Neuroscience and robotics

Gregor Schöner

Neuroscience vs. behavior as interfaces for cognitive robotics

- neuroscientific methods at level of individual cells/population code
  - correlate well with behavior/cognition
  - suggest a process account for behavior… neural networks and the processes they support
  - but: narrow scope of structure and function
    - observable under very constrained conditions…
    - e.g., measure in only one area
    - e.g., only able to pick up neurons that modulate their firing during task

Neuroscience vs. behavior

- neuroscientific methods at the whole brain level
  - correlate only very broadly with behavior/cognition
  - do not provide access to process accounts due to lack of temporal and spatial resolution
  - and are still very restricted in terms of the tasks and behaviors accessible

Neuroscience vs. behavior

- behavioral experiment provides much more access to structure of behavior
  - temporal and spatial resolution at the level of the processes themselves, especially in the link to sensory-motor processes
  - phenomenology based on naturalistic behavior
  - capacity to obtain data in different paradigms that converge on the same underlying processes

Neural process accounts and robotics

- (neural) process accounts for behavior provide a strong interface to robotics
  - testable theories that integrate behavioral data
  - process account provides sketch of robotic solution
  - conversely, robotic solution provides

Neural process accounts and robotics

- conversely, robotic solutions may provide feedback and new ideas for process accounts of behavior
  - discover process components that are missing from account
  - discover elements that are sufficient
  - and elements that are not necessary

Neural mechanistic thinking vs. emergence

- neural mechanism typically understood to provide LOCAL causality
  - e.g., one neuron/area/population is responsible for a well-defined function
  - basis for information processing concepts of psychology/neural imaging
  - and implicit in computational view: input-output functions
  - that is also at the basis of "encoding" /"decoding" concepts

Neural mechanistic thinking vs. emergence

- local causality is not consistent with emergence
  - e.,g in recurrent networks…. or neural dynamics
  - or in closed sensory-motor loops
  - in which function emerges from the coupling among components….
  - and not single component plays a singular role …

Minimal vs. maximal models

- Neuroscience is steeped in the tradition of maximal models
  - include all knowledge in the detail known
  - e.g., if neurotransmitter A is involved and is not in the model then the model is limited or weak
  - based on the descriptive tradition of biology
  - which has been successful

Minimal vs. maximal models

- Engineering is steeped in the tradition of minimal models
  - reduce systems to the essential, to what is necessary
  - select minimal set that is sufficient
  - so as to be able to build on minimal model that provides modules or building blocks
  - this view if inherited from physics, in which laws reduce systems to the lawful part, the minimal needed to make predictions

Minimal vs. maximal models

- Psychology is closer to physics than to biology at this level
  - because behavior is not reproducible….
  - so emphasize laws
  - and describe the non-lawful part as "task" or "setting"

What is the right level of description?

- the neural dogma: assumptions (prejudices?) about the level of description relevant to neural function
  - but: cellular and molecular levels also solve problems unrelated to function, e.g., homeostasis

What is the right level of description?

- the cognitive dogma: an abstract layer between the neural mechanistic level and behavior
  - but: no evidence for a divide between the sensory-motor domain that is tied to neural mechanism and the abstract, higher cognitive domain
  - but: conceptual commitments that may be incompatible with neural mechanism

What is the right level of description?

- computational principles: even more abstract level (according to Marr)
  - but: computation makes conceptual commitments that define the given (on which computation is based) and the to be computed … which may be in conflict with emergence

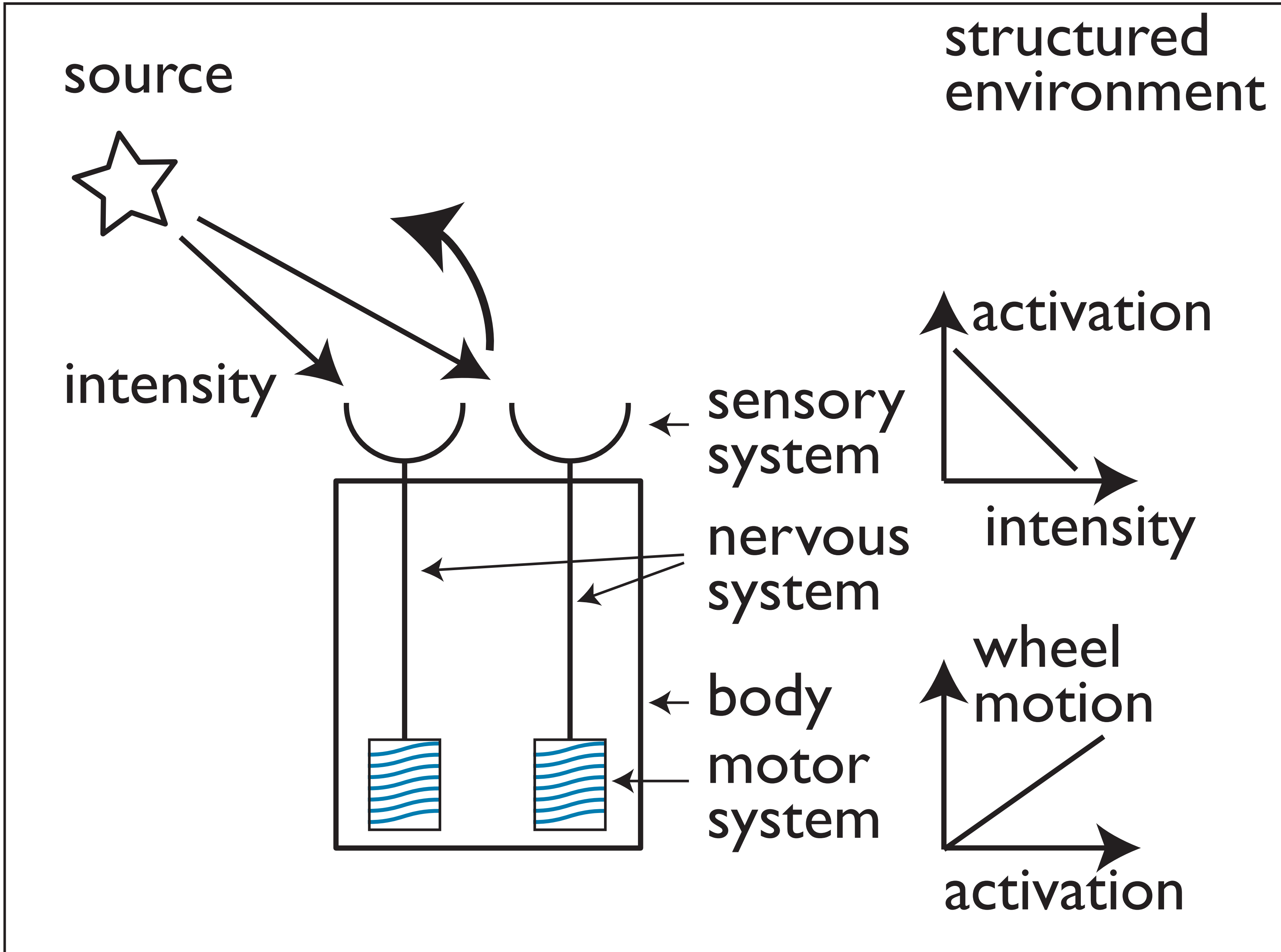
Can we have it all?

- neural principles as a basis for providing process accounts
- of behavior and cognition
- that accomodate emergence
- and are minimal, provide modules on which to build
- are at an intermediate (e.g., the population level) of description
- are open to the environment, task settings etc. including learning

Sensori-motor loops

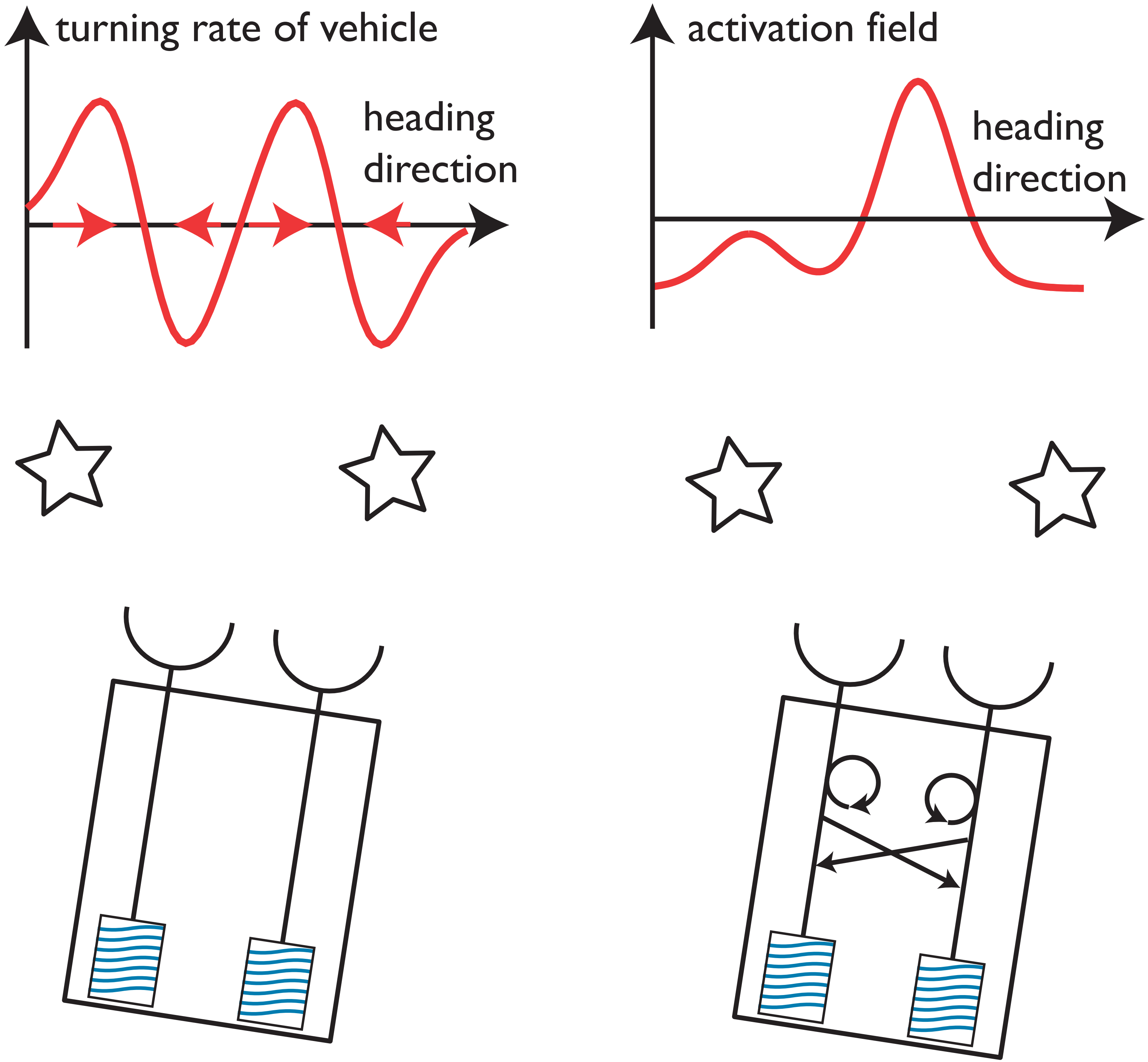
- lead to emergence of function from embedding in environment

Emergent behavior: taxis



Neural dynamics

- internal loops in neural networks… lead to the emergence of (cognitive) funciton


turning rate of vehicle
heading direction
activation field
heading direction

Neural dynamics to make selection decisions and create working memory

[Bicho, Mallet, Schöner, Int J Rob Res 2000]