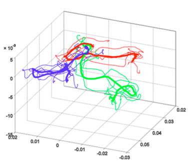
Representation 3

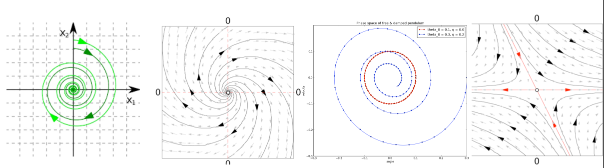
Dynamics

- A set of differential equations specifies how variables characterized in the equations will change over time
- One can use such a set of equations to model a system
  - And represent the behavior of the system as a trajectory through a state space which has a dimension for every variable
  - Time appears not as a variable but as a succession of points



Attractor Structure

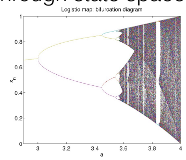
- Many dynamical systems exhibit an attractor structure
  - Starting the system from different values of variables one can trace the resulting trajectories
    - Sometimes all will converge (point attractor)
    - Other times they will diverge (point repeller)
    - Sometimes they will converge to a circle (cyclic attractor)
    - There may be multiple basins of attraction separated by a separatrix



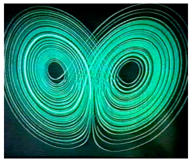
Complex Dynamics

- Some systems, even relatively simple ones, exhibit very complex trajectories through state space

$$x_{n+1} = rx_n(1 - x_n)$$

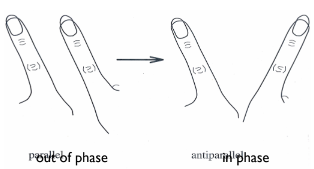


$$\frac{\mathrm{d}x}{\mathrm{d}t} = \sigma(y - x),$$
$$\frac{\mathrm{d}y}{\mathrm{d}t} = x(\rho - z) - y,$$
$$\frac{\mathrm{d}z}{\mathrm{d}t} = xy - \beta z.$$



From Dynamics to Radical Anti-Representationalism

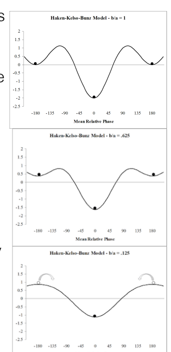
- Chemero rejects the project of understanding systems by identifying representations and operations that alter representations
  - Like van Gelder, he argues that a better approach, motivated by physics, is to characterize cognitive systems by identifying variables and formulating differential equations that specify how values of variable changes
- Kelso introduced the finger waging task: wag your index finger on either hand
  - At slow speeds, you can either move them out of phase or in phase with each other
  - As the speed increases past a critical point, only the in phase motion is possible



The HKB Coordination Model

- A simplest mathematical model that describes this behavior is:
  - V = – a cosϕ – b cos 2ϕ,

    V is change in relative phase, ϕ represents the relative phase and the ratio of the parameters b/a is inversely related to the rate
    - When b/a = a, there are two relatively deep attractors but as b/a declines, a point is reached at which there is only one attractor
- The HKB account describes coordination behavior without representations: “there simply is no likely candidate in the system as described by the HKB model that might serve as an information-bearing state of the animal that mediates between it and the world”



Clicker Question

What role do representations play in finger movement coorindation according to the HKB model (and Chemero)?

The variable φ represents the phase difference between the fingers

Representations are the states within the brain that figure in the control of finger movement

The attractor basins represent the stable phase relations at a given velocity

None

The Dynamical Approach

- Chemero describes his preferred method for explaining behavior
  - "First, observe patterns of macroscopic behavior; then seek collective variables (like relative phase) and control parameters (like rate) that govern the behavior; finally, search for the simplest mathematical function that accounts for the behavior"
- This approach has been applied to a broad range of behavioral and neural phenomena
- Note: the approach is non-mechanistic: there is no attempt to decompose a system into its component parts and operations and to show how they together generate the phenomenon
  - The mathematical function explains the dynamic behavior to which it gives raise

Clicker Question

What does Burnston mean by "absolutism"?

Neuroscience has the final word about what is represented/computed by a brain area

A dynamical account fails to explain the representational/computational role of a brain area, so we must seek a neuroscience account

There is a specific representational function and computational function of a brain area that is not dependent on context

What a brain area represents/computes depends on what is going in other areas and in the world

Absolutism and Context Sensitivity

- "Absolutism: For any area of interest A, there is some univocal description, D, such that D describes the function of A in any *particular context*."
- Burnston's contention is that attributions may have to be context sensitive:
  - "Recent physiological results, however, suggest that individual brain areas contribute to a number of distinct tasks, and process distinct types of information, depending on the perceptual or behavioral context."
- Computational absolutist: Even if the information/representations change, the computation performed by a brain area remains the same

Traditional Absolutism

- "On such accounts, which I call "traditional absolutism" (TA), neural areas are individuated in virtue of *representing* a specific kind of information, and/or *performing*, univocally, a particular kind of task."
  - MT represents motion and performs the task of computing how a stimulus is moving
  - lesions to MT result in deficits in motion perception
  - increased spikes are recorded from MT cells when movement is in a neuron's preferred direction
  - stimulating an MT cell can bias the organisms judgment of direction of motion

Empirical Challenges to the Absolutist Treatment of MT

- MT is also involved in depth perception based on binocular disparity
  - Individual MT cells are responsive to disparity information
    - In the vast majority of cells, response to motion in a direction is modulated by the degree of binocular disparity
    - Over a third of MT cells respond to disparity even when there is no motion
- Motion perception is not *the* task of MT

Discussion Question

Given the number of experiments performed on MT over the decades since it was first identified by Zeki, why was its role in depth perception never recognized?

- In the traditional experimental setup in which stimuli are presented on a computer screen it is hard to test for depth response
- Motion is so much more important than depth that no one had any interest in determining how depth is detected in the brain
- You only experimental test stimuli that you hypothesize would have an effect and no one formed this hypothesis
- Other

Clicker Question

How does Burnston characterize the difference between Computational Absolutism (CA) and Traditional Absolutism?

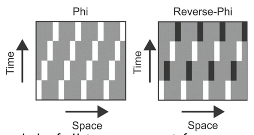
- He argues that they are the same thing
- CA holds that a brain area is computing the same function even if it is used to arrive at different representations
- CA holds that a brain area may represent the same thing as a result of computing different functions
- CA holds that neuroscience should only study what a brain area computes, not what it represents

Computational Models of MT

- Computational models are used to characterize the operations a brain area might employ to reach its output behavior given inputs from other brain regions
  - First model: Motion energy model (Adelson & Bergen, 1984)
    - Displacement cells early in the visual system provide input to MT
    - MT cells perform filtering on this input to arrive at a motion decision
  - This model captured some features of MT's processing of motion
    - But not pattern motion (composed of stimuli moving in two directions) or opponency
  - Subsequent models proposed the MT cells performed more complex operations (e.g., normalization of input)
    - These models succeeded in predicting more of MT's response

Modeling Strategy

- Construct challenging phenomena to test a model
- Phi and reverse phi stimuli



- Subtraction models fail to account for reverse phi-phenomena
  - Alternative competition model (Krekelberg and Albright, 2005) does explain the effect
    - But there are many other known features it does not explain

Upshot

- Burnston's contention is that the practices of the scientists indicate they are not pursuing the computational absolutist strategy
  - None of the models tries to incorporate all the features of MT anatomy
    - Or even those that distinguish MT from other areas
    - The structure that is modeled is that which is needed for a given behavior
      - Different models for different behaviors
    - Krekelberg and Albright model doesn't provide any account of how the relevant input are provided to MT
  - Models are selective in the phenomena they try to explain

Might There Be a Common Syntax to All Models?

- Could the problem be that the different tasks for MT are specified in semantic terms (what is processed) but that there is a common syntax (processing procedure or algorithm)?
  - But there may be no way to individuate the syntax except in terms of the tasks being performed (the semantics)
    - So that trying to explain the varying tasks MT is performing results in different accounts of the underlying computational process
- Related hope: "One might just hope that, given a complete wiring diagram of (e.g.) MT, and a complete list of its physiological responses, we could describe its entire machine table"
  - Describing all the individual activities (presenting the machine table) is not a computational explanation
    - that requires stating the computation in more abstract terms
    - and there is no reason to think that is doable

The Unificationist Gambit

- As modeling research proceeds, it will eventually generate a model that incorporates the explanatory advantages of all the others
  - Identify canonical computations
    - This can be informative about the brain
- Burnston argues such models won't explain what MT specifically does
  - or how it performs the range of activities it performs (e.g., depth perception)
- To explain how MT processes motion *and* depth, one would have to build many, many empirically-determined parameters into the model
  - But then the parameters, not the model, are doing the explanatory work

Computational Modeling Account

- "the usefulness of highly generalizable quantitative models in the sciences is not predicated on their providing an explanation of what individual physical systems do."
  - sufficient to know what they do in particular contexts
- The result is a pluralism about models: different models for characterizing brain function in different contexts

Discussion Question

Should neuroscientists seek one, unified, account of brain function?

Yes. There is one common brain underlying different activities, and we should aim to understand all that it does.

Yes. Even if unified theories keep being confronted with opposing evidence, seeking unification is a productive strategy.

No. Unified theories are a false hope and we must settle for pluralism. Explanation is always partial and local and many things out. If you want the whole brain, you already have one, but that doesn't itself provide understanding.

Other