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Sensorimotor proto-objects: bootstrapping perception from compensable actions

1 BACKGROUND

Sensorimotor Contingencies Theory provides a strong foundation for a mathematical formalization of the bootstrapping problem of robot perception.

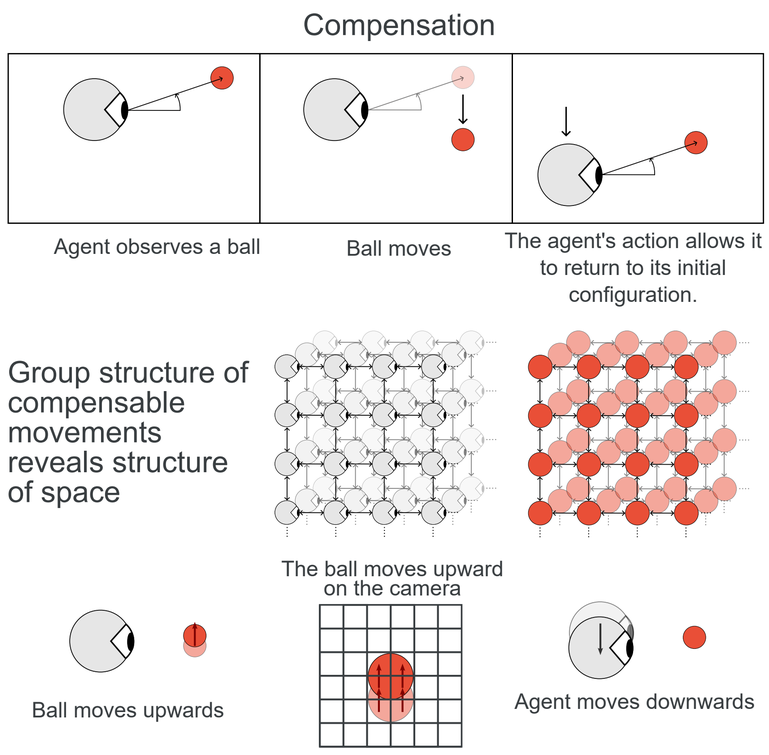
Currently, this framework lacks the ability to deal with the **dynamics of the environment** and, by extension, **objects**.

2 QUESTION

How can a sensorimotor agent with prediction functions acquired by motor babbling infer environment dynamics and detect primitive forms of objects ?

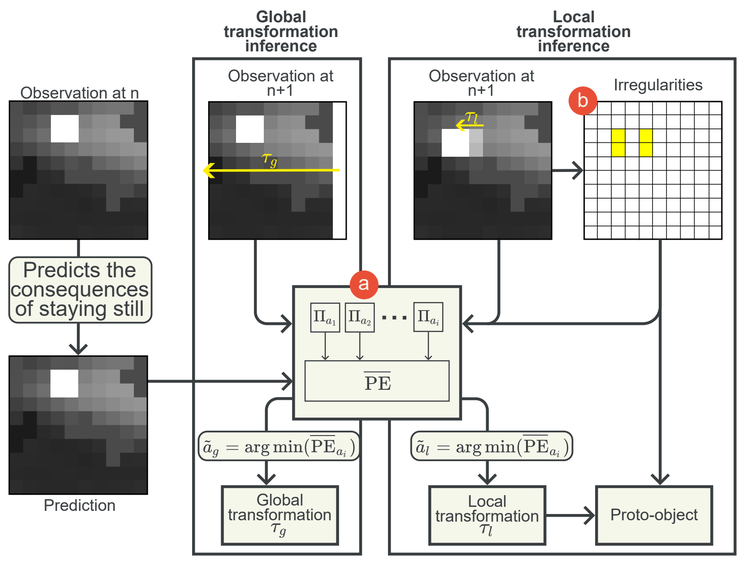
3 METHODS

Establishing an isomorphism between the compensable action group and environmental displacements



A single action prediction function can describe the agent and the environment/object movements

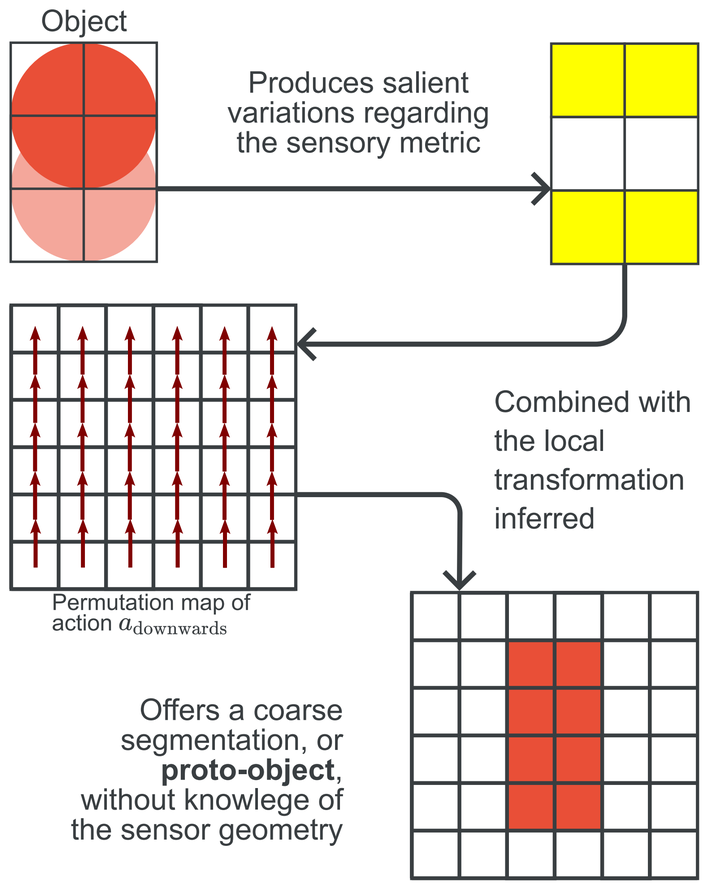
Inference algorithm that uses predictive coding of sensorimotor contingencies



a The agent cycles through its known prediction functions Π_a until finding the one that best explains the discrepency between its prediction and the observation.

b The algorithm is extended to local transformation thanks to a saliency mechanism that highlights irregularities. The sensory metric is learned without supervision based on [Goasguen2022].

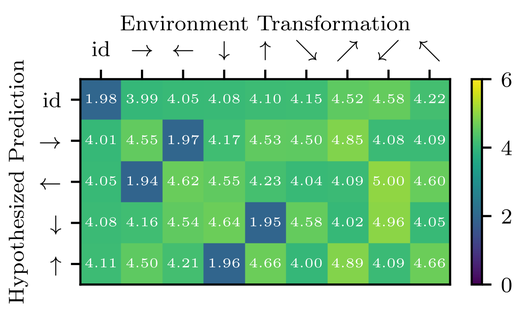
Formalization of proto-objects as sensory elements moving rigidly together



Offers a coarse segmentation, or **proto-object**, without knowlege of the sensor geometry

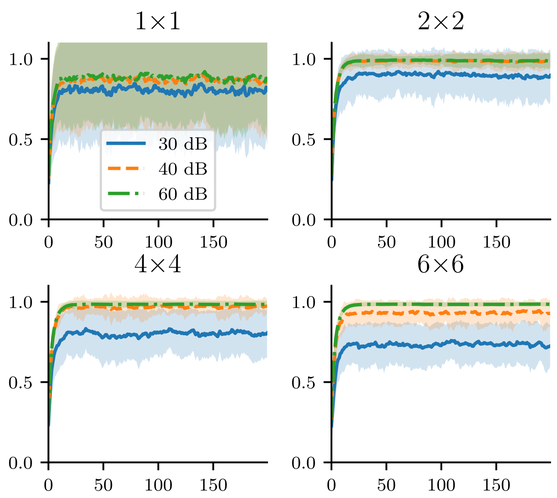
4 RESULTS

In a minimal 2D visual environment, the agent robustly infers the displacement observed for both global and local transformations and produces a coarse segmentation of a single proto-object.



a) Mean global prediction error
The average prediction error is minimal when the agent's hypothesis prediction function corresponds to the equivalent displacement of the environment.

b) Modified F1 score for proto-objects segmentation according to SNR and object size
Objects gets best segmentation when a maximum of its component are salient during a displacement.



5 FUTURE STEPS

Extend algorithm to handle multiple and more complex objects.

Formalization of a sensorimotor notion of objects. Key directions include:
- using the coarse segmentation to developmentally discover fundamental aspects of objects such as proximity or closure.
- leverage interaction in the object's formalization.
- find more scalable prediction functions than permutation maps.

One sentence summary

We use prediction functions of sensorimotor contingencies to bind compensable actions to environmental dynamics, allowing us to infer displacements in the environment and formalize proto-objects for agents with minimal *a priori* knowledge.