# Presentations

People can sign up to present anything they want about capacity limitation (for about 5-10 min, depending on how many people sign up). In the next section of this document, there are some references you can pick to present. Also, feel free to add your thoughts or other references.

| Name | Presentation title or paper |
| --- | --- |
| Yudi | Elman, J. L. (1993). Learning and development in neural networks: The importance of starting small. Cognition, 48(1), 71–99. |
| Fernanda | *In progress:* I will look into predictive coding and try to see how this theory handles cognitive capacity limitations. |
| Nathan | Some thoughts on the computational role of the limited capacity of cognition, based on a simple model |
| Wenjie | Bengio, Y. (2017) ‘The Consciousness Prior’, pp. 1–7 |
| Ali | A discussion I had with Yudi, Chris and Robert. Three provocative questions:   * Is studying the limits of cognitive capacity different than studying why we have 5 fingers? Yes. * The working memory lion (credit: Chris). Are we studying working memory in the right ecological context? * What privileges does an object in working memory have? (I will research a possible link to analogical reasoning) |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

# 

# What is the root of cognitive capacity limitation?

Decades of neural and behavioral research have found that humans have limited working memory capacity of around 4 objects[1]. While there is still a debate about the relation between working memory and attention, a consensus is that attention is limited. Humans have much more neurons than monkeys. However, humans and monkeys have similar capacity limitations. This suggests that capacity limitation is not simply due to the limited number of neurons in our brain. Then, why do humans have limited cognitive capacity?

[1] Cowan, Nelson. "The magical number 4 in short-term memory: A reconsideration of mental storage capacity." Behavioral and brain sciences 24.1 (2001): 87-114.

## Hypothesis 1: There are some computational benefits of limited cognitive capacity.

Some insights could be drawn from these lines of research:

* Conscious prior [1]
* Efficient search in memory [2-3]
* Improve language acquisition [4-5]
* Detection of covariation in the environment [6]
* Improve action control [7]
* Integration with eye movements [8]

etc.

[1] Bengio, Y. (2017) ‘The Consciousness Prior’, pp. 1–7. Available at: <http://arxiv.org/abs/1709.08568>.

[2] Dirlam, D. K. (1972) ‘Most Efficient Chunk Sizes’, Cognitive Psychology, 359(3), pp. 355–359.

[3] MacGregor, J. N. (1987) ‘Short-Term Memory Capacity: Limitation or Optimization?’, Psychological Review, 94(1), pp. 107–108. doi: 10.1037/0033-295X.94.1.107.

[4] Elman, J. L. (1993). Learning and development in neural networks: The importance of starting small. Cognition, 48(1), 71–99.

[5] Newport, E. L. (1990) ‘Maturational constraints on language learning’, Cognitive science. Elsevier, 14(1), pp. 11–28.

[6] Kareev, Y. (2000). Seven (indeed, plus or minus two) and the detection of correlations. Psychological Review, 107(2), 397–402.

[7] Heuer, A., Ohl, S., & Rolfs, M. (2020). Memory for action: A functional view of selection in visual working memory. Visual Cognition, 28(5–8), 388–400.

[8] Van der Stigchel, S., & Hollingworth, A. (2018). Visuospatial working memory as a fundamental component of the eye movement system. Current Directions in Psychological Science, 27(2), 136–143.

One intuition is the todo list example. A todo list is similar to an unlimited working memory. If I keep everything on my todo list, the list will exceed my executing capacity and will keep growing until eventually overwhelm me. Then, all my life becomes checking things on the todo list and I completely lose focus of what is important.

To prove this hypothesis, we can show that in some tasks a limited capacity agent performs better than an unlimited capacity agent. This requires thinking out of the box**,** perhaps out of the framework of the working memory tasks. Because there is no free lunch, there definitely are tasks in which models with limited capacity will perform better. The key is to find those tasks and make a compelling case that those tasks are important for human cognition.

A potential task is to have a sequence of probabilistic transitions between states, but only the most recent few states are useful for predicting the next state. An unlimited capacity agent remembered all the previous states and got distracted. But limited capacity agents only remember a few states that are important and can better predict the next state.

## Hypothesis 2: Having high cognitive capacity is costly and we only have limited resources.

**Evolutionary selection of neural architecture for short-term memory:**

There are many different sensory systems, vision, audition, head directions etc. However, there is a fixed amount of memory resources allocated to each of the sensory systems. Or there are some costs relative to having high capacity memory.

To test this hypothesis, we can create an environment with some tasks that require the agent to use multi-sensory information. Some sensory information is important for survival (like head direction), but others are less important for survival but beneficial in some sense (like remembering numbers).

What we expect is that, over the course of evolution, the agent develops specialized memory systems for sensory information that are critical for survival (eg. head direction); these memories don’t interfere with other sensory information. The agent also develop a shared memory system for many different kinds of information that are beneficial but not critical for survival (eg. numbers, colors). Because they share the same memory space, there is interference and thus the capacity in this shared system is limited.