Using Closed-Loop Real-Time fMRI Neurofeedback to Induce Neural Plasticity and Influence Perceptual Similarity

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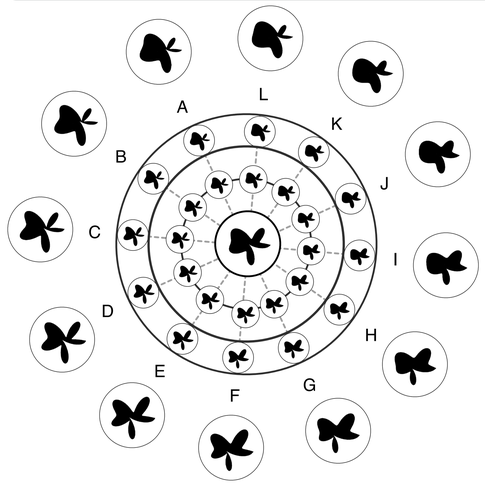
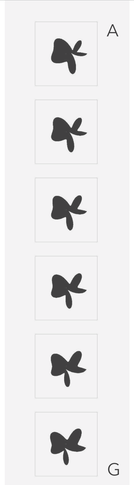
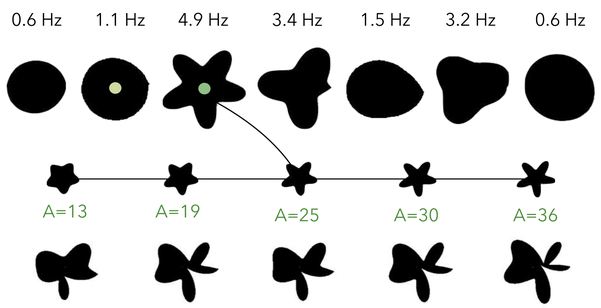
Abstract Multidimensional STIMULUS SPACE







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

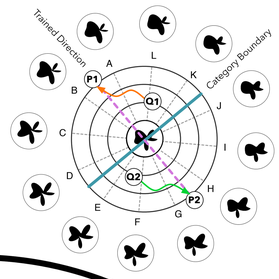
real-time fMRI neurofeedback below threshold of awareness

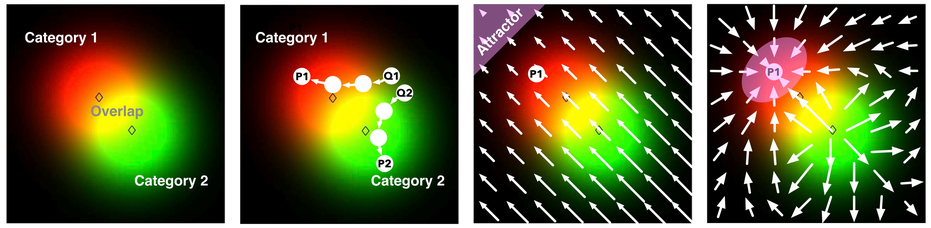
no explicit top-down learning signal

NEUROFEEDBACK: KL-Evidence Model Simulations and Training Task

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

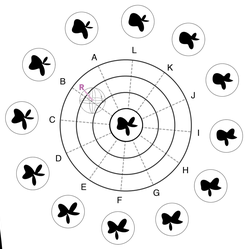
*Drive neural activity for shapes near category boundary towards category prototypes (P1 & P2): KL-Evidence = p1 * log(p1/p2)*





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!*

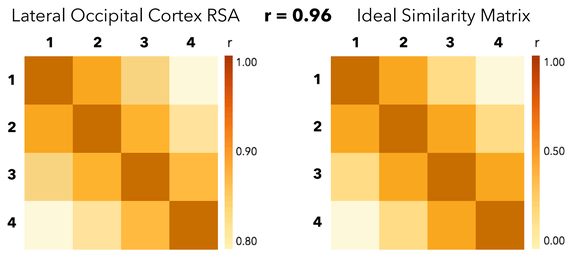
Radius R **Manipulated via Neurofeedback**

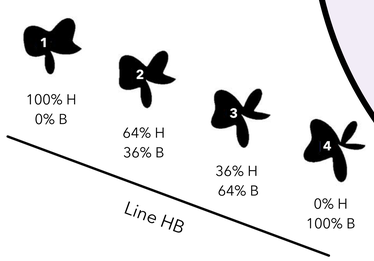
Positive feedback: decrease R
Negative feedback: increase R

NEURAL REPRESENTATION of Shape Space

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

Lateral Occipital Cortex RSA **r = 0.96** Ideal Similarity Matrix





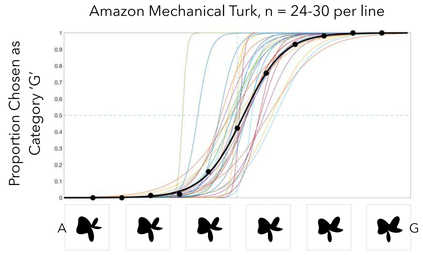
Experimental Design

2AFC between line endpoints

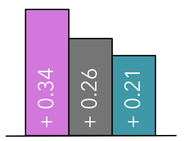
6 diameter directions

Inducing and Measuring PERCEPTUAL CHANGE

Categorical Perception of Shape Space



Preliminary Perceptual Results *n=2*

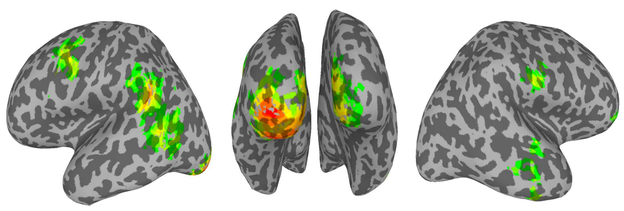


Psychometric function slope: Post - Pre / Pre

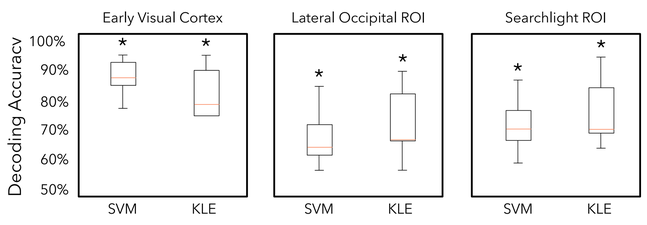
Radial distance from category boundary (degrees)	75	45	15
	Trained	Neutral	Untrained
Line directions in shape space	AG & BH	CI & FL	EK & DJ

preliminary evidence that **we can influence perceived similarity** of novel learned visual categories by using neurofeedback to induce neural plasticity across multiple brain regions

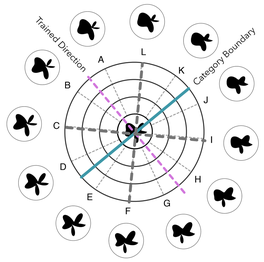
Feedback ROI *Searchlight for parametric regions: r > 0.50*

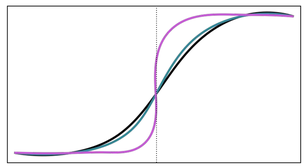


Category Decoding in Neural Feedback ROI *n=2, LORO*



Behavioral Prediction: Pre- vs. Post-Training *psychometric function estimation*





pre-training
post-training untrained direction
post-training trained direction

prediction

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

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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*