Decoding Visual Spatial Attention Control

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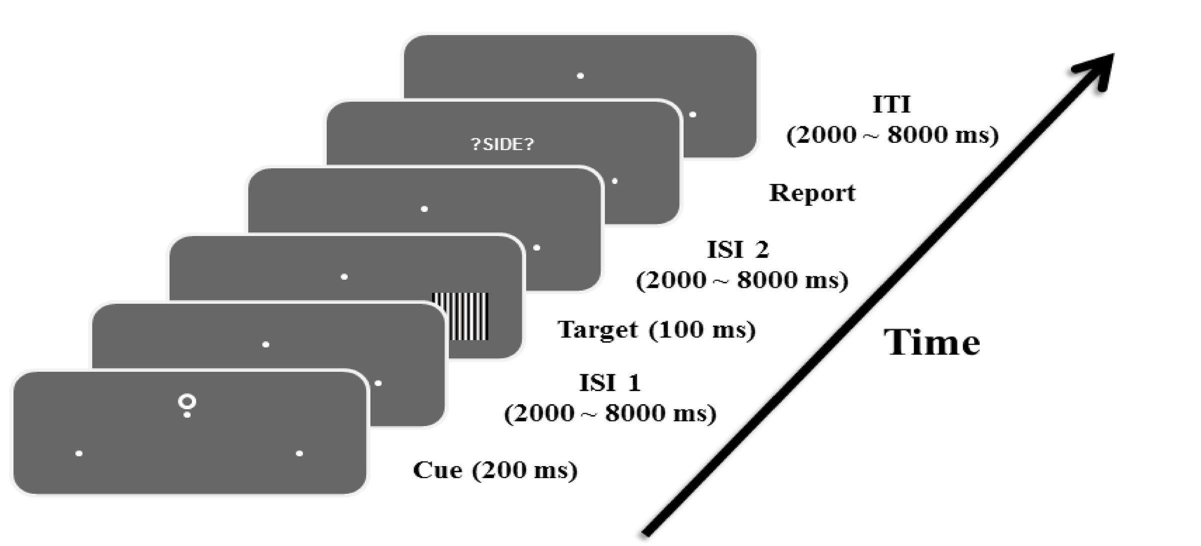
Introduction

- Deploying anticipatory visual spatial attention in advance of stimulus onset enhances the processing of task-relevant stimuli and suppresses distraction.
- This selective processing of information is thought to be achieved by cue-related top-down signals issued by the frontoparietal attention control networks that bias sensory neurons according to behavioral goals.
- How such attention control signals are distributed throughout the visual cortex and in what way they influence behavioral performance remains to be understood.
- In this study we addressed these questions by applying multi-voxel pattern analysis (MVPA) to fMRI data recorded from subjects performing a cued visual spatial attention task.

Methods



- A visual cue instructed the subjects to covertly pay attention to either the left or the right hemi-field.
- A stimulus was presented after a delay and the subjects were asked to discriminate the spatial frequency of the gratings if they appeared in the attended hemi-field.
- Functional MRI data were recorded in two different locations: UF (N=13) and UC Davis (N=18).
- Data were pre-processed using SPM. Single trial BOLD responses (beta values) to the cue were estimated using GLM approach (Rissman et al., 2004).
- ROIs in the visual cortex were defined according to a recently published visuo-topic atlas (Wang et al., 2014).
- Linear support vector machines (SVM) were used to perform MVPA on a given ROI to classify the attended spatial location (attend left versus attend right).
- A non-parametric permutation-based statistic (Stelzer et al. 2013) was used to test the significance of classification results.
- Principal Component Analysis was performed on the classification accuracies across the ROIs. The loading on the first principal component was then correlated (Spearman rank) with the behavioral efficiency (accuracy/RT) to assess the functional relevance of decoding accuracy.

Results

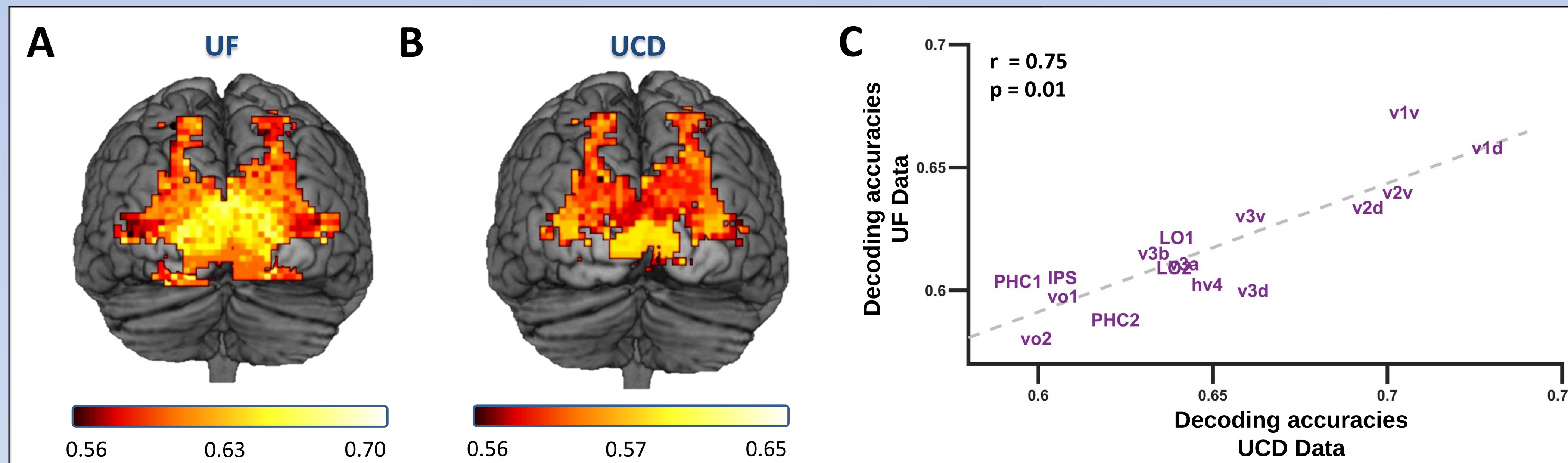


Fig. 2. Decoding accuracy of attend left vs right using visuo-topic ROIs. **(A)** Posterior view of decoding accuracies using UF Dataset. **(B)** Posterior view of decoding accuracies using UCD Dataset. **(C)** Scatter plot comparing UF vs UCD decoding accuracies.

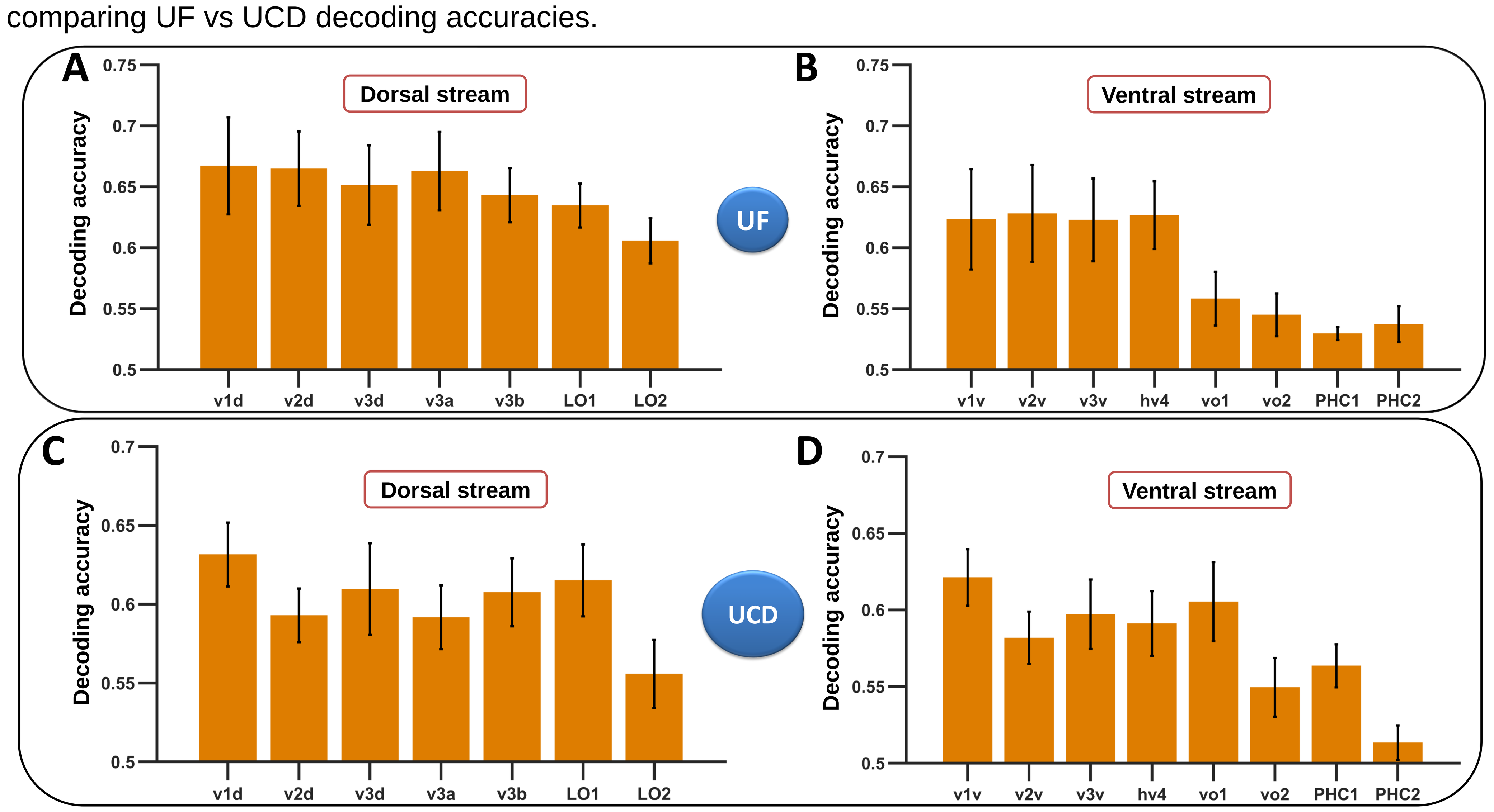


Fig. 3. Decoding accuracy comparison between different visuo-topic ROIs along the dorsal and ventral pathways; early to late visual regions are listed from left to right. **(A,C)** Dorsal stream. **(B,D)** Ventral stream.

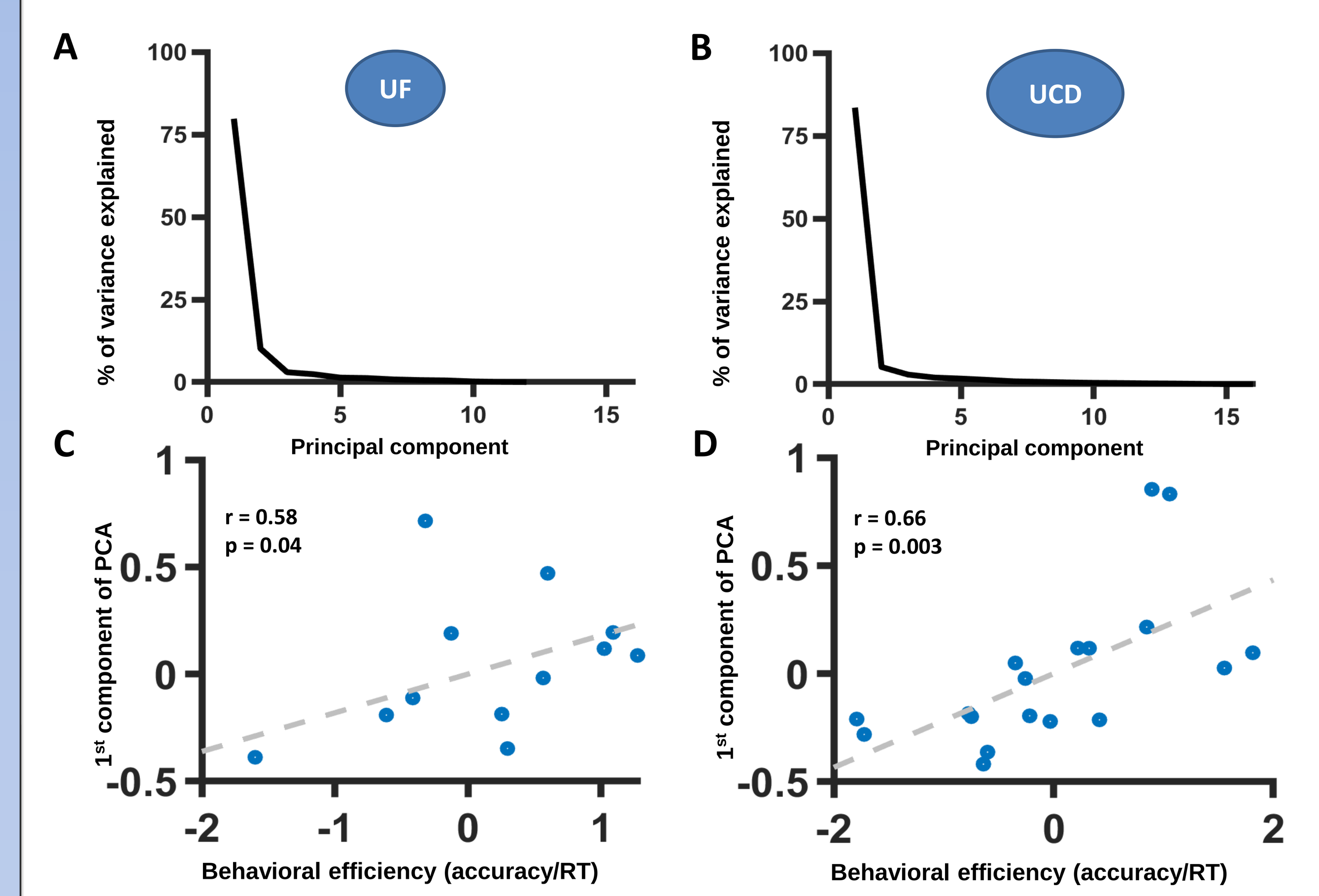


Fig. 4. MVPA classifier performance for visuo-topic ROIs vs behavior for both datasets. **(A)** Plot of percentage of variance explained by the principal components for UF dataset. **(B)** Plot of percentage of variance explained by the principal components for UCD dataset. **(C)** Scatter plot of classification accuracy vs behavioral efficiency for UF dataset. **(D)** Scatter plot of classification accuracy vs behavioral efficiency for UCD dataset.

Summary

- How are attention control signals distributed in different visual cortical regions? How do they influence behavior?
- We addressed these questions by analyzing fMRI data from two experiments utilizing the same paradigm but conducted at two different sites using scanners from different manufacturers.
- Applying MVPA to single-trial, cue-evoked beta values to decode between two attentional states: attend left vs attend right, we found, consistent across two datasets, the following results:
  - Attention control signals are present in all visuo-topic ROIs, ranging from V1 to PHC.
  - Decoding accuracy predicts behavioral performance, namely, higher decoding accuracy, better performance.
  - Regions in the dorsal visual pathway appear to be more predictive of the attentional state than regions in the ventral visual pathway.
  - Lower-order visual regions appear to be more predictive of the attentional state than higher-order visual regions.

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