



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



Marius Cătălin Iordan<sup>1</sup>, Victoria J.H. Ritvo<sup>1</sup>, Kenneth A. Norman<sup>1</sup>  
Nicholas B. Turk-Browne<sup>1,2</sup>, Jonathan D. Cohen<sup>1</sup>

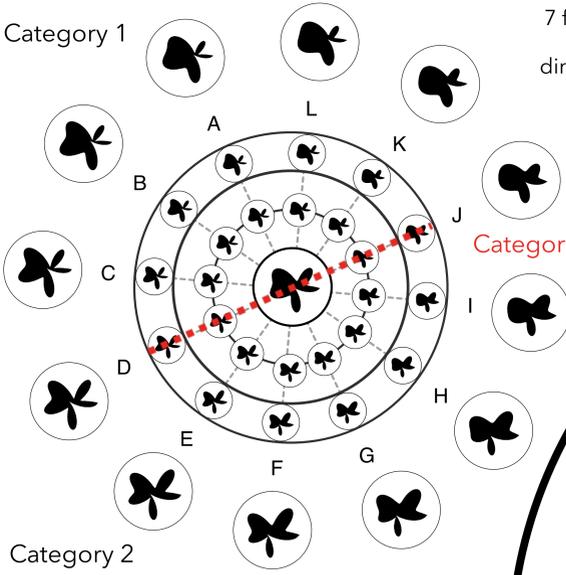
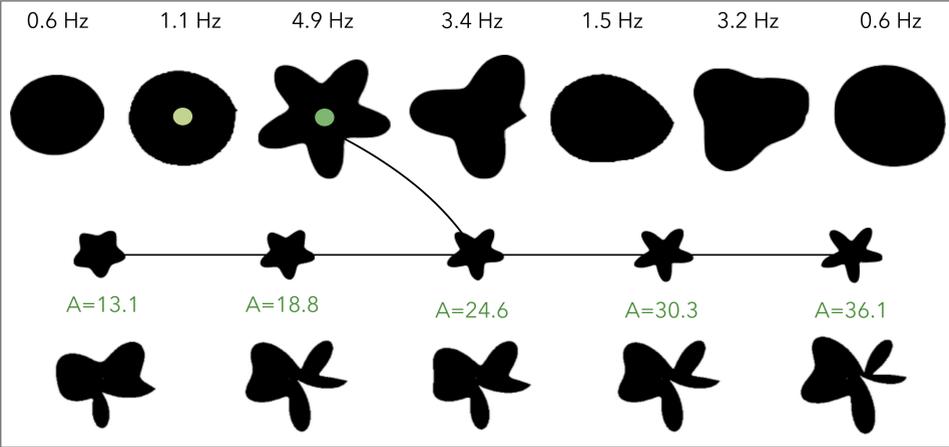
<sup>1</sup>Princeton Neuroscience Institute & Psychology Department, Princeton University <sup>2</sup>Psychology Department, Yale University  
mci@princeton.edu vej@princeton.edu knorman@princeton.edu ntb@princeton.edu jdc@princeton.edu

## Abstract Multidimensional STIMULUS SPACE



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

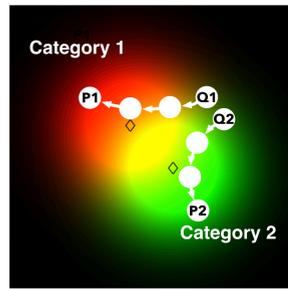
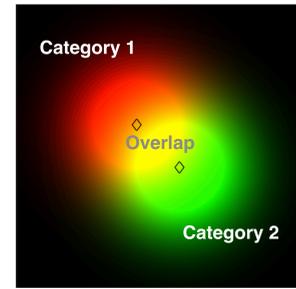
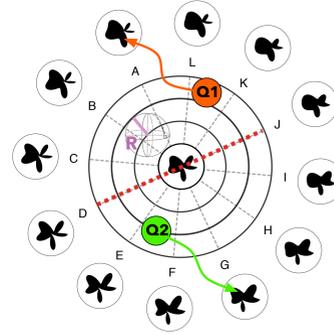
**artificial object space**  
full parametric control  
no extant category bias  
simple, but still 'objects'



7 frequencies = 7 dimensions of variation  
dimension addition yields complex shape  
parametrically vary shape by changing multiple dimensions' amplitude

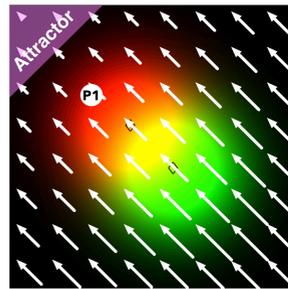
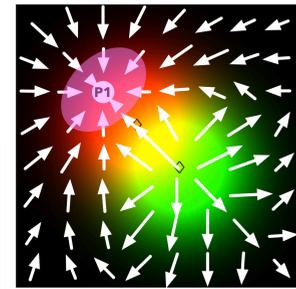
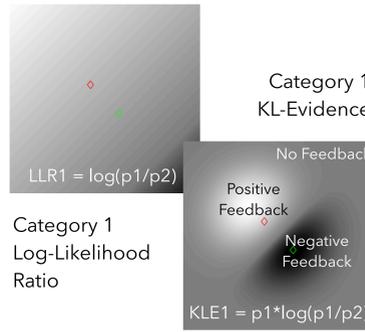
## NEUROFEEDBACK: KL-Evidence Model & Training

**if two shapes become more similar neurally, they may be perceived similarly**  
Drive neural activity for shapes near category boundary towards category prototypes



Category PDFs

Desired Feedback



Feedback based on standard MVPA may drive activity away from boundary in arbitrary directions  
KL-Evidence may shift patterns towards neural prototypes more accurately

## 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

Shape oscillates with variable radius, centered randomly **Task**

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

Make the shape stop oscillating! **Instructions**

**Radius R Neurofeedback Manipulation**

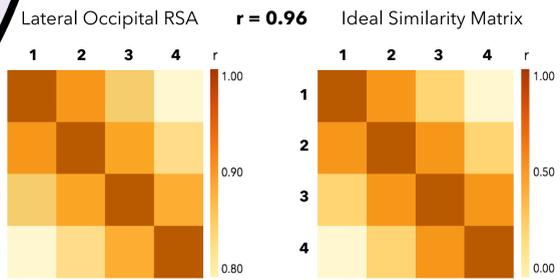


Positive feedback: decrease R  
Negative feedback: increase R

## NEURAL REPRESENTATION of Shape Space

**Cognitive Map Shape Localizer**

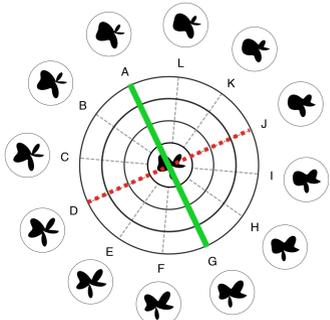
average 6 lines | n=10 | anatomical ROI



## Inducing and Measuring PERCEPTUAL CHANGES

**Categorical Perception of Space**

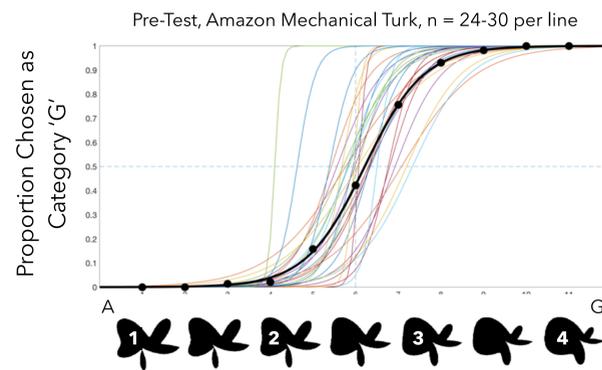
2AFC between line endpoints | 8 lines



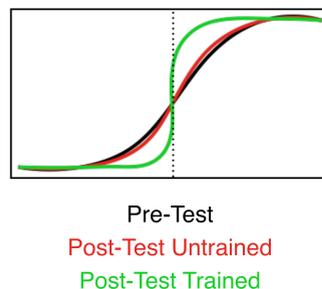
### Prediction

sharper category boundaries (steeper psychometric function) for **feedback dimension** versus **untrained dimension**

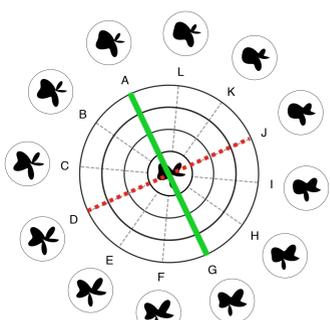
center of space perceived equidistant from endpoints across all dimensions



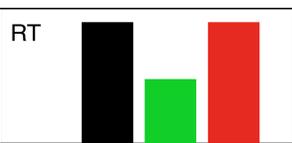
### Behavioral Prediction



**Perceived Distances Across Dimensions** RTs for same-different task



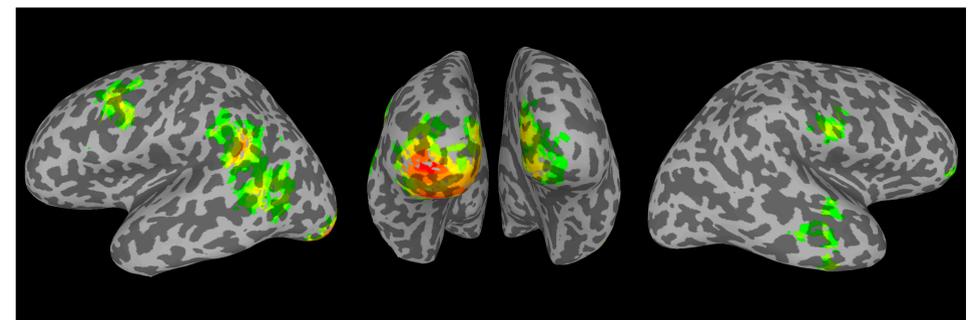
### Behavioral Prediction



### Prediction

equal distances in shape parameter space perceived larger (shorter RT in 'different' condition) **across category boundary** than **parallel to boundary**

**Feedback Training ROI** Searchlight for cognitive map regions:  $r > 0.50$



**Category Prototype Classification: A vs. G** n=3 | LORO

