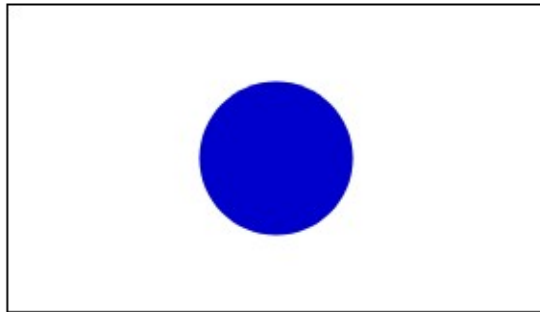
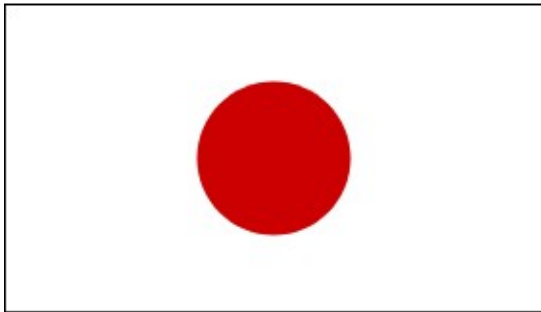
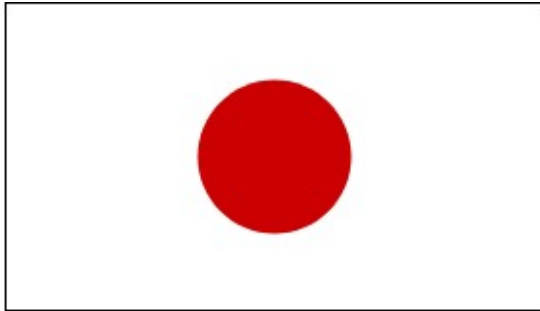
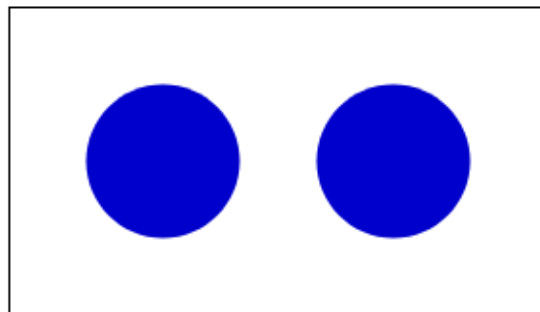
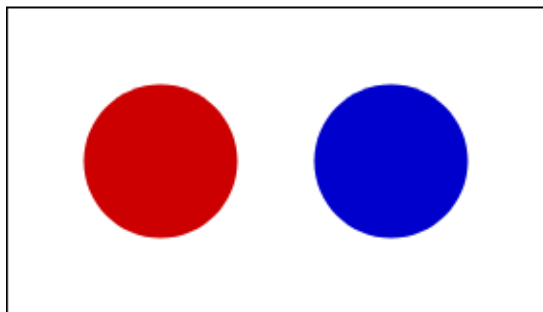
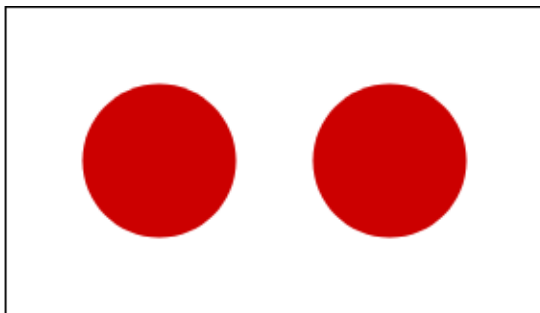


# An embodied account of visual analogical mapping

DFT summer school 2024  
Minseok Kang



match-to-sample task



Relational match-to-sample task

Analogy is a variant of **similarity** with a focus on **shared relations** while **disregarding misalignment** in feature values

# Similarity and categorization

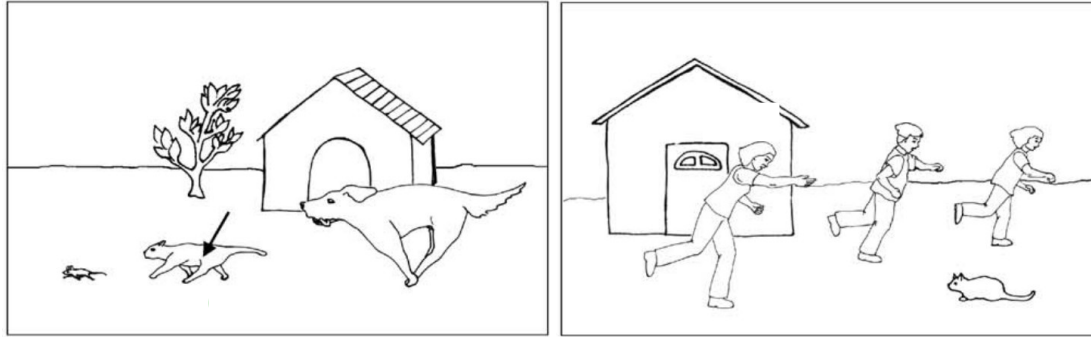
- “The triggering of prior mental categories by some kind of input is an act of analogy-making.... some amount of slippage must occur” (Hofstadter, 2006)
- “In general, we see that understanding a sentence involves finding the best match between what was spoken and our current mental state” (Feldman, 2008)

# Conceptual metaphor

- most of our concepts are understood in terms of other concepts (Lakoff & Johnson, 1980)
  - E.g. HAPPY is UP and SAD is DOWN
  - That boosted my spirits
  - My spirits rose
  - I'm feeling down
  - ...

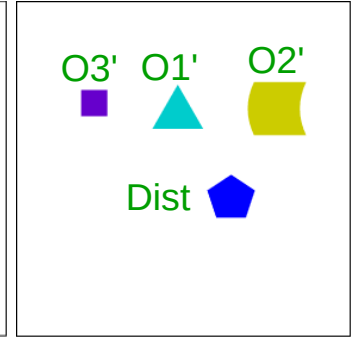
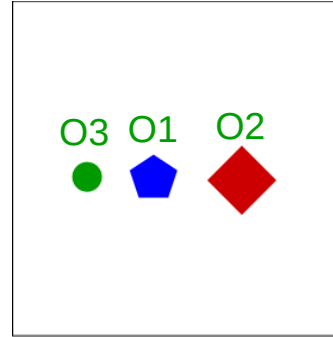
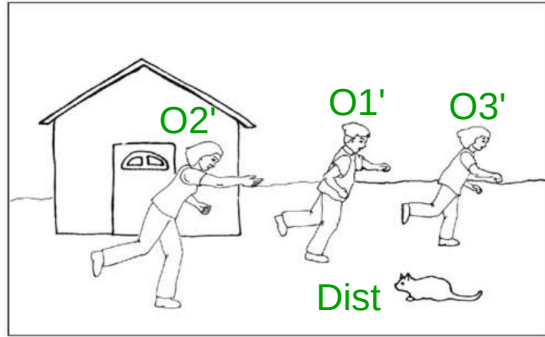
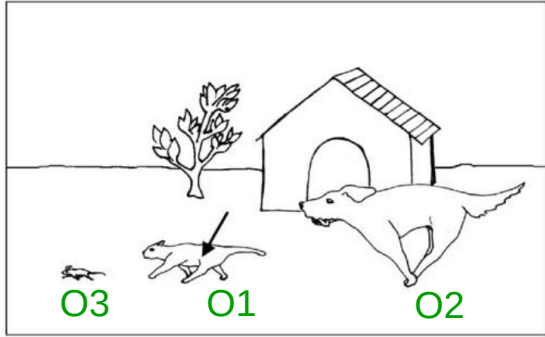
# Embodiment hypothesis

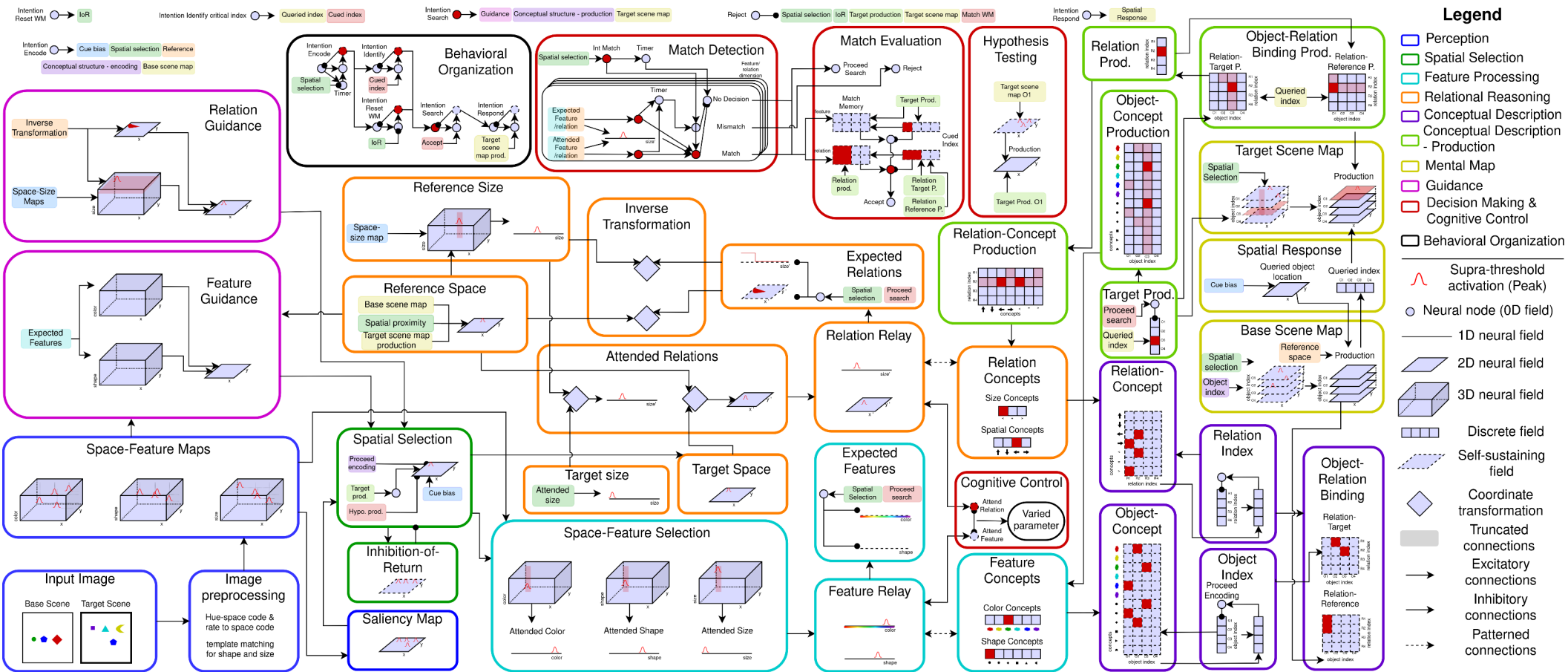
- “all cognition is like soccer playing”
- Explain how **higher-cognitive functions** emerge from sensori-motor operations
  - Visual attention
  - Relational reasoning
  - Conceptual structure
  - Mental mapping
  - ...

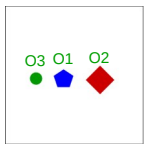


Richland et al. (2006)









Describing

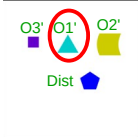
left-of (green, blue)  
right-of (red, blue)

Search

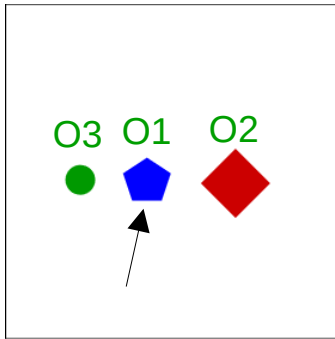
Decide matches

Generating spatial response

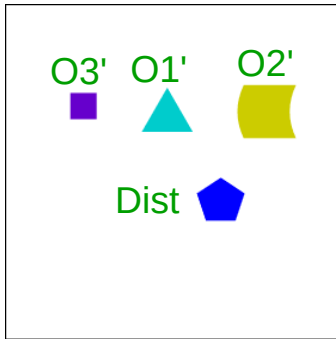
Rejecting the mapping



Base scene

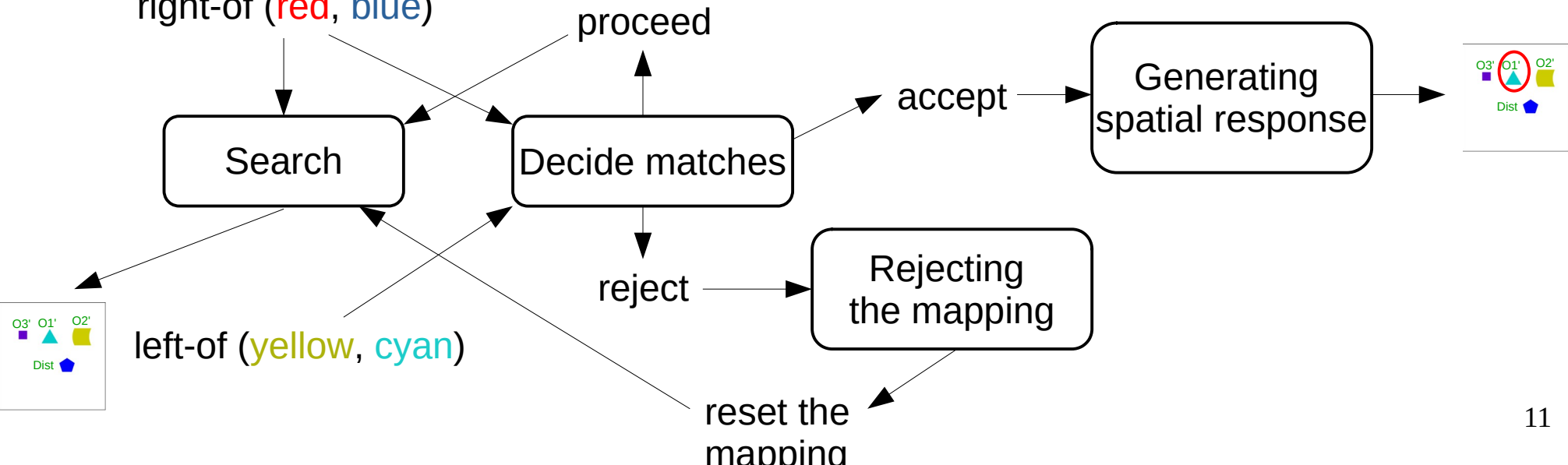
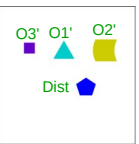


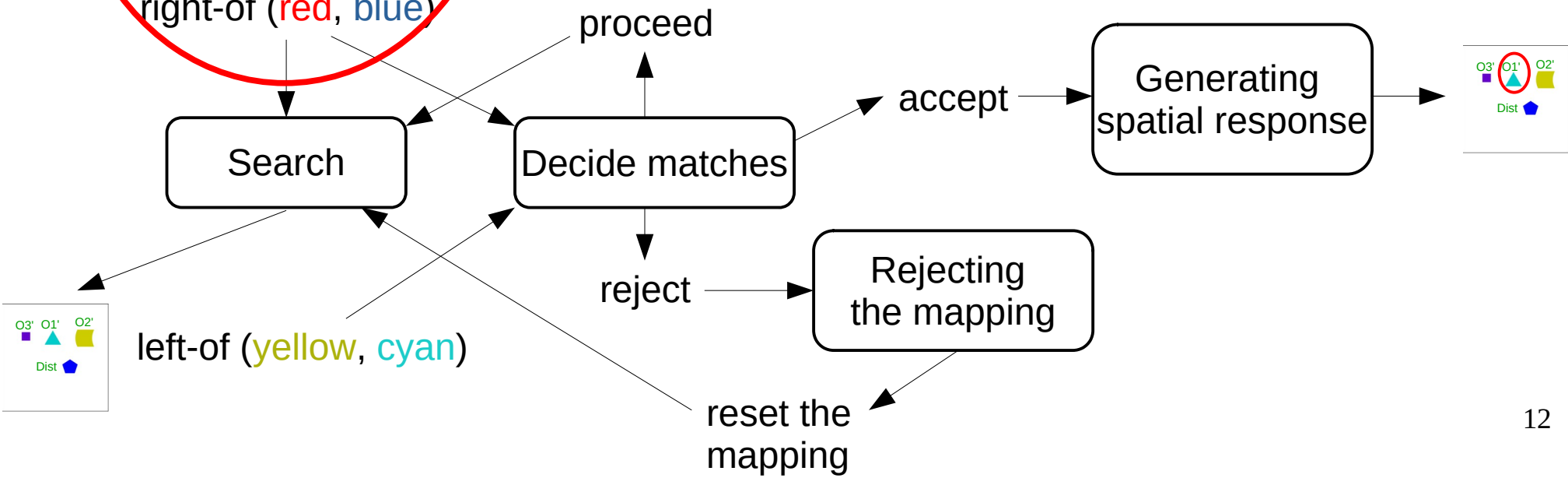
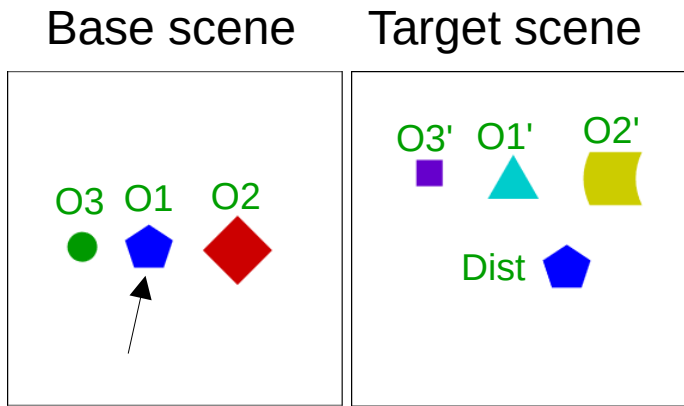
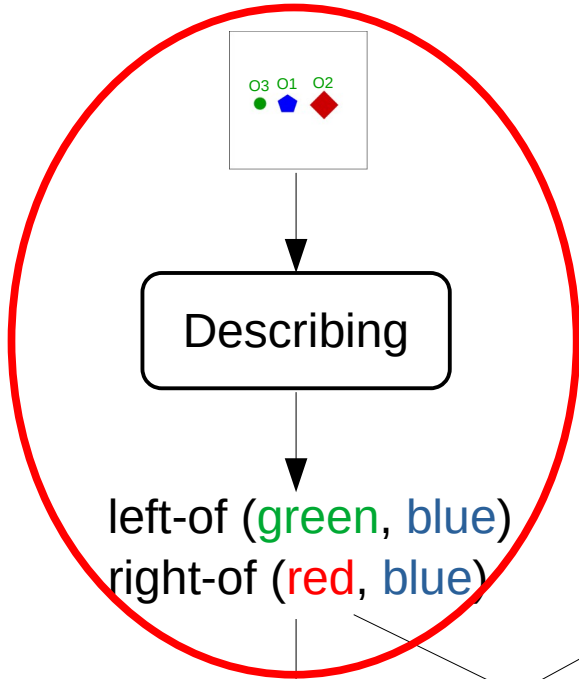
Target scene

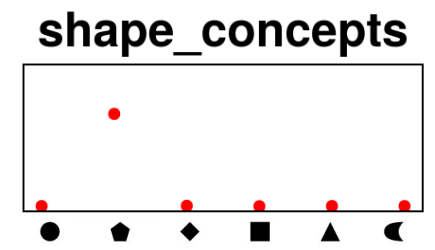
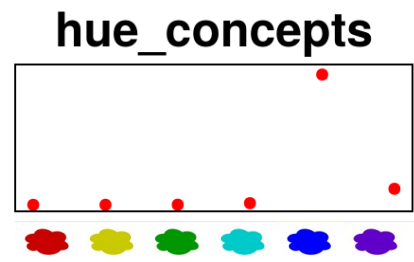
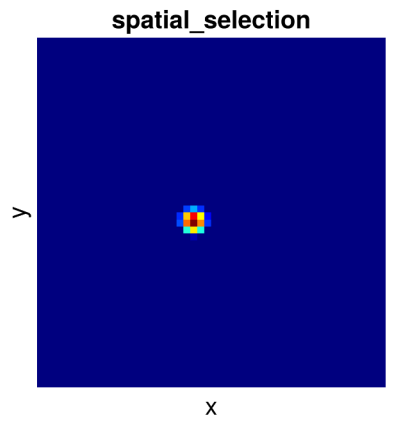
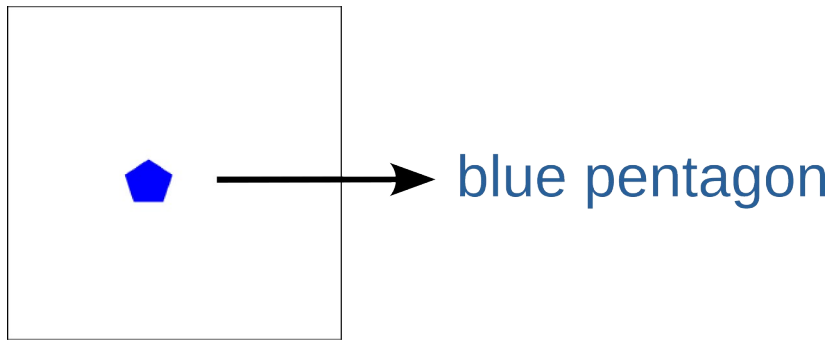
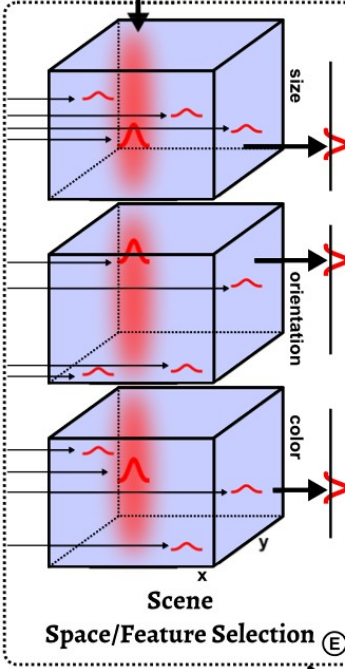
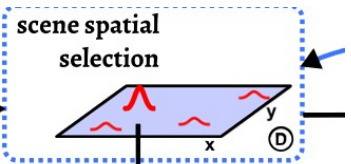


left-of (yellow, cyan)

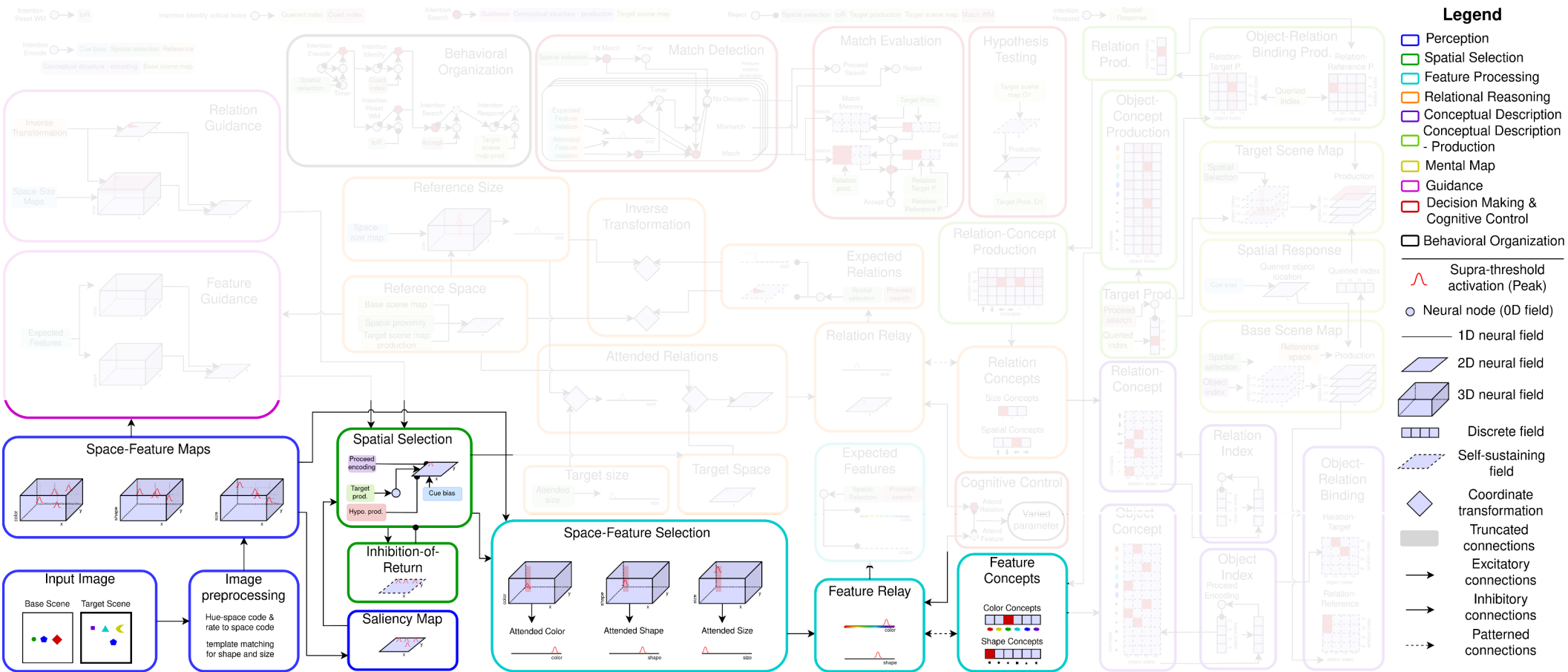
reset the mapping

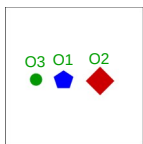






(Grieben et al., 2020)

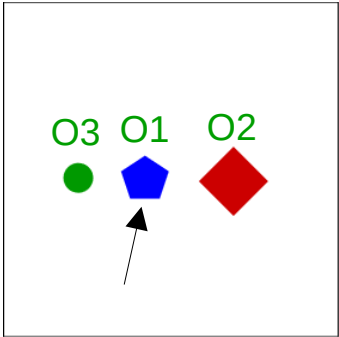




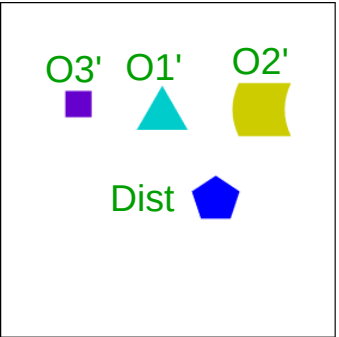
Describing

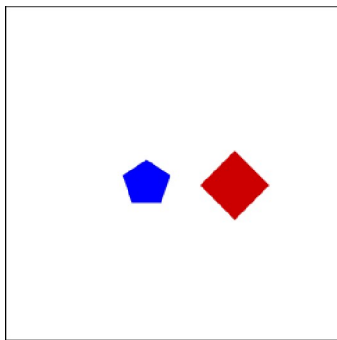
left-of (green, blue)  
right-of (red, blue)

Base scene

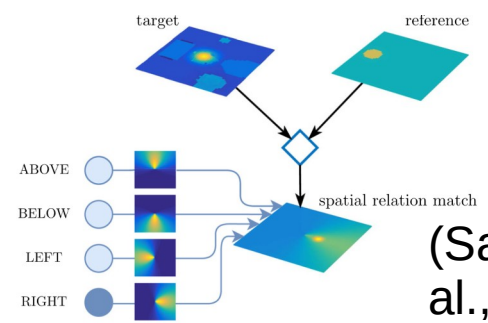


Target scene

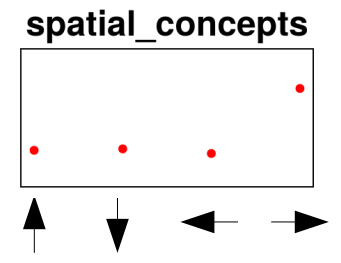
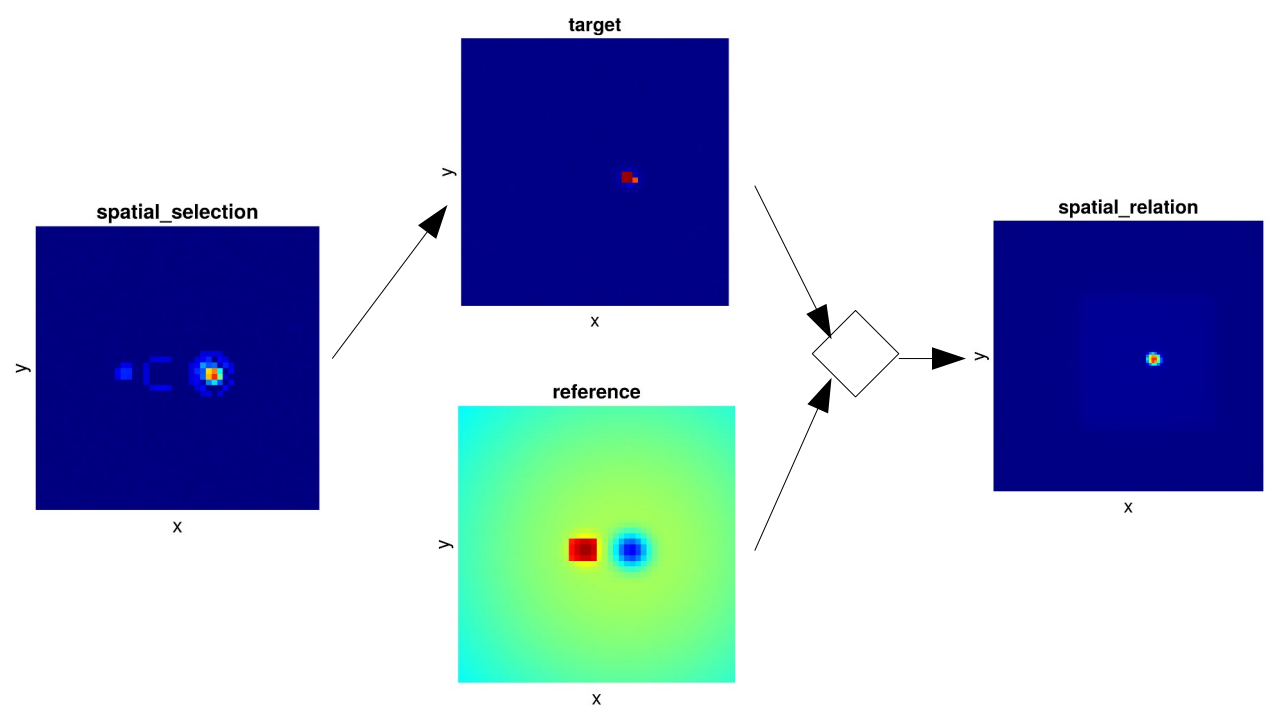




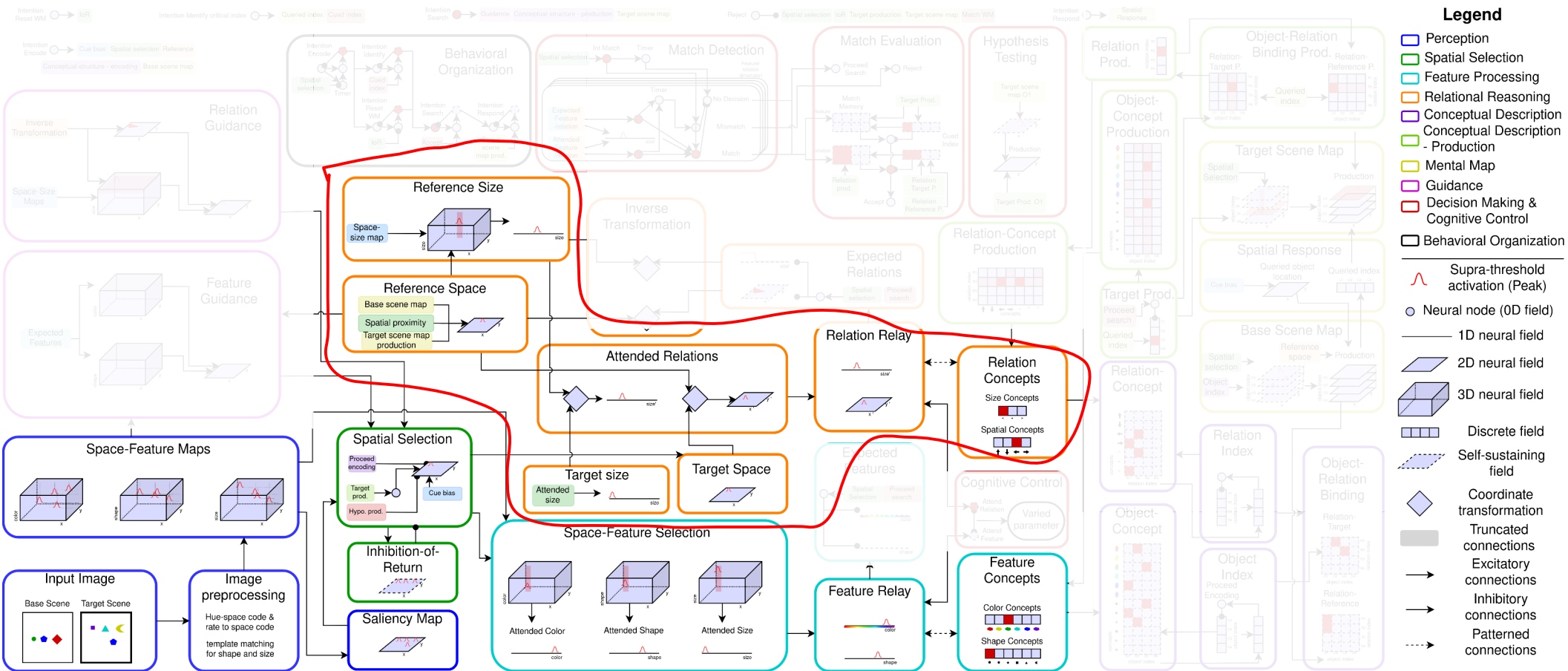
Right-of ( red diamond, blue pentagon)

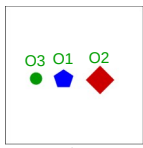


(Sabinasz et al., 2023)





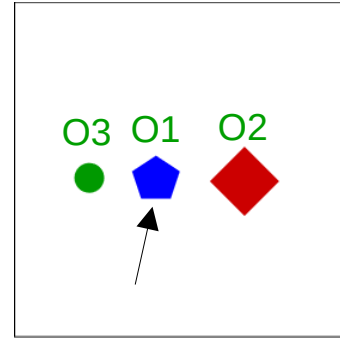




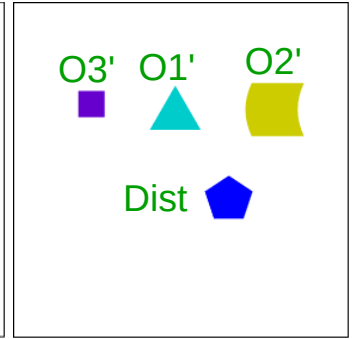
Describing

left-of (green, blue)  
right-of (red, blue)

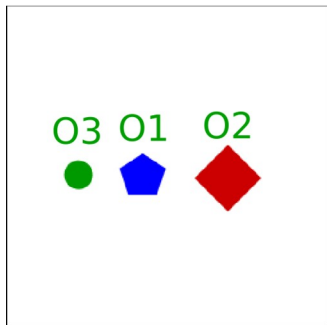
Base scene



Target scene



Base scene



Right-of (red diamond, blue pentagon)  
Left-of (green circle, blue pentagon)

blue pentagon - O1  
red diamond - O2  
green circle - O3

Right-of - R1  
Left-of - R2

R1 - (O1 - Ref.) - (O2 - Tar.)  
R2 - (O1 - Ref.) - (O3 - Tar.)

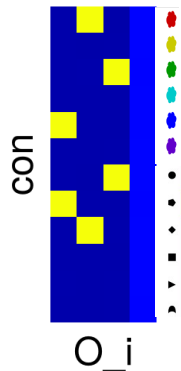
object\_index



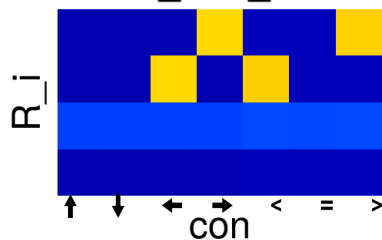
relation\_index



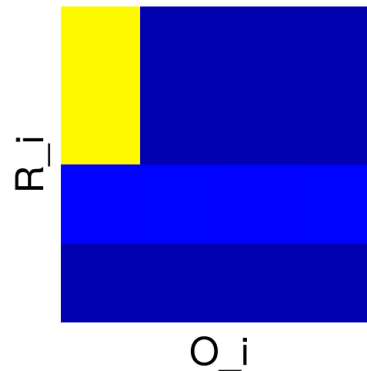
fea\_con\_ind



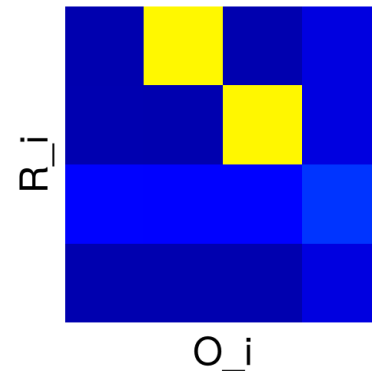
rel\_con\_ind



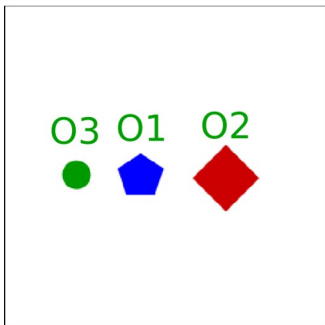
fea\_rel\_ref



fea\_rel\_tar



Base scene



Right-of ( red diamond, blue pentagon)  
 Left-of (green circle, blue pentagon)

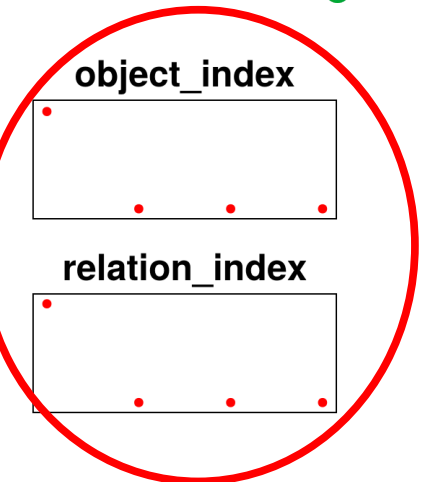
blue pentagon - O1  
 red diamond - O2  
 green circle - O3

Right-of - R1

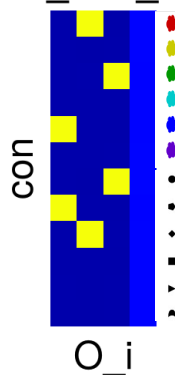
R1 - (O1 - Ref.) - (O2 - Tar.)

Left-of - R2

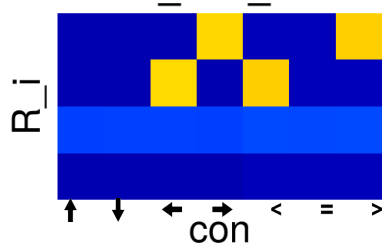
R2 - (O1 - Ref.) - (O3 - Tar.)



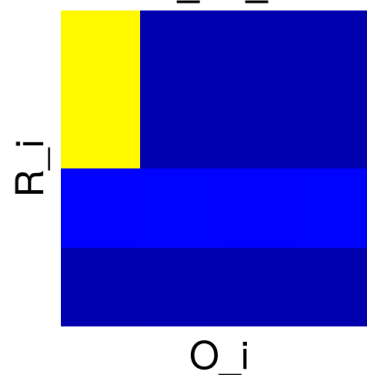
fea\_con\_ind



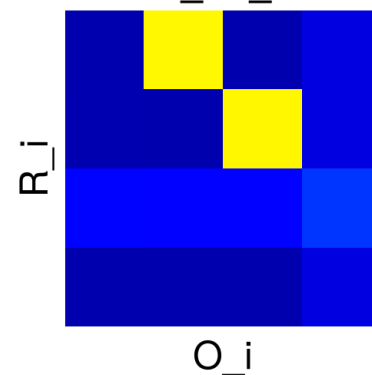
rel\_con\_ind



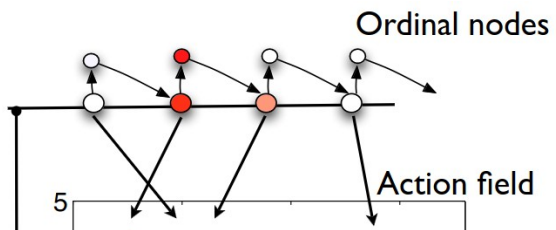
fea\_rel\_ref



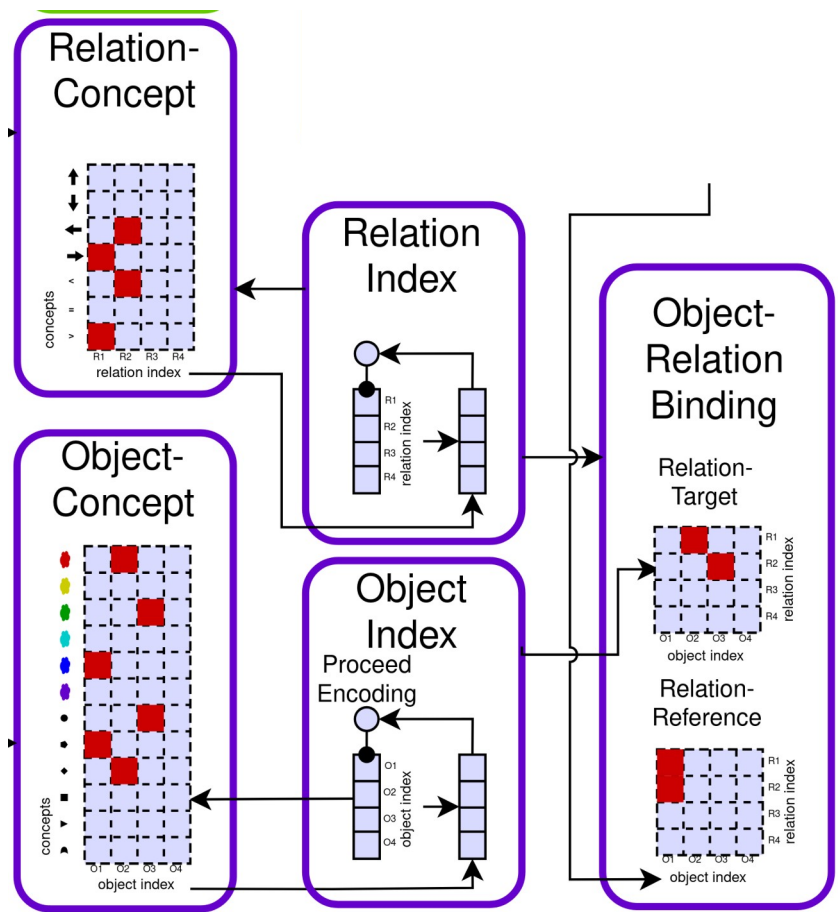
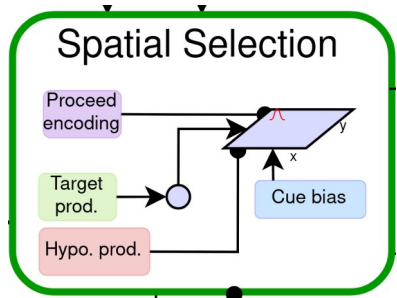
fea\_rel\_tar



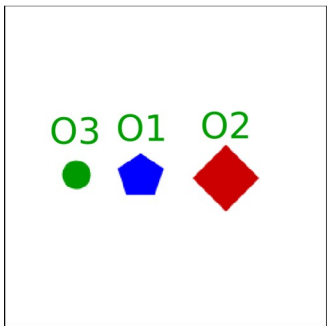
# Autonomous generation of ordinal values



(Sandamirskaya et al., 2010)



Base scene



Right-of ( red diamond, blue pentagon)  
 Left-of (green circle, blue pentagon)

blue pentagon - O1  
 red diamond - O2  
 green circle - O3

Right-of - R1  
 Left-of - R2

R1 - (O1 - Ref.) - (O2 - Tar.)  
 R2 - (O1 - Ref.) - (O3 - Tar.)

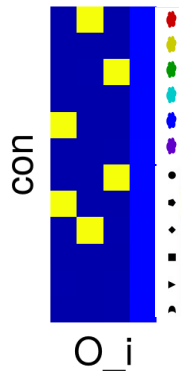
object\_index



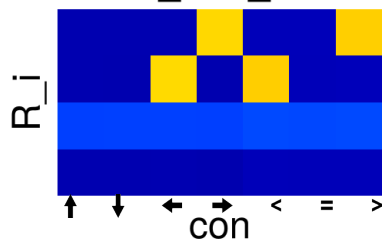
relation\_index



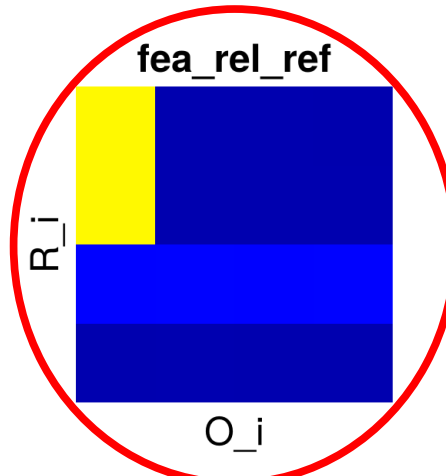
fea\_con\_ind



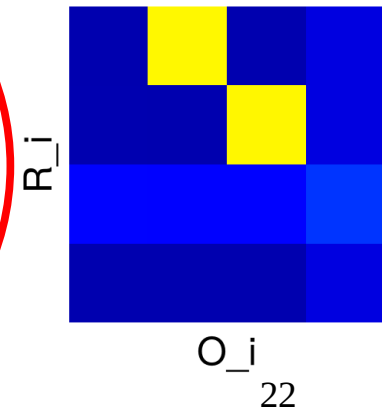
rel\_con\_ind



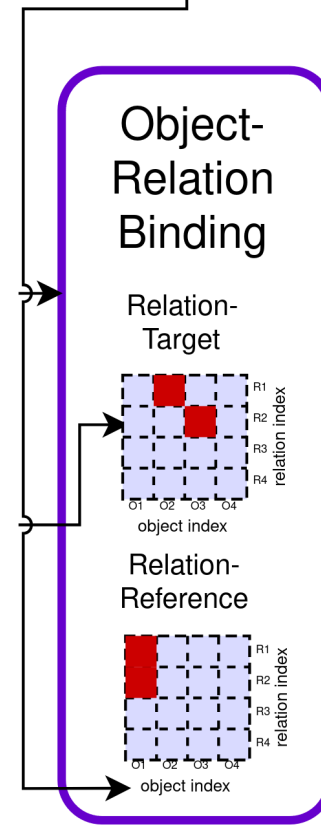
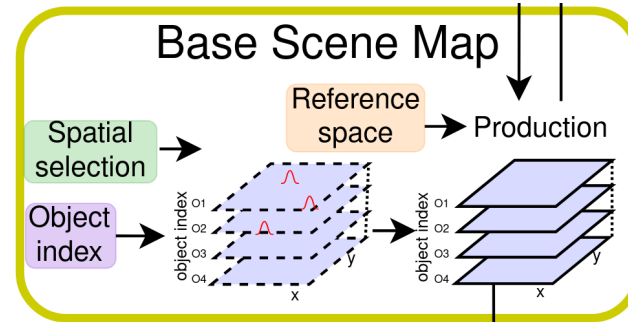
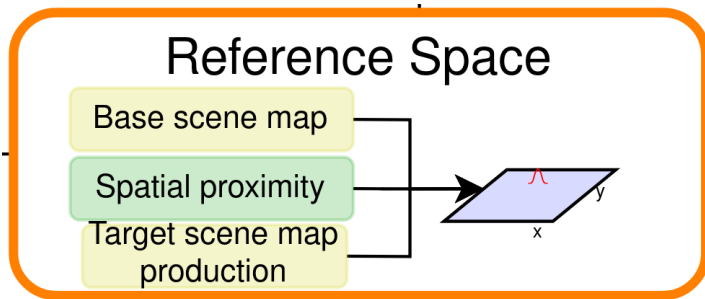
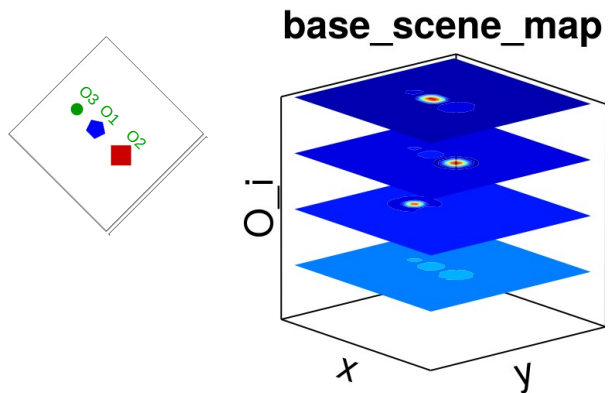
fea\_rel\_ref

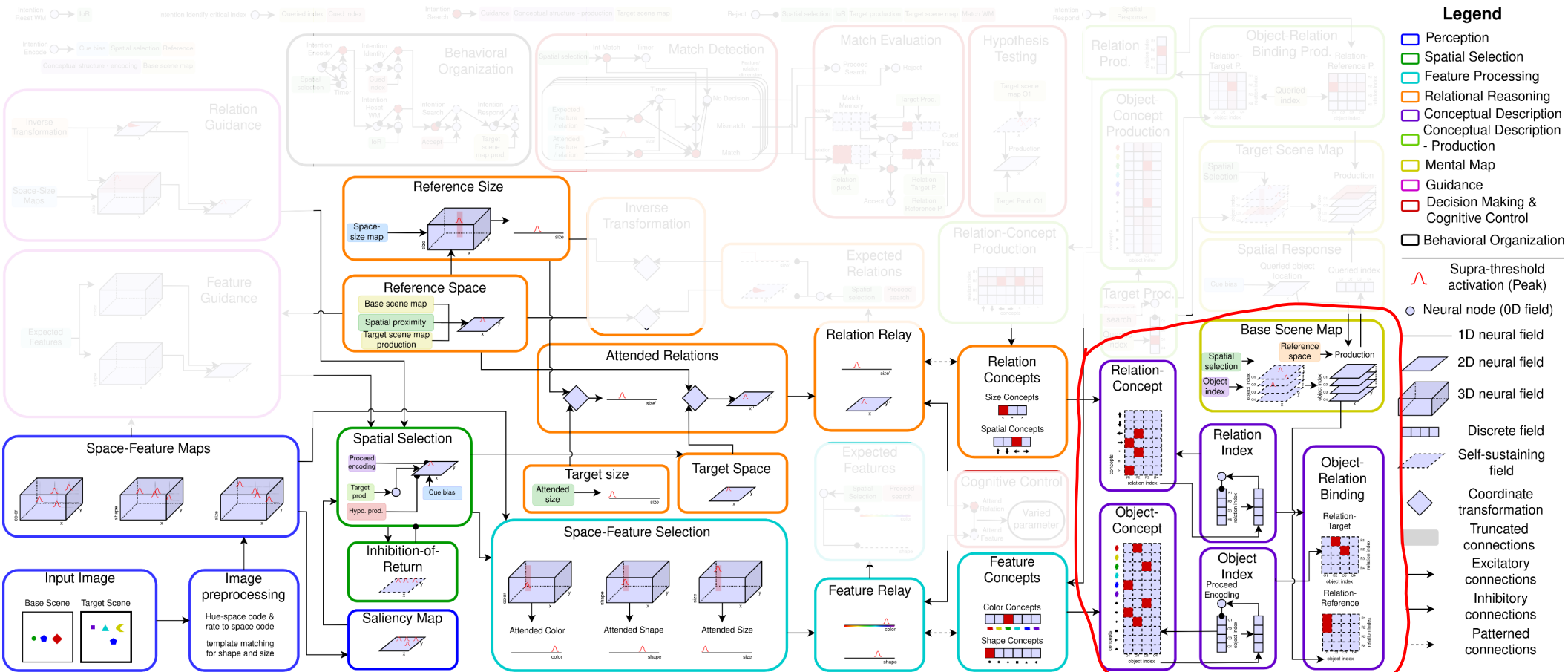


fea\_rel\_tar

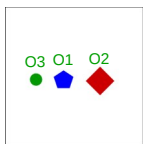


# Selection of reference object





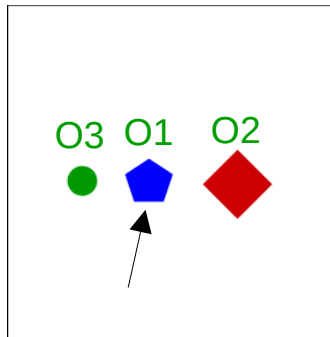




Describing

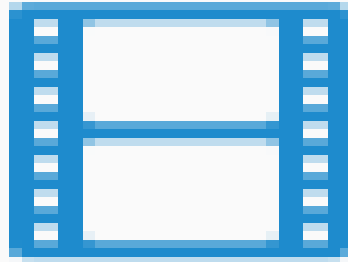
left-of (green, blue)  
right-of (red, blue)

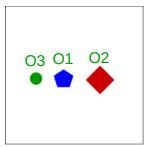
Base scene



Target scene

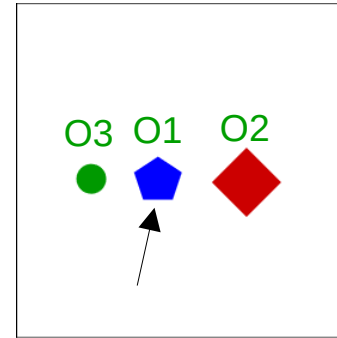




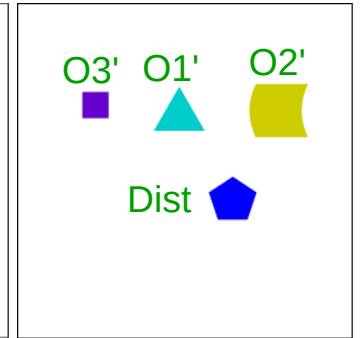


Describing

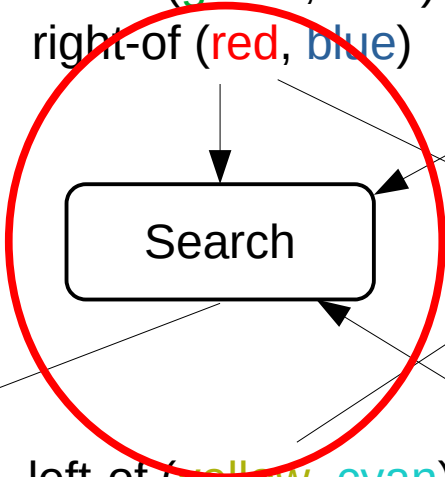
Base scene



Target scene



left-of (green, blue)  
right-of (red, blue)



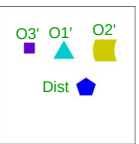
Search

Decide matches

Generating spatial response



Rejecting the mapping



left-of (yellow, cyan)

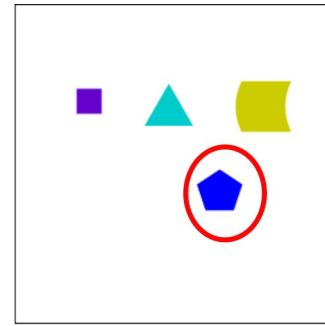
proceed

accept

reject

reset the mapping

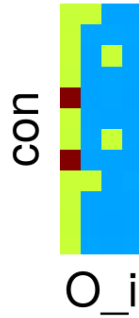
blue pentagon



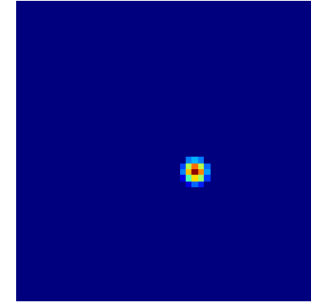
target\_index



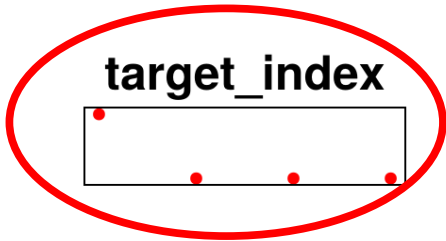
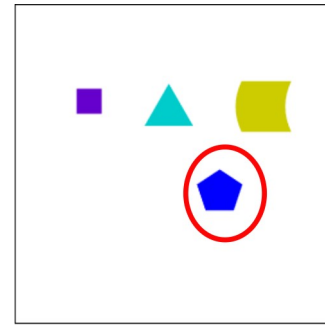
fea\_con\_ind



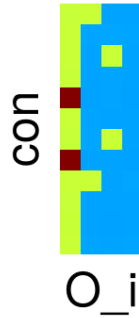
spatial\_selection



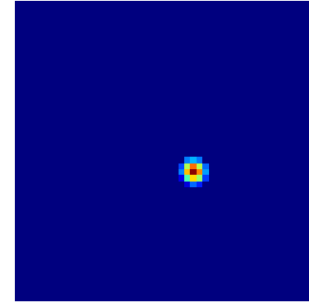
blue pentagon



fea\_con\_ind



spatial\_selection

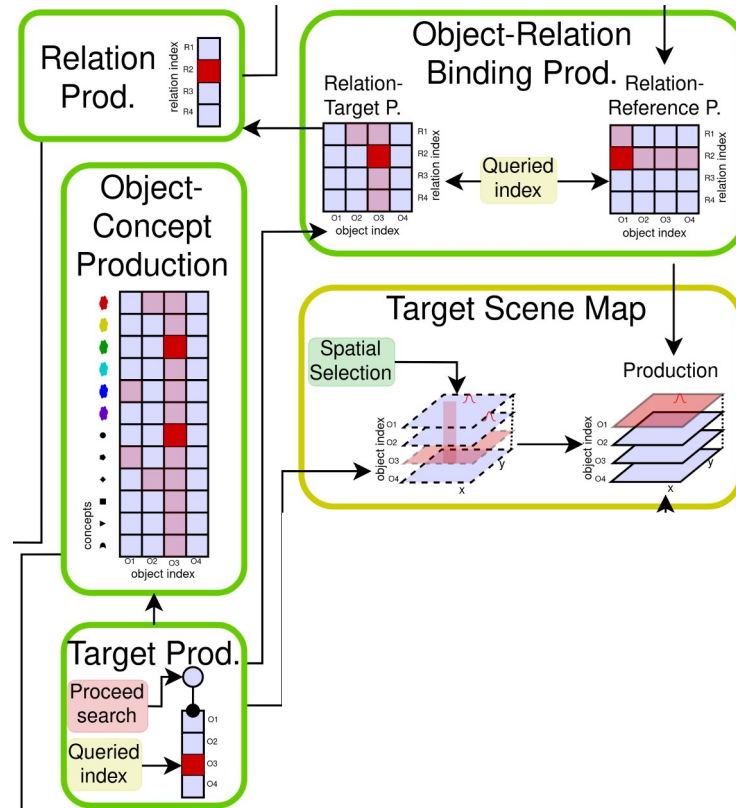


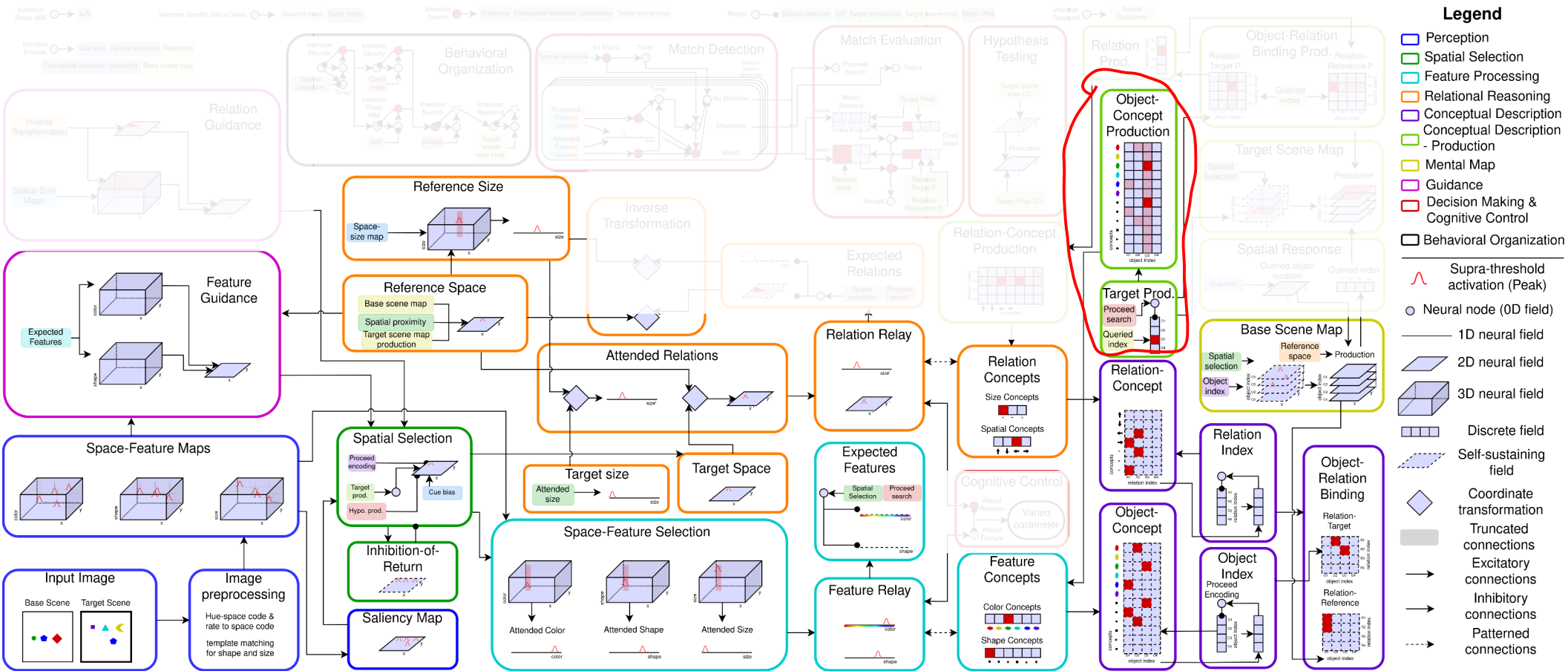
# Sequential selection of the description to guide the search

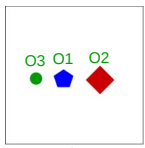
- blue pentagon - O1
- red diamond - O2
- green circle - O3

Right-of - R1  
Left-of - R2

R1 - (O1 - Ref.) - (O2- Tar.)  
R2 - (O1 - Ref.) - (O3- Tar.)







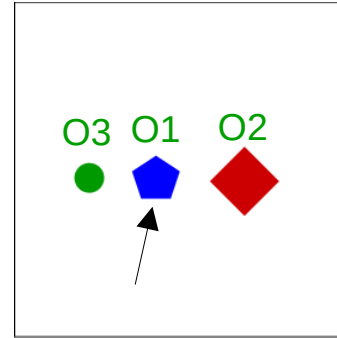
Describing

left-of (green, blue)  
right-of (red, blue)

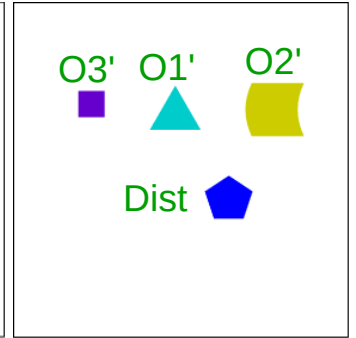
Search



Base scene

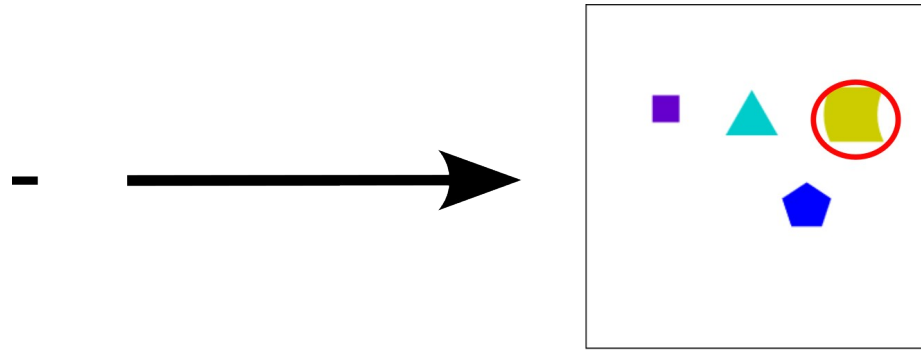


Target scene





Analogy is a variant of similarity with a **focus on shared relations** while disregarding misalignment in feature values



**expected\_hue**



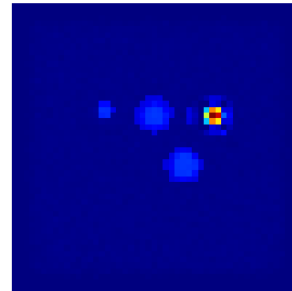
**expected\_shape**



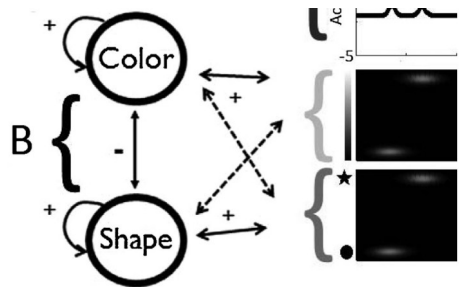
**feature\_guidance**



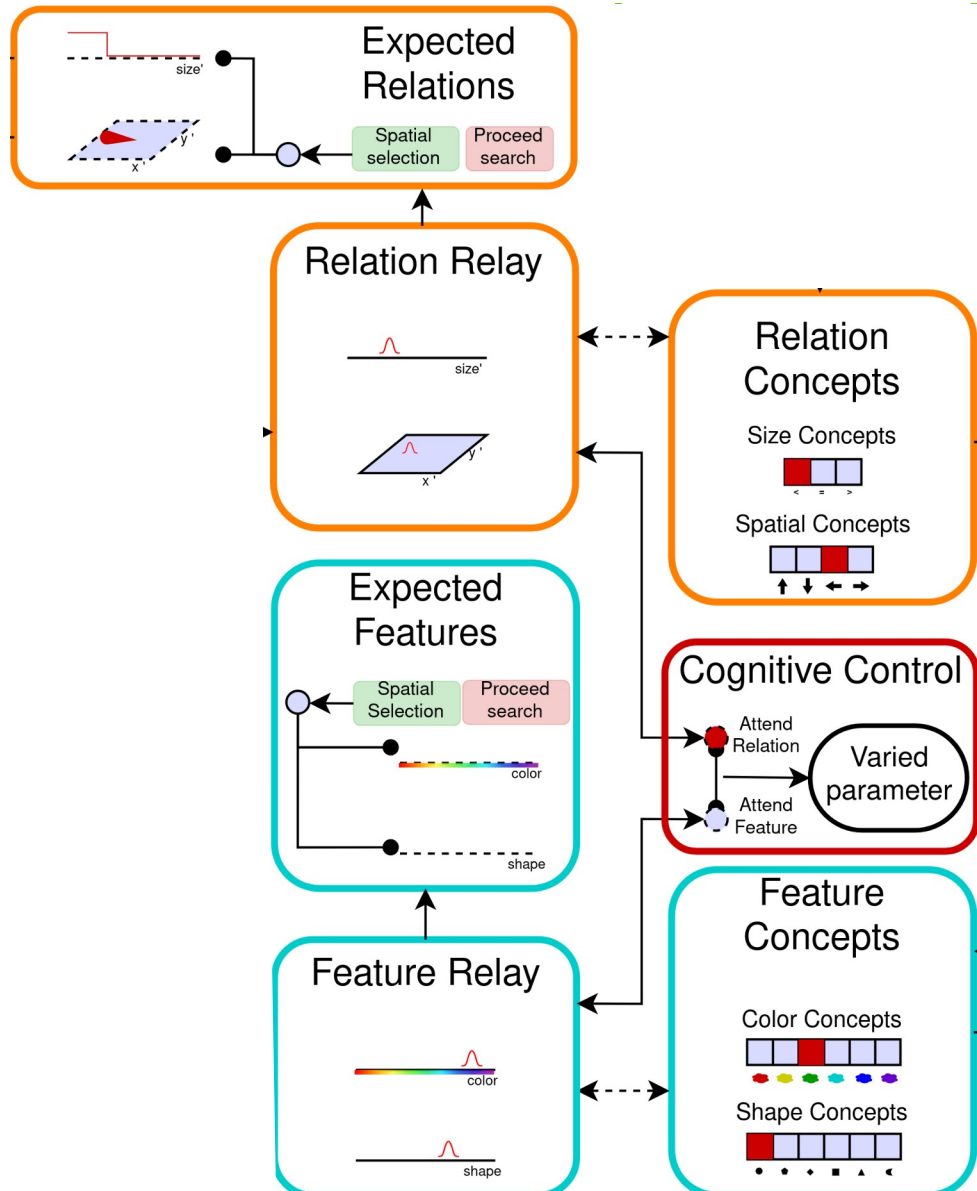
**spatial\_selection**

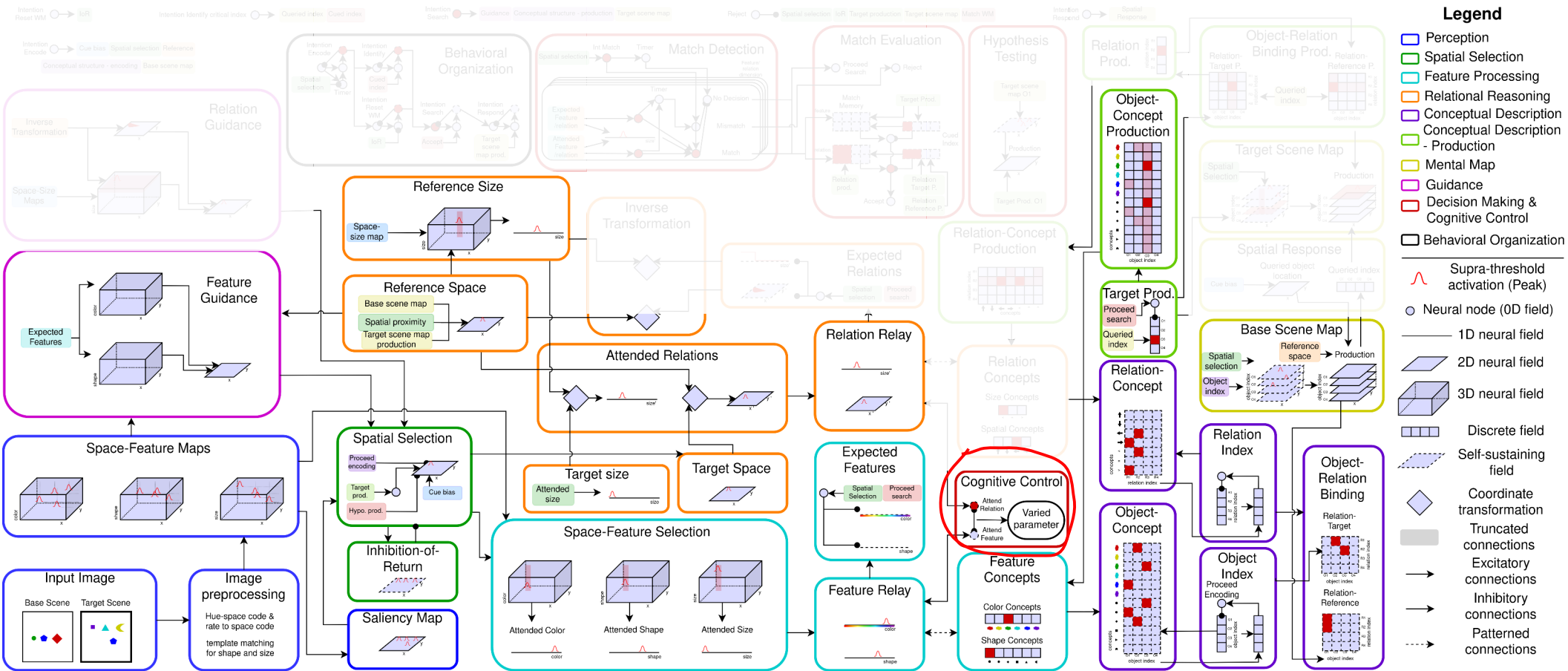


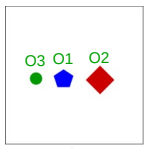
# Cognitive control of guidance



Buss, A. T., & Spencer, J. P. (2014)



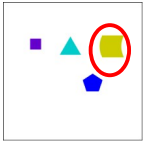




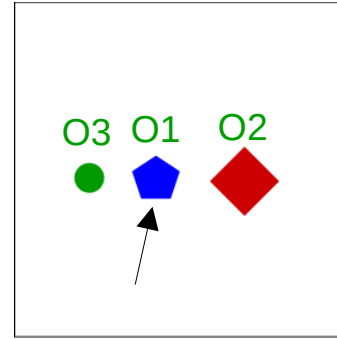
Describing

left-of (green, blue)  
right-of (red, blue)

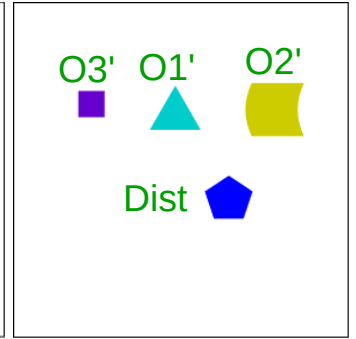
Search

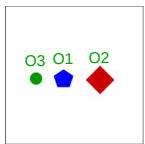


Base scene



Target scene

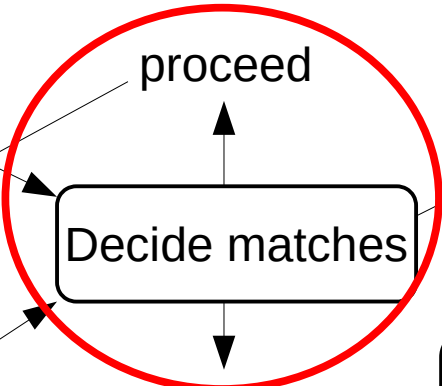




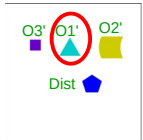
Describing

left-of (green, blue)  
right-of (red, blue)

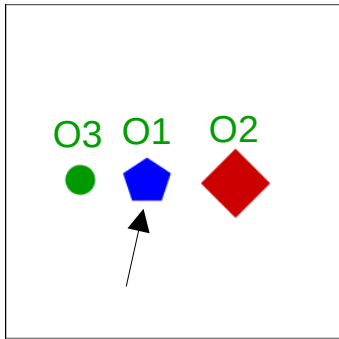
Search



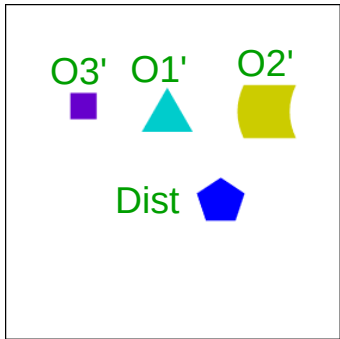
Generating spatial response



Base scene



Target scene



left-of (yellow, cyan)

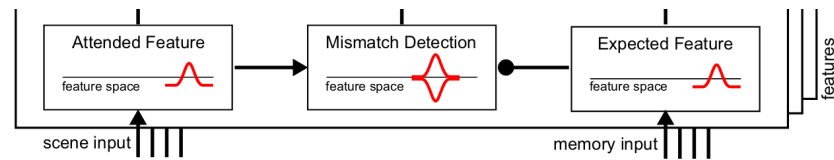
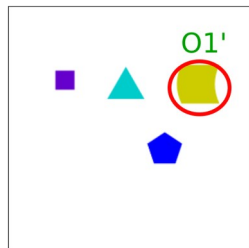
Rejecting the mapping

reset the mapping

blue pentagon

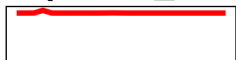


→ proceed



(Grieben et al., 2020)

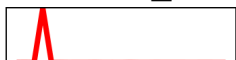
expected\_hue



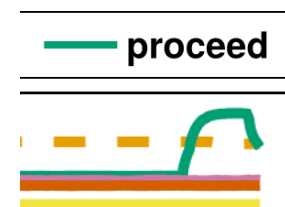
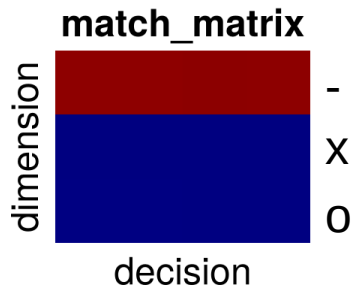
expected\_shape



attended\_hue



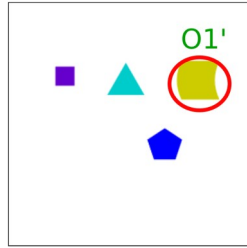
attended\_shape



blue pentagon



→ proceed



expected\_hue



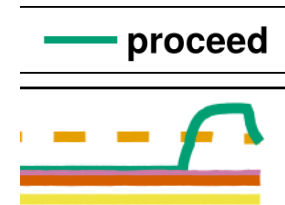
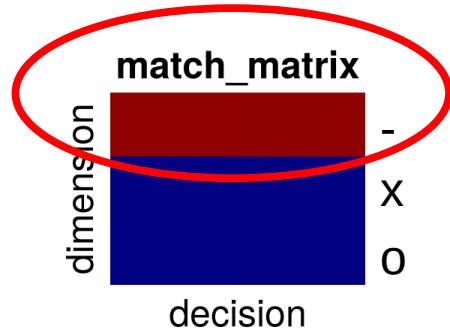
expected\_shape



attended\_hue

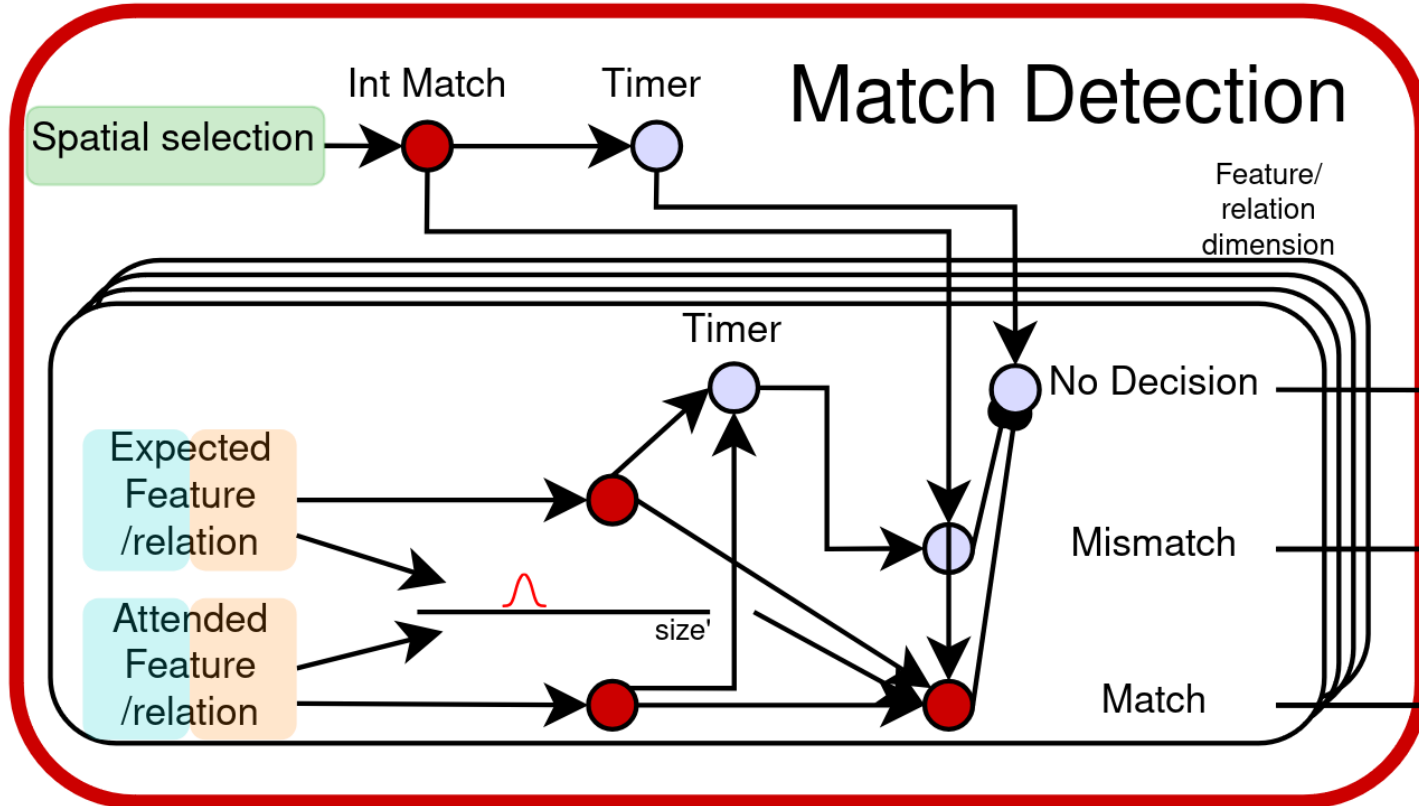


attended\_shape

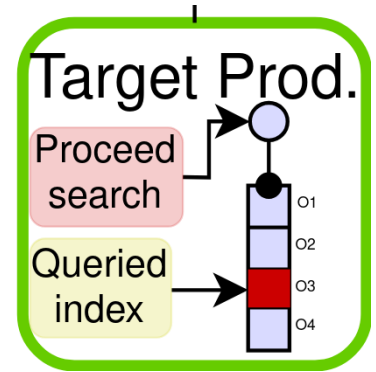
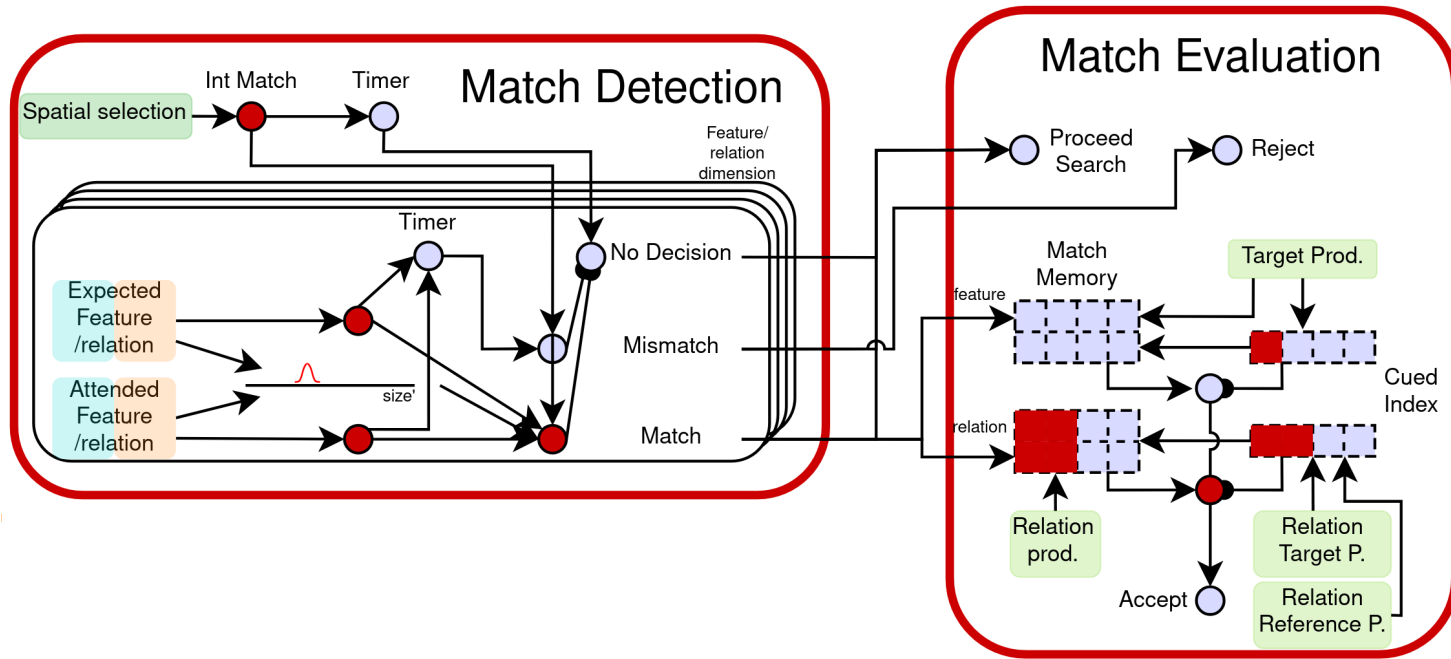


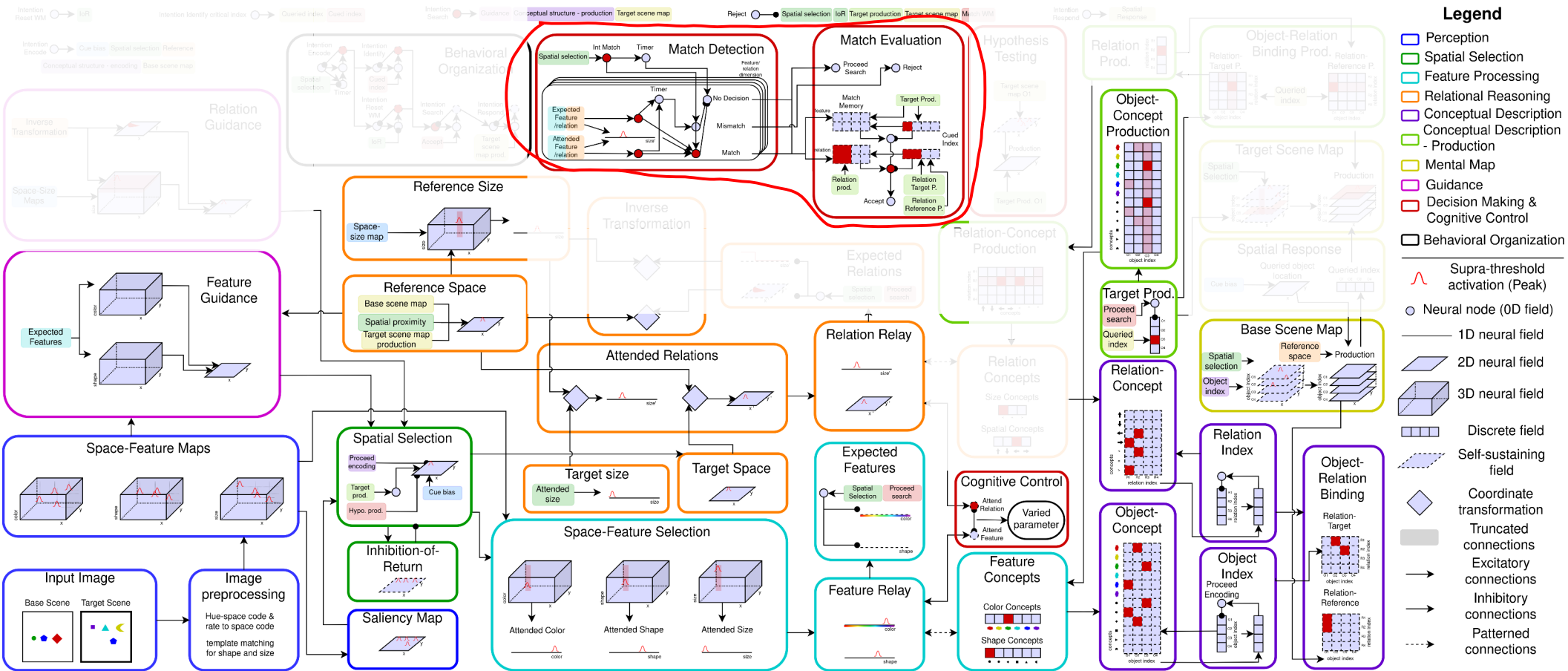


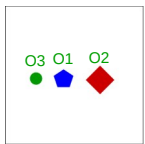
# Detecting cases of absent expected dimensions



# Deciding what to do next – keep on searching







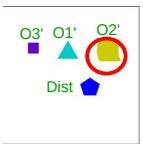
Describing

right-of (red, blue)  
left-of (green, blue)

Search

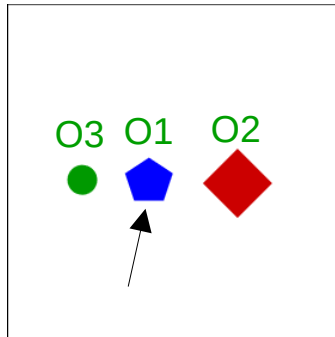
Decide matches

proceed



yellow

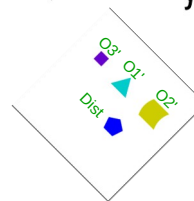
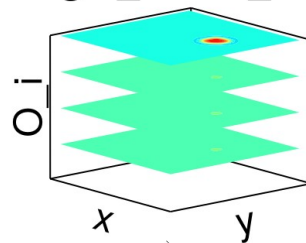
Base scene



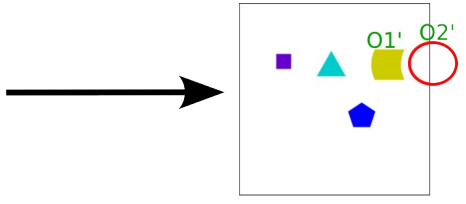
Target scene



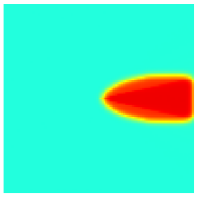
target\_scene\_map



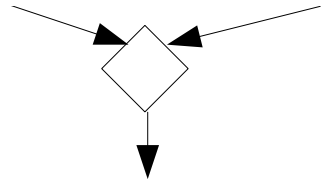
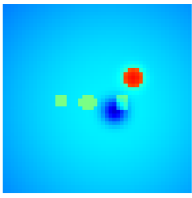
Right-of (red diamond, blue pentagon)



expected\_spatial



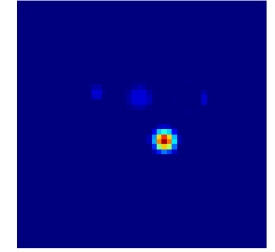
reference



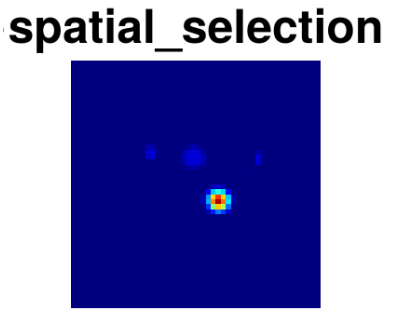
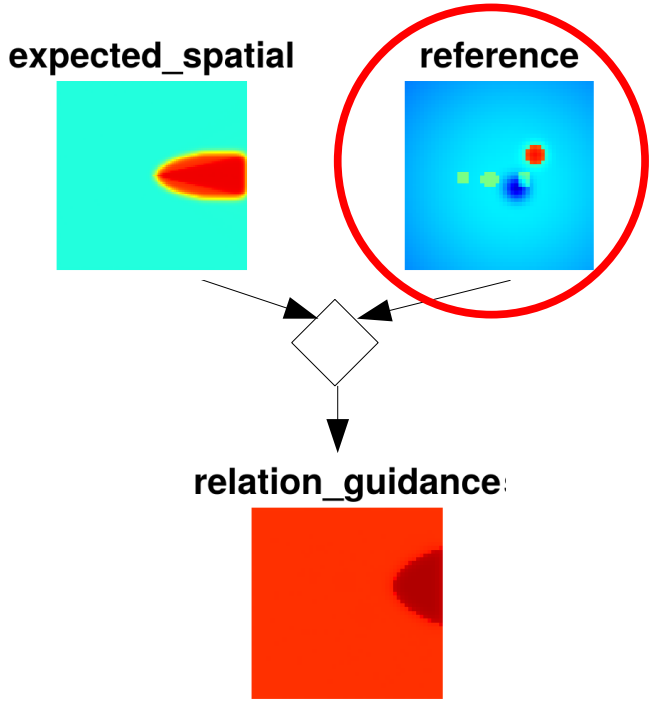
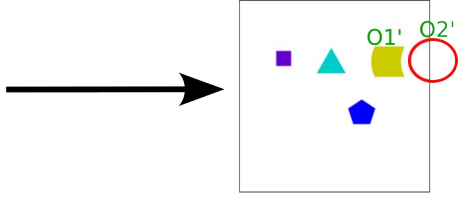
relation\_guidance:



spatial\_selection



Right-of (red diamond, blue pentagon)



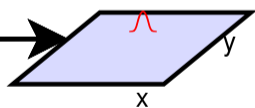
Retrieve the spatial location of the reference object

## Reference Space

Base scene map

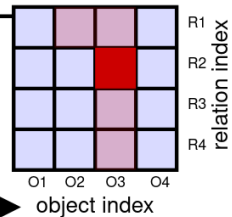
Spatial proximity

Target scene map  
production



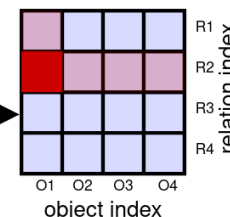
## Object-Relation Binding Prod.

Relation-  
Target P.



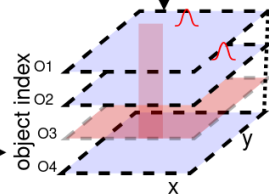
Queried  
index

Relation-  
Reference P.

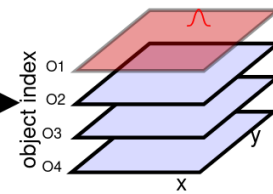


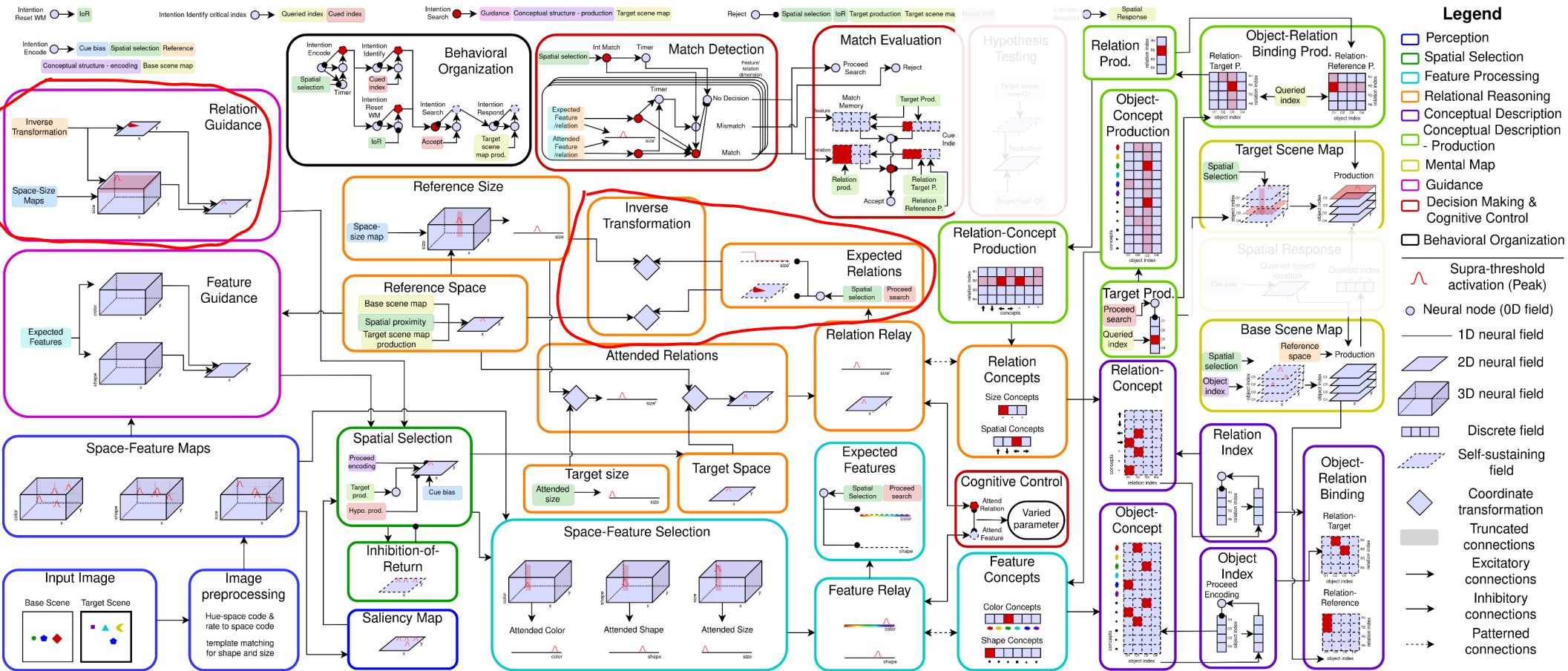
## Target Scene Map

Spatial  
Selection

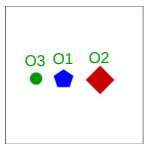


Production





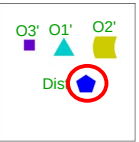




Describing

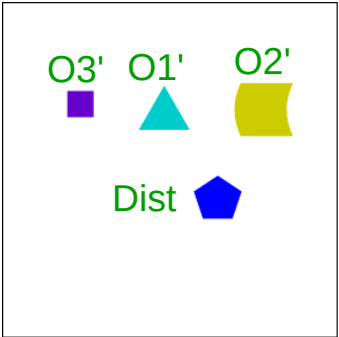
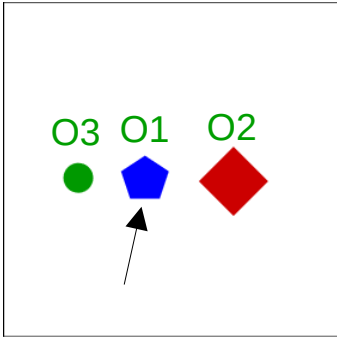
right-of (red, blue)  
left-of (green, blue)

Search

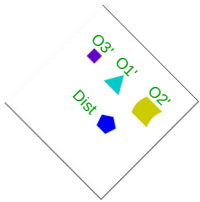
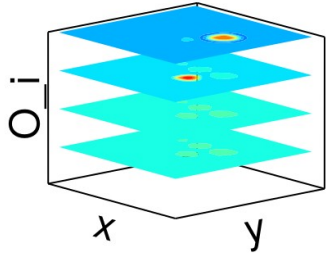


Base scene

Target scene



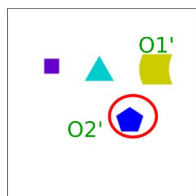
target\_scene\_map



right-of(O2,O1)



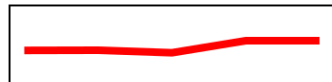
reject



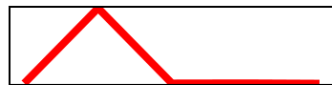
target\_index



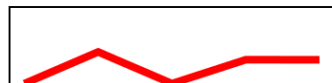
expected\_size



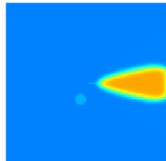
size\_relation



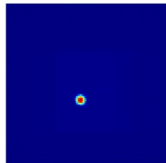
match\_size



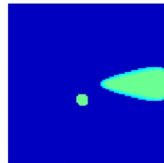
expected\_spatial



spatial\_relation



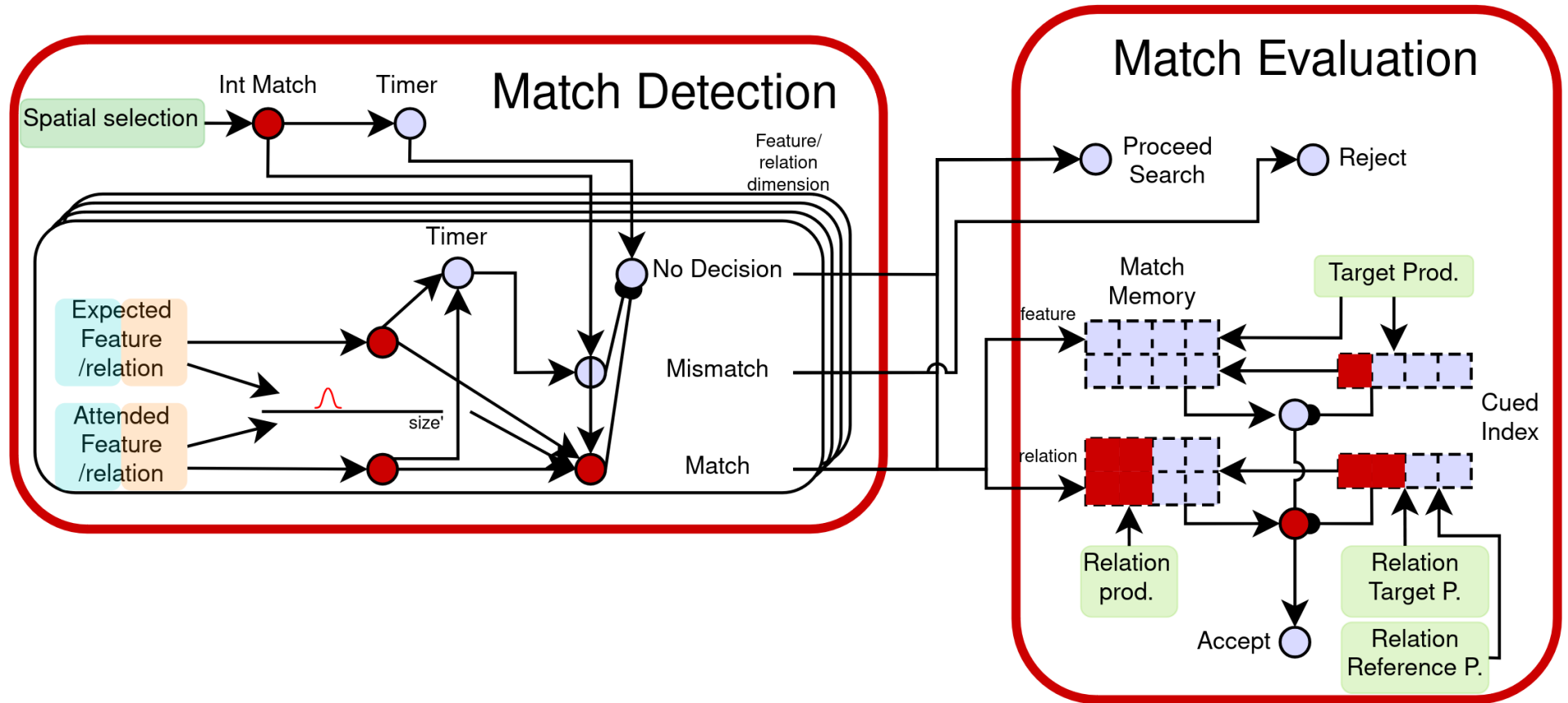
match\_spatial

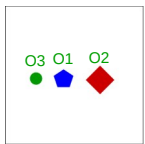


match\_matrix



# Rejecting a hypothesis





Describing

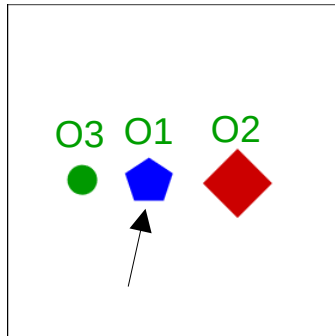
right-of (red, blue)  
left-of (green, blue)

Search

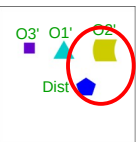
Decide matches

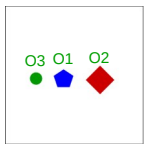
reject

Base scene



Target scene





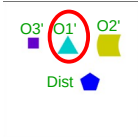
Describing

left-of (green, blue)  
right-of (red, blue)

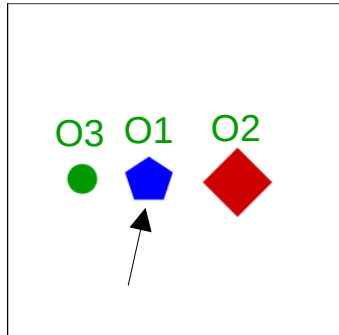
Search

Decide matches

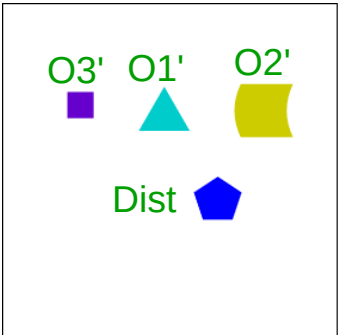
Generating spatial response



Base scene



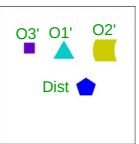
Target scene

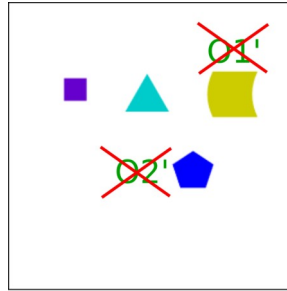


left-of (yellow, cyan)

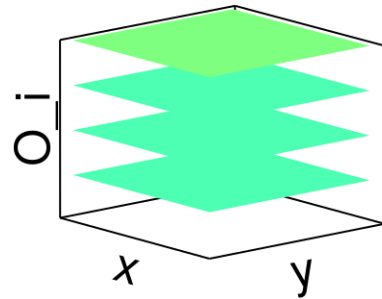
Rejecting the mapping

reset the mapping

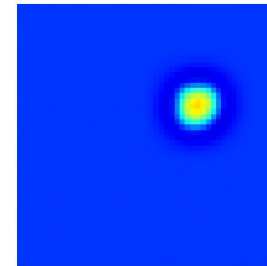




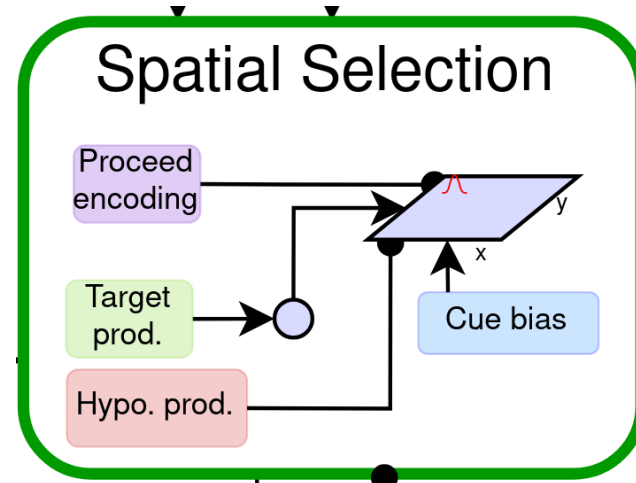
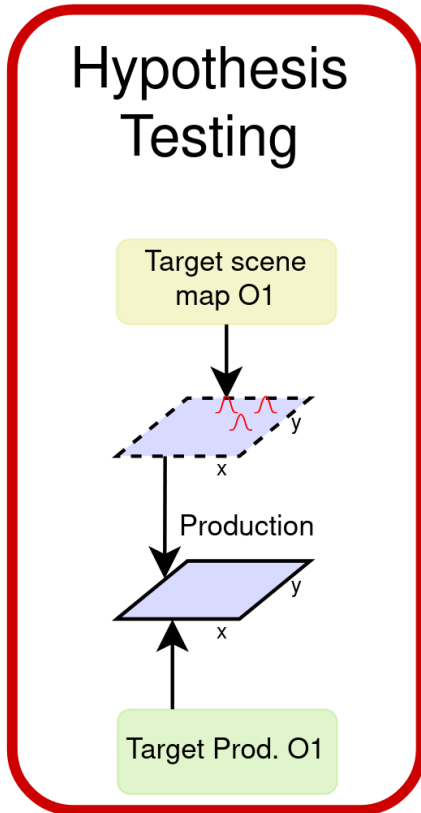
target\_scene\_map

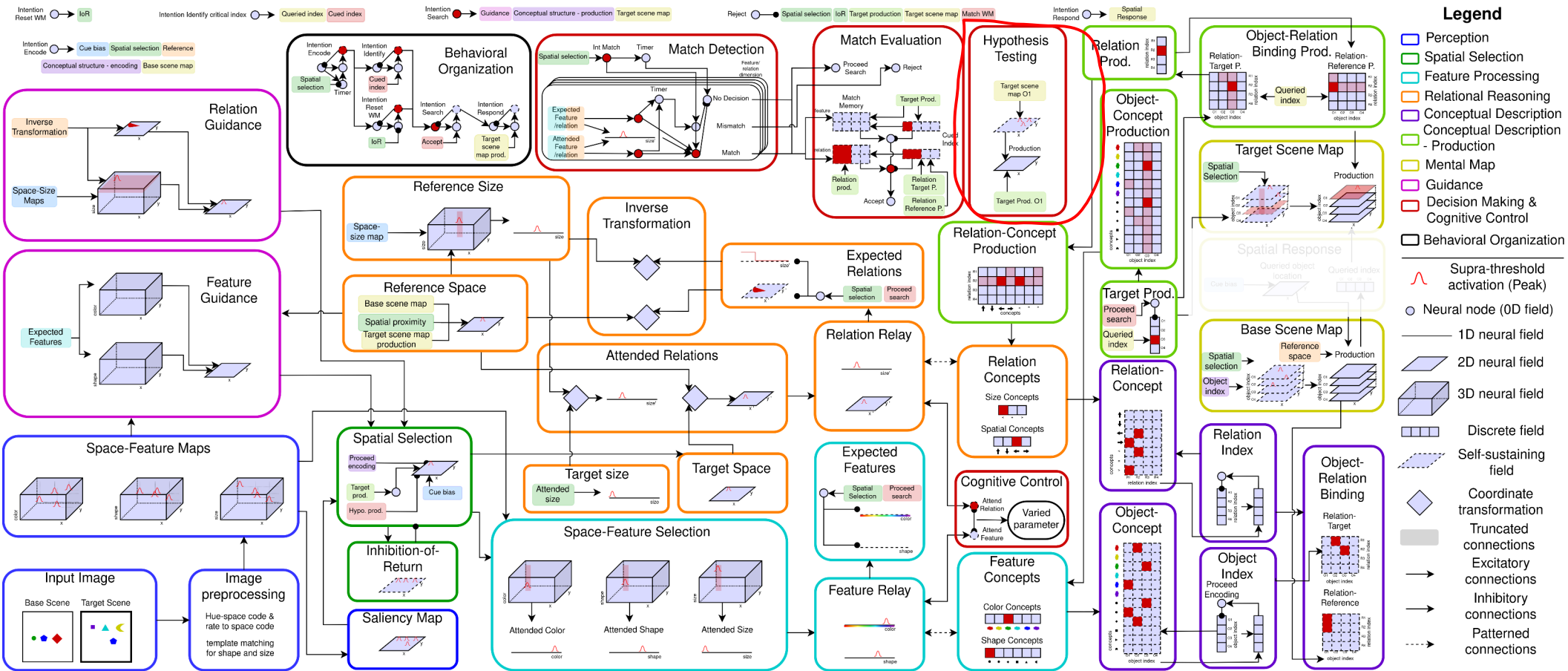


hypotheses\_O1

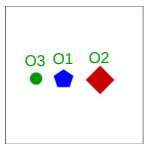


# Keep track of hypotheses in a limited way









Describing

right-of (red, blue)  
left-of (green, blue)

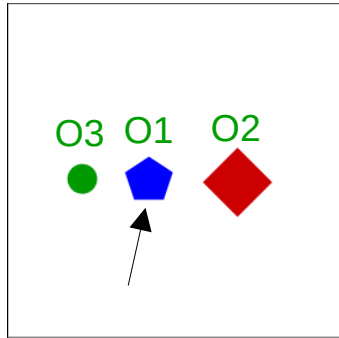
Search

Decide matches

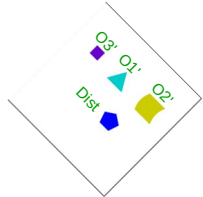
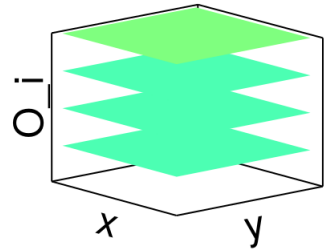
Rejecting the mapping

Base scene

Target scene



target\_scene\_map

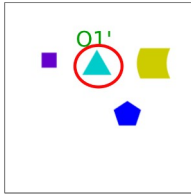


reset the mapping

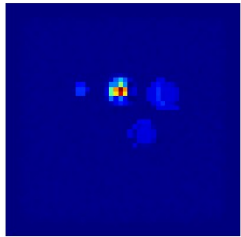
blue pentagon



proceed



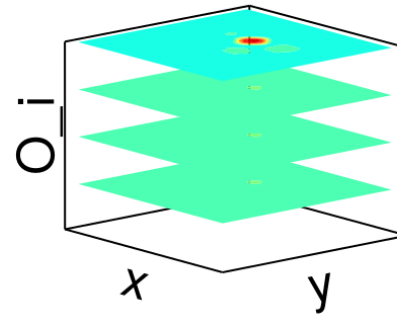
spatial\_selection



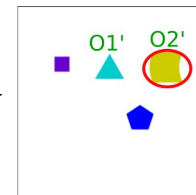
match\_matrix



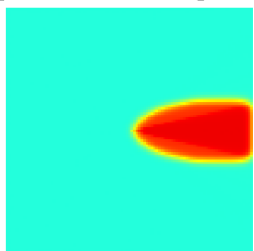
target\_scene\_map



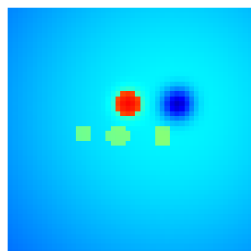
Right-of ( red diamond, blue pentagon)



expected\_spatial



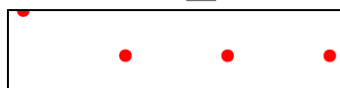
reference



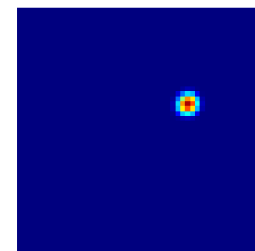
target\_index



relation\_index



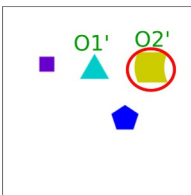
relation\_guidancespatial\_selection



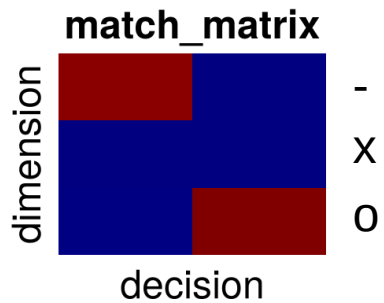
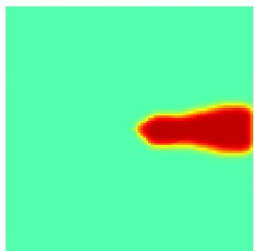
right-of(O2,O1)



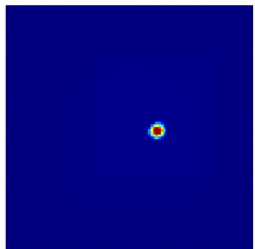
→ proceed



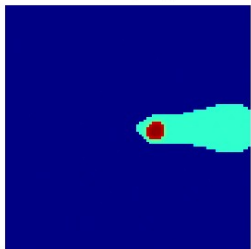
expected\_spatial



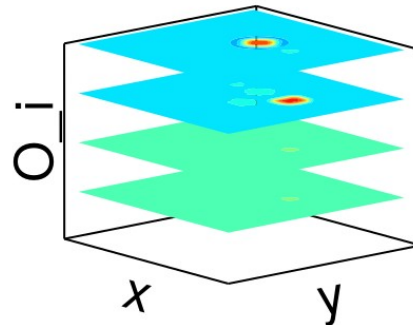
spatial\_relation



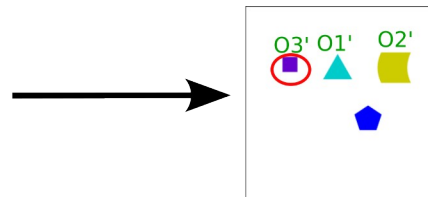
match\_spatial



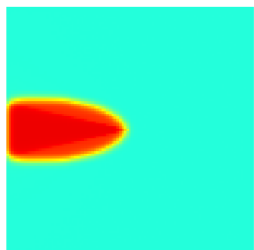
target\_scene\_map



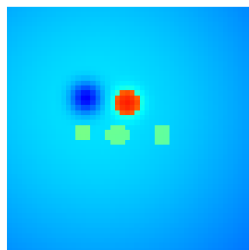
Left-of (green circle, blue pentagon)



expected\_spatial



reference



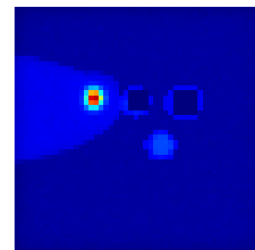
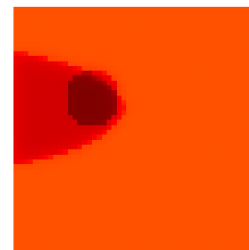
target\_index



relation\_index



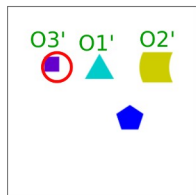
relation\_guidancespatial\_selection



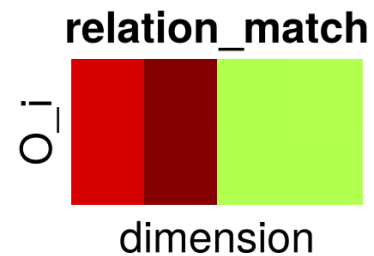
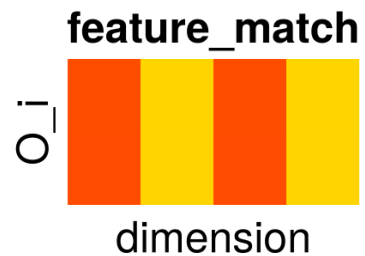
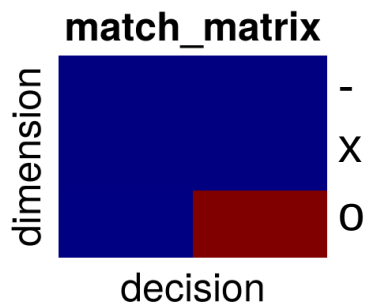
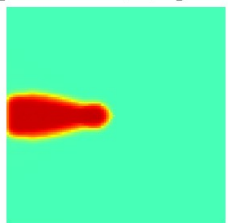
left-of(O3,O2)



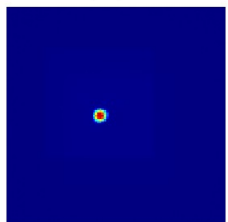
accept



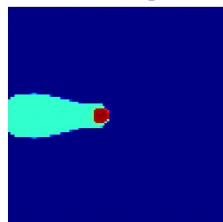
expected\_spatial



spatial\_relation

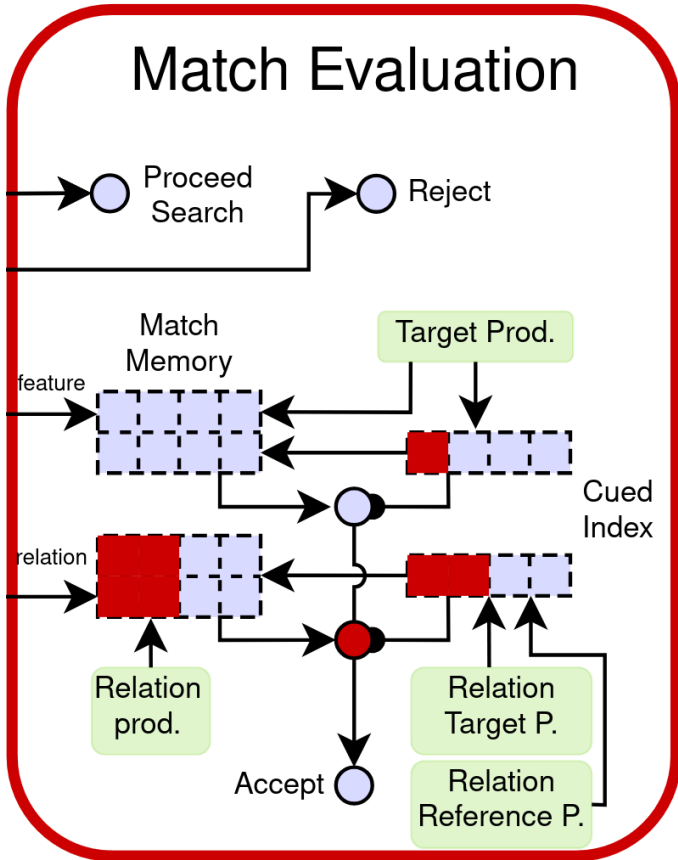


match\_spatial

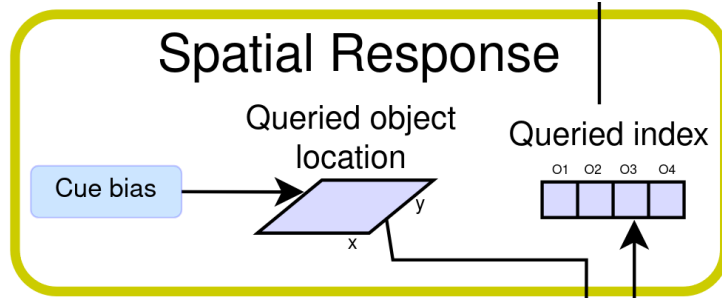


Accepting the mapping depends on how many relations and objects need to be considered

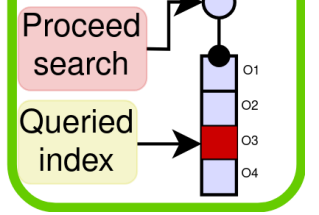
## Match Evaluation



## Spatial Response



## Target Prod.



## feature\_match

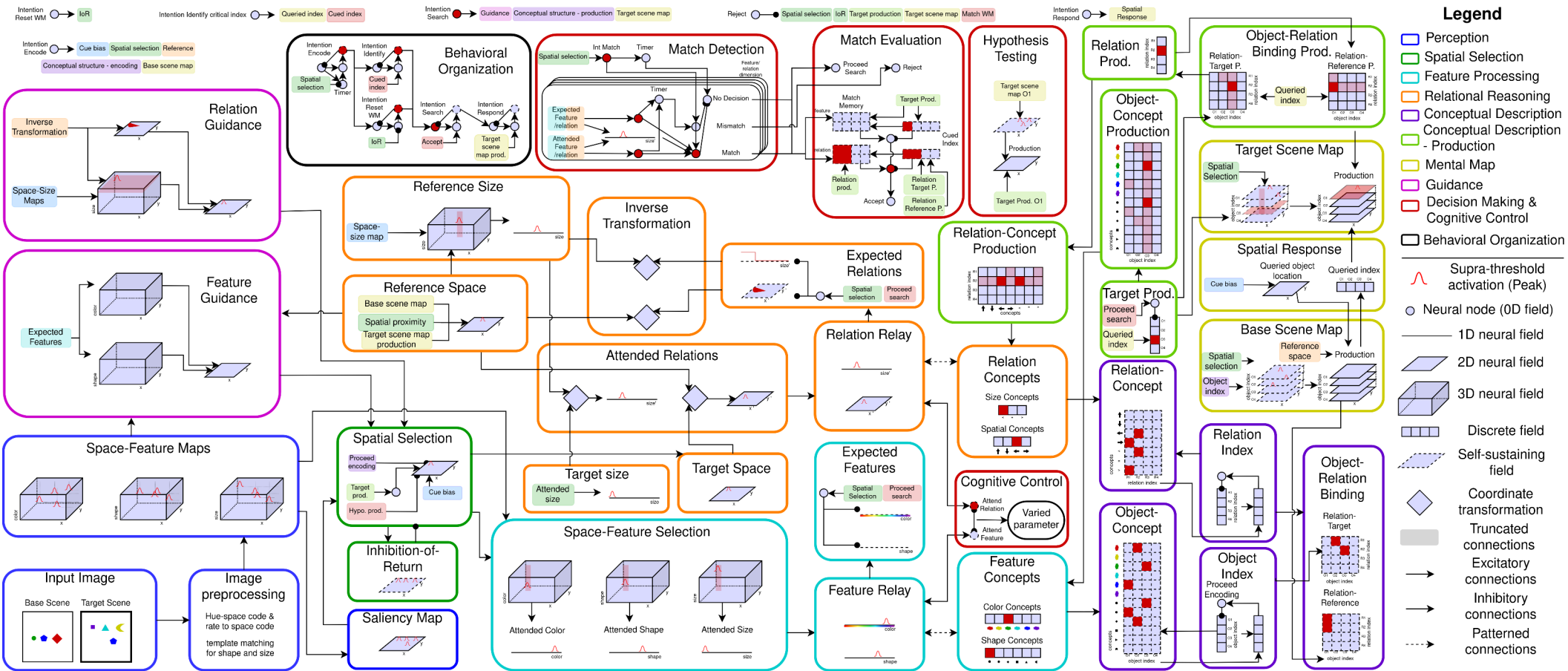


dimension

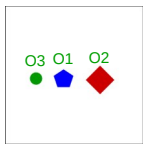
## relation\_match



dimension







Describing

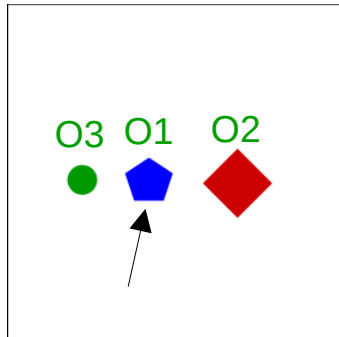
right-of (red, blue)  
left-of (green, blue)

Search

Decide matches

Rejecting the mapping

Base scene

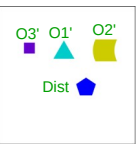


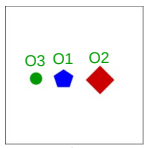
Target scene



left-of (yellow, cyan)

reset the mapping

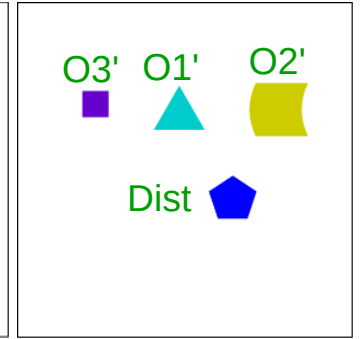
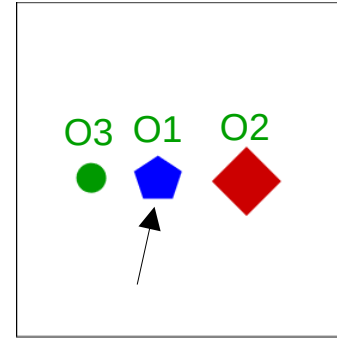




Describing

Base scene

Target scene



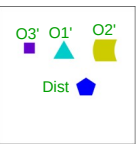
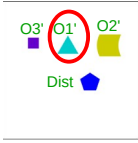
right-of (red, blue)  
left-of (green, blue)

Search

Decide matches

Generating spatial response

Rejecting the mapping



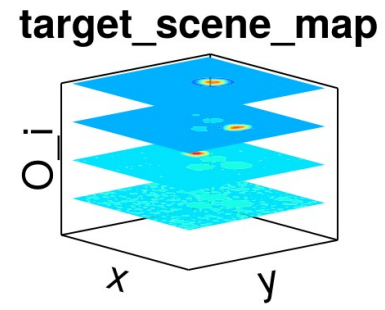
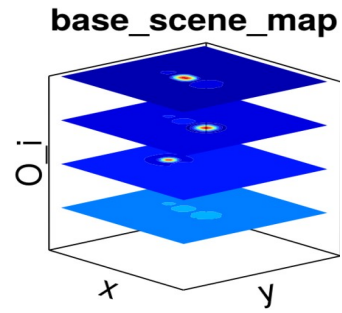
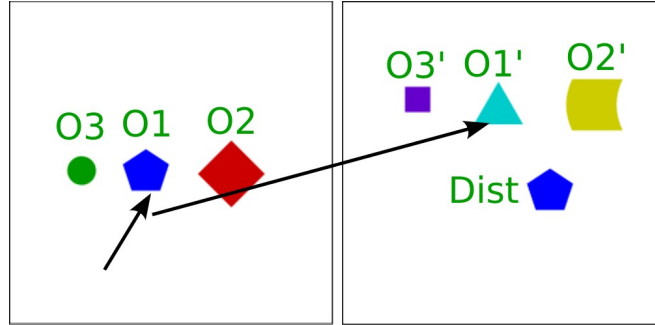
left-of (yellow, cyan)

reset the mapping

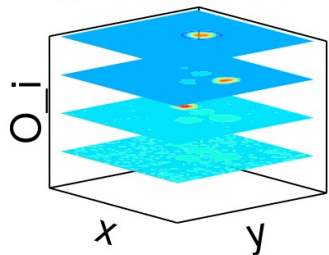
proceed

accept

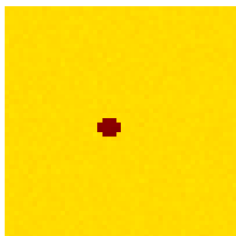
reject



target\_scene\_map



queried\_location



queried\_index



base\_scene\_map

