

# CAUSAL COGNITIVE ARCHITECTURE 3 (CCA3): A SOLUTION TO THE BINDING PROBLEM

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*Cognitive Systems Research, in press*  
Supplementary Video File

GITHUB Username: "CausalCog"  
<https://github.com/CausalCog>

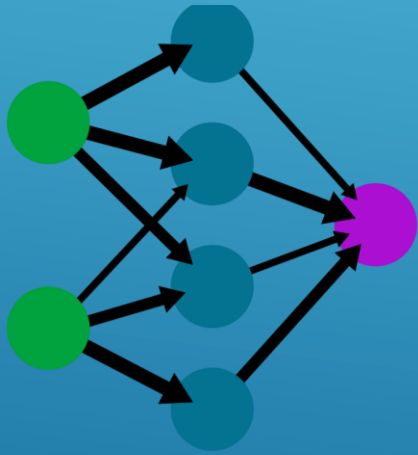
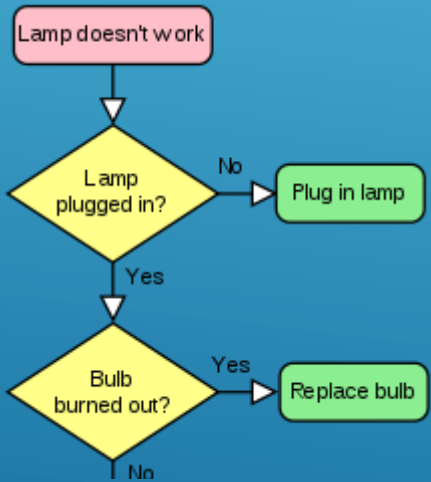
VIDEO #1



- 
- CCA3 Overview ←
  - Binding Problem Overview ←
  - Software Overview
  - Operations Overview
  - Operations Causal
  - Software in More Detail
  - More videos, code on GitHub “CausalCog”
- 



# What are mechanisms we can use to think.... to make decisions?



Symbolic  
Logic  
GOFAI

Neural  
Networks  
ANN, SNN

Navigation  
Maps/ with  
Causality



# Navigation Maps:

Different way of making  
decisions

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Most animals – invertebrates  
and vertebrates use some  
sort of navigation system

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## Navigation Maps:

Vertebrates – all have formal navigation systems similar to mammalian hippocampus (place and grid cells)



## Navigation Maps:

-use in an artificial cognitive architecture not just for navigation but all decisions

→ Causal Cognitive Architecture





# WHY PREVALENCE OF PSYCHOSIS IN HUMANS?

17% some other psychosis  
or psychosis-like (van Os et  
al 2001)  
(albeit, 1% schizophrenia)



*Not an actual patient. Professional model.*





# WHY NO PSYCHOSIS IN ANIMALS?

animal – unsplash license





# WHY NO FULL CAUSAL BEHAVIOR IN ANIMALS?





FOOD IN  
PLEXIGLASS TUBE

GRAVITY TRAP

CHIMPANZEE WITH  
STICK

youtube image modified by author  
plus unsplash license chimpanzee  
face



# Richard Sutton's “Bitter Lesson”

methods that use lots of data and lots of compute just work much better than attempts to create ingenious AI systems

vs.

## “Clues”

humans – causal, psychosis but not other animals

*still the only ‘system’ in the world capable of AGI*





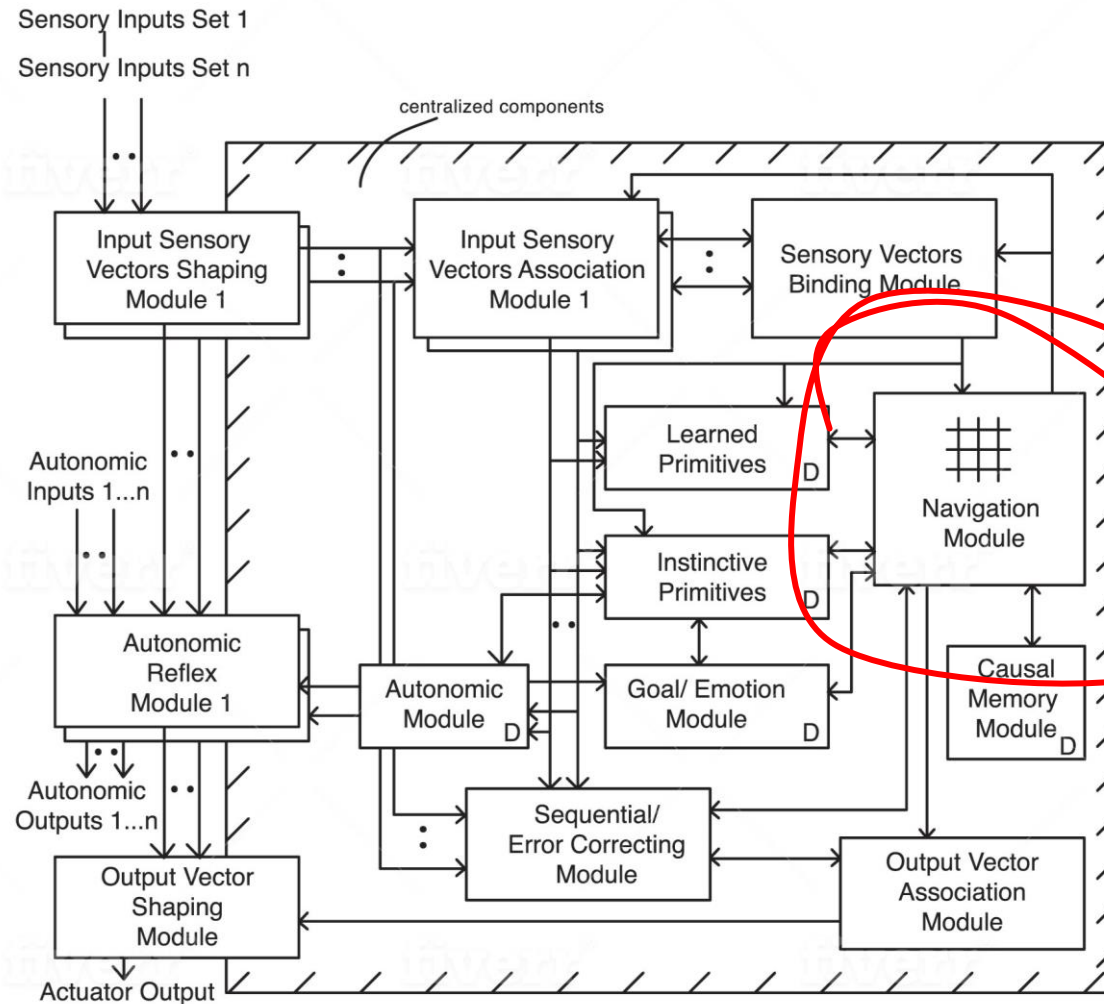
## More “Clues”

- ▶ Navigation in all animals
- ▶ Navigation center (hippocampus) controls memories
- ▶ Rapid evolution: non-causal primate → causal human
- ▶ Rapid evolution: no psychosis → psychosis human
- ▶ Schizophrenia Paradox
- ▶ Explainability emerges automatically
- ▶ Language emerges automatically
- ▶ Lifelong (‘continual’) learning
- ▶ Generalization to new and novel environments



# CAUSAL COGNITIVE ARCHITECTURE 1 (CCA1)

BICA 2018, 2019, 2020

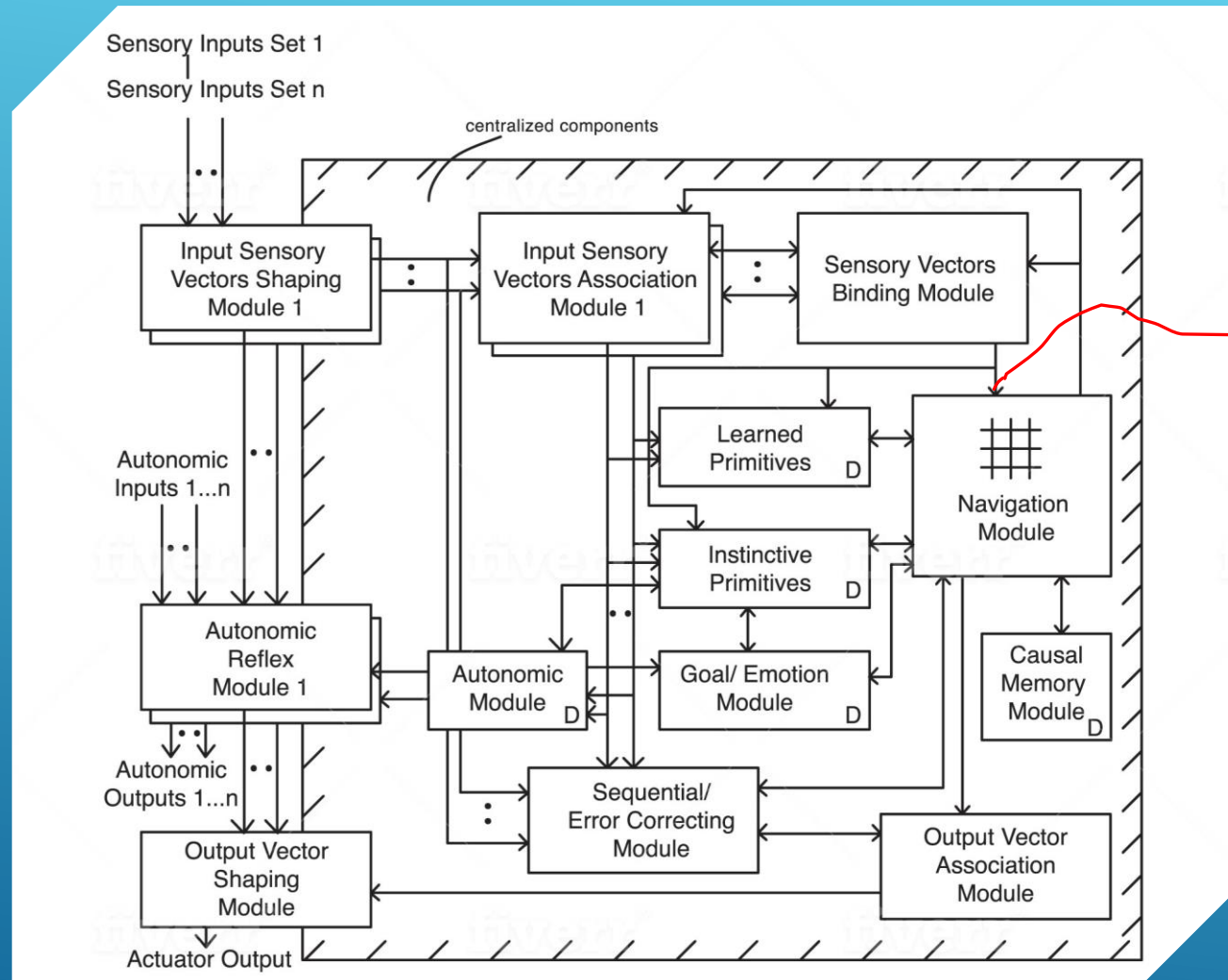


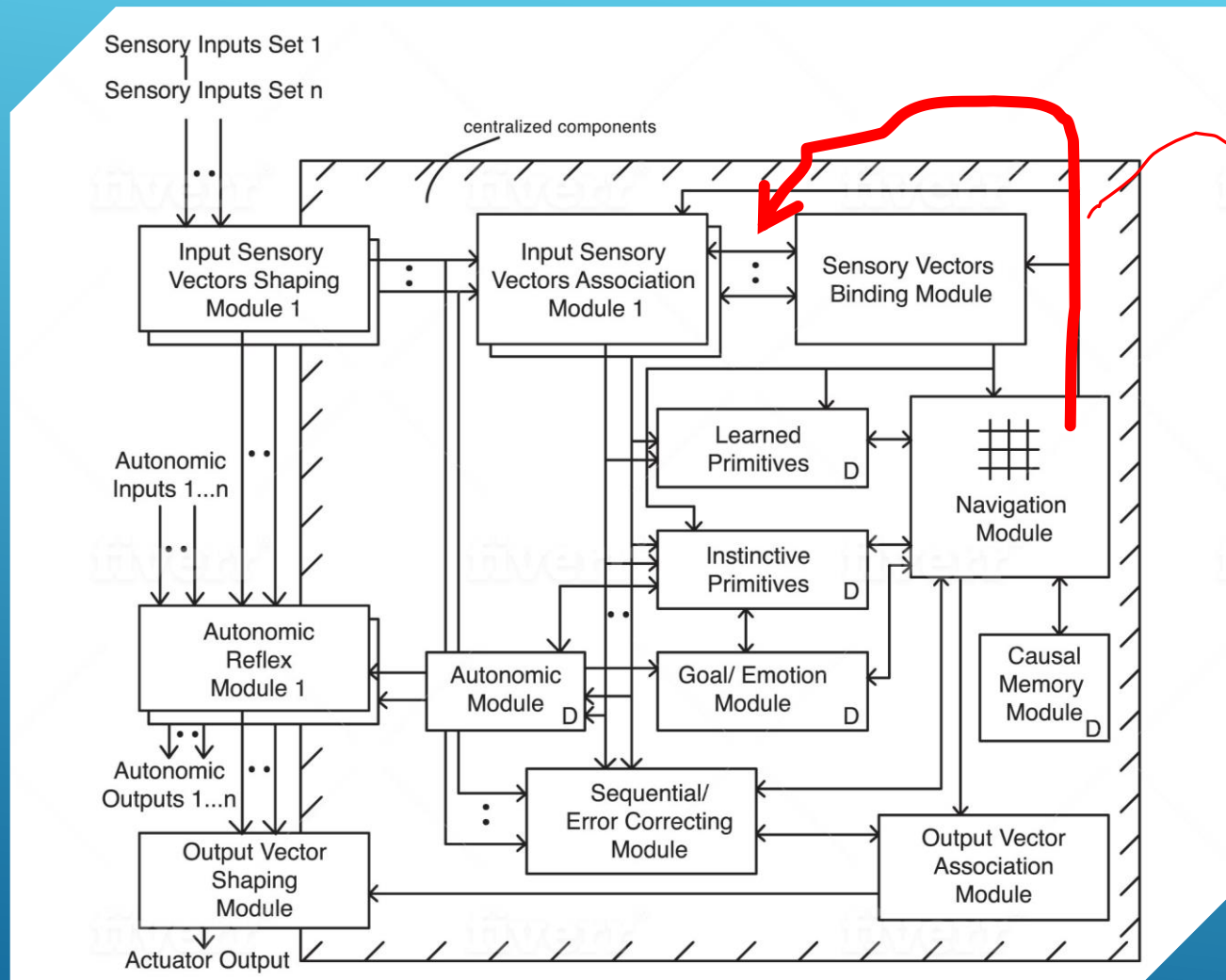
*everything based on navigation maps!!*





The navigation maps allow associative and pre-causal behavior

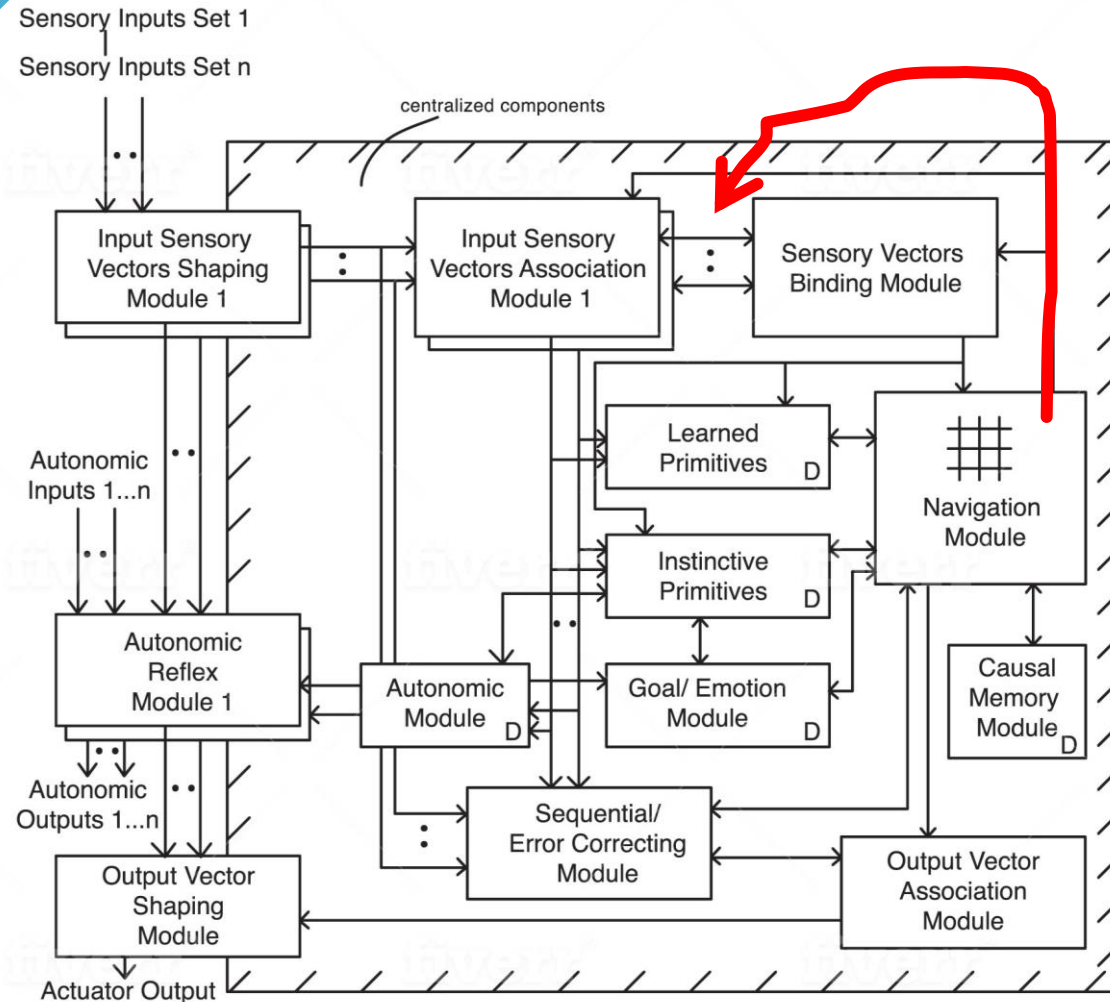




Feedback of  
intermediate  
results, and  
re-operate  
on them  
→causal  
behavior  
→increase  
risk psychosis



# The model explains all the “clues” from the only existing AGI system (humans)

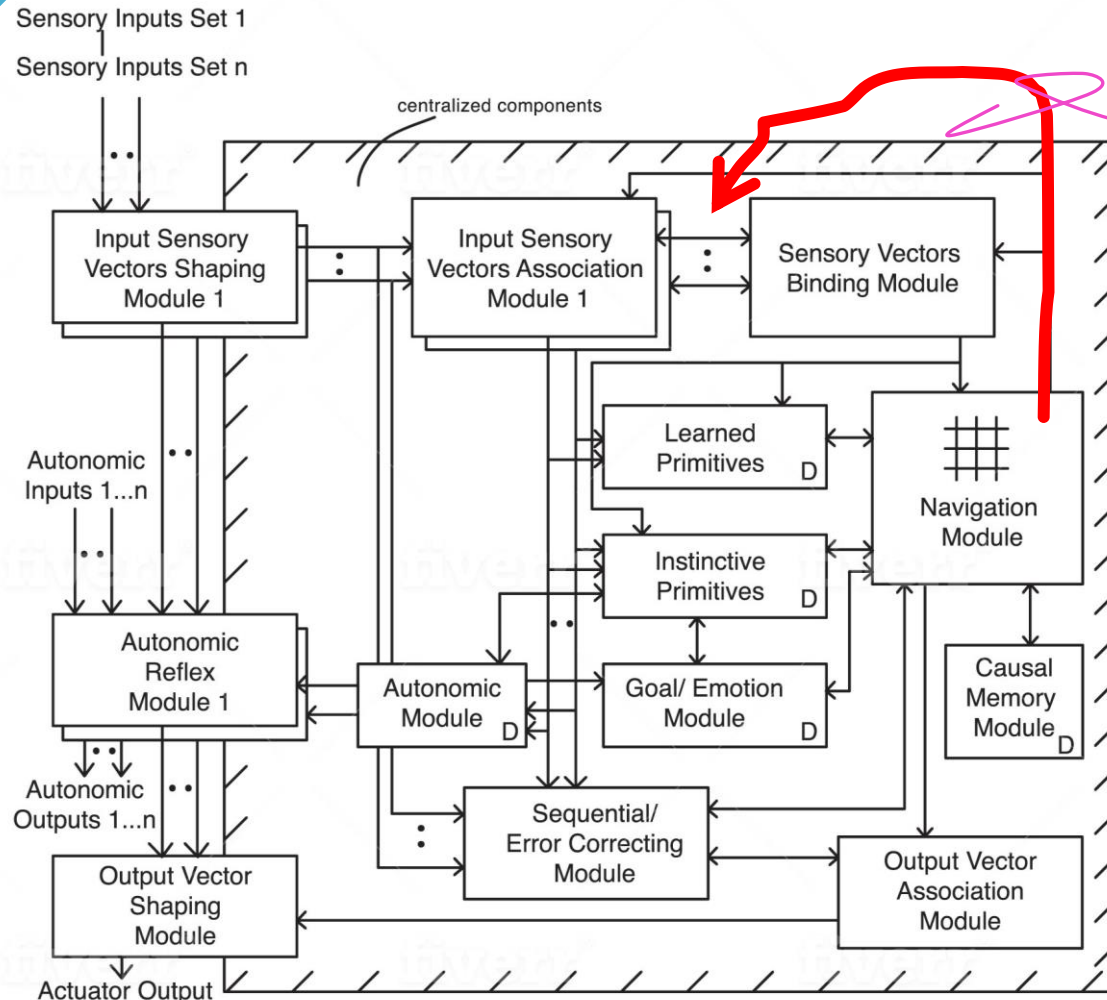


Navigation in all animals ✓

Navigation controls memories ✓



# The model explains all the “clues” from the only existing AGI system (humans)



Rapid evolution: non-causal primate → causal human ✓

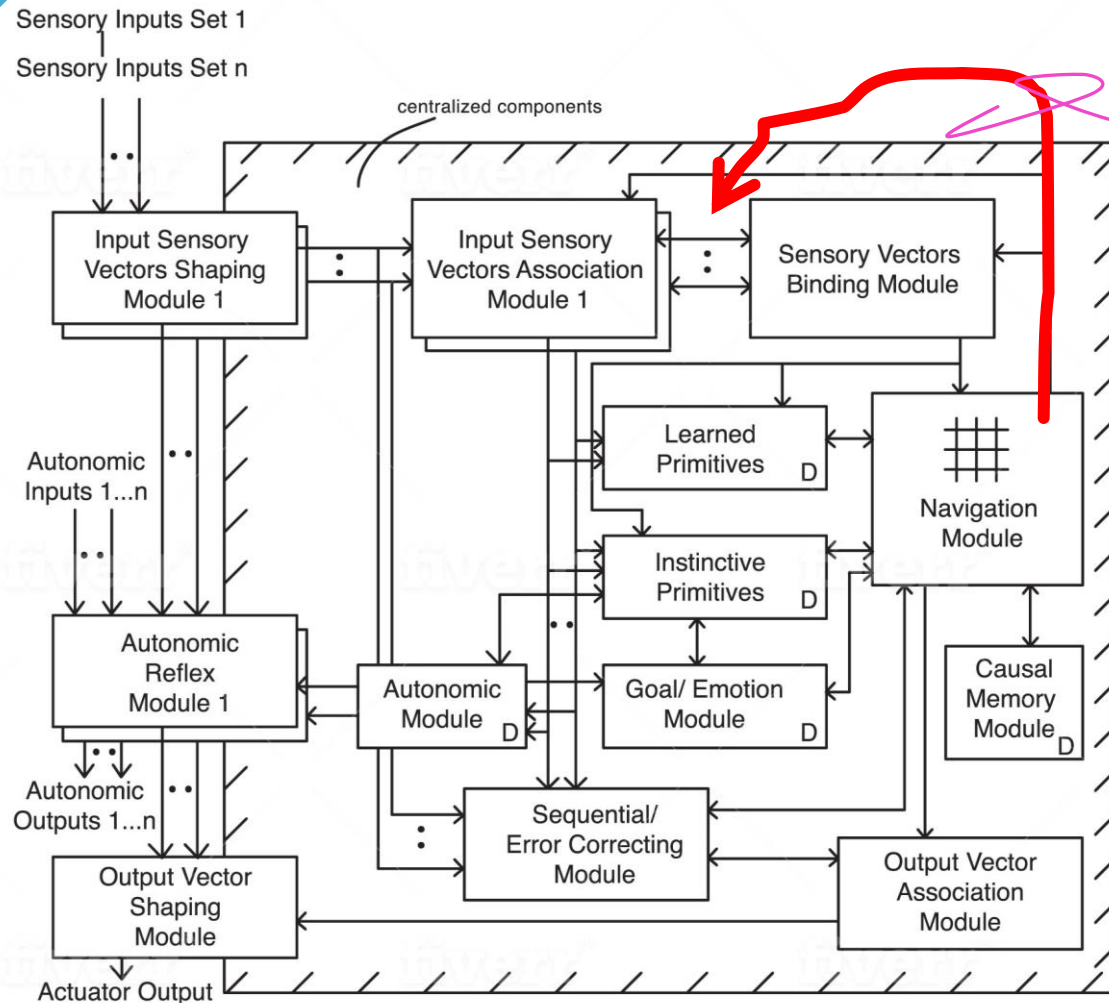
Rapid evolution: little psychosis in primates → much more psychosis in humans ✓





# The model explains all the “clues” from the only existing AGI system (humans)

Schizophrenia paradox – explained (it's a design issue, not a typical disease) ✓

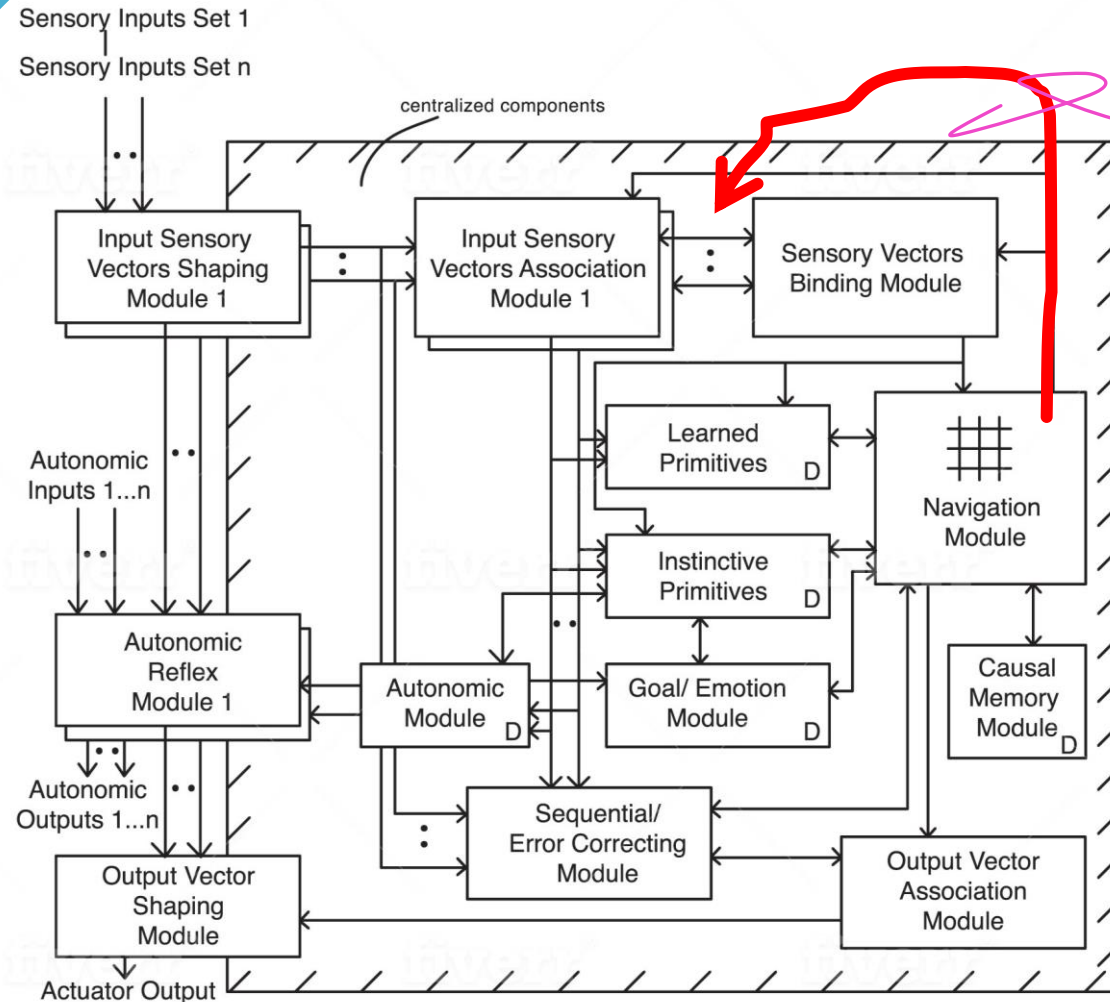




# The model explains all the “clues” from the only existing AGI system (humans)

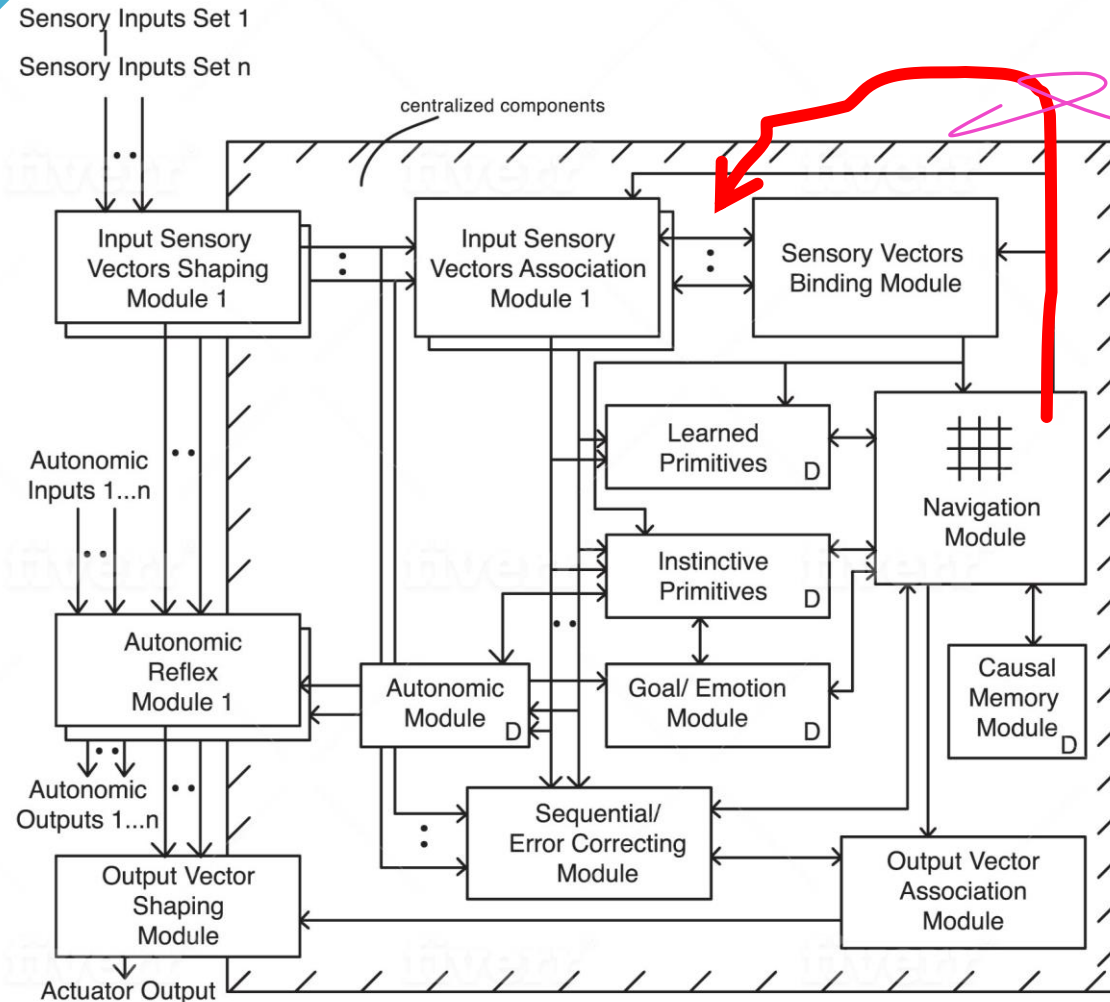
Explainability emerges automatically ✓

Language emerges automatically ✓



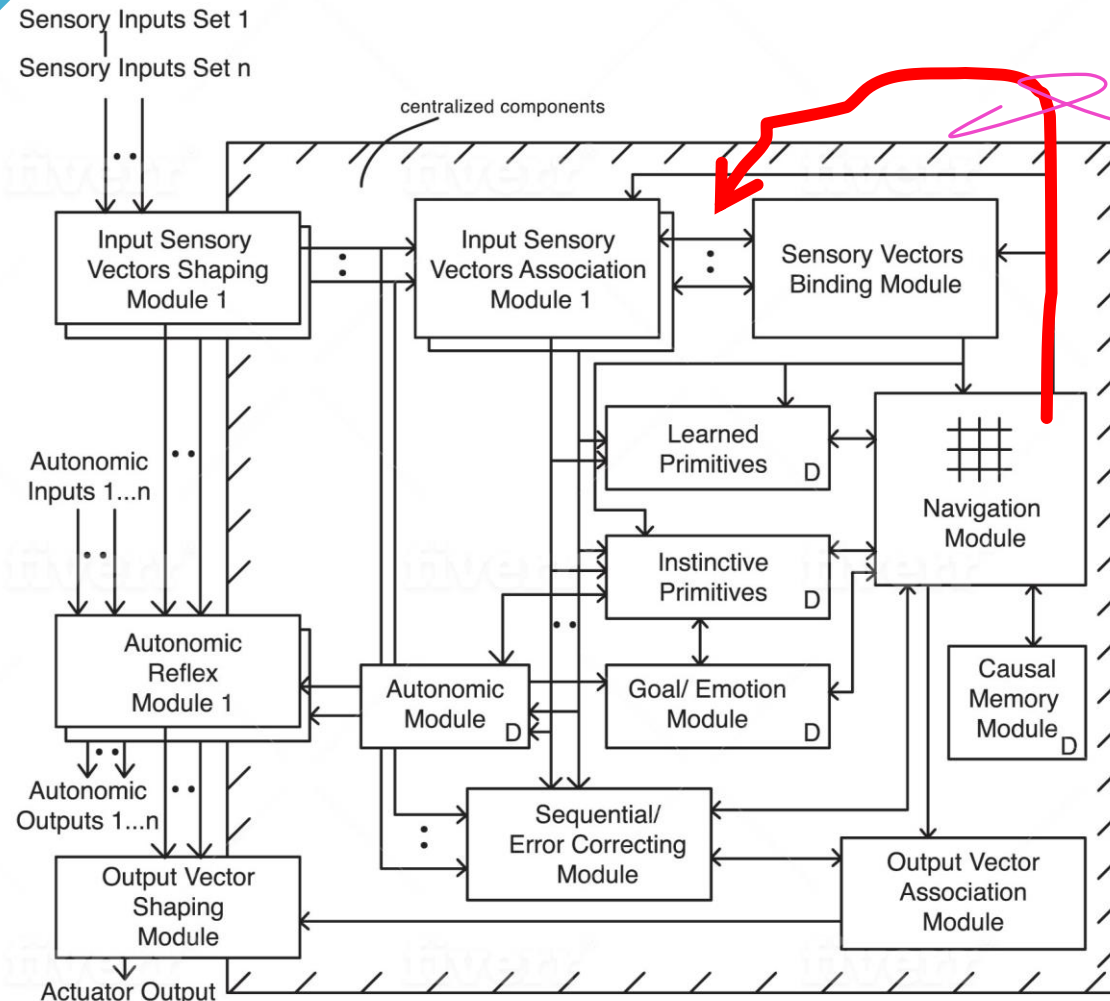
# The model explains all the “clues” from the only existing AGI system (humans)

Lifelong (‘continual’) learning ✓

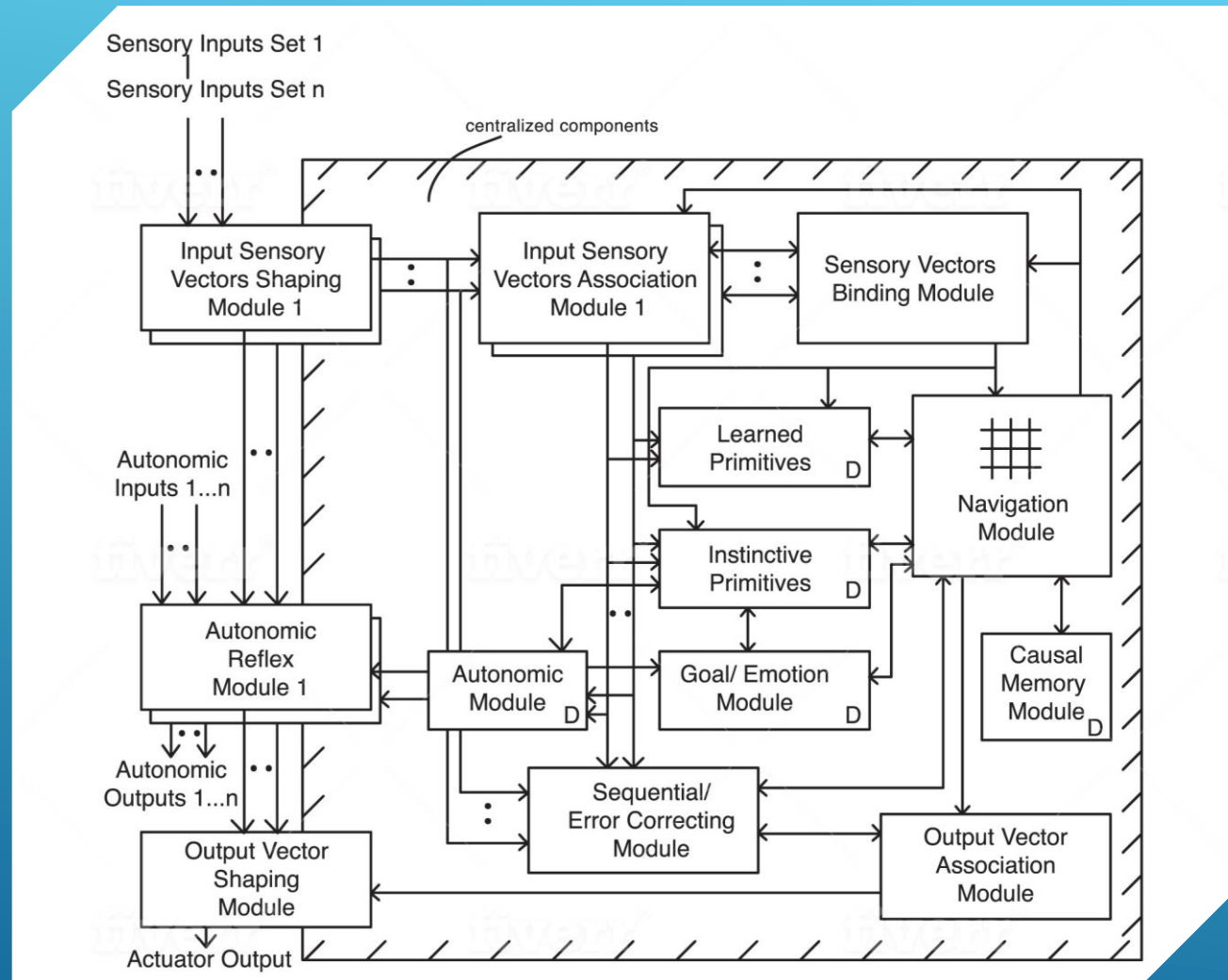


# The model explains all the “clues” from the only existing AGI system (humans)

Automatic generalization to new and novel environments ✓



# GREAT MODEL!!



## CAUSAL COGNITIVE ARCHITECTURE 1 (CCA1)

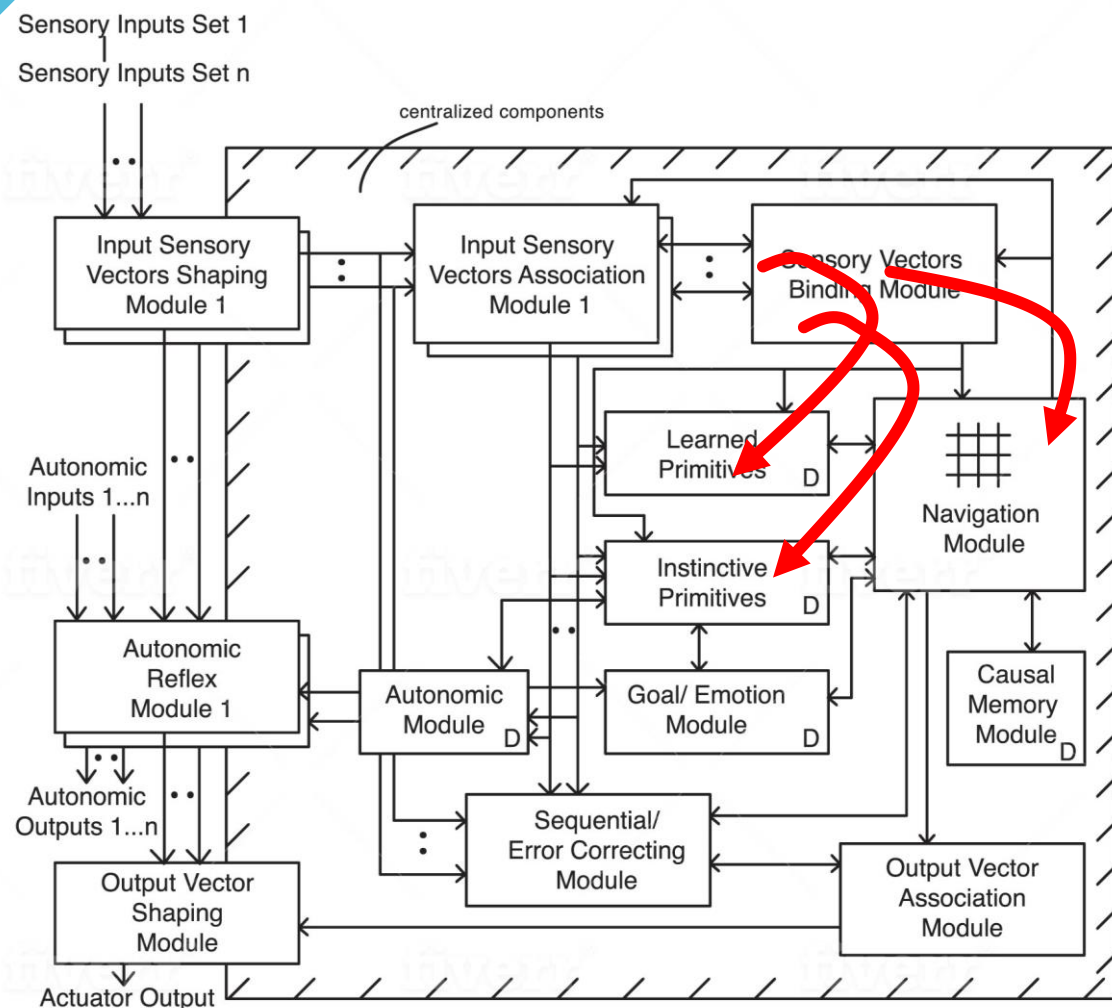
BICA 2018, 2019,  
2020

Works for toy  
problems





# Do we need a “binding language” ?



["river", "water"] →  
river, water

Or maybe: water,  
river

→ ?? 10! = 3 million  
possible steps ??

["river", "water",  
"object", "bubbling",  
"algae", "floating",  
"lines", "turn right",  
"turn left", "straight"]





TO HANDLE REAL WORLD  
PROBLEMS, THE BINDING  
ISSUE NEEDS TO BE  
ADDRESSED



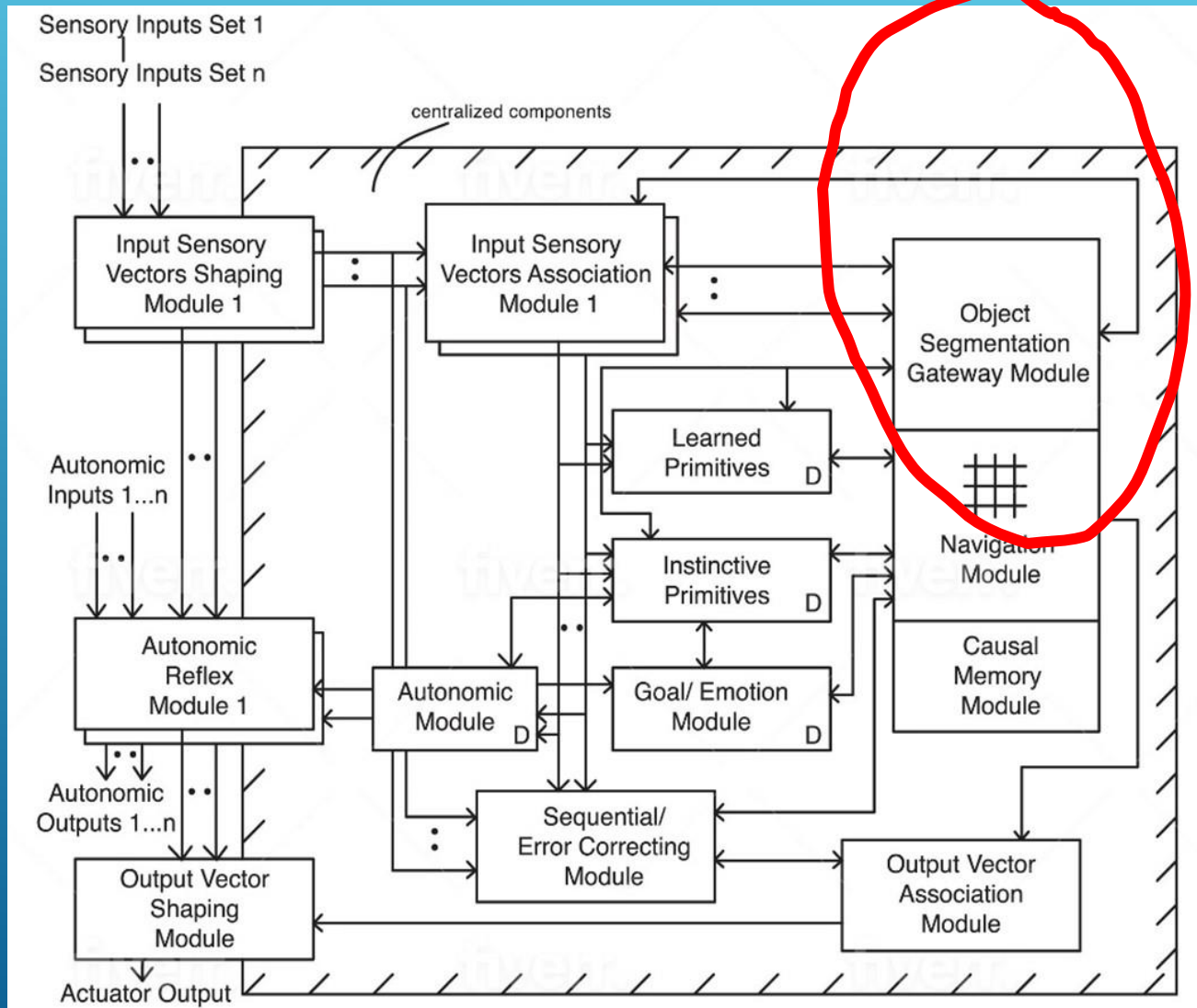
# The Binding Problem (Feldman, 2013):

- General coordination of objects and activities
- The subjective unity of perception
- Visual Feature-Binding
- Variable Binding such as the binding of words in a sentence that allow reasoning

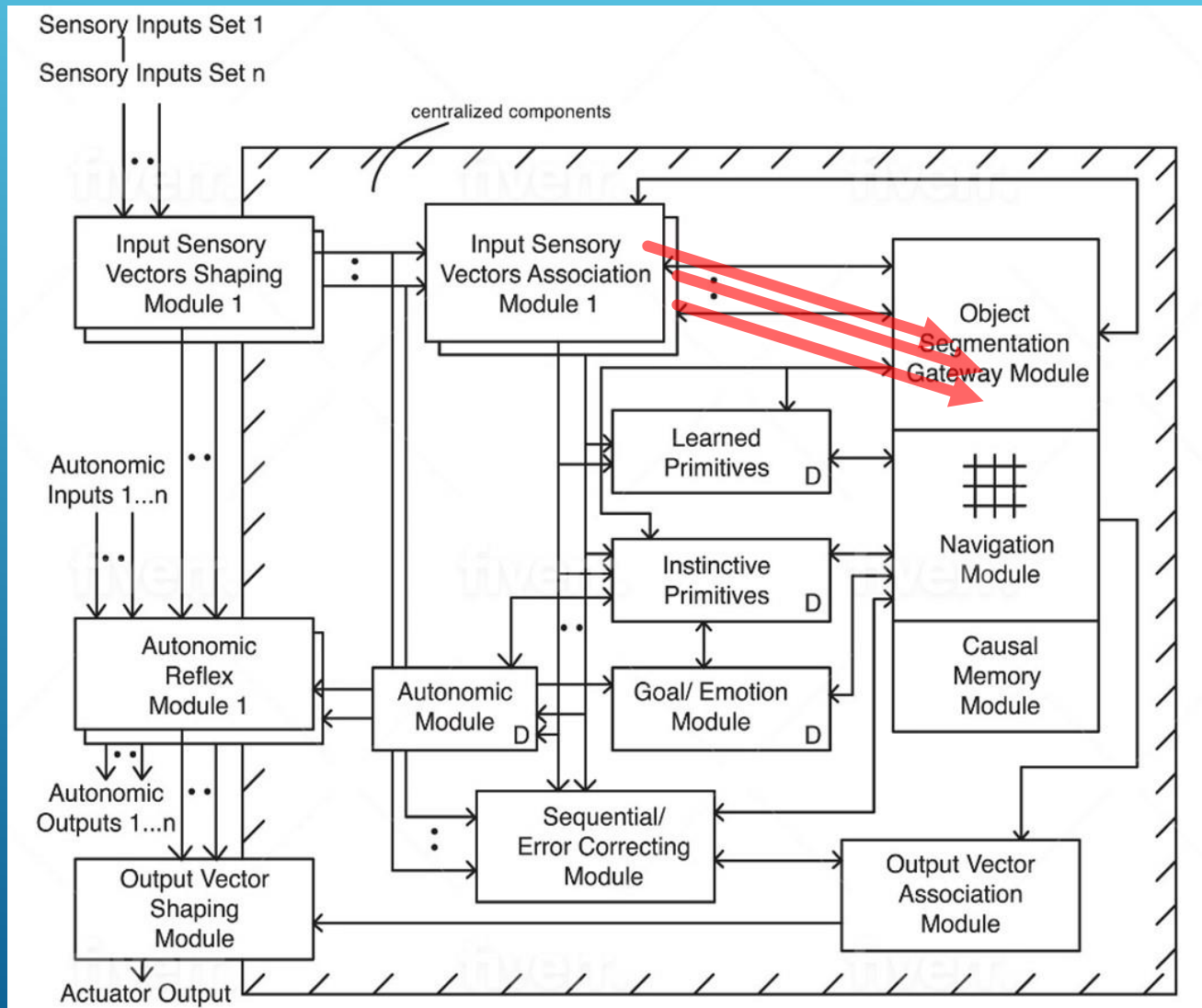


# CCA2

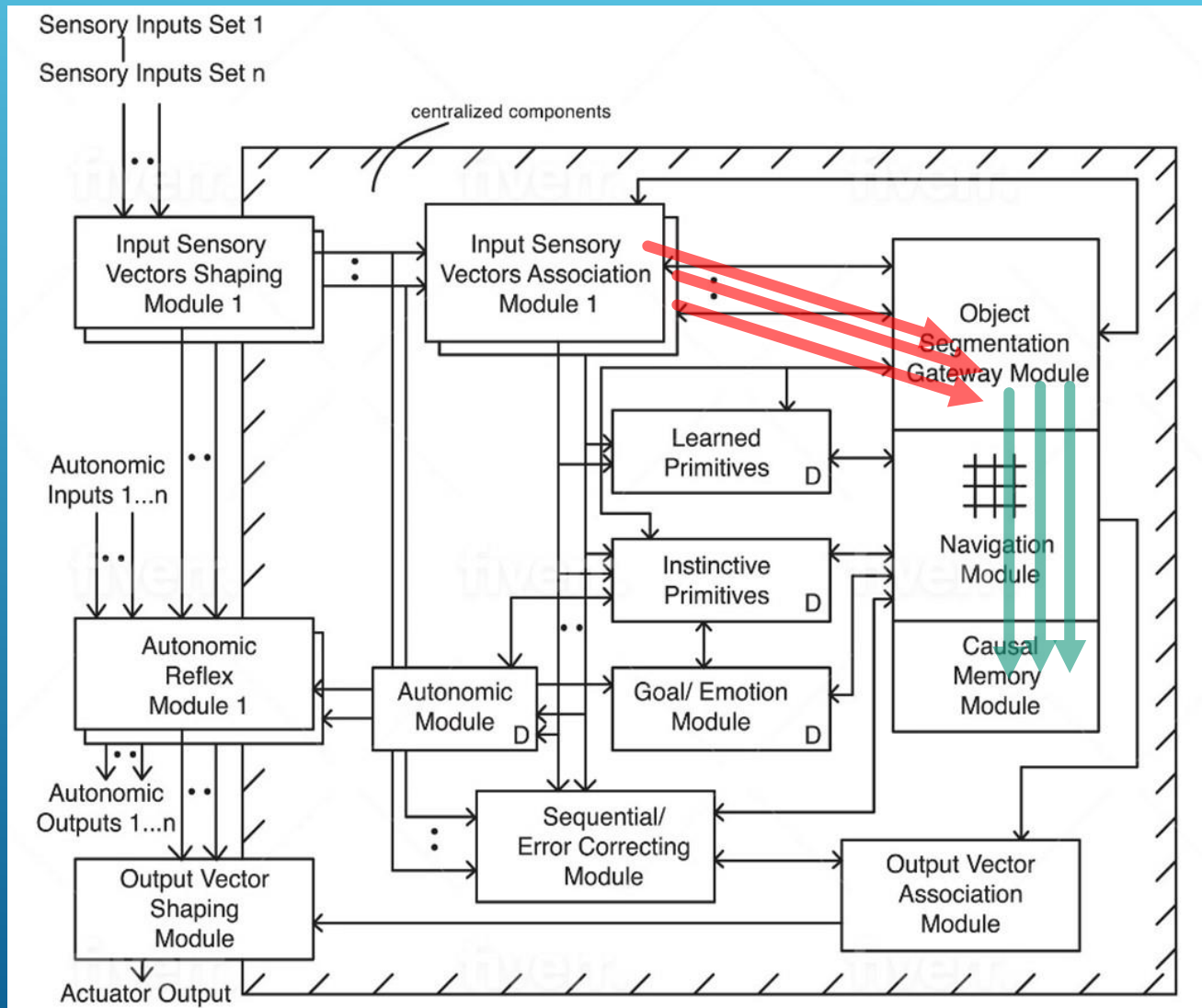
To handle real world problems, the binding issue needs to be addressed



← CCA2

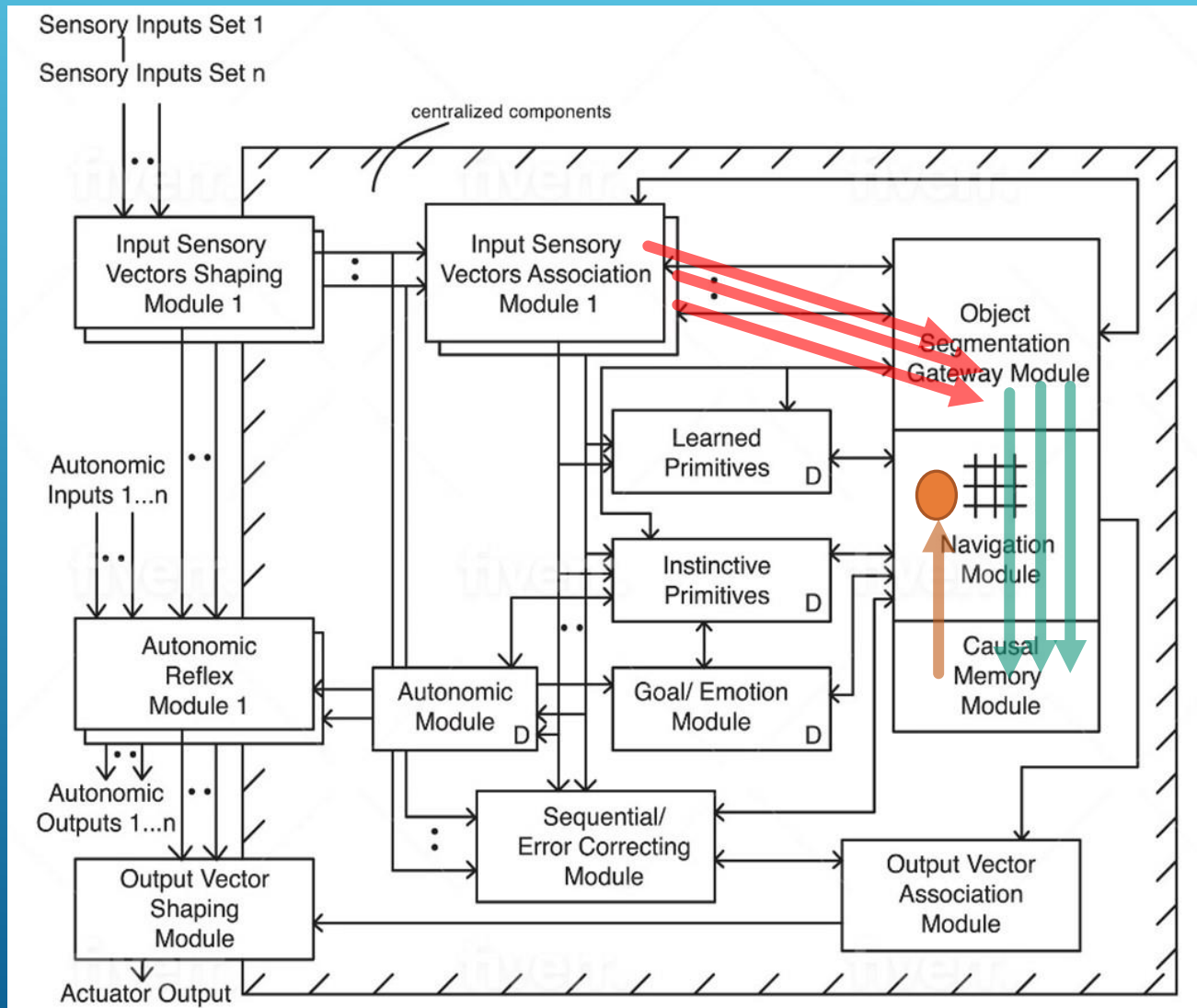


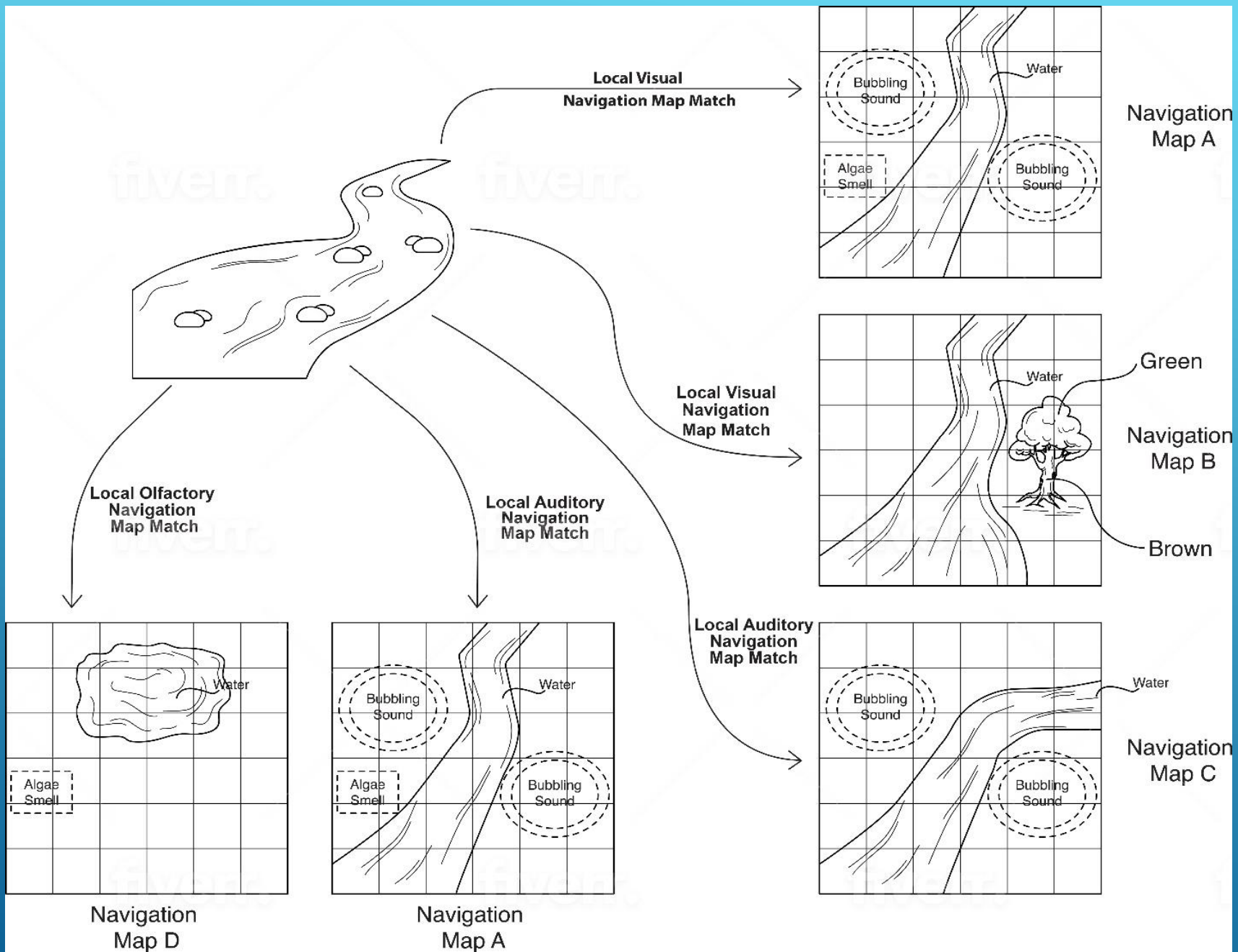
← CCA2

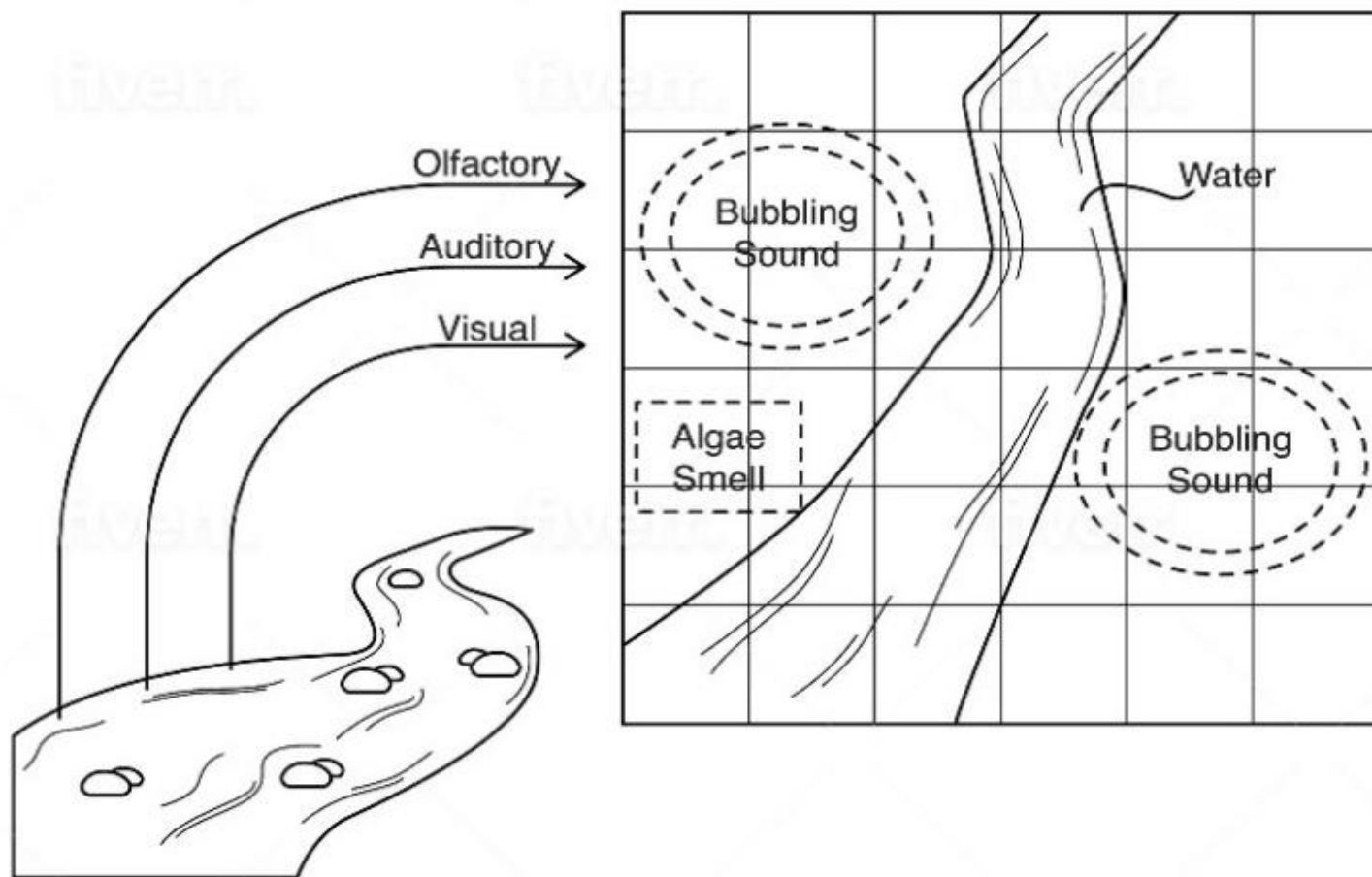




# ← CCA2







# The Binding Problem (Feldman, 2013):

- General coordination of objects and activities
- The subjective unity of perception
- Visual Feature-Binding
- Variable Binding such as the binding of words in a sentence that allow reasoning





# 1. Sub-problem: General coordination of objects and activities

Use of navigation maps  
as a basic data  
element

Instinctive Primitives  
and Learned Primitives  
are applied against  
objects on the current  
navigation map

As such, a coordination  
of objects and activities  
occurs



## 2. Sub-problem: The subjective unity of perception

Best match navigation map represents the CCA2's perception of reality of the sensory scene in front of it

Current best match navigation map will be updated with current input sensory information, and represents CCA2's perception of the world

There is a subjective unity perception



### 3. Sub-problem: Visual Feature-Binding

**Spatially mapping visual features onto a spatial navigation map solves this binding sub-problem**

**No longer require a binding language; rather, binding occurs in the Vectors Association module and the Navigation Module**



## 4. Sub-problem: Binding of Words Allow Reasoning

**Verbs and nouns  
provide  
explanations to  
the user**

**Explanations  
generated via  
saved navigation  
maps**



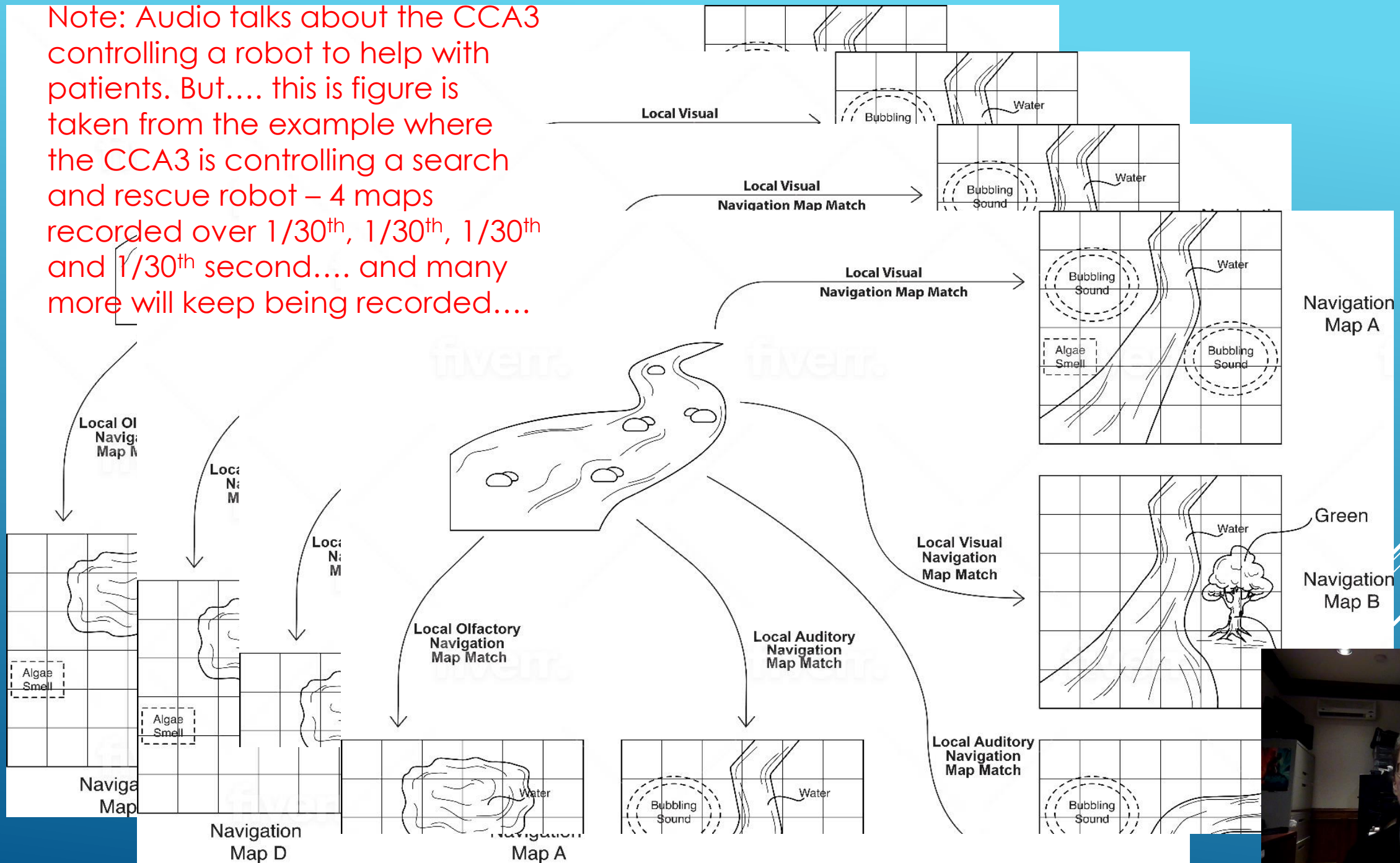


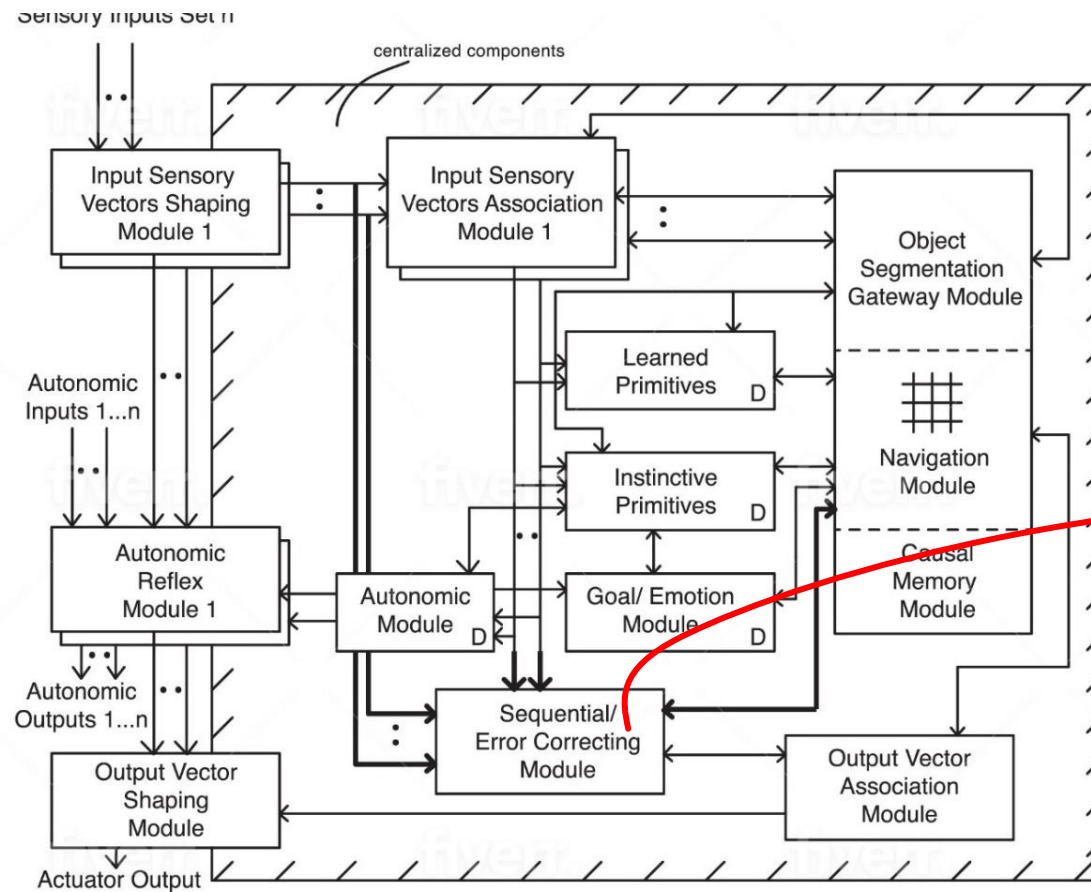
**Most definitions of the  
'Binding Problem' do not  
take time into account,  
ie, binding changes**

- However, CCA2 shows changes in sensory inputs with time, that *\*must\** bind time also
- **CCA3** – bind space time



Note: Audio talks about the CCA3 controlling a robot to help with patients. But.... this figure is taken from the example where the CCA3 is controlling a search and rescue robot – 4 maps recorded over 1/30<sup>th</sup>, 1/30<sup>th</sup>, 1/30<sup>th</sup> and 1/30<sup>th</sup> second.... and many more will keep being recorded....



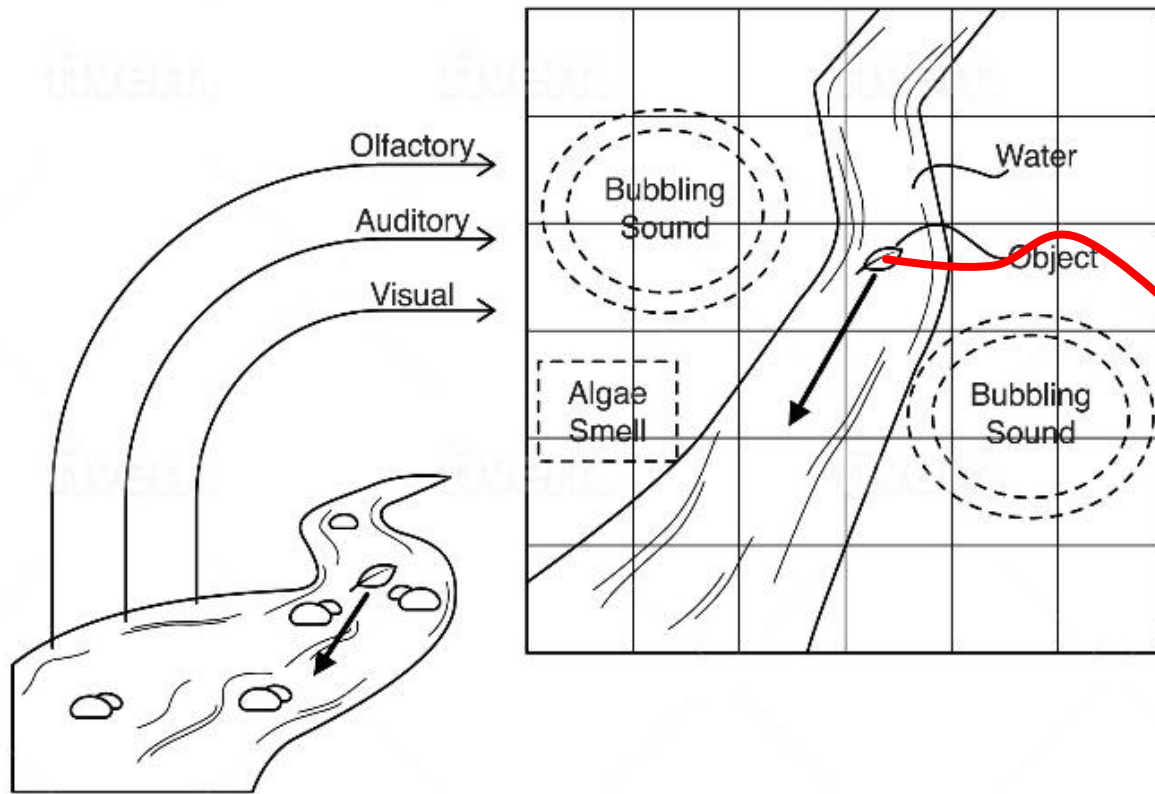


► CCA2 – binding of space

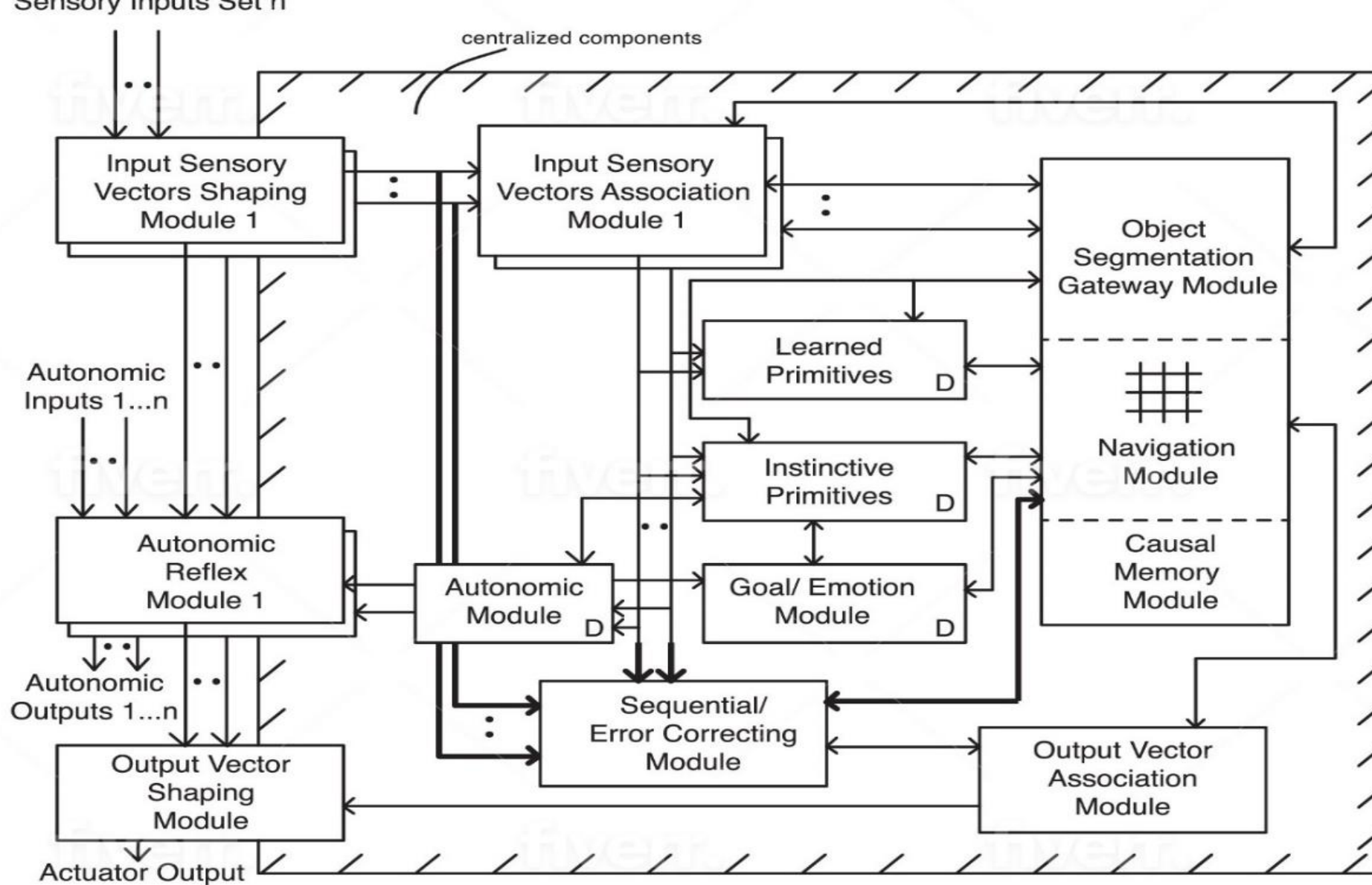
► CCA3 – need to bind changes with time also



# GENERATE MOTION PREDICTION VECTORS









....continued in VIDEO 2

balloon from powerpoint stock image

