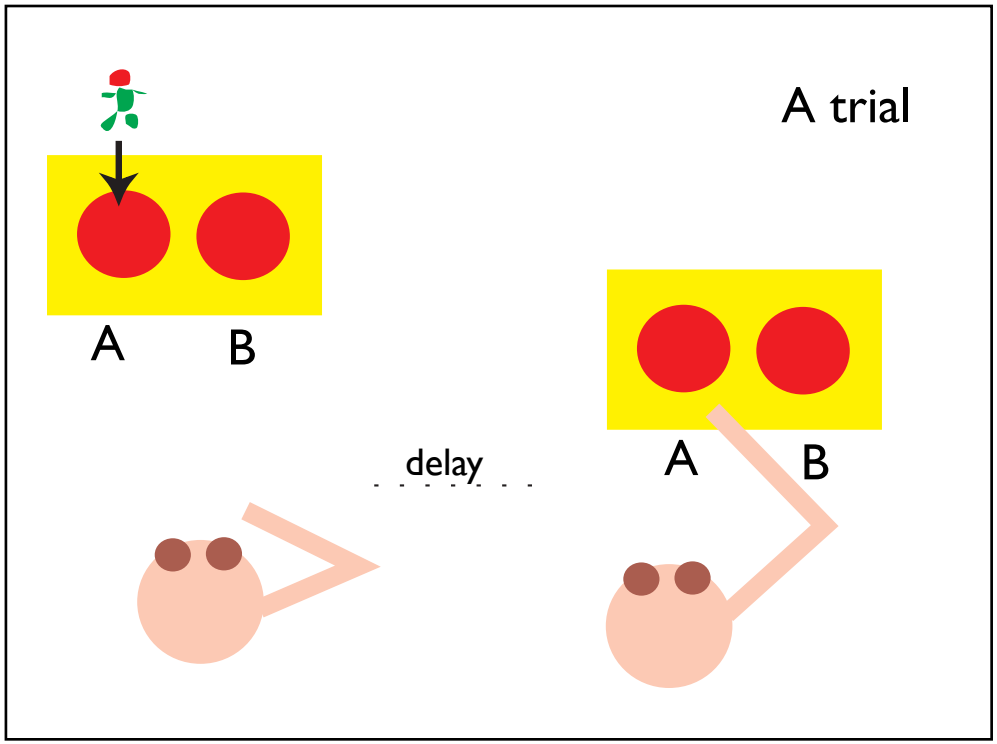
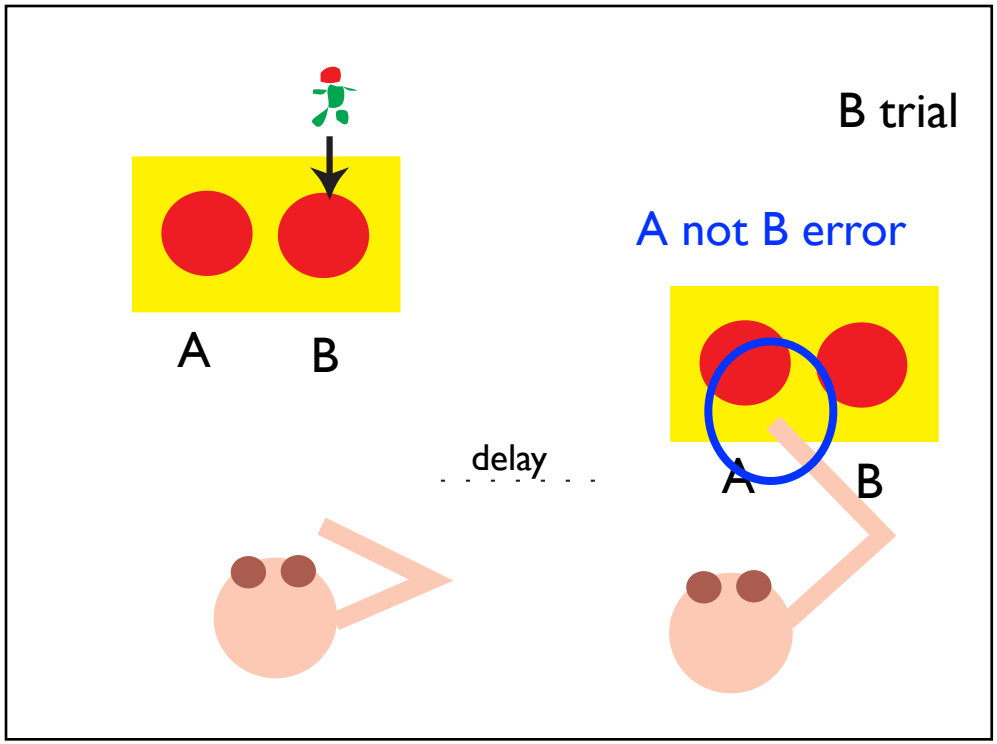
Linking neural to behavioral dynamics: the A not B robot

Gregor Schöner

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

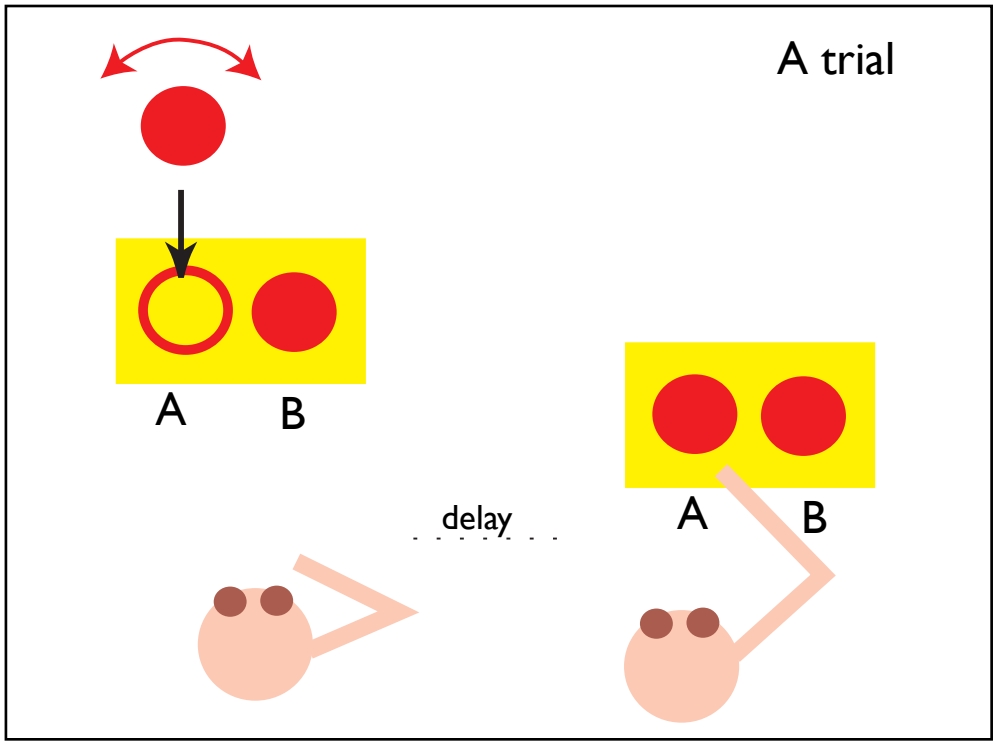


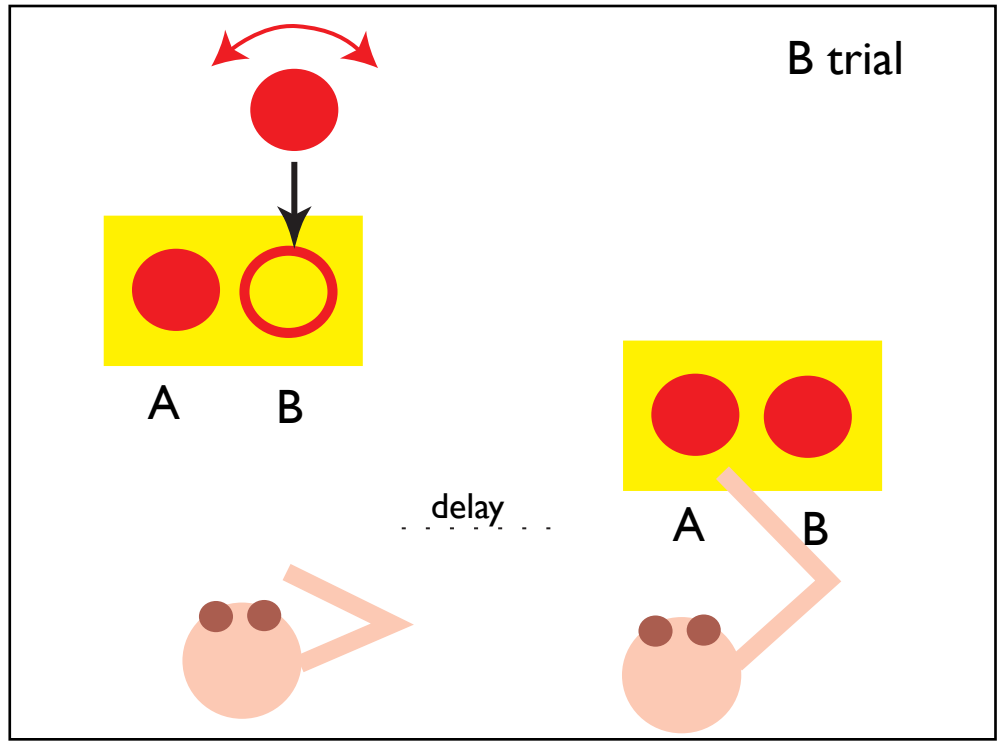


Toyless variant of A not B task

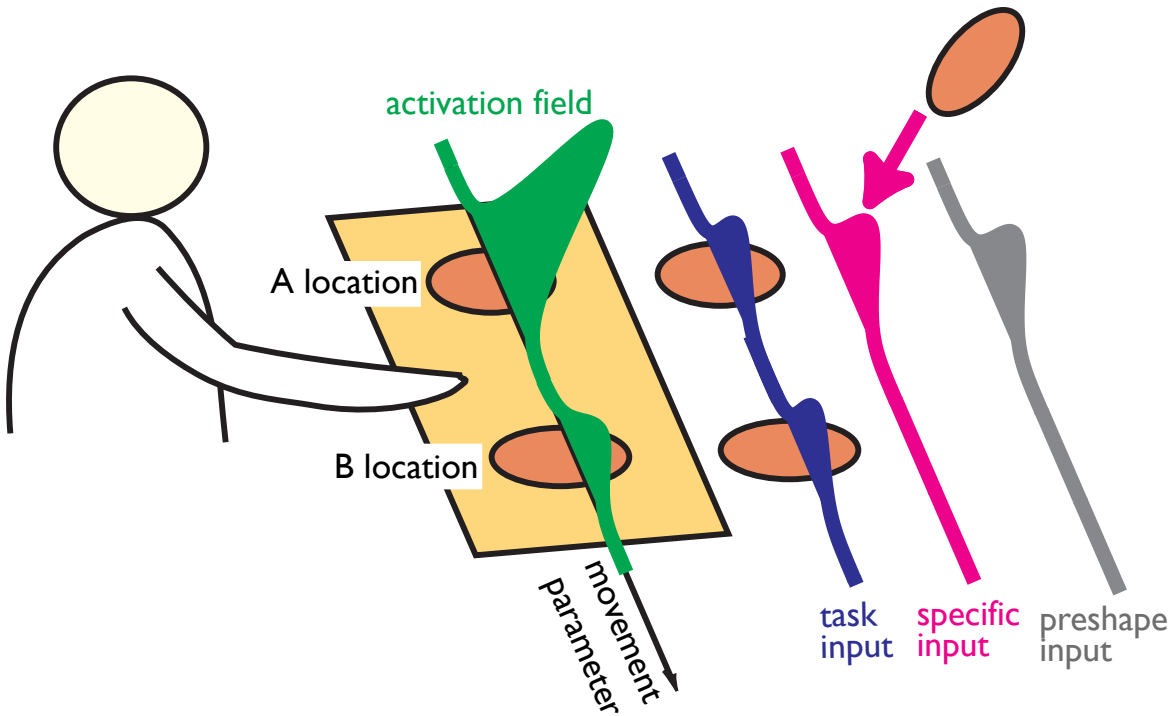
[Smith, Thelen et al.: Psychological Review (1999)]

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

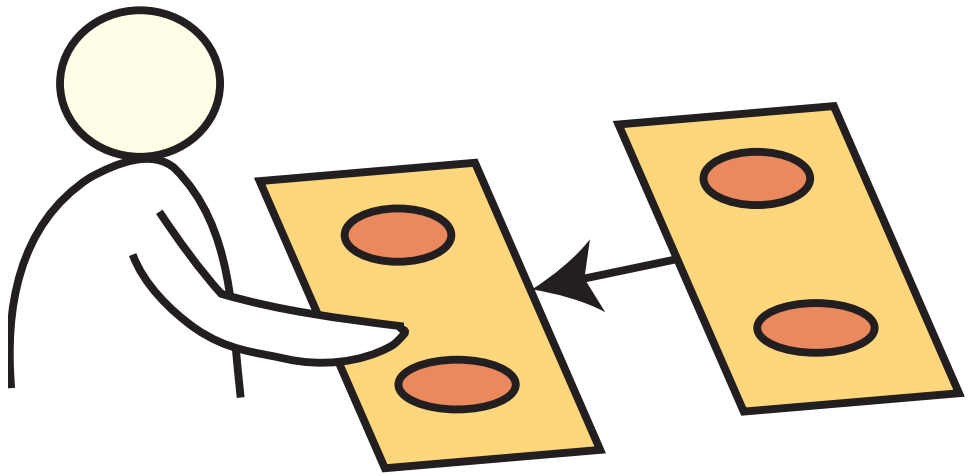




[Smith, Thelen et al.: Psychological Review (1999)]

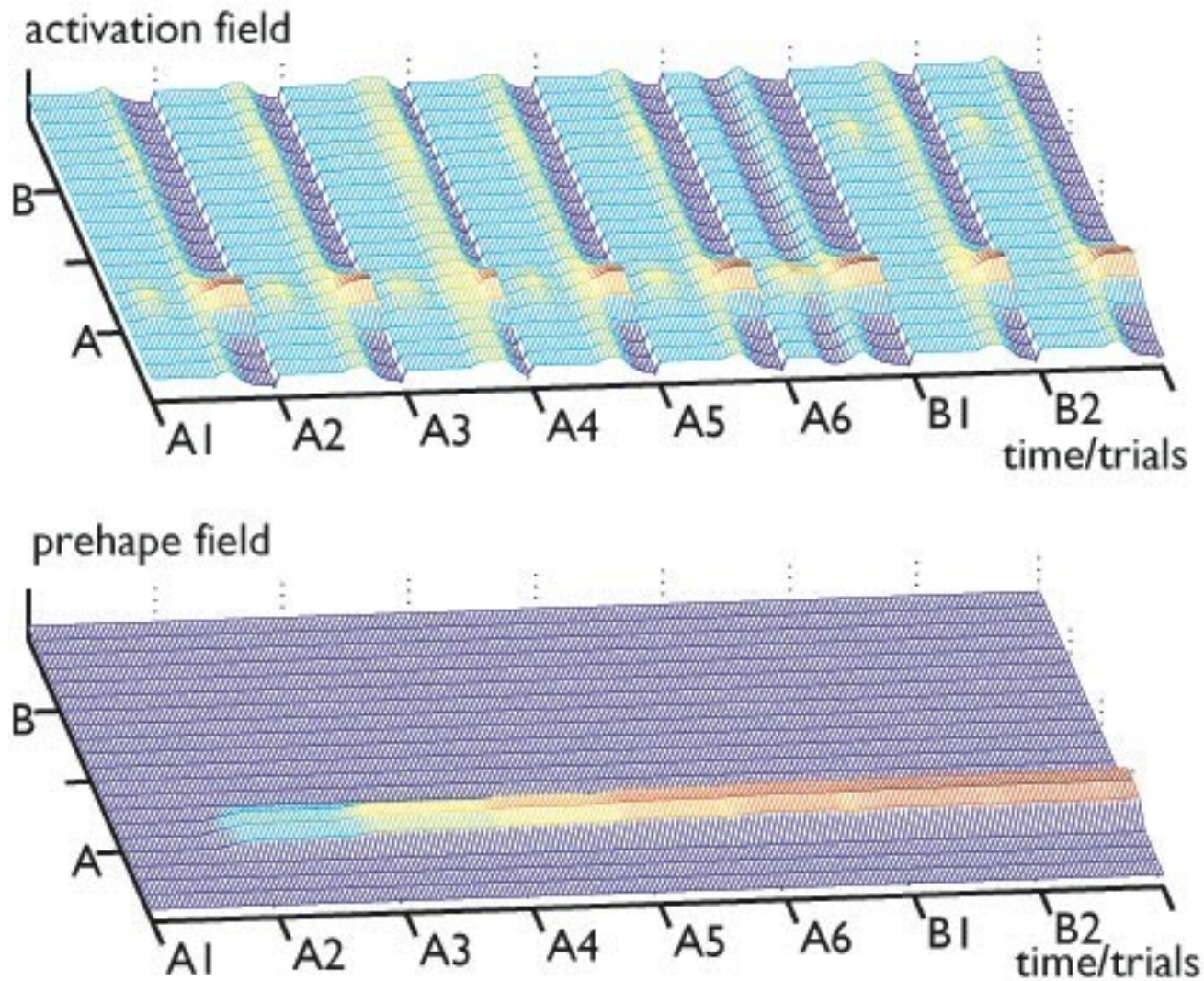


[Thelen, et al., BBS (2001)]



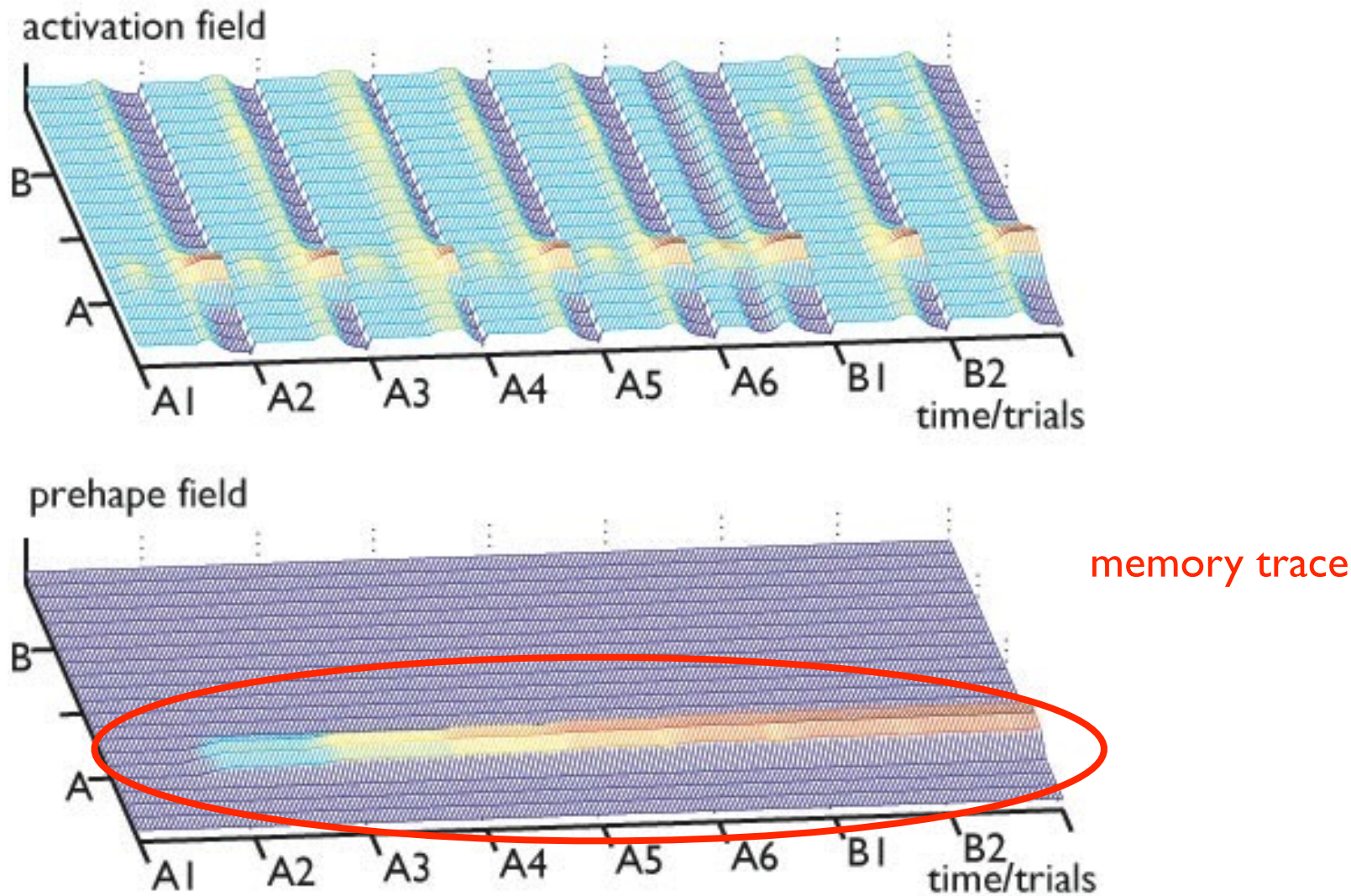
[Dinveva, Schöner, Dev. Science 2007]

DFT of infant perseverative reaching



[Dinveva, Schöner, Dev. Science 2007]

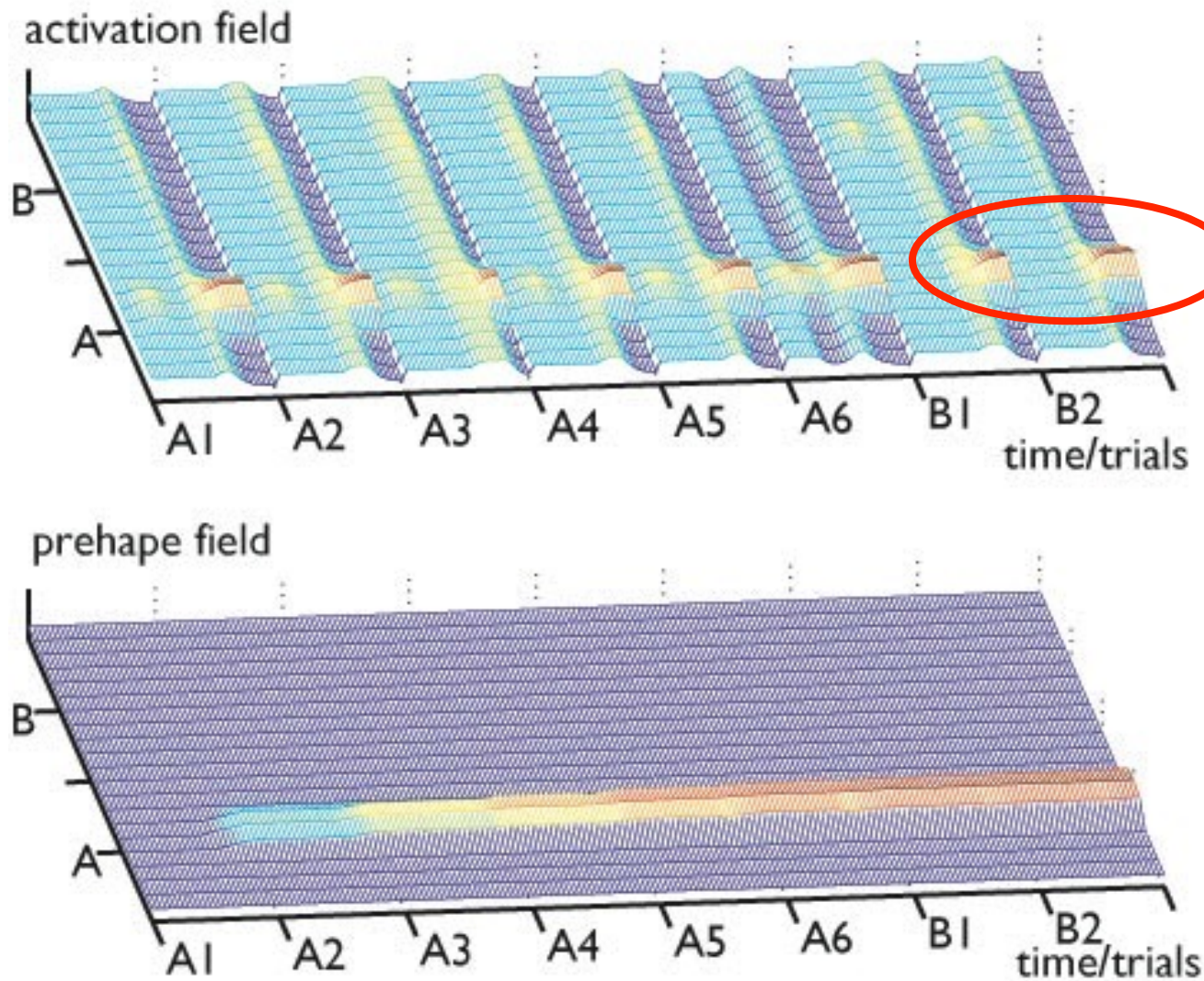
DFT of infant perseverative reaching



memory trace

[Dinveva, Schöner, Dev. Science 2007]

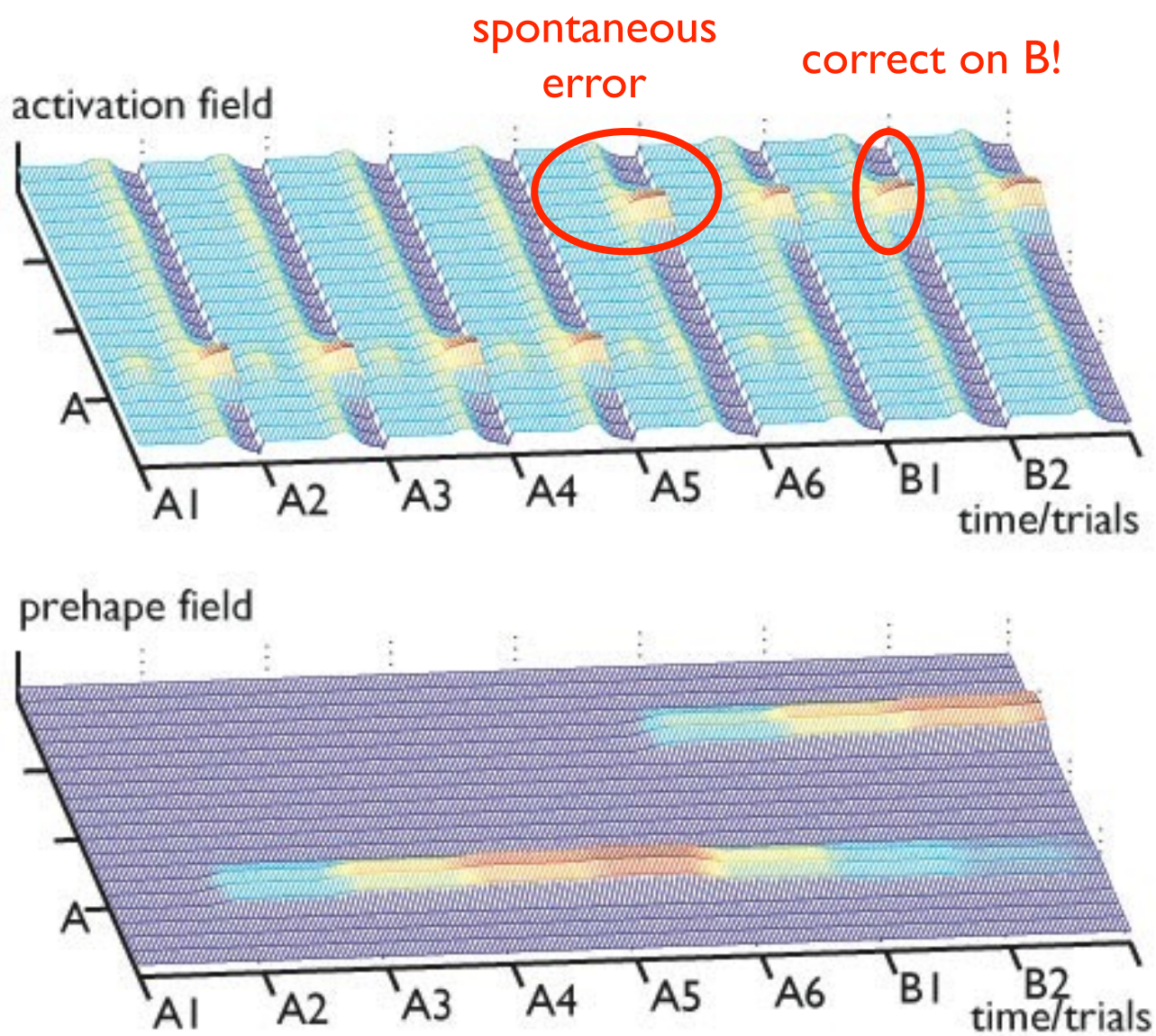
DFT of infant perseverative reaching



[Dinveva, Schöner, Dev. Science 2007]

DFT of infant perseverative reaching

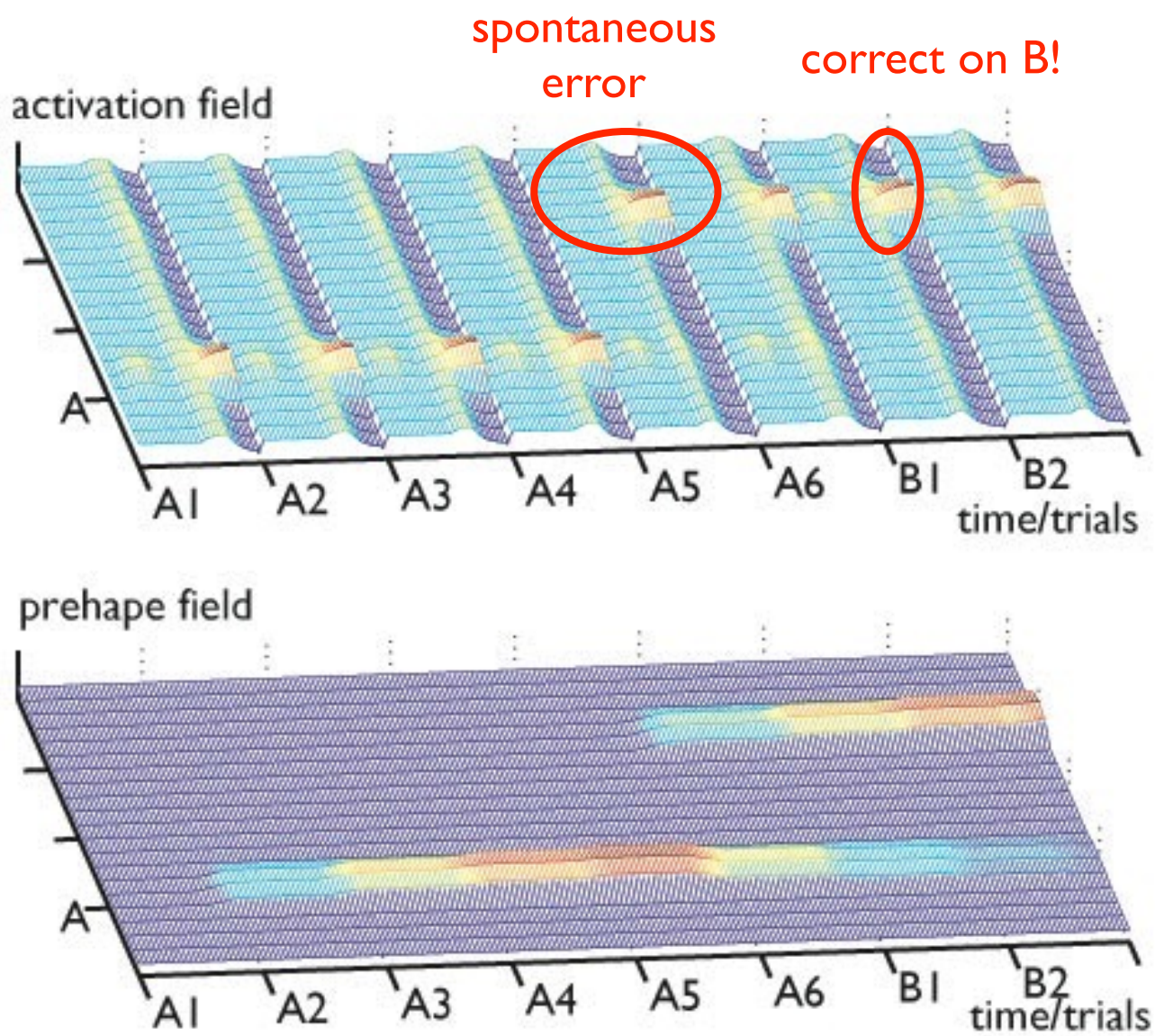
- in spotaneous errors, activation arises at B on an A trial
- which leads to correct reaching on B trial



[Dinveva, Schöner, Dev. Science 2007]

DFT of infant perseverative reaching

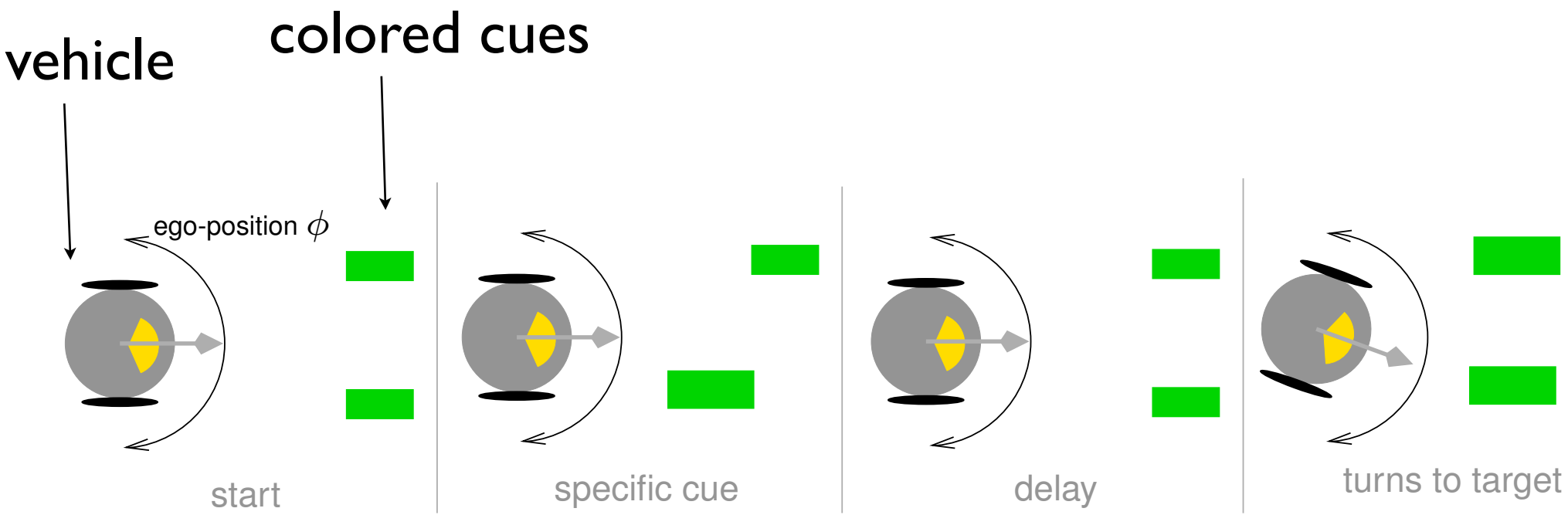
- that is because reaches to B on A trials leave memory trace at B



[Dinveva, Schöner, Dev. Science 2007]

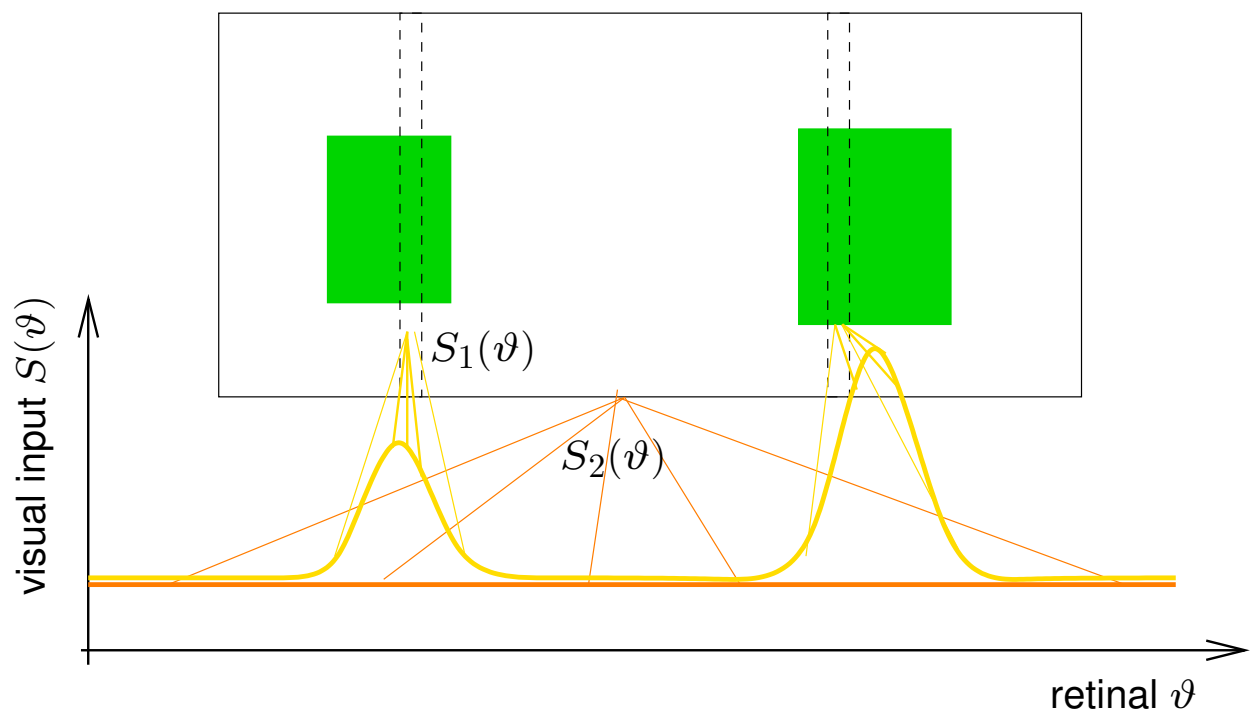
Embodied A not B

- implementing the A not B model on a autonomous robot with continuous link to sensory and motor surfaces...



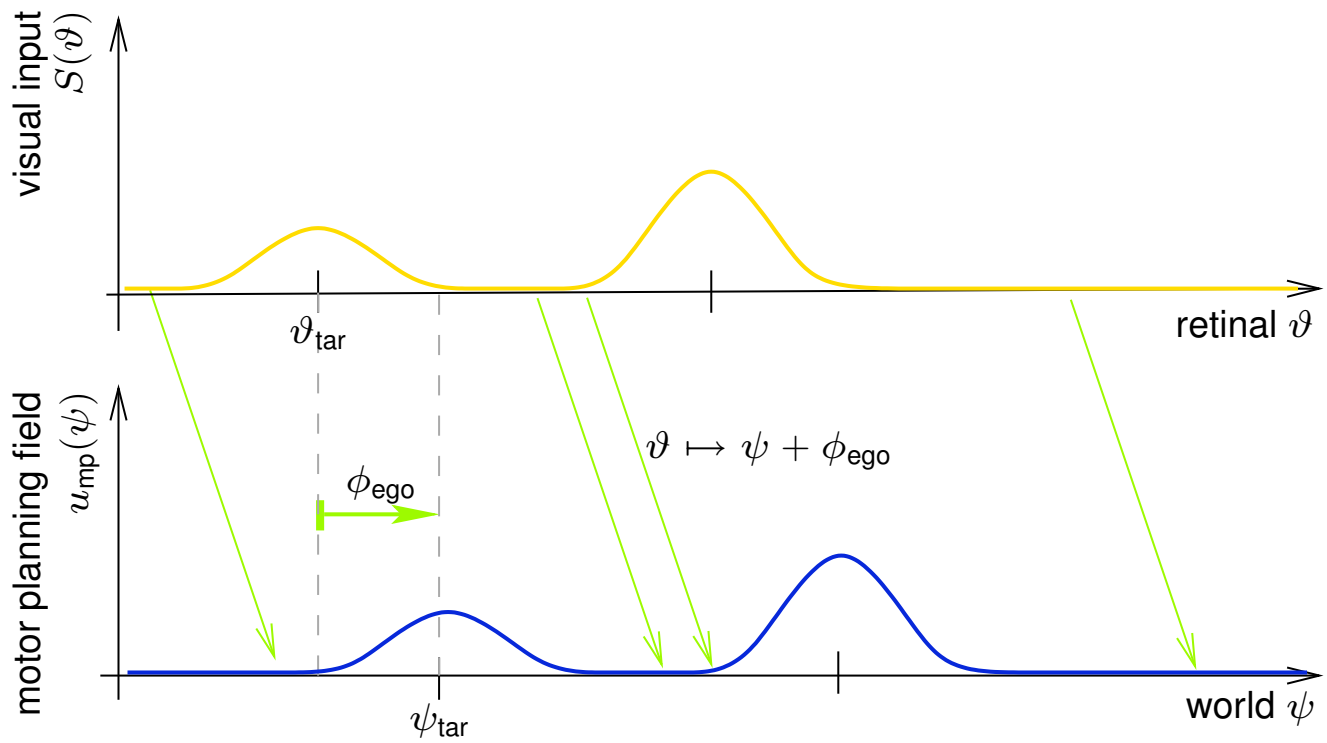
Visual input

- color-based segmentation
- summing color pixels within color slot along the vertical
- spatially filter at two resolutions



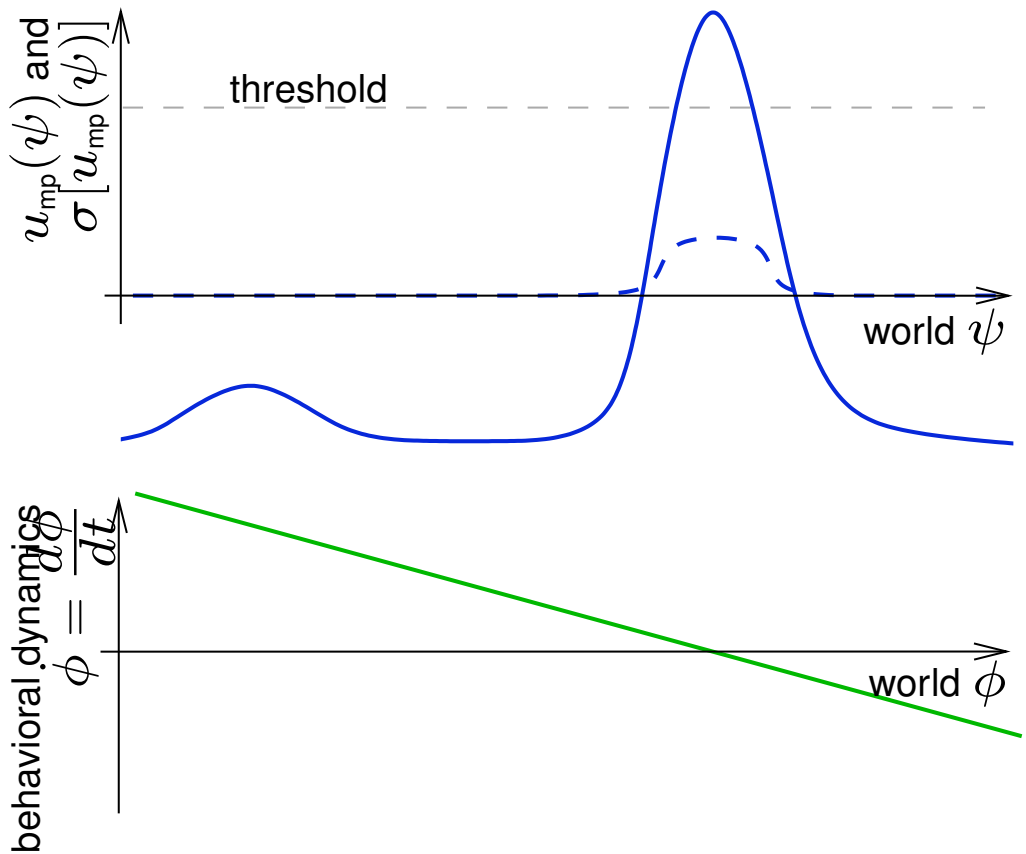
Dynamic field

- defined over direction in the world
- (requires coordinate transform from retina based on dead-reckoning)



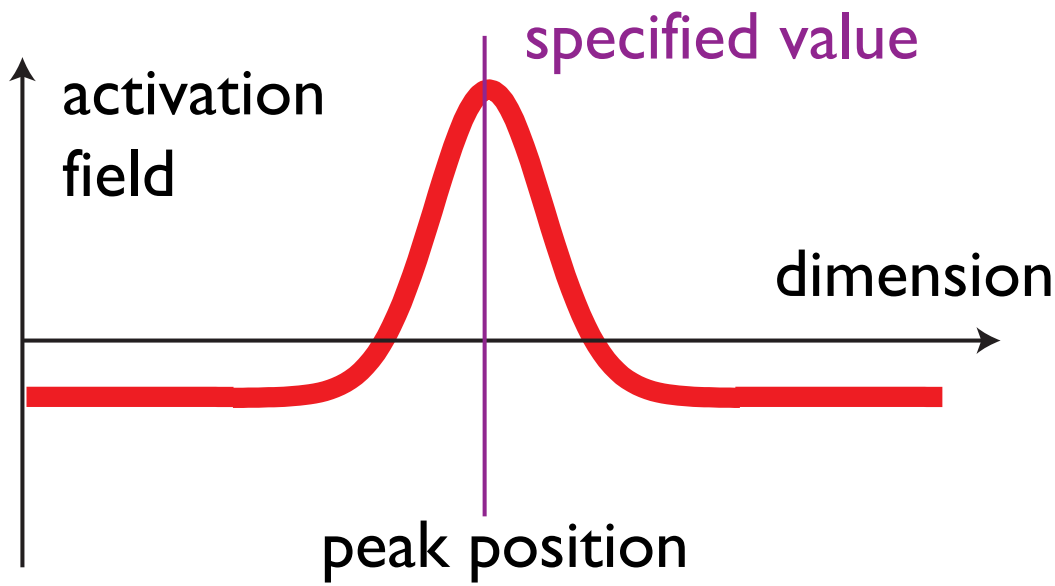
Motor dynamics

- couple peak in direction field into dynamics of heading direction as an attractor



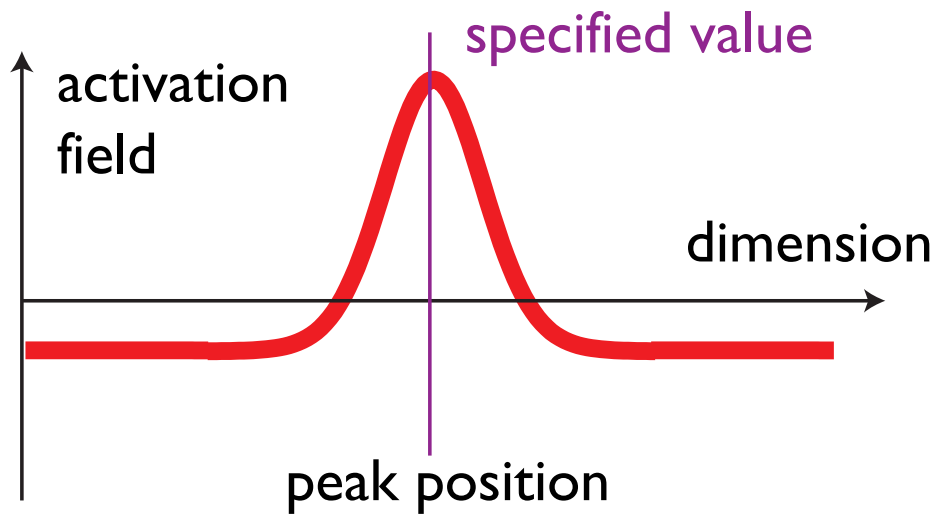
“Read-out” by generating attractor dynamics for motor system

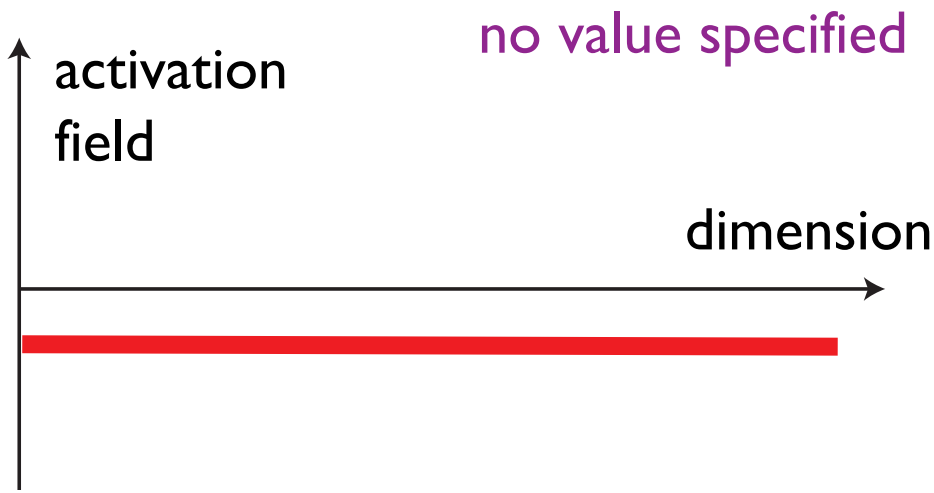
- peak specifies value for a dynamical variable that is congruent to the field dimension



- treating sigmoided field as probability: need to normalize
  - => problem when there is no peak: devide by zero!

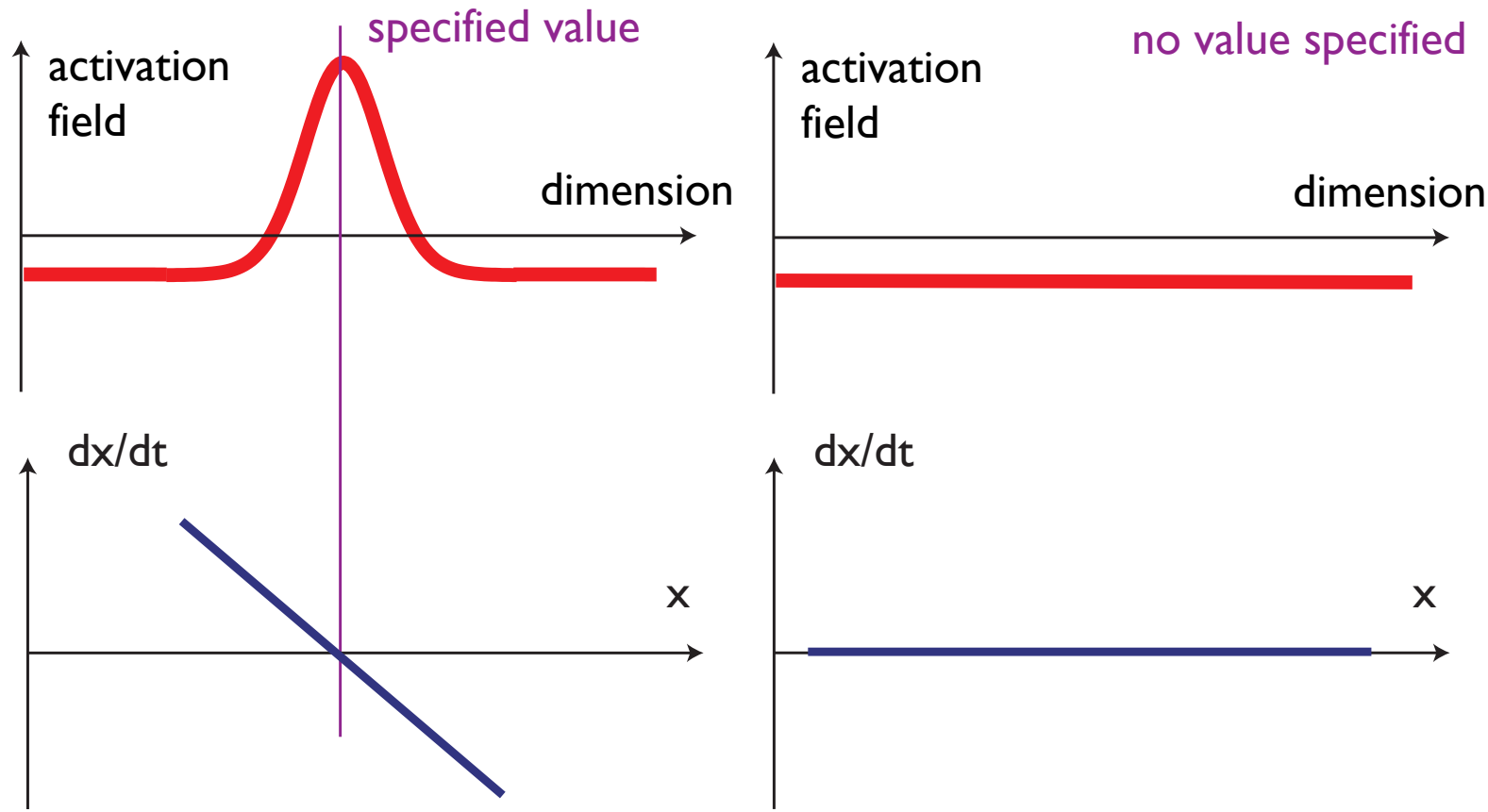
$$x_{\text{peak}} = \frac{\int dx' \; \sigma(u(x',t))x'}{\int dx' \; \sigma(u(x',t))}$$





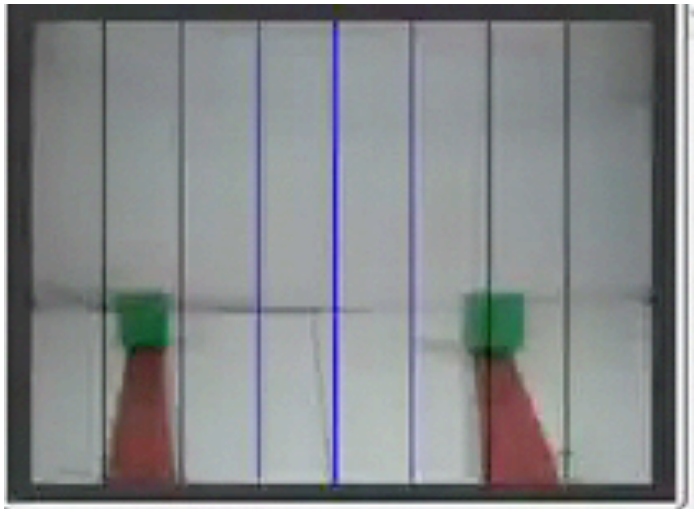
instead:

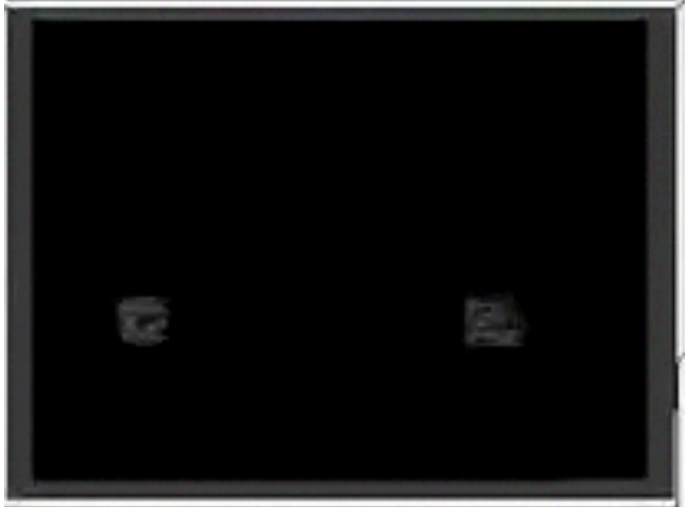
- create attractor

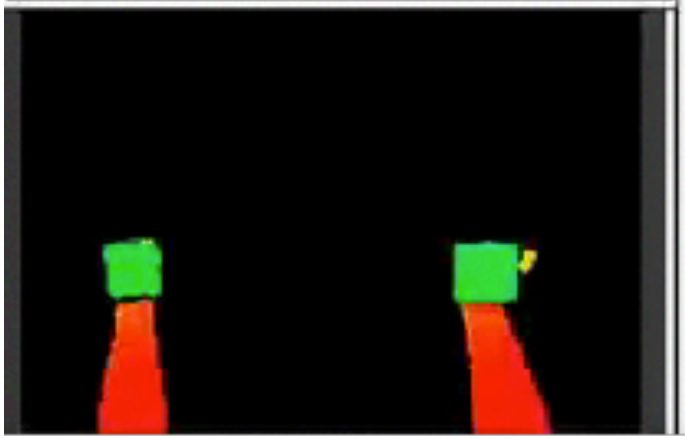


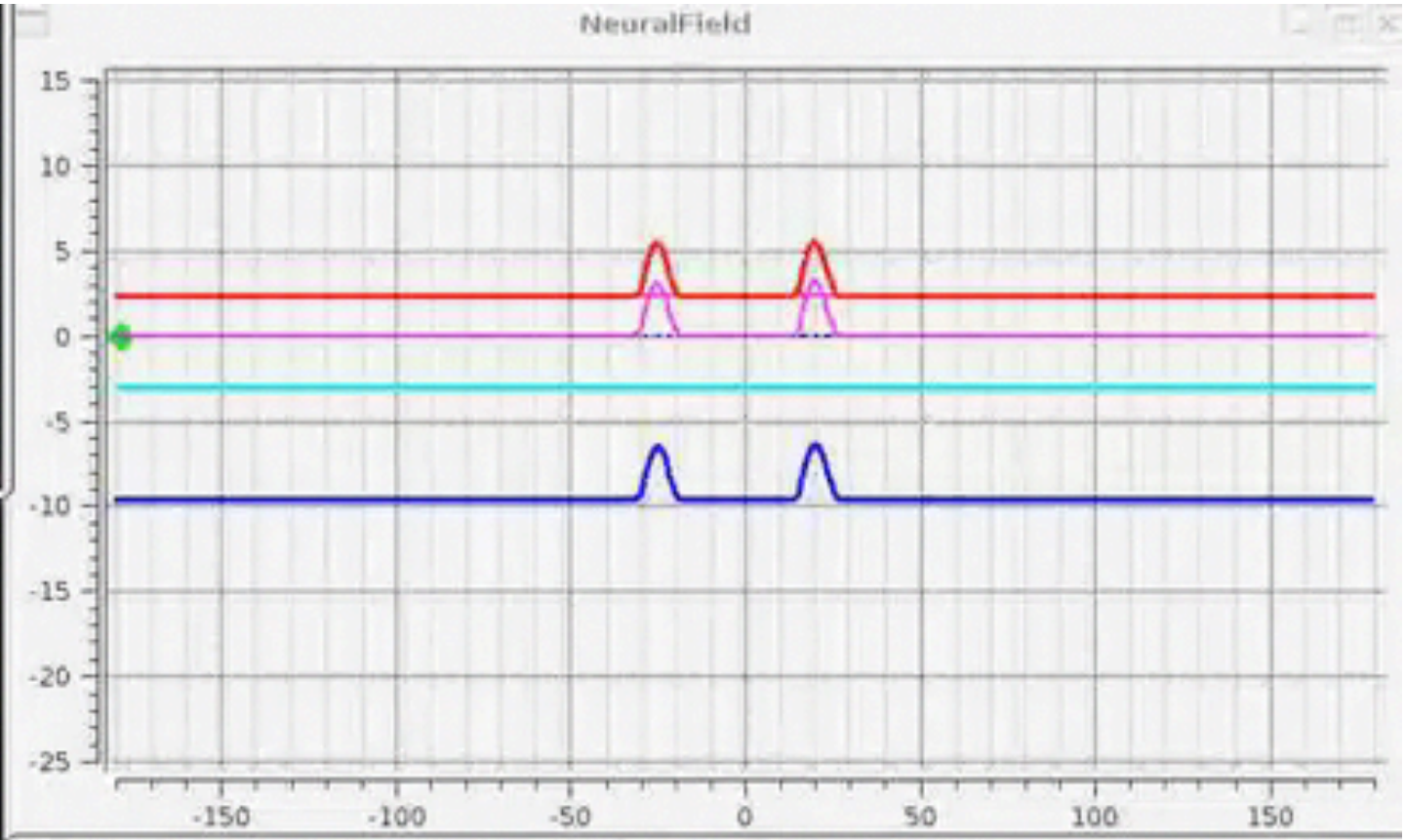
- solution: peak sets attractor
  - location of attractor: peak location
  - strength of attractor: summed supra-threshold activation

$$
\begin{aligned}
x_{\text{peak}} &= \frac{\int dx' \; \sigma(u(x',t))x'}{\int dx' \; \sigma(u(x',t))} \\
\dot{x} &= -\int dx' \; \sigma(u(x',t)) \, (x - x_{\text{peak}}) \\
&= -\left[\int dx' \; \sigma(u(x',t)) \; x - \int dx' \; \sigma(u(x',t)) \; x_{\text{peak}}\right] \\
&= -\left[\int dx' \; \sigma(u(x',t)) \; x - \int dx' \; \sigma(u(x',t)) \; x'\right] \\
&= -\int dx' \; \sigma(u(x',t)) \; (x - x')
\end{aligned}
$$








NeuralField
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-5
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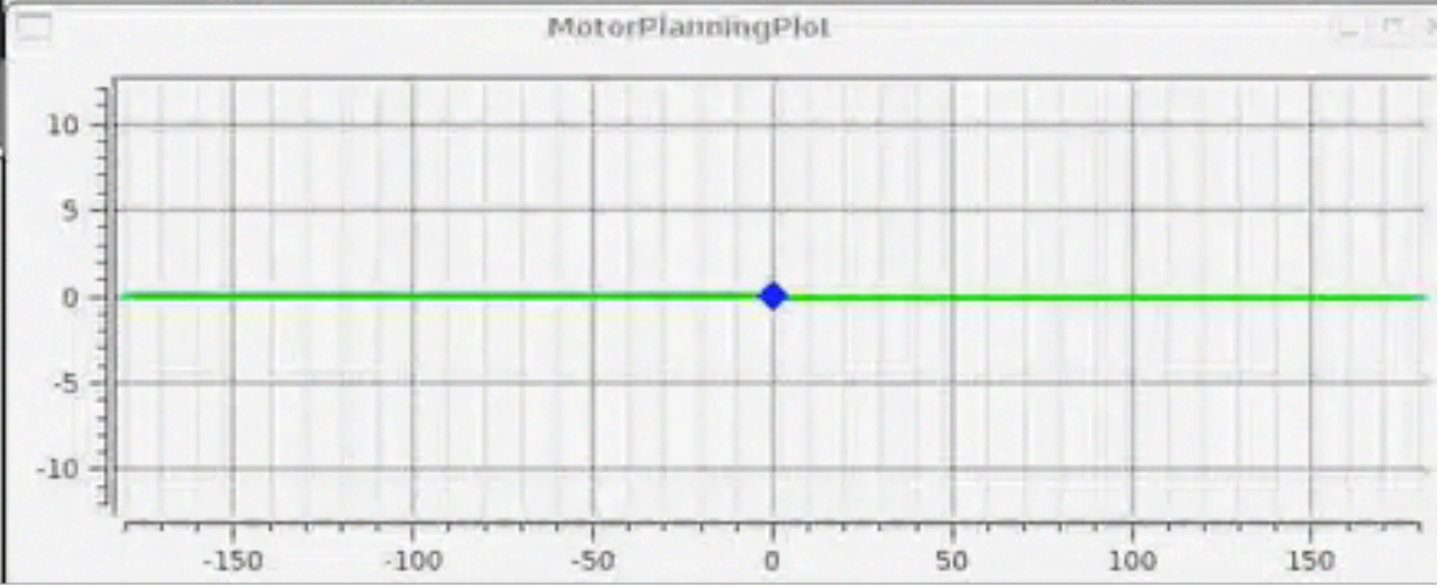
-15
-20
-25
-150
-100
-50
0
50
100
150


MotorPlanningPlot
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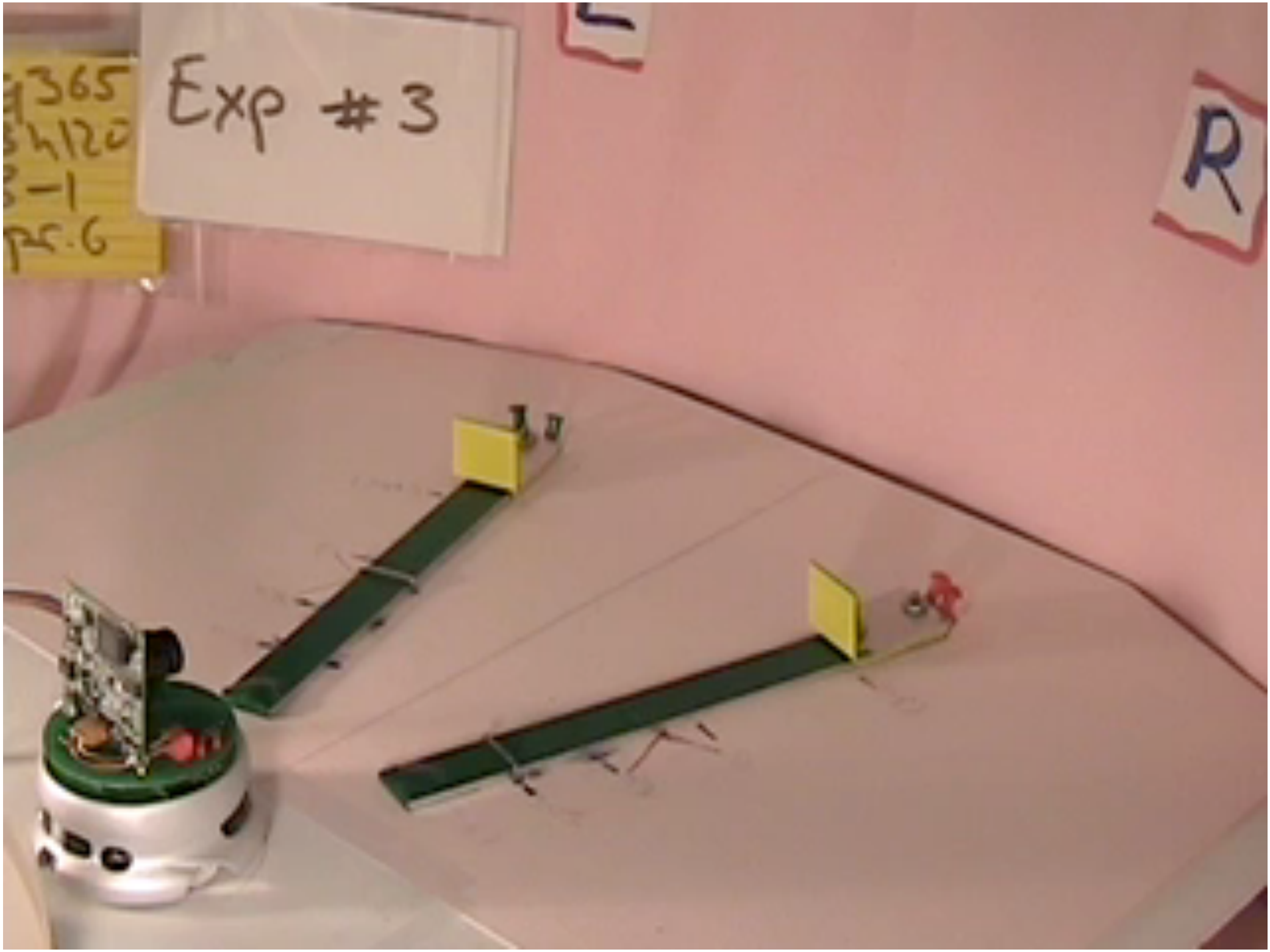
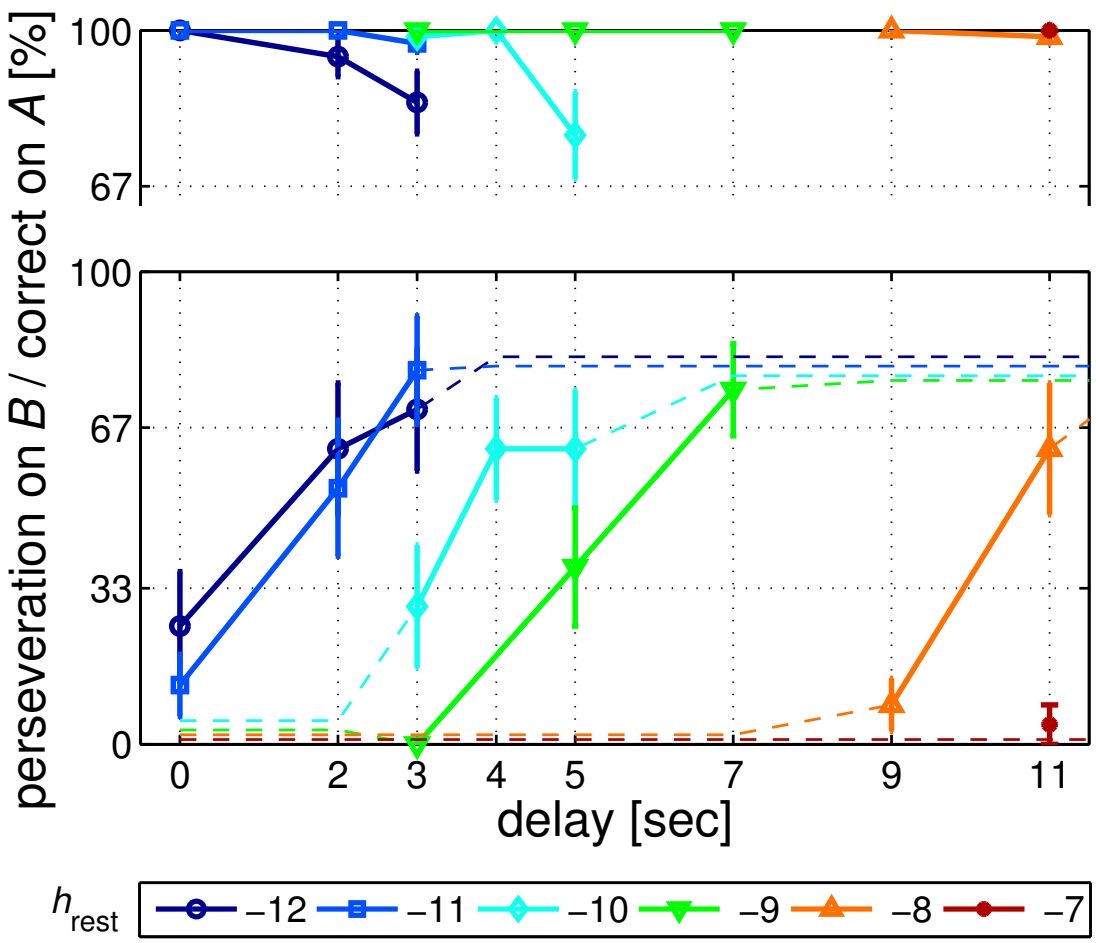
-5
-10
-150
-100
-50
0
50
100
150

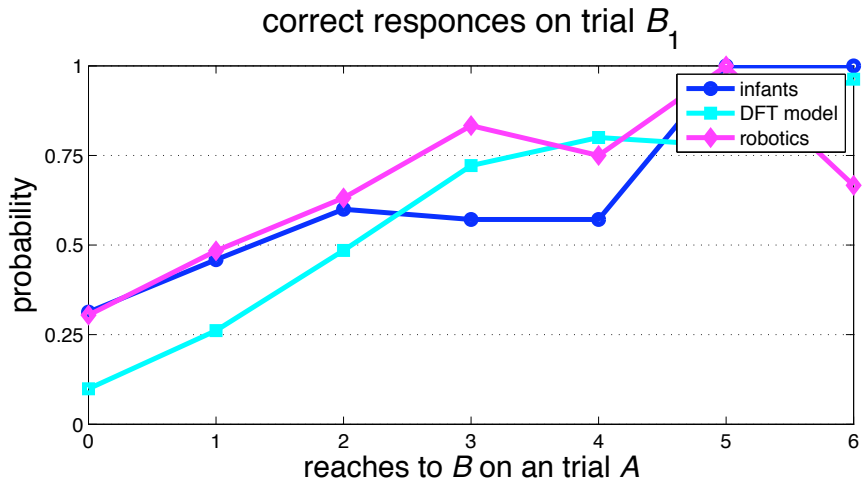

Exp #3
R

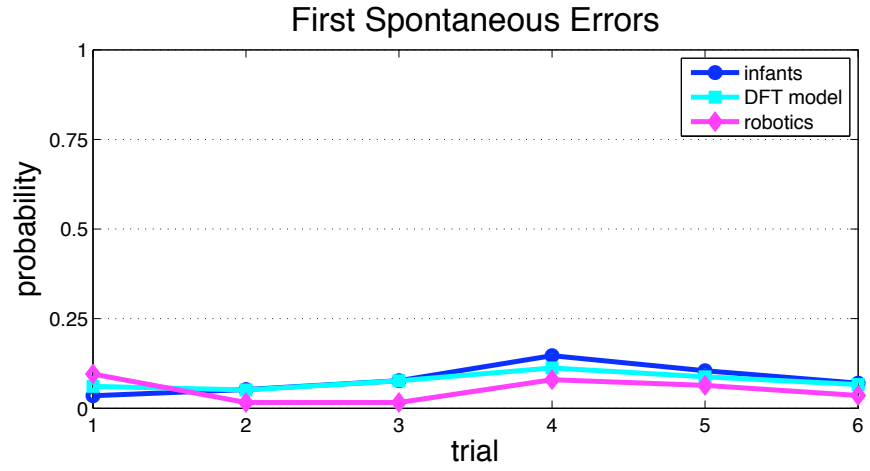
result: reproduce fundamental age-delay trade-off in A not B

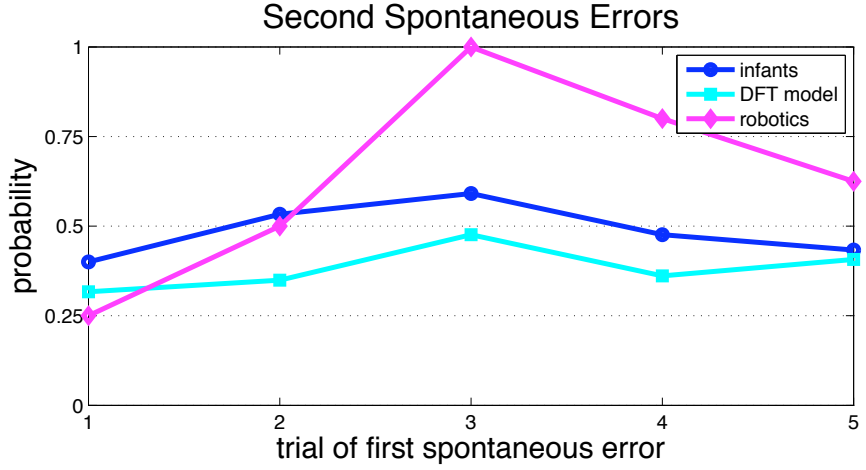


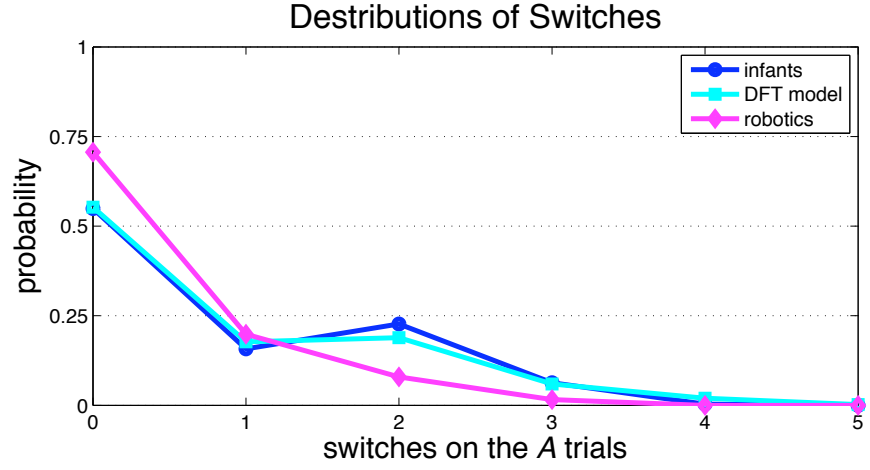
young

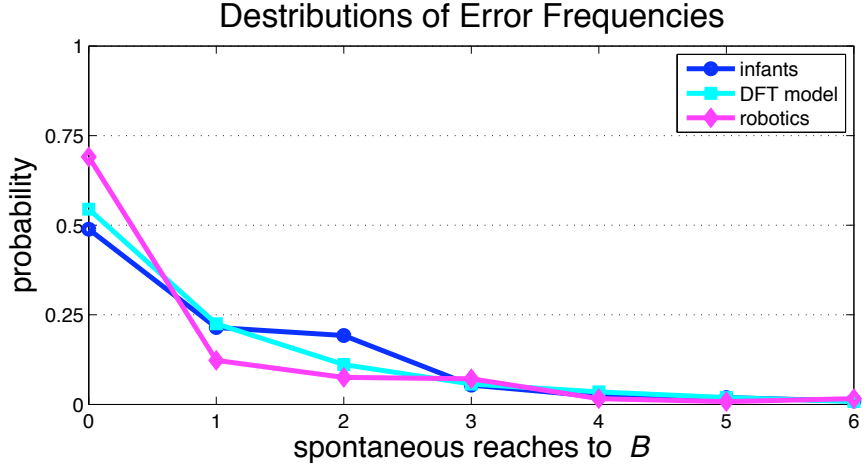
old


correct responces on trial B_1
probability
reaches to B on an trial A
infants
DFT model
robotics

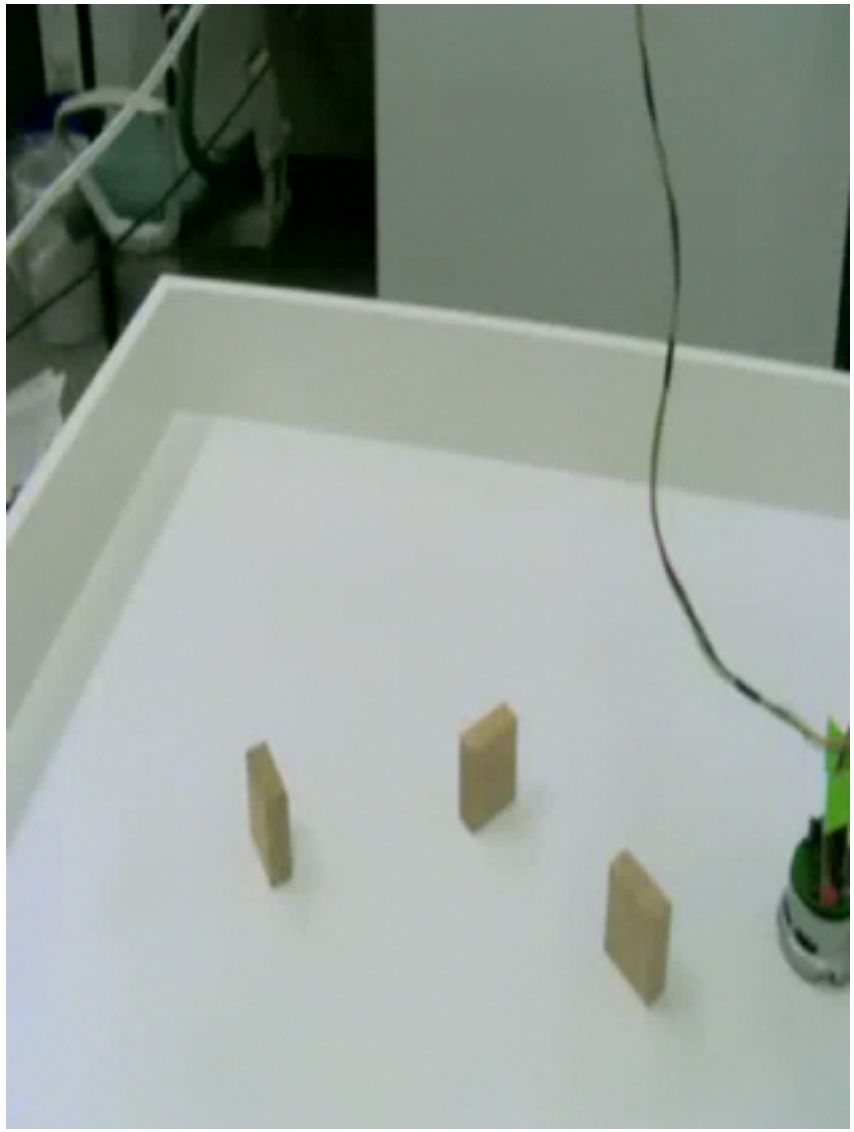

First Spontaneous Errors
probability
trial
infants
DFT model
robotics


Second Spontaneous Errors
probability
trial of first spontaneous error
infants
DFT model
robotics

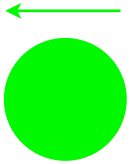

Destributions of Switches
probability
switches on the A trials
infants
DFT model
robotics


Destributions of Error Frequencies
probability
spontaneous reaches to B
infants
DFT model
robotics

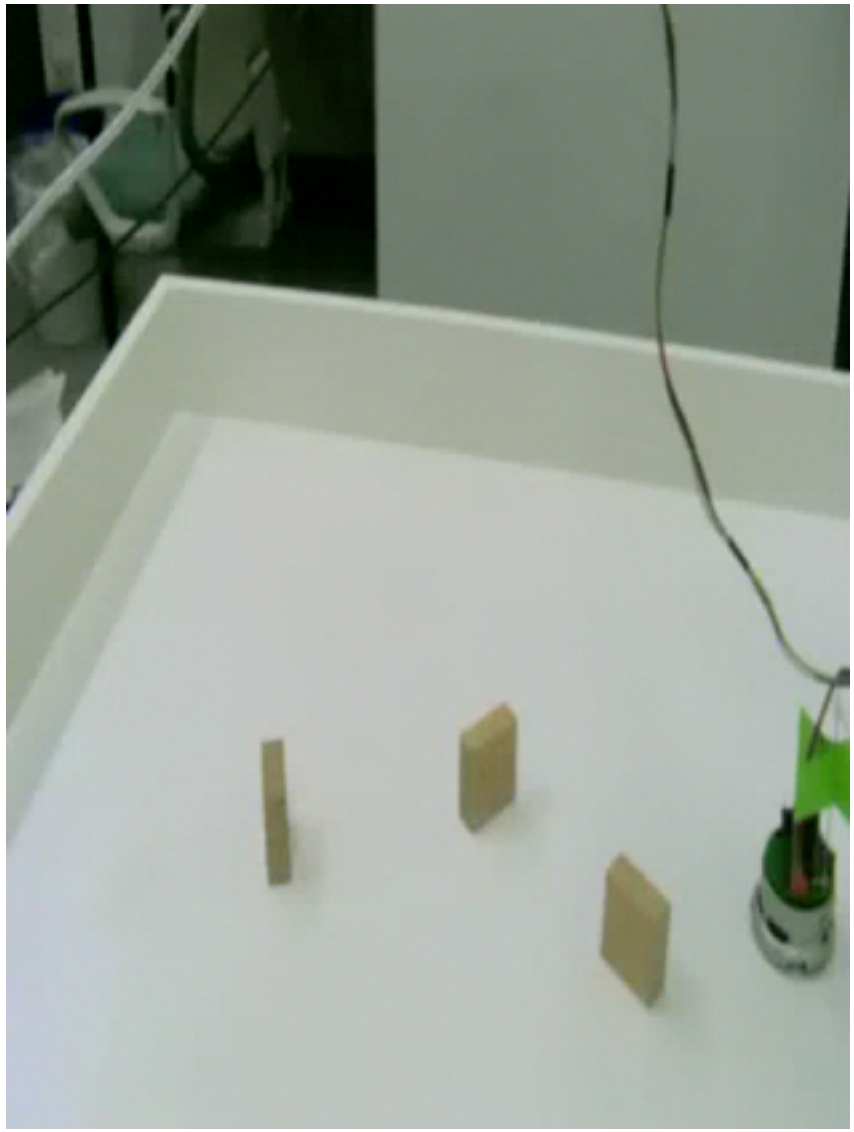
"young" robot



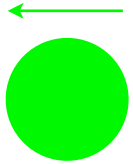
target



"old" robot

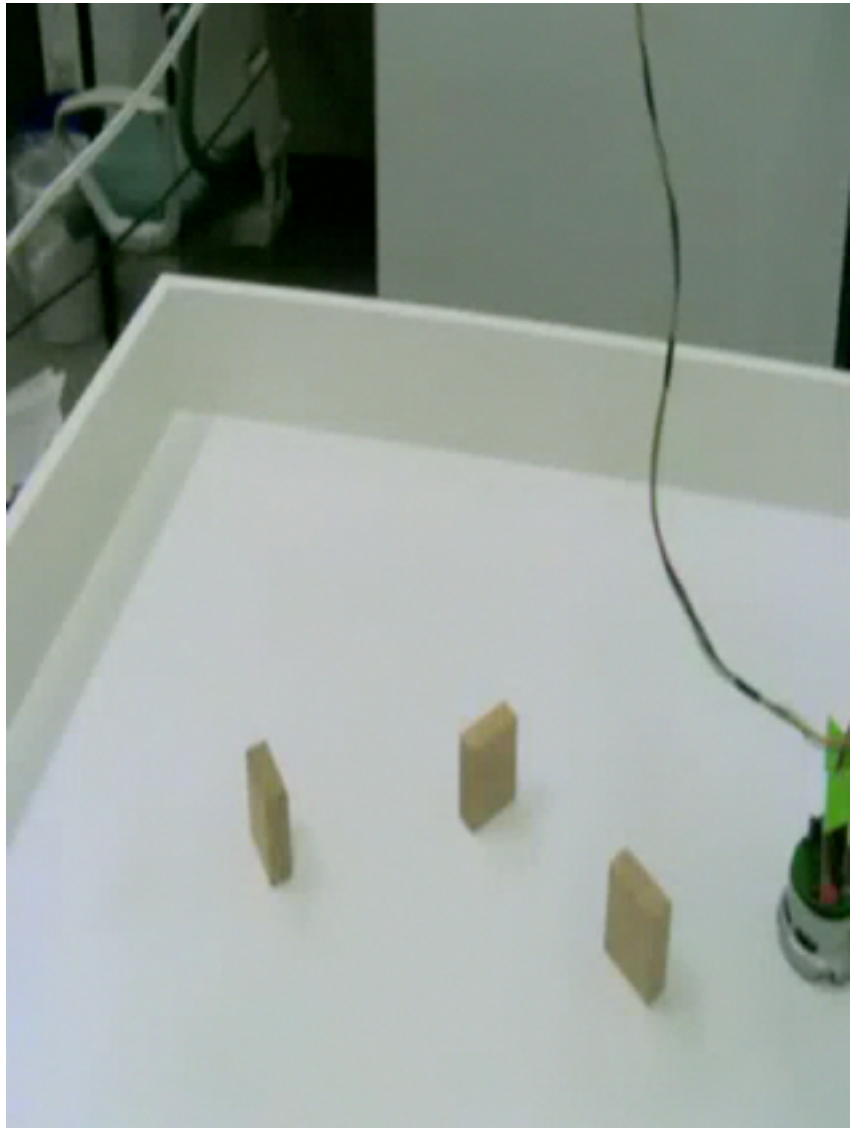


target



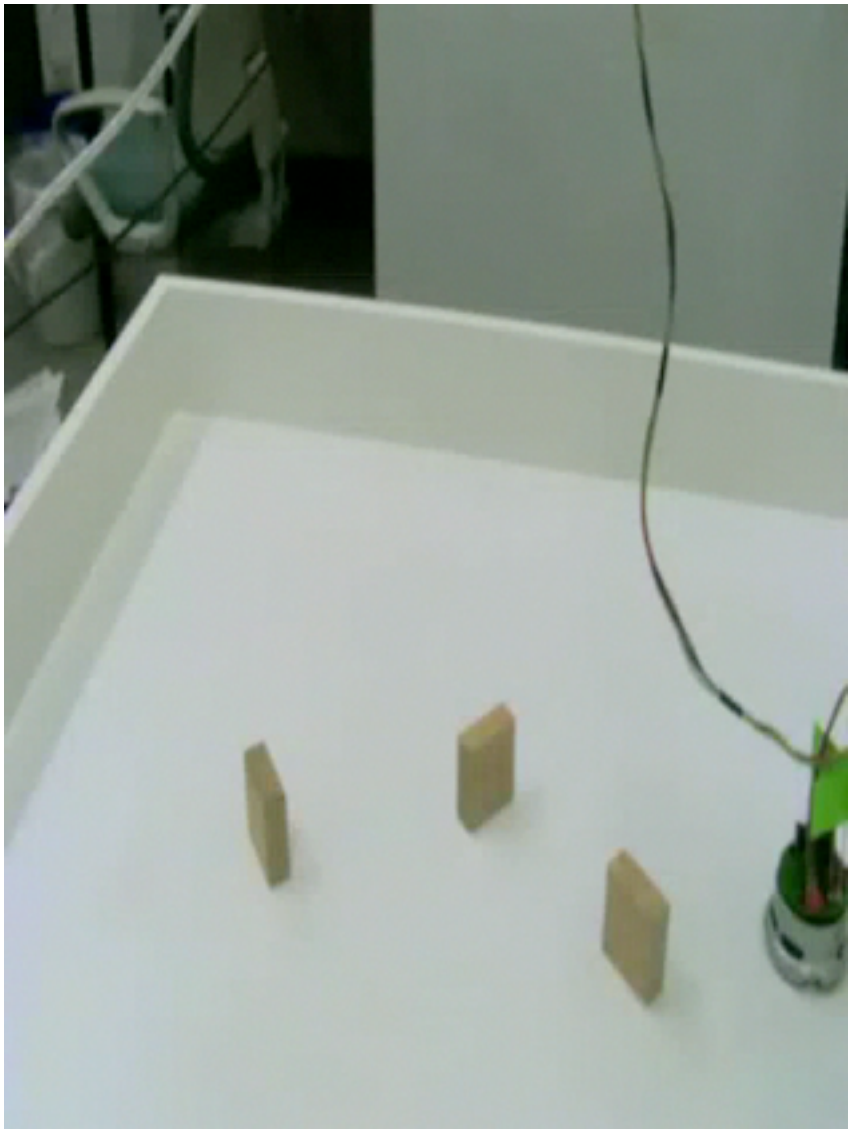
"young" robot

target



"young" robot with memory trace

target



DFT models can be embodied

- stabilization of decisions is critical
- (when we failed to do so, by just "reading out" the location with maximal activation after the delay, that location fluctuate from moment to moment leading to meandering of the robot in an averaged direction)

The conceptual framework of DFT