

**Problem 2.** Write up your Project Proposal with the following sections. The result should be 2-3 pages long.

**2a. Goal: What is your primary project goal? What you would like to learn?**

To understand how the organization of information emerges out of the recurrent dynamics of perception and environment.

**2b. System: Describe how the dynamical system is nonlinear and time-dependent.**

Sensory modalities (vision, auditory signals, somatosensory signals) organize into cortical fields across the neocortex and they do so in a way that is sensitive to “initial conditions” conditions being their exposure to information in environments usually during developmental time, although there is plasticity at later times as well.

I am not totally sure how to characterize this as a dynamical system, but I think it has recurrent dynamics because perception changes the incoming input, and the incoming input changes the structure of perception. In buddhist thought this might be called “mutually co-arising.” There are a number of papers relating the edge of order and chaos to neuroscience in general, most recently: <https://pubmed.ncbi.nlm.nih.gov/35145021/>, but I haven’t yet formulated how this organization might involve criticality. I think by applying information theoretic measures to it this might become more clear?

**What's the state space?**

The space of possible organizations of sensory modalities on the mammalian cortex.

**What's the dynamic?**

Incoming information from different environments during development and throughout life paired with attentional properties. There might be a lot of dynamics going on.

**Why is the system behavior interesting?**

This is interesting for a few reasons. The amount of cortical space devoted to a specific sensory modality can affect the future trajectory of the sensory evolution of a species, it can for example lead to sensory specific adaptations. Changing sensory modalities is one of the most striking dynamics of evolution, for example, animals which are blind because they occupy niches in dark spaces, or animals that have very acute vision because they hunt at a great distance. Environmental-Behavioral dynamics are shaping the underlying encoding of “relevant” sensory information. It is also interesting from a computational perspective because it has a topological organization that preserves spatial structure, and at some layer/level there is integration of multiple types of information. There is the possibility that it is a structure that is encoding more

dimensions of information. Plus it is fundamental to how many living things work, they organize and integrate sensory information in order to interact with their environments.

**2c. Dynamical properties: What dynamical properties are you going to investigate?**

I think based on our discussion that one approach would be to try to understand cortical fields as an information channel between environment and behavioral response (organism), in which case, I am looking at the dynamics of how information is getting encoded based on behavioral experiences. The different sensory modalities grow in the space they take up or shrink in the space they take up, across different species who occupy different environmental niches.

**2d. Intrinsic computation properties: What information processing properties are you going to investigate?**

What is the channel capacity of a “unit” of space on the cortical sheet, how much information could potentially be encoded there. Why is it important to allocate a certain amount of space to one sensory modality versus another. What does having multiple modalities do to the amount of information, the entropy, and the statistical complexity of an incoming environmental feature.

**2e. Methods: What methods will you use? Why are they appropriate?**

I am still unclear on how to model this or how to convert the data I have into a form that would allow me to use information theoretic measures on it. I think a possible way to do this is to abstract things a lot and potentially use markov chains to model different modalities as states of a machine, and somehow have these states organized based on what information I input to it. I will input different kinds of media/data perhaps and try to see if there is a process that represent the correlations in the media/data. This is still a little unclear.

Another option is to literally draw out some of the space of possible organizations that already exist, and somehow encode them in a 2D way and be able to think about the space that is being used as a percentage of the total space and do coarse information theory measures on that, but this seems like a stretch.

This section would be great to discuss. I would like to use an e-machine in some way as to represent what the sensory modality organization might be optimizing for if that makes sense. Like maybe the specific structure of the senses allows for perception to have an e-machine model of the environment, with which it can predict causes and retrodict over memories. See below.

**2f. \*Hypothesis: What is your current guess as to what you will find?**

I think there is an organization of modalities that will correspond in some way to the statistics of a given environment, or that there will need to be some kind of “relevance” factor that will influence how the modalities organize (grow or minimize). I also think that the organization has to do, in living things, with multi-sensory integration for the purpose of optimizing the capacity for inference. I think that the idea of inference is like predictive casual states, and that memory

storage might correspond to retrodiction over casual states, so that maybe the organization of sensory modalities is creating an e-machine like process conditioned on environmental specific statistical aspects. It would be great to get to that step, but I am not sure how to implement this.

**2g. Steps: List the appropriate steps for your investigation; for example, read literature, write simulator, do mathematical analysis, estimate properties from simulation, write up report, and so on.**

This is what I am very unsure of.

1. Clarity: I think I need to draw things out to visually understand how cortical field organization might relate to information, how it emerges from “dynamics” within an environment, and then how it might be producing a model that is like an e-machine. Perhaps focusing on one of these steps is a better approach.
2. Precedents: I need to research if there are algorithms that generate e-machine like models out of data, or if there are processes that can model something like an e-machine (grouped casual states). Or are there other examples similar to my goal.
3. Experiment: I need to try different ways of modeling the cortical fields and the total space of the cortex as an information channels.
4. Get Suggestions..?

**2h. Time: Estimate how long each step will take. Can you complete the project within one month?**

I hope so.

I think step 3 will be the most time consuming, possible a week of 8 hours, which is too much. But the other steps could minimize the time for step 3, and the others may be one 3-5 hour chunk each.

Tentative titles:

Evolving Inferential Representations

Inferential/Information capacity of the senses

Organization of sensory modalities required for inference