Higher Cognition in DFT

Jonas Lins
2014-Aug-29

Higher Cognition

Thinking
Reasoning
Problem solving
Inference
Insight

Skills for controlled, complex manipulation of information.

Extracting information that is provided only implicitly.

Analytical, multi-stage operations.

Amodal Cognition

Cognition as processing of arbitrary symbols

As in propositional logic:

if (faster(rabbit, turtle) and faster (turtle, snail))
then faster(rabbit,snail)

Amodal symbols

no semantics.
not structurally related to what they represent
unless interfacing with sensory motor level
even then, their semantics lie in the patterns there

Grounded cognition

Cognition is based on modal simulations. E.g., Barsalou, 2008; Lakoff 19XX

Representations capture semantics

Patterns of activation during sensorimotor experience are stored

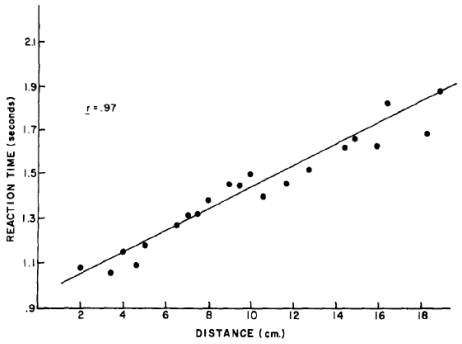
Reasoning: same systems as actual experience

Re-enactment in a common multimodal “representational system”

Grounded cognition: Evidence

Mental scanning

Kosslyn1978

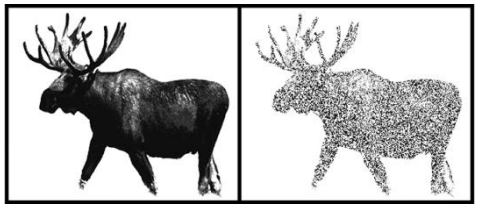


Perceptual simulation

Yaxley2006

Through the fogged goggles, the skier could hardly identify the moose.

Through the clean goggles, the skier could easily identify the moose.

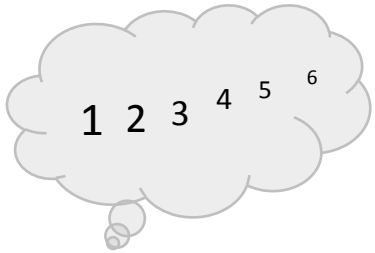


SNARC

Dehaene1993

Small numbers
→ Faster response with left hand

Large numbers
→ Faster response with right hand



DFT and grounded cognition

Grounded cognition: Inspired our higher cognition line of work

DNFs close in format to sensorimotor level

- Close to sensorimotor surfaces
- Mimic the structure of the world (e.g., space)
- Come with a “natural” metric
- Pre-defined relations -- useful for implementing rules HalfordEtAl2010

The spatial language model

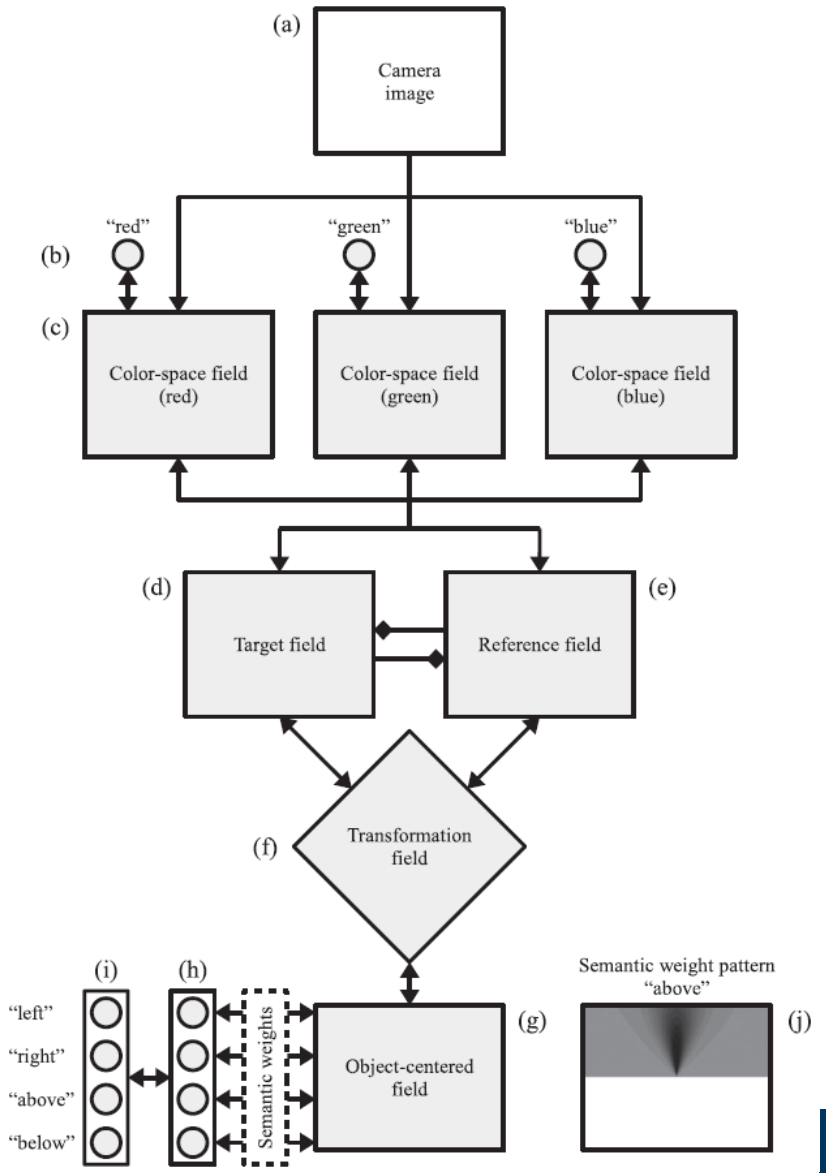
Lipinsky, Schneegans, Sandamirskaya, Schöner, Spencer, 2011

First step in DFT for extracting implicit information: relations

Extract spatial relation
„Where‘s the red object relative to the green one?“

Guide attention given relation
„The red object left of the green one.“

Select fitting refrence object
„Where‘s the red object?“



The spatial language model

Assessing a spatial relation

LoganSadler1996

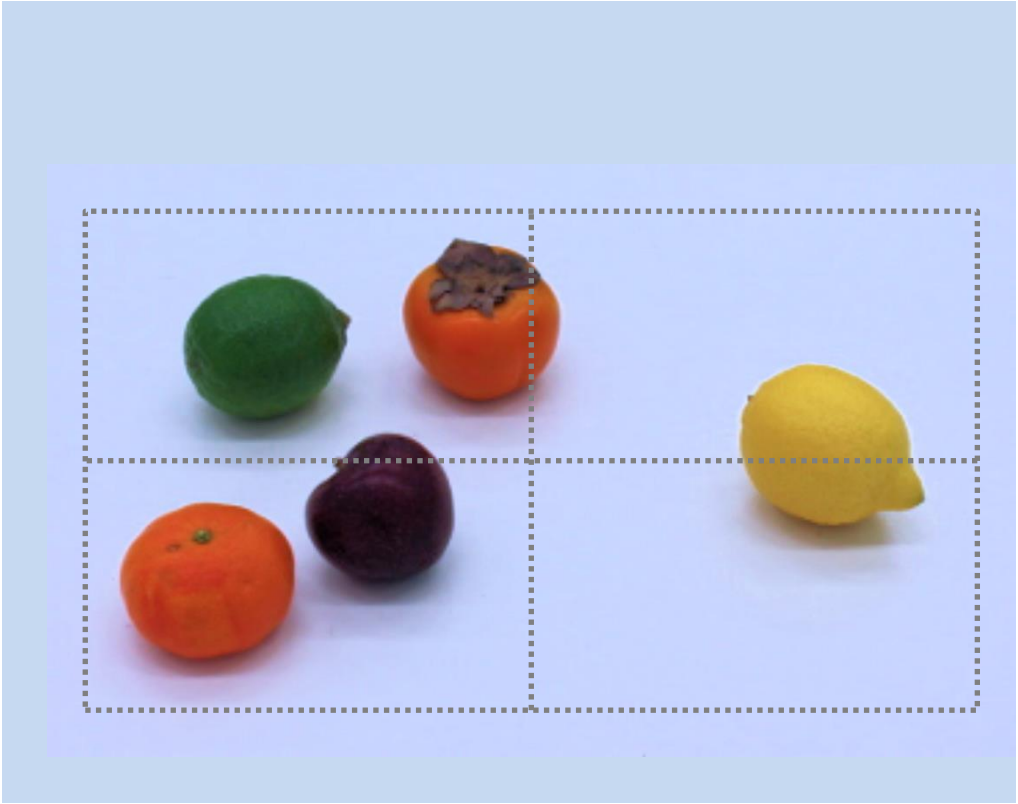
„The lime left of the kaki“

Bind each object to its role

Center reference frame on reference object

Map spatial term onto frame

Does target position match spatial term?



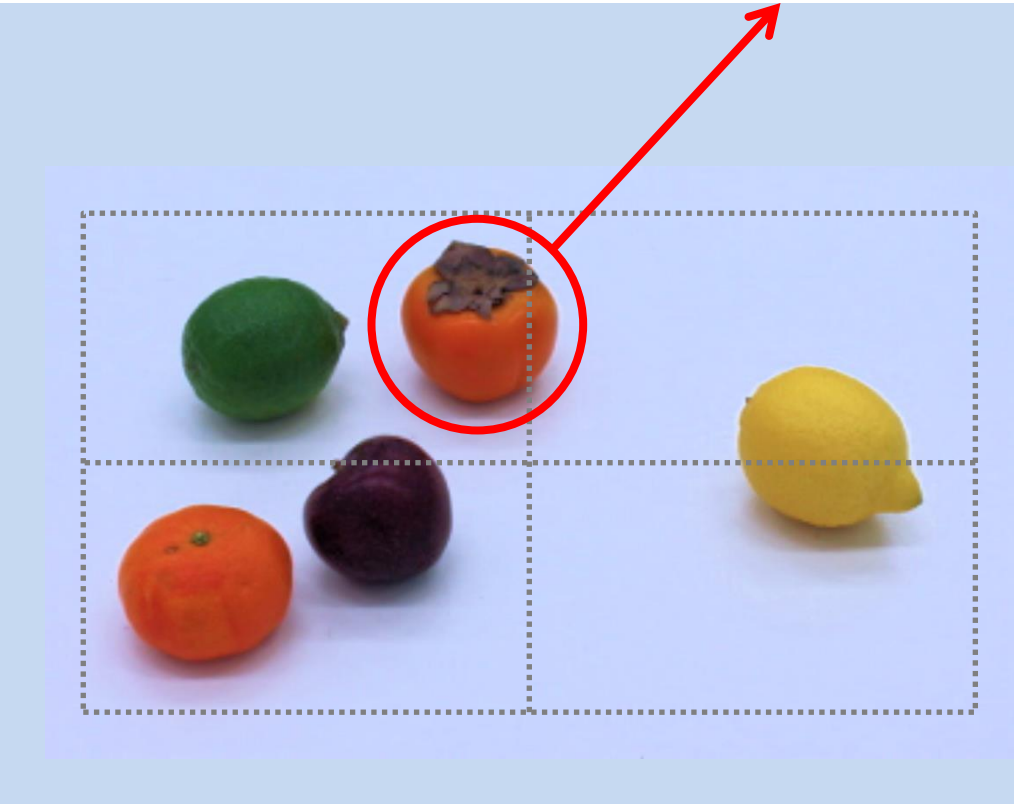
The spatial language model

Assessing a spatial relation

LoganSadler1996

„The lime left of the kaki“

reference



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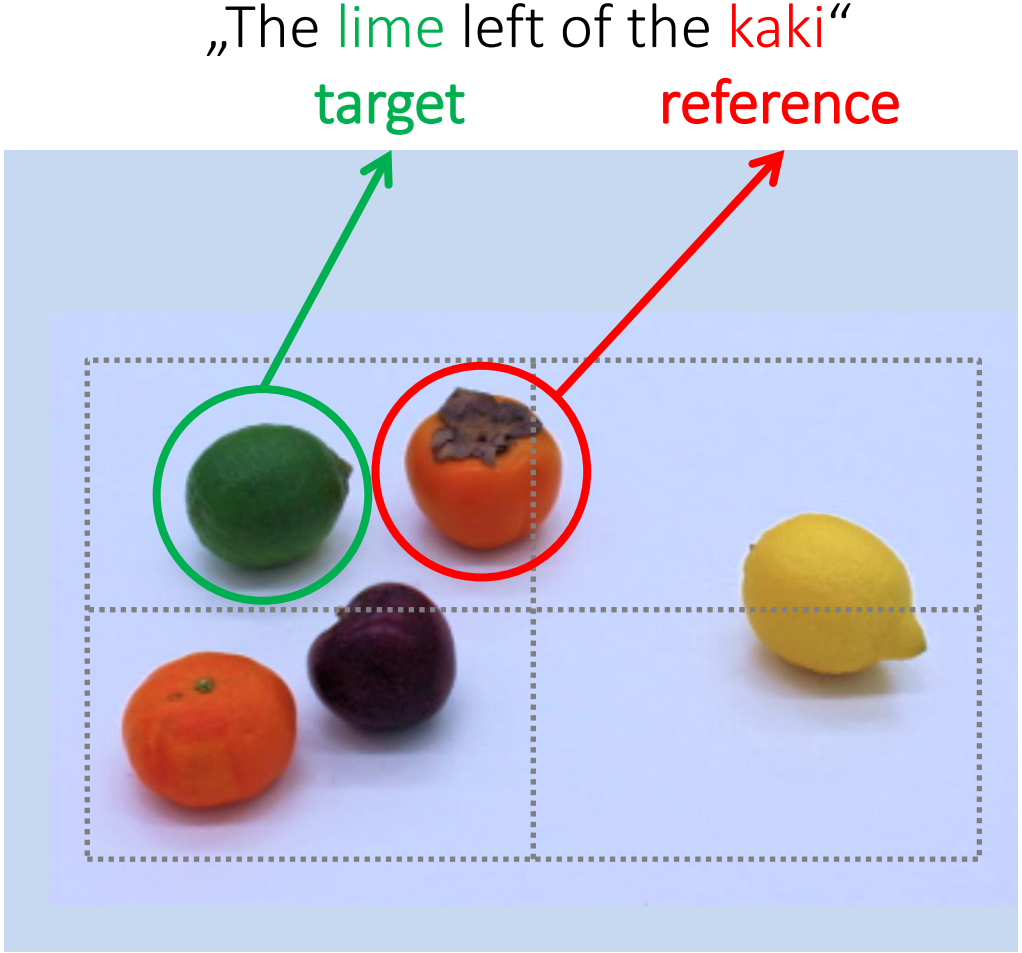

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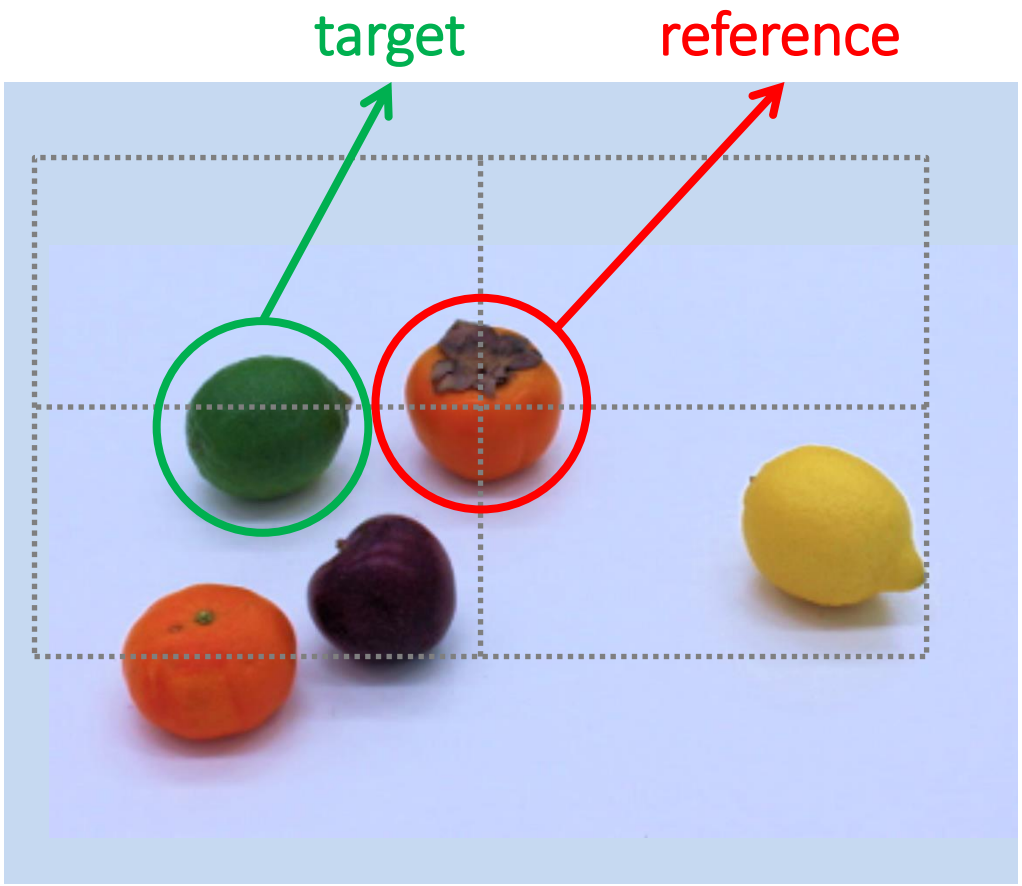

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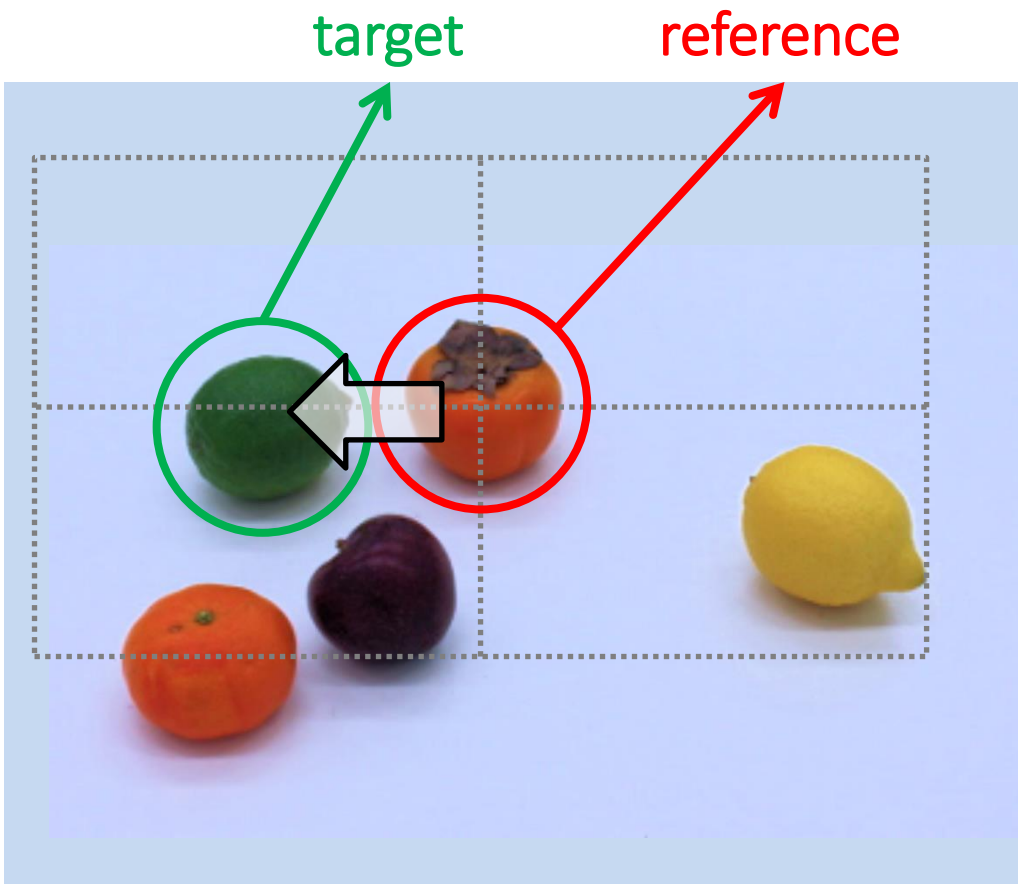

The spatial language model

Assessing a spatial relation

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Center reference frame on reference object

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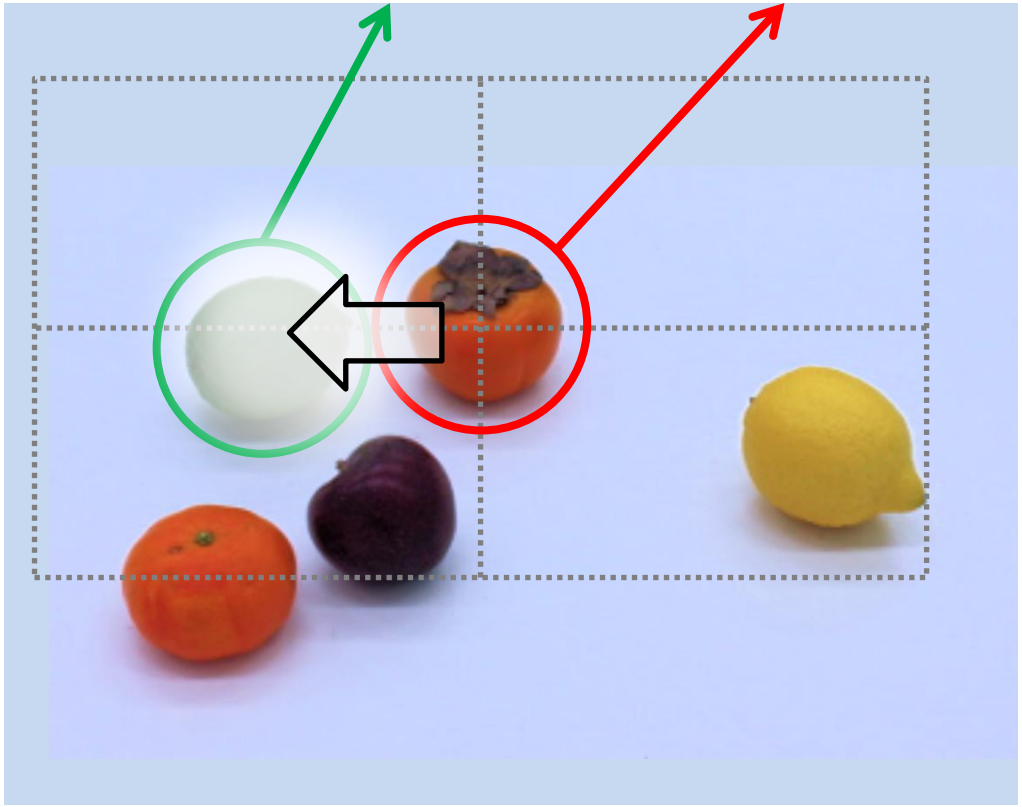
Does target position match spatial term?

„The lime left of the kaki“

target reference



The spatial language model LipinskyEtAl2011

Bind objects to roles

target field

reference field

Center frame on reference object

transformation field

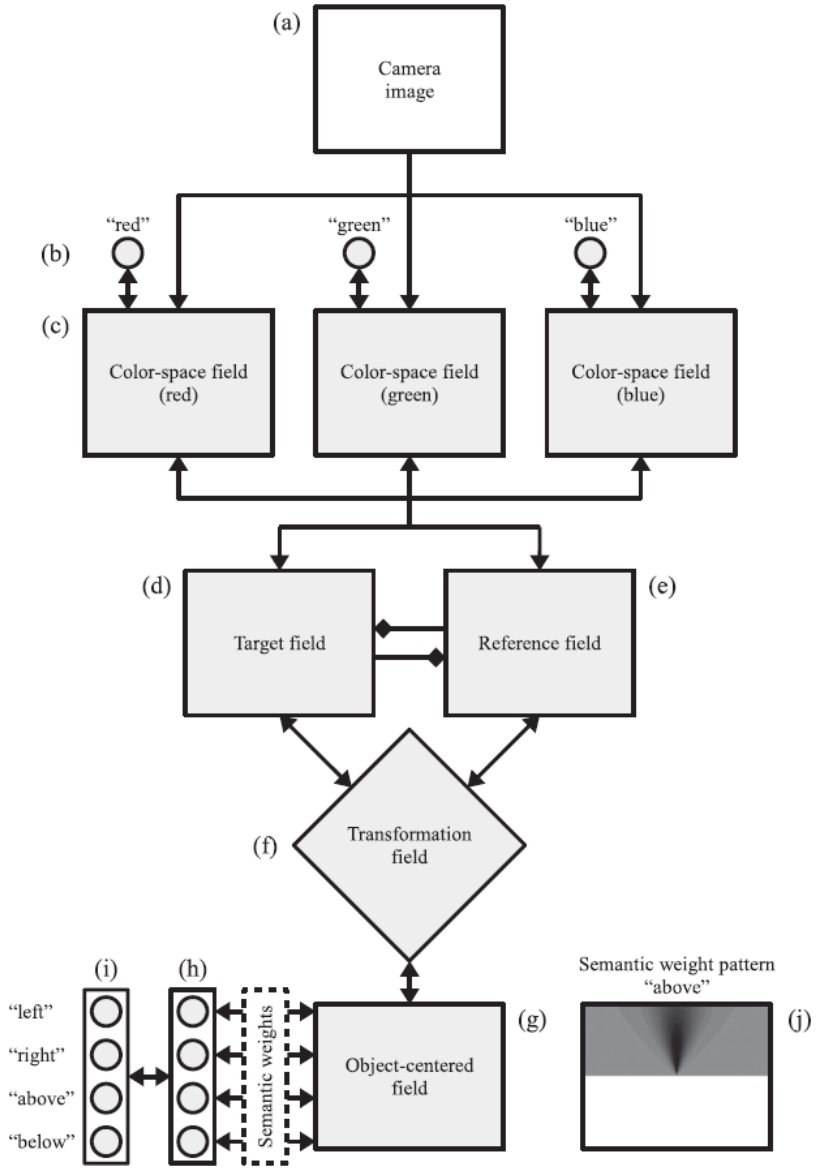
Map spatial term onto frame

spatial relation nodes

semantic weights

Match target and spatial term

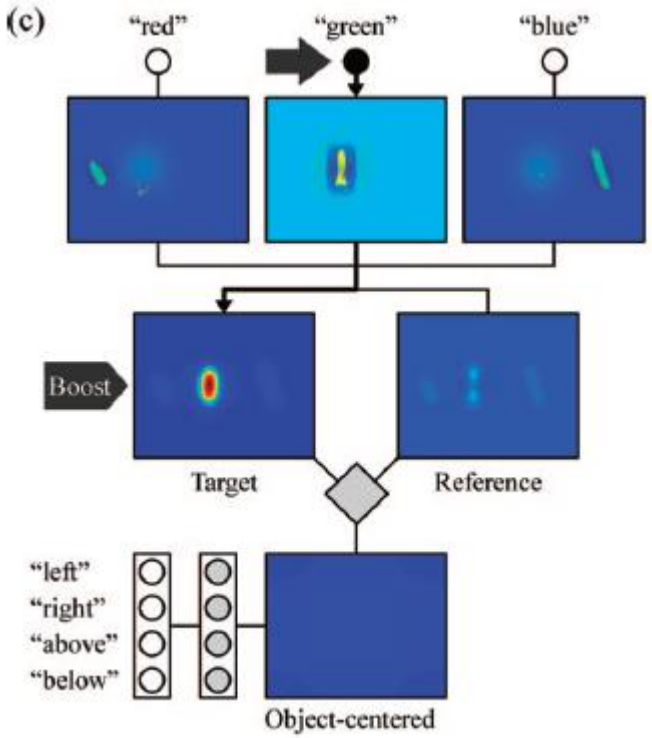
spatial term nodes

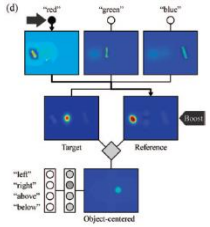


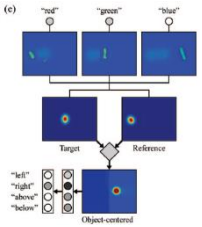
The spatial language model

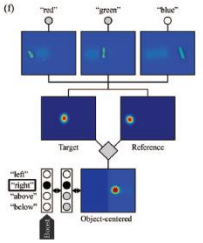
Spatial term selection

Given: target, reference









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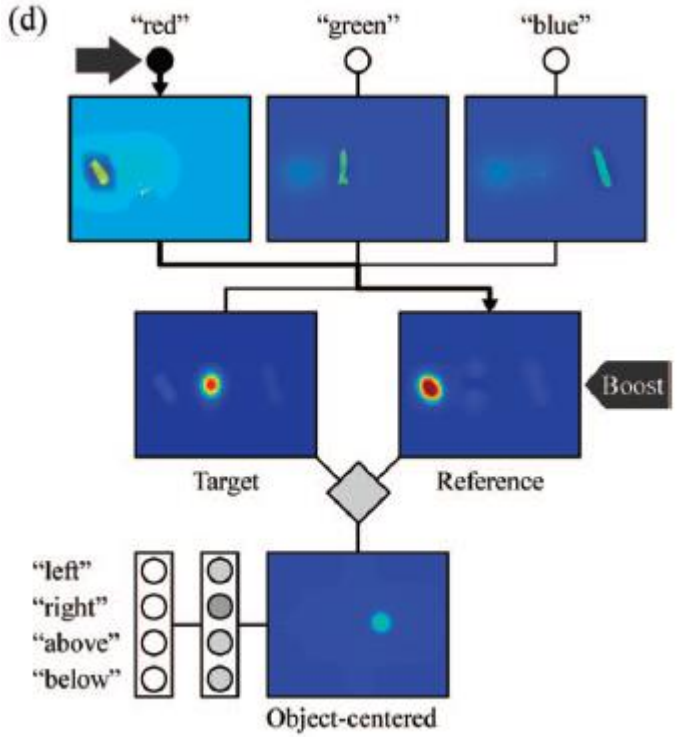

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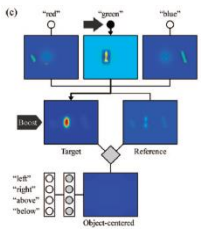

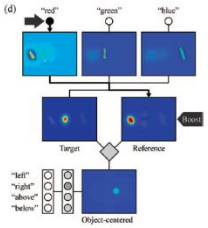

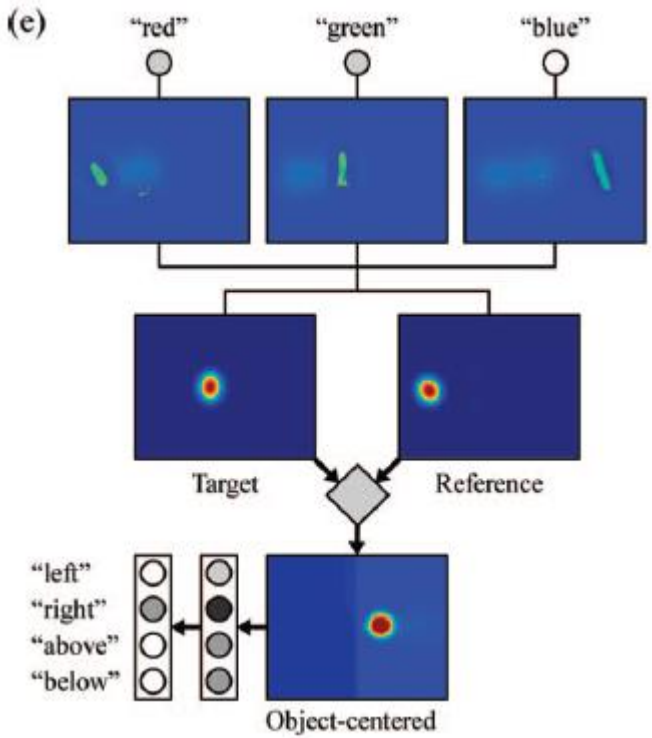

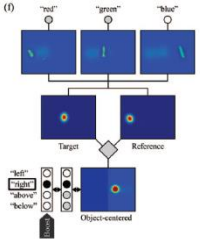

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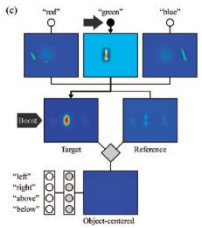
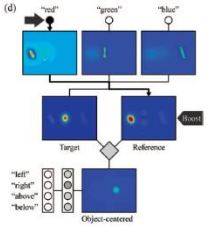
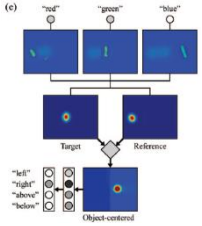
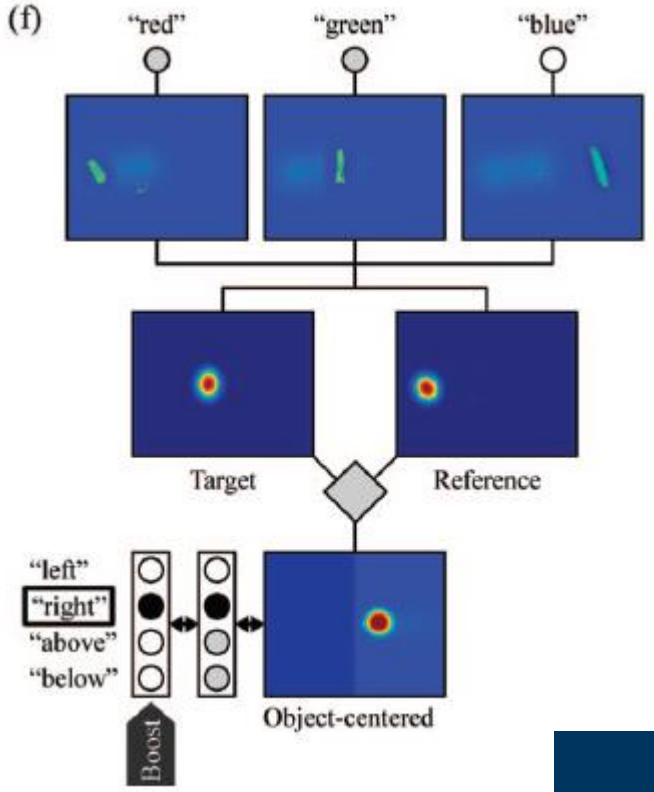






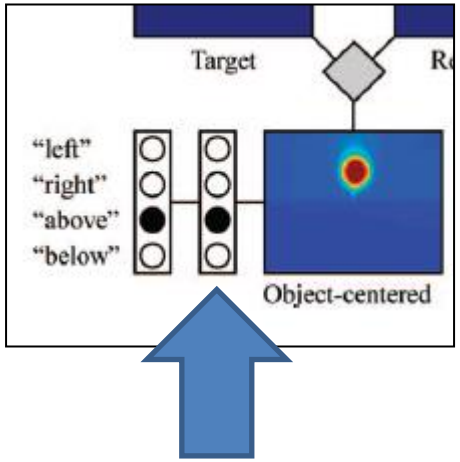


The spatial language model

Spatial term selection -- Comparison to human data

from Regier & Carlson, 2001

5x5 grid
Reference object in the middle
rate applicability 0-9



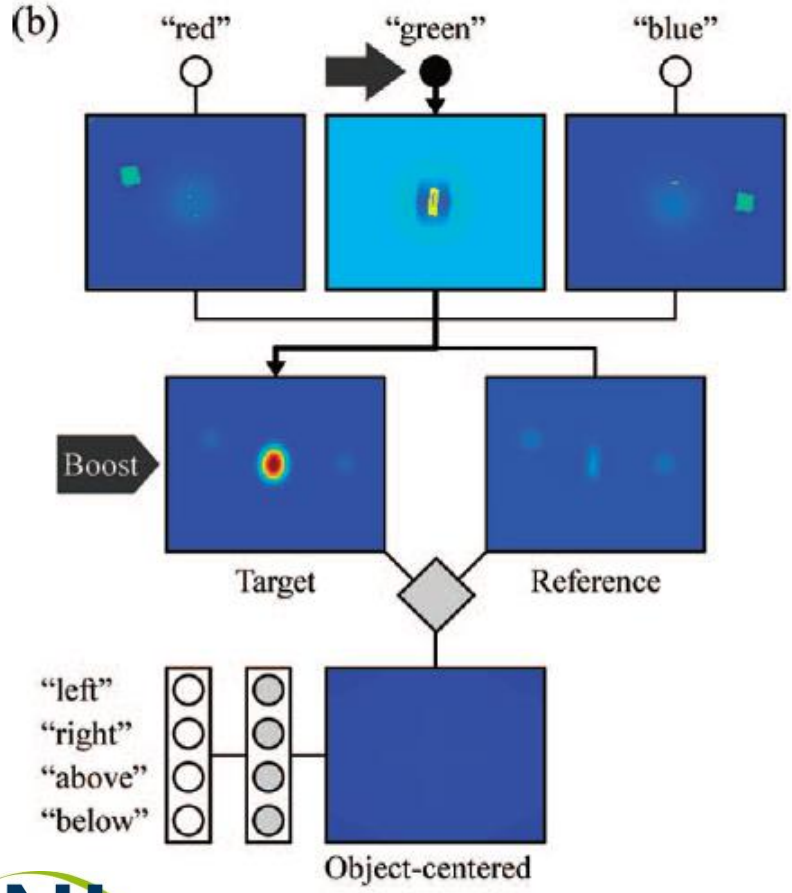
Example for term „**above**“ (parentheses = humans)

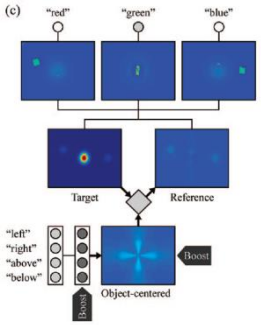
	Column				
Condition and row	1	2	3	4	5
Tall					
1	6.0 (6.7)	8.3 (7.4)	8.8 (8.9)	8.3 (7.4)	6.0 (6.8)
2	5.4 (5.6)	7.3 (6.6)	8.6 (8.9)	7.3 (6.2)	5.4 (6.0)
3	0.9 (0.9)	0.9 (0.9)		0.9 (1.0)	0.9 (1.3)
4	0.0 (0.6)	0.0 (0.3)	0.0 (0.6)	0.0 (0.4)	0.0 (0.6)
5	0.0 (0.4)	0.0 (0.4)	0.0 (0.3)	0.0 (0.6)	0.0 (0.3)
Wide					
1	5.9 (6.5)	8.3 (7.3)	8.8 (8.9)	8.3 (7.0)	5.9 (6.9)
2	5.5 (6.2)	7.6 (6.4)	8.6 (8.4)	7.6 (6.9)	5.5 (6.2)
3	0.9 (0.7)	0.9 (0.8)		0.9 (0.7)	0.9 (0.8)
4	0.0 (0.4)	0.0 (0.5)	0.0 (0.3)	0.0 (0.4)	0.0 (0.3)
5	0.0 (0.4)	0.0 (0.4)	0.0 (0.4)	0.0 (0.3)	0.0 (0.3)

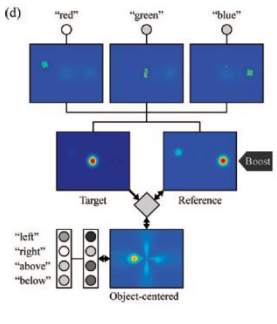
The spatial language model

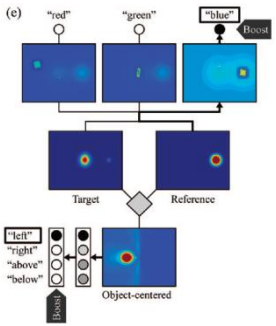
Reference object & spatial term selection

Given: target









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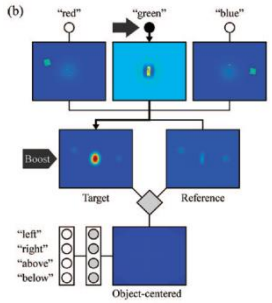

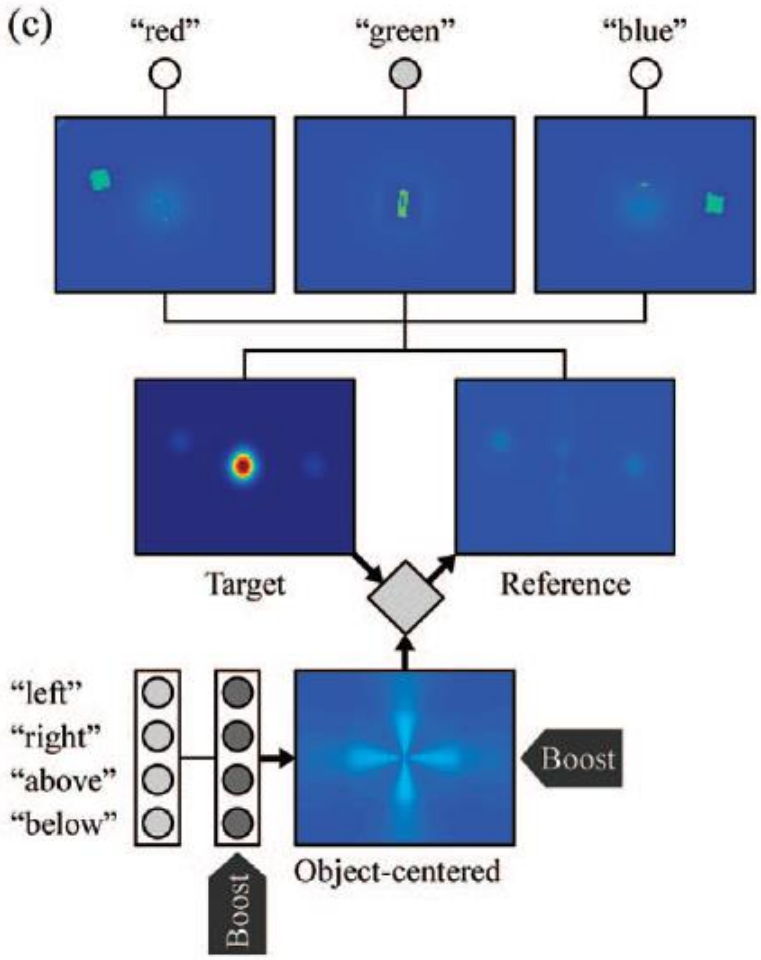

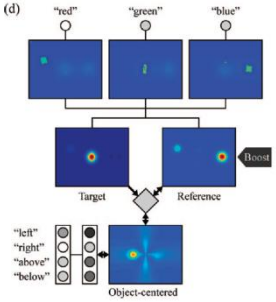

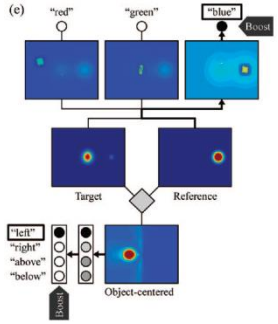

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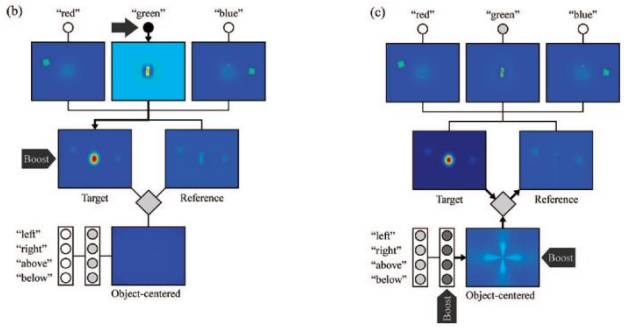

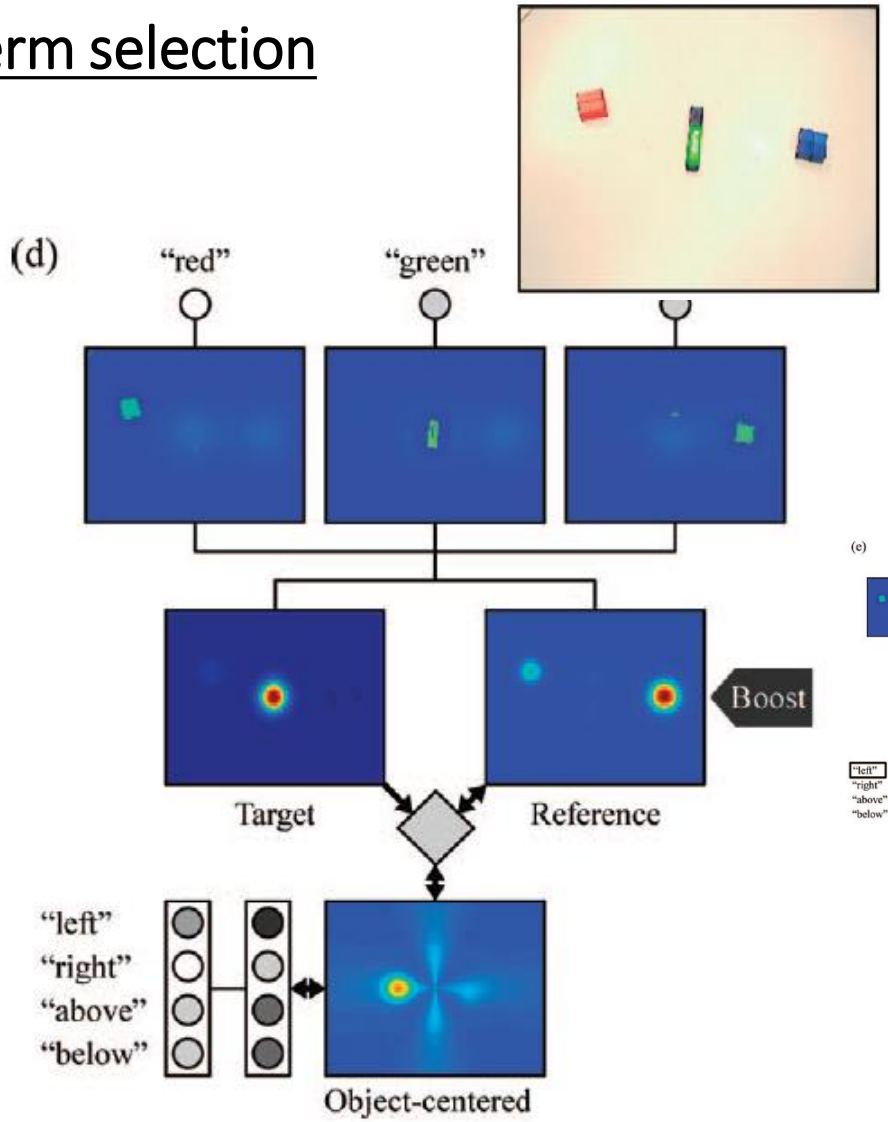

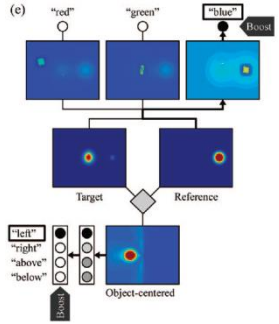

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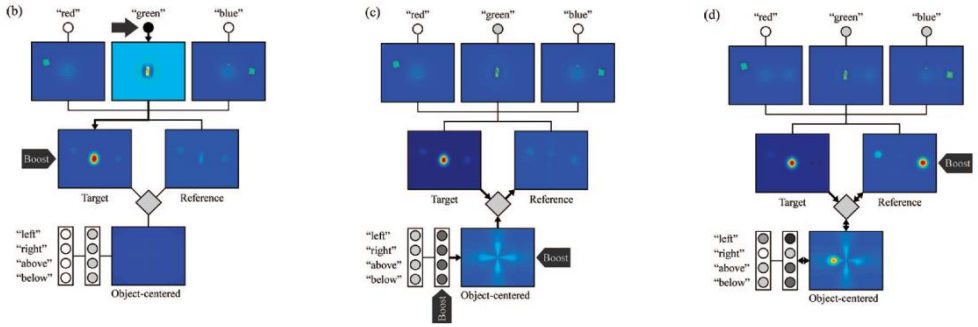
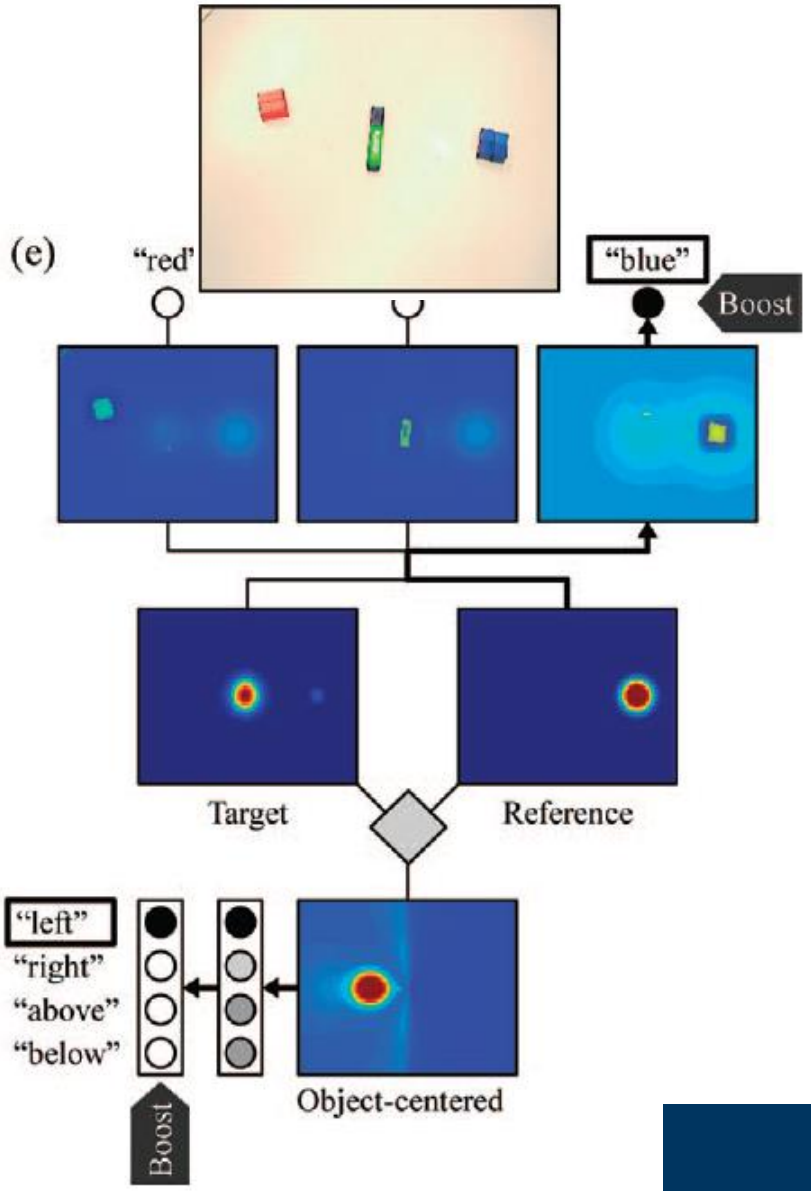


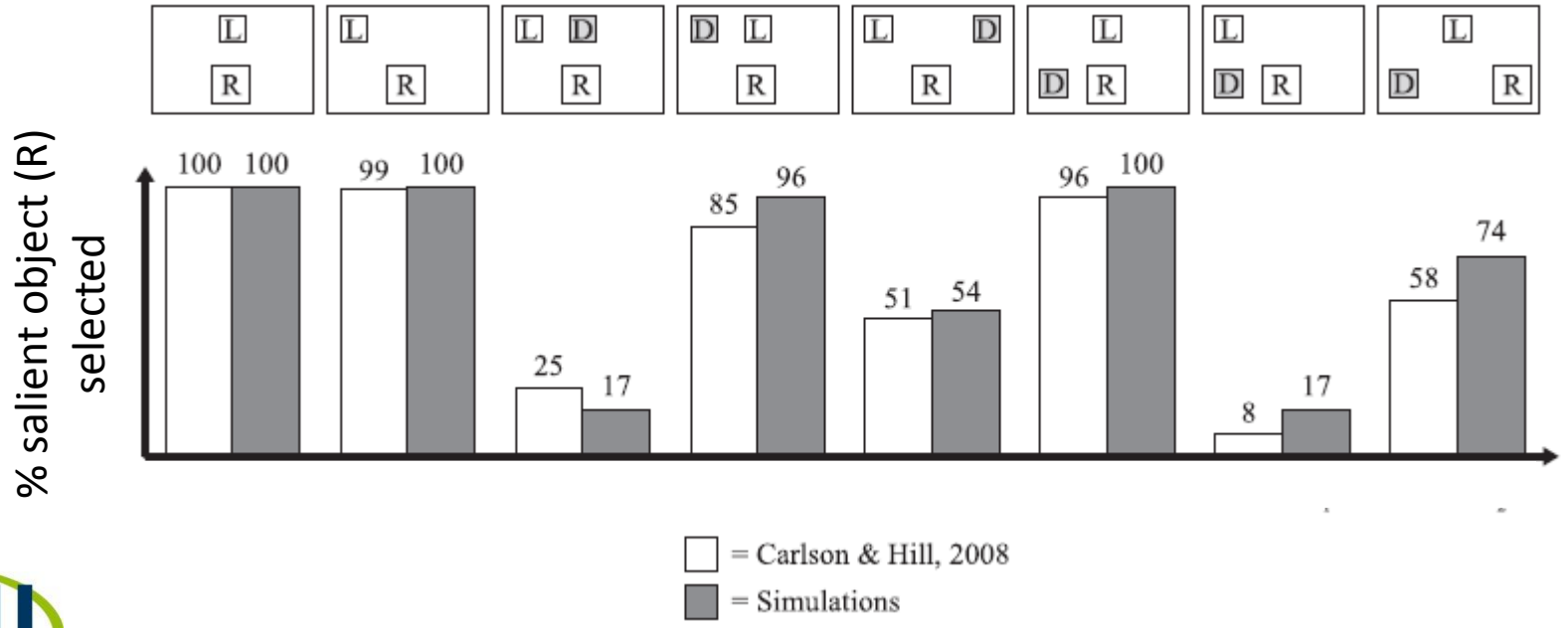


The spatial language model

Reference & spatial term selection -- Comparison to human data
from Carlson & Hill, 2008

Photos with 2-3 objects , name a relation that involves target object

Factors: saliency (R was most salient), placement of non-salient item (D)



The spatial language model

Overall

Pretty general, flexible model, similar in spirit to attentional vector-sum model (Regier & Carlson,2001)

Provides operational neural process account

One step closer to “higher cognition”

Exemplar neural mechanism extracts implicit information

Modal representational substrate

What’s missing?

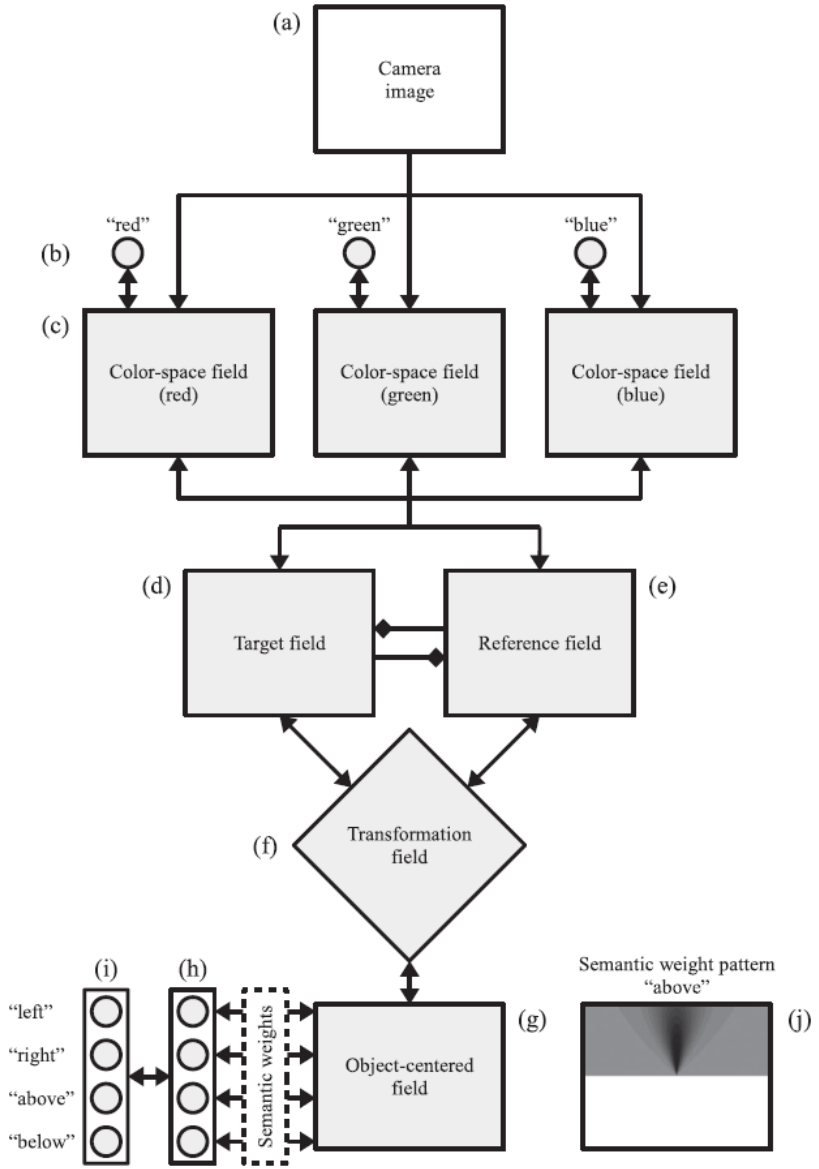
The spatial language model

Doumas & Hummel (2013):

conjunctive coding

dynamic binding

specify relation of these



The spatial language model

Doumas & Hummel (2013):

conjunctive coding

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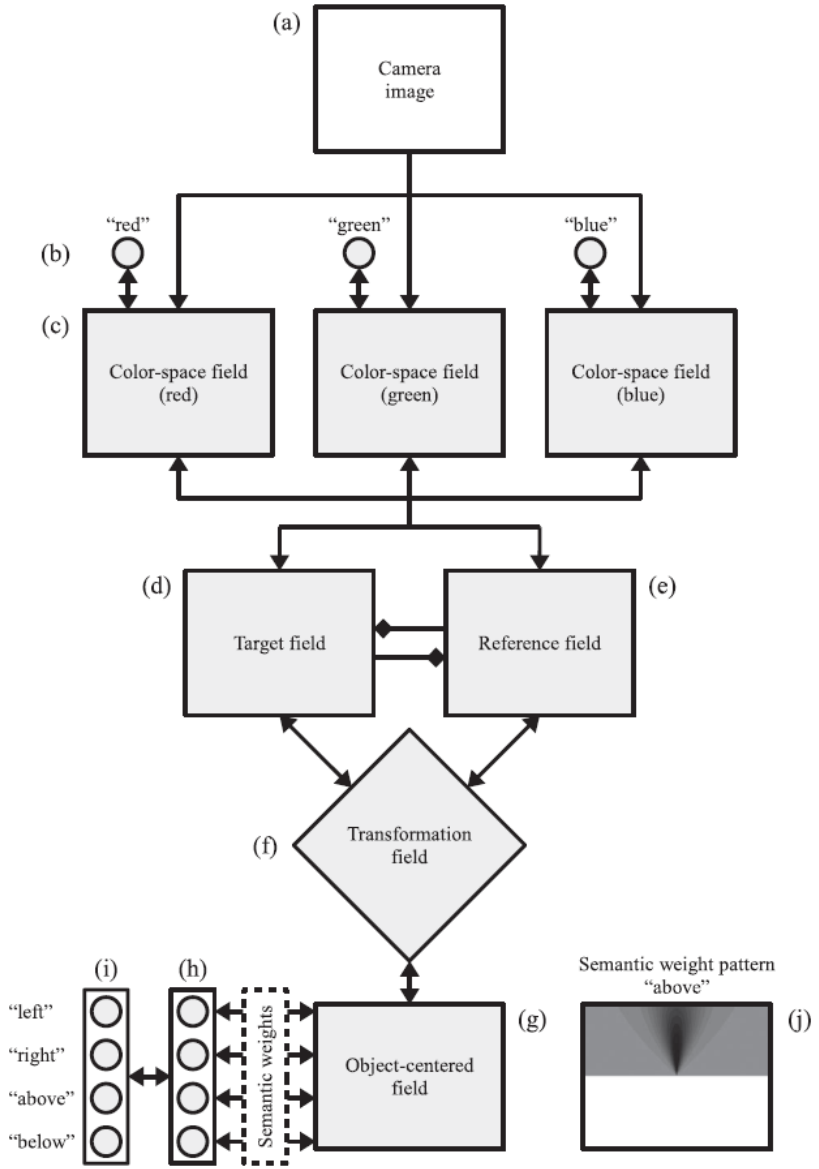


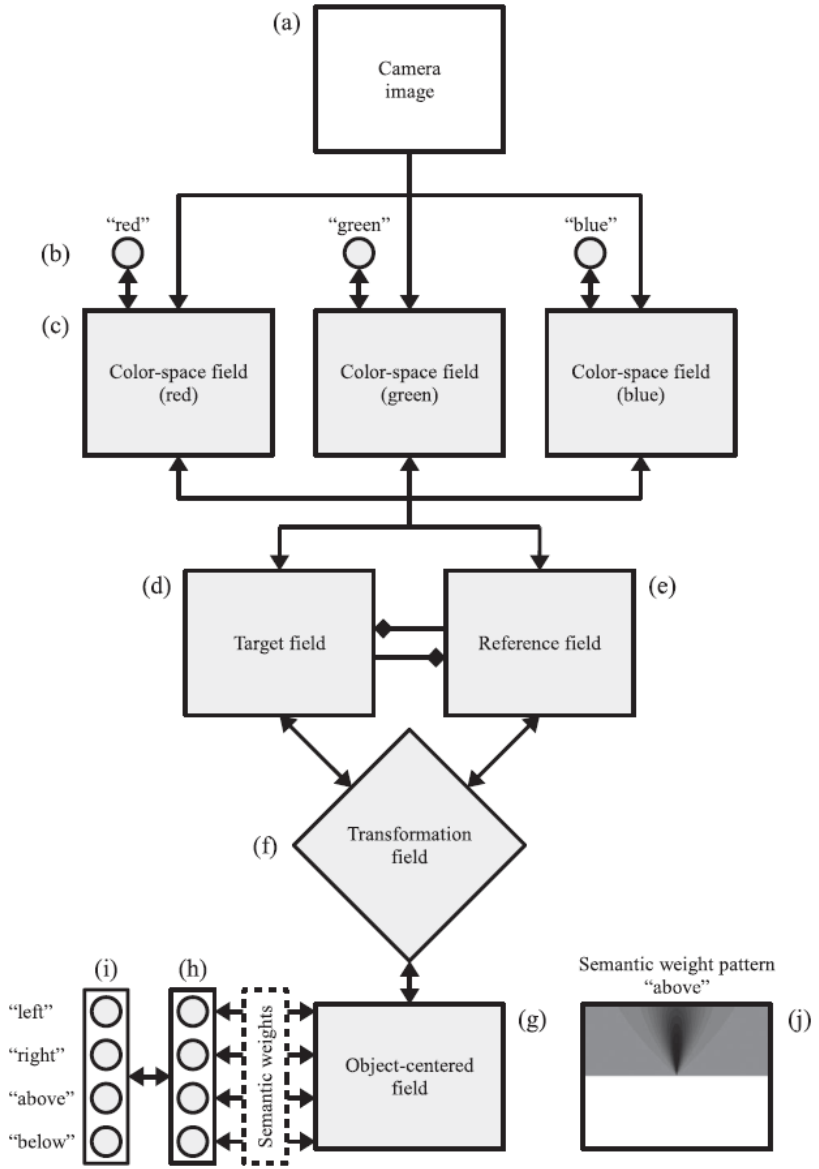
The spatial language model

Doumas & Hummel (2013):

conjunctive coding NO

dynamic binding

specify relation of these



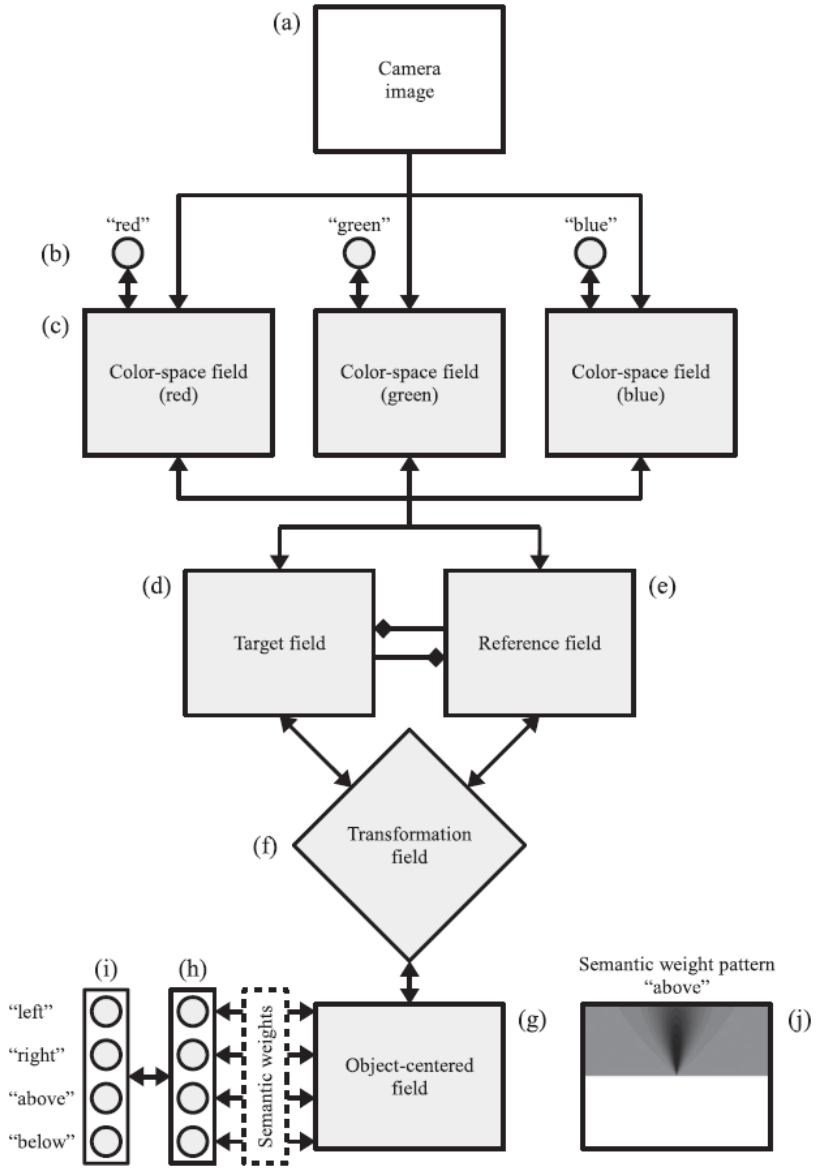
The spatial language model

Doumas & Hummel (2013):

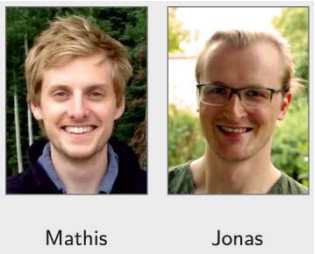
conjunctive coding NO

dynamic binding YES

specify relation of these NO



The extended spatial language model



Richter, Lins, Schneegans, Sandamirskaya, Schöner, 2014
Proceedings of the 36th Annual Conference of the Cognitive Science Society

conjunctive coding YES

System of localist units
to control instantiation of stored patterns

dynamic binding YES

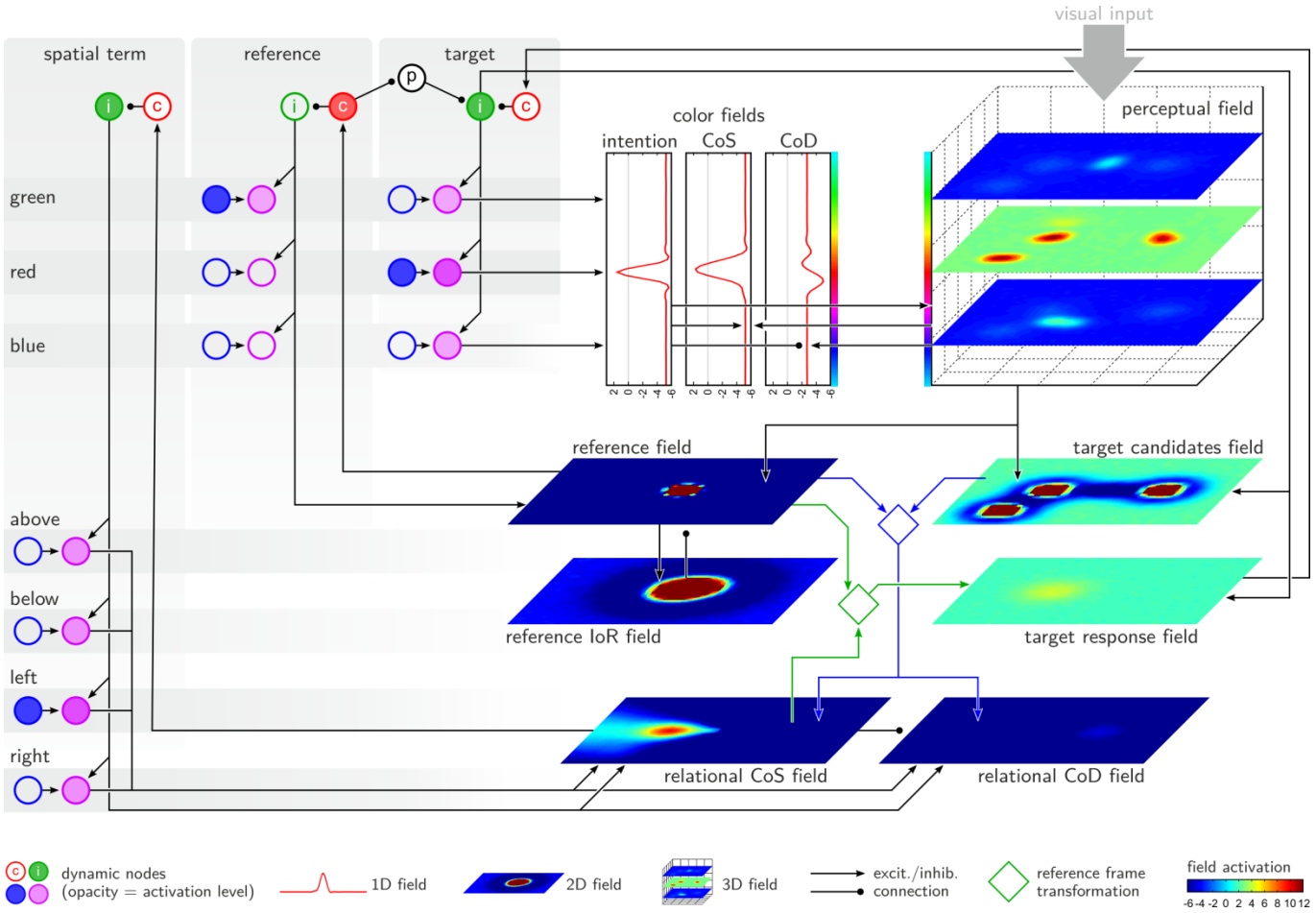
through space

Specify relation of these YES

adding neural organization
for sequential operation

Sandamirskaya2010 Richter2012

The extended spatial language model



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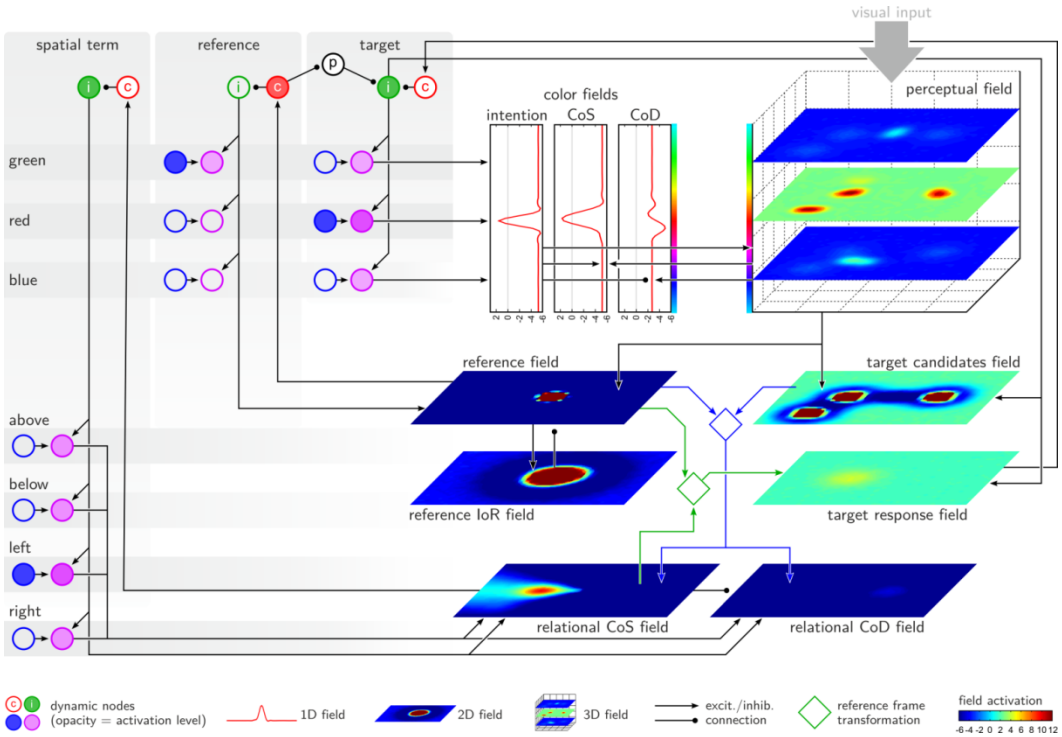
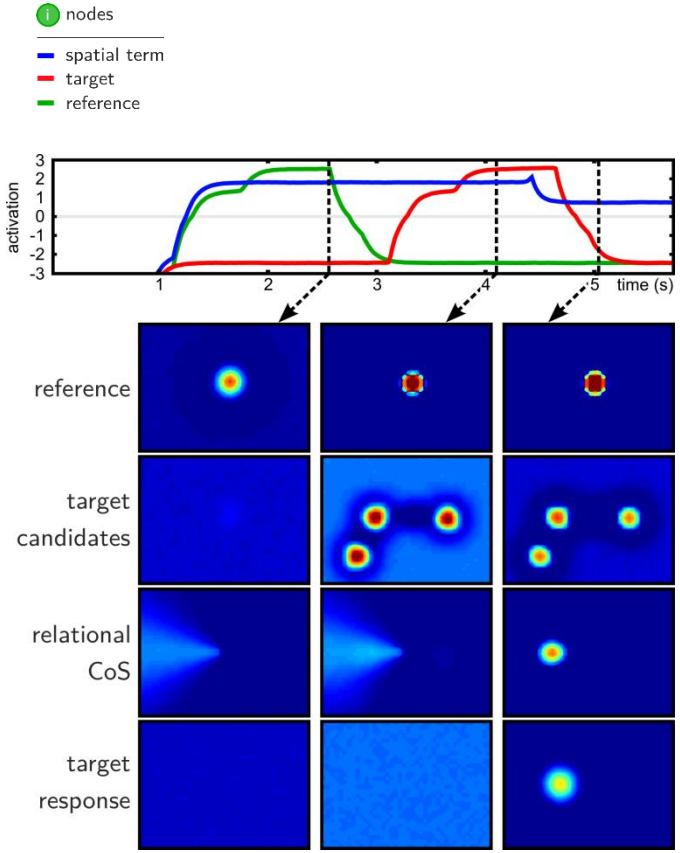
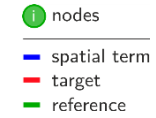
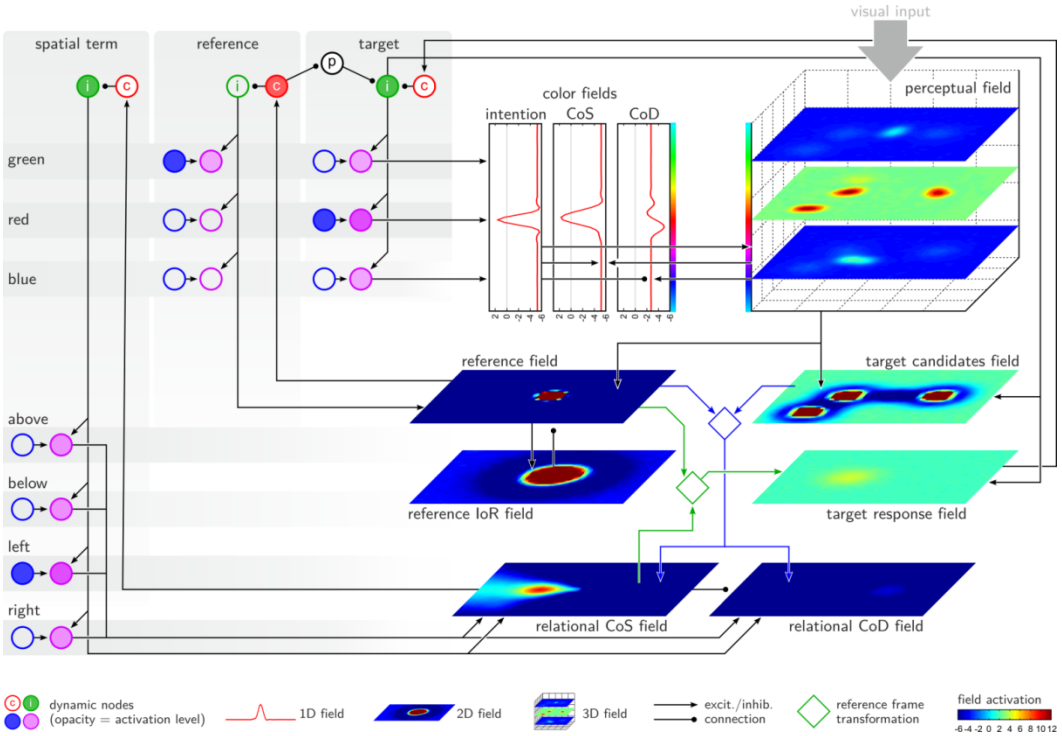
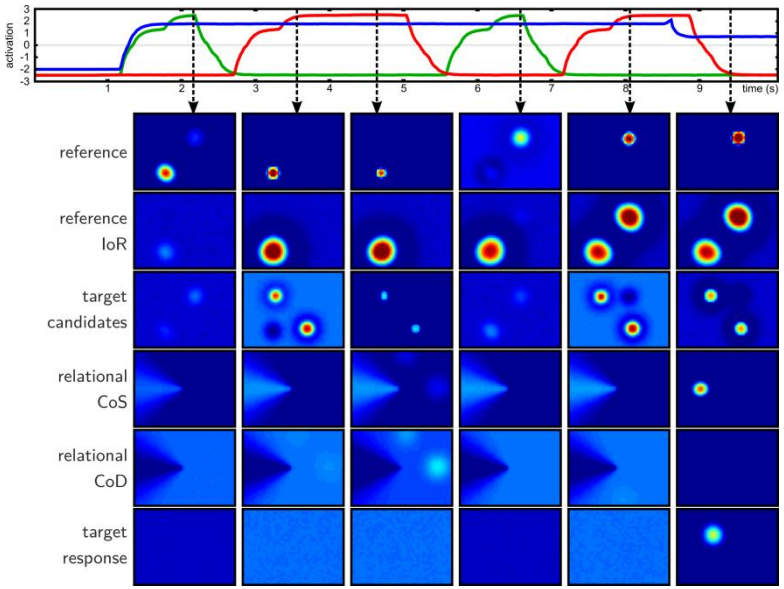




The extended spatial language model

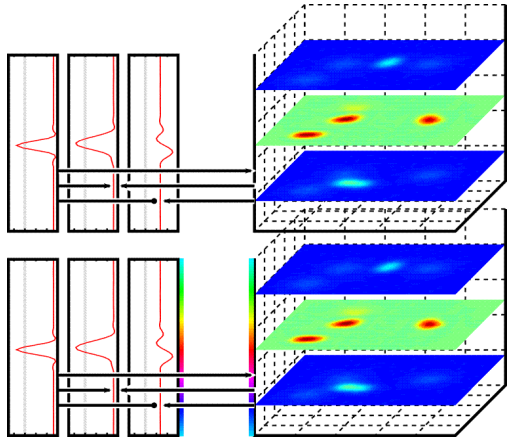






Outlook – immediate future

More features: easy to incorporate



Free scene description

Embodiment: head movements /robot arm movement

Outlook – near furture

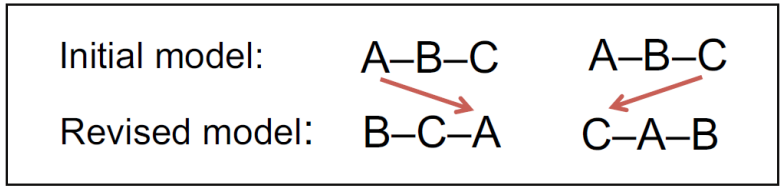
Near future

Build mental models from verbal data
Infer new things from that

requires spatial working memory

Relate to human data
(e.g., KnauffEtAl, 2013, Knauff, 2013)

Premise 1:	A is to the left of B
Premise 2:	B is to the left of C
Initial model:	A – B – C
Contradictory fact:	A is to the right of C
Revision alternative 1 [discard P1, retain P2]:	B – C – A
Revision alternative 2 [retain P1, discard P2]:	C – A – B



Outlook – well… future

Bootstrap to higher forms of non-spatial cognition?

Relational reasoning = core capability for higher cognition

HalfordEtAl2010

Reasoning may rely on space as a “canvas dimension”

Knauff2013

Working assumptions

limited number of basic operations, strung together flexibly
relatively limited number of basic concepts in LTM
LTM for complex scenes or episodes: control sequences
much is composed “on demand” in WM

Thanks for your attention!

Questions? Ideas? Discussion?