Decoding of natural scene categories from transformed images using distributed patterns of fMRI activity

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Introduction

Perceiving natural scene categories is fast (Potter et al. 1976, Thorpe et al. 1996, Fei-Fei et al. 2007) and can be done with only little attention (Fei-Fei et al. 2002). How and where is this information represented in the brain?

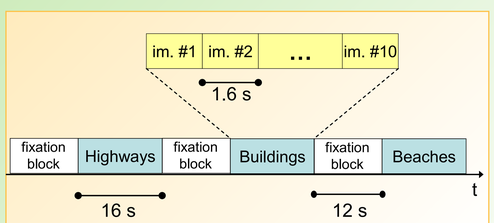
We investigate the contribution of several visual areas—V1, lateral occipital complex (LOC), fusiform face area (FFA) and parahippocampal place area (PPA)—to scene categorization.

Behavioral Experiments

- Six-way scene categorization (6 AFC) task with keys randomly assigned to the categories
- SOA staircased to 60% classification accuracy
- Training and staircasing on upright images:

- Testing on blocks of novel upright and inverted natural scenes:

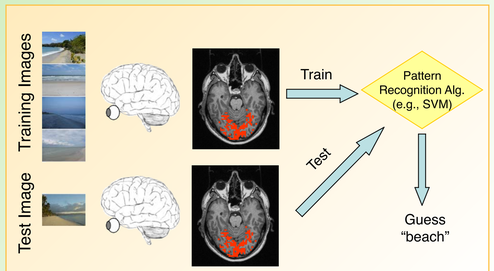
fMRI Experiments



- Passive viewing
- 6 blocks per run (all 6 categories)
- 12 runs for each subject
- Alternating runs of upright or inverted images

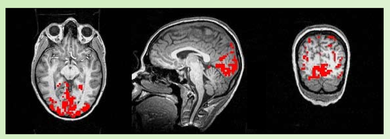
Pattern Recognition

- Linear Support Vector Machine (SVM)
- Strict leave-one-run-out cross-validation
- Separate fMRI data and separate image sets for training and testing



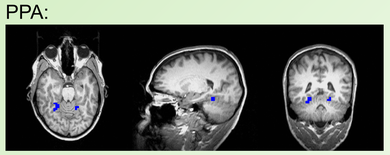
Voxel Selection

-1000 most active voxels selected from whole brain



- Functional regions of interest

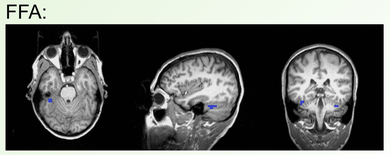
PPA:



V1:

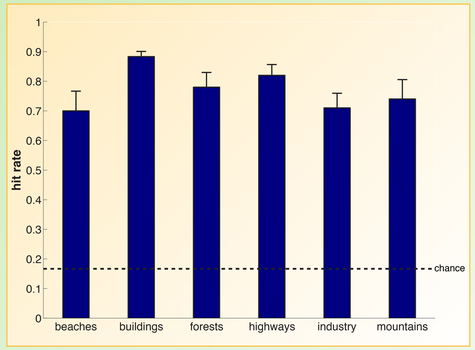
LOC:

FFA:



Behavioral Results

- 6-alternative forced-choice detection of the category of a briefly presented natural scene:

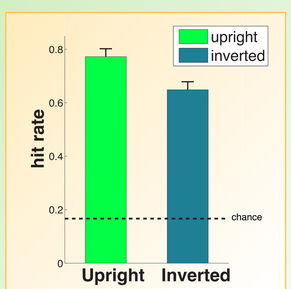


- Confusion matrix for subjects' responses for a given image category.
- Chance level is 0.167.

Subjects' response

Viewed image category	beaches	buildings	forests	highways	industry	mountains
beaches	**0.70**	0.02	0.03	0.10	0.03	0.04
buildings	0.02	**0.88**	0.02	0.00	0.03	0.01
forests	0.06	0.04	**0.78**	0.01	0.02	0.05
highways	0.03	0.03	0.01	**0.82**	0.02	0.03
industry	0.02	0.12	0.04	0.02	**0.71**	0.02
mountains	0.08	0.02	0.06	0.02	0.02	**0.74**

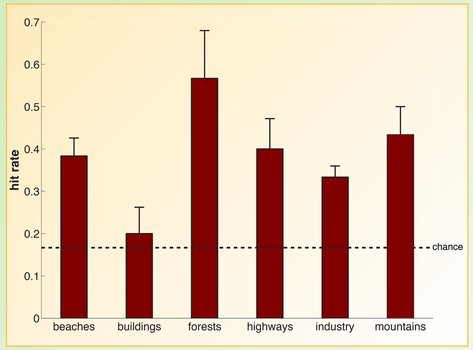
Inversion: behavior



- Significant inversion effect in subjects' behavioral response

fMRI Decoding Results

- 6-way decoding of viewed natural scene category from subject's BOLD response:

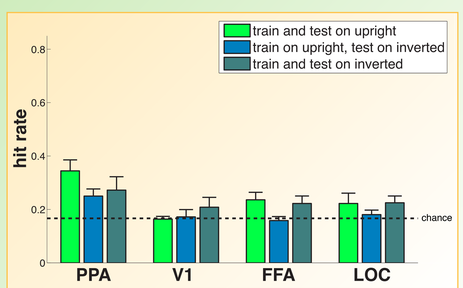


- Confusion matrix for algorithm decoding for a given image category.
- Chance level is 0.167.

Classifier prediction

Viewed image category (whole brain)	beaches	buildings	forests	highways	industry	mountains
beaches	**0.38**	0.03	0.02	0.30	0.12	0.15
buildings	0.13	**0.20**	0.07	0.18	0.25	0.17
forests	0.03	0.10	**0.57**	0.08	0.08	0.13
highways	0.25	0.10	0.07	**0.40**	0.12	0.07
industry	0.07	0.32	0.12	0.08	**0.33**	0.08
mountains	0.08	0.17	0.22	0.10	0.00	**0.43**

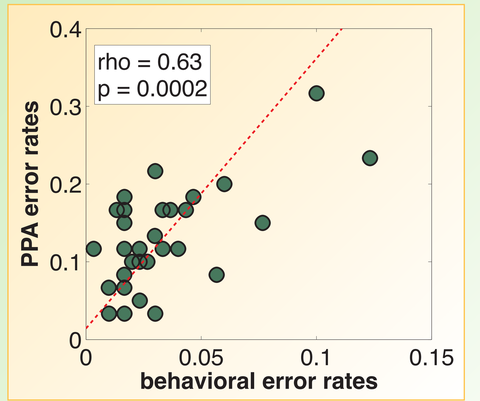
Inversion: fMRI Decoding

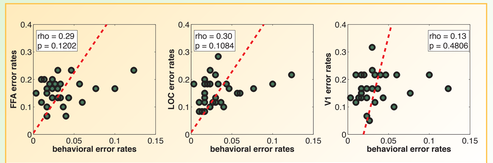


- Significant inversion effect for PPA
- No inversion effect in other regions of interest.

Correlating Error Patterns

- Compare misclassifications of fMRI data with mistakes made by human observers
- Each point represents off-diagonal confusion matrix entry (e.g., industry→buildings)





- PPA shows highest error pattern correlation with behavioral data

Conclusions

Decoding scene categories from distributed patterns of fMRI activity in the PPA provides the best match with human scene categorization.

	1000	V1	PPA	FFA	LOC
Decoding accuracy	++	-	++	+	+
correlation of error pattern	++	-	++	-	-
test on upright > test on inverted	+	-	+	+	-
train and test on upright > train and test on inverted	-	-	+	-	-

References

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