Predicting Human Memory Performance through Multi-Voxel Pattern Analysis

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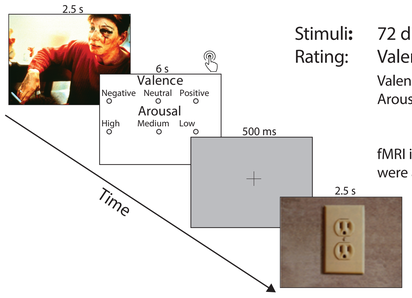
1. Introduction

- Human declarative memory is a complex phenomenon that engages various cognitive processes and a multitude of distinct neural systems.
- Although a number of brain areas critical to memory have been identified, the exact neural correlates and brain activity patterns that give rise to it are not very well understood.
- **Aims**: We applied several Multi-Voxel Pattern Analysis (MVPA) techniques[1] to investigate if we can reliably predict (**i**) **free recall**, (**ii**) **recognition**, (**iii**) **emotional valences**, (**iv**) **arousal**, and (**v**) **memorability of pictures**.

2. Experimental Design

Analyses were performed on an existing dataset obtained from a Basel fMRI study[2]. Here, we used a subsample of this dataset containing information from 100 subjects.

I. Picture Encoding & Rating Task



Stimuli: 72 different pictures (IAPS)[3]
Rating: Valence & Arousal
Valence: Negative/Neutral/Positive
Arousal: High/Medium/Low

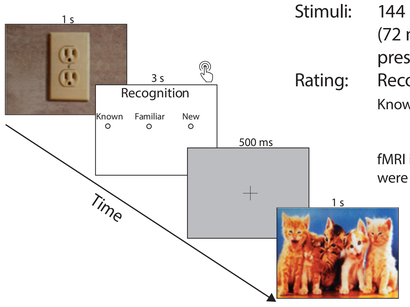
fMRI images (MAGNETOM Verio 3-T) were acquired during this task.

II. Free Picture Recall Task

Participants were asked to write down a short description (a few words) of the previously seen pictures.

III. Picture Recognition Task

Following a short delay, participants were repositioned in the MR scanner and conducted a picture recognition task that lasted 20 minutes.



Stimuli: 144 different pictures (72 new and 72 previously presented ones)
Rating: Recognition
Known/Familiar/New

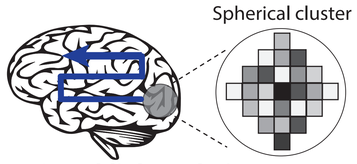
fMRI images (MAGNETOM Verio 3-T) were acquired during this task.

3. MVPA Approaches

I. "Top" Voxel Approach

- Extraction of beta values from most significant 'top' voxels (one-way ANOVA for valences, arousal, and memorability; two-sample t-tests for free recall and recognition memory phenotypes), with an exclusion radius around the selected voxels to ensure broader representation.
- Main classification algorithm: Support Vector Machines

Prediction domains	Conditions
Free Recall	Remembered vs. not remembered
Recognition Memory	Old vs. familiar-new
Emotional Valences	Negative vs. neutral vs. positive
Arousal	Low vs. medium vs. high
Memorability	Weak vs. medium vs. strong



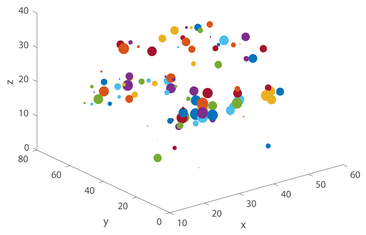
II. Searchlight-based MVPA

- Using a sliding window containing a spherical subset ('searchlights') of a selected radius centered around each voxel.
- The average classification accuracy was then assigned to the center voxel (depicted in black) in each sphere. This yielded whole-brain accuracy maps.

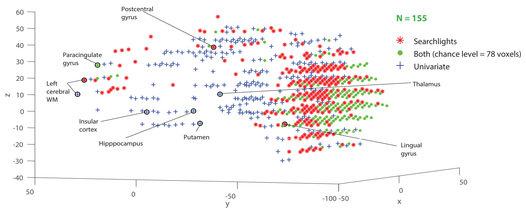
4. Individual Predictions

Emotional Valences

A. "Top Voxel" Approach



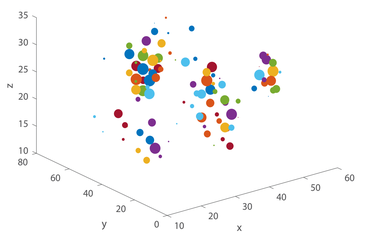
B. Searchlight Approach (positive vs. negative)



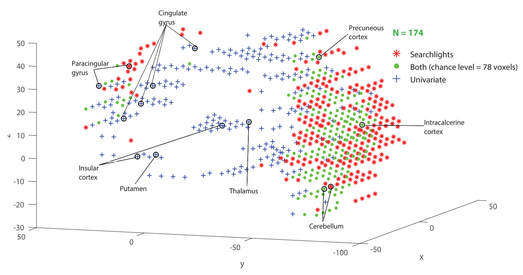
Here, we show the 400 most significant voxels from univariate and searchlight analyses. When they overlap, common voxels are depicted in green. The overlap is always higher than expected by chance.

Arousal

C. "Top Voxel" Approach

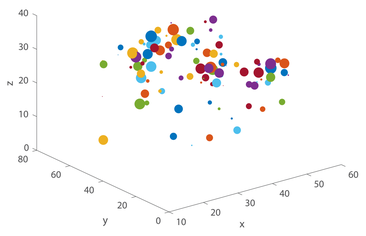


D. Searchlight Approach (high vs. low)

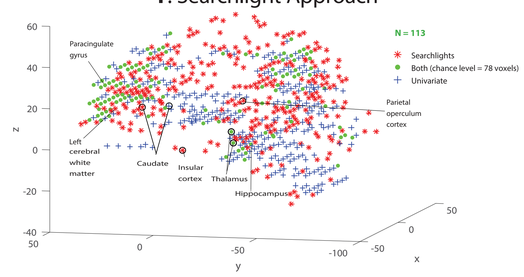


Free Recall

E. "Top Voxel" Approach



F. Searchlight Approach



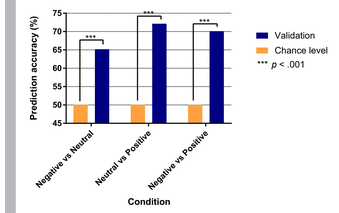
Recognition

Prediction of the recognition phenotype yielded no significant results.

5. Group Predictions

IAPS Valences

A. "Top Voxel" Approach

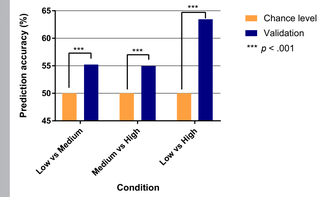


B. Searchlight Approach

Predictive brain areas	Voxel count
Lateral Occipital Cortex, inf.	19
Temporal Occipital Fusiform	17
Intracalcarine Cortex	11
Occipital Fusiform Gyrus	9
Precuneous Cortex	8

Memorability

C. "Top Voxel" Approach

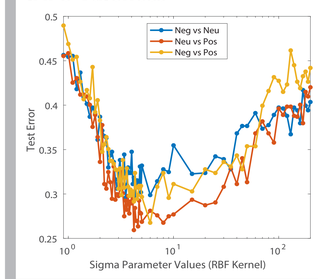


D. Searchlight Approach

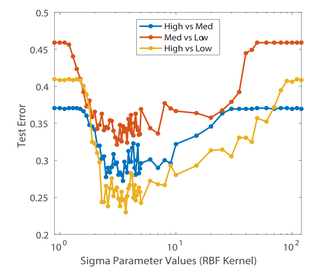
Predictive brain areas	Voxel count
Intracalcarine Cortex	32
Lingual Gyrus	25
Precuneous Cortex	18
Paracingulate Gyrus	17
Supracalcarine Cortex	15

6. Bias-Variance Analysis

IAPS Valences



Arousal



7. Conclusions and Future Work

- This study predicted emotional valences, arousal, and memorability of pictures with reasonably high accuracies.
- In accordance with recent literature, however, our findings confirm the difficulty of predicting individual memories of concrete items. The most predictive voxels in univariate vs. searchlight analyses are not the same, and their overlap patterns differ between arousal/valence (where parietal and occipital areas are mostly represented) and free recall (where there is a substantial frontal representation).
- For future work, we will expand our current MVPA approaches by using other dimensionality reduction techniques (e.g. Principal/Independent Component Analyses). Furthermore, we will use masks derived from Neurosynth database[for selection of voxels. Finally, we will use the full fMRI dataset containing data of ~1000 participants for prediction.

References

1. Haynes, J.D. et al. (2015). A Primer on Pattern-Based Approaches to fMRI: Principles, Pitfalls, and Perspectives. Neuron, 257-270
2. Luksys, G.I., et al. (2015). Computational dissection of human episodic memory reveals mental process-specific genetic profiles. Proc Natl Acad Sci U S A 112, E4939-4948
3. Lang, P.J., et al. (1997). International Affective Picture System (IAPS): Affective Ratings of Pictures and Instruction Manual. Gainesville: University of Florida
4. Yarkoni, T. et al. (2011). Large-scale automated synthesis of human functional neuroimaging data. Nature Methods, 665-670

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