DNF Models of Spatial Language Behaviors

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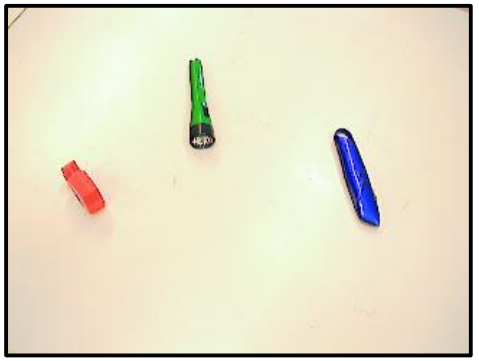
DNF Approach to Cognitive Behaviors

- cognition emerging from sensori-motor processes
- simulation for reasoning
- uses metric representations over perceptual spaces (compare e.g. Barsalou 1999, 2008)

contrast to symbolic processing:

- separate processes and representations for perception and cognition
- cognition based on amodal symbol systems

Relational spatial language



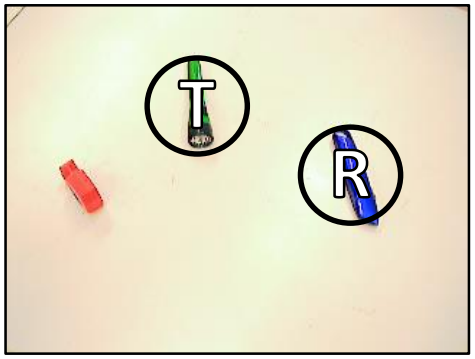
„Where is the green flashlight relative to the blue box cutter?“

Why are we interested in spatial language?

- provides a natural means to communicate about objects and locations
  - ⇨ relevant for interactive robotic scenarios
- forms a junction point between metric spatial representations and symbolic verbal descriptions
  - ⇨ relevant for understanding spatial cognition

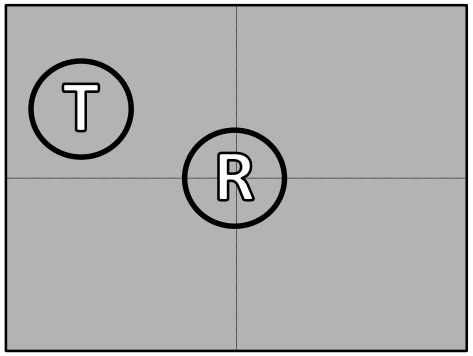
Relational spatial language

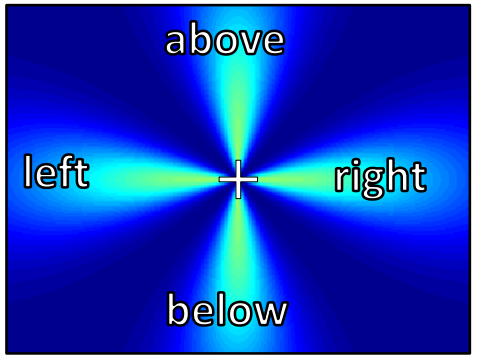
According to Logan & Sadler (1996):



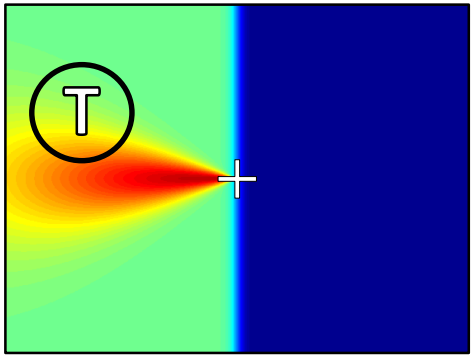
1. Spatial Indexing: Locate target and reference item

2. Reference frame alignment





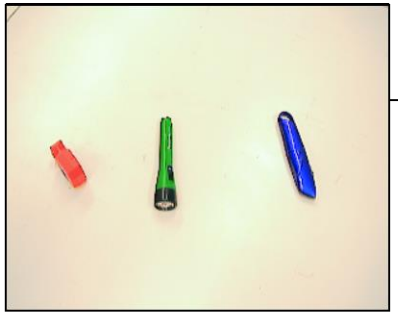
3. Mapping spatial relations onto reference frame



4. Assessment of fit and response selection

„To the left!“

DNF model of spatial language behaviors



„red“ „green“ „blue“ color term nodes

color-space fields

target field

reference field

transformation field

spatial term nodes

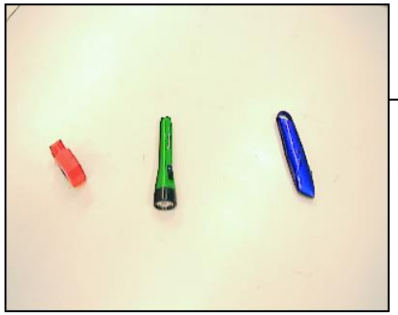
spt. relation nodes

„left“
„right“
„above“
„below“

object-centered field

[Lipinski, Schneegans, Sandamirskaya, Spencer, Schöner 2012]

DNF model of spatial language behaviors



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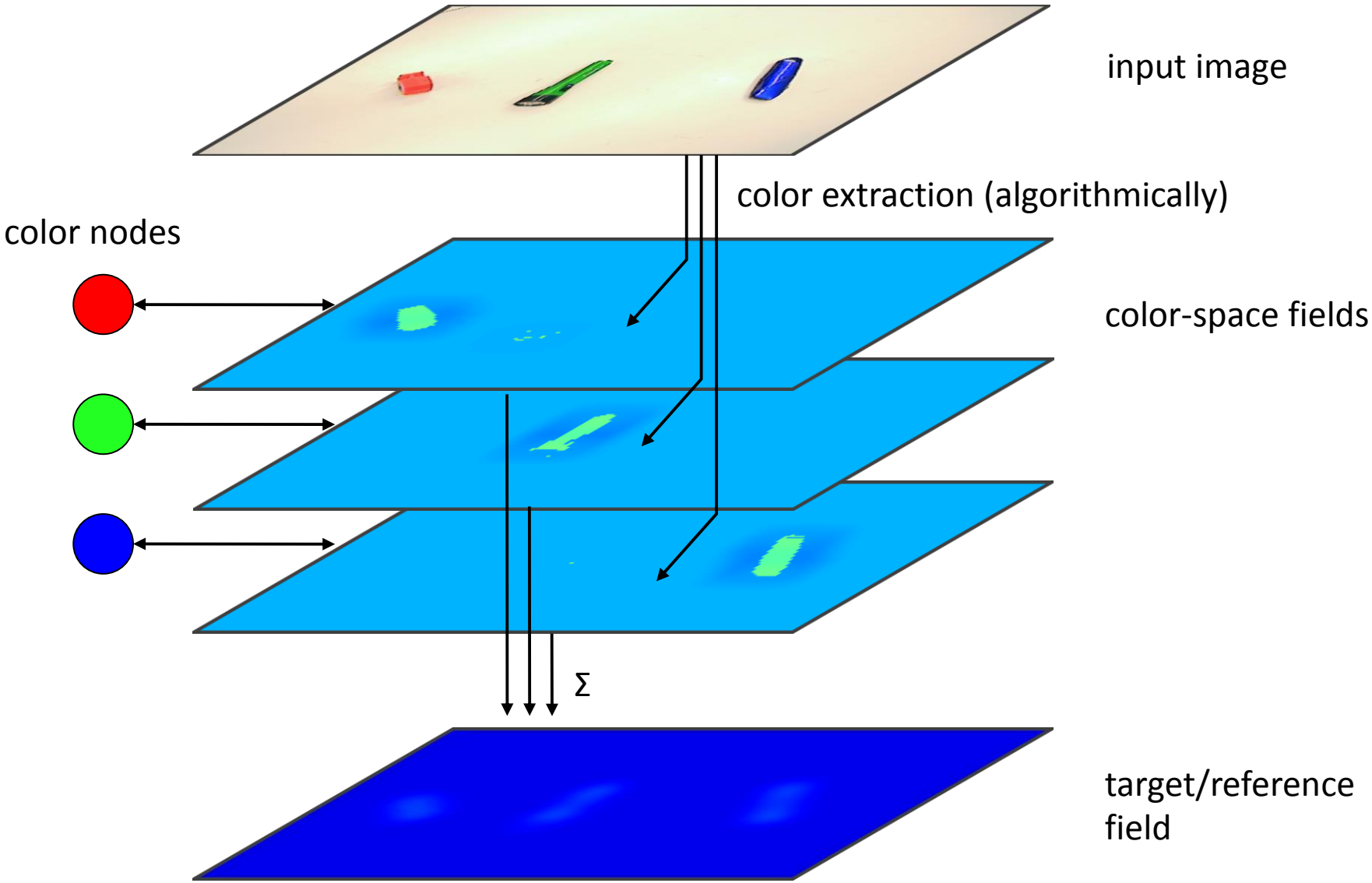
mapping to spatial terms

coordinate transformation

Color-space associations



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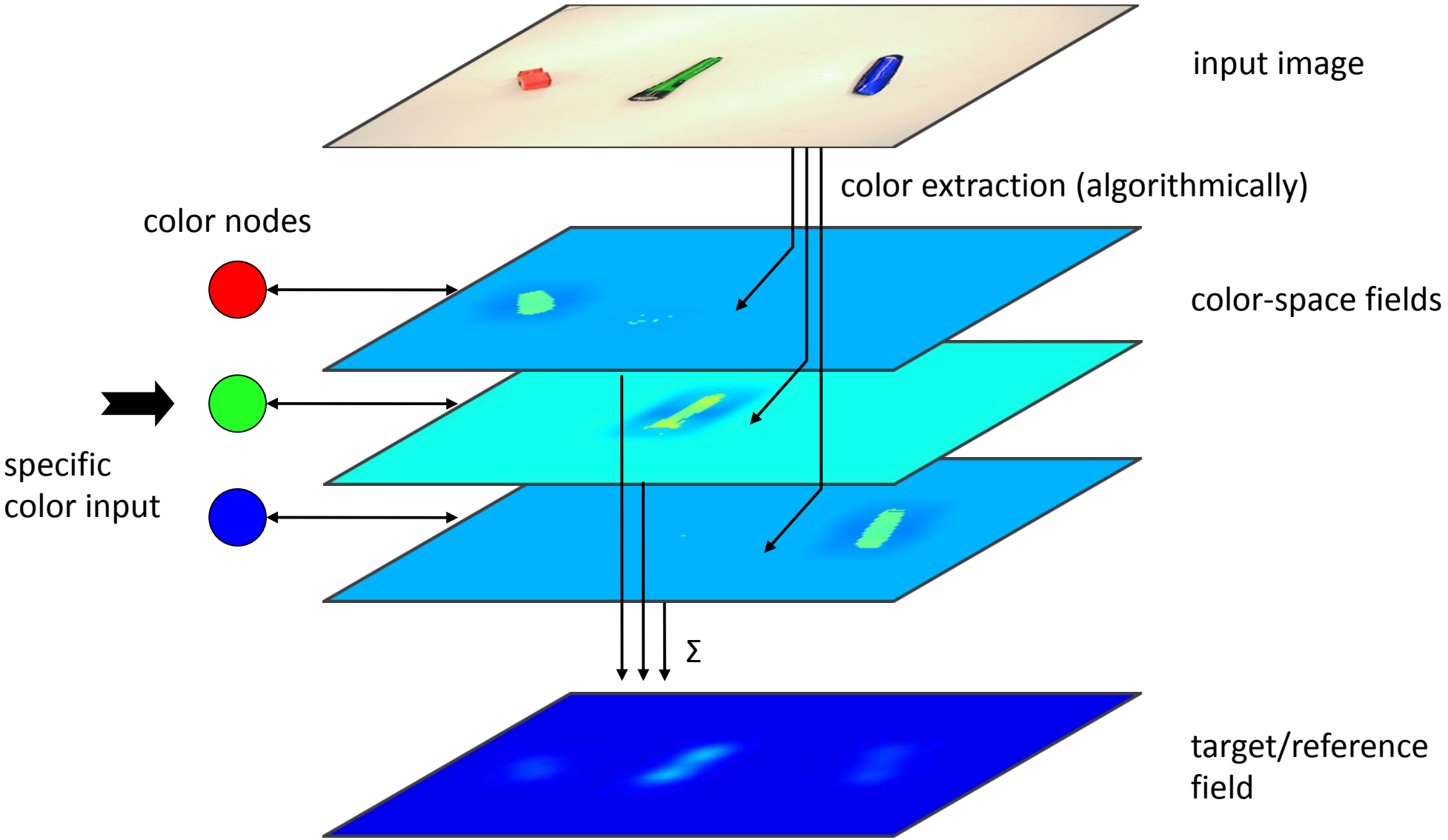

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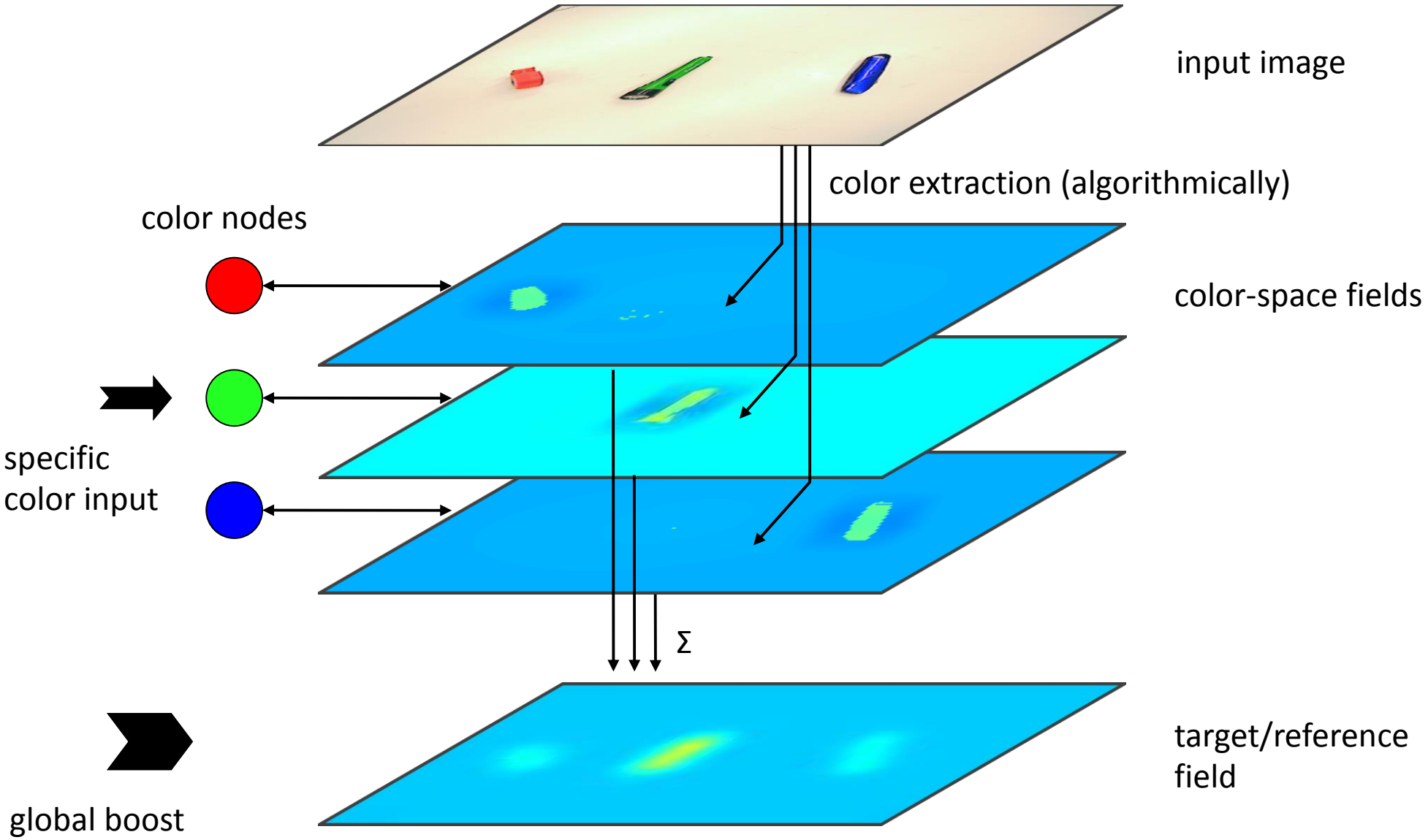

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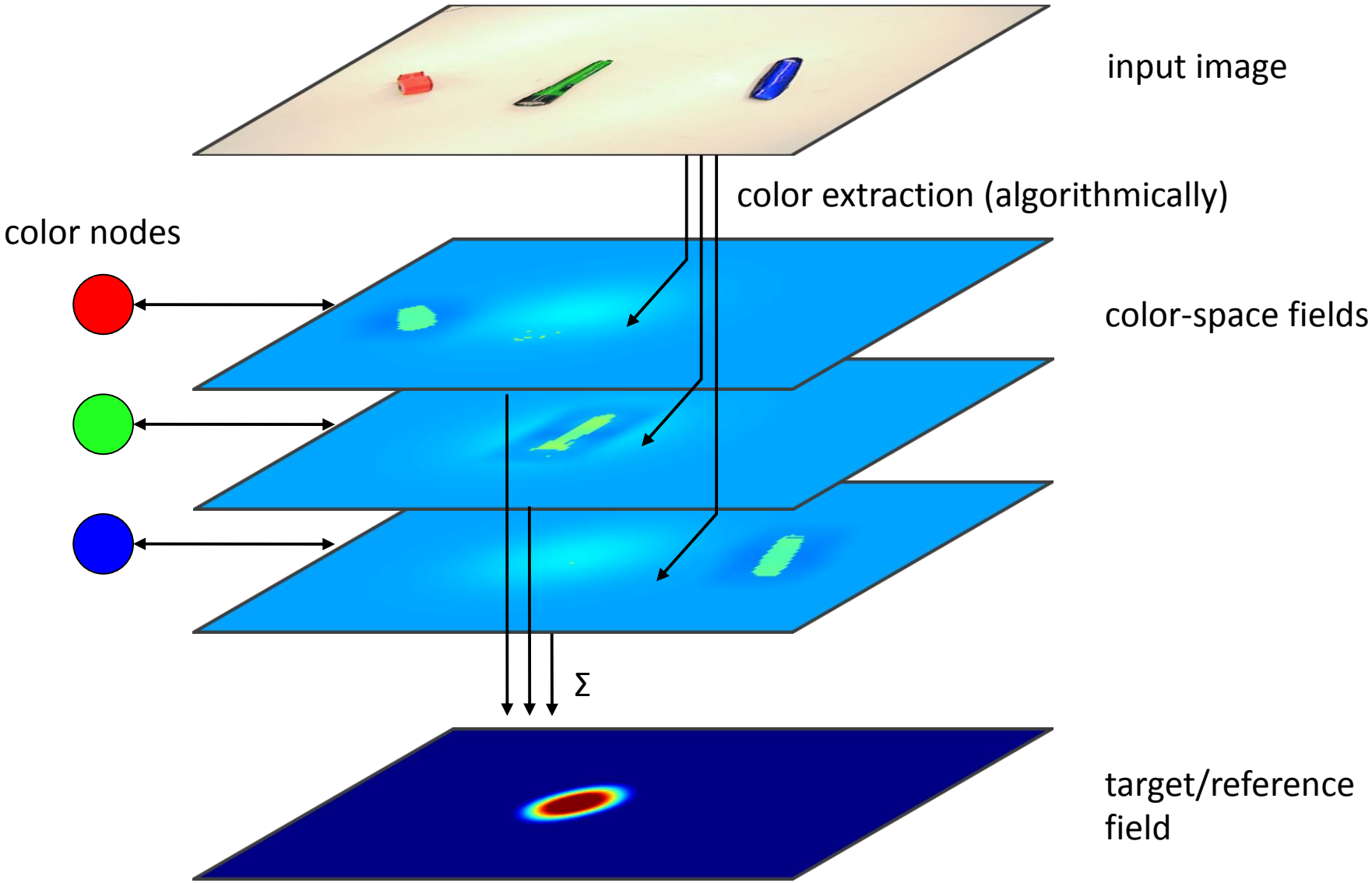
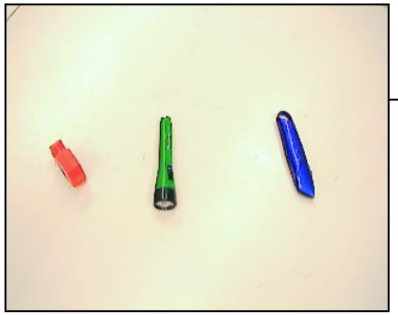


DNF model of spatial language behaviors



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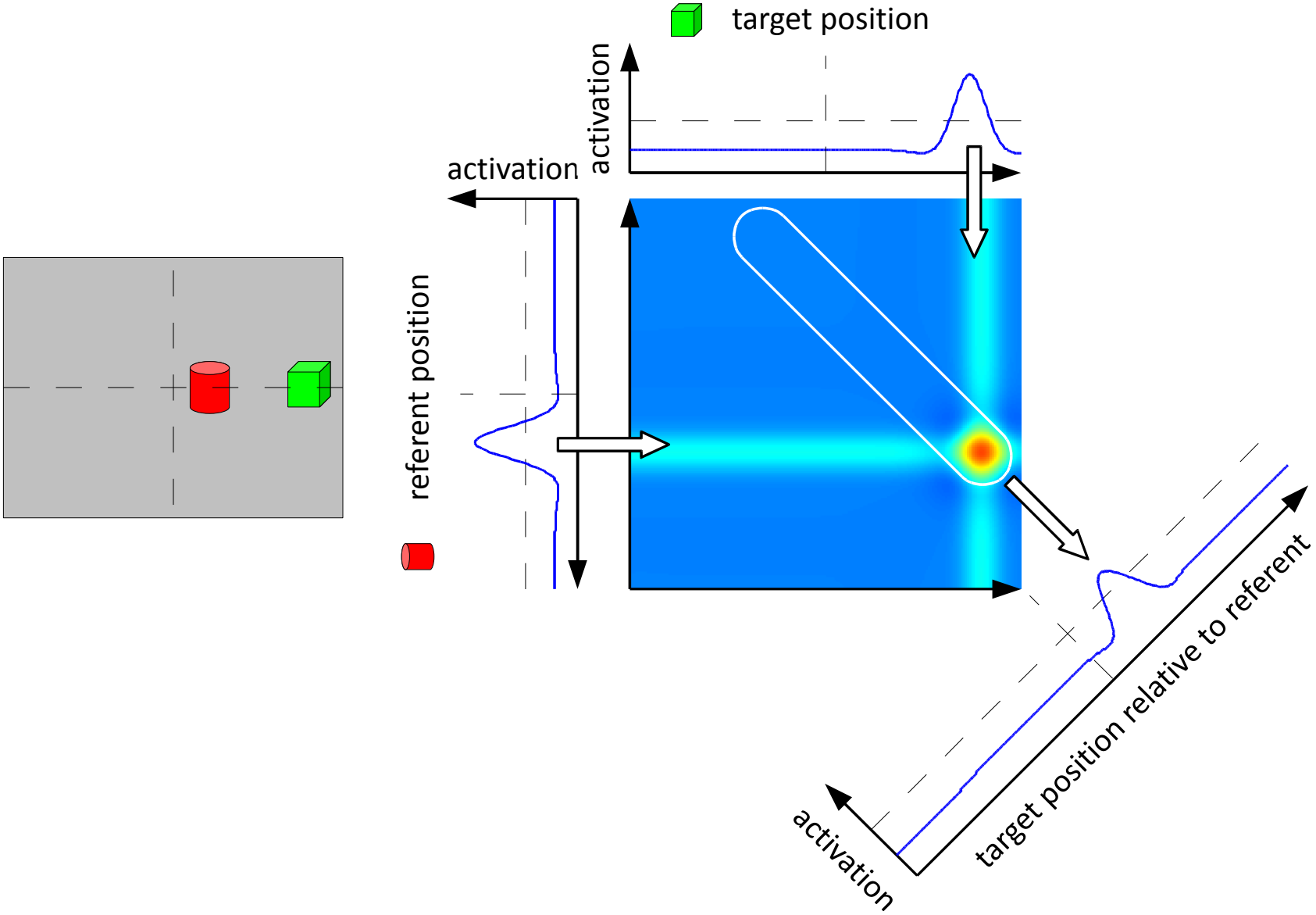
Spatial Transformation for Spatial Language (1D)



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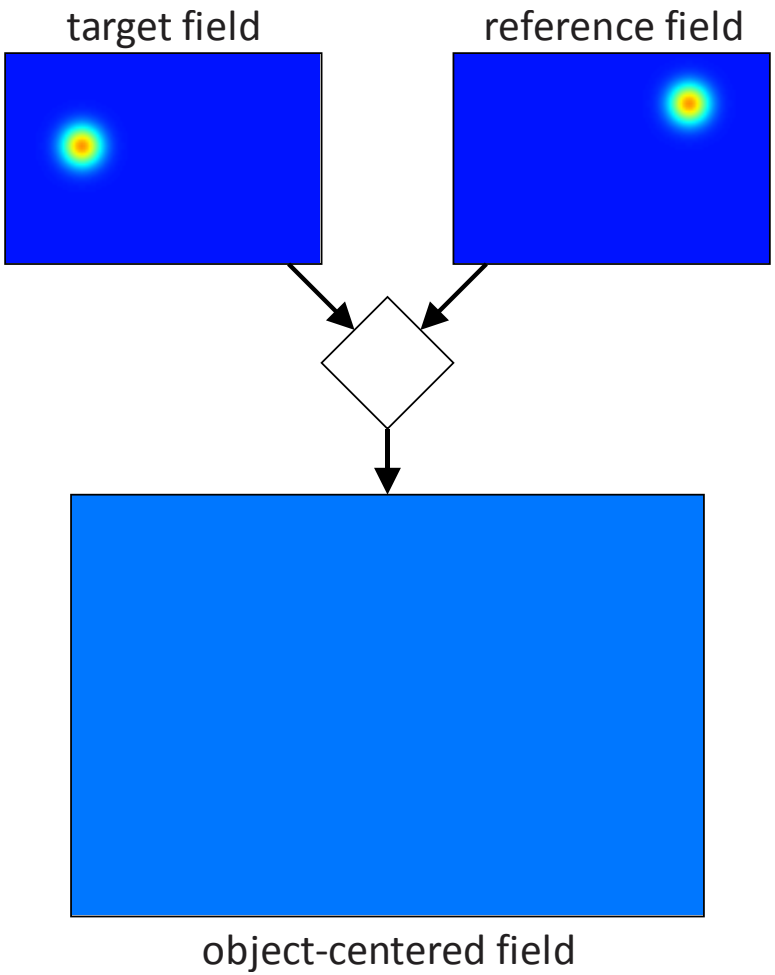

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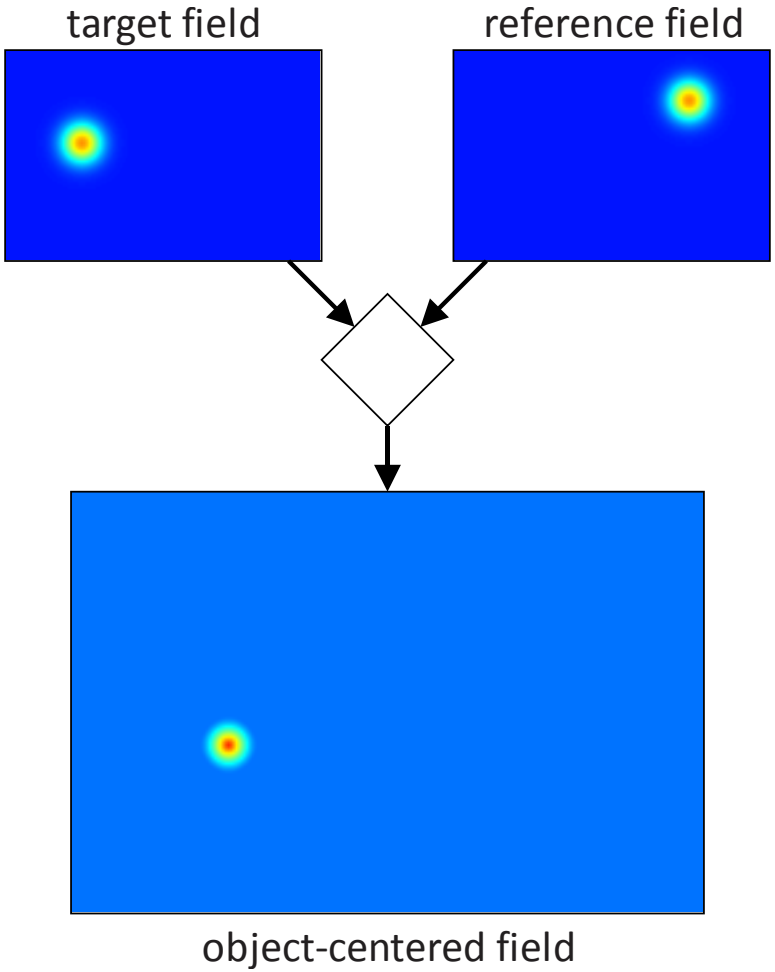

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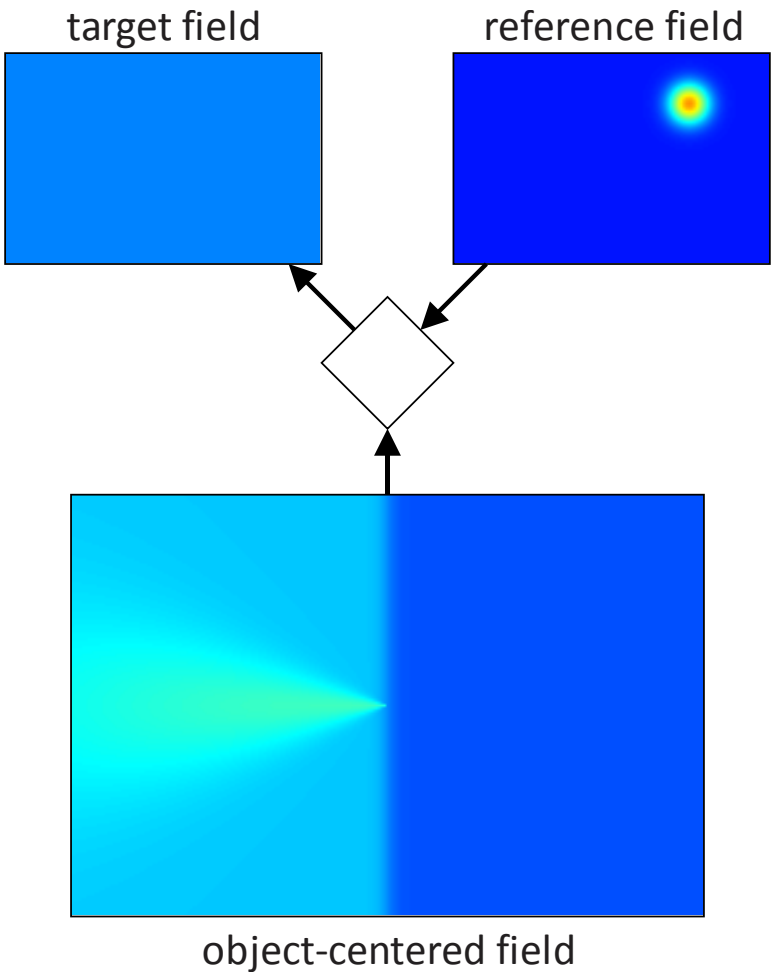

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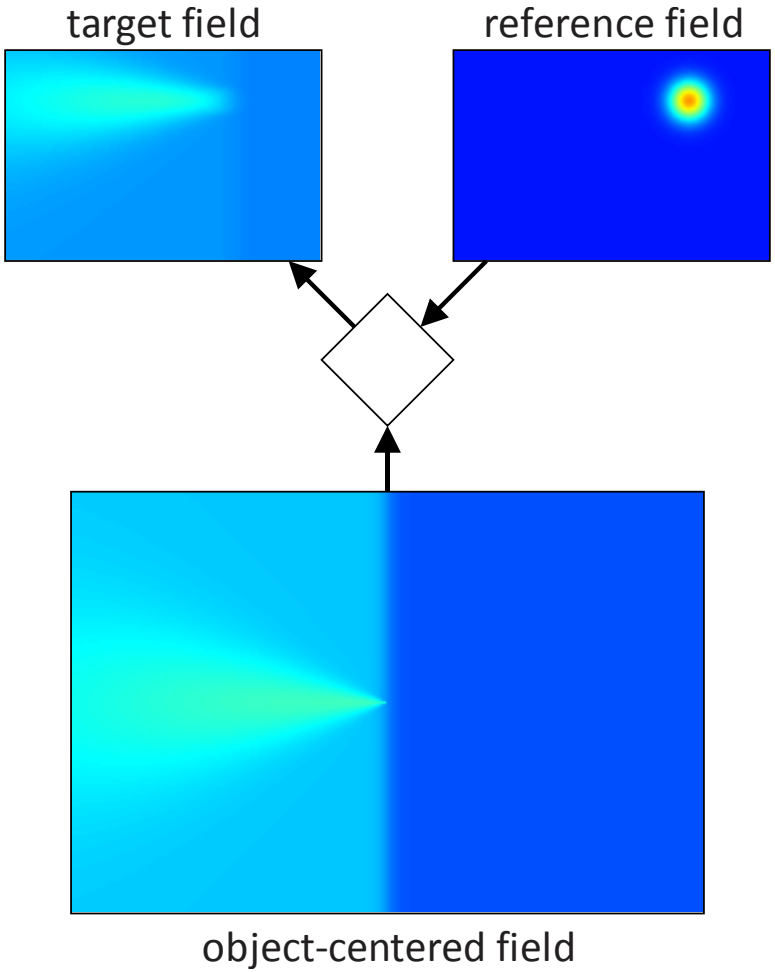

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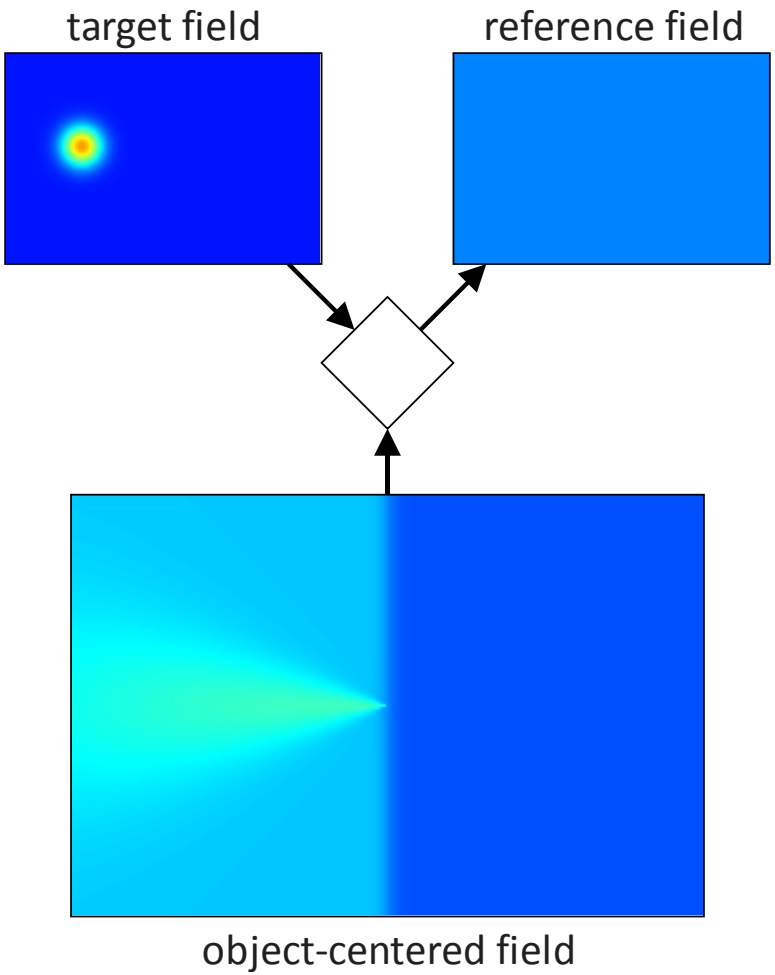

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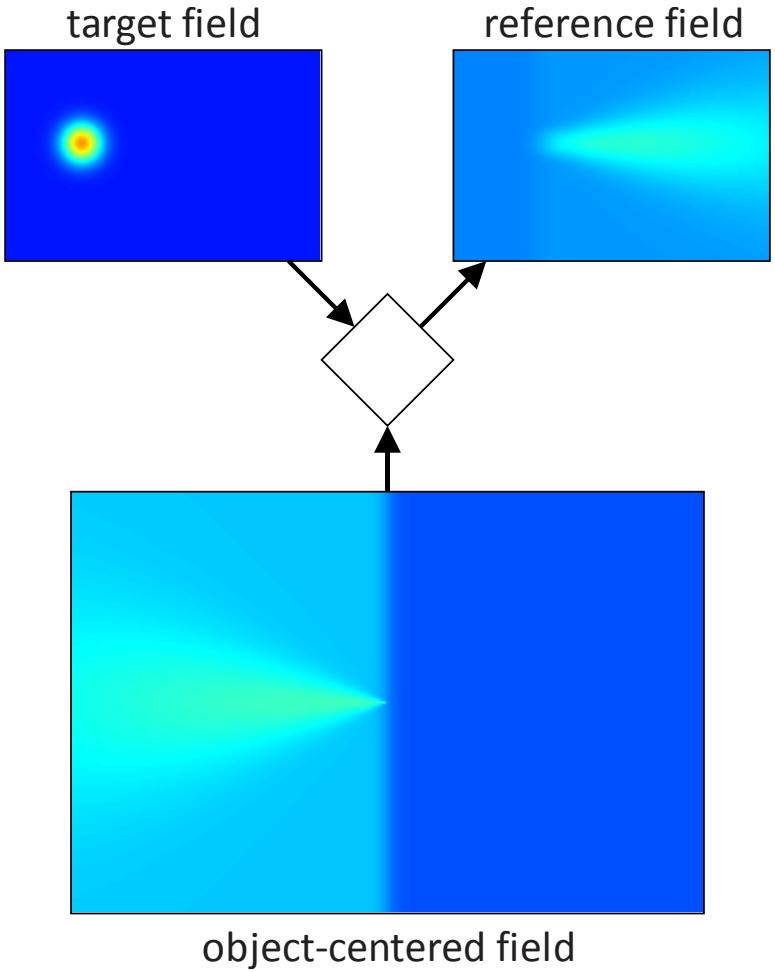
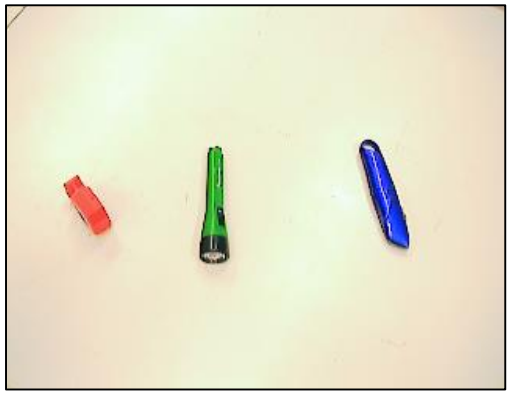


Model Demonstrations

Q: Where is the green flashlight relative to the red tape dispenser?



A: To the right.

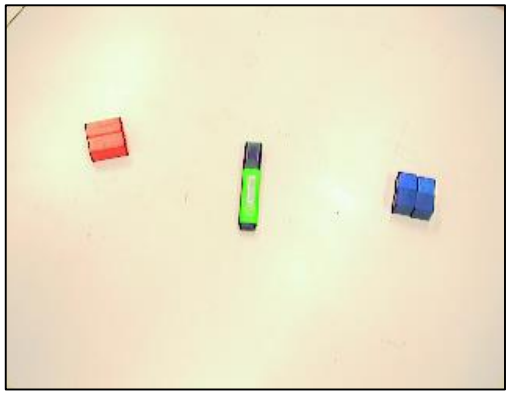
Demo 1

Q: What is above the blue deoderant stick?

A: The red box cutter.

Demo 2

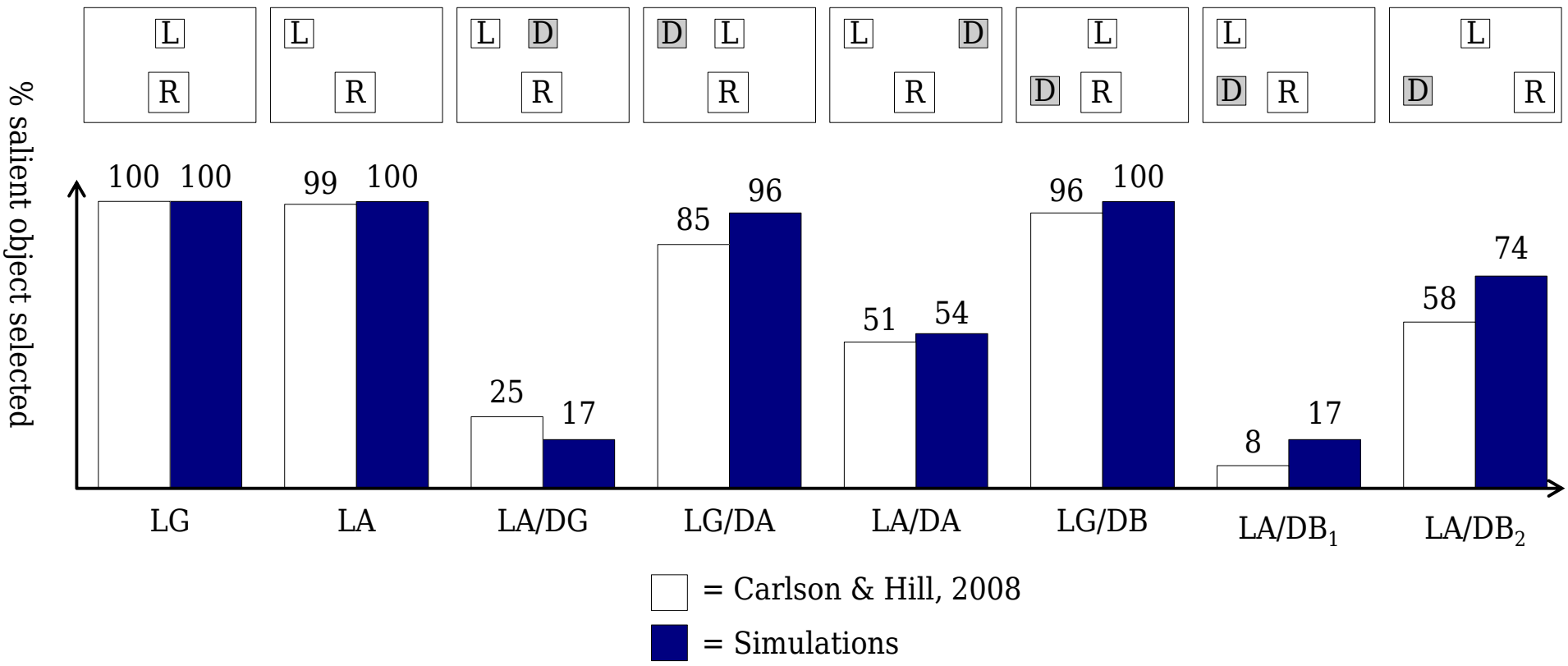
Q: Where is the green highlighter?



A: To the left of the blue stack of blocks OR to the right of the red stack of blocks.

Demo 3

Simulation Results



[Lipinski, Schneegans, Sandamirskaya, Spencer, Schöner 2012]

Strengths and Limitations of the Model

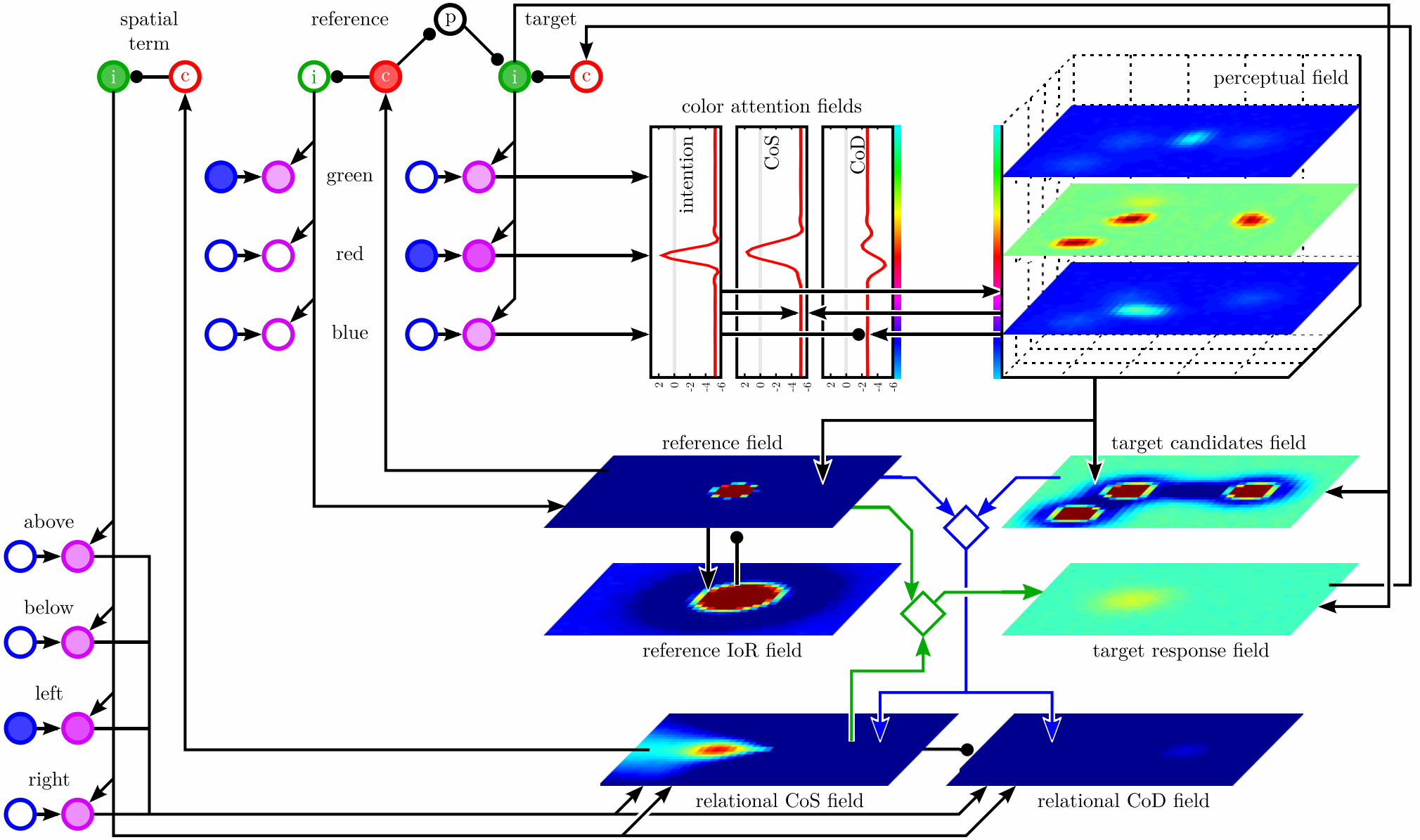
Strengths:

- general and flexible system
- neural process model (contrast e.g. to AVS)

Limitations:

- behavioral flexibility induced by fixed sequence of external inputs
- verbal representations largely outside of the model
- limited autonomy

Extended Architecture for Autonomous Behavior



[Richter, Lins, Schneegans, Sandamirskaya, Schöner 2014]

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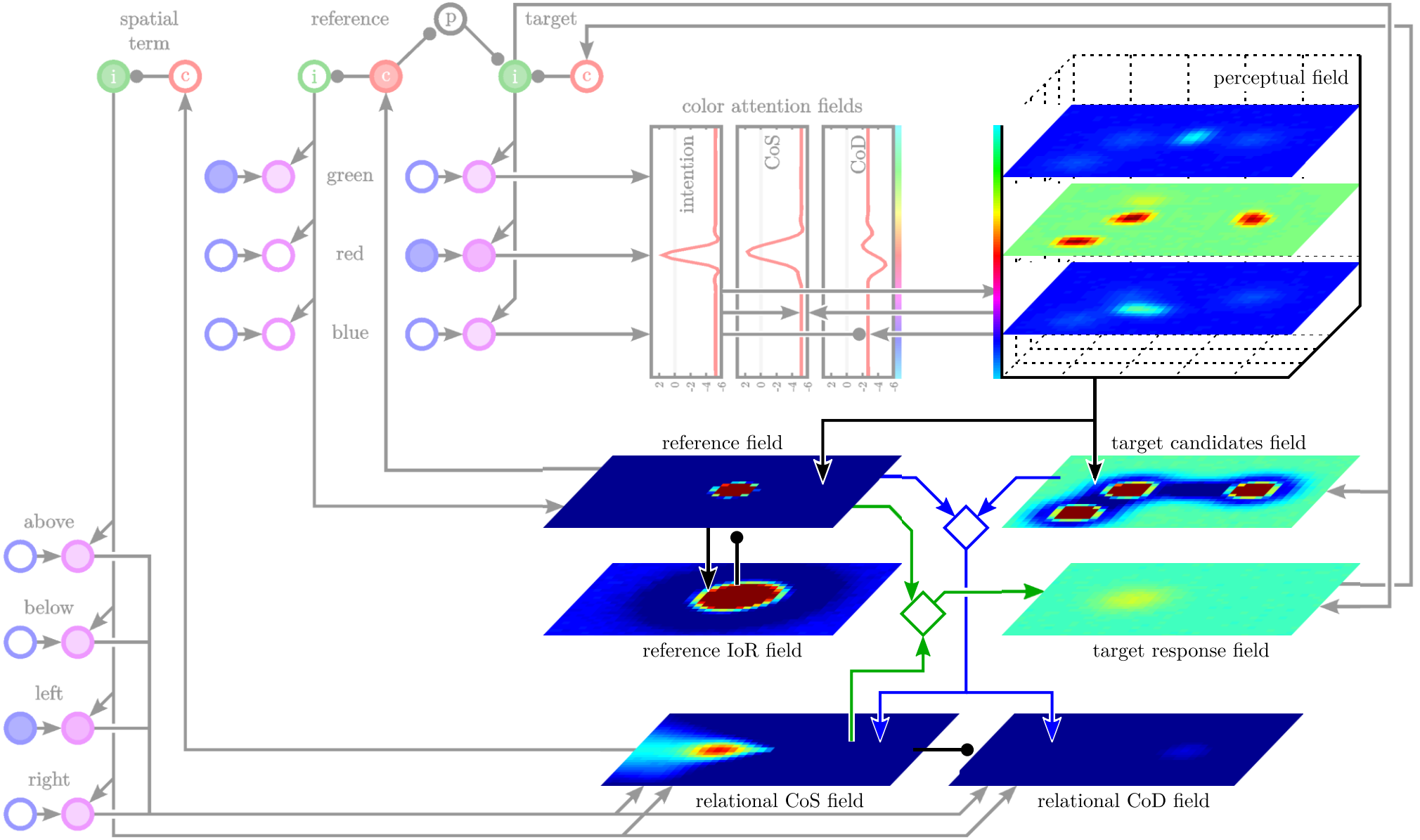

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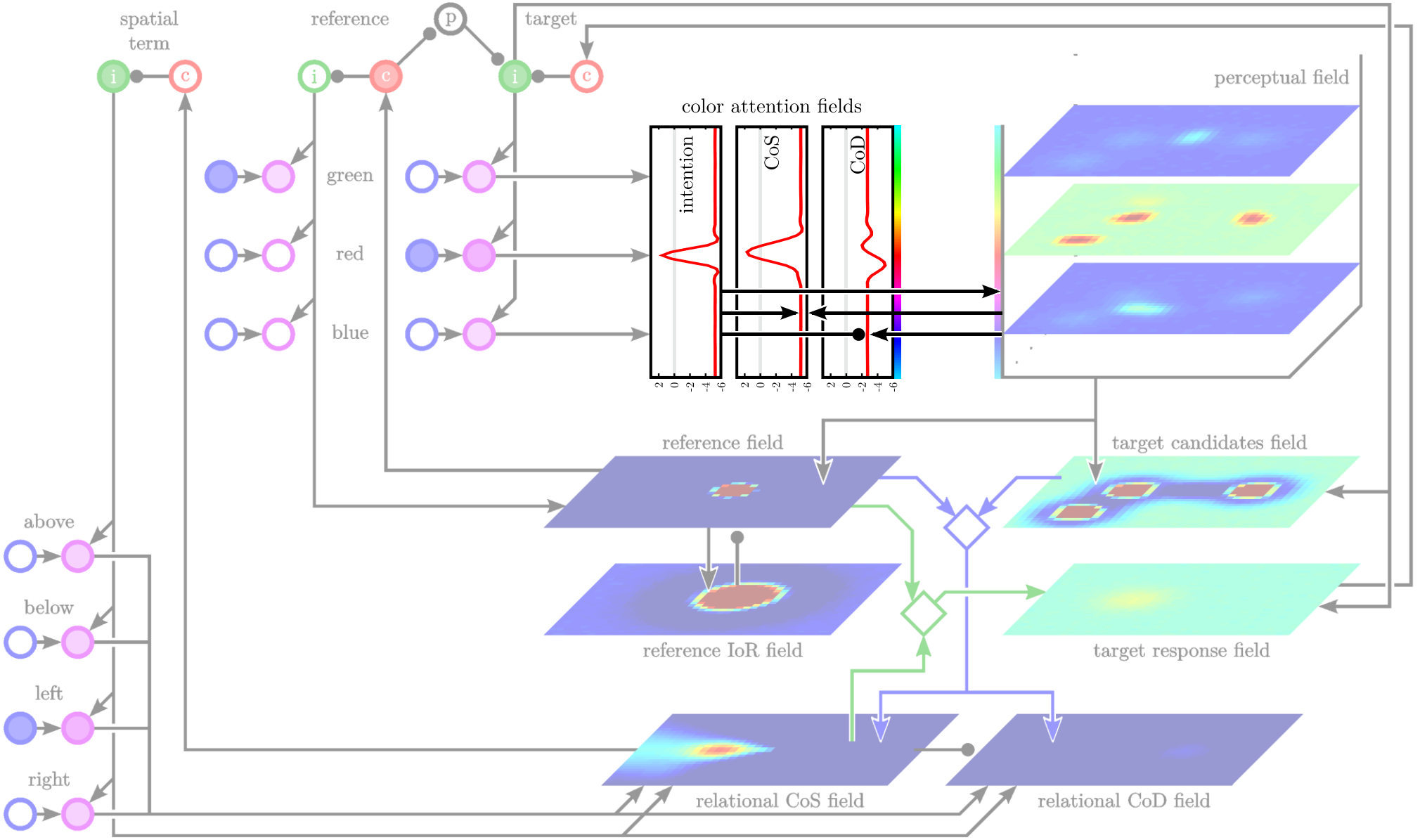
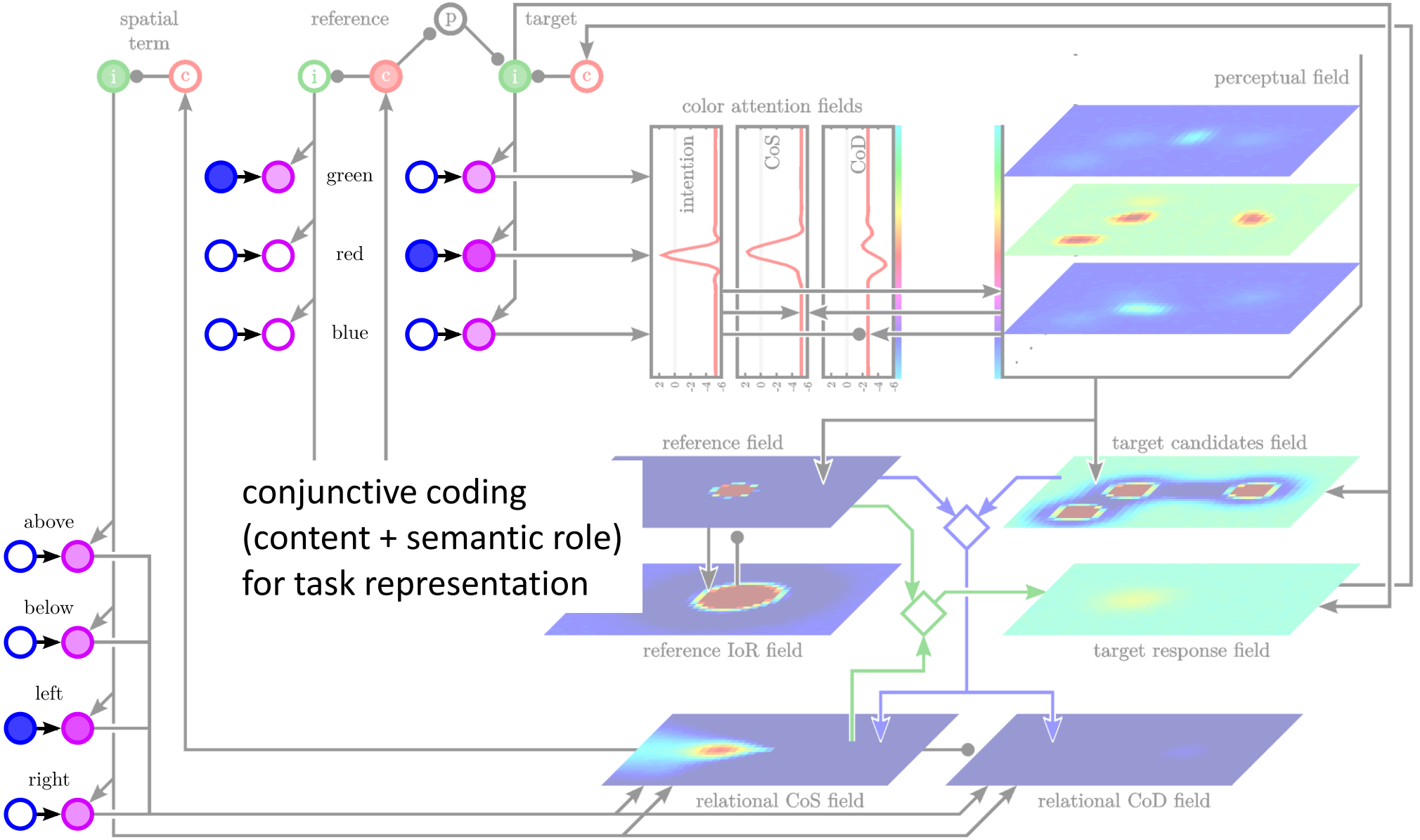


Concept Nodes



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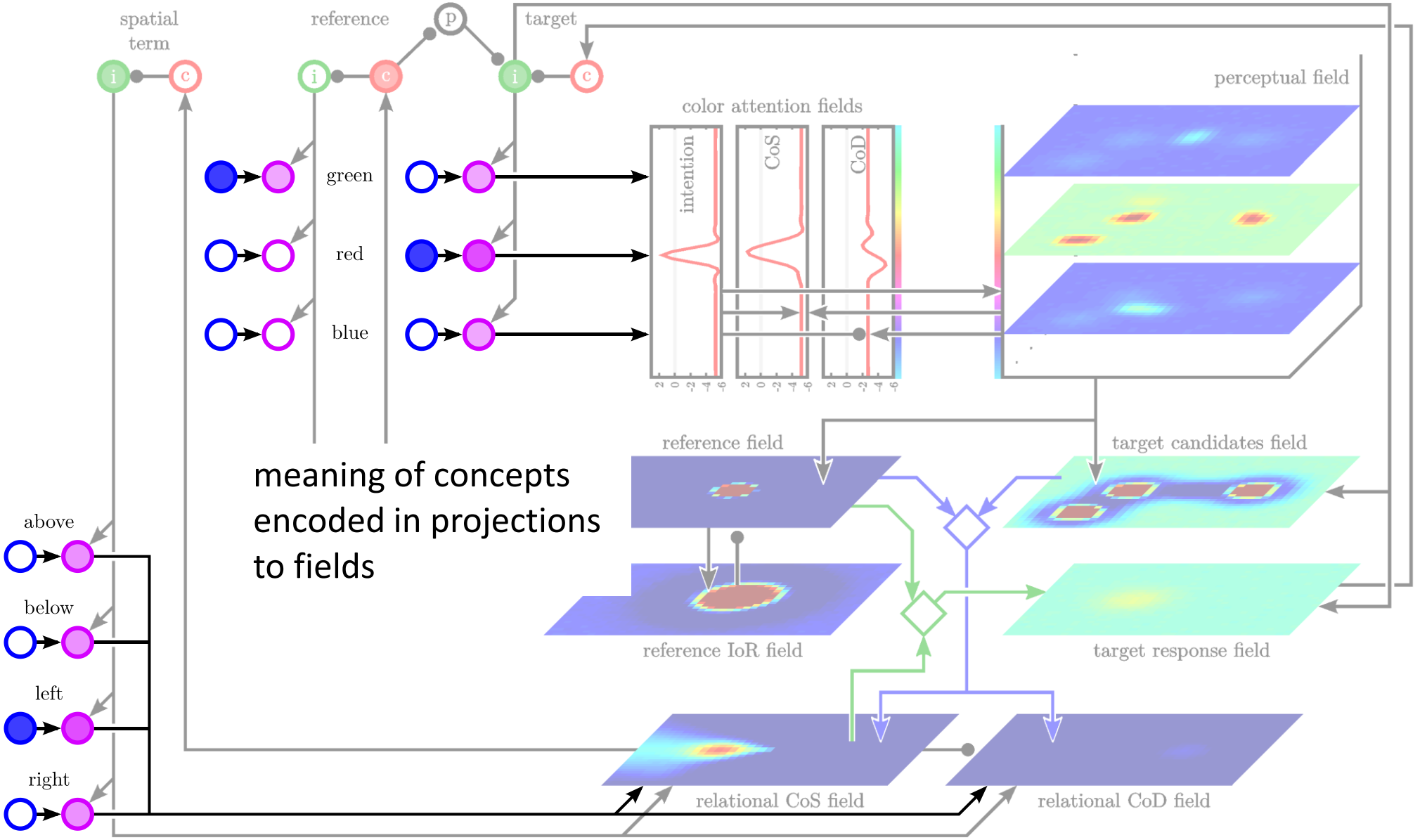
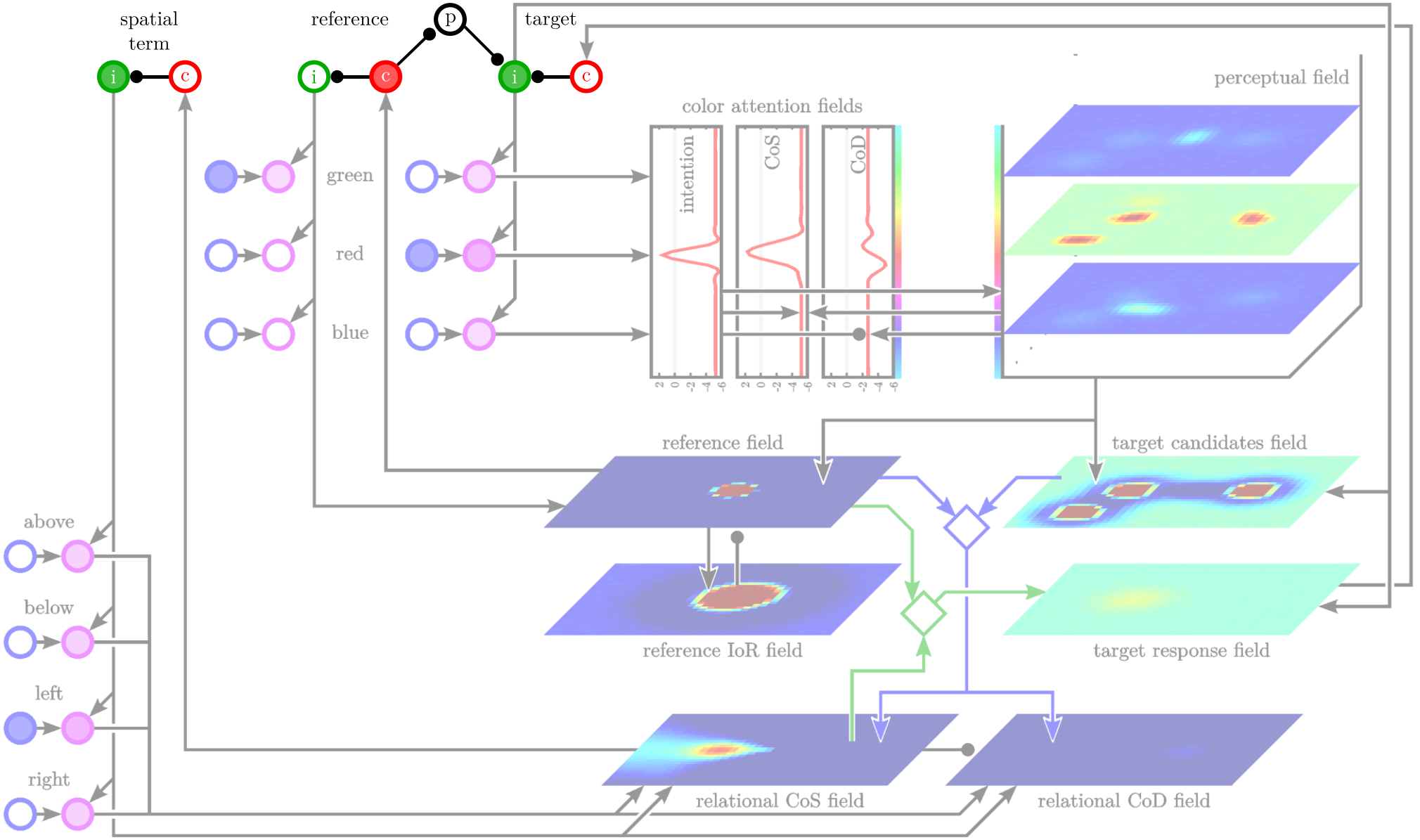


Behavior Organization



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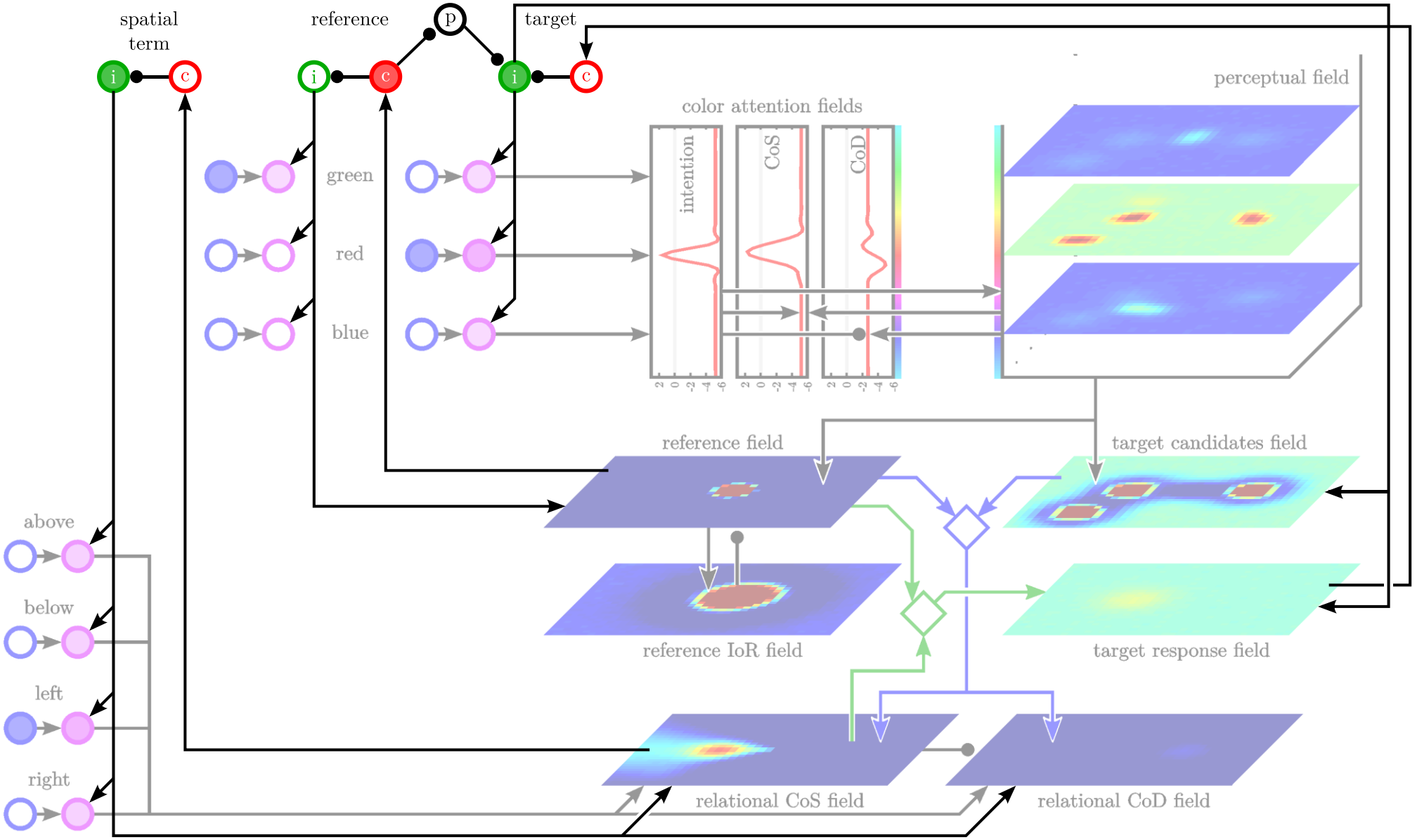
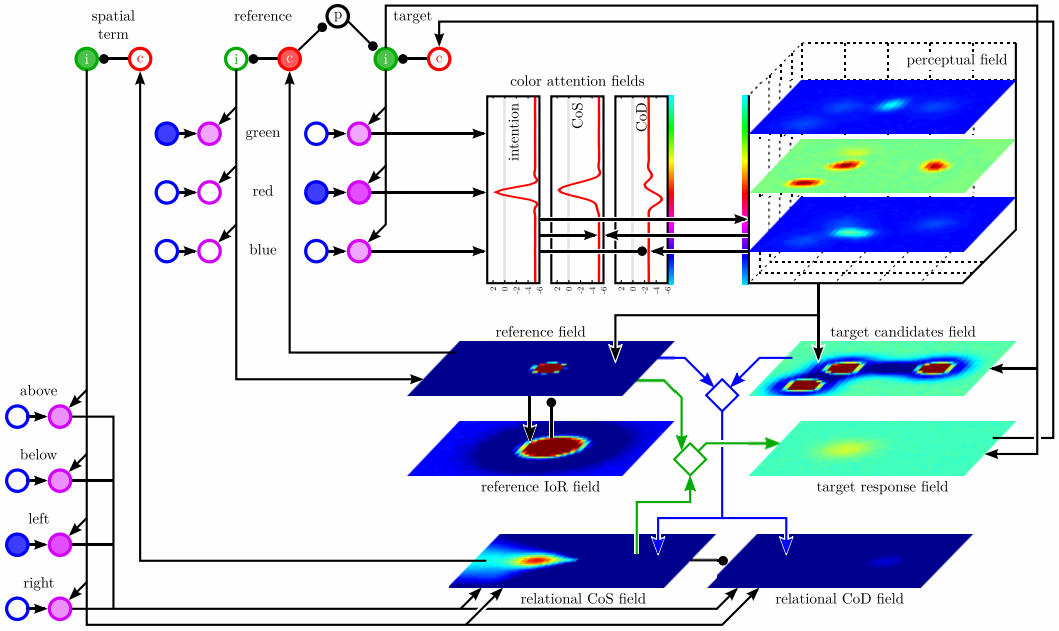
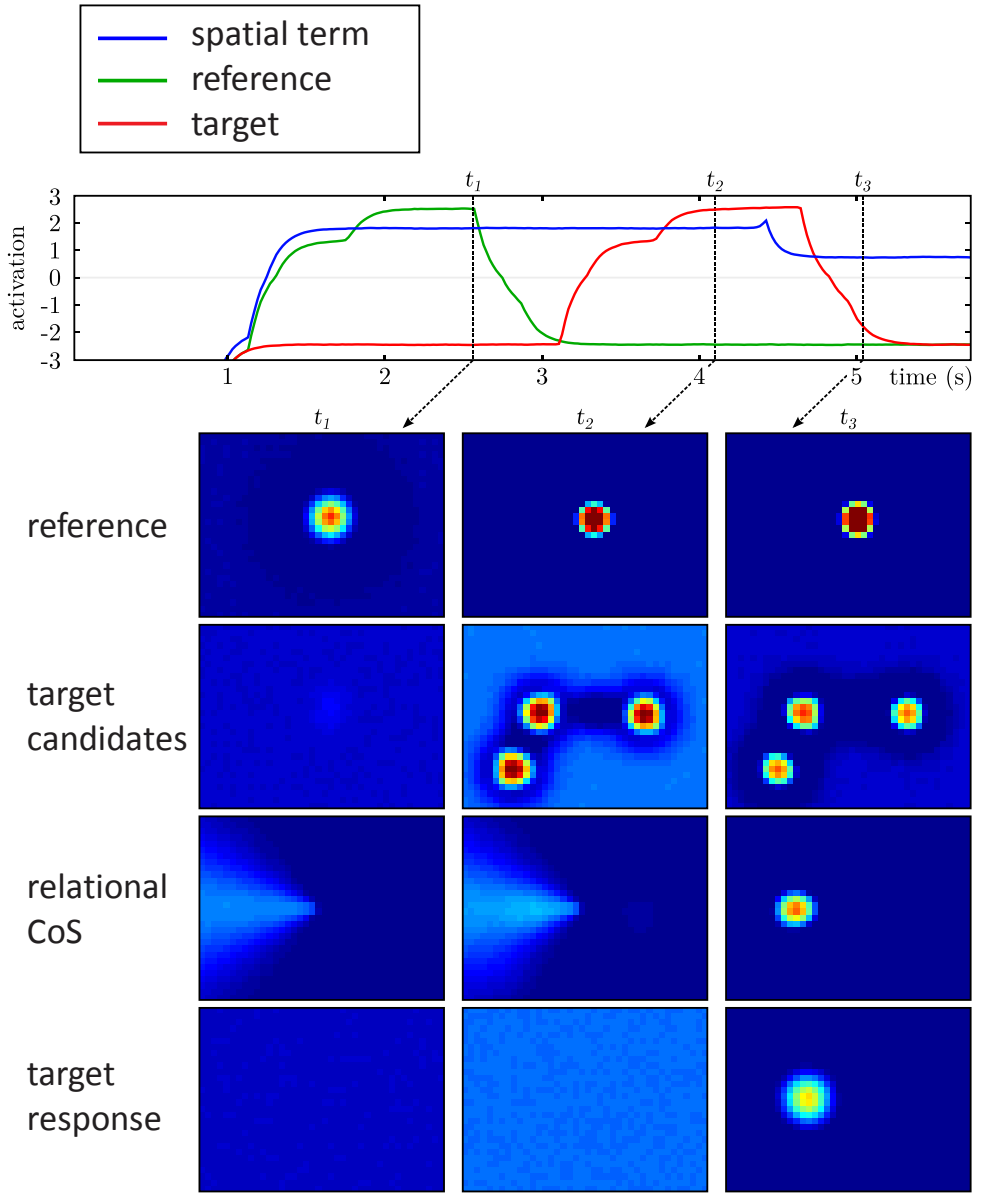


Grounding Spatial Expressions

„the red item to the left of the green item “





Hypothesis Testing

„the red item

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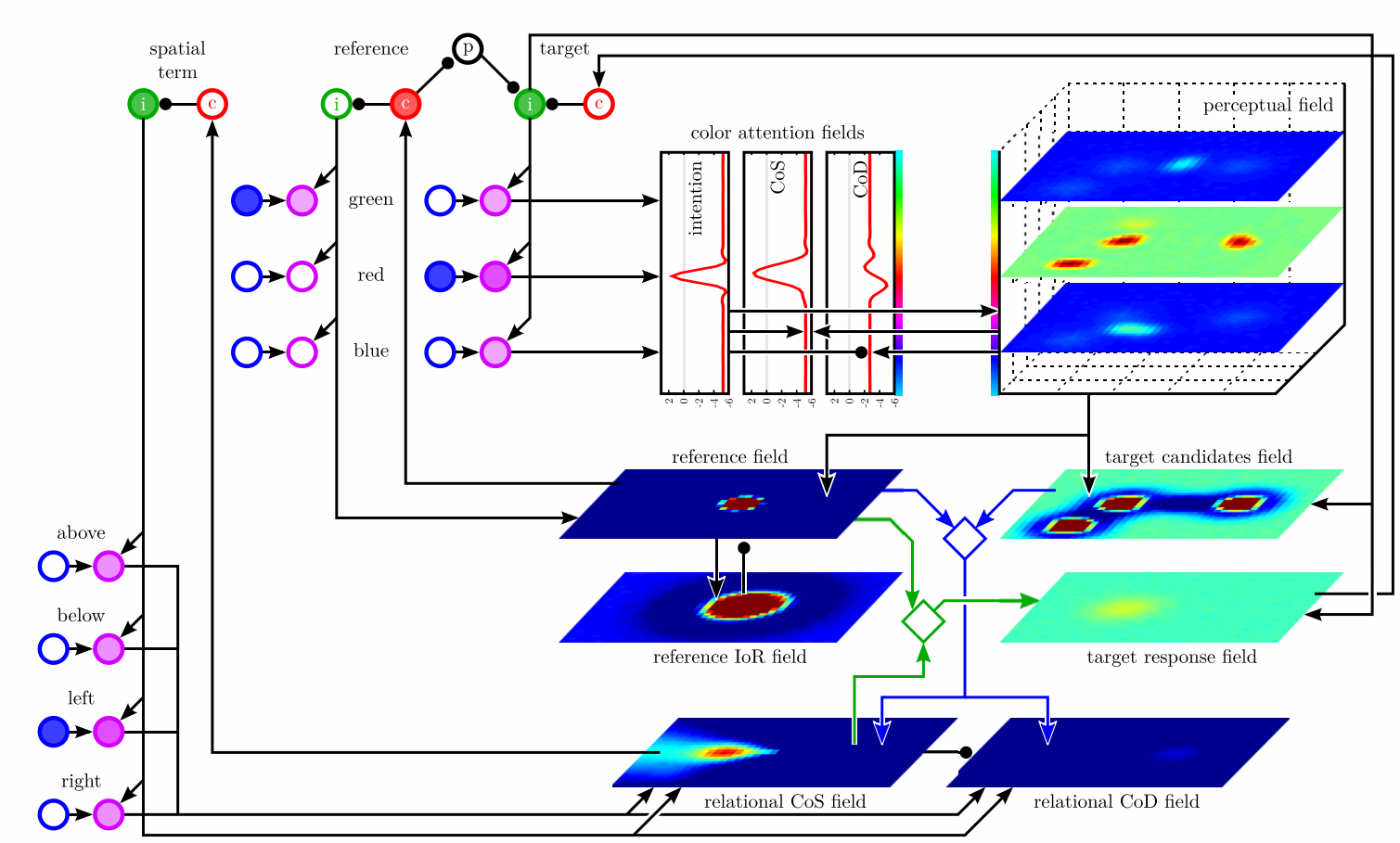

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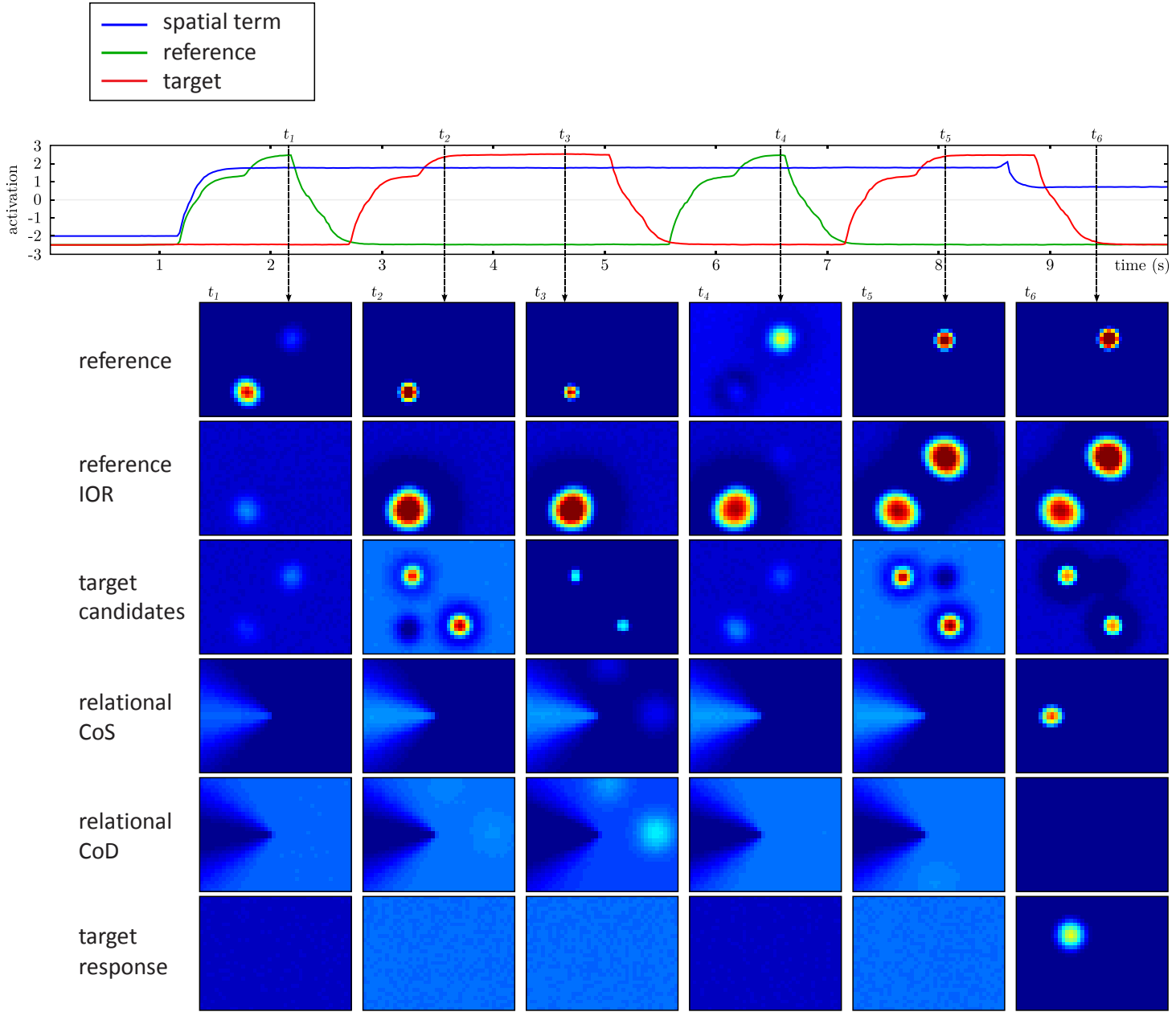

Overview and Outlook

- symbolic representation for verbal task, but processing in modal, metric representations
- autonomy through dynamic behavior organization
- sequential processing to solve binding problem, consistent with human behavior (Logan 1994; Franconeri 2012)

future work:

- combination with DNF model of scene representation: building mental models from verbal descriptions, reasoning through simulation
- relate to human data (e.g. Knauff 2013)