Inducing Neural Plasticity and Perceptual Similarity via Real-Time fMRI Neurofeedback

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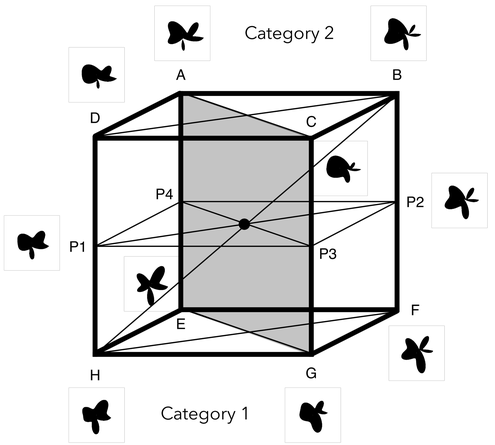
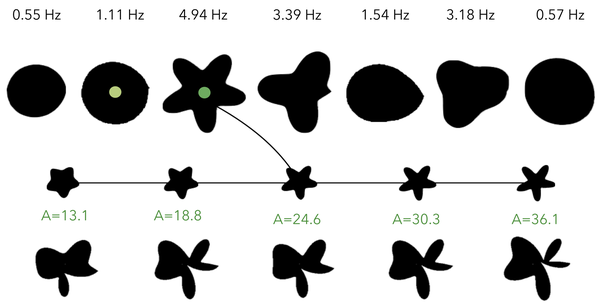
Abstract Multidimensional STIMULUS SPACE





7 frequencies = 7 dimensions of variation

dimension addition yields complex shape

parametrically vary shape by changing dimension amplitude

real-world objects
features difficult to control
decades of experience
changes too transient?

artificial object space
full parametric control
no extant category bias
simple, but still 'objects'

Hypothesis

Reinforcing differential neural activity patterns in ventral temporal cortex for visually similar shapes will drive apart their neural representations and reduce perceptual similarity

trial-level fast timescale | access neural pattern | change neural representation

real-time fMRI neurofeedback below threshold of awareness

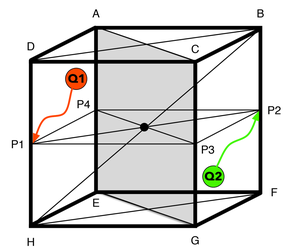
no explicit top-down learning signal

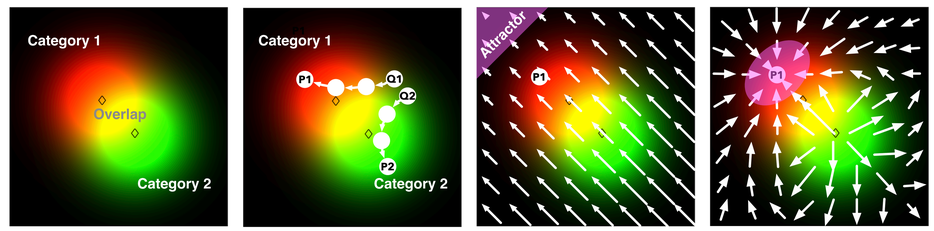
Experimental Design

NEUROFEEDBACK: KL-Evidence Model Simulations and Training Task

If the Neural Representations of Two Shapes Become More Similar, They May Be Perceived More Similarly

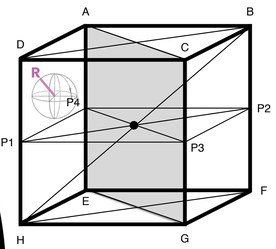
*Drive neural activity for shapes near category boundary towards category prototypes (P1 & P2): KL-Evidence = p1 * log(p1/p2)*





Category PDFs | Desired Feedback | SVM Evidence - Category 1 | KL Evidence - Category 1

Feedback based on standard MVPA classifier (SVM) drives activity away from category boundary in arbitrary directions
KL-Evidence may do a better job at shifting activity patterns towards specific points in neural space: P1 & P2



Task *Shape oscillates with variable radius R, centered at random position*

Goal *Push neural pattern of current shape towards appropriate prototype*

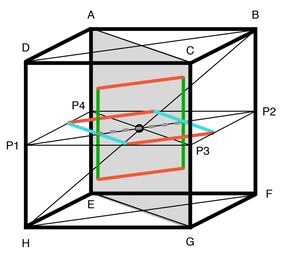
Instructions *Explore any strategy to make the shape stop oscillating!*

Radius R Manipulated via Neurofeedback

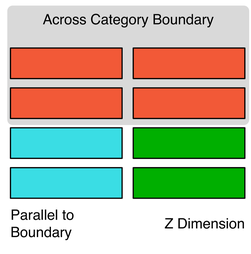
Positive feedback: decrease R
Negative feedback: increase R

Inducing and Measuring PERCEPTUAL CHANGES

Perceived Distances Along / Across Dimensions *RT for same-different behavioral task*



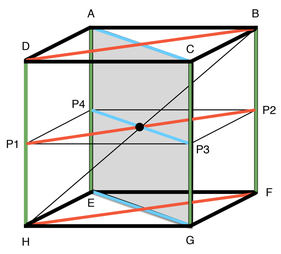
Behavioral Pre- and Post-Test



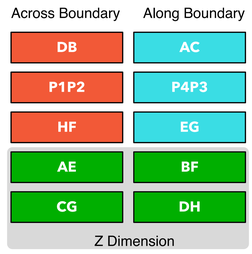
prediction

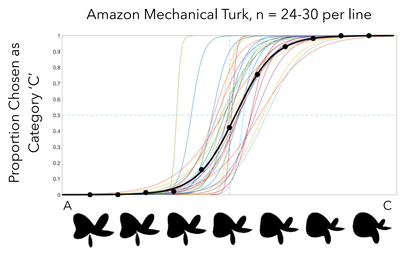
equal distances in shape parameter space perceived larger (shorter RT in 'different' condition) across category boundary than parallel to category boundary or along irrelevant Z dimension

Categorical Perception of Shape Space *2AFC for parameterized shapes between line endpoints | 10 lines in shape space*



Behavioral Pre- and Post-Test





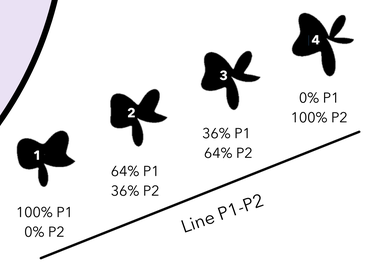
center of space perceived equidistant from endpoints across all dimensions

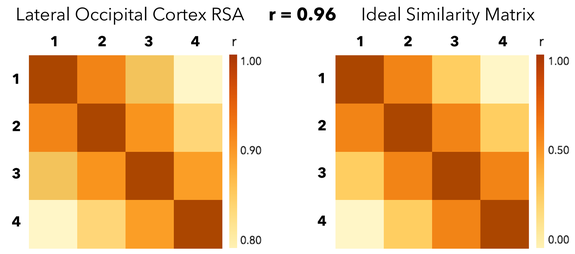
prediction

sharper category boundary (steeper psychometric function) for trained dimension compared to untrained dimensions

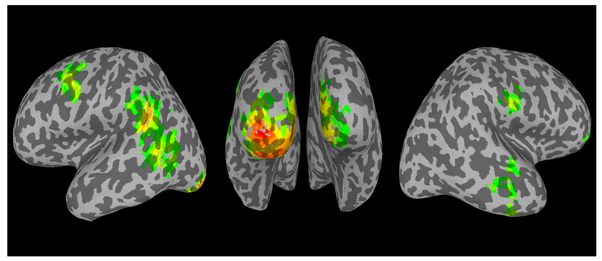
NEURAL REPRESENTATION of Shape Space

Parametric Shape Representation Localizer *average 6 lines, n=8, anatomical ROI*

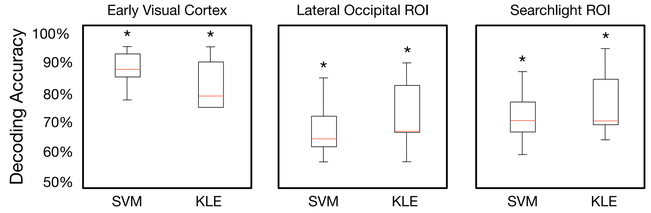




Training ROI *Searchlight for parametric regions: r > 0.50*



Category Prototype Classification: P1 vs. P2 *n=1, 10 runs*



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References: Op de Beeck, Wagemans, Vogels (2001) *Nat Neurosci* ✦ Brouwer & Heeger (2009) *J Neurosci* ✦ Shibata, Watanabe, Sasaki, Kawato (2011) *Science* ✦ Carlson, Simmons, Kriegeskorte, Slevc (2014) *J Cogn Neurosci* ✦ Jackson-Hanen, Tompary, deBettencourt, Turk-Browne (2014) *SfN* ✦ deBettencourt, Cohen, Lee, Norman, Turk-Browne (2015) *Nat Neurosci*