Sequential processing in DFT

Gregor Schöner

Sequences

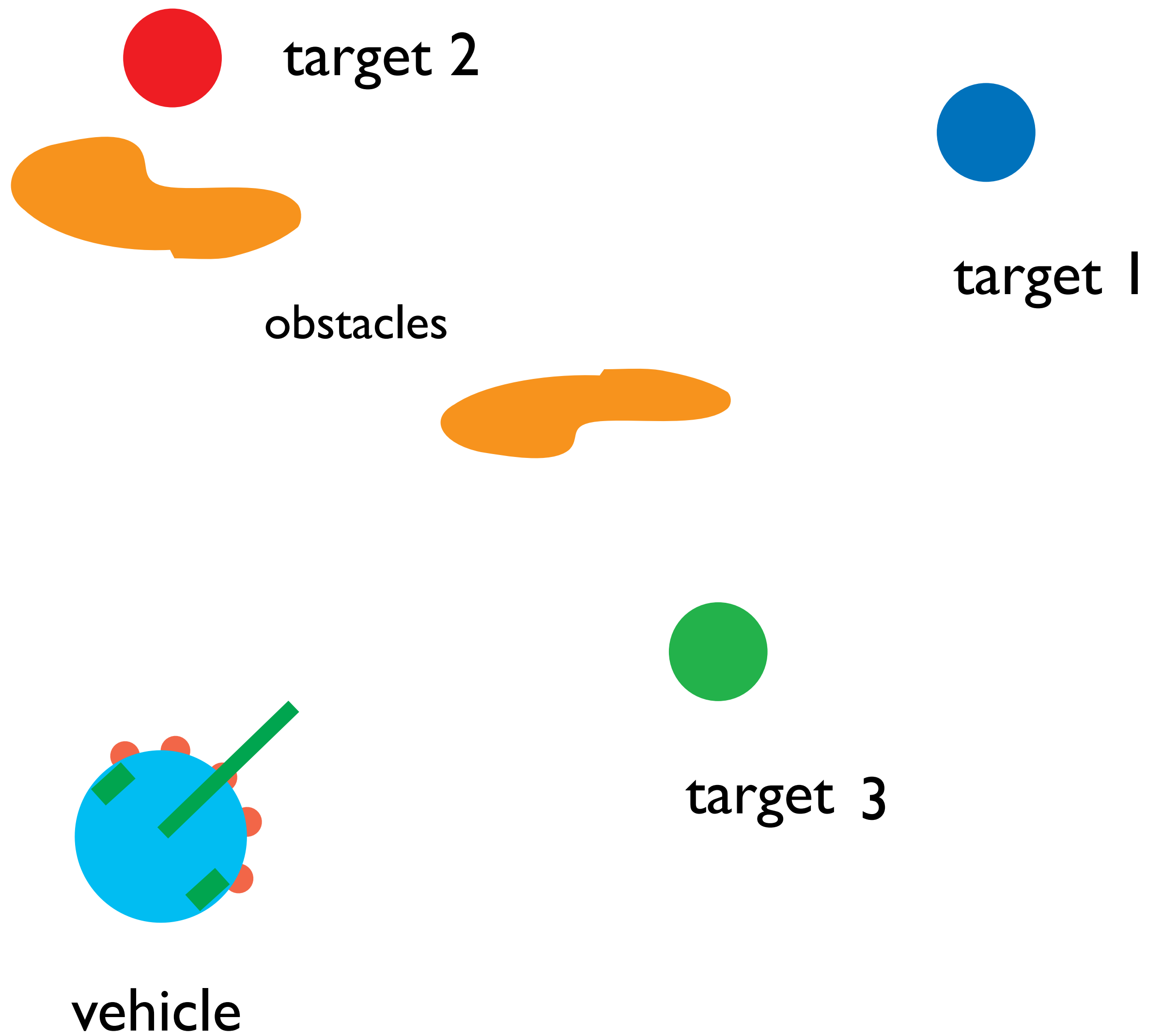
- all actions in real life consist of sequences of movements, perceptual acts, inferences
  - often fixed by the logic of action
  - often highly automated: routines
- but also flexible:
  - serial order: arbitrary sequences

Challenge in DFT

- behaviors/representations are stable states
- in sequence: need to switch out of one behavior to the next. How to do that?
- answer: induce an instability

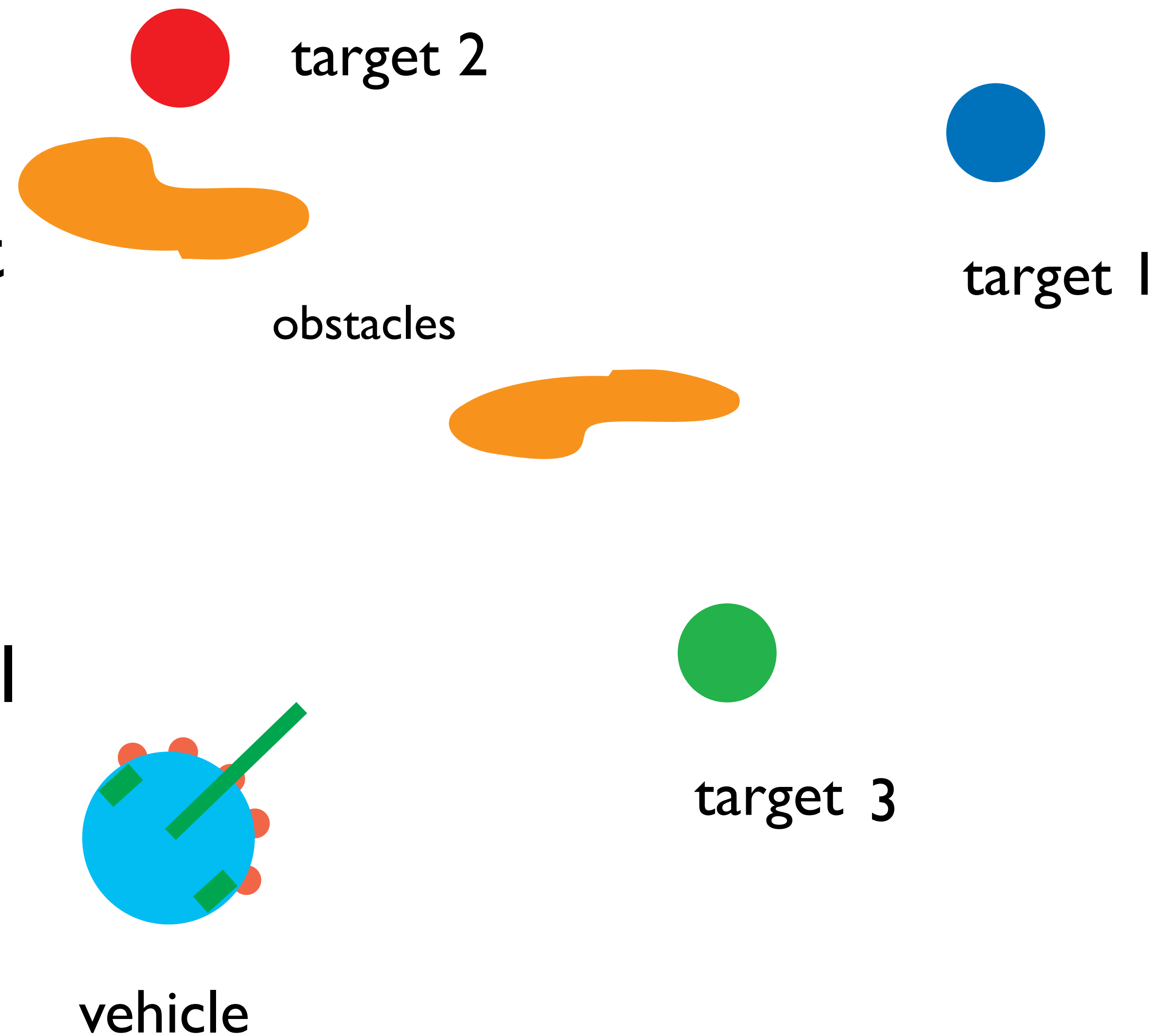
Illustration

- search for objects of a given color in order
  - 1 blue
  - 2 red
  - green



The problem of sequential processing

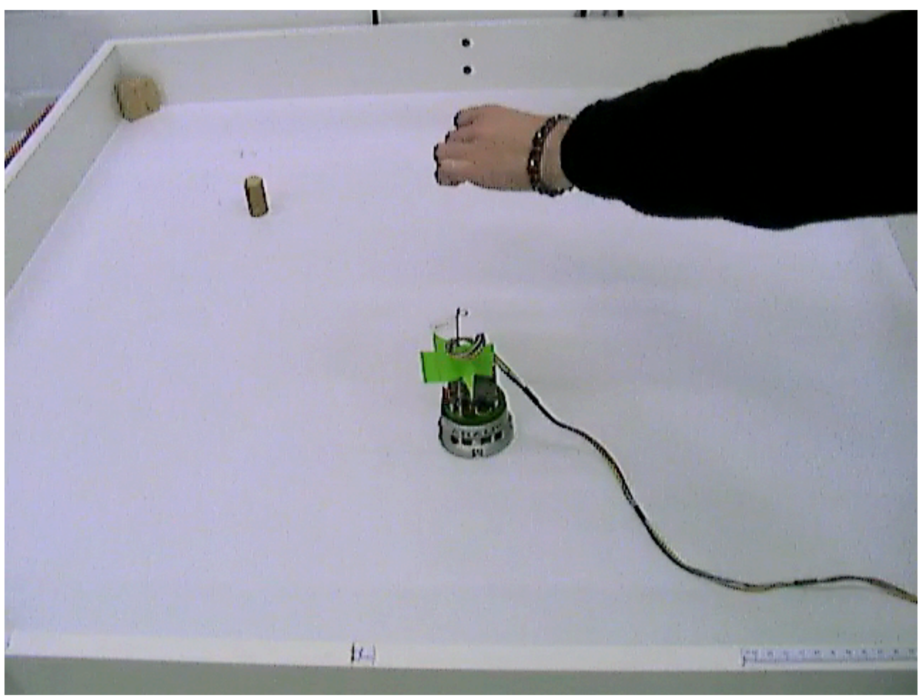
- each step in the sequence is a visual search, which takes a variable (here: unpredictable) amount of time
- so stabilize the goal of the visual search until the search is successful
- only then switch to the next element of the sequence



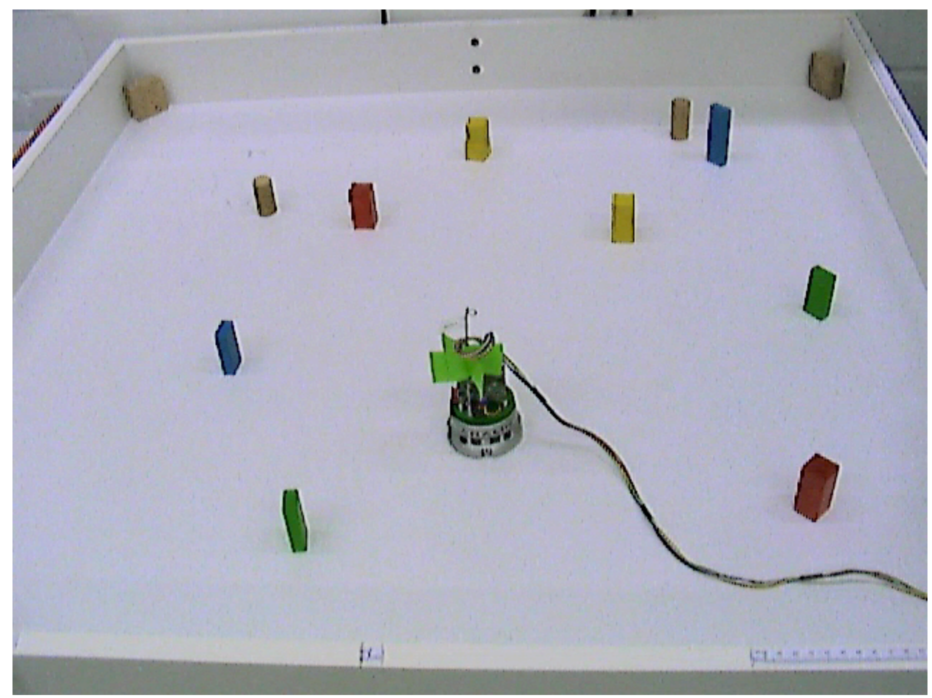
Implementation as an imitation task

- learn a serially ordered sequence from a single demonstration
- perform a serially ordered sequence with new timing

yellow-red-green-blue-red



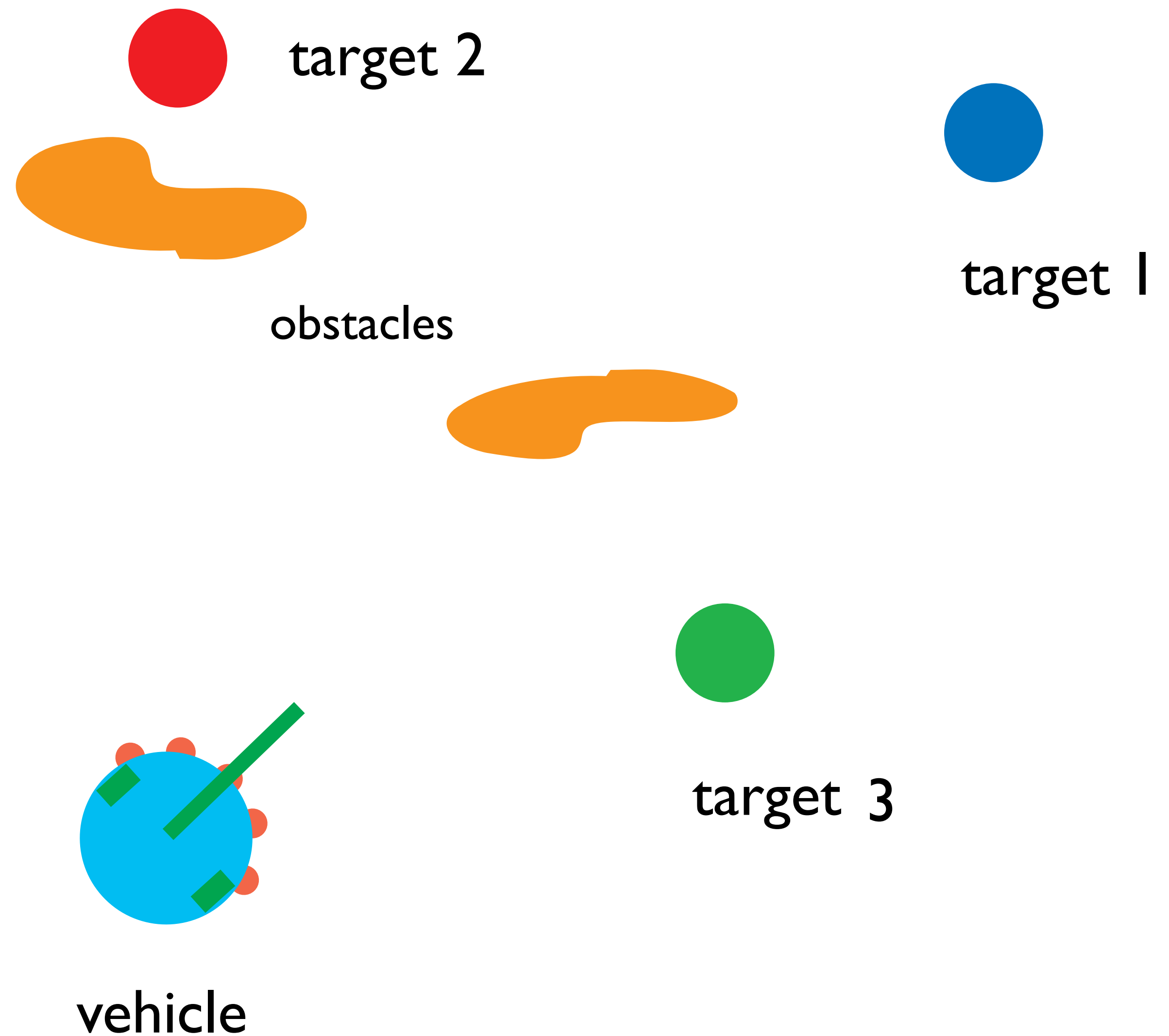
yellow-red-green-blue-red



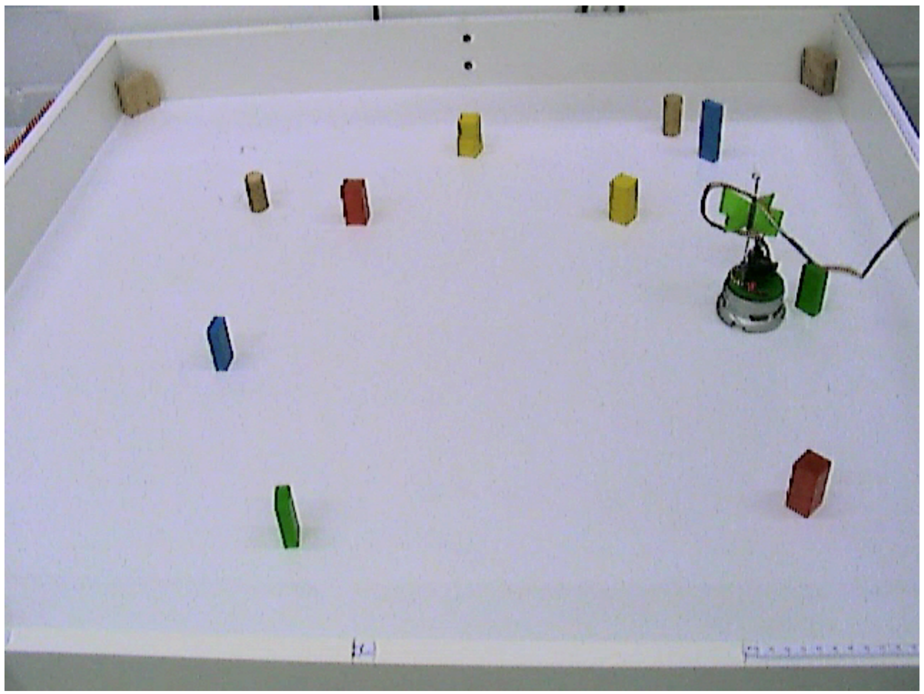
[Sandamirskaya, Schöner: Neural Networks 23:1163 (2010)]

Neural dynamics of sequence generation

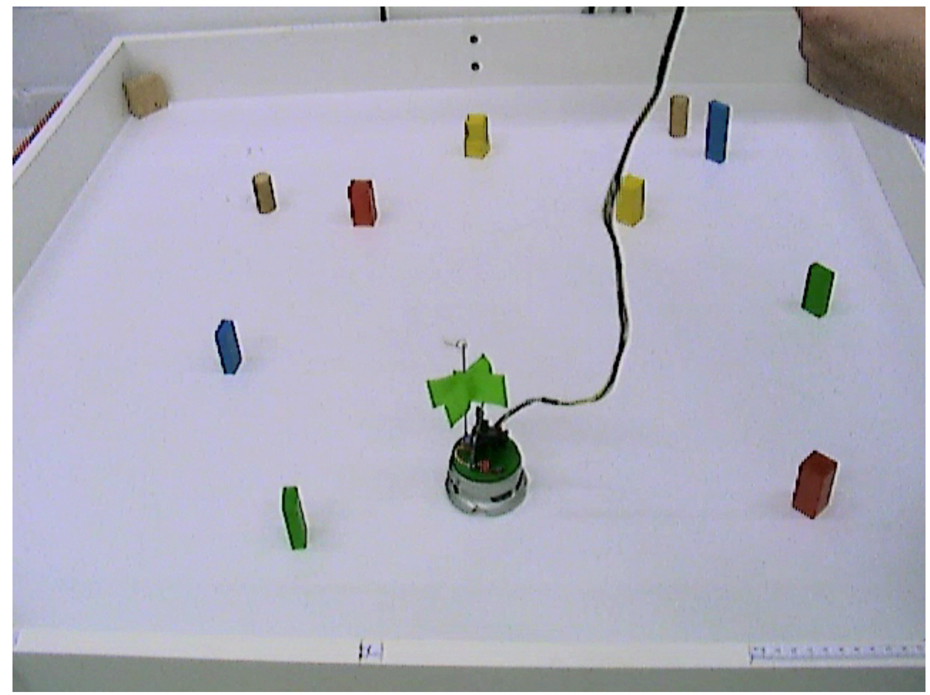
- represent the target color by a stable peak that resists attractors



red a distractor



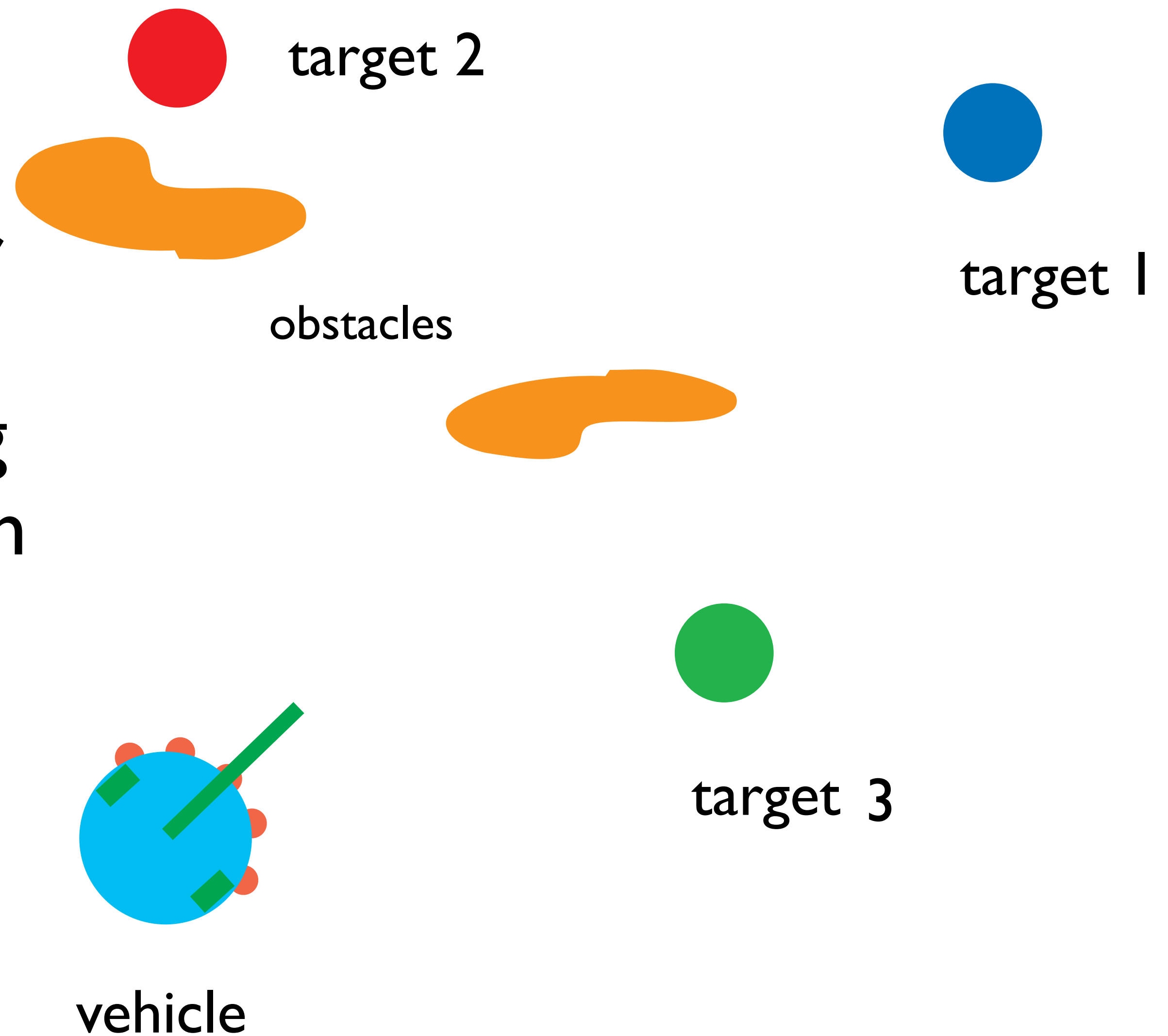
red a target



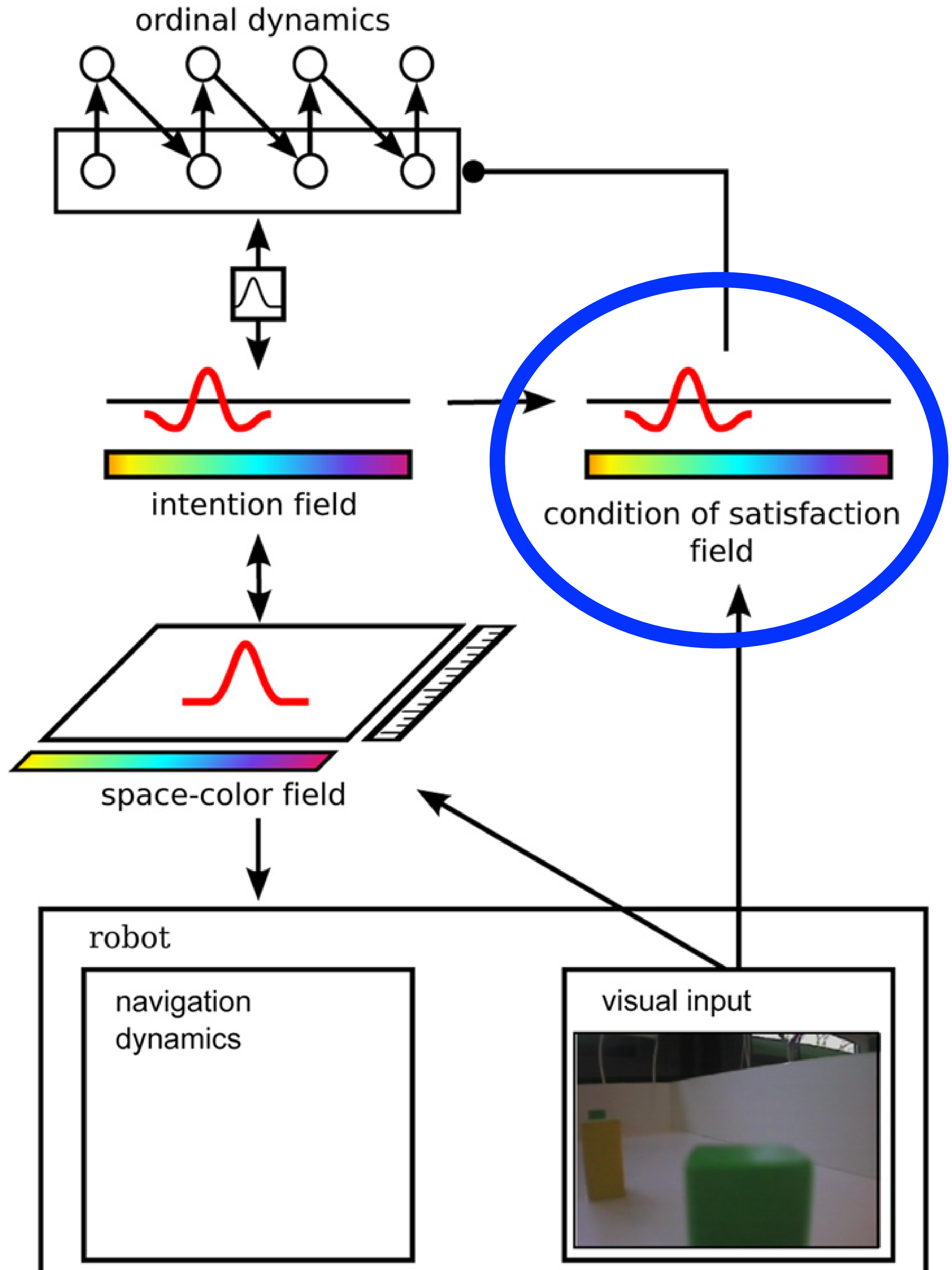
[Sandamirskaya, Schöner: Neural Networks 23:1163 (2010)]

Neural dynamics of sequential processing

- when the sought color is found, switch to the next color by releasing the previous state from stability…through an instability

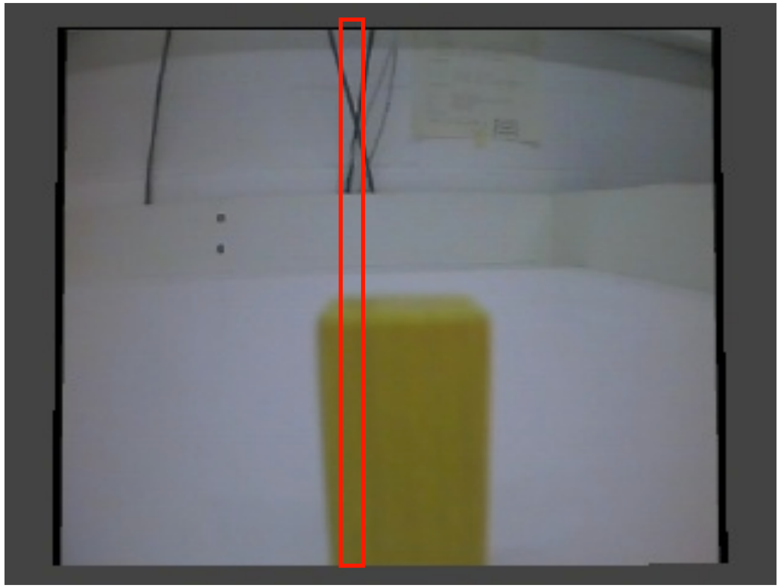


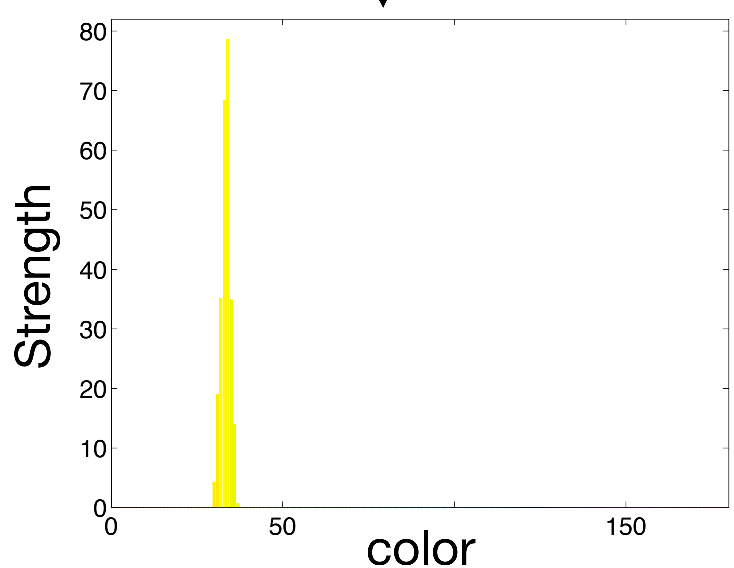
“Condition of Satisfaction” (CoS)



[Sandamirskaya, Schöner, 2010]

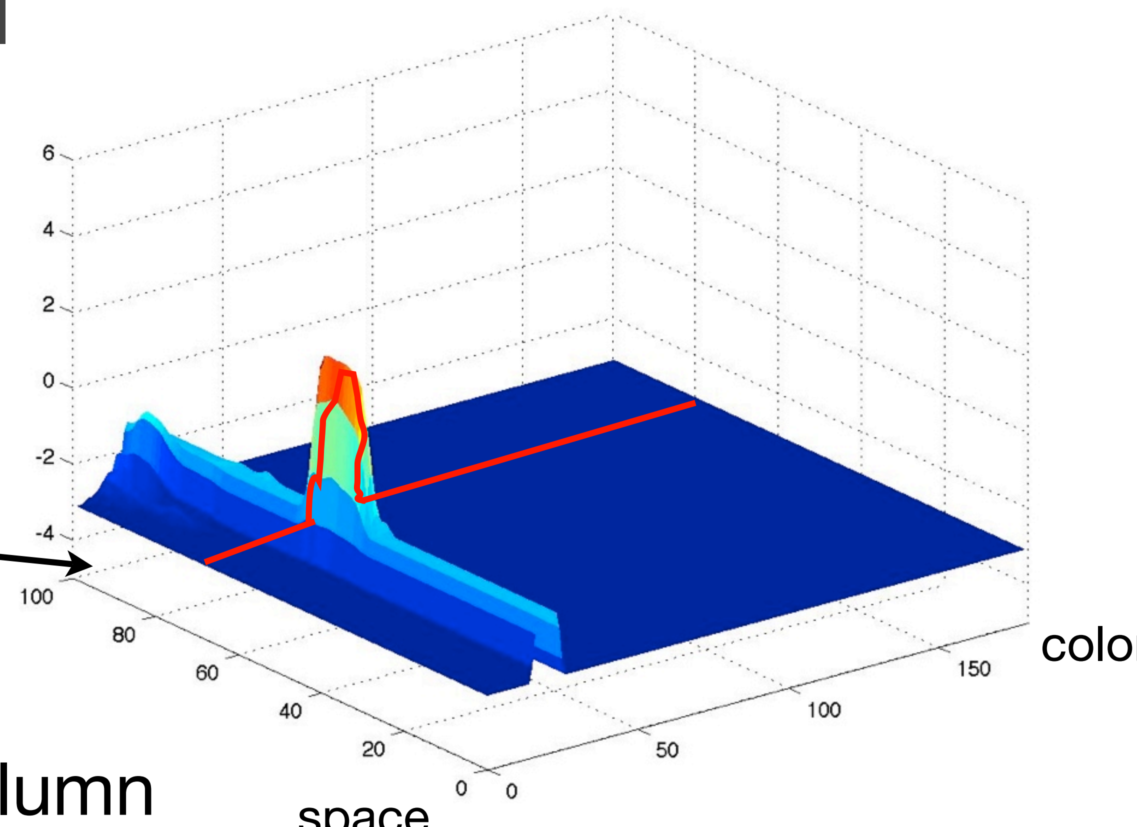
Camera image

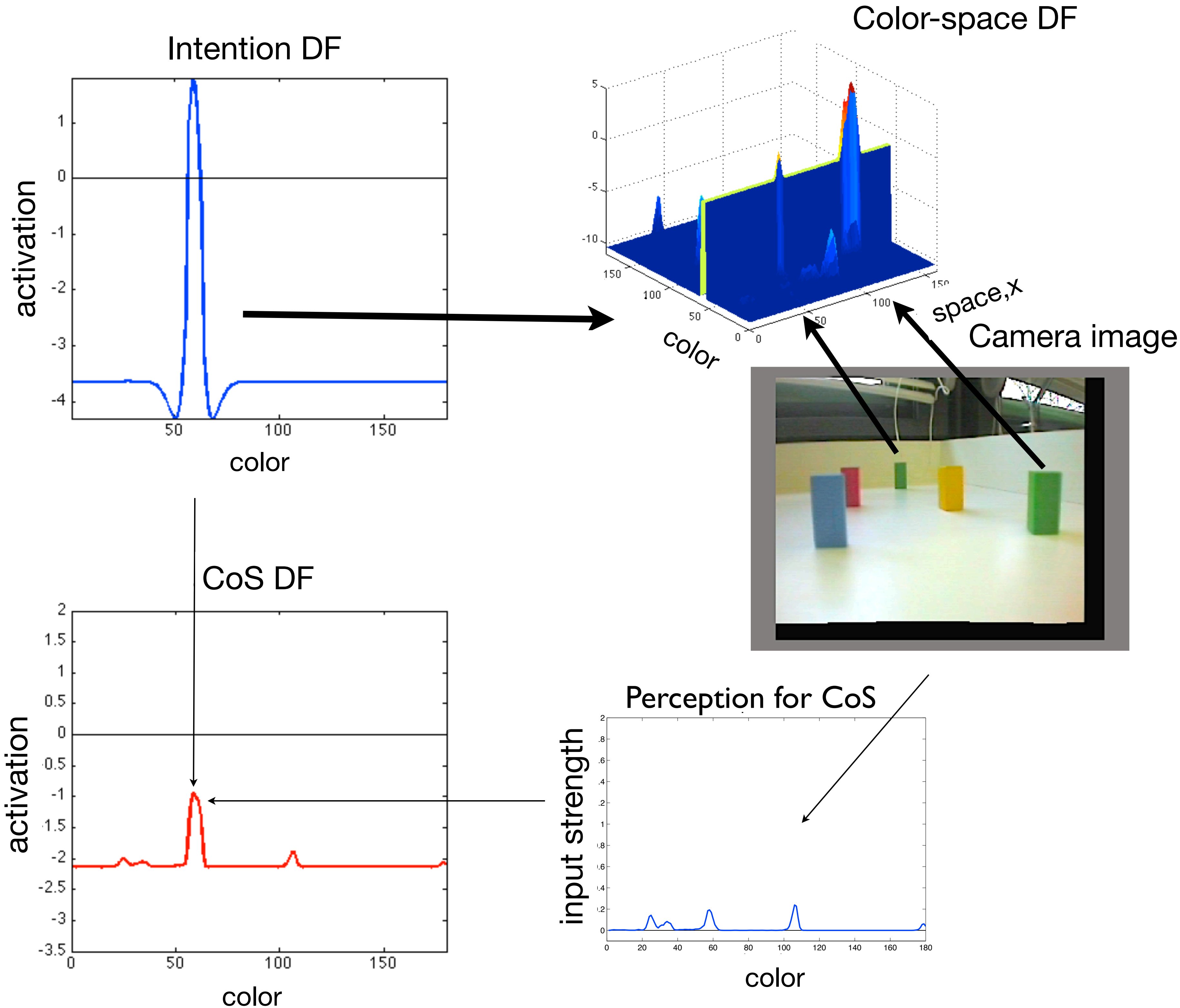




Color histogram of the column

Color-space DF



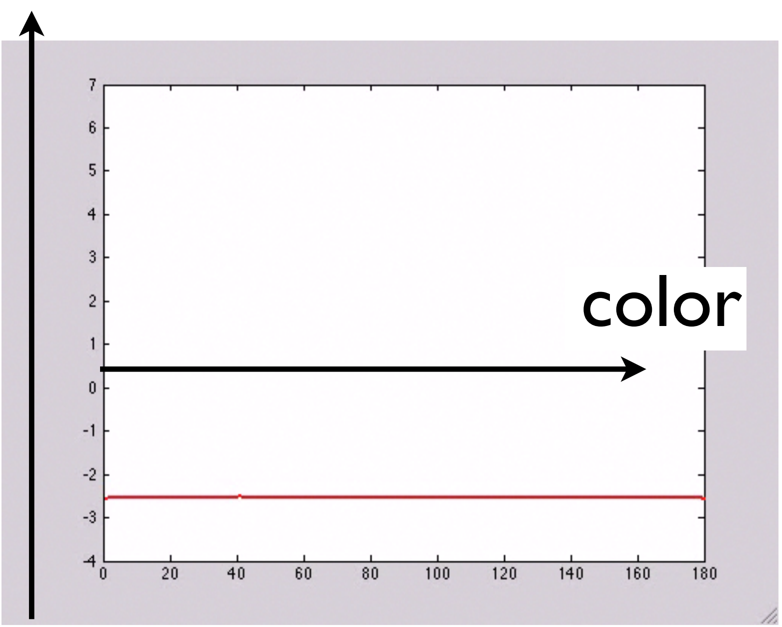


Intention DF
activation
color
Color-space DF
space,x
color
Camera image
CoS DF
activation
color
Perception for CoS
input strength
color

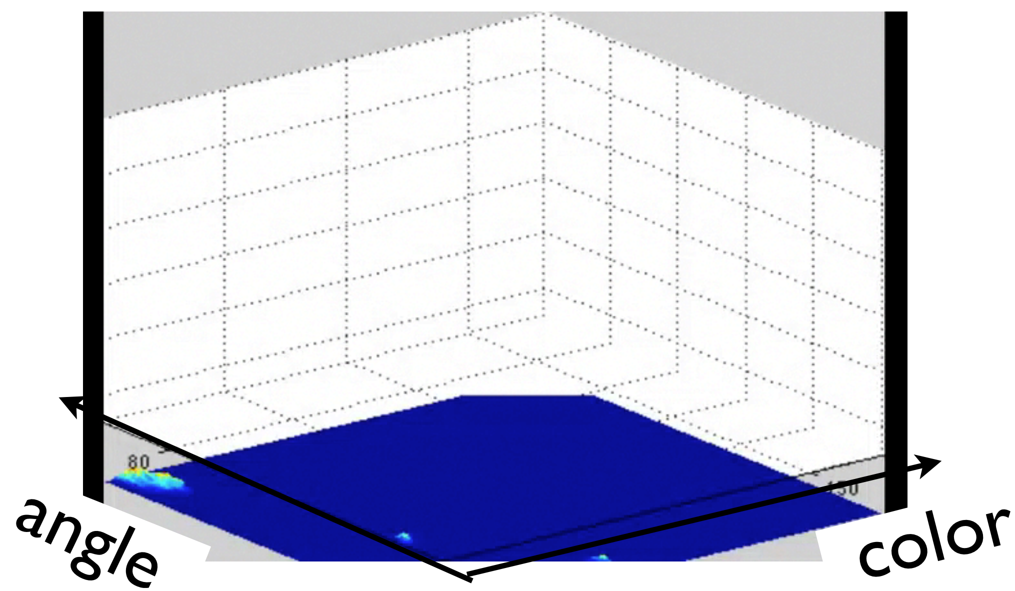
ordinal stack

condition of satisfaction (CoS)

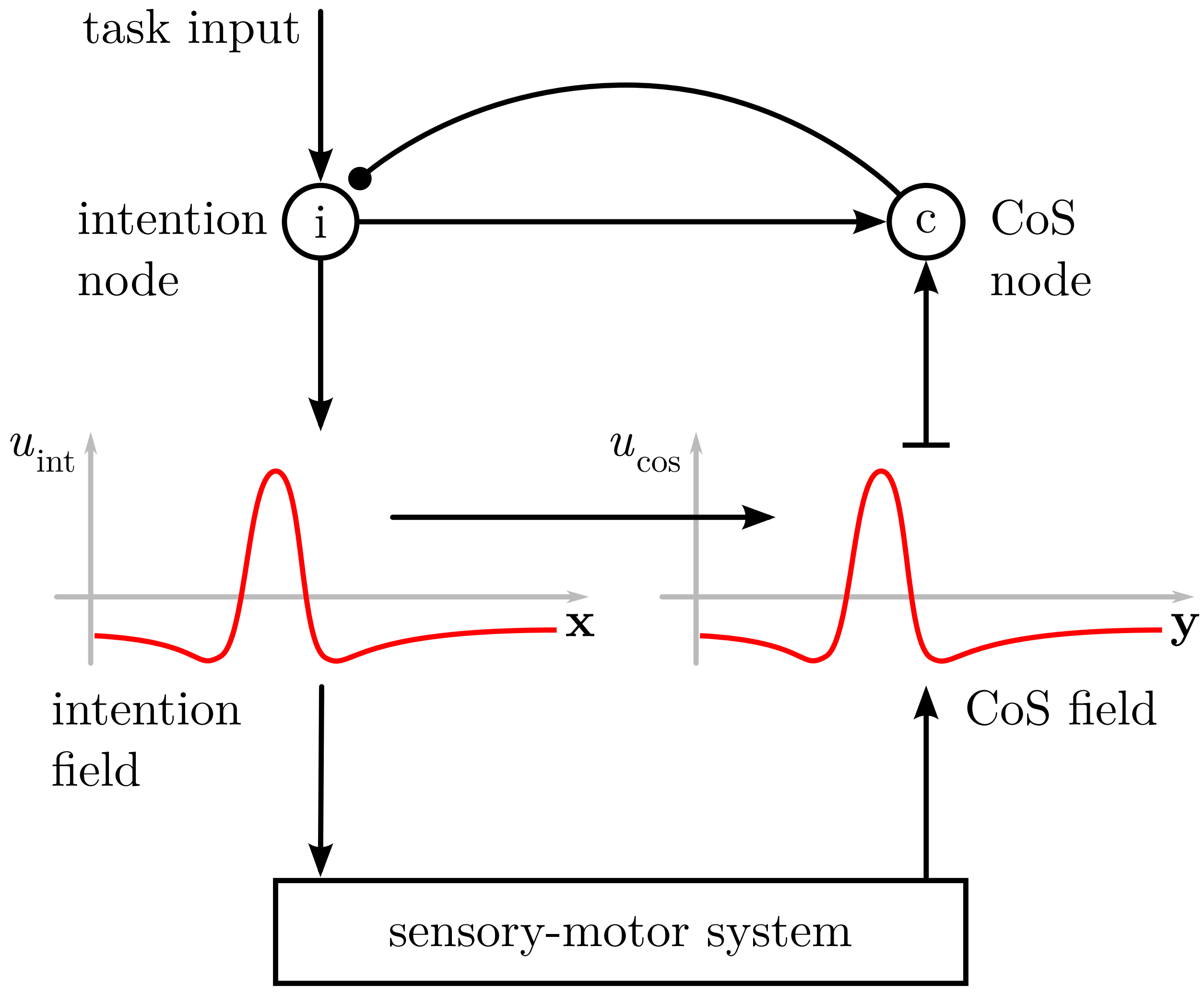
intentional state



2D feature-space field



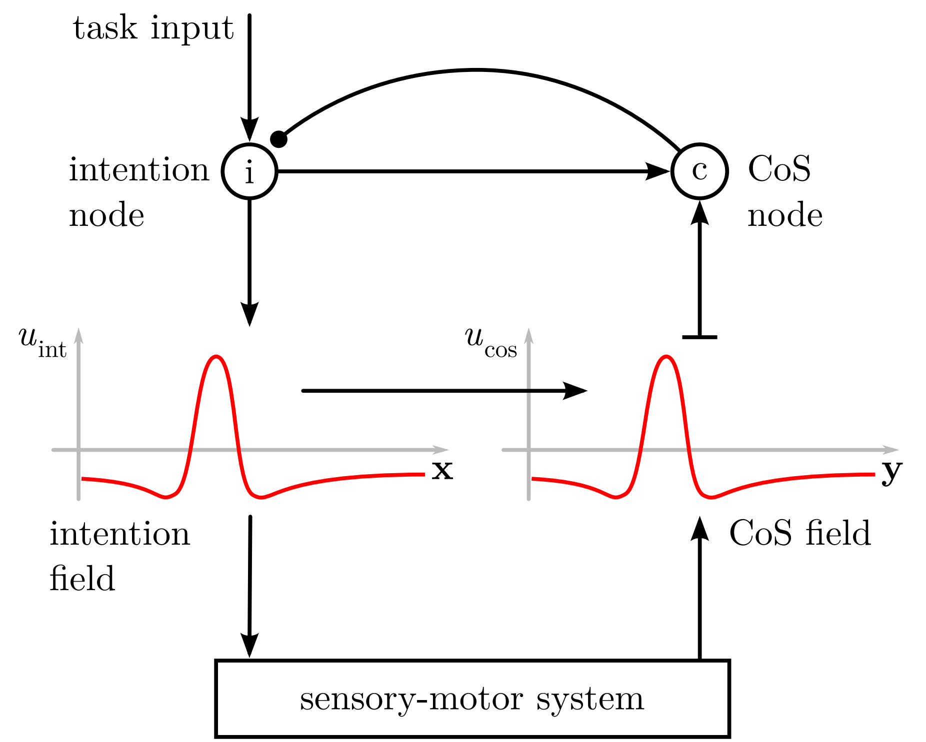
Generalization



A DFT cognitive architecture for sequence generation

- every action is represented by an "intentional" node

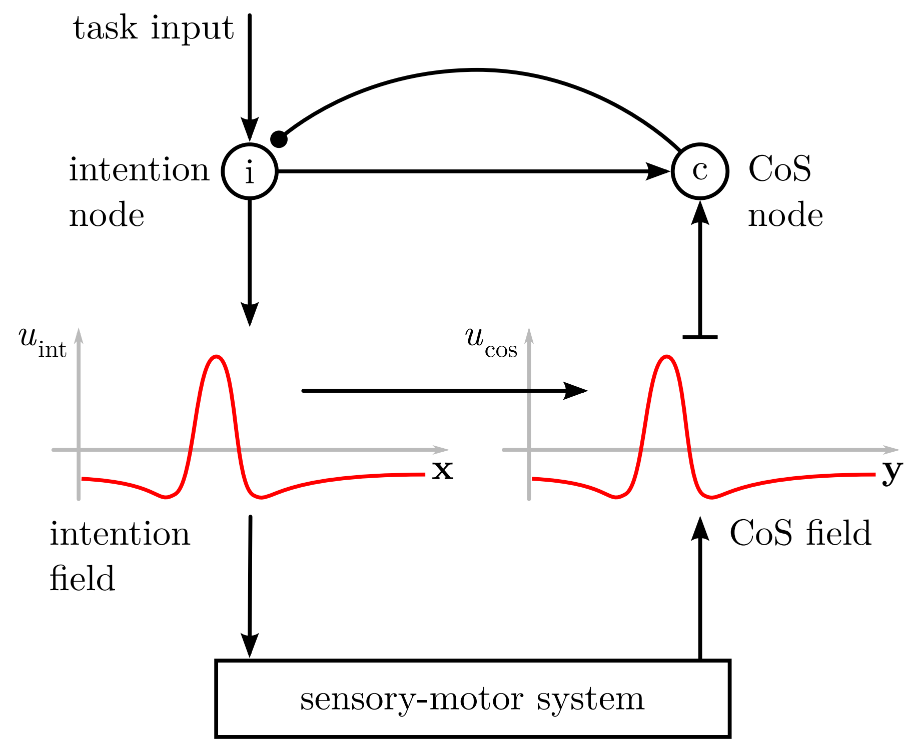
- an an "intentional field" that represents the specific action (parameter value) that is to be enacted



[Sandamirskaya, Zibner, Schneegans, Schöner: New Ideas in Psychology (2013)]

A DFT cognitive architecture for sequence generation

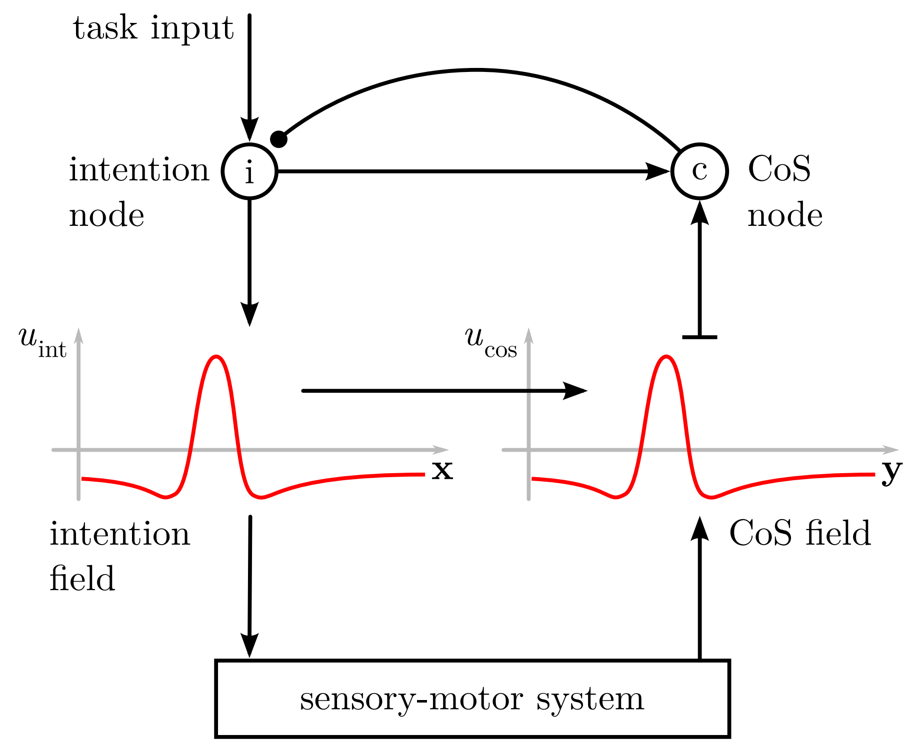
- the intention pre-activates a "condition of satisfaction" field with the predicted sensory information
- the CoS field goes through a detection instability as sensory input matches the prediction



[Sandamirskaya, Zibner, Schneegans, Schöner: New Ideas in Psychology (2013)]

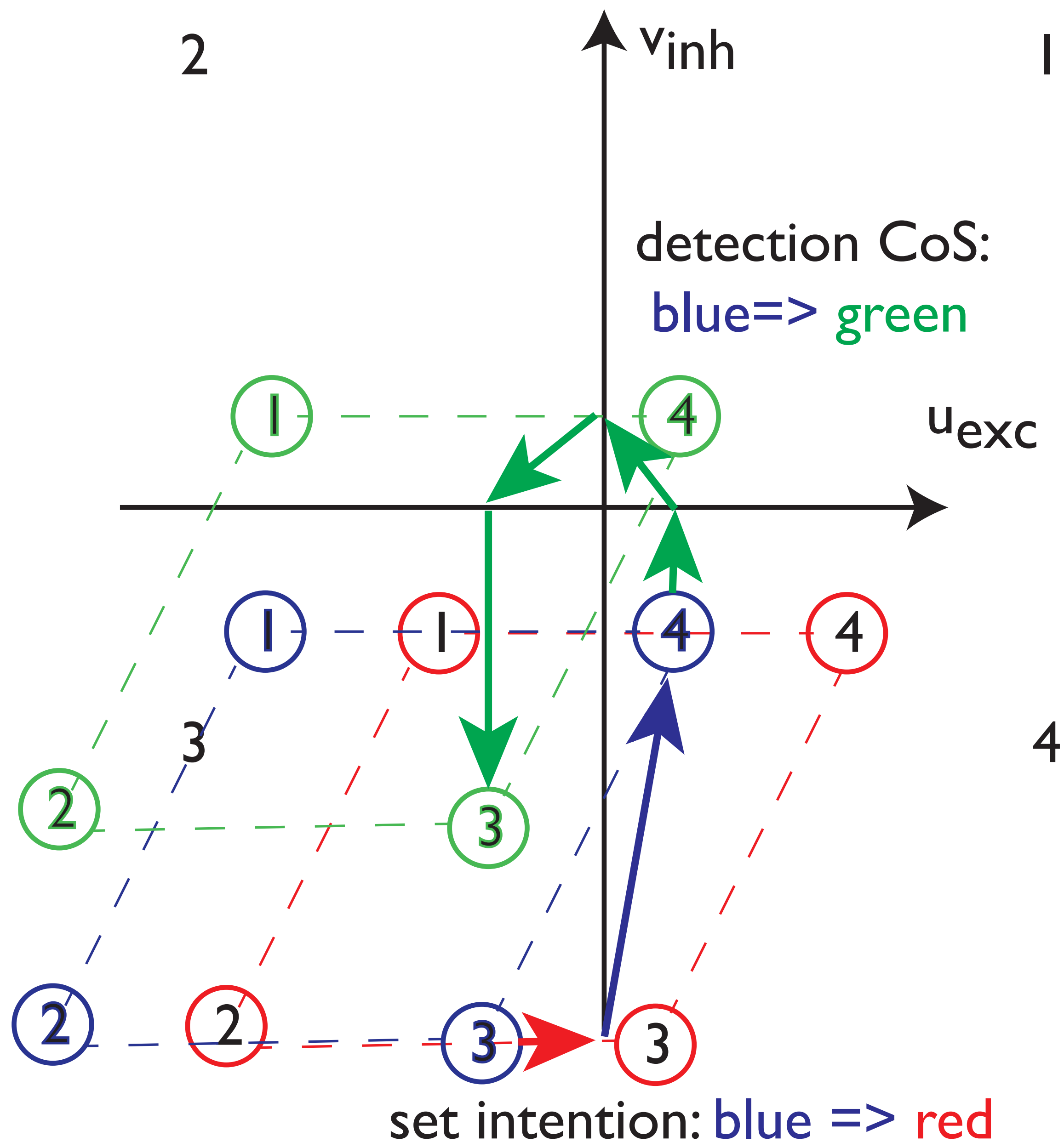
A DFT cognitive architecture for sequence generation

- this detection instability in CoS triggers the sequential transition by inhibiting the intention



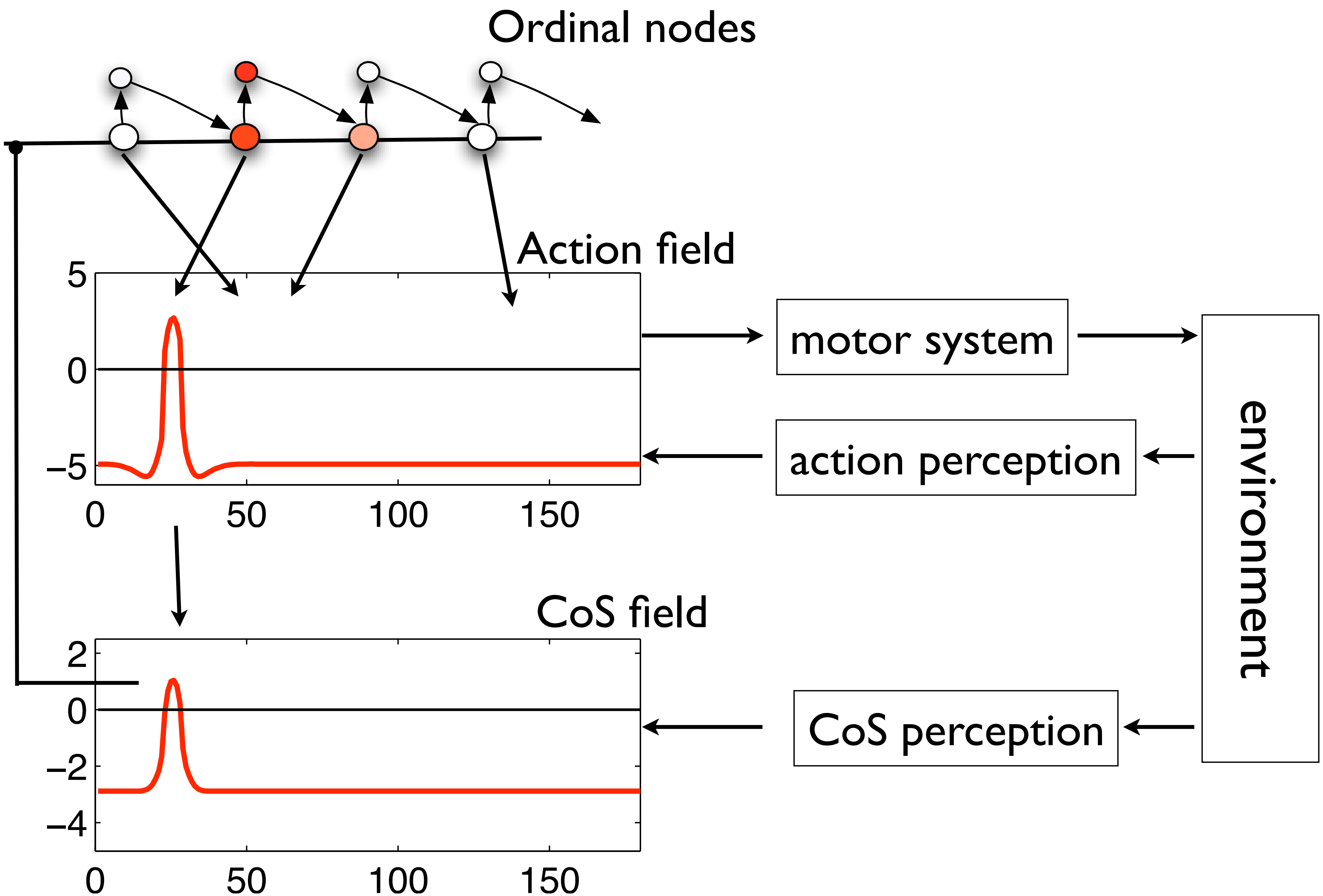
[Sandamirskaya, Zibner, Schneegans, Schöner: New Ideas in Psychology (2013)]

active transient of the CoS

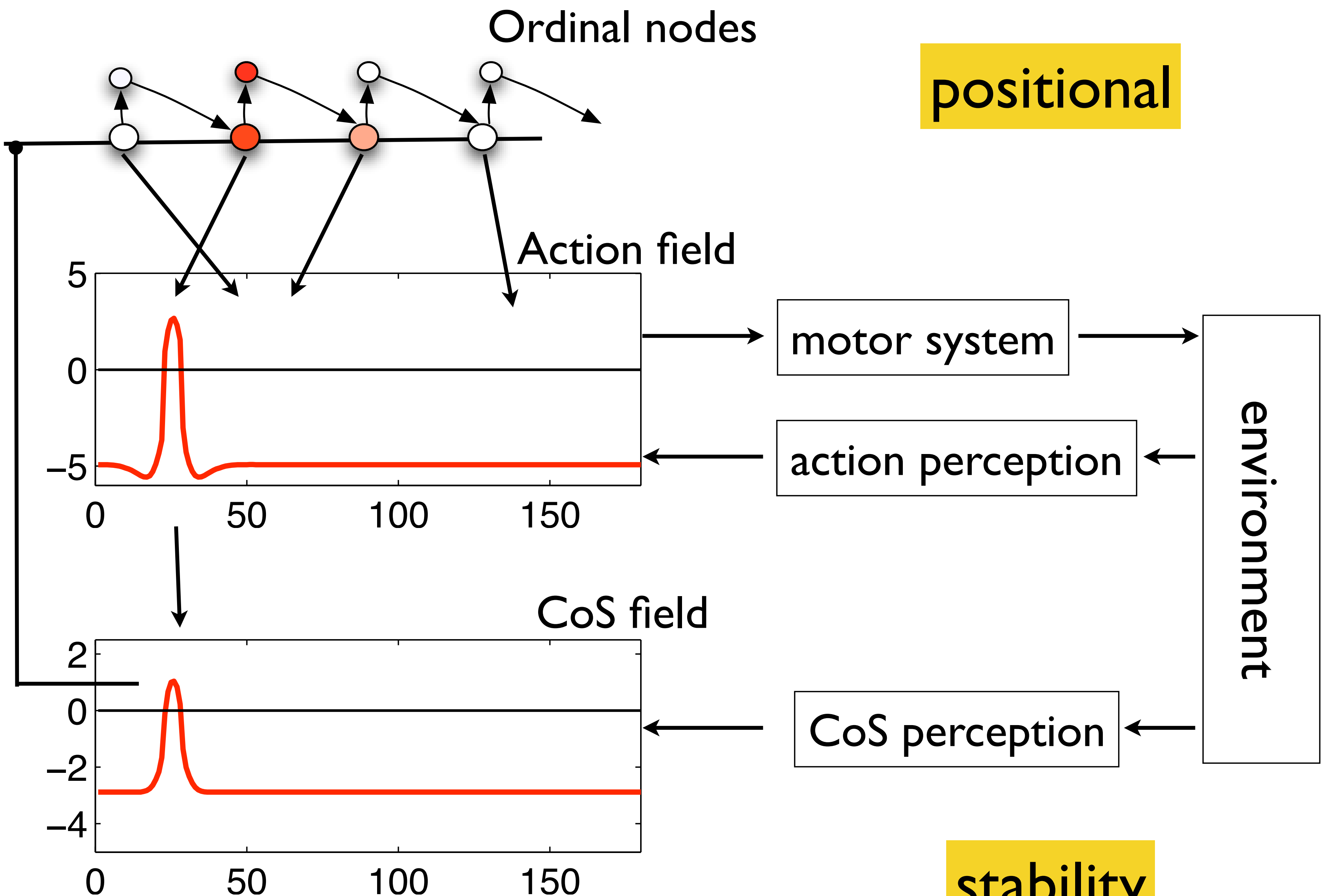


back to the DFT model

- the DFT model we have so far clearly is an instance of the positional model
- in which a positional context (ordinal node) is associated with the contents of an item
- the generic mechanism makes this link more explicitly as a neural (synaptic) association



[Sandamirskaya, Schöner: Neural Networks 23:1163 (2010)]

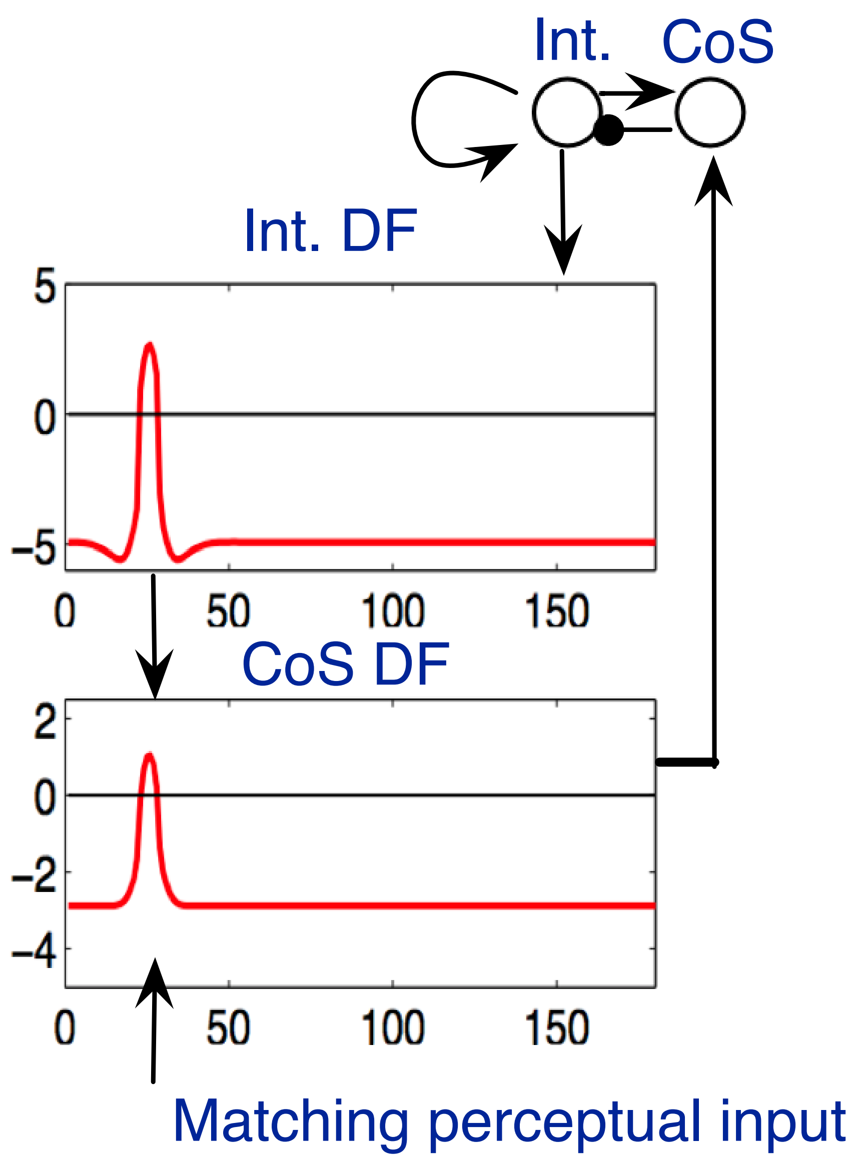


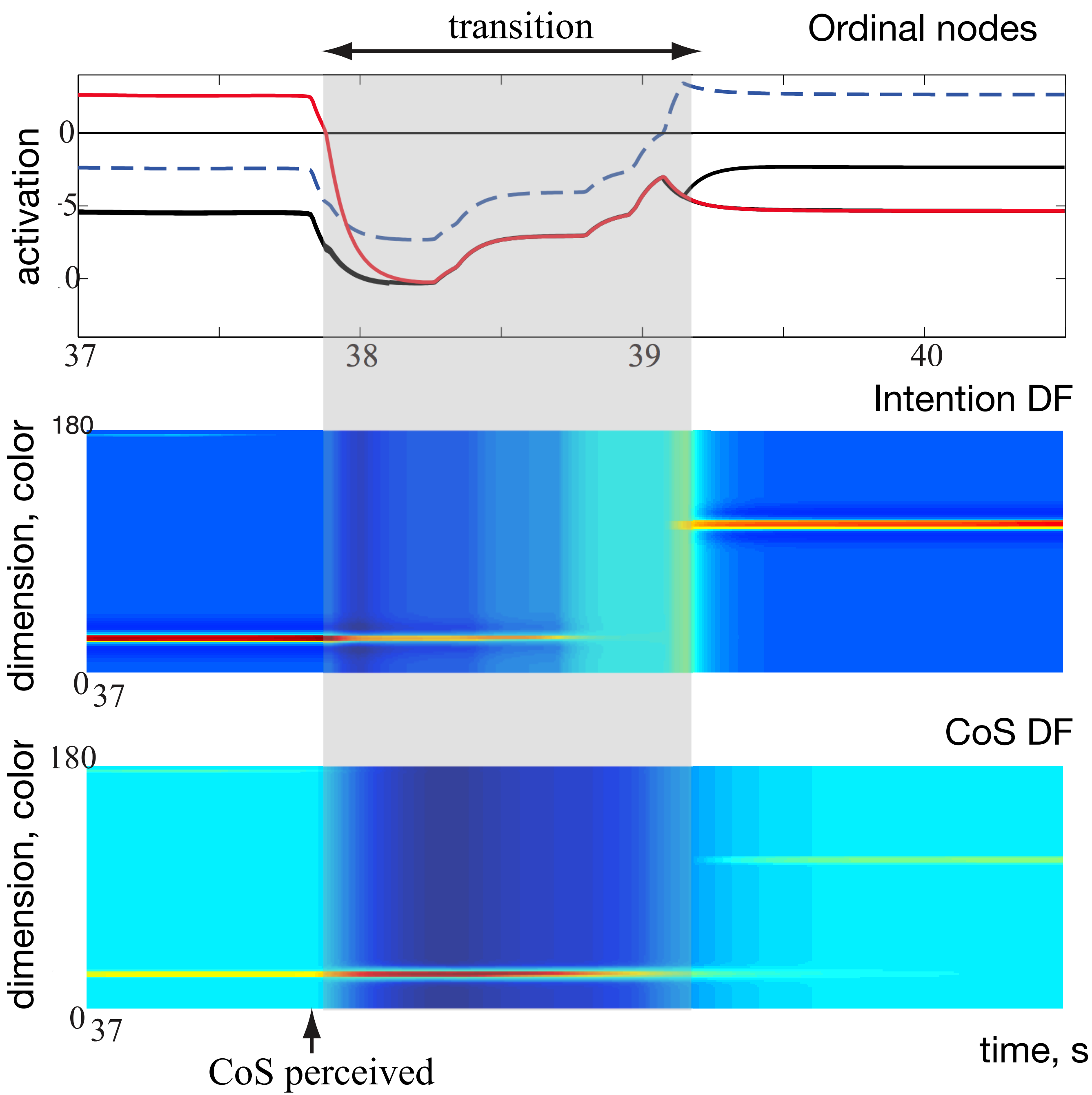
positional

stability

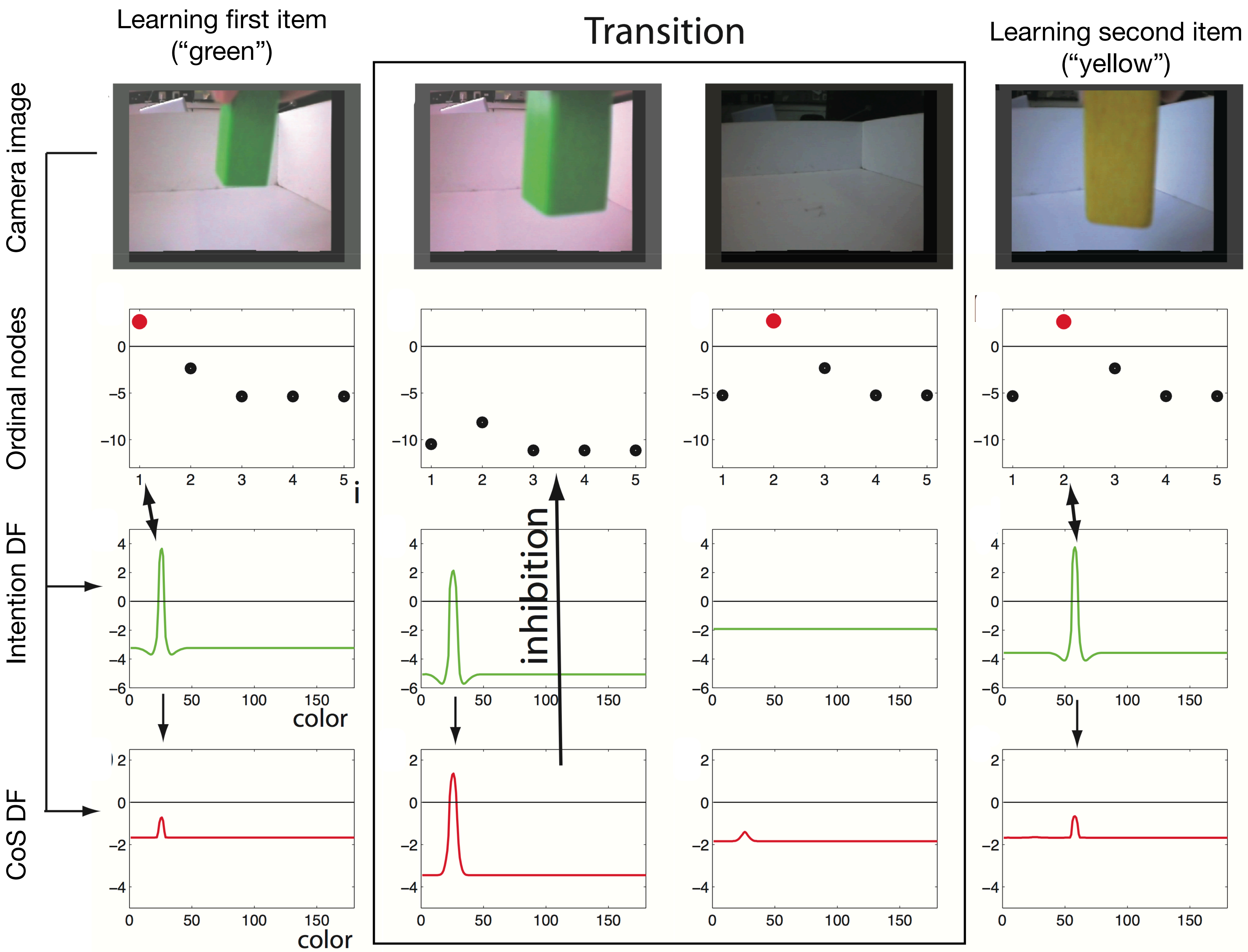
[Sandamirskaya, Schöner: Neural Networks 23:1163 (2010)]

mechanism for transition



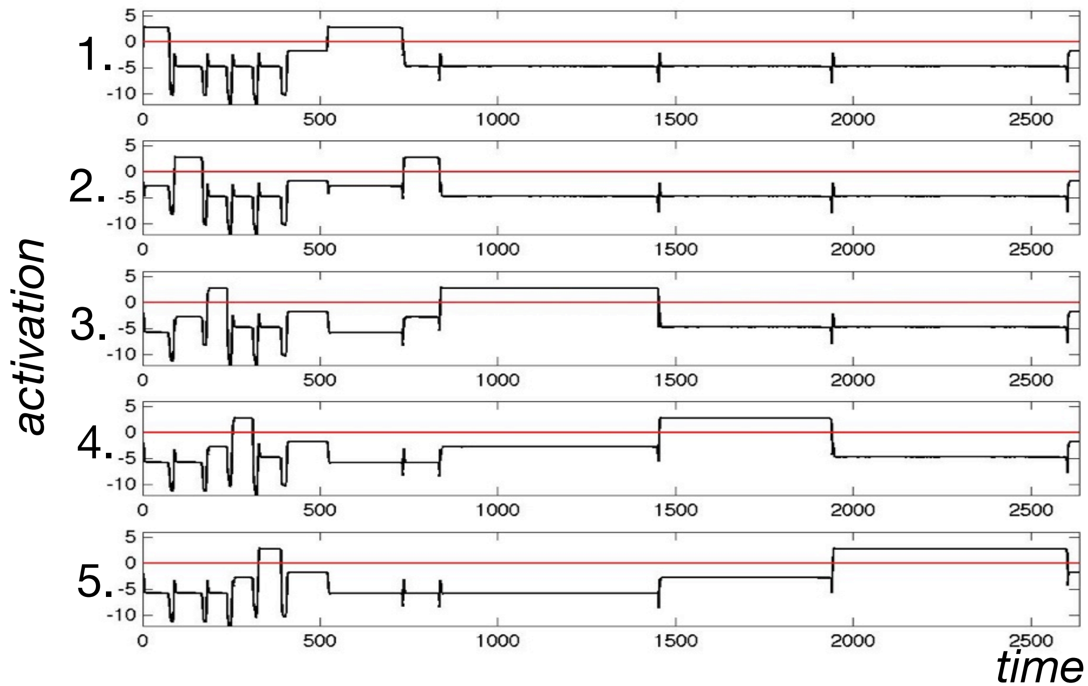


transition
Ordinal nodes
activation
0
-5
-10
37
38
39
40
Intention DF
dimension, color
180
0
37
CoS DF
dimension, color
180
0
37
CoS perceived
time, s

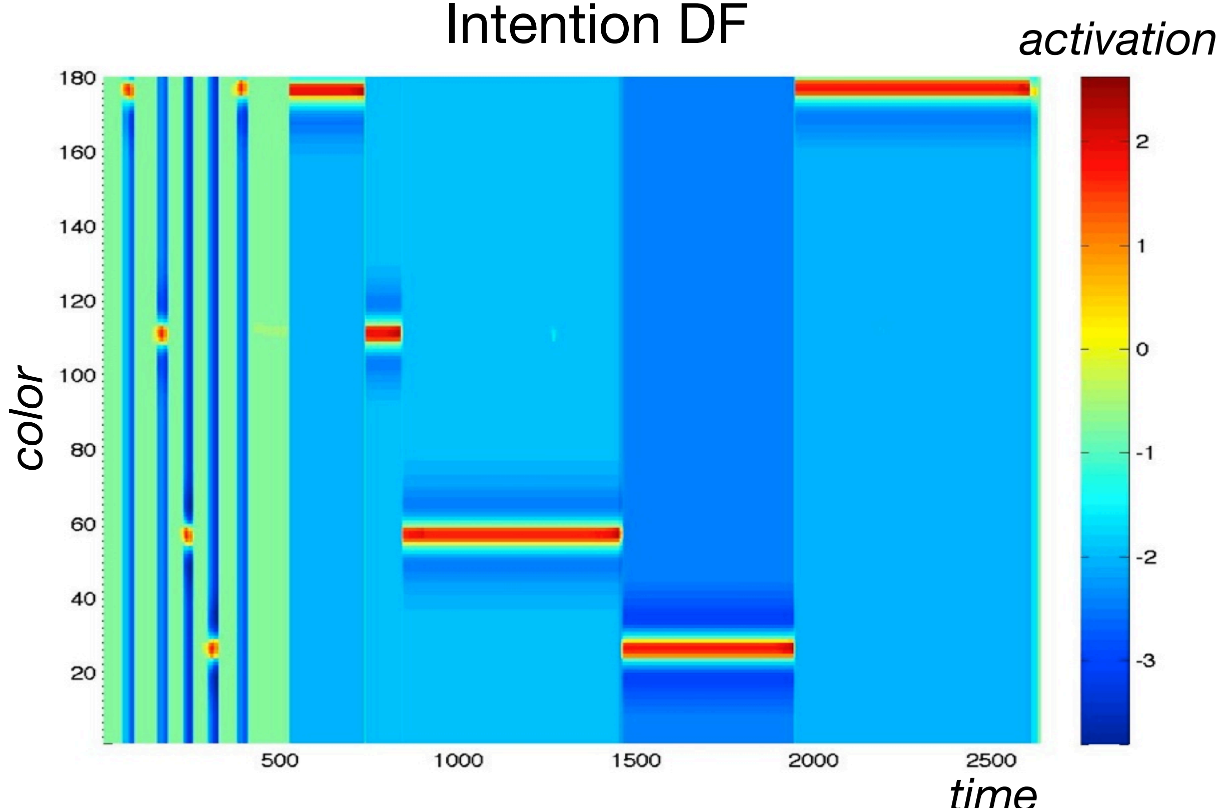


Learning first item
("green")
Transition
Learning second item
("yellow")
Camera image
Ordinal nodes
Intention DF
CoS DF
i
color
color
inhibition

Ordinal nodes

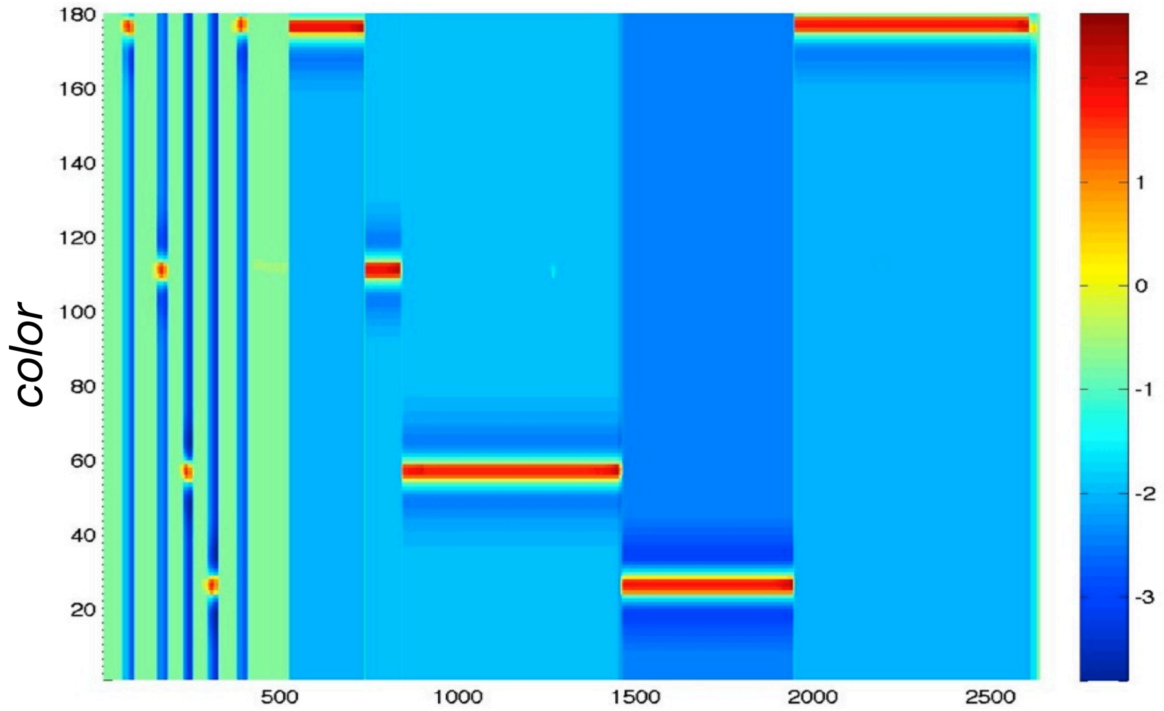


Intention DF

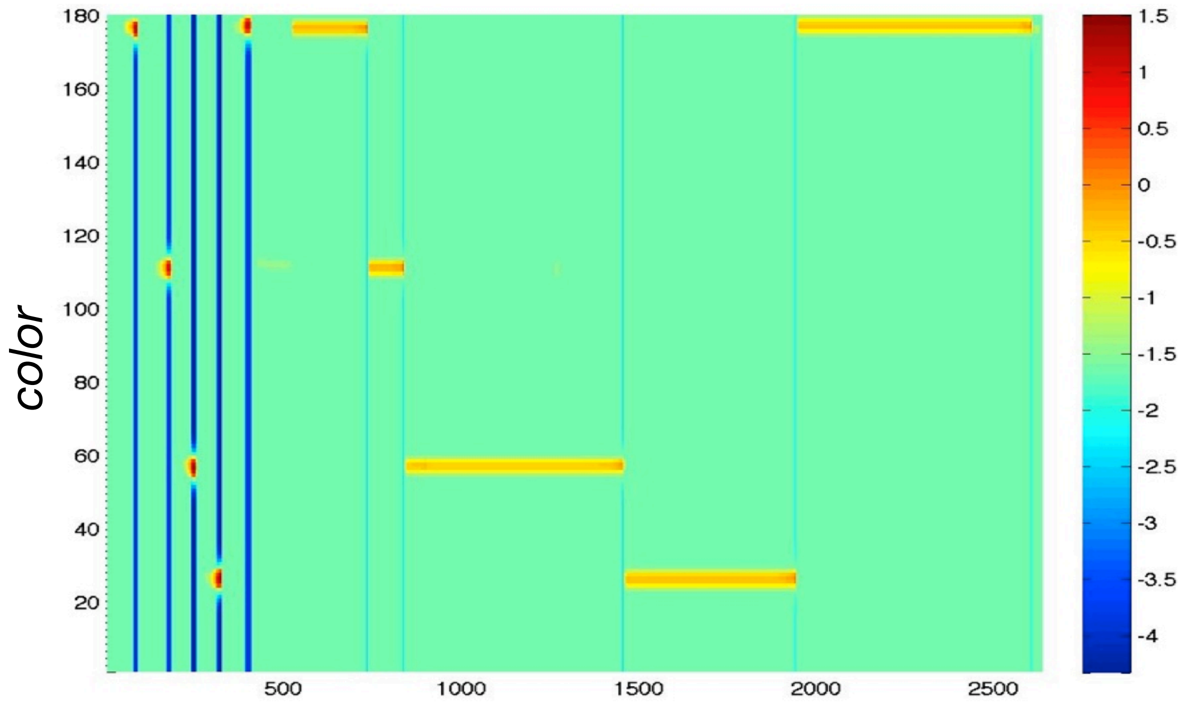


time

Intention DF

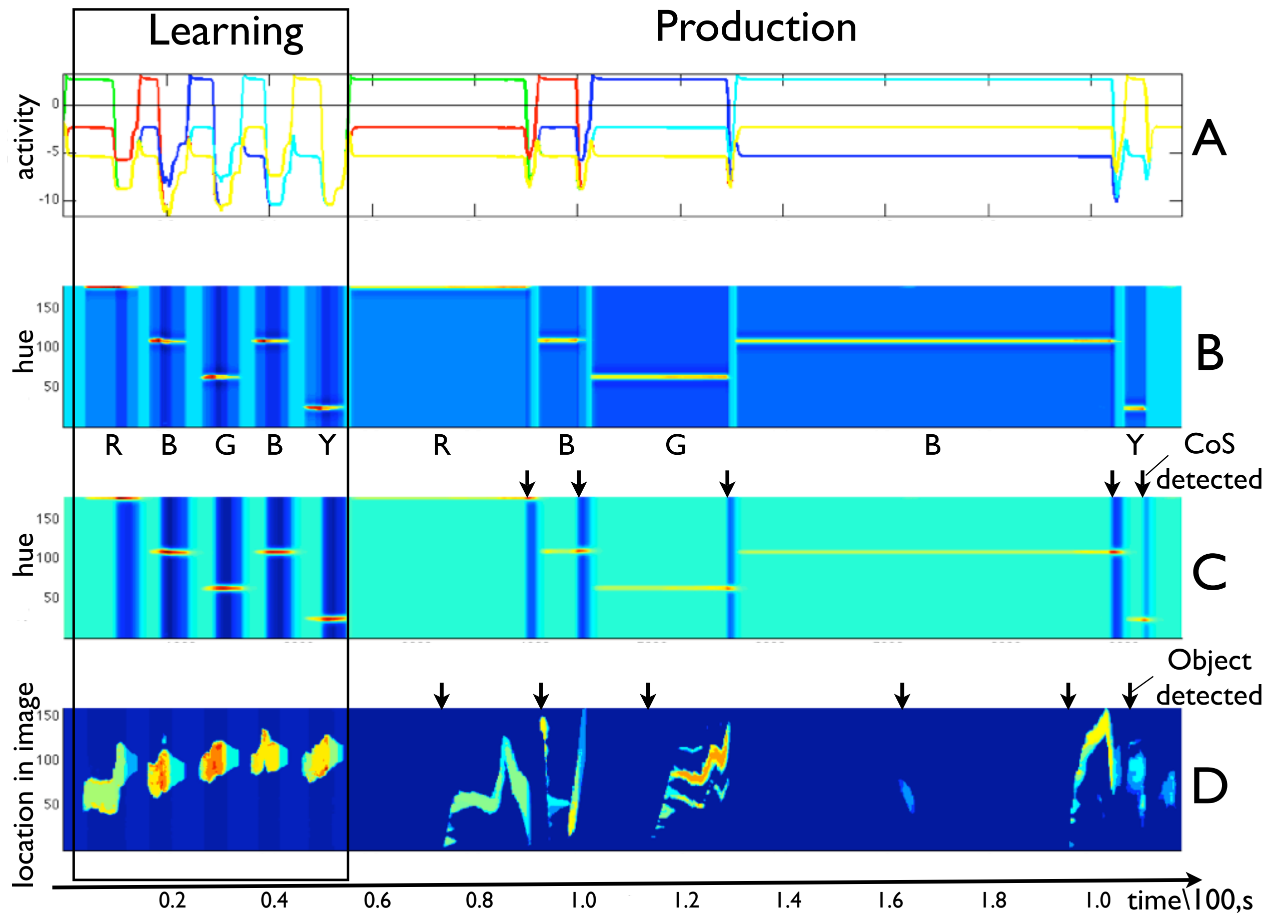


CoS DF



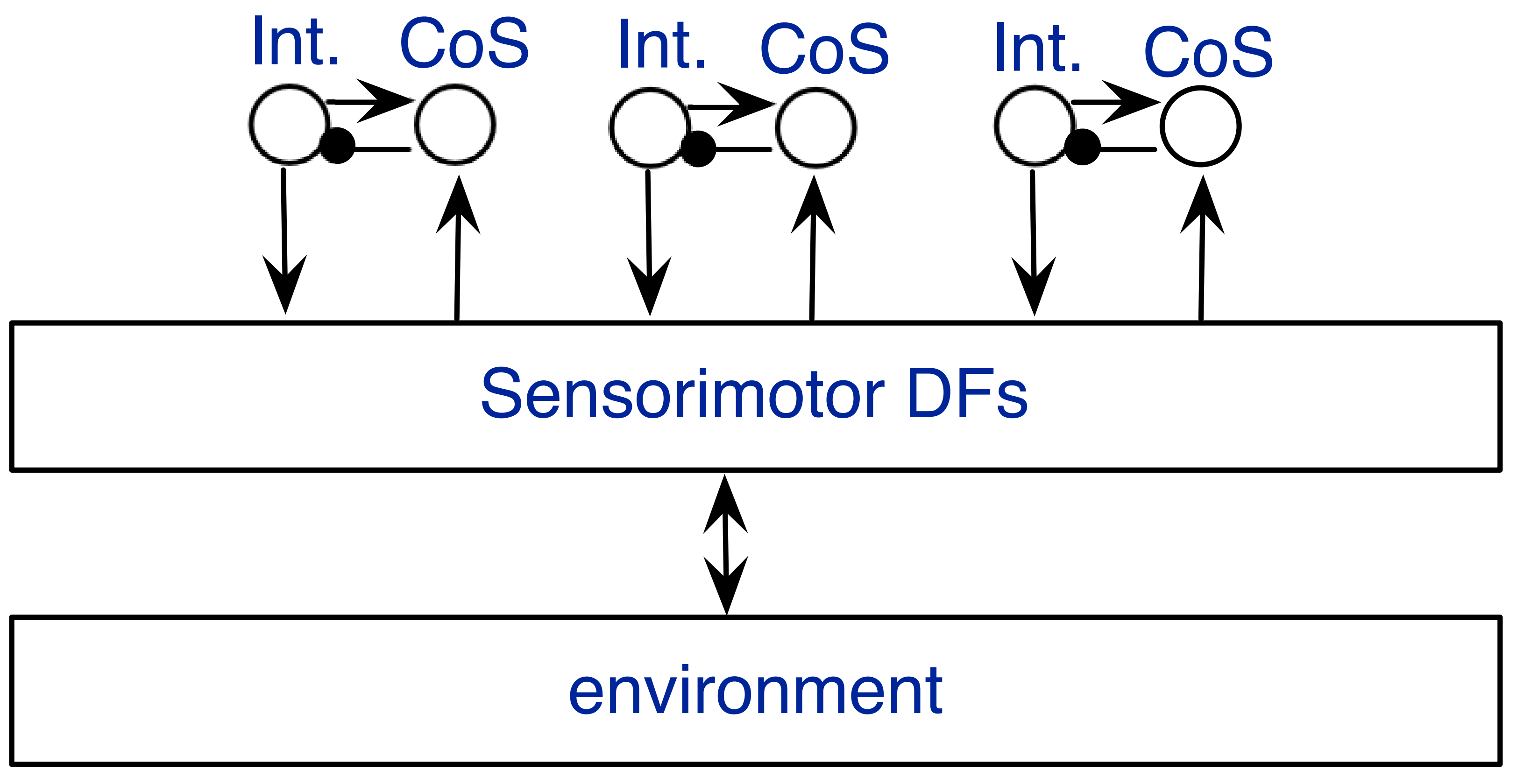
Autonomous sequence generation

- discrete events in time are autonomously generated
- when the world matches the intention: condition of satisfaction

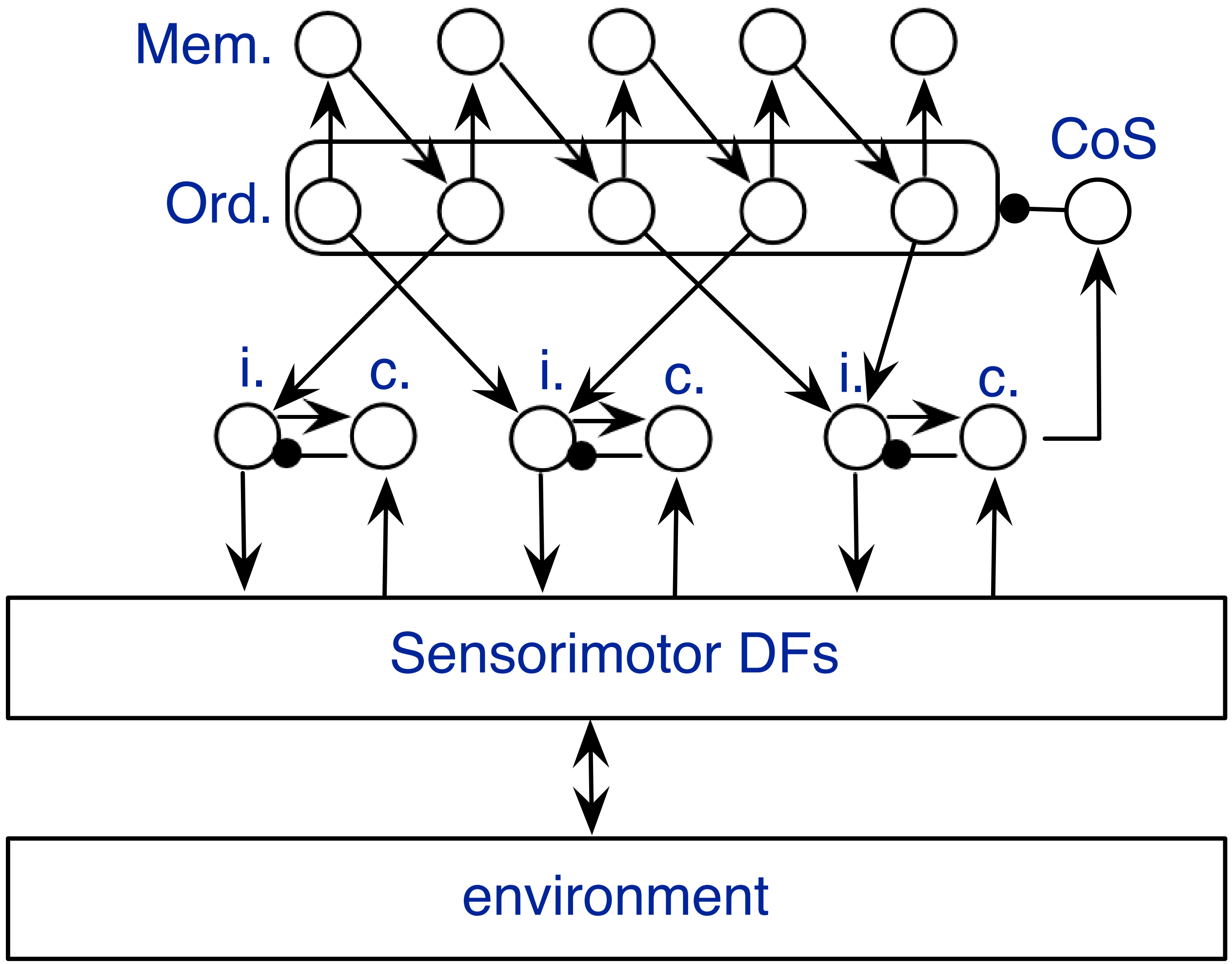


[Sandamirskaya, Schöner: Neural Networks 23:1163 (2010)]

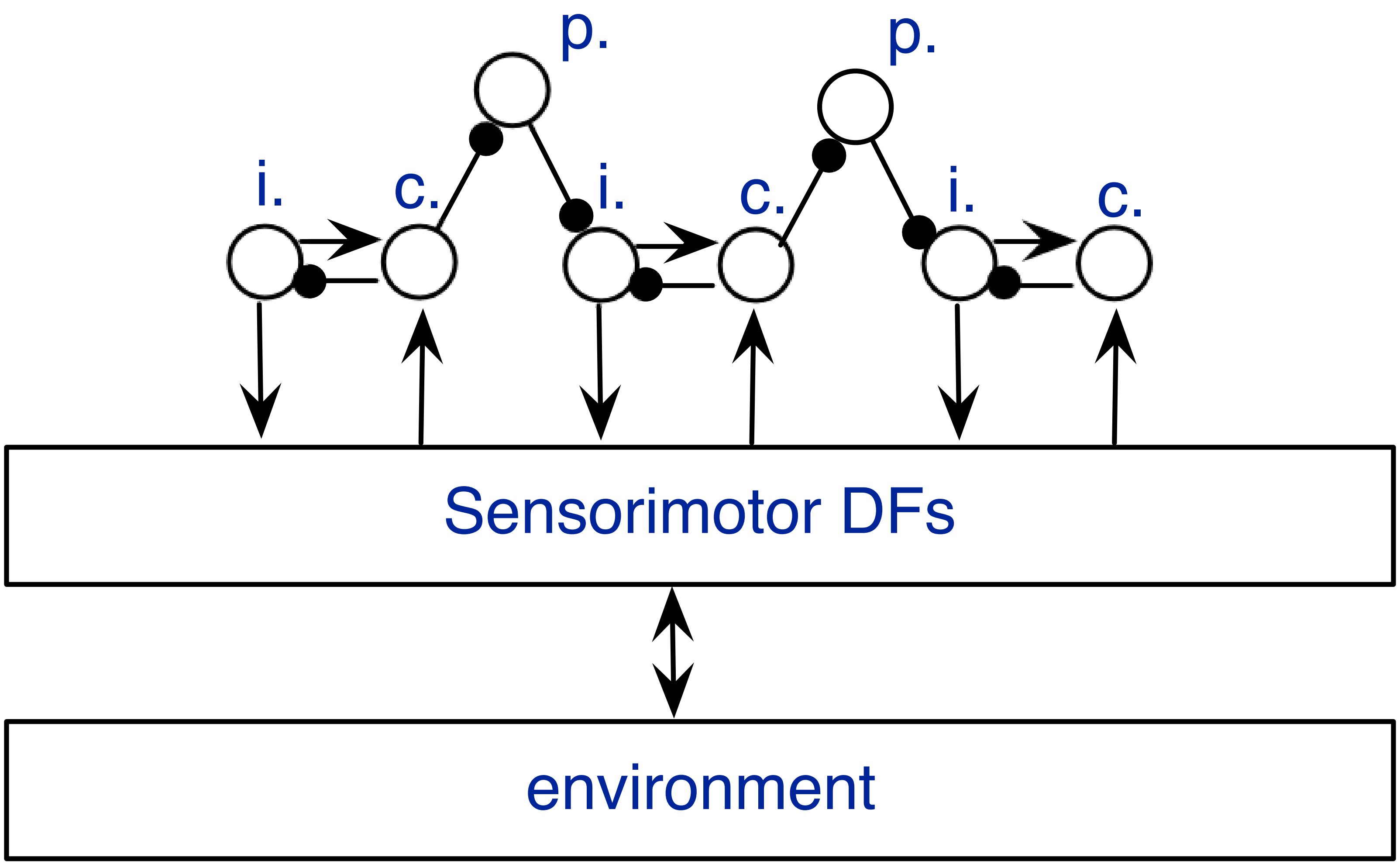
Generalization

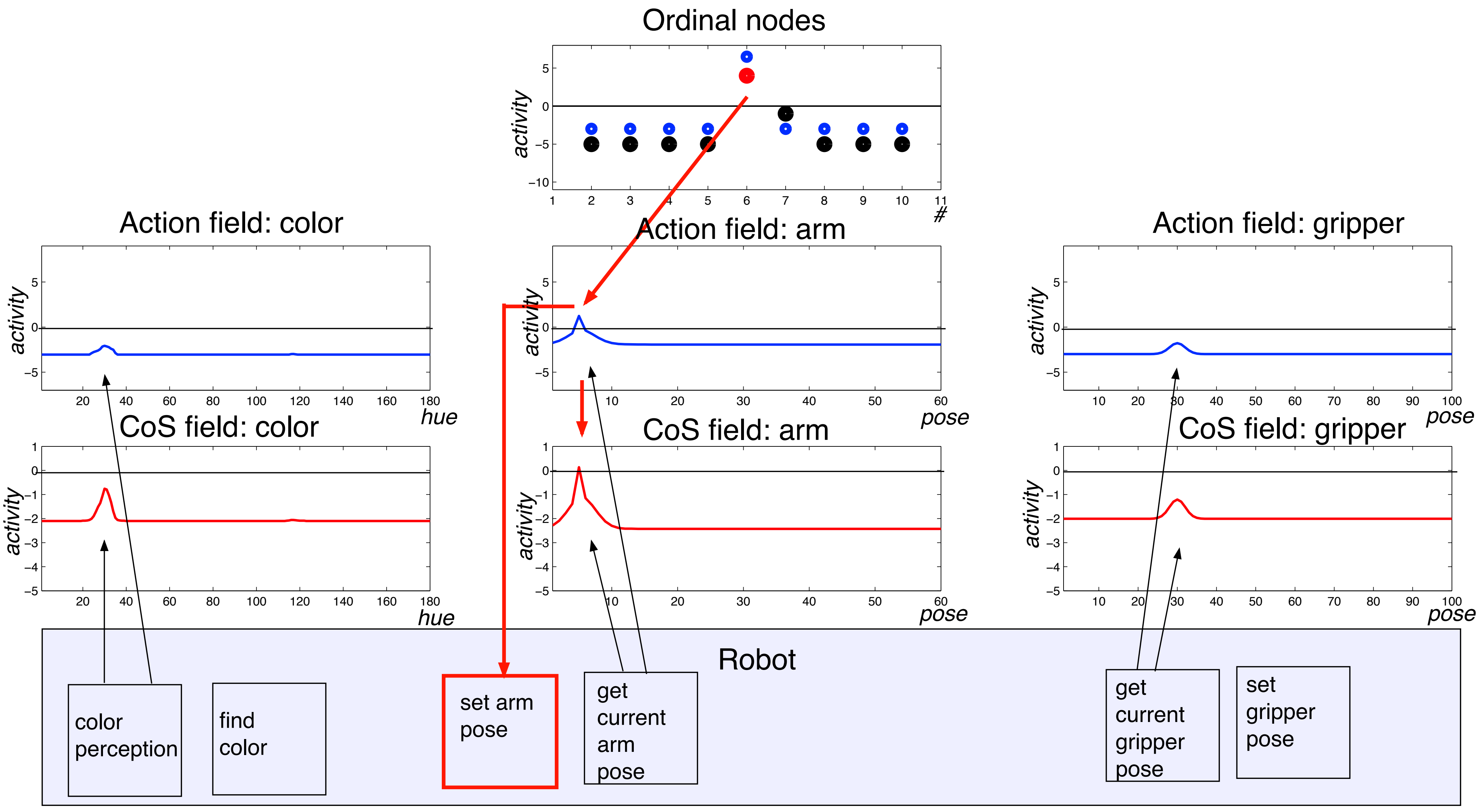


Int.
CoS
Int.
CoS
Int.
CoS
Sensorimotor DFs
environment

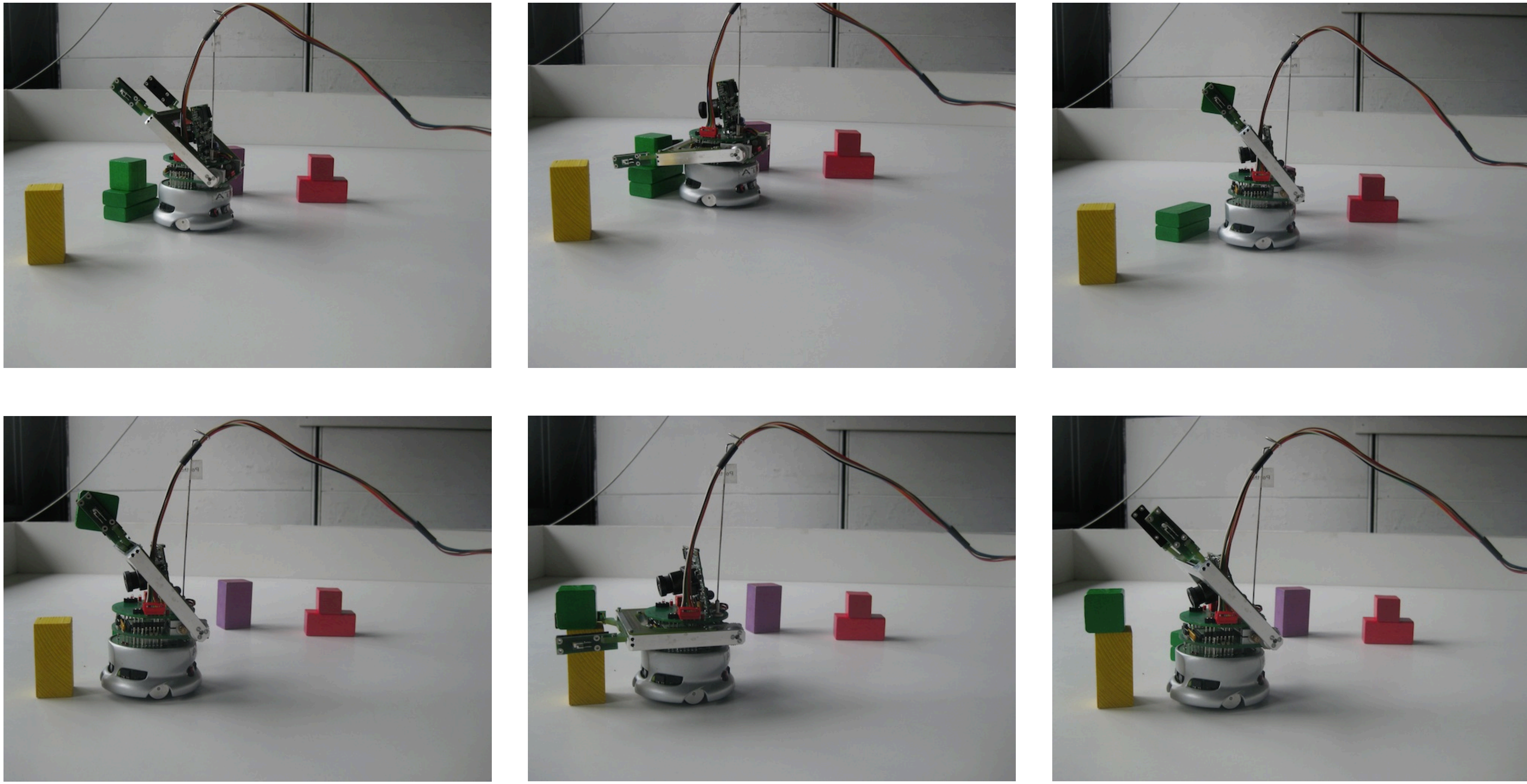

Mem.
Ord.
CoS
i.
c.
i.
c.
i.
c.
Sensorimotor DFs
environment

chaining



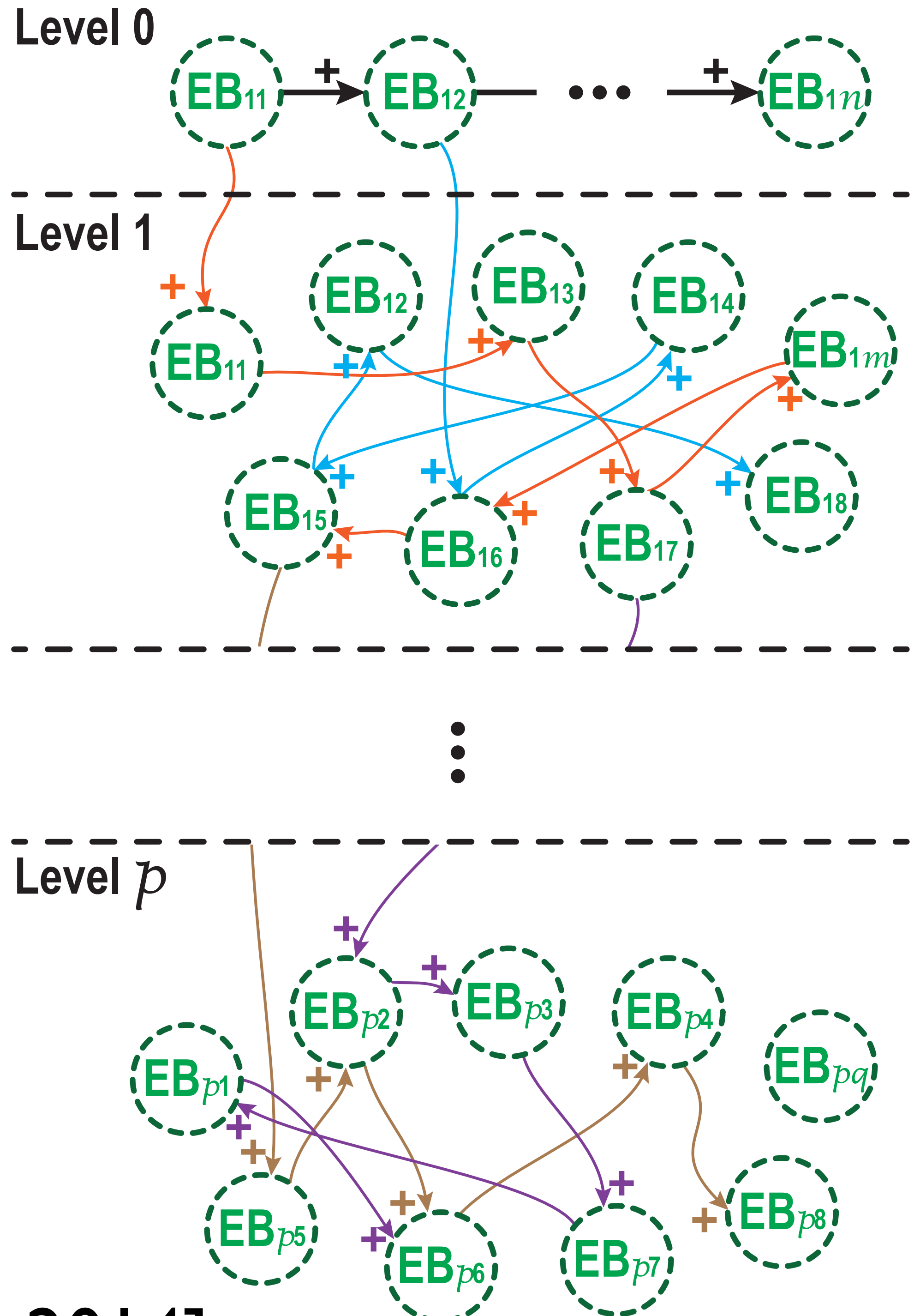


[Sandamirskaya, 2011]



[Sandamirskaya, 2011]

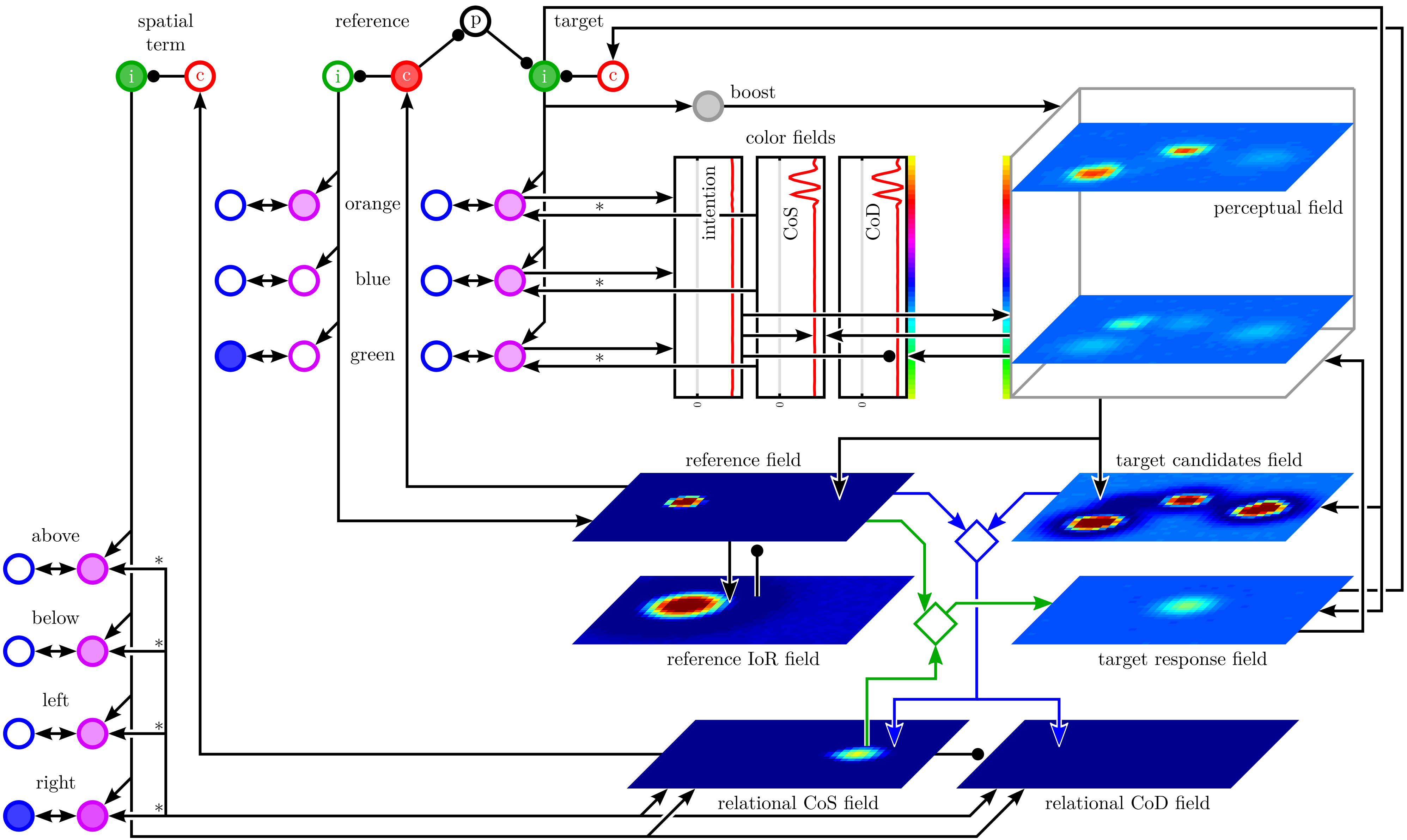
hierarchy



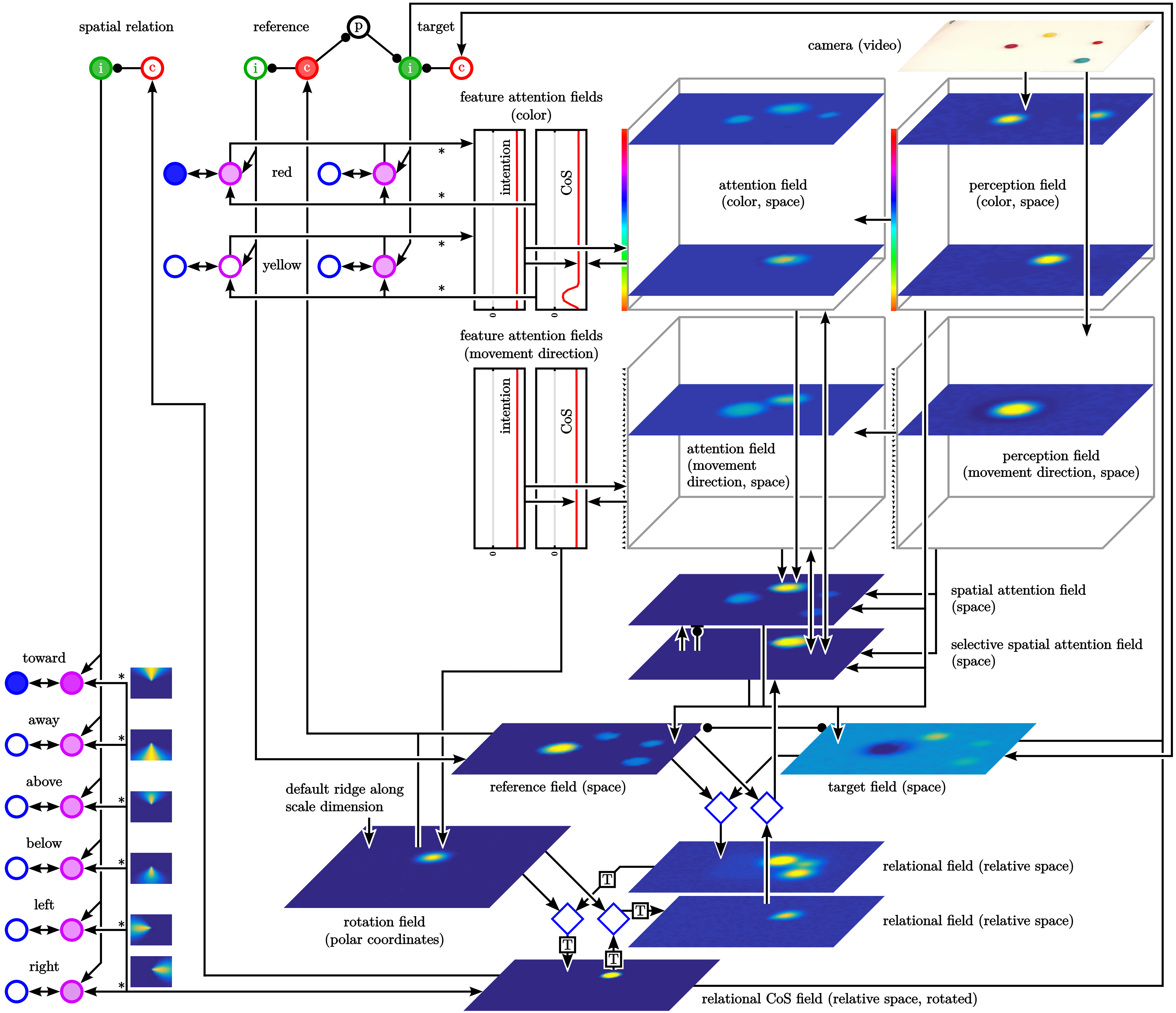
[Duran, Sandamirskaya, 2014]

Neural Dynamic Architectures

- that we reviewed earlier… all use the CoS mechanism



[Richter, Lins et al. ICANN 2014]



[Richter, Lins, Schöner, ToPiC (2017)]

Conclusions

- I reviewed the mechanism of transitions between stable (intentional) state by the condition of satisfaction and its underlying dynamical mechanism of active transient generation
- This is a critical element that enables DFT to account for complex sequential behaviors and autonomous cognitive processes
- This key mechanism sets apart DFT architectures from almost all other neural processing accounts