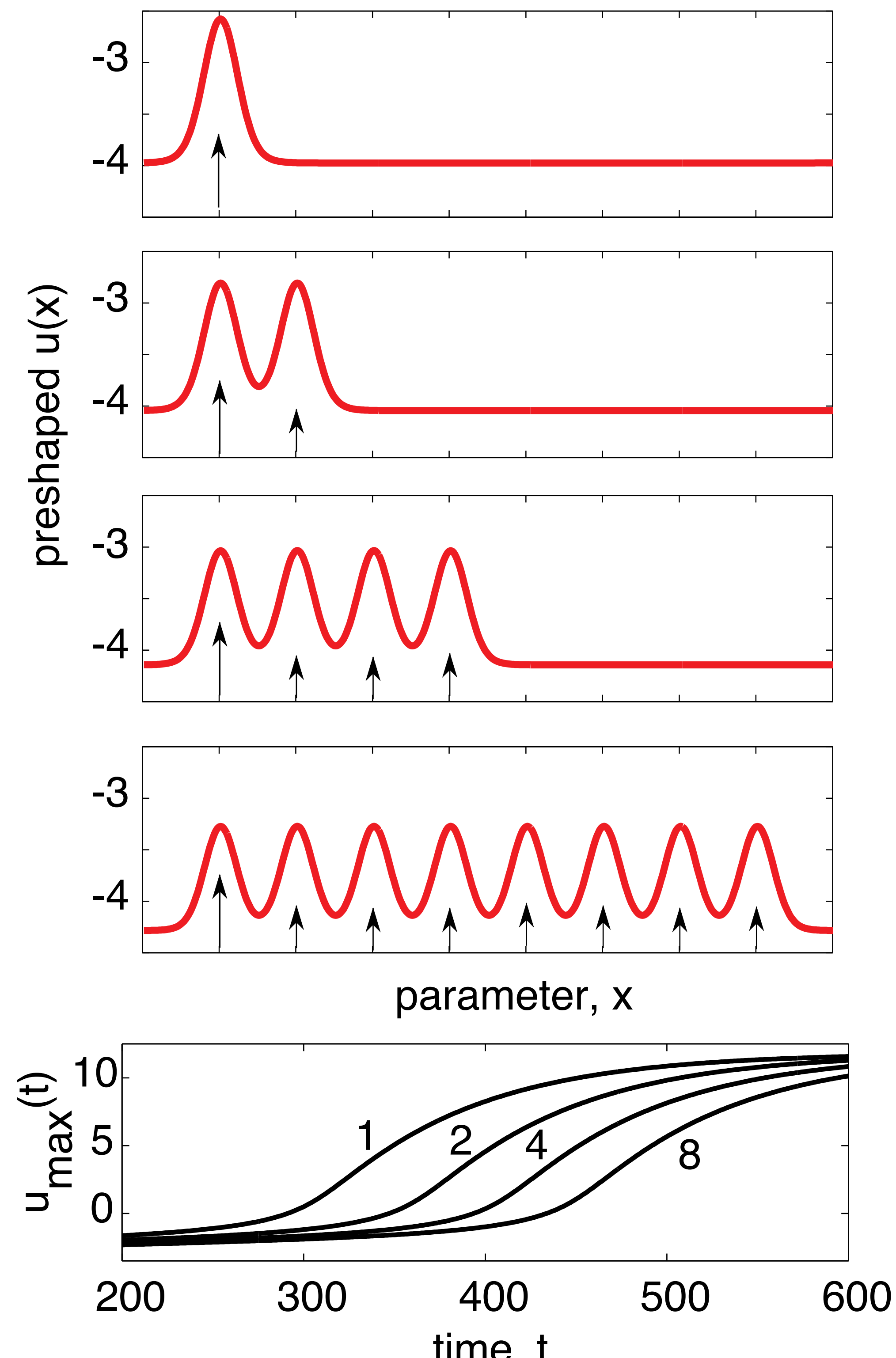


[Wilimzig, Schöner, 2006]

using preshape to account for classical RT data

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

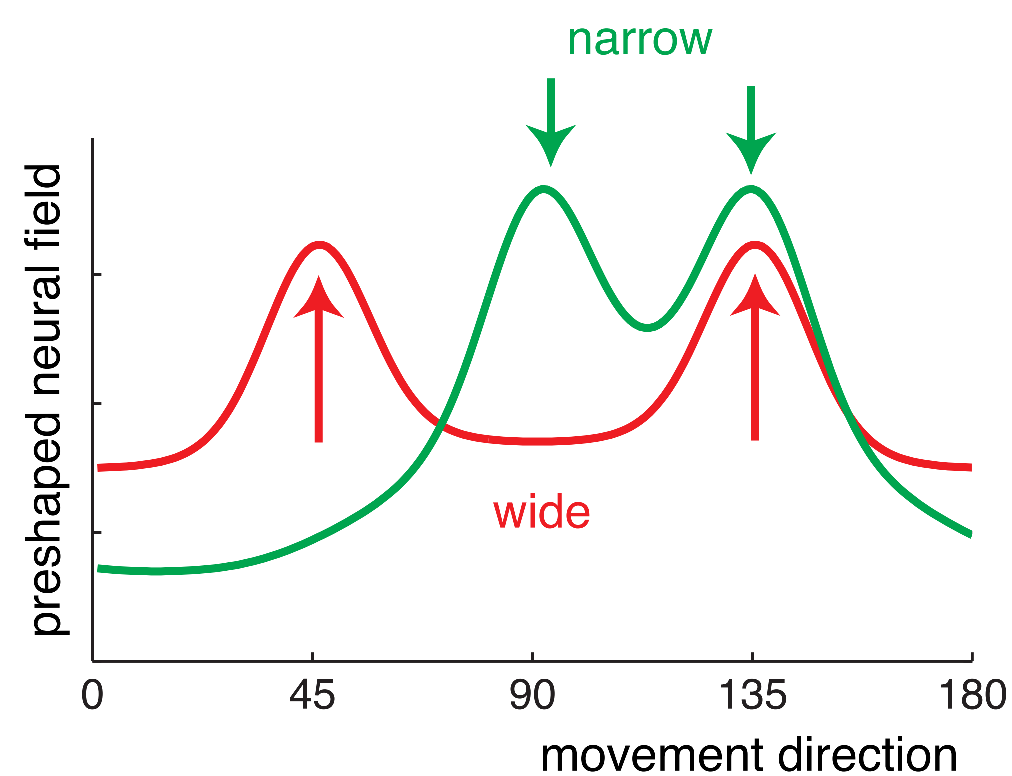


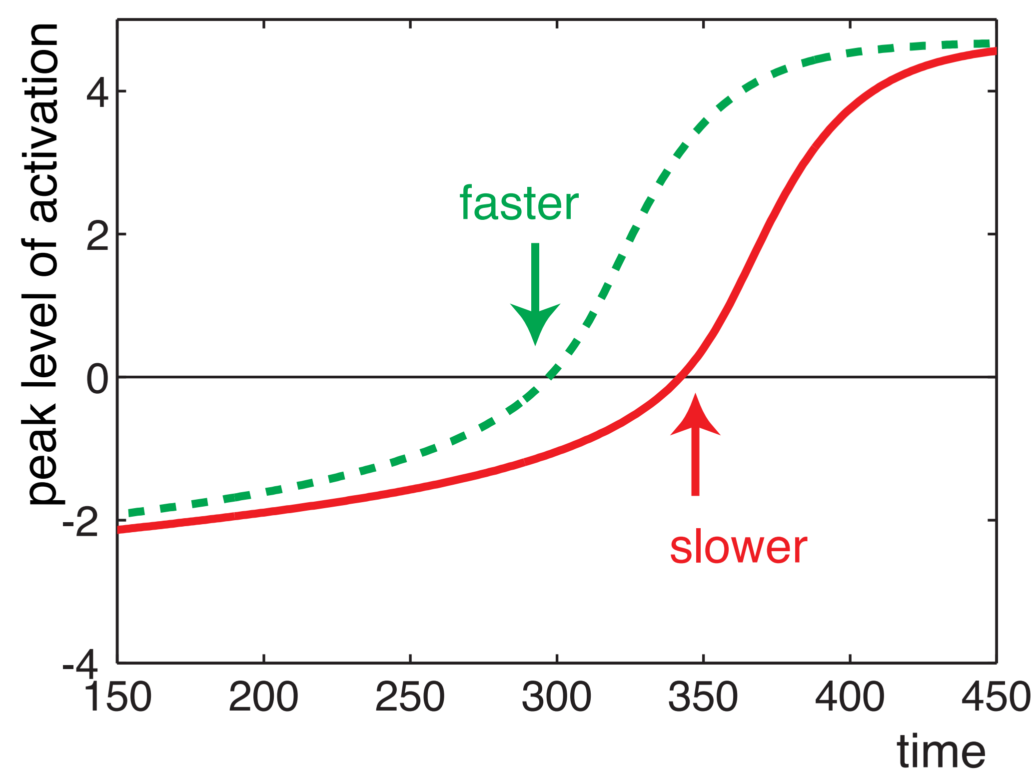


[Erlhagen, Schöner, Psych Rev 2002]

metric effect

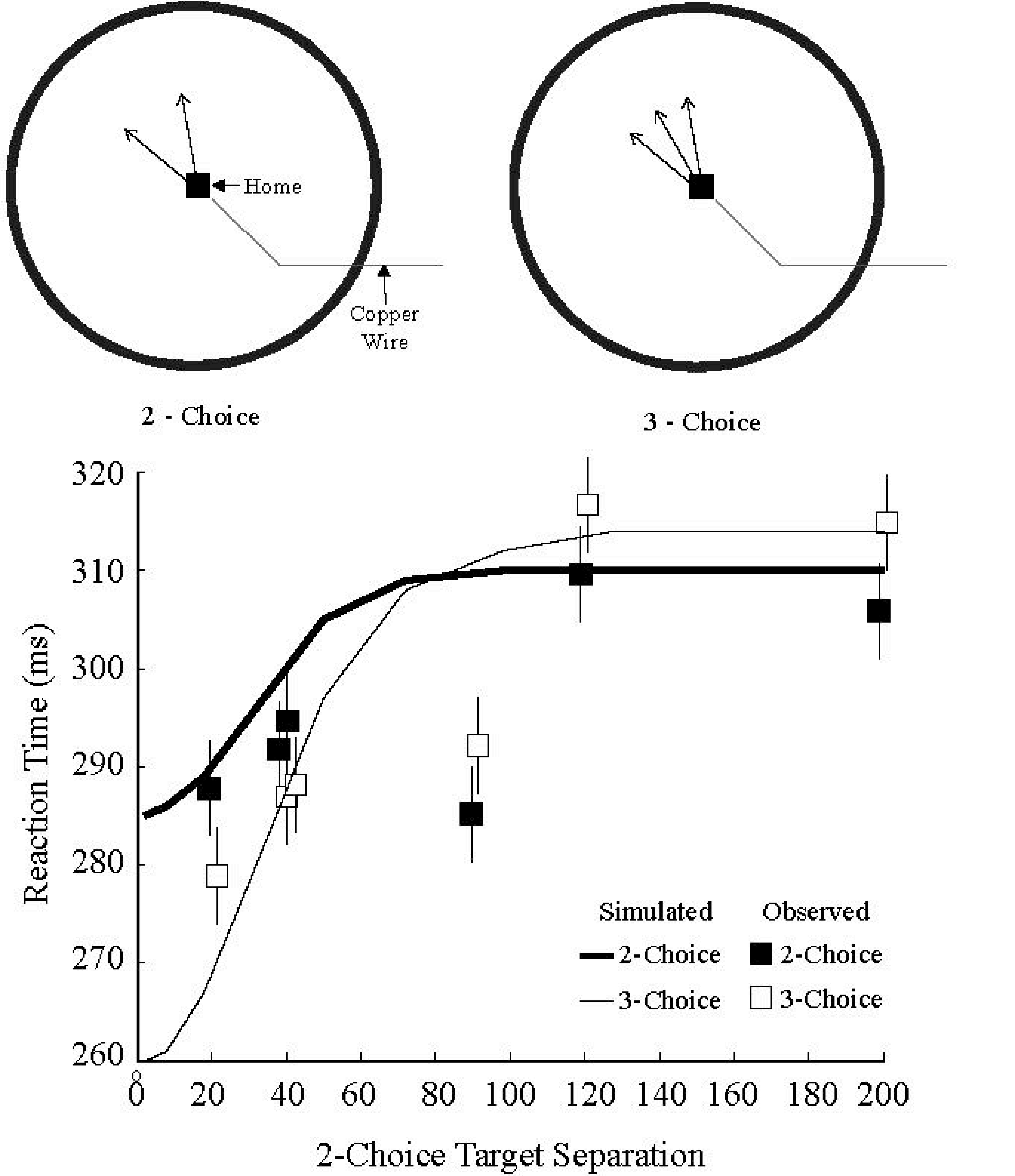
- predict faster response times for metrically close than for metrically far choices



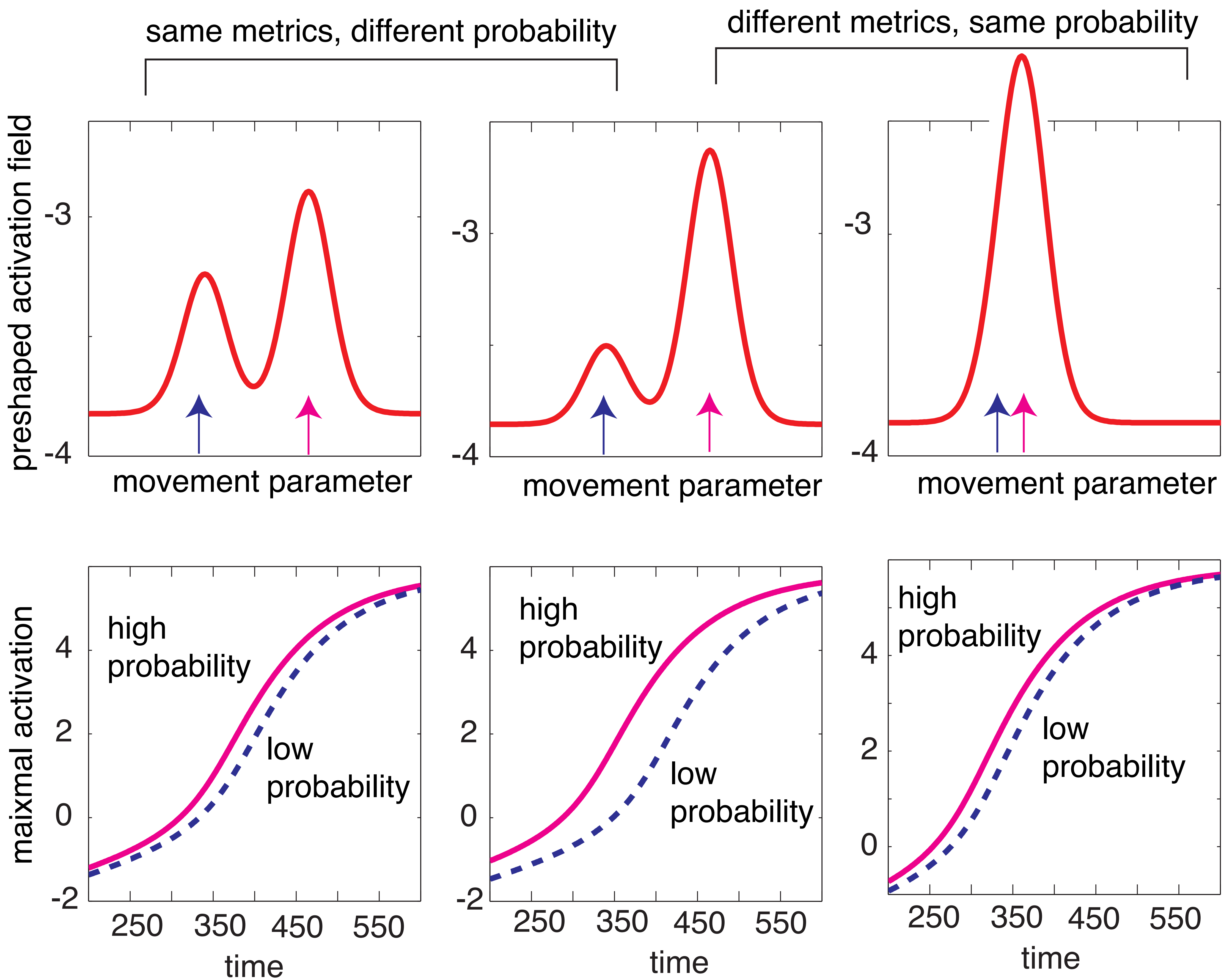


[from Schöner, Kopecz, Erlhagen, 1997]

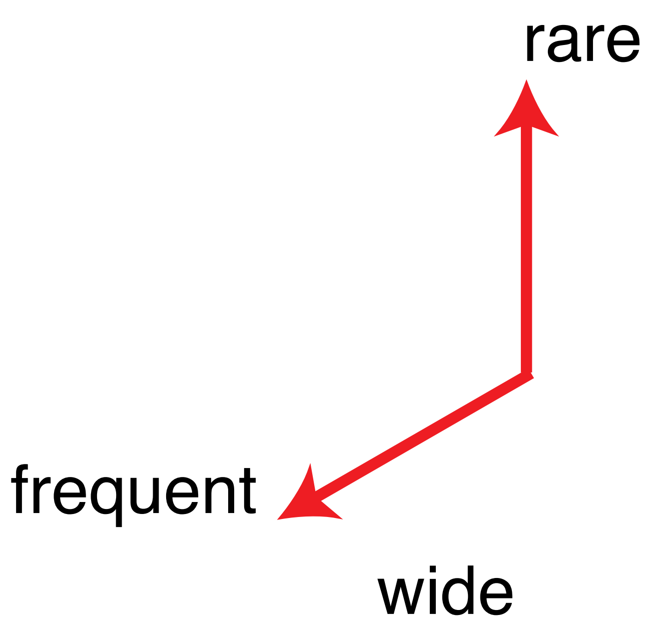
experiment: metric effect

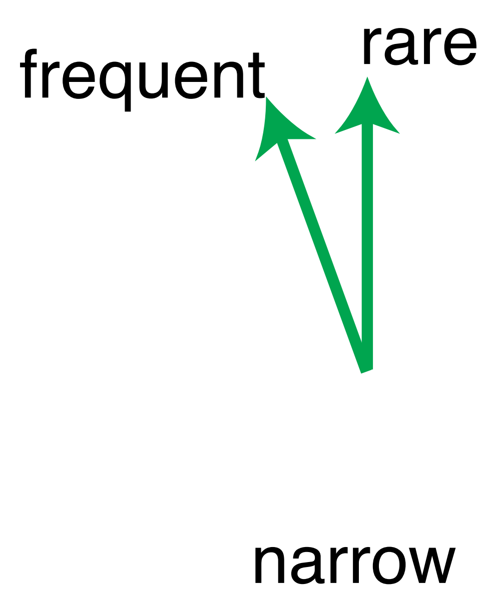


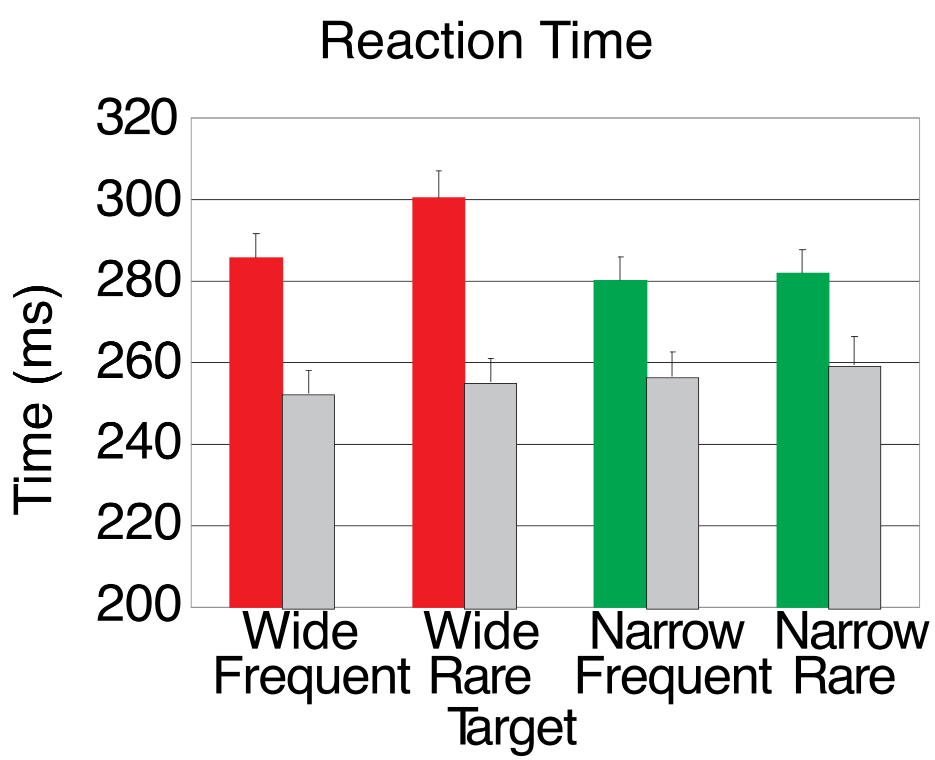
[McDowell, Jeka, Schöner]

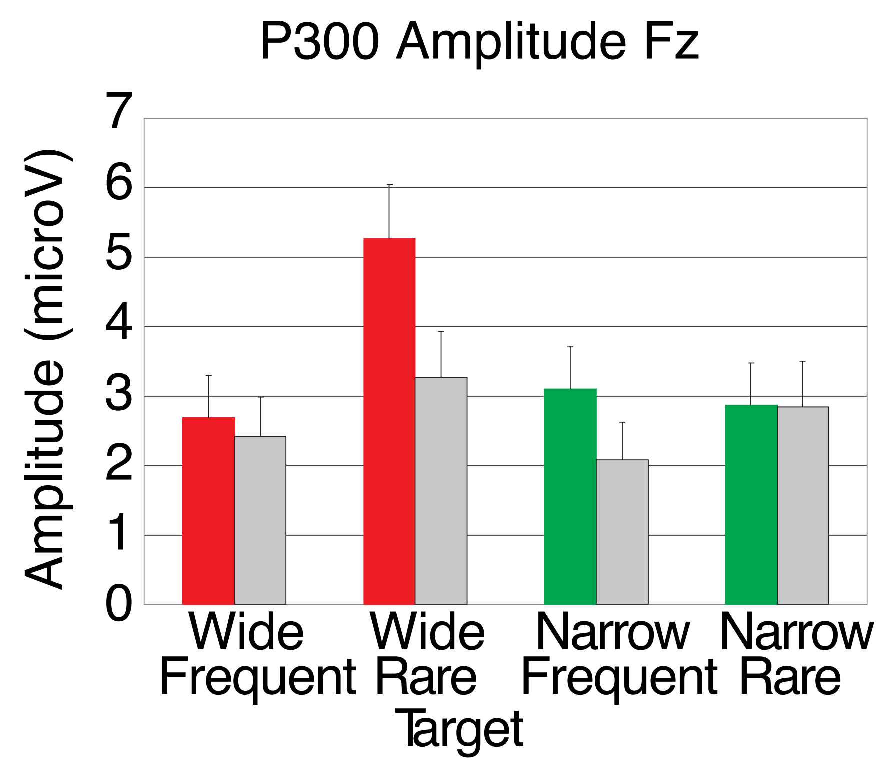


[from Erlhagen, Schöner: Psych. Rev. 2002]





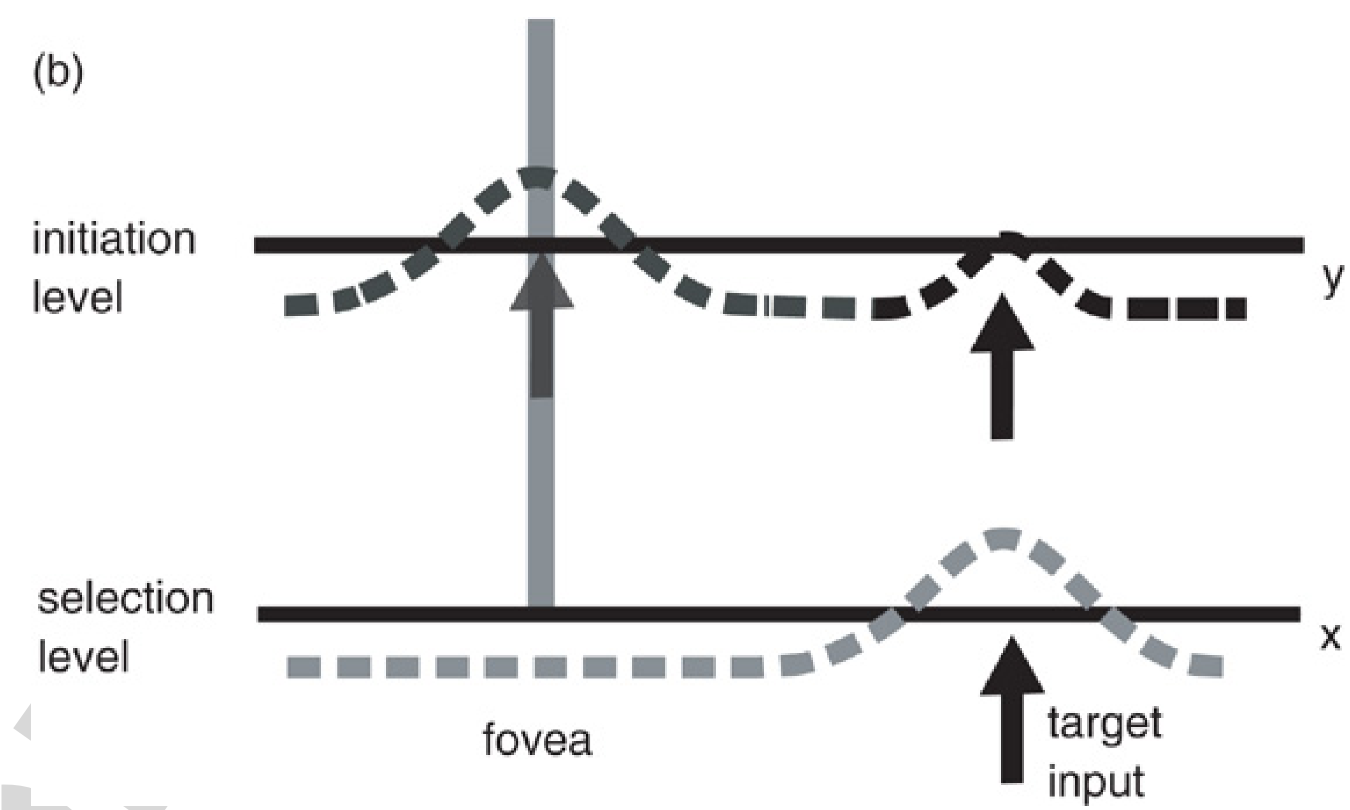


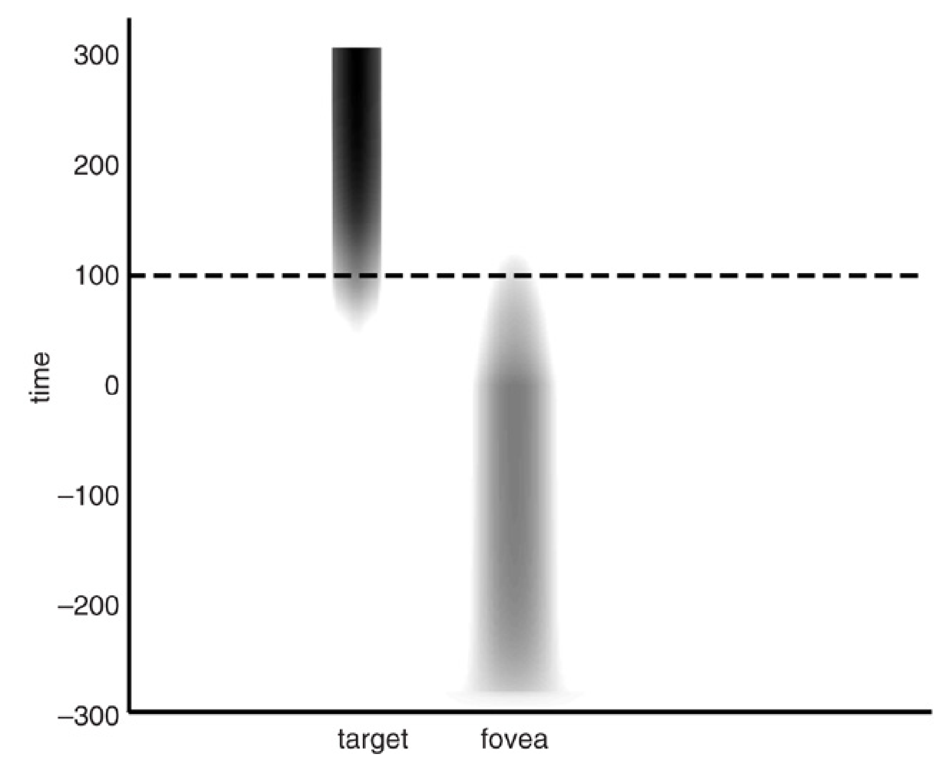


[from McDowell, Jeka, Schöner, Hatfield, 2002]

detection-selection: overcoming fixation

- detection can be like selection: initiating an action means terminating the non-action=fixation or posture
- example: saccade initiation

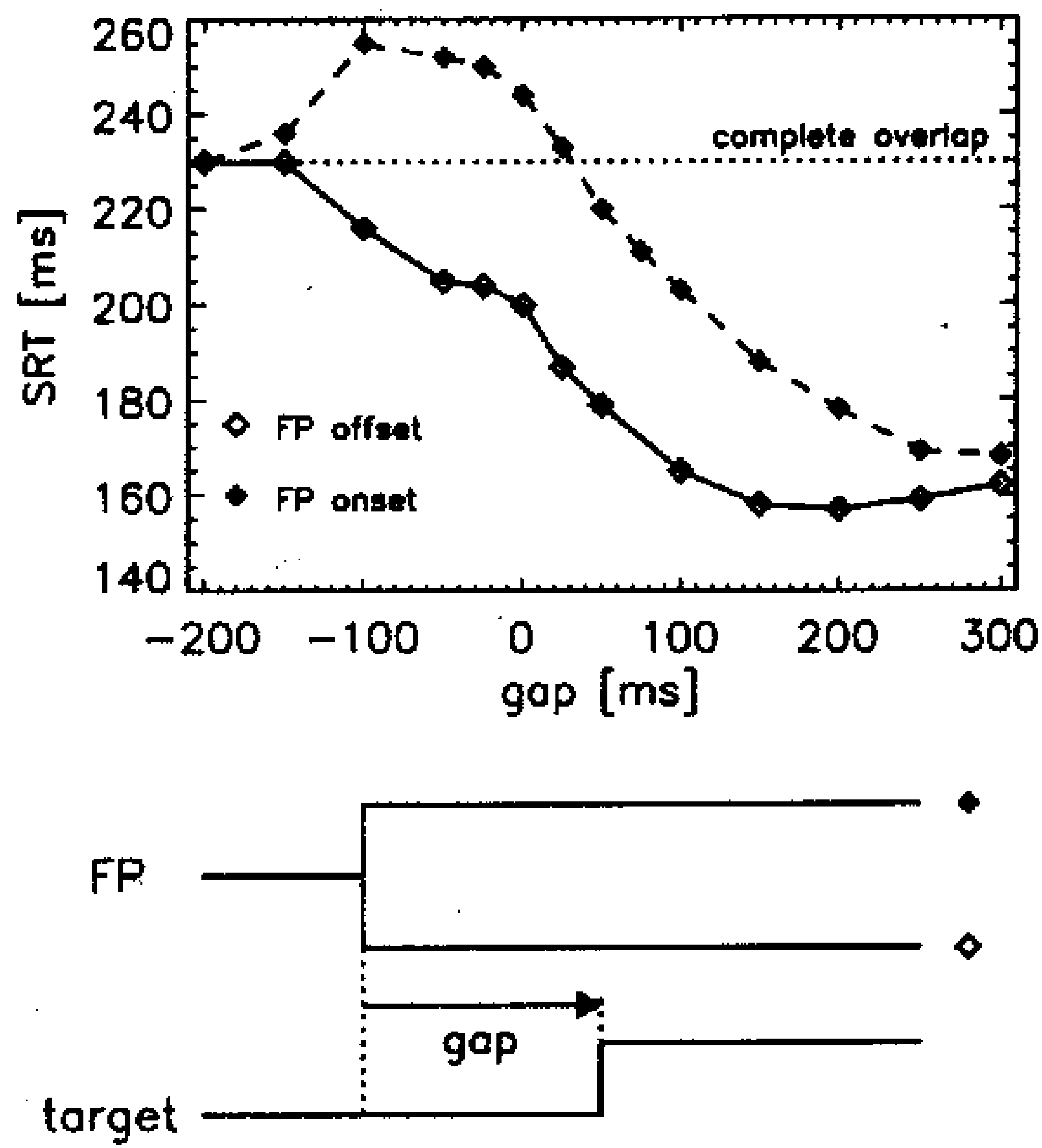




[Wilimzig, Schneider, Schöner, 2006]

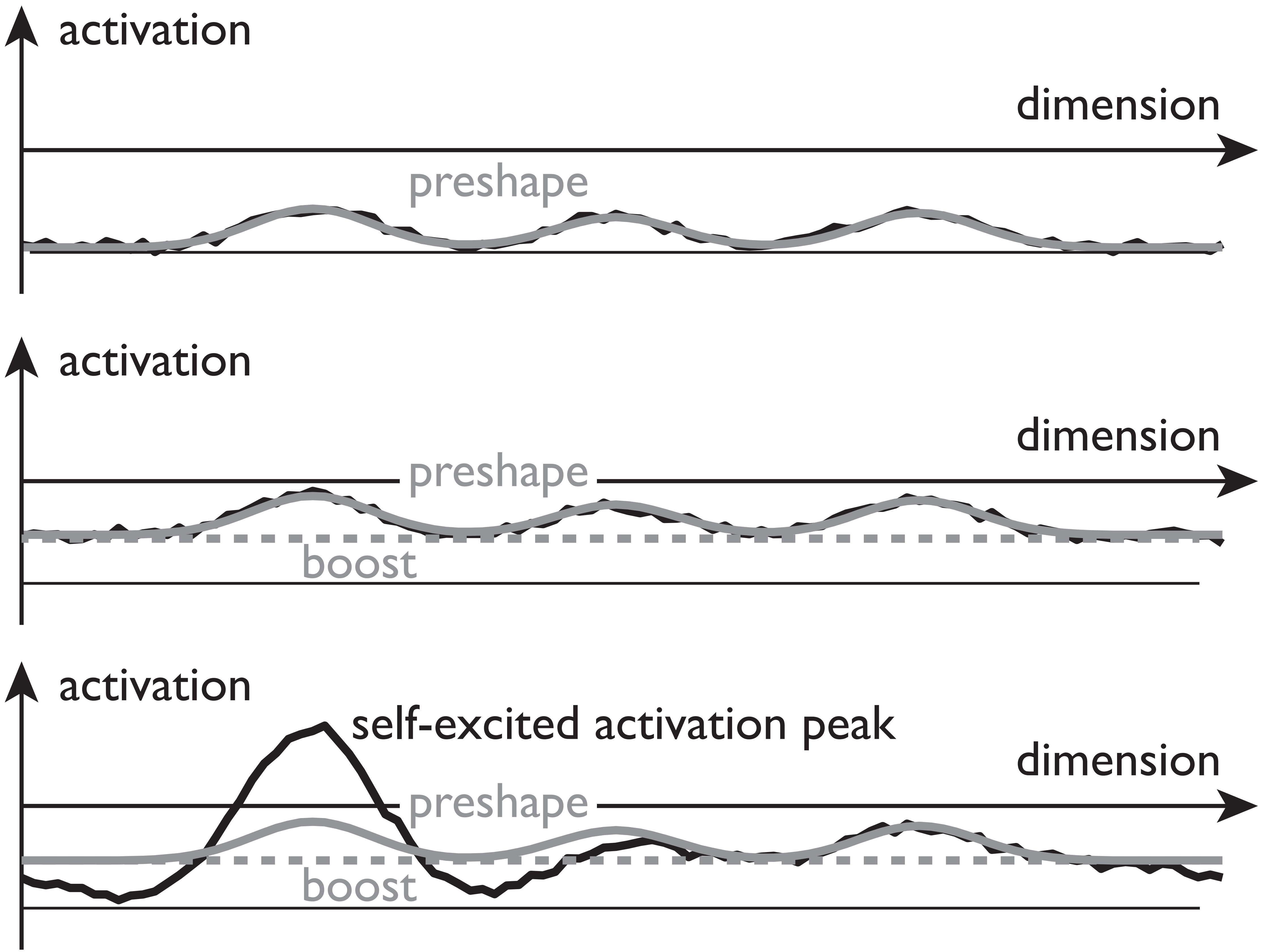
initiation vs. fixation

- such models account for the gap-step-overlap effect



[Kopecz, 95]

boost-induced detection instability



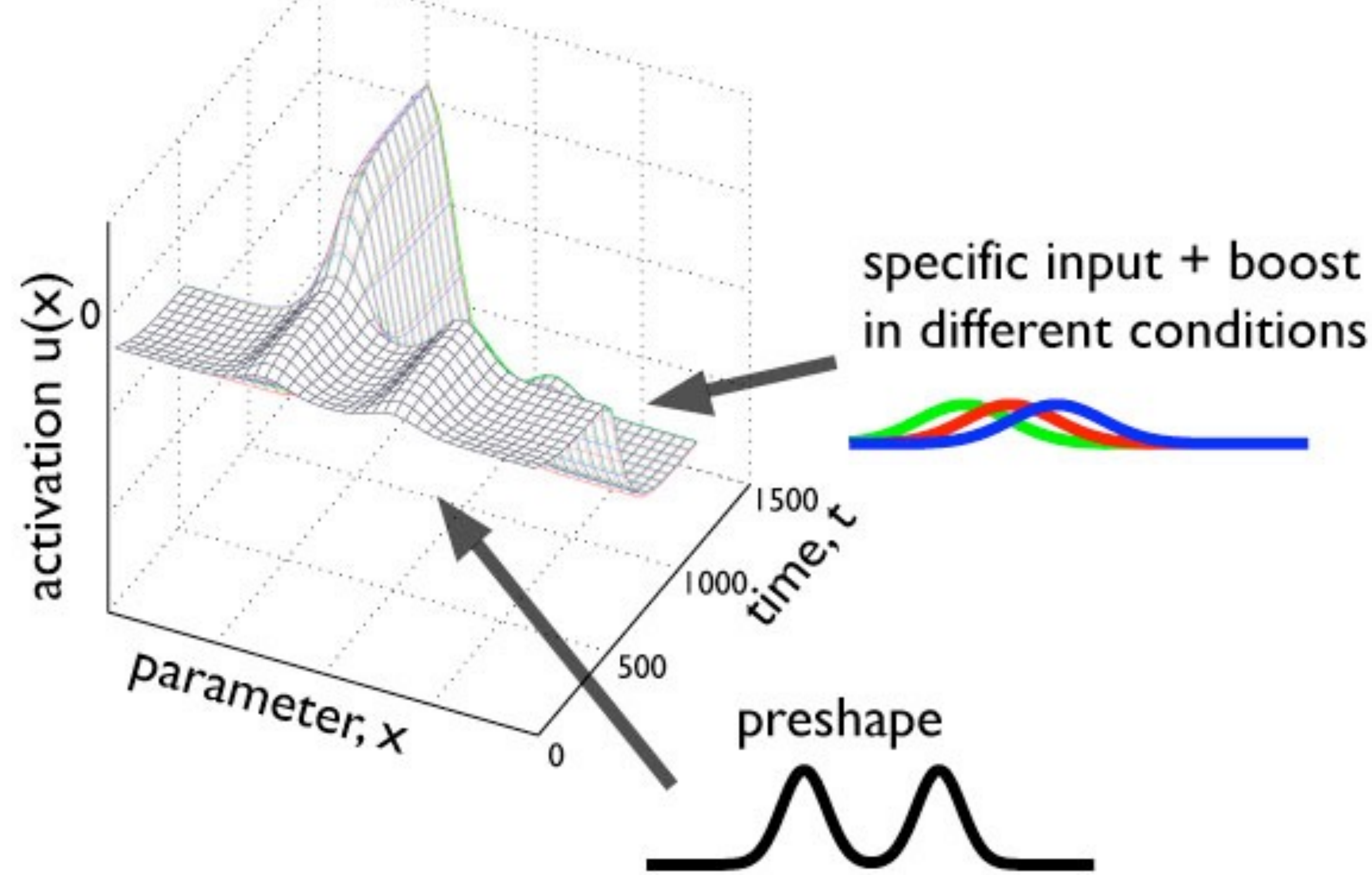
boost-driven detection instability

- inhomogeneities in the field existing prior to a signal/stimulus that leads to a macroscopic response="preshape"
- the boost-driven detection instability amplifies preshape into macroscopic selection decisions

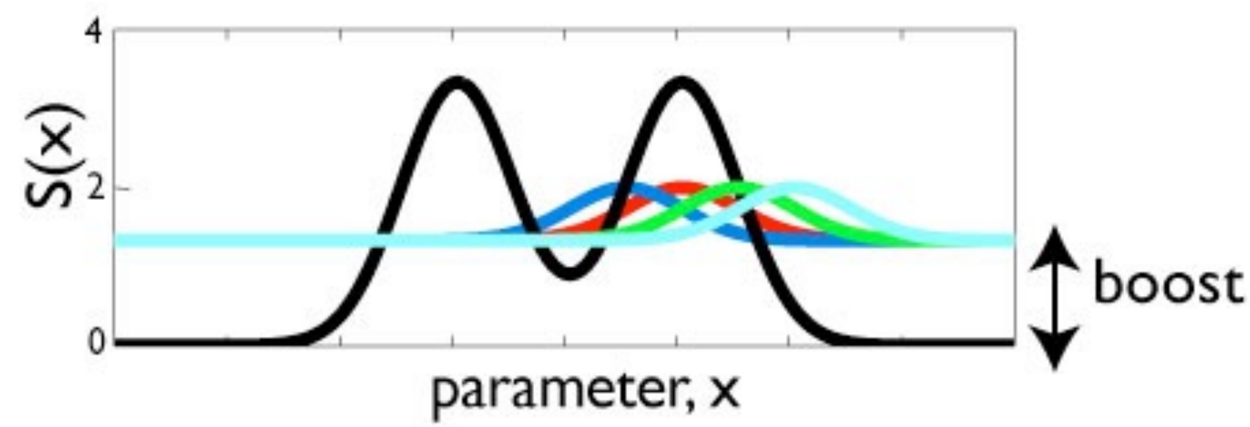
… emergence of categories?

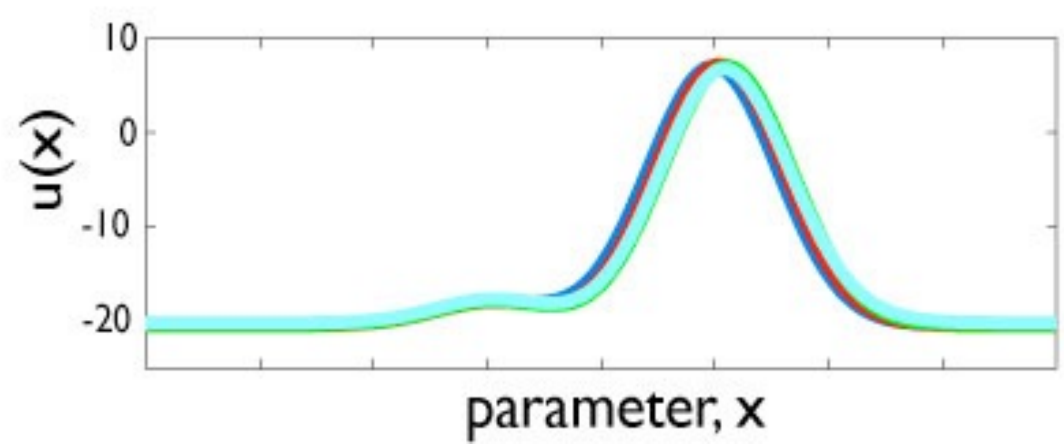
- if we understand, how such inhomogeneities come about, we understand the emergence of categories…

this supports categorical behavior



- when preshape dominates

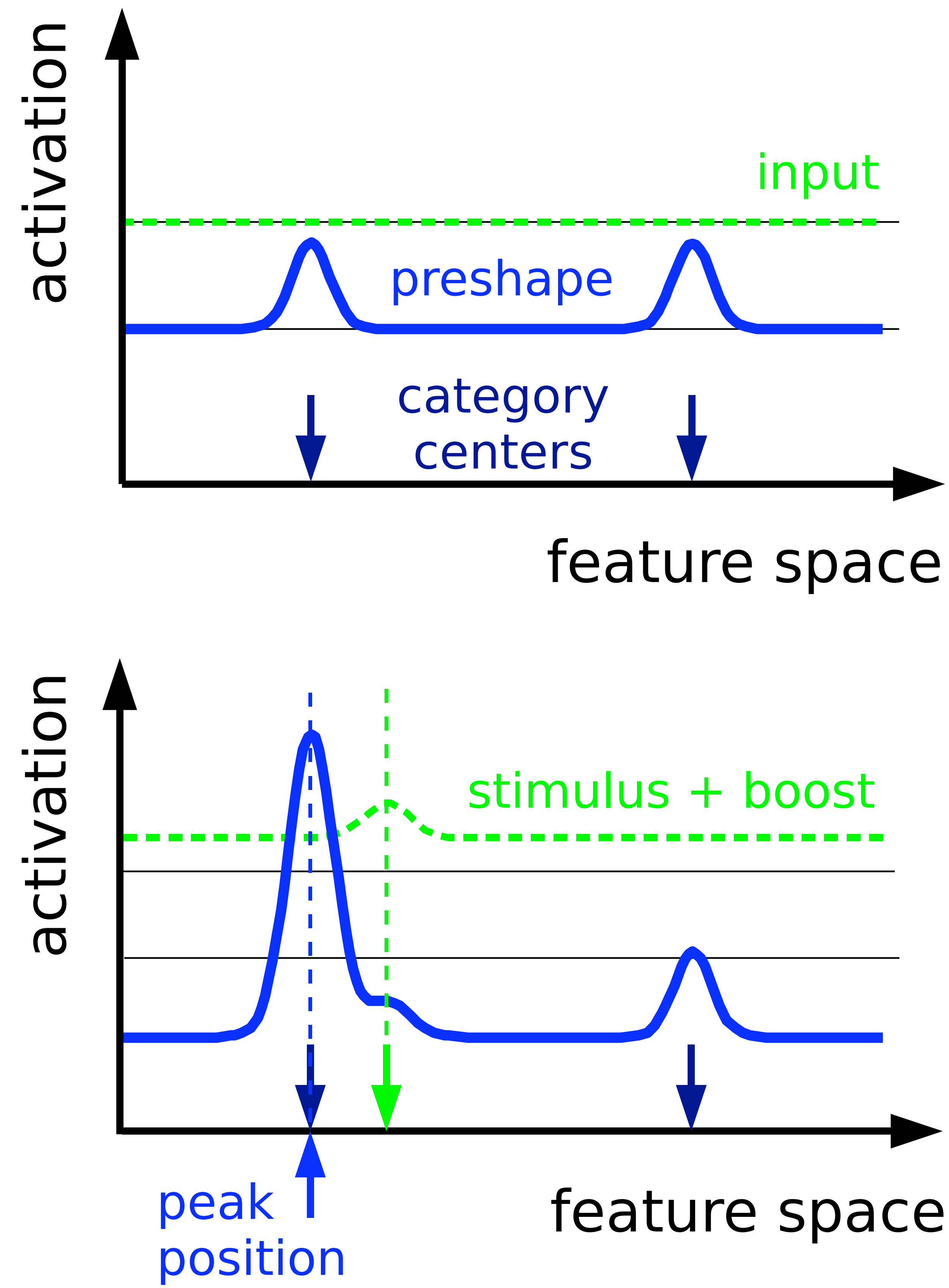




[Wilimzig, Schöner, 2006]

categorical responding

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

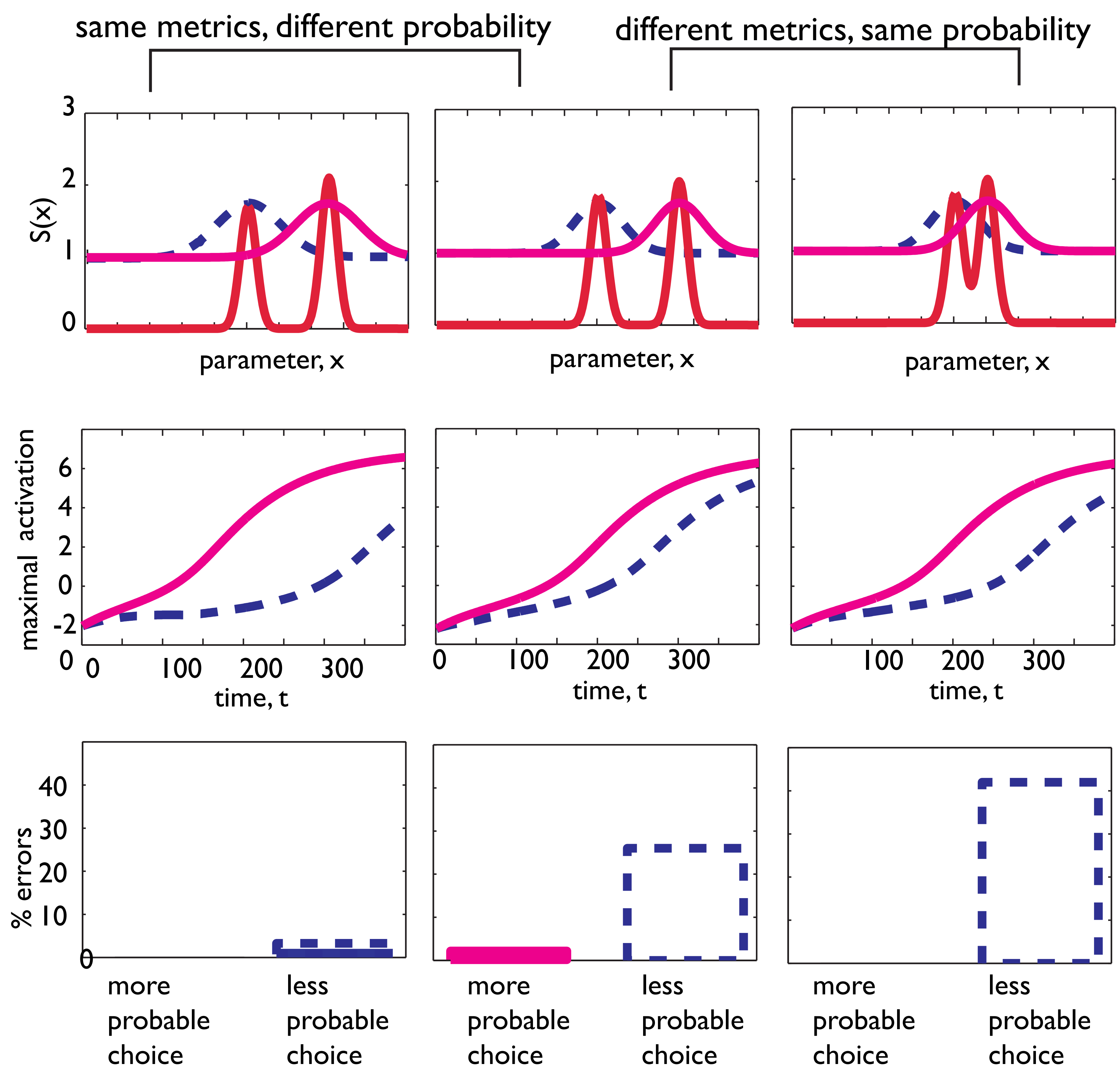


distance effect

- 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

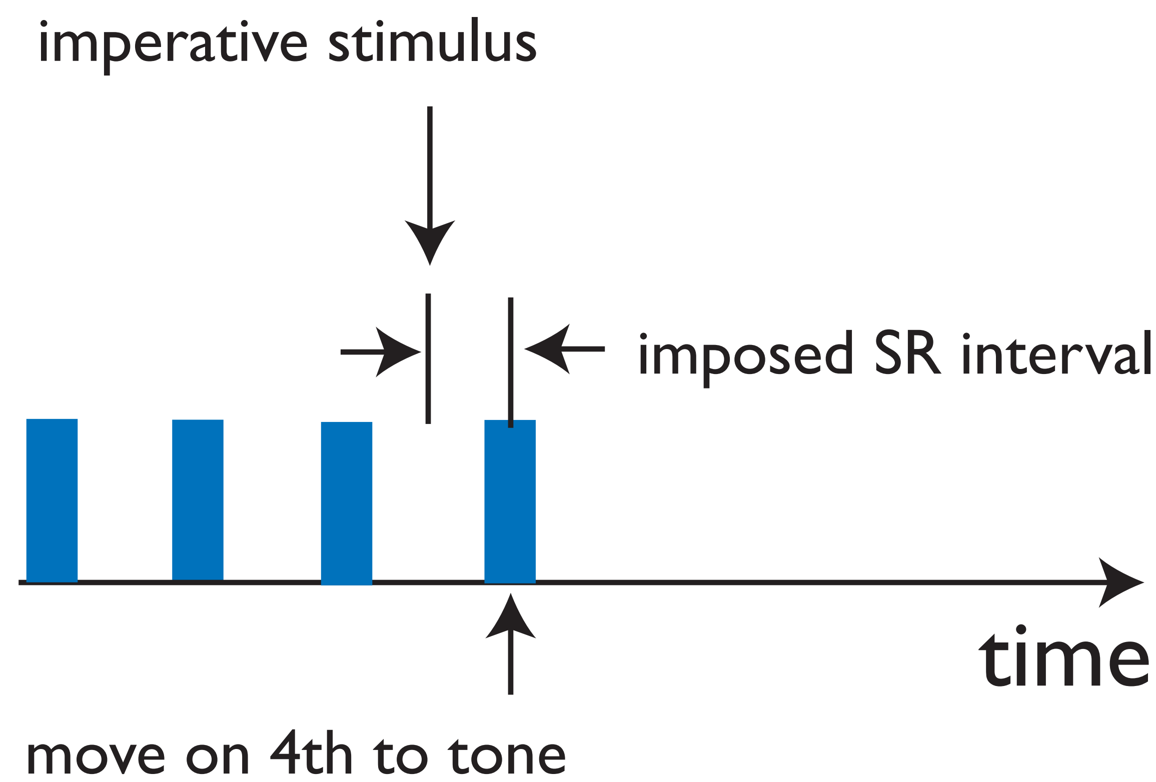
- opposite to that predicted for input-driven detection instabilities:
- metrically close choices show larger effect of probability



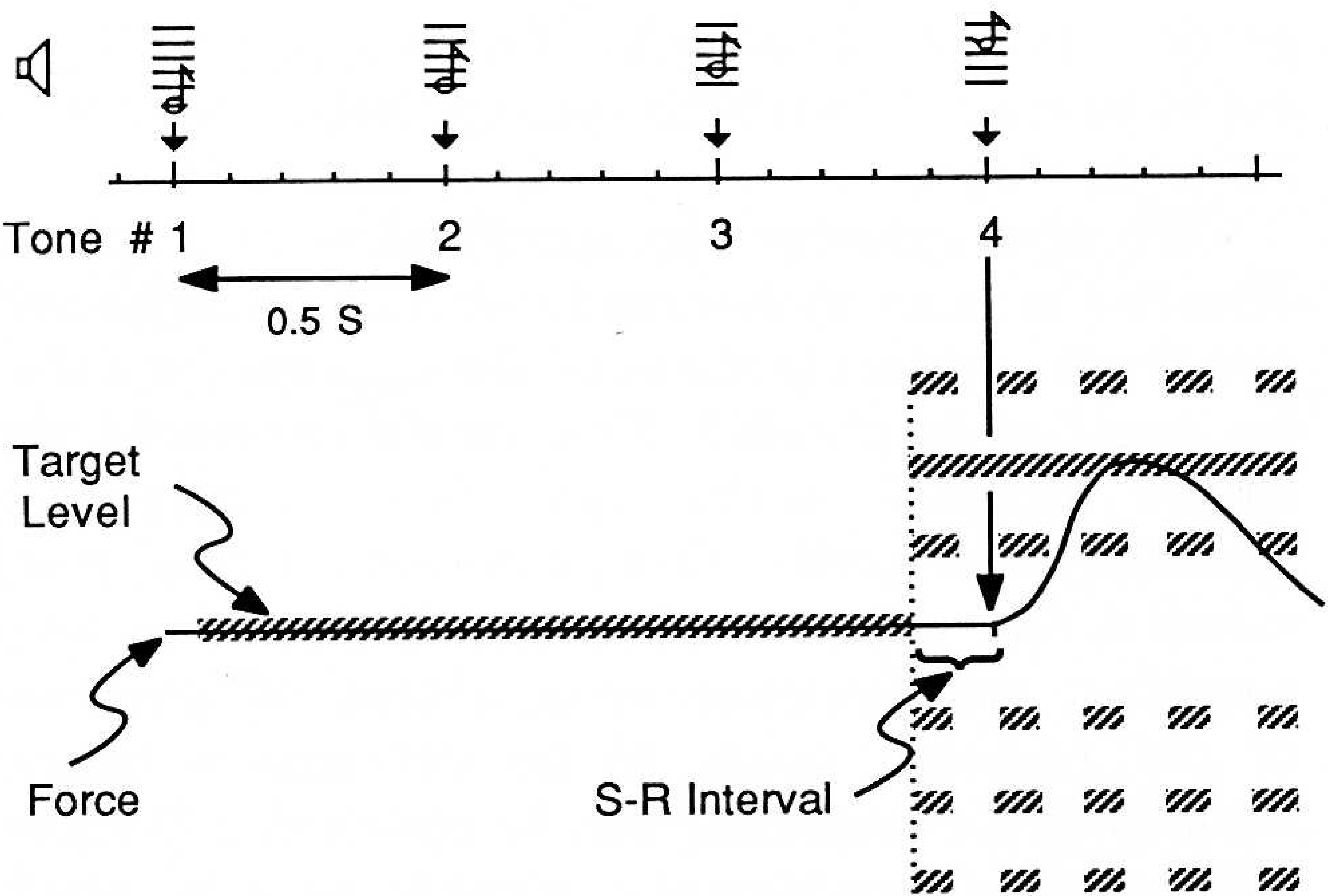
Wilimzig, Schöner, 2006

Time course of selection decisions: Behavioral evidence for the graded and continuous evolution of decision

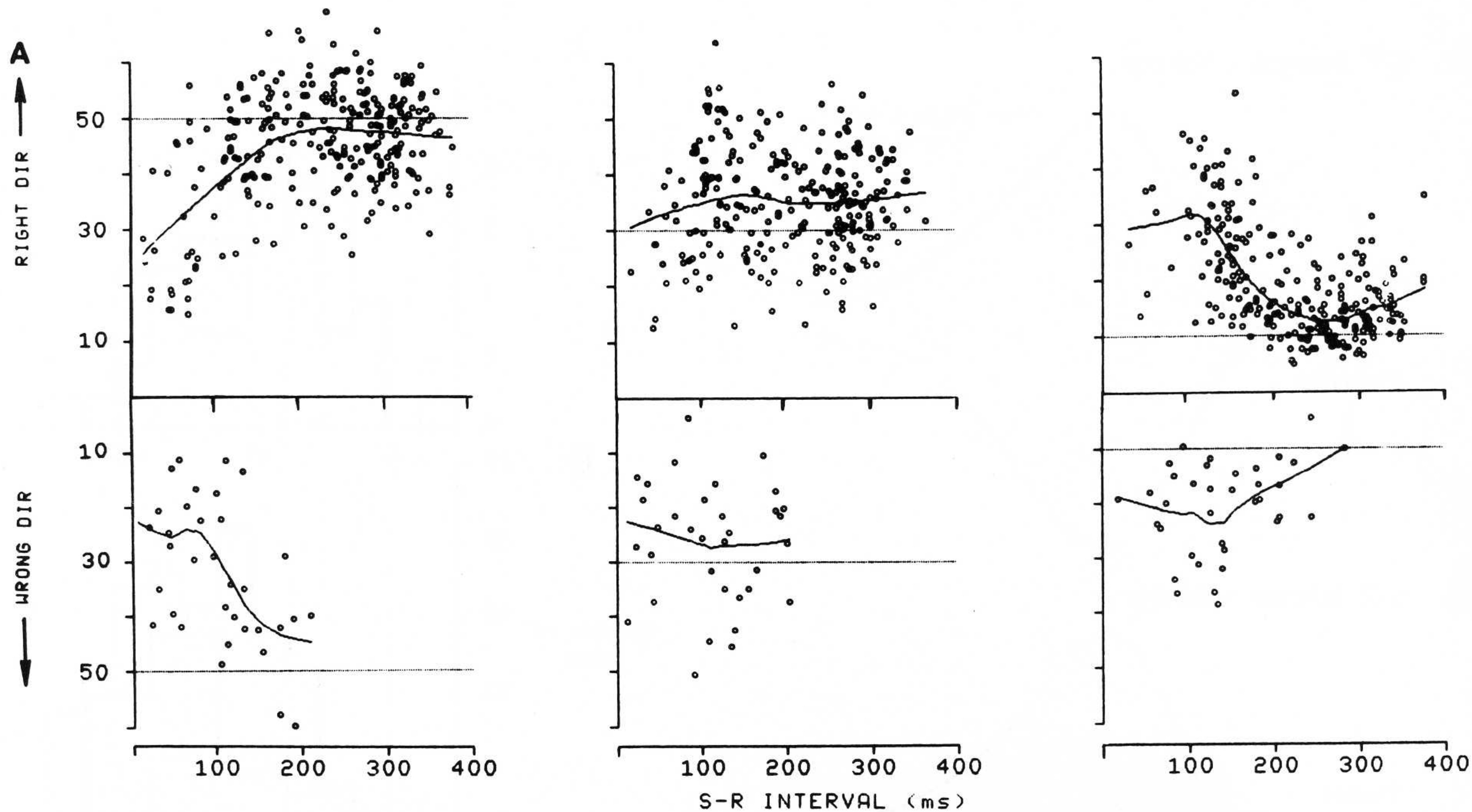
timed movement
initiation paradigm



[Ghez and colleagues, 1988 to 1990's]

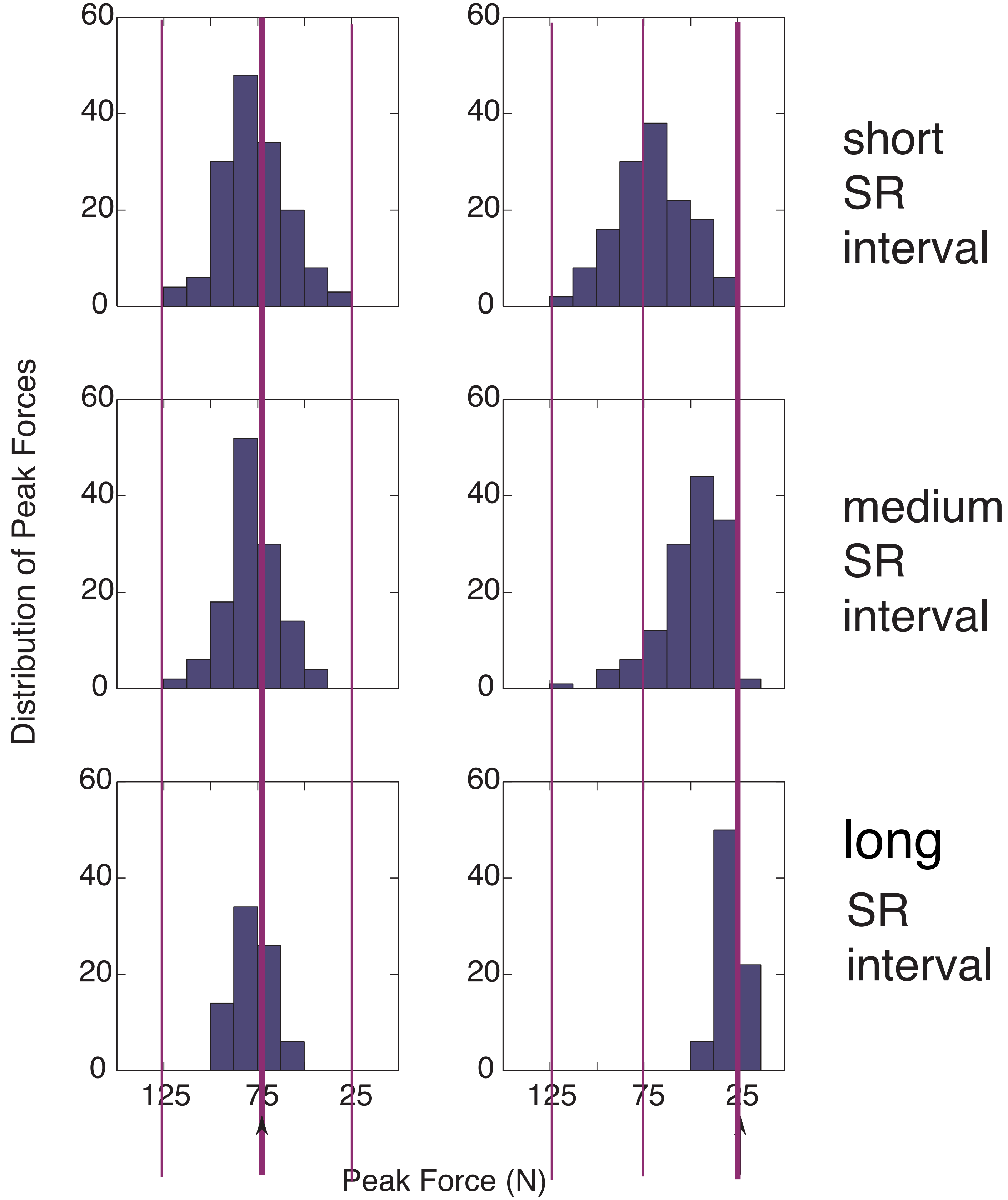


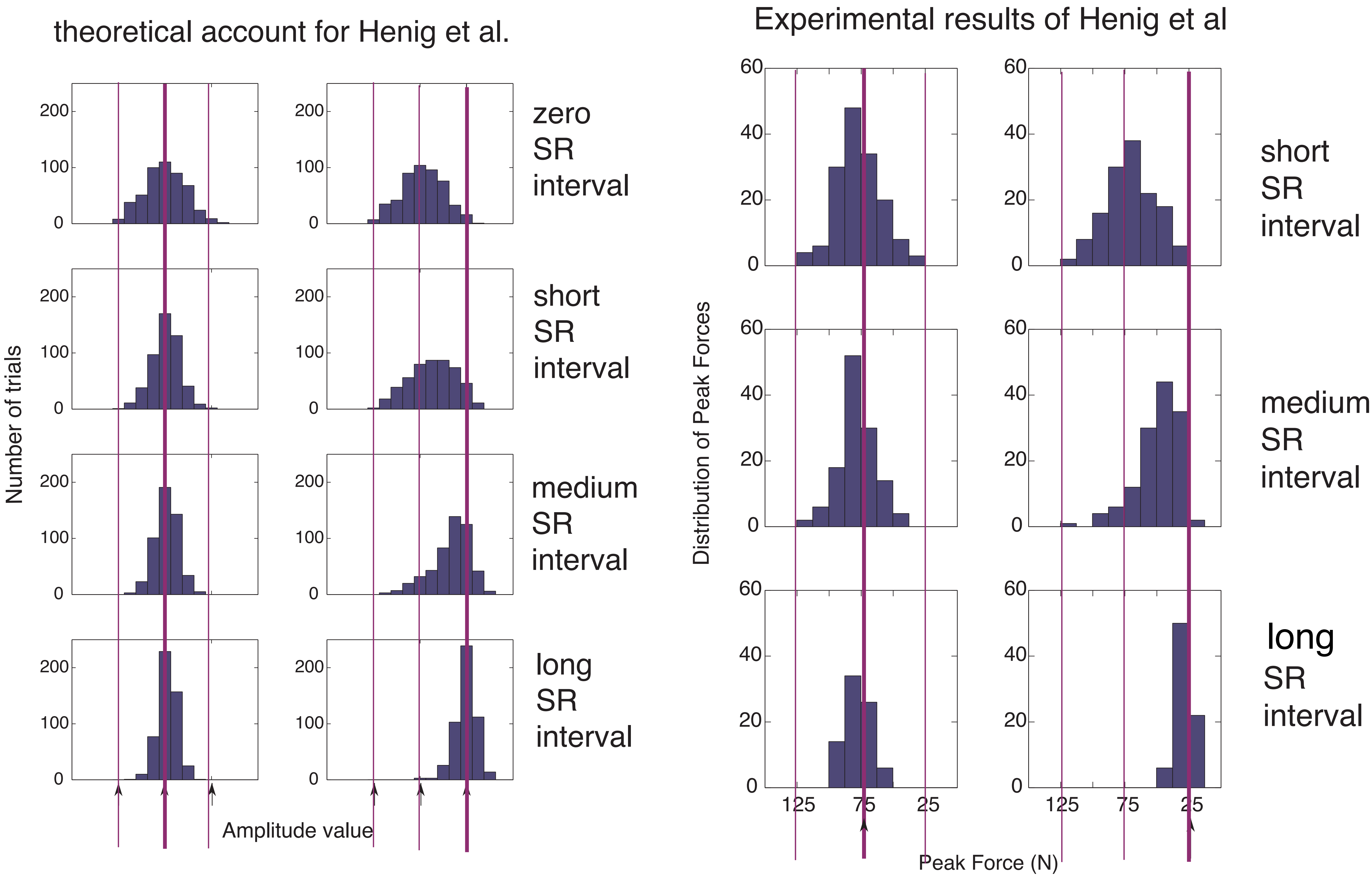
[Favilla et al. 1989]



[Favilla et al. 1989]

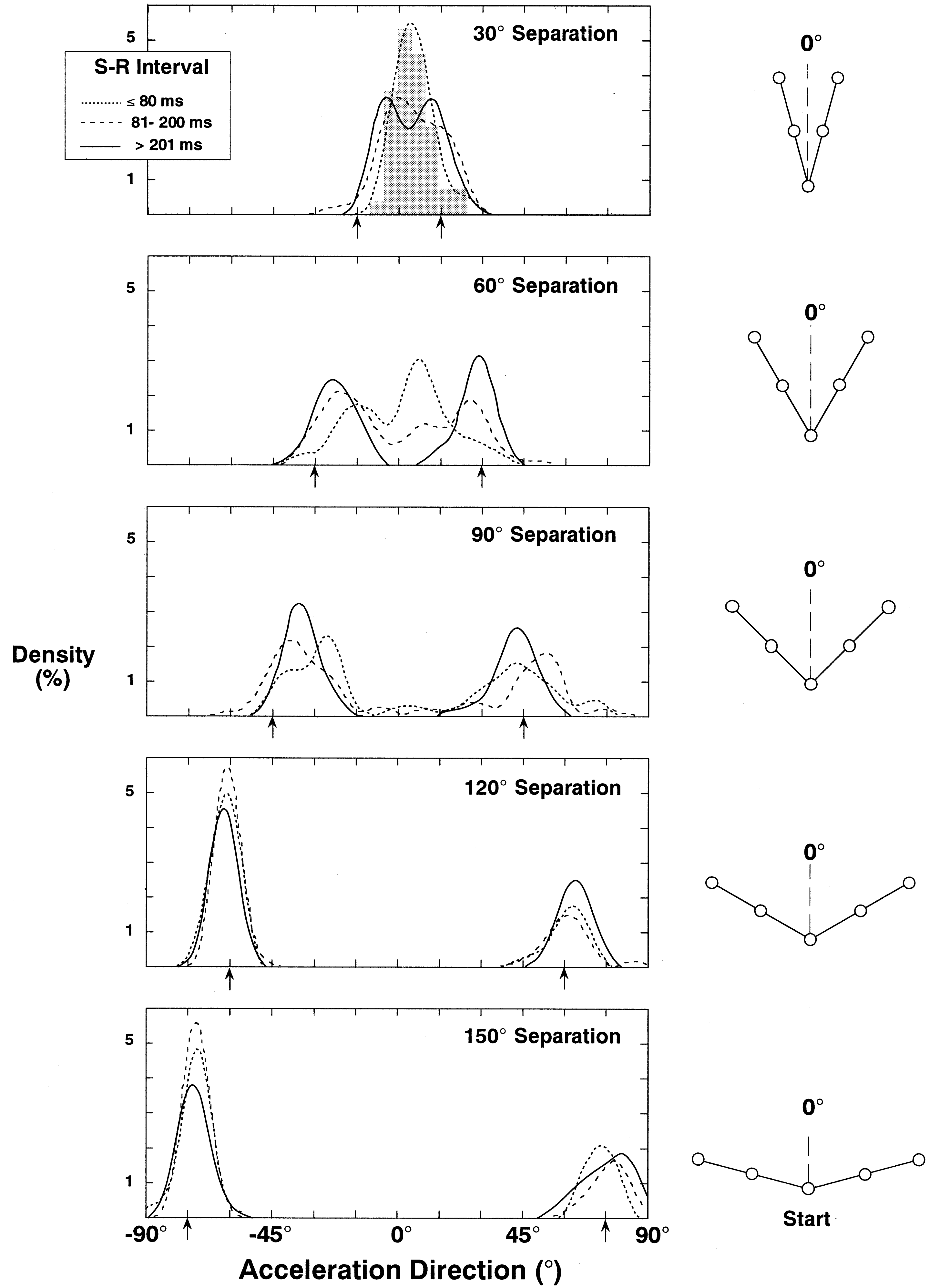
Experimental results of Henig et al





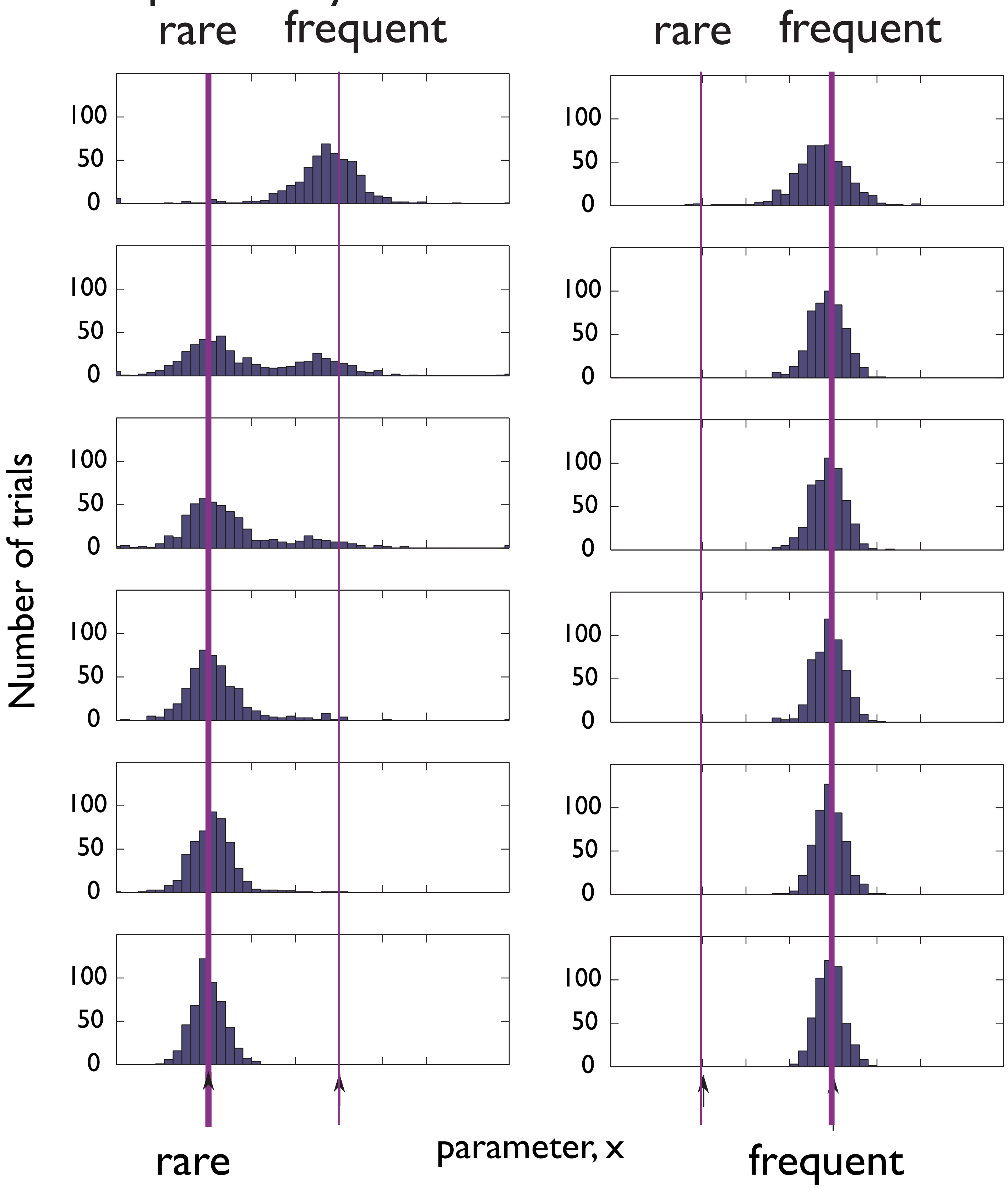
[Erlhagen, Schöner. 2002, Psychological Review 109, 545–572 (2002)]

- 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

Conclusion

- DFT concept of selection decisions supported by ample behavioral signatures
- multiple contributions to specification
  - task set/preshape
  - imperative signal /go signal
- metrics of task layout matters
- time course of decision making can be understood …