Effective learning is accompanied by high dimensional & efficient representations of neural activity

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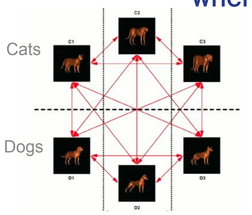
How do we map values onto objects when learning?

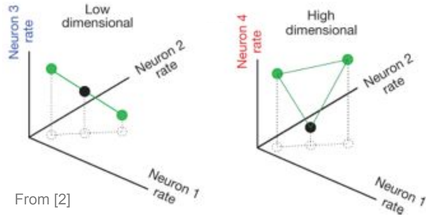


Activity in lateral prefrontal cortex of monkeys reflects animal type [1]

How does this mental space and new mapping get organized?

When we have more categories?

Neural responses can be described in spaces of different effective dimension



From [2]

High dimensional representations can contain more information

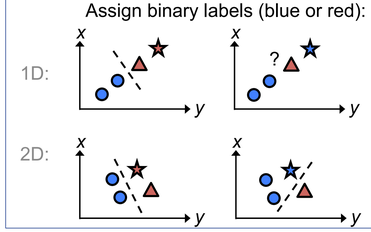
Questions

- Study organization of neural activation (dimension) in whole-brain patterns from fMRI
- How is neural activity represented during learning?
- What organization is used by a fast learner?

Method: dimension estimation

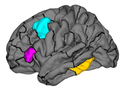
Given three categories (shapes): ○ △ ☆

Assign binary labels (blue or red): ● ▲ ★

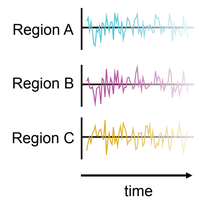


Their separability (over different assignments) estimates the dimension [2]

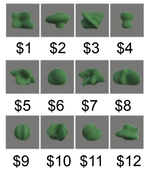
In a value learning experiment



BOLD activation

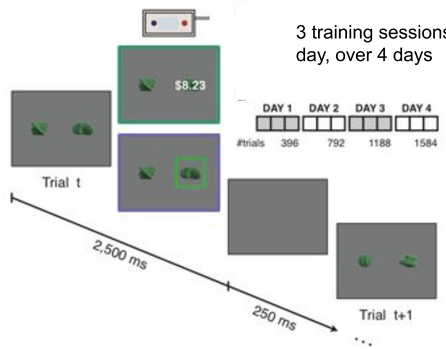


Whole-brain parcellation of 83 regions



Computer-generated shapes assigned dollar values [3]

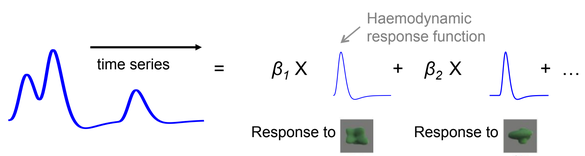
Adults learned values through feedback

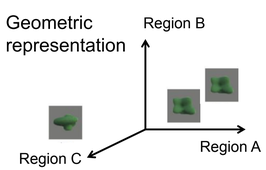


3 training sessions a day, over 4 days

Neural responses to each shape form a geometric representation

Use a general linear model to obtain responses to each shape

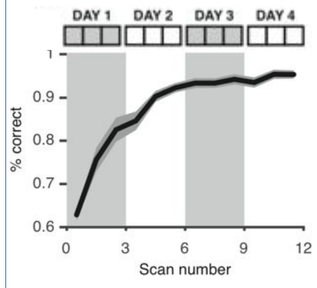


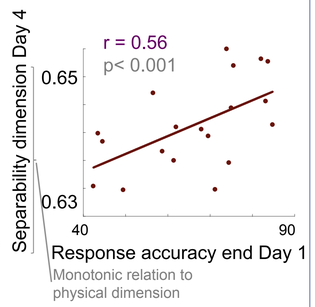


For *n* categories: 2^n ways to assign binary labels

Due to averaging over hyperplanes, method can be robust to noise

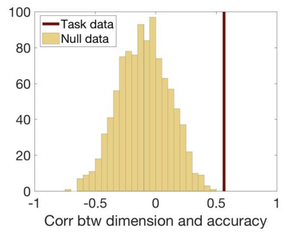
Fast learners have higher dimensional hence more easily distinguishable representations

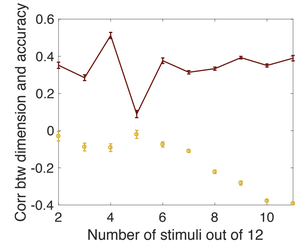




Positive correlation between response accuracy and dimension of neural activity across subjects [4]

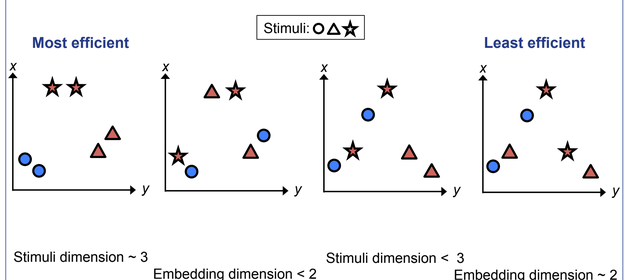
Scrambled labels: null model and embedding dimension





Fast learners have higher stimuli dimension and lower embedding dimension simultaneously – overall efficient with large ratio of information to resources used

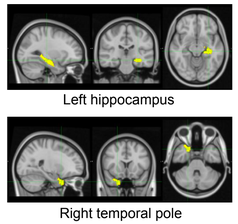
Representations of varying efficiency



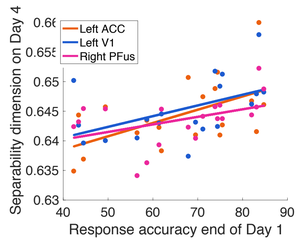
Looking on a finer scale

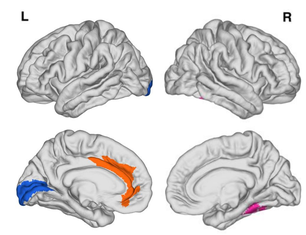
Virtual lesioning:

Which region when omitted causes largest change in result (correlation of response accuracy with dimension)



At the voxel-level, some regions also show this result:





Summary

- Fast learners have higher dimensional representations of neural activity
- Allows objects of different value to be more easily distinguished
- Fast learners also have smaller embedding dimension, hence more efficient representations with high ratio of information to resources used
- Identified regional drivers and showed this also occurs at the voxel level in some regions
- What can we learn about the mental mapping in other cognitive processes?

References & acknowledgements

1. Freedman, Riesenhuber, Poggio & Miller, *Science* 2001
2. Rigotti et al., *Nature* 2013
3. Mattar, Thompson-Schill & Bassett, *Network Neuro* 2017
4. Tang et al., arXiv: 1709.10045

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