Using Dynamically Adaptive Imaging with fMRI to rapidly characterize neural representations

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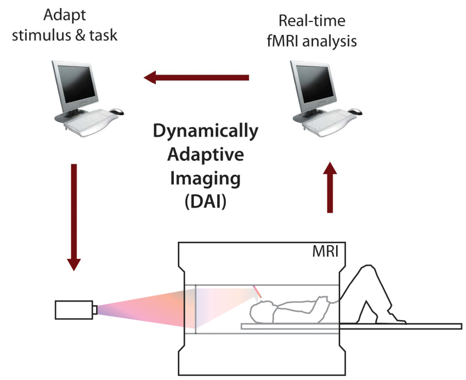
Introduction

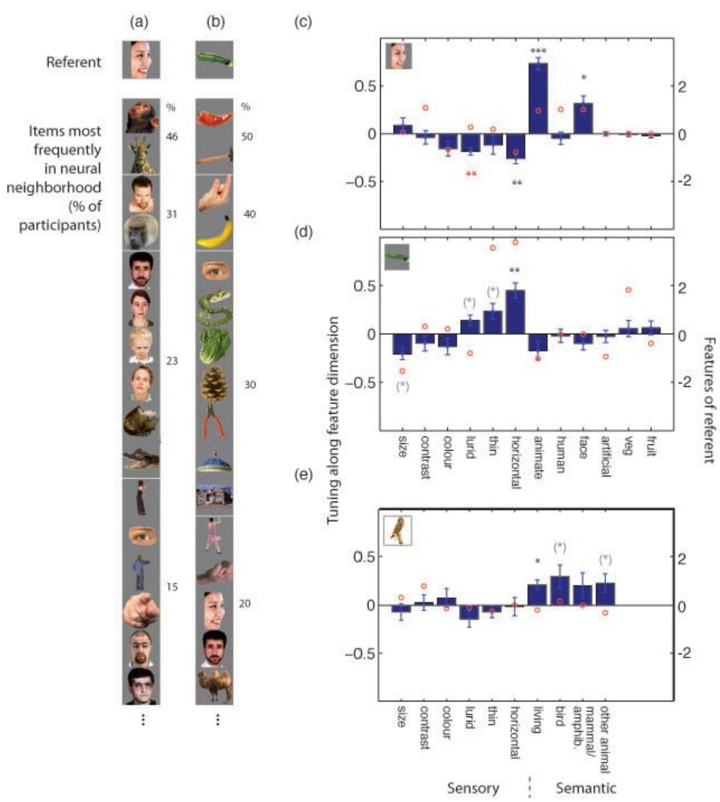


We demonstrate a novel real-time fMRI method, Dynamically Adaptive Imaging (DAI). In conventional fMRI experiments, the stimulus and task for the volunteer are fixed in advance. The imaging data are recorded and analyzed at some later time. Typically, a small number of experimental conditions are pre-specified, and the neural response to each is the outcome of the analysis. In contrast, in DAI the imaging data are analyzed in real-time and used to contingently adapt the stimulus or task. Thus, DAI reverses the mapping, from *stimuli->neural pattern* to *neural pattern->stimuli*, which avoids the *a-priori* assumptions about the representation within a region inherent in choosing stimulus categories.

Ventral visual cortex and object recognition: We use DAI to characterize neural representations in the ventral temporal and occipital regions implicated in visual object recognition. Evidence from electrophysiology and computational modeling suggests that neural tuning to visual objects reflects multidimensional selectivity to conjunctions of features. Thus, attempts to characterize these regions' response based on abstracted stimuli that manipulate single features at a time are inherently flawed. In contrast, with DAI we measured the simultaneous tuning to a number of features (both sensory and semantic) of naturalistic stimuli

Methods

Stimuli & task: Volunteers passively viewed colored object images (inter-stimulus interval 4s) presented through back-projection onto a screen in the bore of the scanner. *DAI Similarity Search:* A single referent object was chosen for each scanning run. Initially, 91 objects were presented consecutively and the similarity of the neural response to each object was compared to that evoked by the referent, using multi-voxel pattern analysis. The objects that evoked the most similar response were presented again. This procedure was repeated to iteratively converge upon the "Neural Neighborhood" (NN) of the 10 objects that evoked the most similar neural pattern to the referent. Three different referents were used in different sessions. We then examined which sensory and semantic features characterized the NN. *Imaging acquisition:* Anatomy - MPRAGE T1 (1 mm^3); Activation - T2* BOLD EPI (3x3x3.75 mm, TE=30 ms, TR=1 s, FA=78, 15 mins duration). *Real-time analysis:* This was conducted on a Linux workstation in Matlab using our open-source real-time analysis system based upon SPM.



Results

DAI converged rapidly across 5 iterations, with significant selection across participants even for the first single visual presentation. For each referent, the items constituting the NN were consistent across volunteers. The characteristics of the NN revealed tuning to multiple features, both sensory and semantic, but different patterns of invariance versus selectivity to these features defined the NN of different referent objects.

Conclusions

These results suggest: (1) Dynamically Adaptive Imaging provides a powerful novel tool for the investigation of complex neural representations; (2) studying single features in regions that code for complex feature combinations could produce misleading results; and (3) feature selectivity differs between object classes, as would be expected from computational models of object recognition.