Neural Process Models for Intentional States

Jan Tekülve
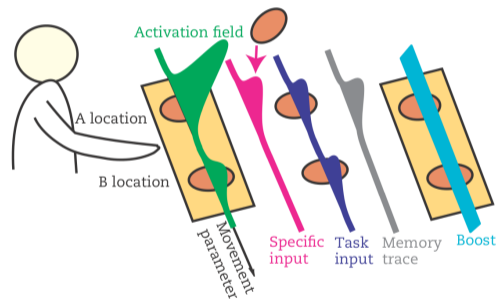
Institute for Neural Computation
Ruhr-Universität Bochum

04.09.2020

Motivation

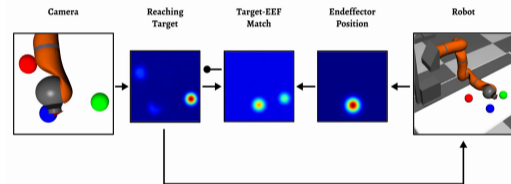Spectrums of Dynamic Field Theory

▶ Models capturing psycho-physical data

[Thelen et al., 2001]
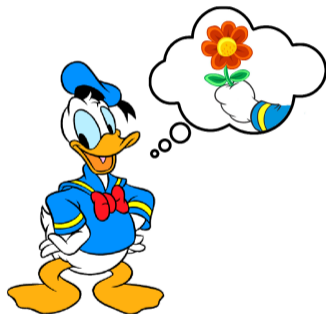
Motivation

Spectrums of Dynamic Field Theory

- ▶ Models capturing psycho-physical data

- ▶ Models capturing behavioral competences

Motivation

Spectrums of Dynamic Field Theory

- ▶ Models capturing psycho-physical data

- ▶ Models capturing behavioral competences

- ▶ Models capturing intentional agents?

Intentionality

The capacity of the nervous system to generate mental states that are "about" things in the world.

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▶ "Things in the world" include the agent's body and its mental states

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► How may intentional states emerge from neural processes?

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- ▶ "Things in the world" include the agent's body and its mental states

▶ How may intentional states emerge from neural processes?

▶ How are intentional states stabilized in time?

Intentionality

The capacity of the nervous system to generate mental states that are "about" things in the world.

- ▶ "Things in the world" include the agent's body and its mental states

▶ How may intentional states emerge from neural processes?

▶ How are intentional states stabilized in time?

▶ Under which circumstances are intentional states destabilized?

Intentional States

▶ Defined through a **content** and a **psychological mode**

World-to-Mind Direction of Fit

- ➤ Picking a *red flower* in front of me   (Intention-in-Action)
- ➤ Pick a *red flower* later in the park   (Prior Intention)
- ➤ Wanting a *red flower*   (Desire)

Mind-to-World Direction of Fit

- ➤ Seeing a *red flower* in front of me   (Perception)
- ➤ Recall a *red flower* growing in the park   (Memory)
- ➤ *Red flowers* have a green stem   (Belief)

content

[*Intentionality: An essay in the philosophy of mind*, Searle, 1983]

Directions of Fit: Mind-to-World

1.
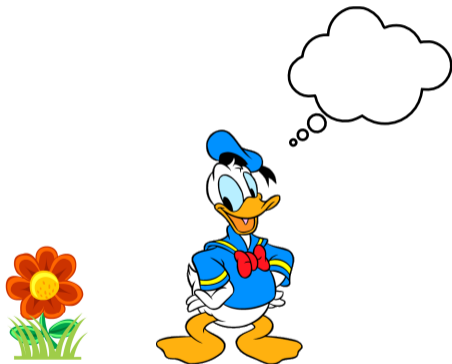
Example: *Perception*

Directions of Fit: Mind-to-World
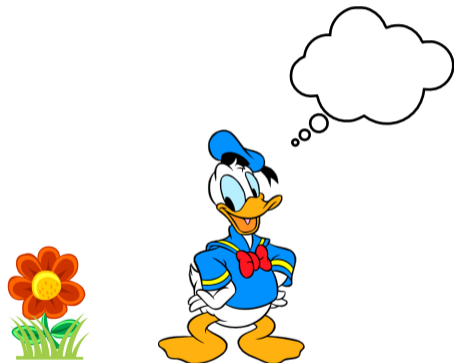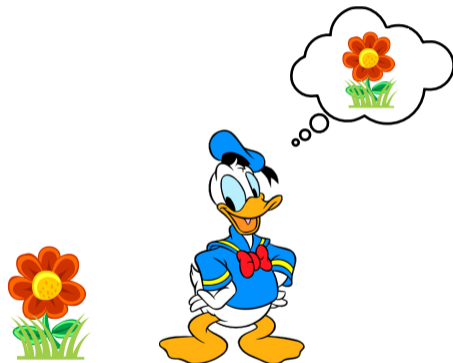
Example: *Perception*

Directions of Fit: World-to-Mind

1.

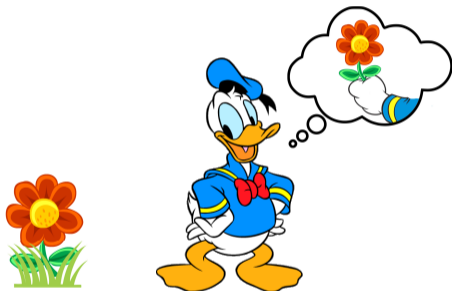Example: *Intention-in-Action*
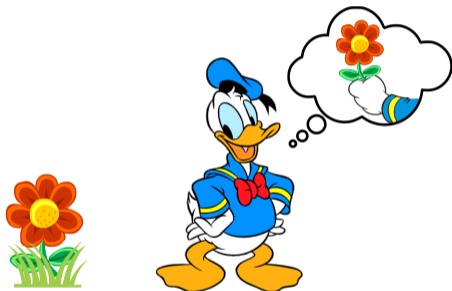
Directions of Fit: World-to-Mind

1.

2.

Example: *Intention-in-Action*
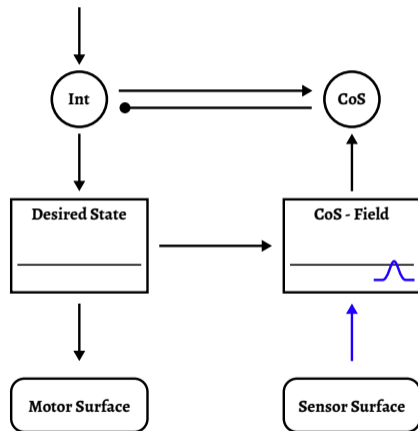
Directions of Fit: World-to-Mind

1.

2.

Example: *Intention-in-Action*

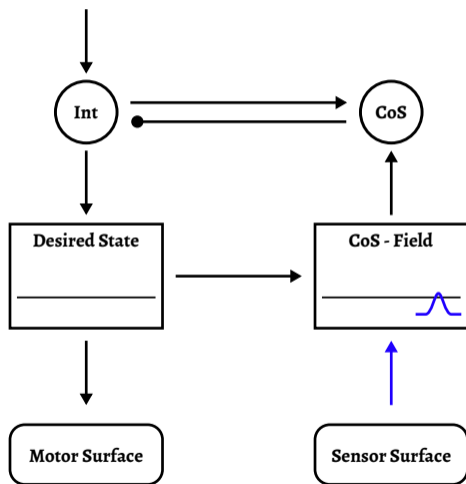**Condition of Satisfaction**: Is the fit achieved?

A neural Process Model

▶ Detects CoS based on sensor information

▶ Represents action initiation and termination

▶ Drives motor behavior

[Sandamirskaya and Schöner, 2010]

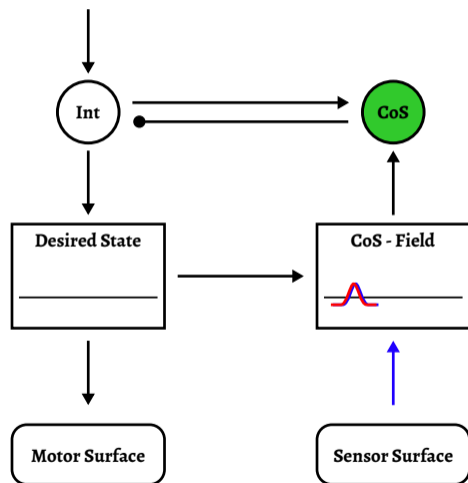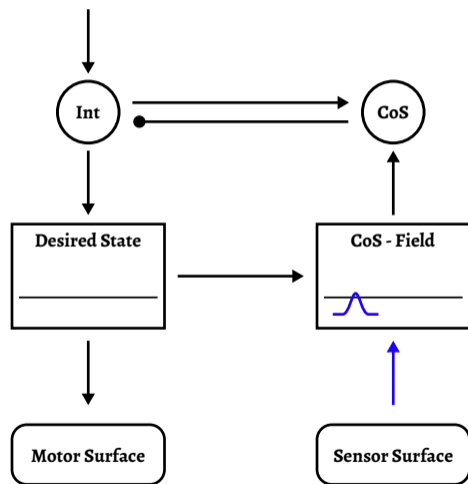# Condition of Satisfaction Network
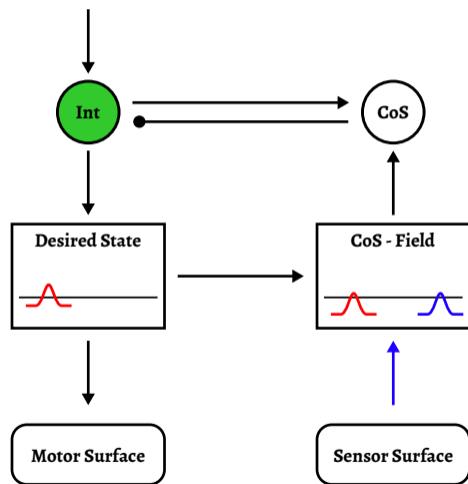
Condition of Satisfaction Network

Condition of Satisfaction Network
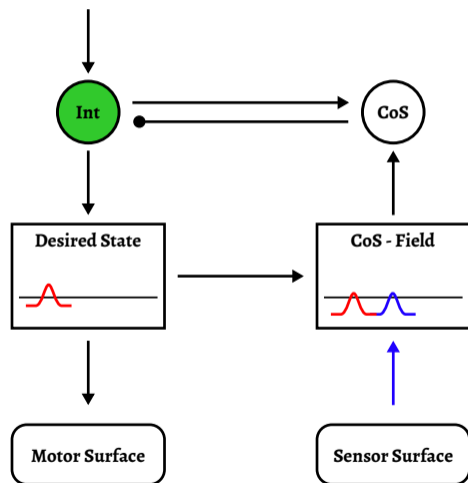
# Condition of Satisfaction Network
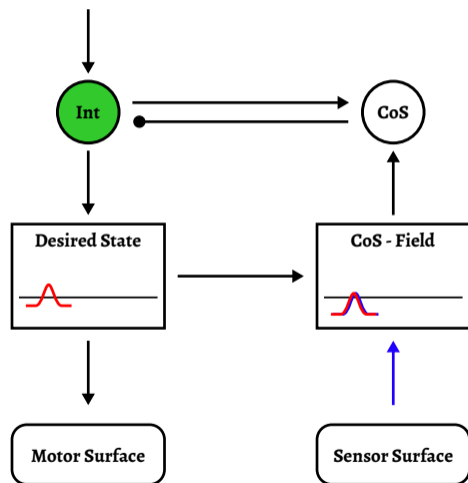
Condition of Satisfaction Network
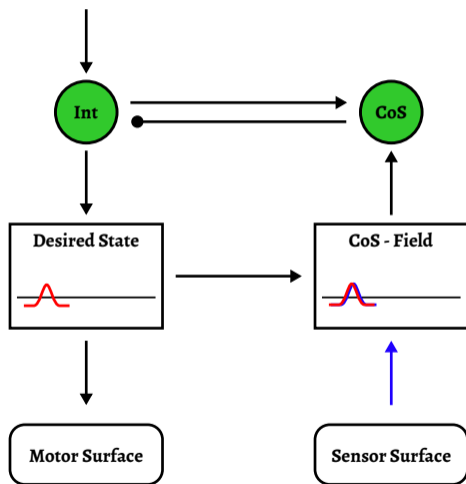
Condition of Satisfaction Network

Condition of Satisfaction Network

A simple Painting Scenario

► Toy scenario includes six different psychological modes

► Behavior emerges from autonomous transitions between intentional states

► Stabilized intentional states make up experience

► Experience allows the formation of categorical beliefs
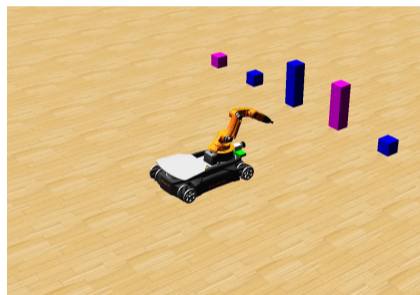
[Tekülve and Schöner, 2019]

Mind-To-World States

▶ **Perception**
  ▶ See Objects (Position, Height, Color)
  ▶ Observe Color Change
  ▶ Sense Position, Arm, Paint-Device Status

▶ **Memory**
  ▶ Objects in World Space

▶ **Belief**
  ▶ Paint Rules
    (Coat Color + Canvas Color = Result Color)
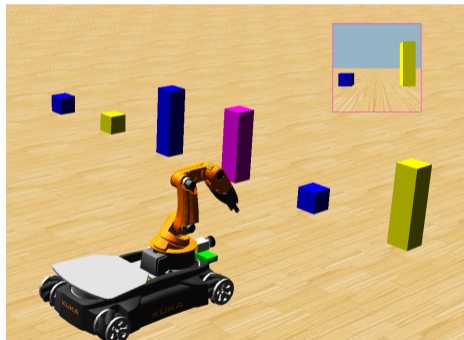
World-To-Mind States

▶ **Intention-in-Action**
  ▶ Move in 1-D Space
  ▶ Reach for Objects
  ▶ Pick-Up/Dispense Color
  ▶ Invoke certain Mind-to-World States

▶ **Prior Intention**
  ▶ Locate an Object
  ▶ Collect a certain Coat
  ▶ Apply Coat on a certain Canvas

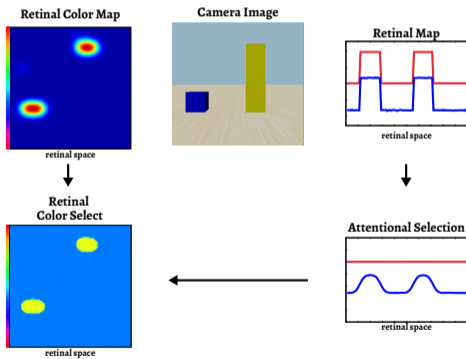▶ **Desire**
  ▶ Create a certain Color
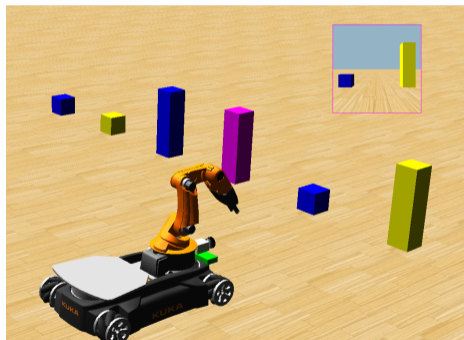
Architecture Overview

From Sensor to Field

Camera Image

retinal space

Background Extraction

retinal space

Integration to 1D

retinal space

Retinal Space/Color Map

color

retinal space

Retinal Salience Map

retinal space

Retinal Space/Height Map

height

height

retinal space
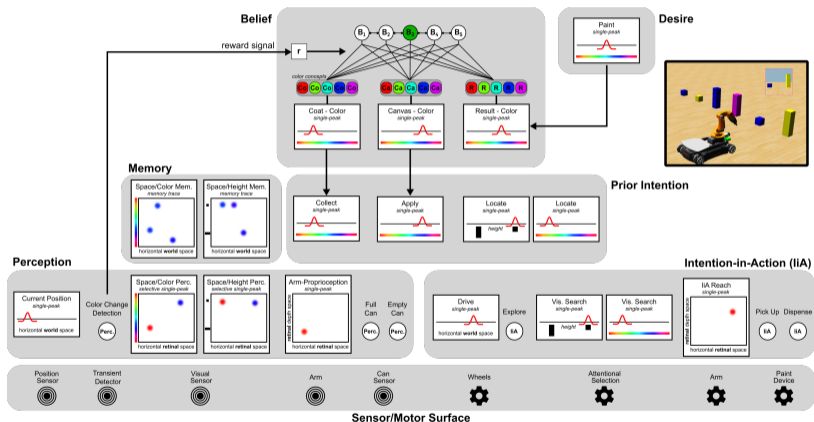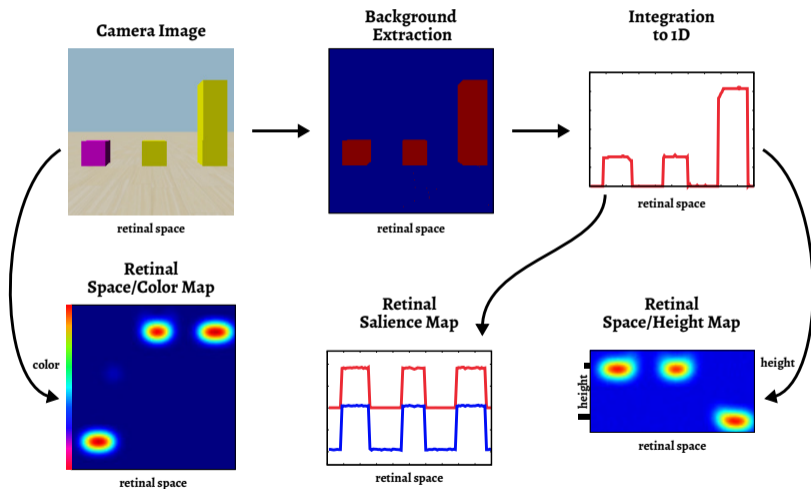
Process Model: Perception

No Perception
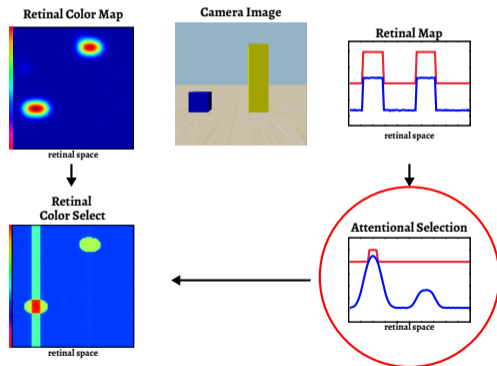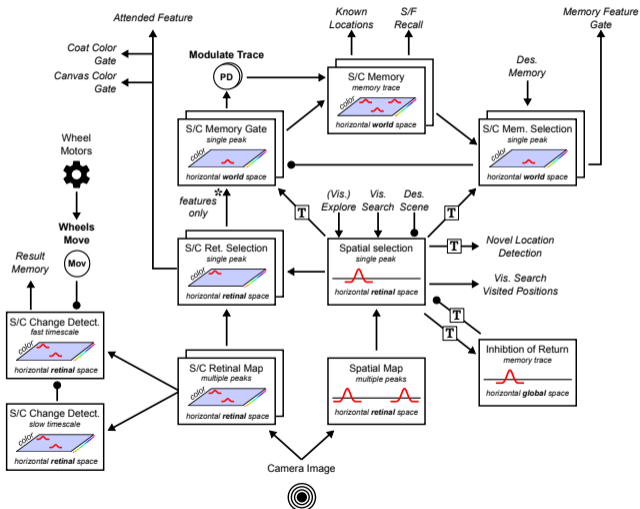
Retinal Color Map

Camera Image

Retinal Map

retinal space

Retinal
Color Select

Attentional Selection

retinal space

retinal space

Perception

Retinal Color Map

Camera Image

Retinal Map

retinal space

Retinal
Color Select

Attentional Selection

retinal space

retinal space

Scene Representation: Perception and Memory

Scene Representation: Perception and Memory
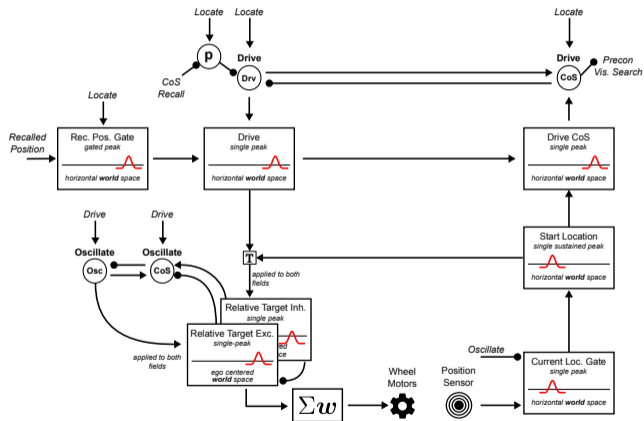
Scene Representation: Perception and Memory
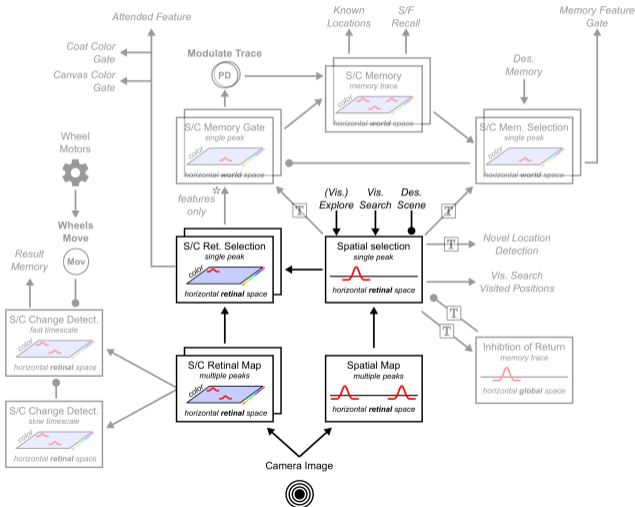
Scene Representation: Perception and Memory

Memory Buildup
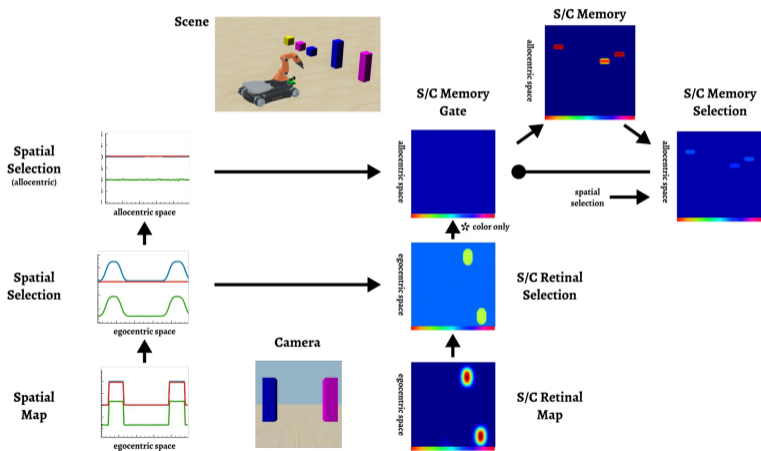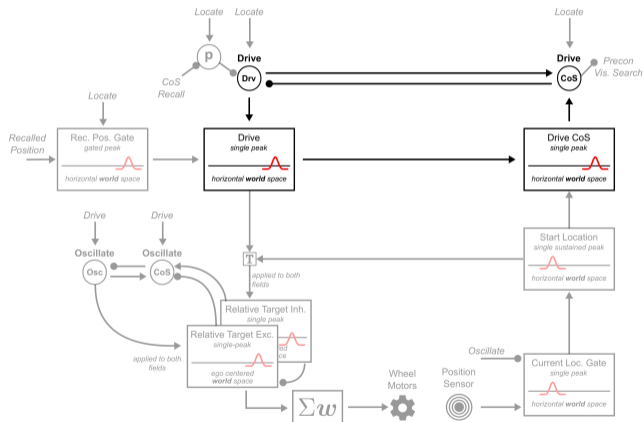
Scene

S/C Memory

S/C Memory Gate

S/C Memory Selection

Spatial Selection (allocentric)

Spatial Selection

Spatial Map

Camera

S/C Retinal Selection

S/C Retinal Map

✻ color only

spatial selection

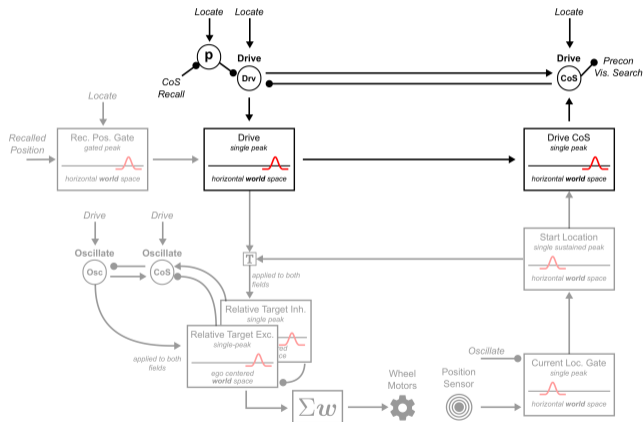# Example: Goal-Directed Driving

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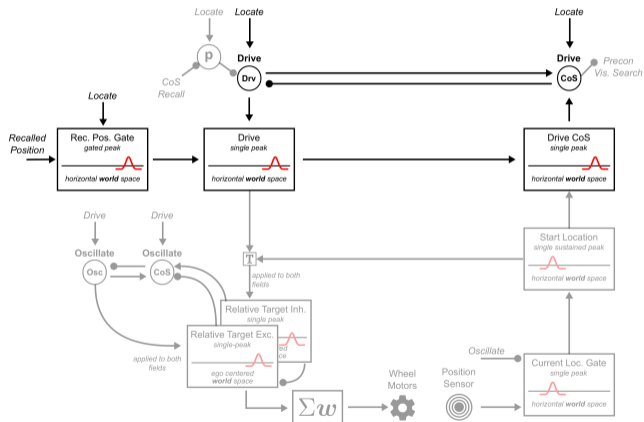
Example: Goal-Directed Driving
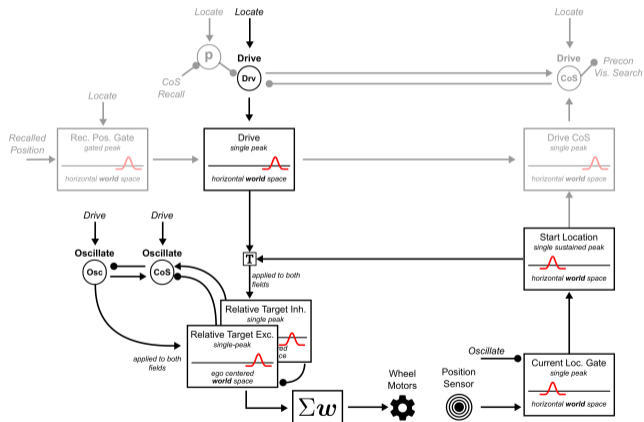
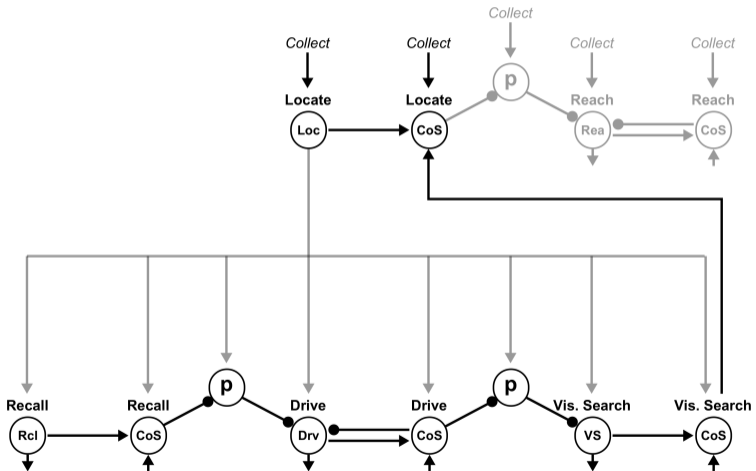# Example: Goal-Directed Driving
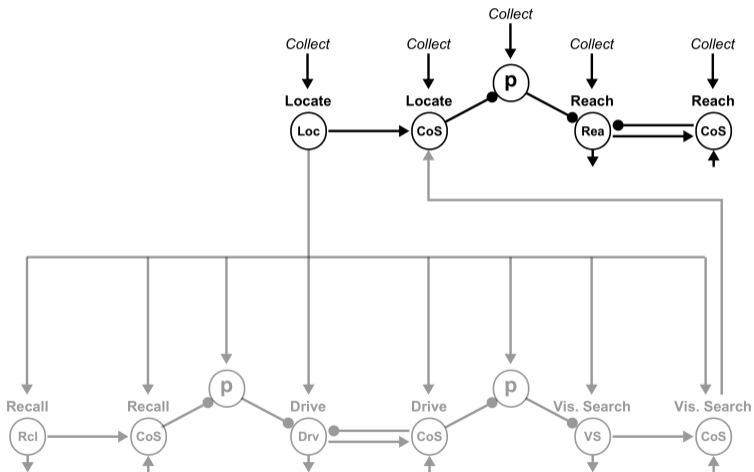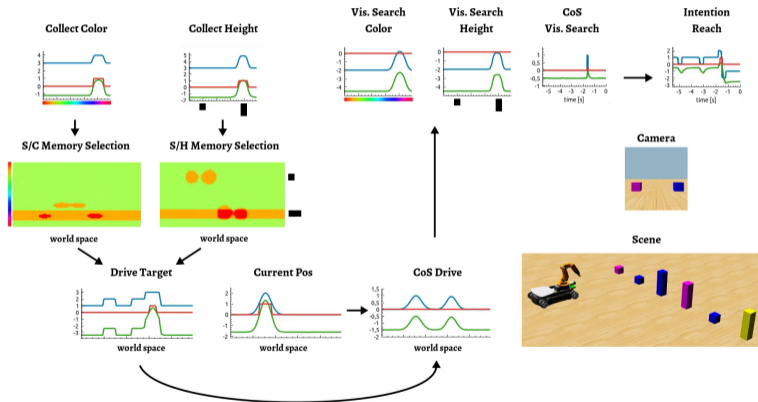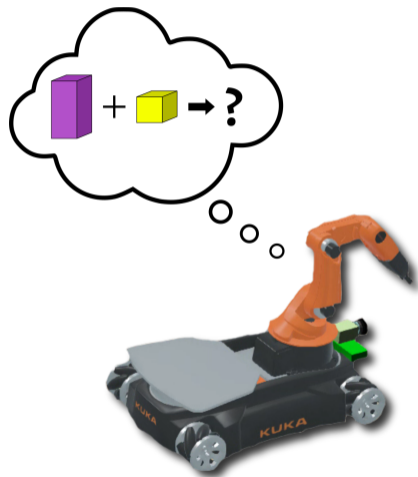
Prior Intentions
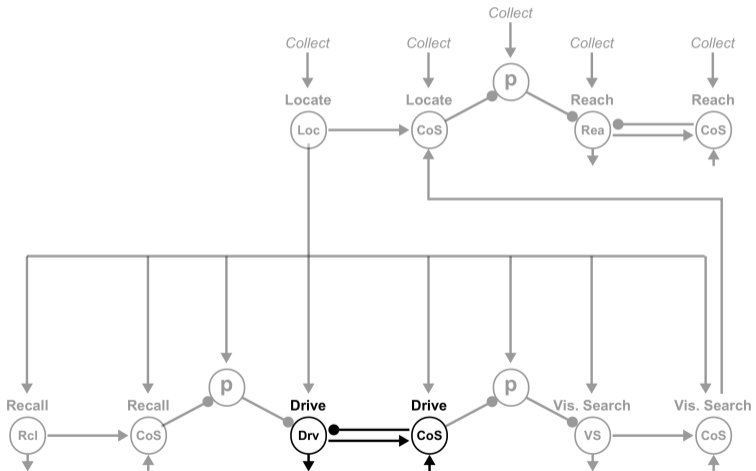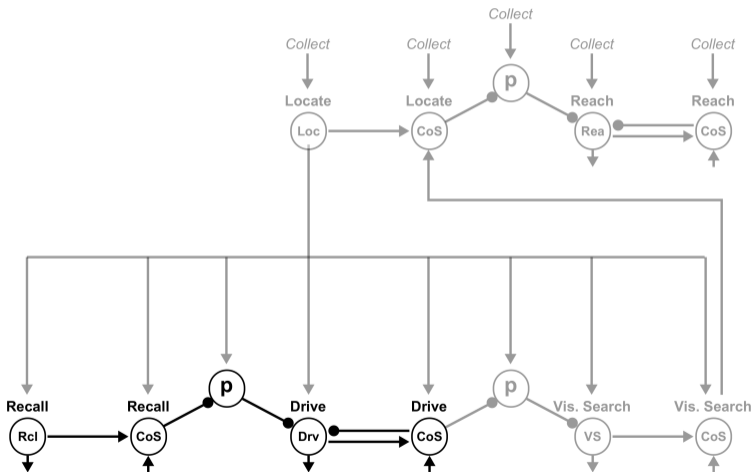
Prior Intentions
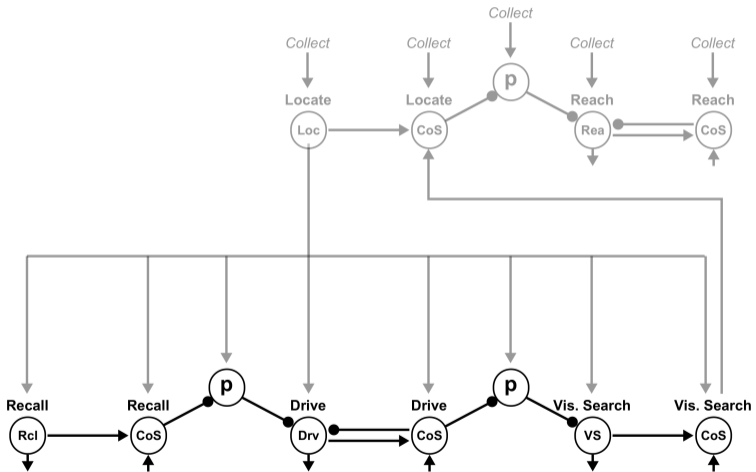
Prior Intentions
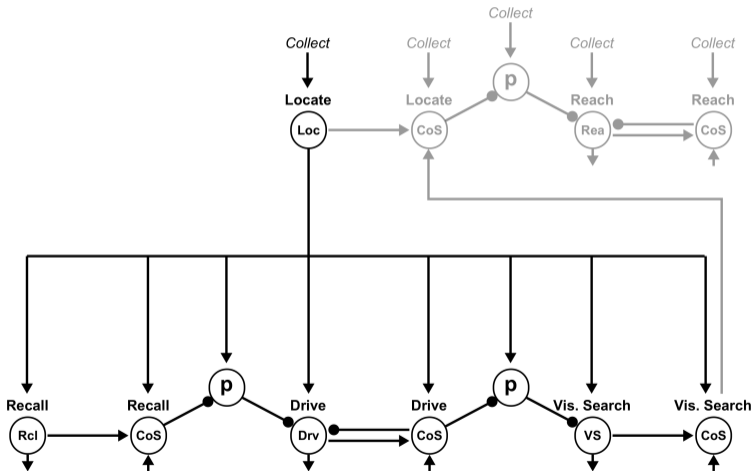
Prior Intentions

Prior Intentions

Prior Intentions

Collecting Sequence

Autonomous Learning

- **Requirements:**
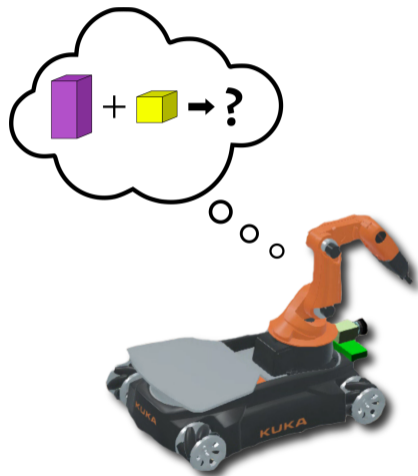   - Autonomous action
    - Meaningful experience

Autonomous Learning

- **Requirements:**
  - Autonomous action
  - Meaningful experience

- **Problems:**
  - Content abstraction
  - Temporal organization
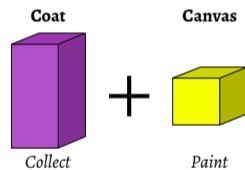
Beliefs

▶ Learning from a single episode
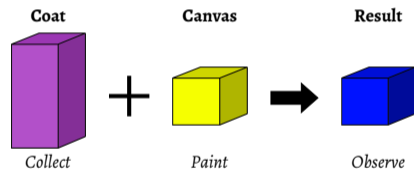
Beliefs

▶ Learning from a single episode

Coat

Collect

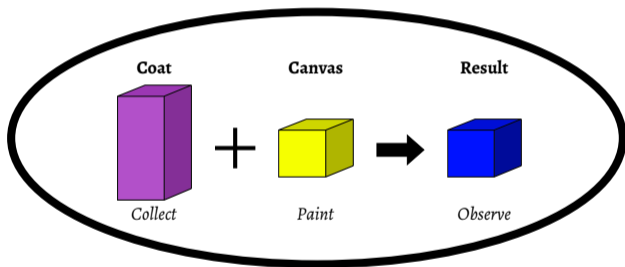# Beliefs

► Learning from a single episode

Coat — *Collect* + **Canvas** — *Paint*

Beliefs

▶ Learning from a single episode

Coat   **Canvas**   **Result**

Collect   *Paint*   *Observe*

Beliefs

▶ Learning from a single episode

Beliefs

▶ Learning from a single episode
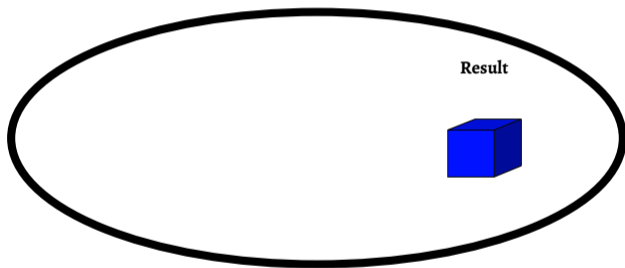
▶ Cued activation to guide behavior

Beliefs

► Learning from a single episode
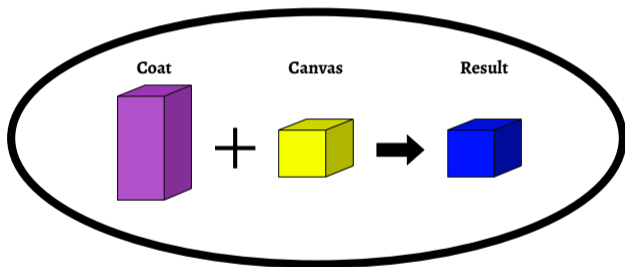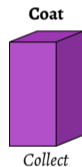
► Cued activation to guide behavior

Result

Beliefs

- ▶ Learning from a single episode

- ▶ Cued activation to guide behavior

Result

Beliefs

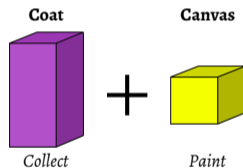- ▶ Learning from a single episode
- ▶ Cued activation to guide behavior

Beliefs

► Learning from a single episode

► Cued activation to guide behavior

► Rejection in the face of conflicting
  evidence

Beliefs

- ▶ Learning from a single episode

- ▶ Cued activation to guide behavior

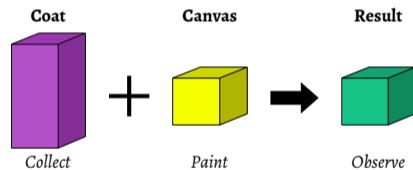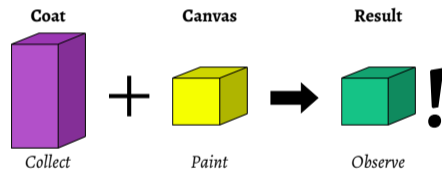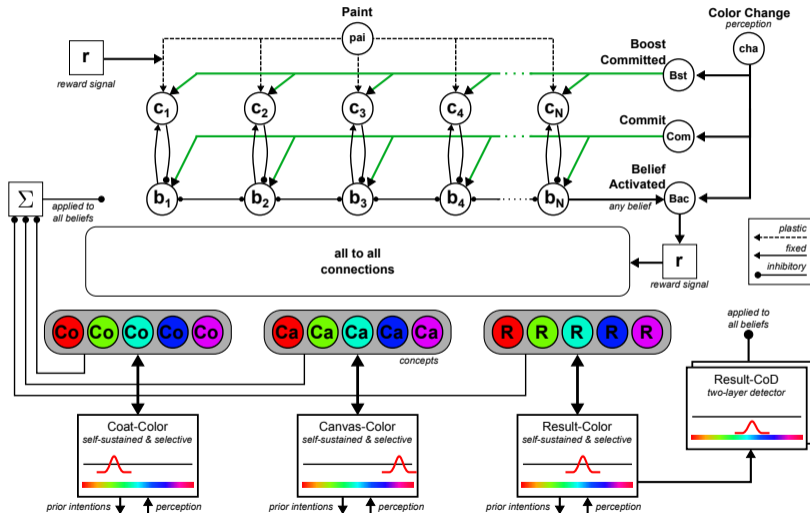- ▶ Rejection in the face of conflicting evidence

Coat

Collect

Beliefs

- Learning from a single episode

- Cued activation to guide behavior

- Rejection in the face of conflicting evidence

Coat   **Canvas**

Collect   *Paint*

Beliefs

▶ Learning from a single episode

▶ Cued activation to guide behavior
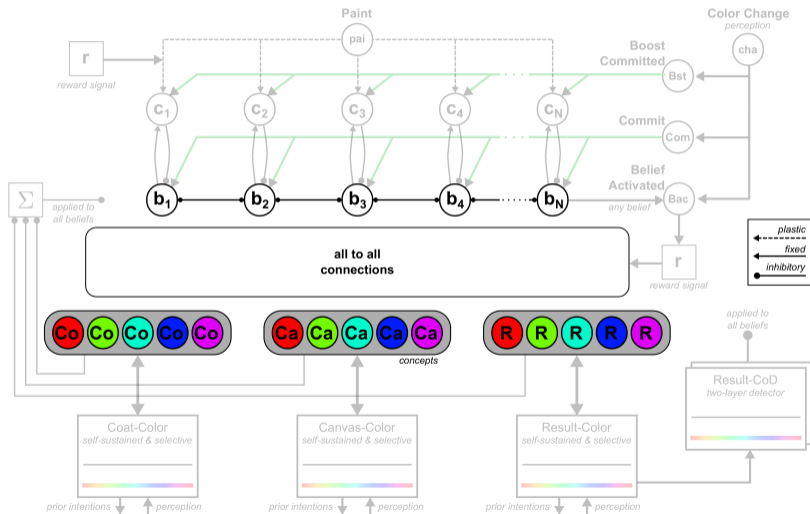
▶ Rejection in the face of conflicting evidence

Coat   **Canvas**   **Result**

Collect   *Paint*   *Observe*

Beliefs

- ▶ Learning from a single episode

- ▶ Cued activation to guide behavior

- ▶ Rejection in the face of conflicting evidence

Coat **Canvas** **Result**
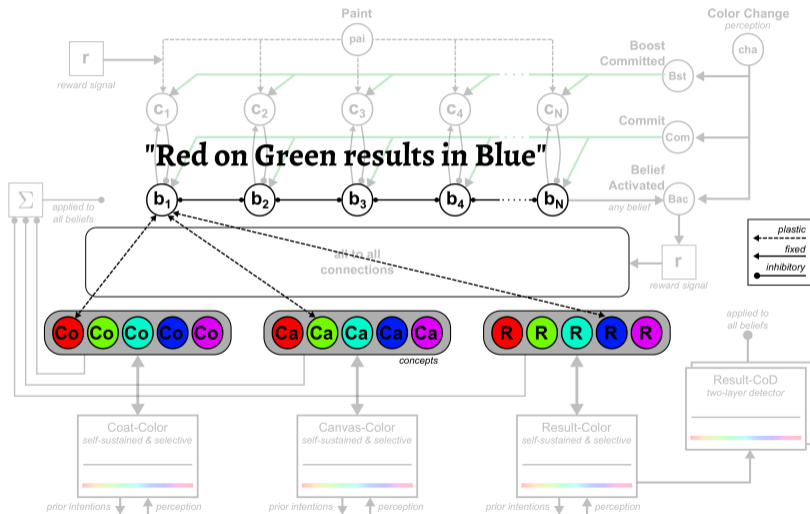
Collect *Paint* *Observe*
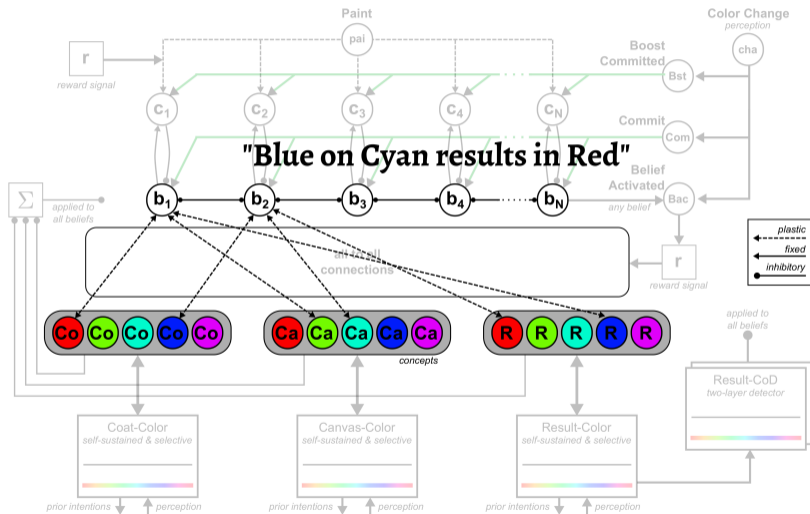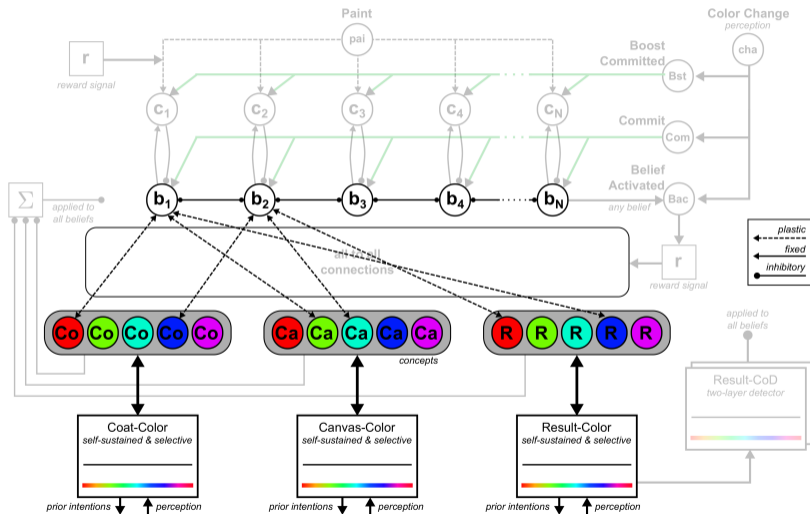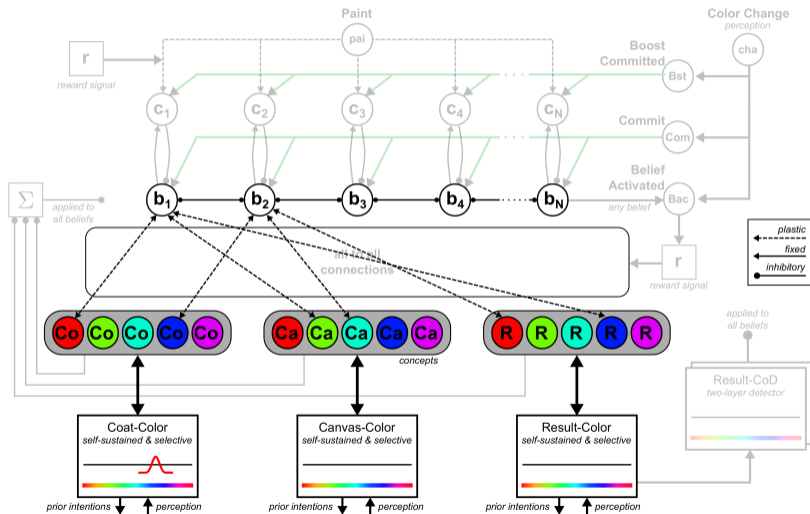
Belief Architecture

Belief Architecture

Belief Architecture

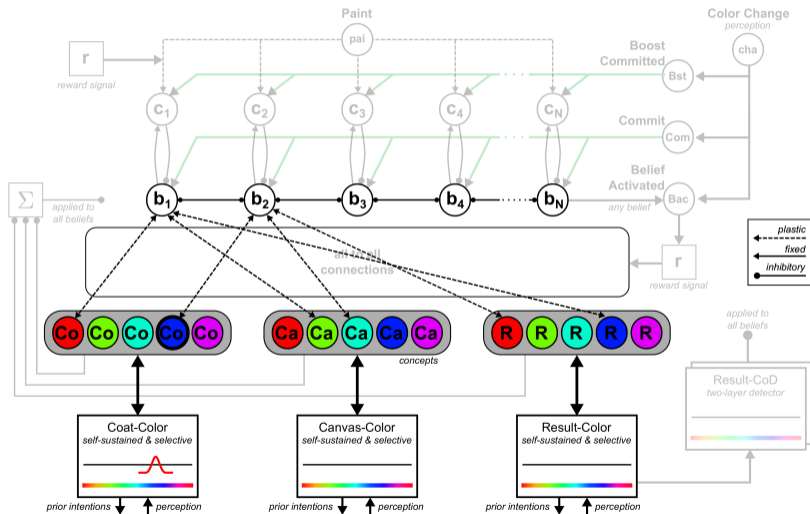# Belief Architecture

Belief Architecture

Belief Architecture

Belief Architecture

Belief Architecture

Belief Architecture

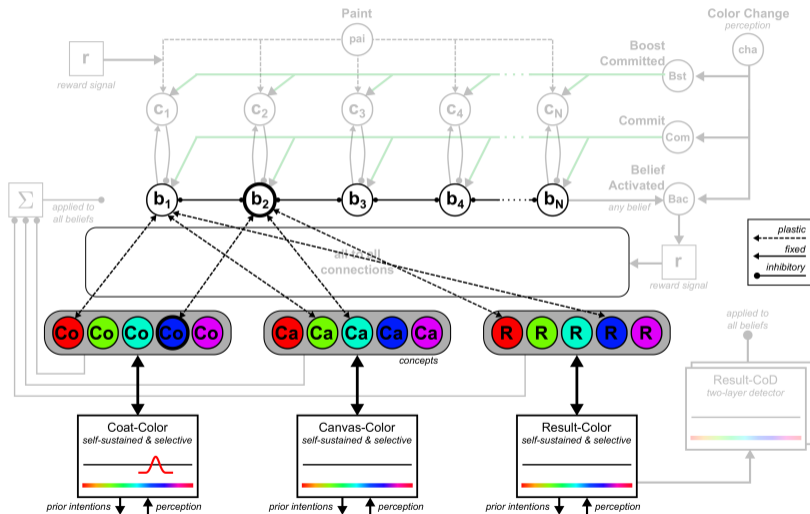# Belief Architecture
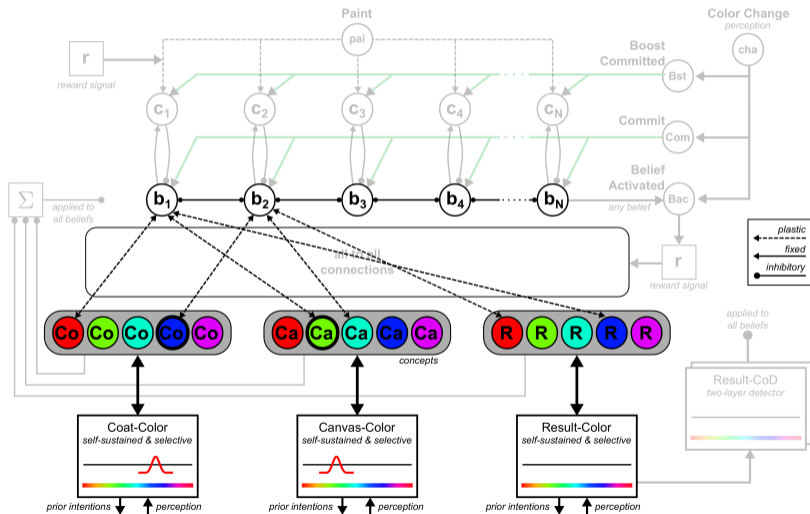

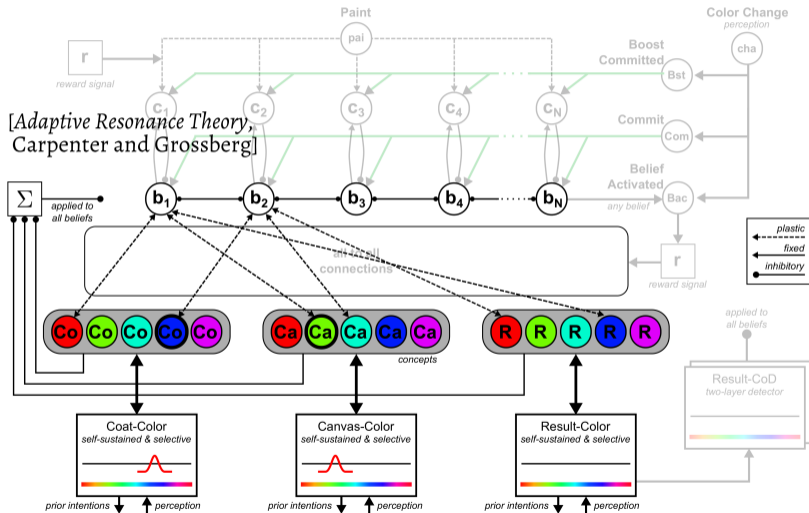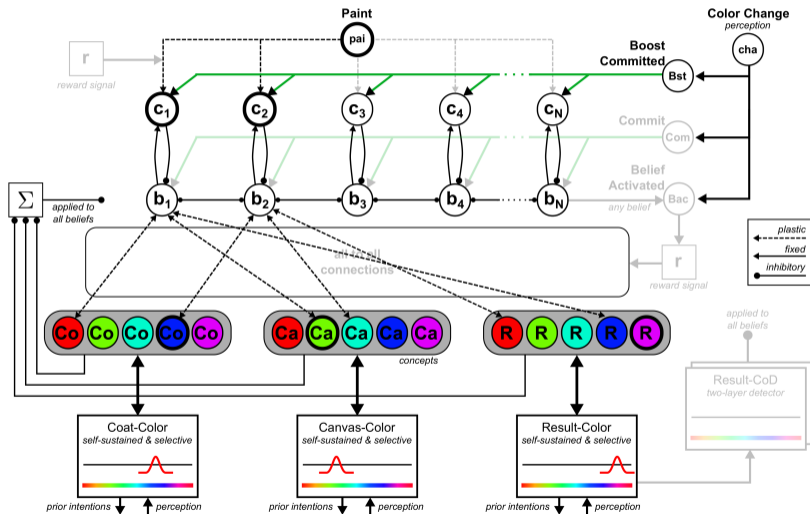[*Adaptive Resonance Theory*, Carpenter and Grossberg]

Belief Architecture

Belief Architecture

Belief Architecture

Belief Architecture

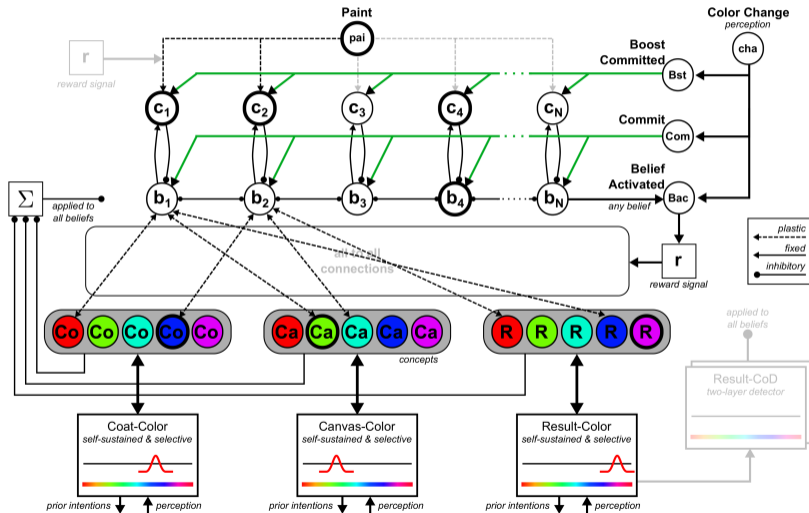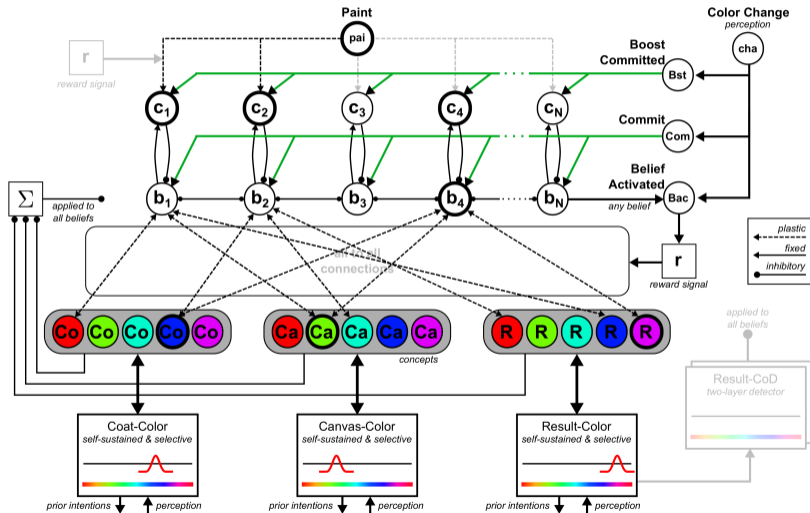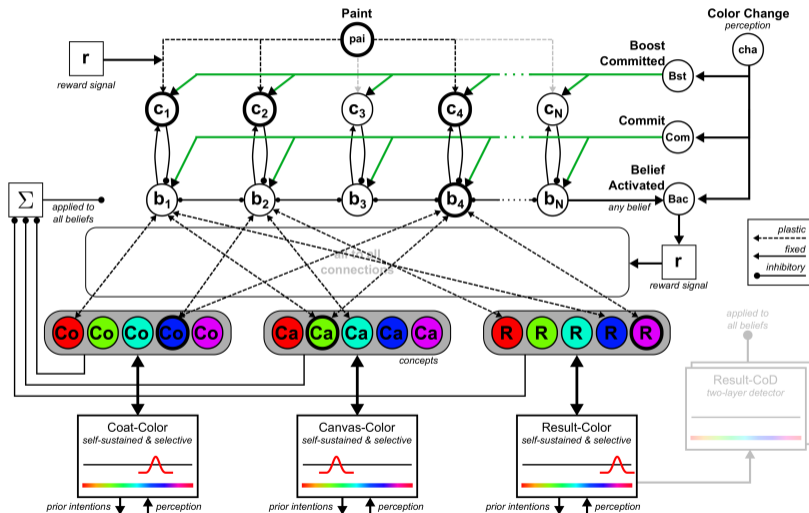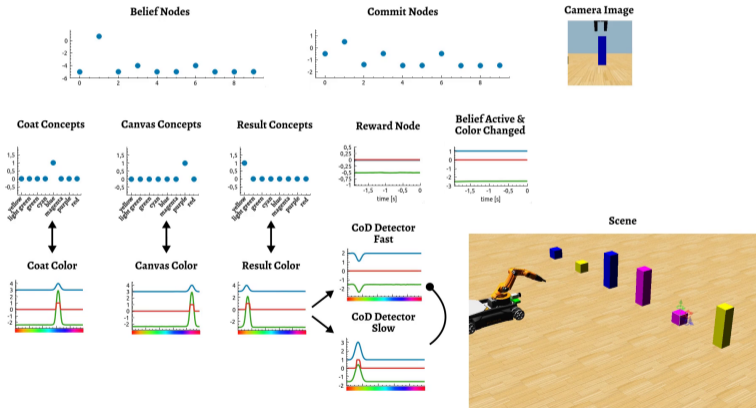# Belief Recall and Rejection

Belief Nodes

Commit Nodes

Camera Image

Coat Concepts   Canvas Concepts   Result Concepts   Reward Node   Belief Active & Color Changed

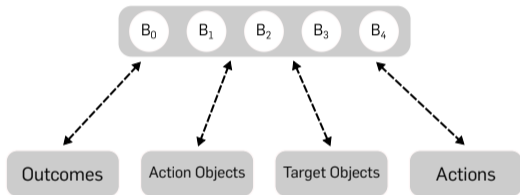Coat Color   Canvas Color   Result Color   CoD Detector Fast

CoD Detector Slow

Scene

Conclusion

► From sensorimotor surface to abstract representations in continuous time

► Process models of different psychological modes

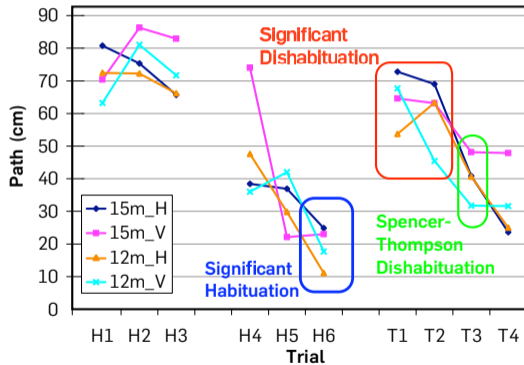► Models reveal necessary infrastructure to stabilize learning
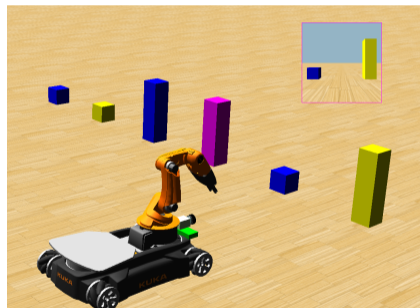
Outlook

Generalizing Beliefs

Desire Dynamics

[Aerdker, Feng, Schöner, 2020]

Thank you for your attention!

Interested in Dynamic Field Modeling?
Try our simulation framework cedar!

cedar.ini.rub.de

Pre-built apps for:
Linux, Mac OS and Windows

Bibliography

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Intentionality: An essay in the philosophy of mind.
Cambridge university press, 1983.

Jan Tekülve and Gregor Schöner.
Neural dynamic concepts for intentional systems.
In *41th Annual Conference of the Cognitive Science Society (CogSci 2019)*, 2019.