Real-time fMRI search for the visual components of object perception

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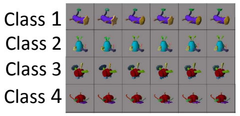
Cortical perception of complex visual properties

- The visual features encoded by mid- and high-level cortical visual regions are not obvious
- Very limited number of stimuli can be shown in neuroimaging study, compared to diversity of potentially cortically-relevant features
- We used realtime fMRI to explore cortical responses to specific features within restricted visual feature spaces for complex real-world or novel objects

Methods

- Participants shown photos of real-world or synthesized Fribble objects (Williams, 2000), drawn from 1 of 4 classes
- BOLD signals recorded with fast event-related design (2 sec TR, partial coverage) for 20 subjects

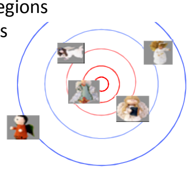
Real-world objects



Fribble objects

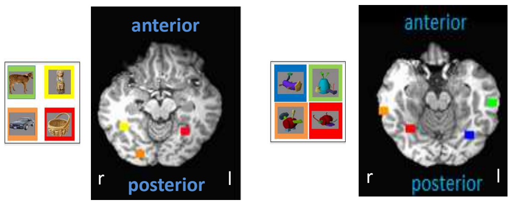
Search for preferred visual properties

- For each subject, select 4 brain regions associated with 4 stimulus classes
- Search in class-specific feature space for stimulus most activating brain region



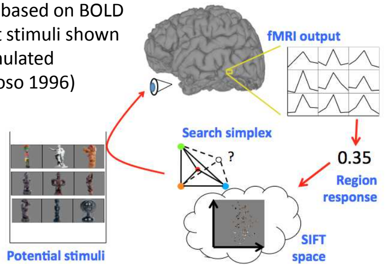
Example stimuli used in search for feature (center **red** circle) producing greatest activity

Example voxel regions studied



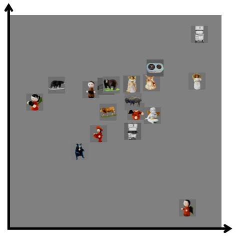
Realtime stimulus selection

- Stimuli selected based on BOLD response to past stimuli shown with simplex simulated annealing (Cardoso 1996)

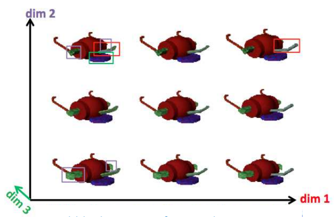


Visual feature space

Feature spaces defined to capture visual similarities between stimuli, defined by SIFT (Lowe 2005) and defined by geometric morphs



Two dimensions of SIFT space

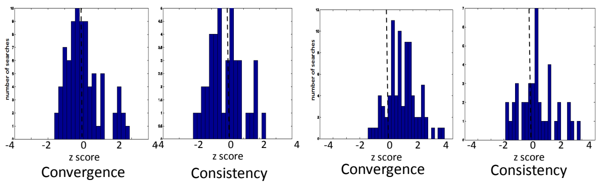


Fribble dimensions for morph operations

Behavior of search for preferred stimuli

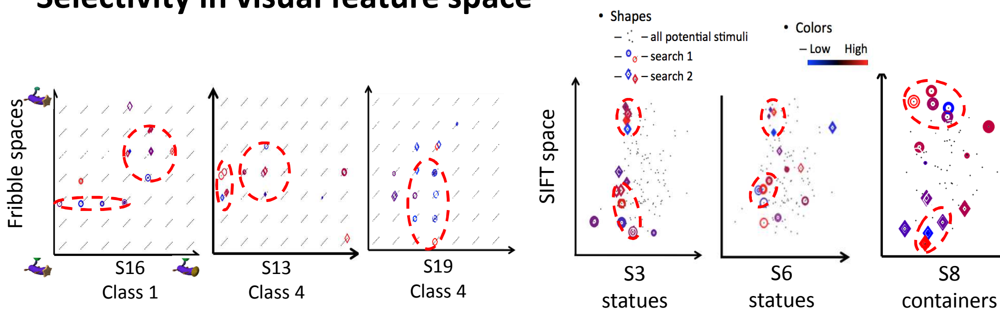
Testing for desired performance

- **Convergence:** focus on stimuli producing maximal response
- **Consistency:** find similar features of interest regardless of where in space we start the search



Searches in Fribble space show above-chance ***consistency*** *and* ***convergence***

Selectivity in visual feature space



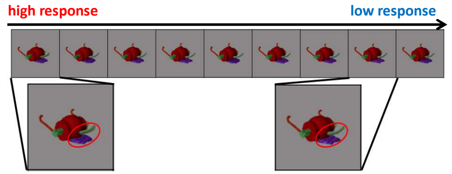
Invariance across subset of dimensions

Multiple selectivities within brain region

Objects highlighted by search

Stimuli sorted by S3 cortical response magnitude

Surface and shape properties elicit marked cortical responses



Stimuli sorted by S9 cortical response magnitude

Discussion

- Multiple feature-selective centers in the 125-voxel ROI within human ventral pathway
- ROI may be selective to variable sets of features (e.g., variable number of axes in feature space)
- Realtime searches converge on preferred stimuli with limited stimulus displays
- There is room for improvement in search performance

References

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Acknowledgments

NSF IGERT, **R.K. Mellon** Foundation, **Pennsylvania Department of Health**'s Commonwealth Universal Research Enhancement Program, **NIH** EUREKA Award #1R01MH084195A01, and the Temporal Dynamic of Learning Center at UCSD (NSF Science of Learning Center #SMA-1041755)