Exercise 1 - Understanding Neuroscience Papers

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1 Questions

1.1 a) Explain concepts from Bashivan et al.

1. cRF : The classical receptive field (cRF) is the spatial location where the macaques had their focus of attention. The cRf over an 8° by 8° window was determined by fitting a 2D Gaussian map to the activations caused by flashing 1° by 1° windows at different locations on the 8° by 8° window.

2. Stretch experiment : Using the DNN model of the ventral visual stream, the authors synthesized input images that aimed at driving one targeted neural site in V4 of the macaques past the standard level of activation.

3. One-hot population control : This experiment was similar to the one described above, with the only difference being that the other neural sites should be suppressed while the target neural site was activated, hence the name "one-hot" population control.

1.2 b) Explain concepts from Freeman et al.

1. Orientation columns : Neurons in the primary visual cortex are selective to orientations anywhere in the receptive field (complex cells) or to narrower regions in the receptive field (simple cells). These neurons are typically arranged in a column, hence the name orientation column.

2. Pinwheel representation : 2D representation where the orientation columns point at a singularity. Color-coding of the columns then causes the map to look like pinwheel.

3. Retinotopic map : Retinotopic maps are a way to project the image that is received on the retina to a 2D map of any layer in the visual cortex so that neighboring input stimuli are also spatially close in the higher order representation.

1.3 c) Bashavin et al. : What recording method and why?

Multi-electrode arrays, which is an extra-cellular method that enables the recording of neuronal activity on the neural scale (small ensembles of neurons). They used this method since it gave them a high spatial resolution of the activity and it was feasible since they performed the experiments on monkeys.

1.4 d) Freeman et al. : What recording method and why?

Since the experimenters investigated human beings and required a high spatial resolution, they used functional magnetic resonance imaging (fMRI). Other methods such as EEG recordings have the benefit of higher temporal resolution since they measure potentials rather than blood flow. But this was not needed in this experiment so the experimenters decided to use fMRI.

1.5 e) On what spatial scale is information represented in the visual system according to the two papers?

In both papers, different *information* is considered: In Bashavin et al. the information is more abstract and is required to contain semantic features, rather than descriptive information (orientation, etc.) as in Freeman et al.
In Bashavin et al., information is represented on the neuronal level in V4. In Freeman et al. the "information" is represented on a voxel scale (thousands of neurons) in V1.

1.6 f) What are merits and limitations of using DNNs as a model of the visual system?

Merits:

1. Easy to train due to high level of abstraction
2. Perform well on complex benchmarks

Limitations:

1. DNNs have no time component
2. Backpropagation is definitely not the way the brain is/was trained so this is a fundamental flaw
3. DNNs lack biological realism (no spikes, no synapses, no time constants, no Dale's law)

1.7 g) Could incorporating more biological realism in the DNN model improve the performance of DNNs as a model for the visual system?

This is a complicated question that none of us can answer. Intuitively, having a more precise model of neurons and their interconnections (synapses) brings us a step closer to the real world. However, the current model implements a mapping from DNN activations to actual activations in the brain of the macaques and one could argue that this replaces the need for biological realism in the nature of the neurons.
Another question to ask is whether a more plausible learning rule would improve the performance. The answer to that is also not clear since we don't know what biological plausible learning rule the brain really uses (there are multiple) and picking anyone is probably just as good as using backpropagation.
On a more practical note: Training biological neural networks on such a large scale is probably close to infeasible at the moment if backpropagation can't be used (in fact, surrogate activations could also be a deal-breaker already).