Composing Moves: How Procedural Memory Builds Novel Action

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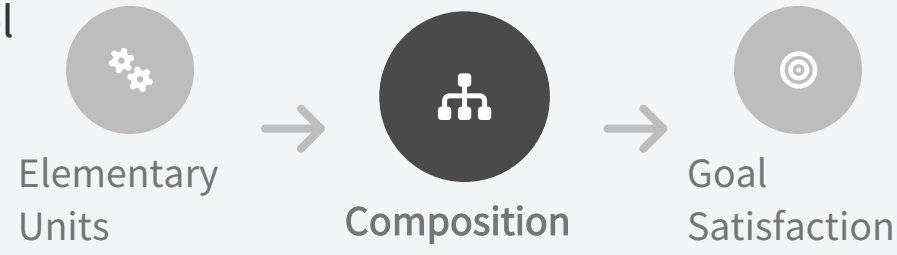
CONTENTS

01 Why Compositionality?

The Serial-Order Problem

Lashley’s challenge to stimulus-response chaining

Stimulus-response chaining fails to explain the flexible sequencing of novel skilled acts. The motor system must compose elementary units into hierarchically ordered, context-sensitive sequences that satisfy a distal goal.



From Novel Gestures to Tools

Apraxia data reveals a specific deficit in composing unfamiliar kinematic chunks into a coherent plan. Patients can grasp objects but fail to assemble multi-step tool-use actions or imitate meaningless gestures, pointing to a failure of compositional reasoning, not low-level execution.

Intact Execution

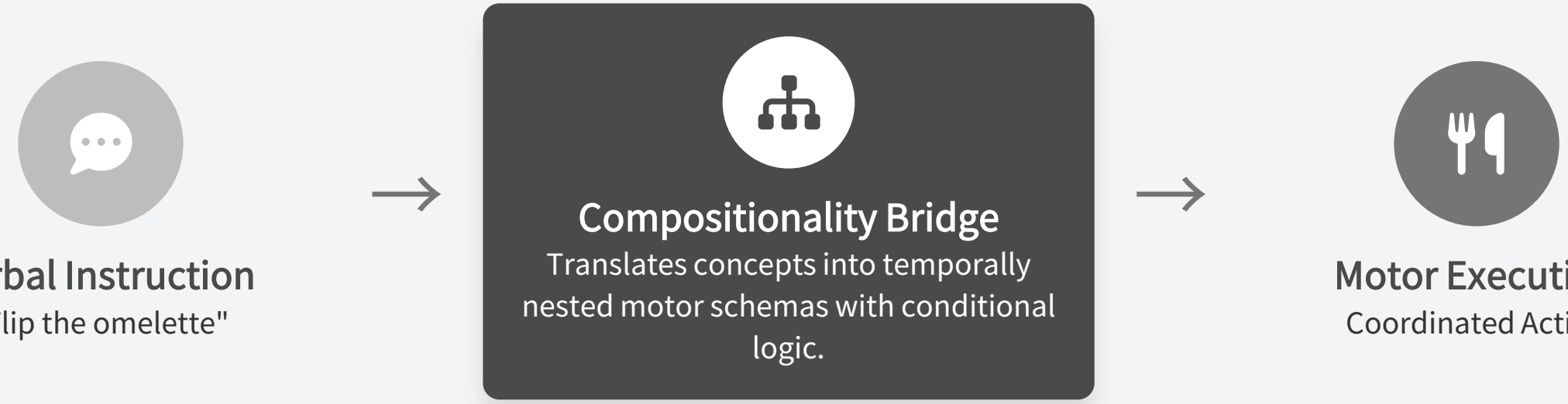
Basic grasping and simple movements are preserved.

Compositional Failure

Cannot assemble sub-actions for novel tool use.

The Declarative–Procedural Interface

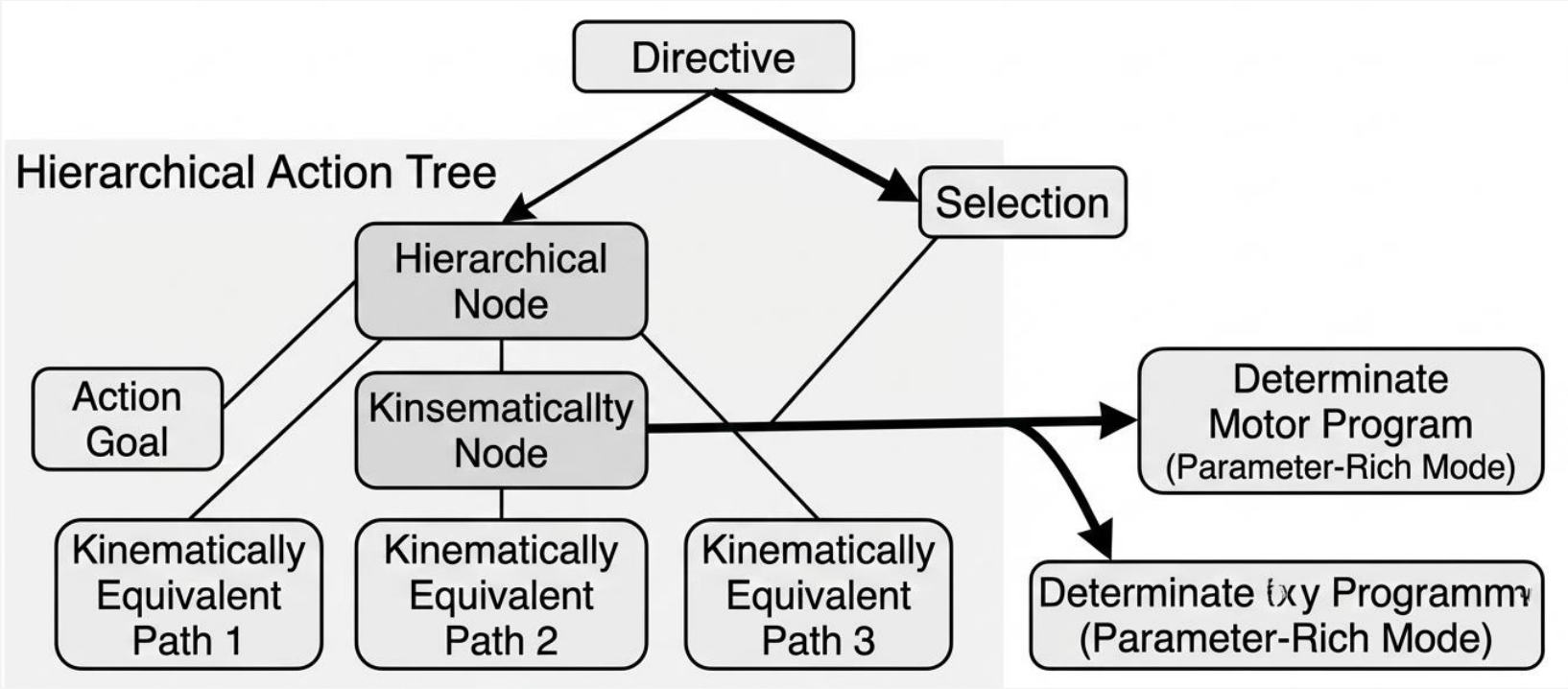
How sparse symbols guide complex action.



02 Three Desiderata

Method-Specific Directivity

A directive must pick out one determinate motor program among kinematically equivalent paths.



Sequencing & Branching

Real skills demand conditional logic and parallel coordination.

Conditional Branching

Encoding "if-then" transitions based on context.

Parallel Synergies

Coordinating multiple effectors simultaneously.

Nested Timing

Tracking sub-goal completion to gate the next chunk.

Only **compositional representations** can encode this level of complexity.

Error Evaluation: Two Types of Failure

Execution Noise

The appropriate action is performed, but with spatial or temporal flaws (e.g., tremor, weakness). The **content** is correct, but the **precision** is lacking.

Content Mismatch

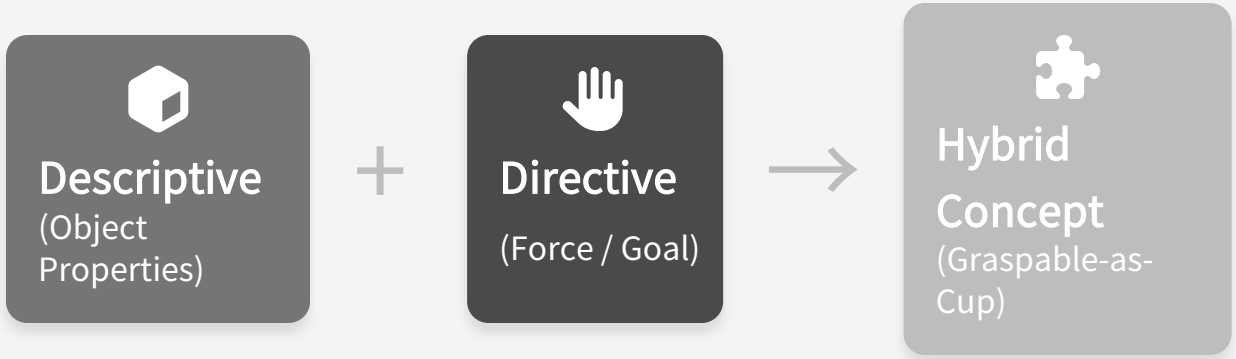
A well-formed but inappropriate action is produced (e.g., brushing teeth vs. circular motion). The **content** itself is wrong, a true **misrepresentation**.

Compositional structure supplies the **internal standards** needed to distinguish these errors.

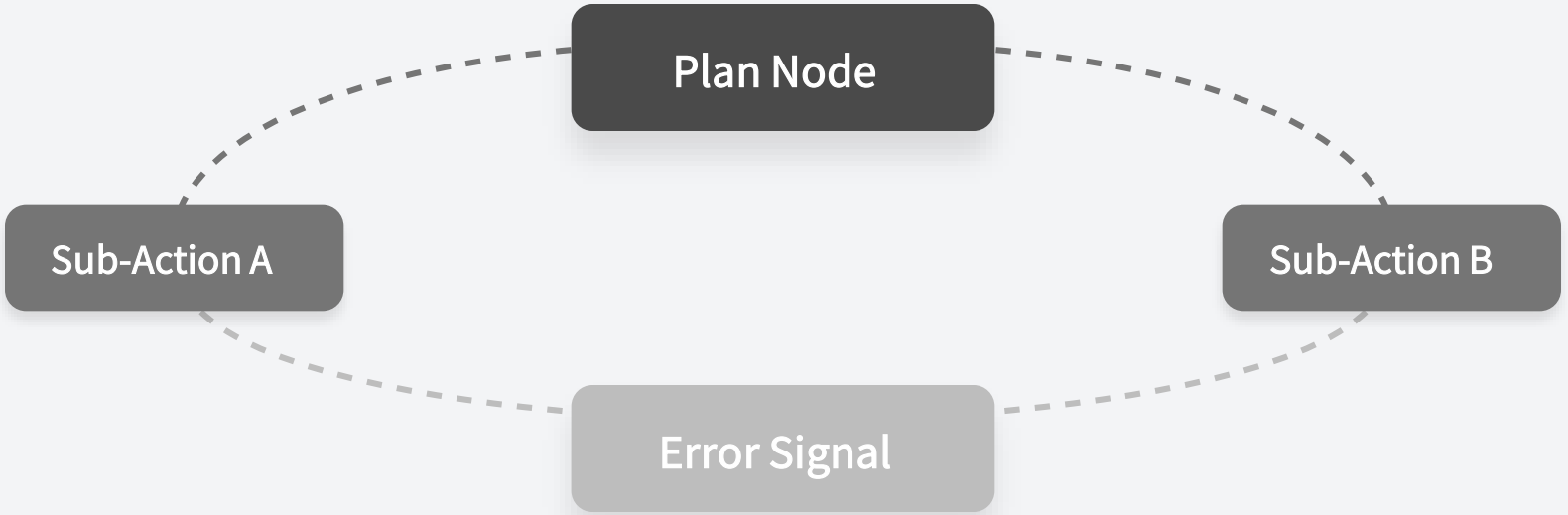
03 Architectural Sketch

Hybrid Practical Concepts

Drawing on Pavese, primitive action concepts combine descriptive object-properties with directive force. Their Fregean modes of presentation are recombined by productive reasoning to assemble novel yet determinate motor plans.



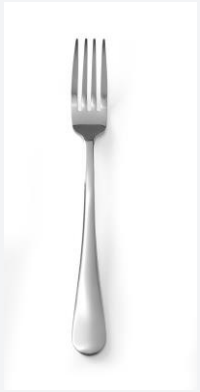
Hierarchical Forward Models



Each node pairs an efference copy with a predicted sensory effect. Mismatches propagate upward, supplying **fine-grained error signals** that target the offending constituent.

04 Compositionality in Action

Case Study: The Novel Tool Test



Familiar Object

Stored motor program: "Stab/Pierce"

New Context

Requires novel action: "Scoop"

Apraxic Failure

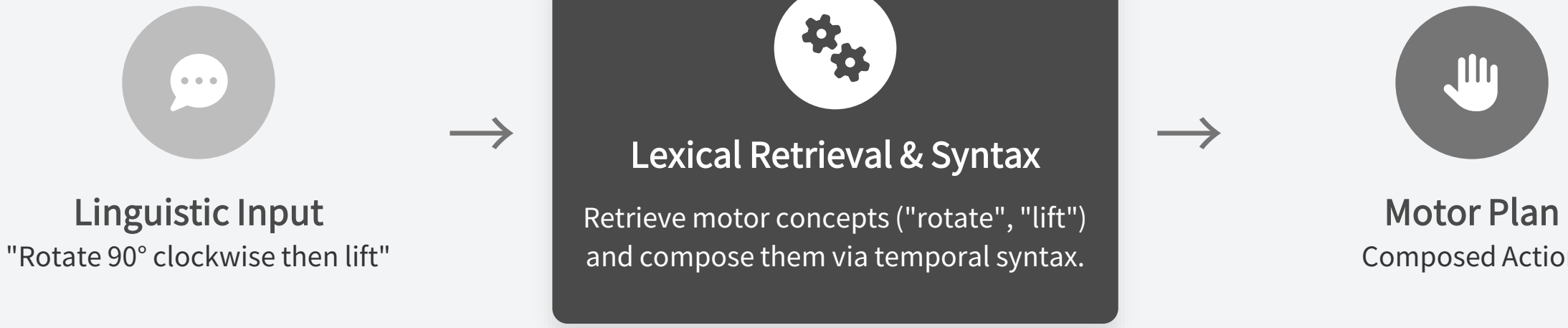
Cannot re-compose sub-actions.

Successful agents compose **"scoop"** kinematics with container affordance; apraxics cannot re-compose stored sub-actions under new functional goals.

Meaningless Gesture Imitation

Copying an arbitrary hand-configuration requires parsing the demonstration into joint-angle constituents, reordering them, and aligning with one's own body schema. This offline assembly is enabled by compositional representation.

Language-Driven Composition



The same **combinatorial engine** underlies both invented and routine acts.

05 Normative Profile

External Goal (Success)

Did the action achieve the desired outcome in the world? This is a matter of **success**.

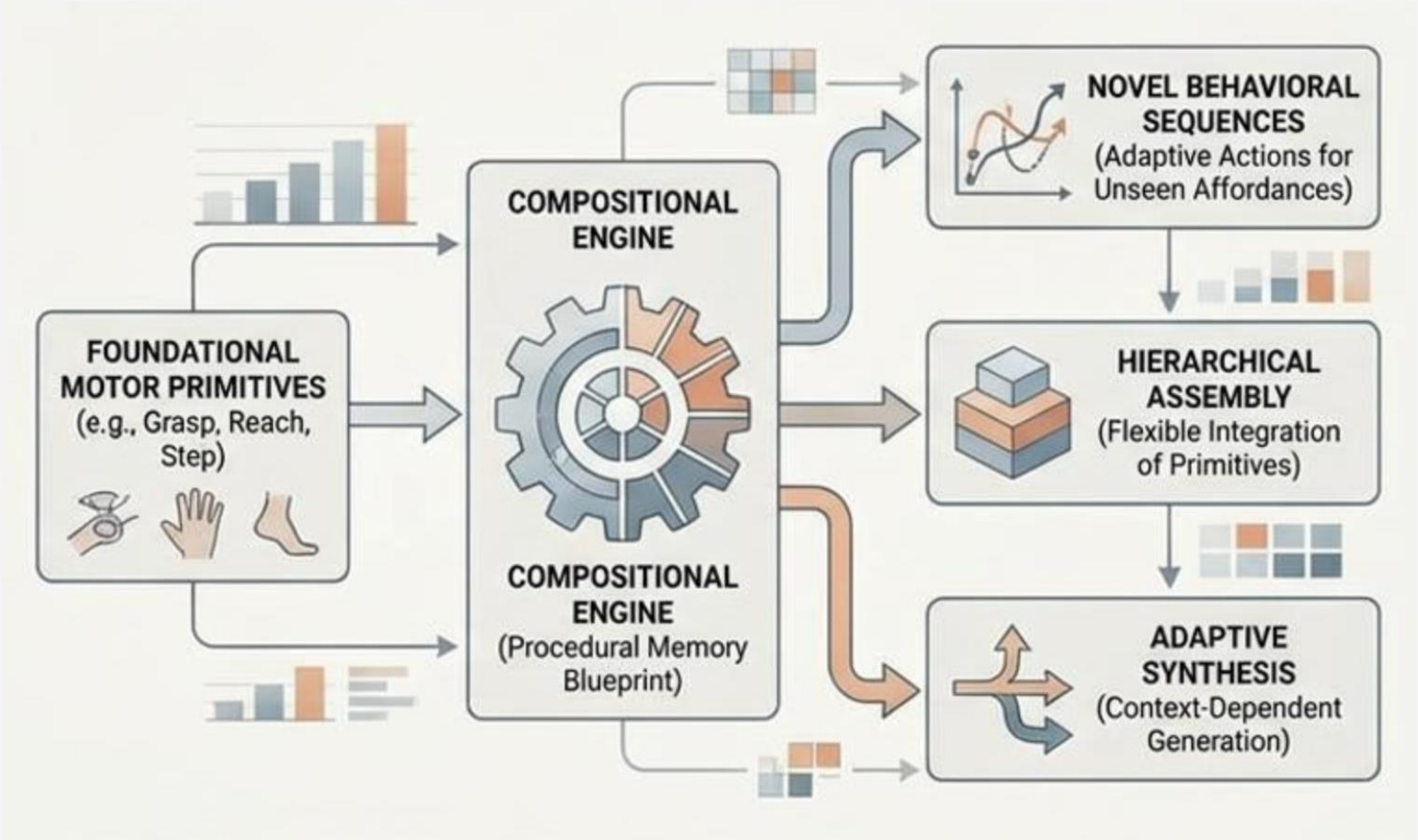
Internal Goal (Correctness)

Did the action conform to its learned internal standard? This is a matter of **correctness**.

An action can be a "success" but still be "incorrect" (false procedural memory). Only a **content-based account** can distinguish them.

Context Without Explosion

Compositional schemes avoid encoding infinite context-action pairs. Variables are bound online during execution, letting finite schemas generate context-appropriate muscle patterns while keeping satisfaction conditions intact.



Rationality Preservation

Expert Error

A proficient agent makes a mistake.

Misrepresentation

Fault is located in a mis-composed constituent.

Preserved Rationality

Global rationality and agency are shielded.

This explains **graded responsibility** and distinguishes skill error from agentive failure.

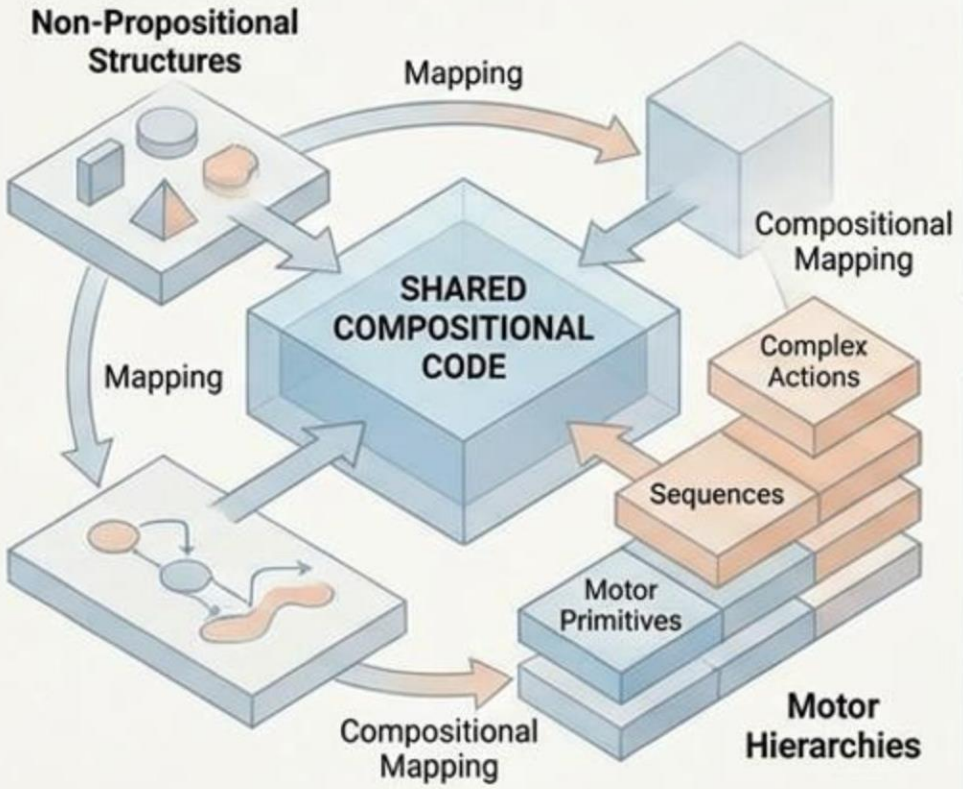
06 Anti-Rep Challenges

The Enactivist Challenge

- Radical enactivism denies symbolic-to-motor translation.
- Pre-linguistic infants compose novel actions without symbols.

The Paradox

The Compositional Framework



Evidenced Solution

- Only evidenced solution: Shared Compositional Code.
- Maps non-propositional structures onto motor hierarchies.
- Explains generation of novel behavioral sequences.

Challenge: Interface Without Translation

Pre-linguistic Infant
Composes novel actions.

→

Shared Compositional Code
Maps non-propositional structures onto motor hierarchies.

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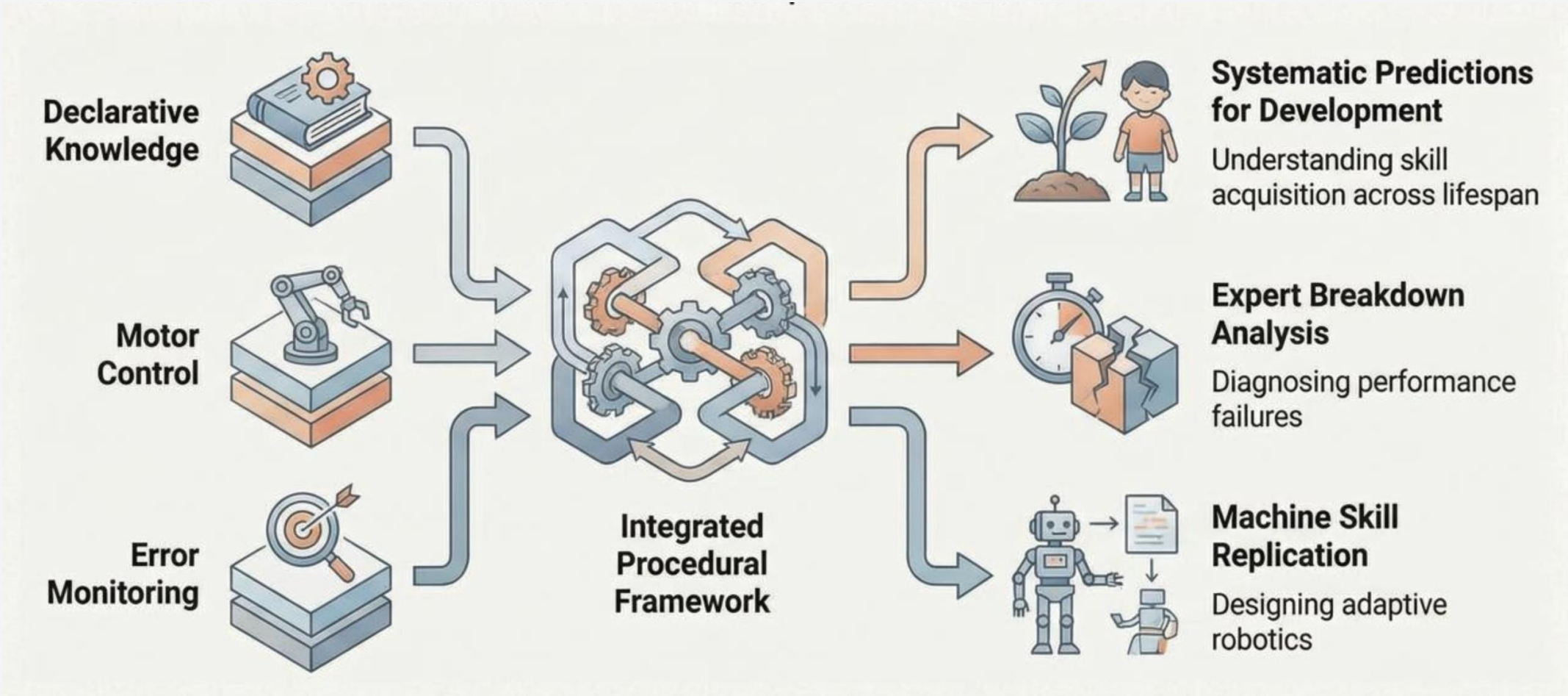
Radical Enactivism
Denies symbolic-to-motor translation.

The only evidenced solution is a **shared compositional code**.

07 Upshot & Outlook

Upshot: A Unified Explanation



Upshot: AI Ramifications

- Agentic systems, to be useful, must act, and their plans are obviously compositional. To make them more robust, we should understand that they need equally informative success / failure signals to adapt to their situation.

THANK YOU