

Objectives

- The aim of this work is to show that the existing idea of embodied cognition applies to a multiplicity of scales, from subcellular to behavioral
- Embodied cognition is modeled as an emergent pattern in the complex dynamical system of perceptual and motor components of the brain/body in interaction with the (internal and external) environment
- Distilling the essential aspects of emergent phenomena at various scales reveals three principles of change that are common to these scales: the '3T's':

Transition; Transformation; Transcendence

What is Embodied Cognition?

- Embodied cognition is the notion that knowledge of the world around us is inseparable from our bodily actions in the world—it is the real-time formation of patterns in the simultaneous and correlated interactions of multiple sense modalities and motor functions with the environment and with each other.
 - In particular, embodied cognition *does not presume* pre-existence of: {physical structures, hierarchical functional structures, algorithms, symbolic representation}
 - Embodied cognition is a direct challenge to objectivist ideas of cognition that envision a world of objective truths that exist externally to our minds, and our minds learn to symbolically represent these truths.

"...humans can and do use propositional logic to describe and think about their experiences. However, the stuff that our logic works on is non-propositional and, indeed, is totally based on bodily experiences." (Thelen, 1995)

Adaptive Behavior as Embodied Cognition

"Adaptive behavior is an **emergent property** which spontaneously arises through the interaction of simple components. Whether these components are neurons, amino acids, ants or bit strings, adaptation can only occur if collective behavior of the whole is qualitatively different from that of the sum of the individual parts. This is precisely the definition of **nonlinear.**"

-- quote of Farmer and Packard from Thelen, 1995.

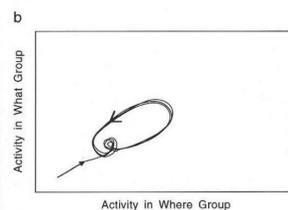
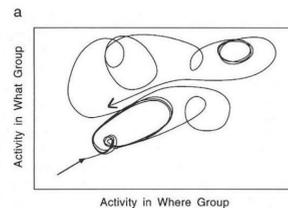
- Hence we may model the arising of knowledge of the world as an adaptive outcome of mutually informing interactions between actions, perceptions and objects.

Reentrance as Condition for Cognition

Gerald Edelman defines reentrance as the "anatomical interrelating of several or many simultaneous perceptual and motor representations. Reentry is necessary to account for the coordination of responses across several sensory modalities." (Thelen, 1995)

Emergence of Attractors in Coupled Reentrant "What and Where" Systems

"By simple Hebbian notions of increasing strength of connections in all three mappings with joint activity, paths that are commonly repeated will become attractors—stimuli and actions that formerly gave rise to close but distinct patterns of activity will now yield a single trajectory." (Thelen, 1995)



Example of Attractor Landscape: Ontogeny of Locomotion

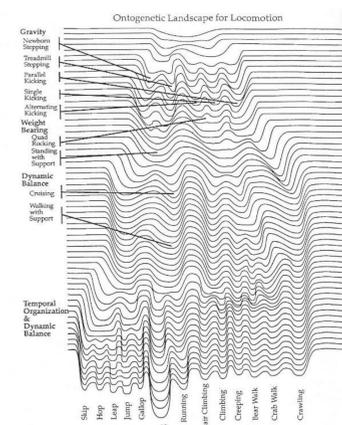


Figure 4.17. Ontogenetic landscape for locomotion. (From Mucka, Gershkoff-Stowe, Cole, and Thelen, 1995.)

The 3T's

- Transition:** real-time adaptive response based on existing cognitive/behavioral landscape
- Transformation:** significant changes in adaptive landscape (e.g. changes in stable points)
- Transcendence:** repurposing of adaptive landscape

Scalability—consciousness is more process than structure

- Sub-neurons (microtubules?)
- Neurons
- Cell assemblies/ neuronal groups
- Lobes
- Central nervous system
- Peripheral nervous system
- Interpersonal networks

Does Consciousness have a Particular Substrate?

Three Phases in the Development of Consciousness

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Substrate = Layer/Dimension

- Each scale and level of organization that is attributed with some essential function of consciousness may be one of multiple layers, all of which, together, constitute consciousness
- Causative dependency among layers and substrates
 - Smaller scales are causative in the moment
 - Larger scales are causative through selection and intervention

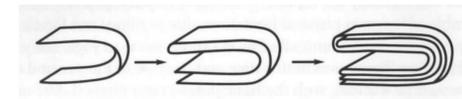
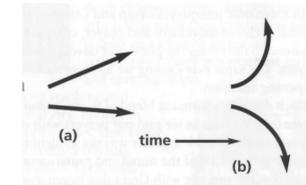
Physics of Process A

- Attractive and repulsive forces → transport of materials and energy
- Linear regime
 - Recurrence: periodic phenomena (e.g. oscillations)
 - Linear stability and instability
- Nonlinear regime
 - Nonlinear stability and instability
 - Hyperbolic points
 - Stable and unstable manifolds
 - Exponential divergence of trajectories

Physics of Process B

- Stretching, contraction and folding—e.g. kneading bread dough
 - Exponential divergence of nearby points in time, coupled with boundedness and dissipation leads to self-symmetric attractors
- Self-symmetry: repetition of structure at multiple spatiotemporal scales (or 'level of organization')
- Coupling of different scales permits transport of information from one scale to another
 - Mechanical: axons and dendrites
 - Dynamical coupling: resonance, entrainment
- Emergence of order from complex dynamics

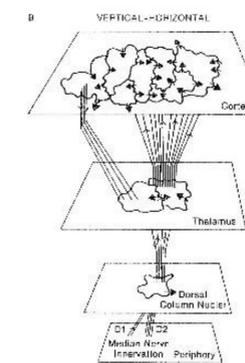
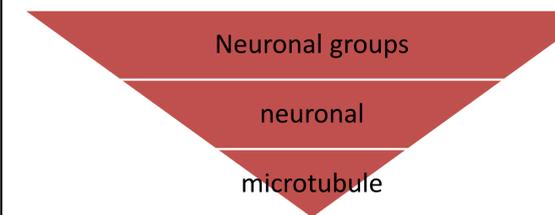
Nonlinearity + Boundedness → Scale Symmetry



Paradigm for 3T's: Learning a Concept or Skill

- Transition: encounter and absorption of concept or skill **Stretch**
- Transform: reorient existing views to new information **Fold**
- Transcendence: reorganize worldview/ sense of self **Emerge**

Sample Multiscale System



Example of Reentrant Connectivity

From Edelman, 1989, showing reentrant connectivity among anatomical structures that have hierarchical organization by scale

Links Between Scales

- How are the functions of consciousness connected from one scale or level of organization to another?
- Agents at lower level of organization interact with other agents through an interface or coupling, which can be mechanical or dynamical (e.g. resonance)
- The interface from scale L_0 to the larger scale L_1 is the boundary of a single agent at scale L_0
 - The boundary of element A, ∂A , is the interface with both the interior of A, and its exterior,
- Dynamics at the smallest scales are governed by quantum entanglement

Summary

- Consciousness is more process than structure
- The processes that govern the functions of consciousness are essentially nonlinear, and can be described by modern dynamical systems theory (→ **Transitions**)
- Emergence of conceptual categories (→ **Transformations**) and learned behavior are characteristics of the formation of dynamical attractors in nonlinear systems
- These processes occur at various scales that are coupled through 'reentrant' links between them (two-way communications across the interfaces separating different scales)
- There is a preferential scale which occupies a causal position relative to the other scales. Changes in preferential scale (→ **Transcendence**)
- The smallest scales are characterized by quantum entanglement that can have perceivable effects to the experiencing subject

References

- Edelman, Gerald "The Remembered Present: A Biological Theory of Consciousness", Harcourt Brace & Company, 1999
- Freeman, Walter, The Physiology of Perception, Scientific American 264, 78-85, 1991
- Haken, H., Synergetics, Springer-Verlag, 1983
- Thelen, Esther and Linda B. Smith, "A Dynamic Systems Approach to the Development of Cognition and Action," MIT Press, 1994