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Category Learning in the Brain

The key to human intelligence

Based on the article by: Seger, C.A. & Miller, E.K. (2010). Annual Review of Neuroscience, 33, 203-219.

Categorization

- ▶ Ability to group experiences into meaningful concepts
 - ▶ Without it: experiences → fragmented + unrelated
- ▶ Allows us to generalize about future situations
 - ▶ Shared fundamental elements
- ▶ Category: Knowledge of groupings + patterns
 - ▶ Functional Relevance
- ▶ Results from recruitment of a variety of neural systems depending on task demands
 - ▶ Type of category + how it is used

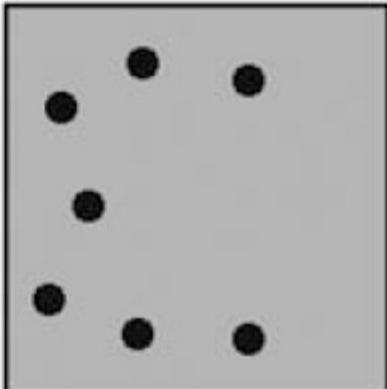
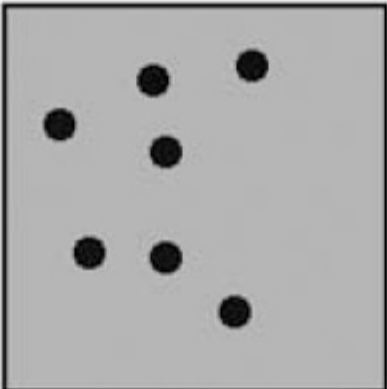


Visual Cortex

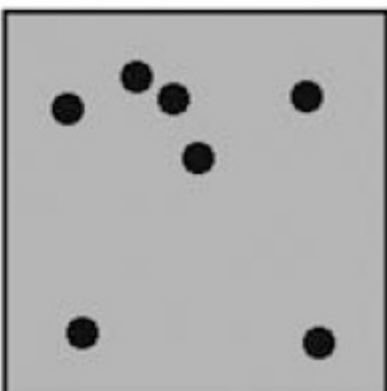
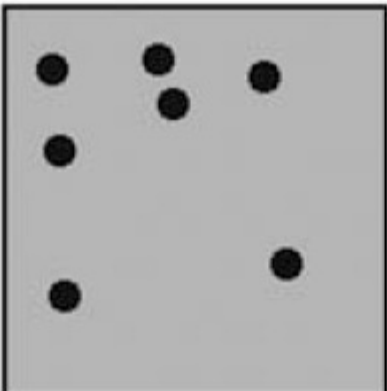
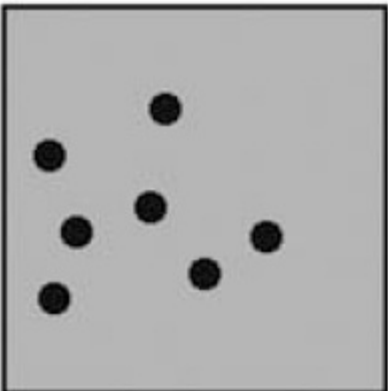
- ▶ Human imaging studies:
 - ▶ Inferotemporal cortex (ITC): sensual to
 - ▶ perceptual features of stimuli
 - ▶ perceptual distance b/w stimuli
- ▶ Prototype learning
 - ▶ Category learned by observing category members
 - ▶ Hebbian learning of synapses
 - ▶ Preserved in patients with amnesia
 - ▶ Independence from MTL memory systems



Prototype learning task



A



not
A

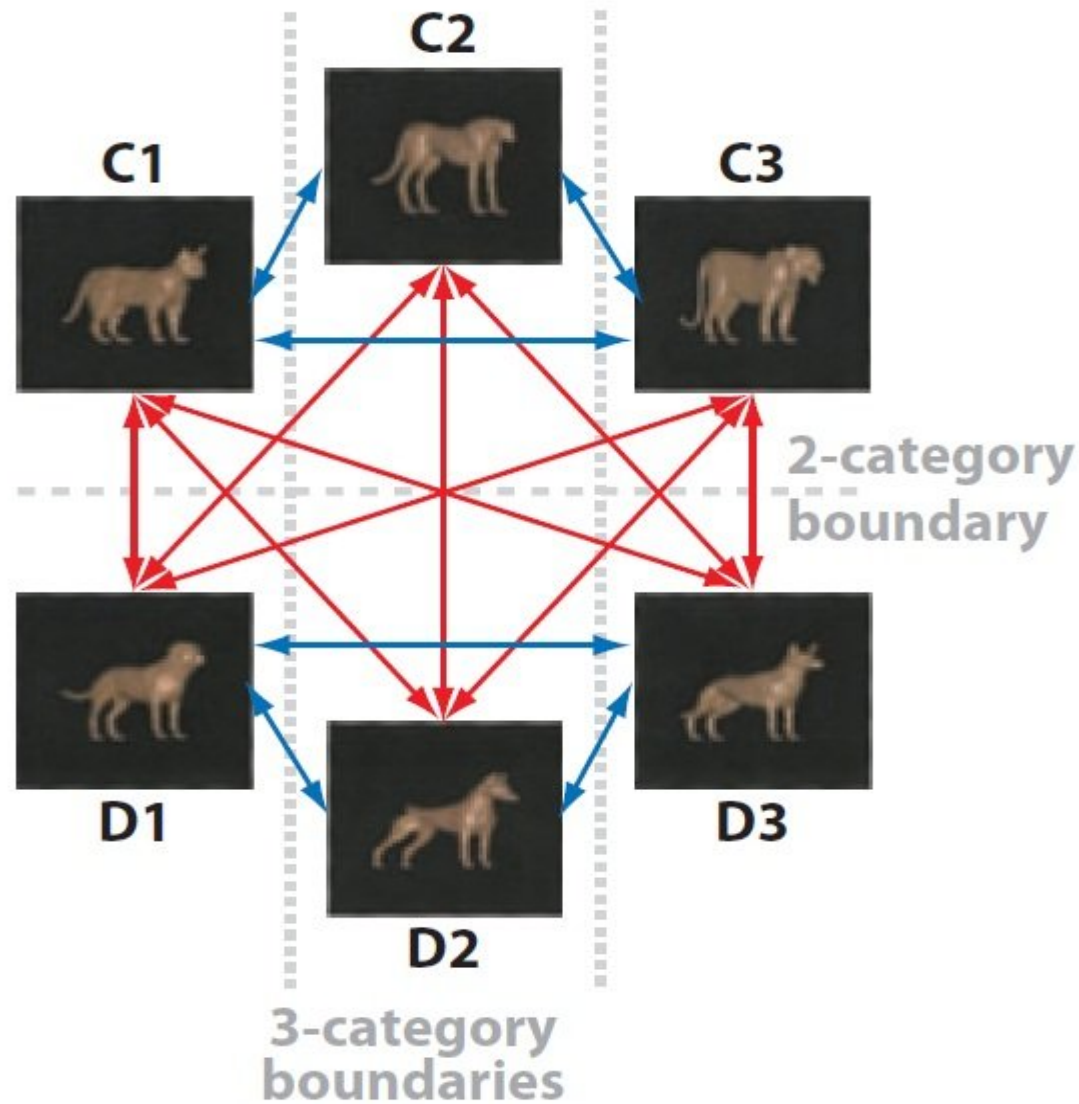
▶ Taken from: Ashby, F.G. & Maddox, W.T. (2005). Human Category Learning. Annual Review of Psychology, 56, 149-178.

Prefrontal Cortex

- ▶ More modifiable by experience than sensory cortex
- ▶ Morphed continuum categorization task
 - ▶ boundary b/w categories
 - ▶ conjunctions b/w features



Morphed continuum



Prefrontal Cortex

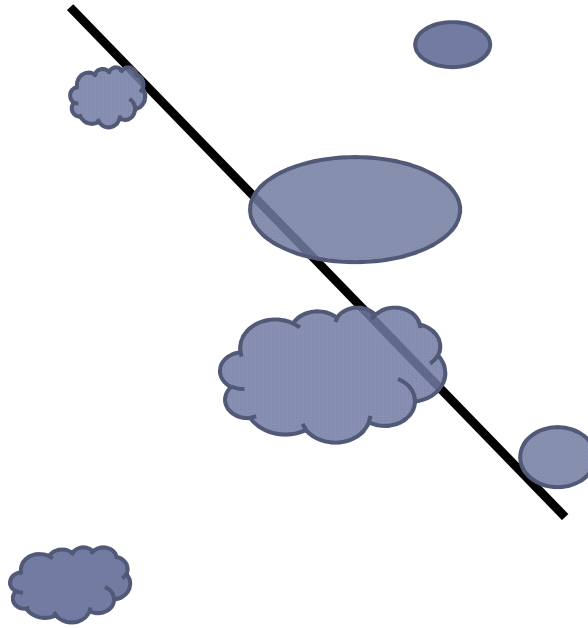
- ▶ More modifiable by experience than sensory cortex
- ▶ Morphed continuum
 - ▶ boundary b/w categories
 - ▶ conjunctions b/w features
- ▶ Interaction ITC + PFC
 - ▶ ITC: selectivity for individual members
 - ▶ PFC: category boundaries



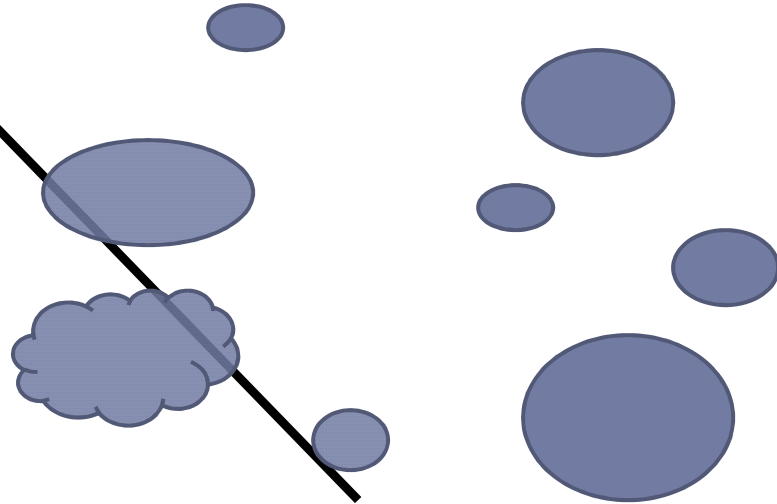
in-category



boundary



out-category

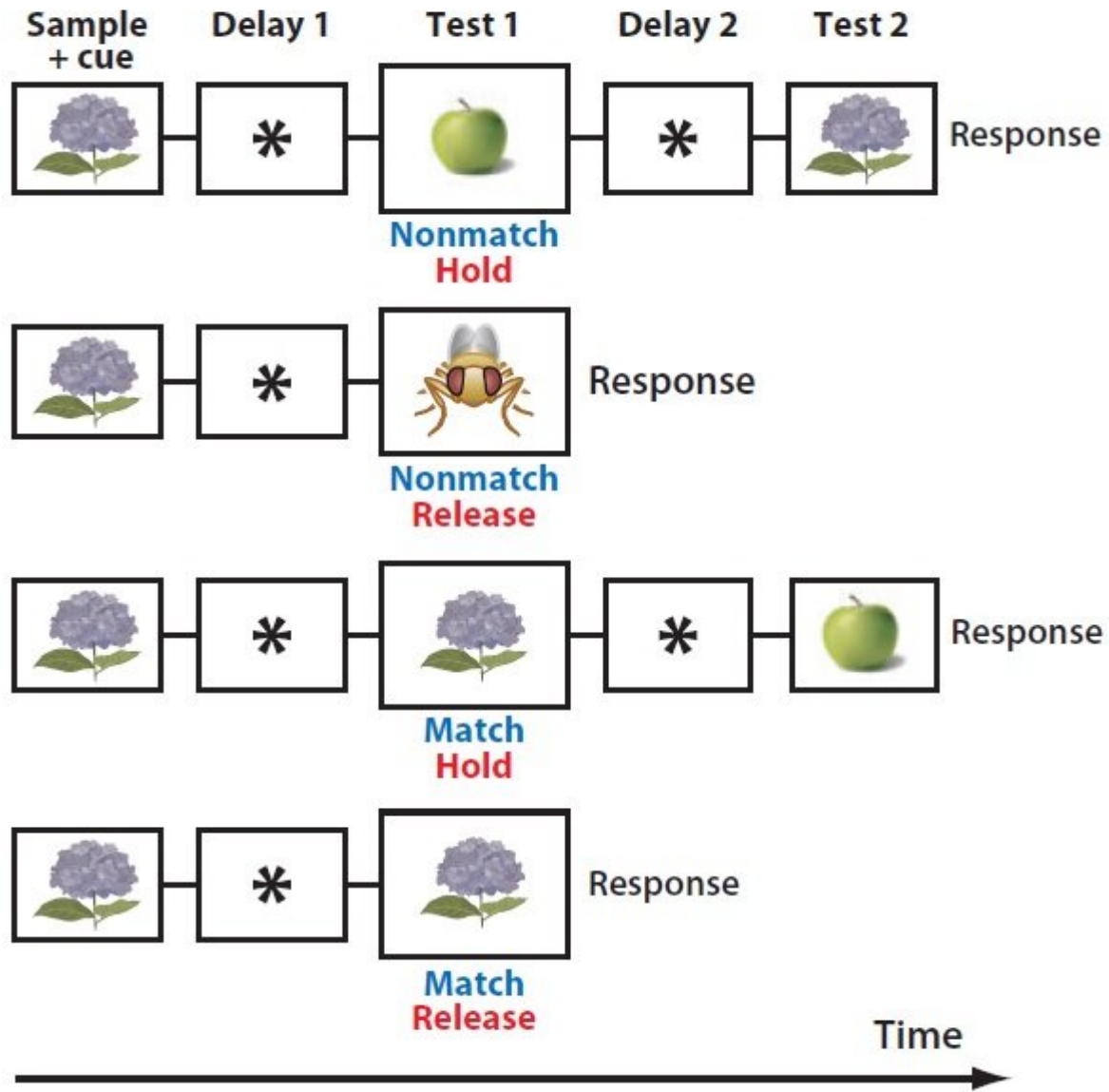


Prefrontal Cortex

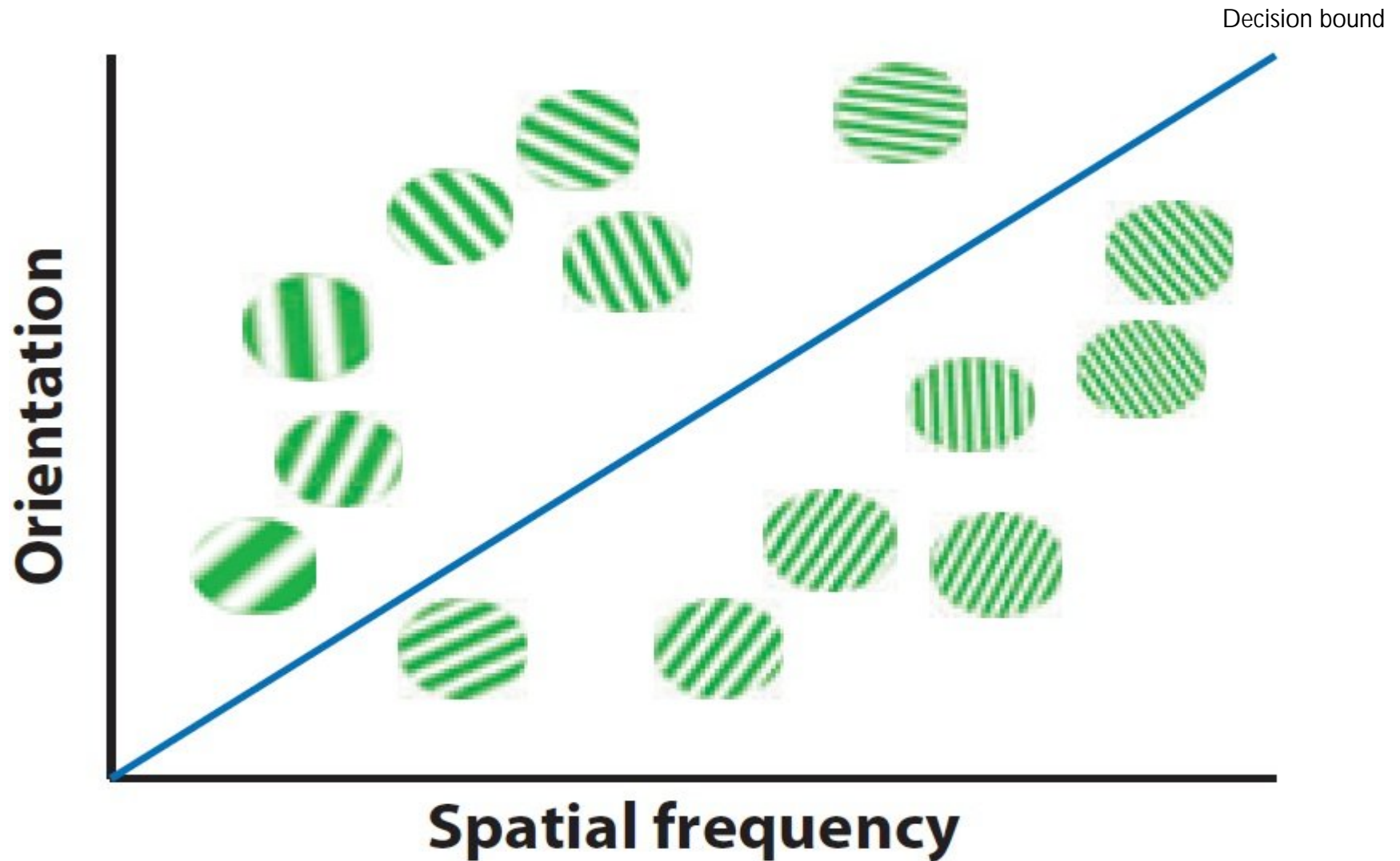
- ▶ More modifiable by experience than sensory cortex
- ▶ Morphed continuum
 - ▶ boundary b/w categories
 - ▶ conjunctions b/w features
- ▶ Interaction ITC + PFC
 - ▶ ITC: selectivity for individual members
 - ▶ PFC: category boundaries
- ▶ **Rule-based categorization**
 - ▶ abstract rule-based categorical distinctions



Rule-based categorization



Information integration



Taken from: Seger, C.A. & Miller, E.K. (2010). Category Learning in the Brain. Annual Review of Neuroscience, 33, 203-219

Premotor Cortex + Motor Cortex

- ▶ Categorical decisions: selection + execution of behavior
- ▶ More expertise → more reliance on motor systems
 - ▶ PFC: more activated during new learning
 - ▶ PMC: activated during familiar classifications



Hippocampus + MTL

- ▶ Specialized in rapid learning of individual instances
 - ▶ Single-trial learning
 - ▶ Exceptions to a rule
- ▶ Arbitrary categorization task
 - ▶ Membership of each item must be remembered individually



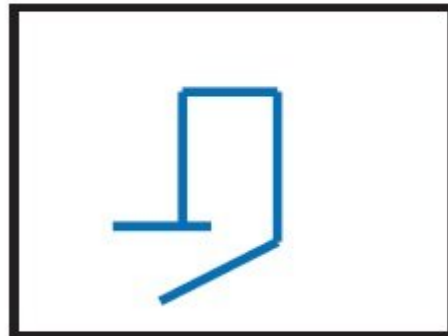
Arbitrary categorization



80% category 1
20% category 2



20% category 1
80% category 2



80% category 1
20% category 2



20% category 1
80% category 2



Hippocampus + MTL

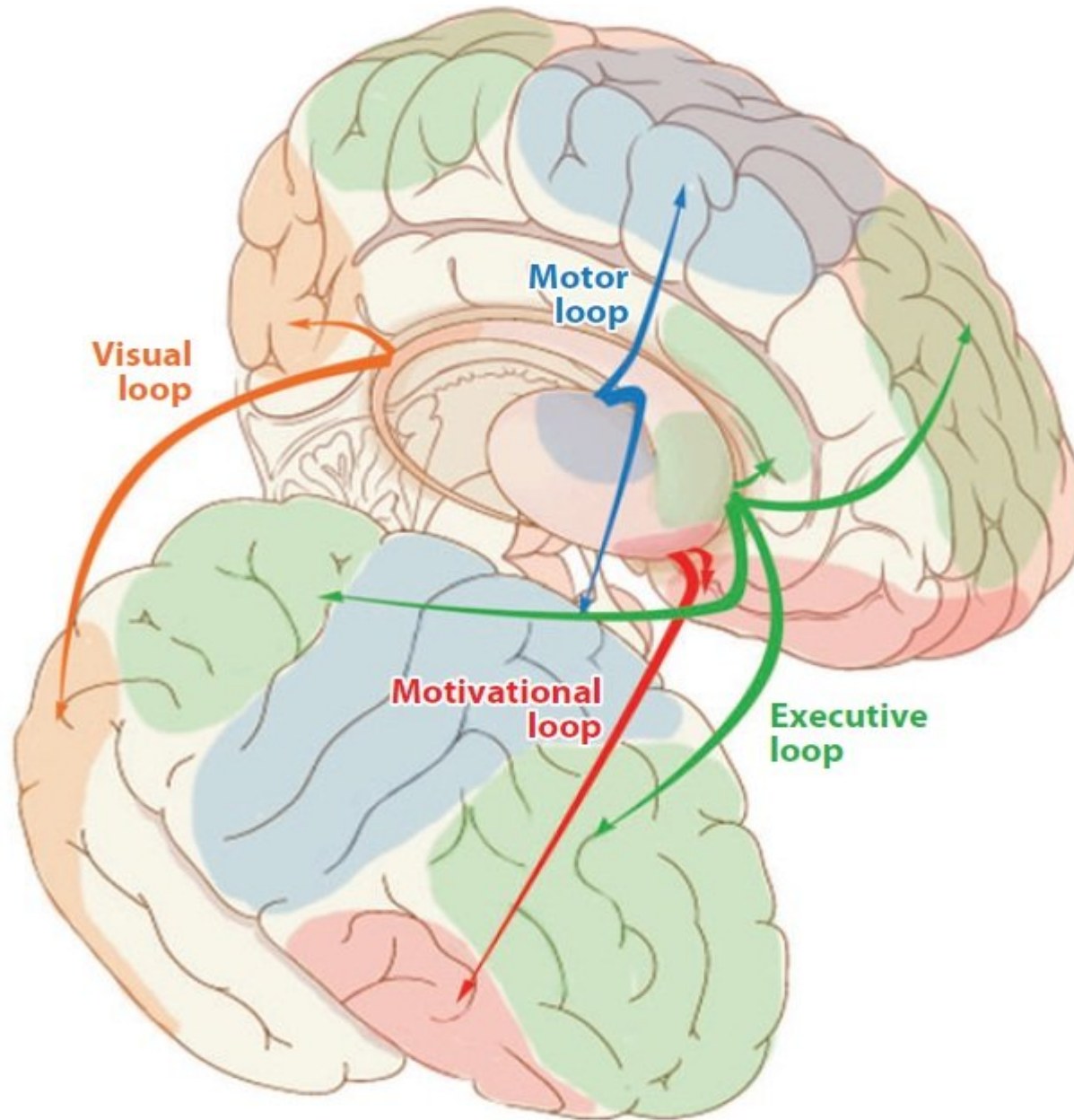
- ▶ Specialized in rapid learning of individual instances
 - ▶ Single-trial learning
 - ▶ Exceptions to a rule
- ▶ Arbitrary categorization task
 - ▶ Membership of each item must be remembered individually
- ▶ Set up memory representation accessible to other systems
- ▶ Info acquired via MTL: can be transferred to new situations



The Basal Ganglia

- ▶ 4 output loops to different cortex areas
 - ▶ Executive, motivational, visual, + motor
- ▶ Inhibition of the cortex
 - ▶ Selective release to allow for selection of movement/cognitive strategy
- ▶ Categorization tasks:
 - ▶ Help with selection of appropriate category representation + related strategies/behaviors





▶ Taken from: Seger, C.A. & Miller, E.K. (2010). Category Learning in the Brain. Annual Review of Neuroscience, 33, 203-219

The Key to Human Intelligence

- ▶ Ability to learn new categories quickly, even when they are multivariate + abstract

(e.g. 'FreeJazz', 'gastropub')



Fast & Specific

- ▶ Fast learning of Specific representations
 - ▶ Error prone
 - ▶ Spurious associations
 - ▶ coincidences

Slow & General

- ▶ Slow acquisition of Generalized knowledge
 - ▶ Slow
 - ▶ Identify commonalities
 - ▶ Regularities of predictive relationships

Trade-off b/w generalization + specificity

Fast plasticity in subcortical systems

→ Large synaptic weight changes

Slower plasticity in the cortex

→ Smaller weight changes



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- ▶ Normal learning = balance b/w fast + slow systems
 - ▶ Hypothesis: neuropsychiatric disorders (e.g. Autism)
 - ▶ Imbalance of the systems:
 - ▶ Faster plasticity in subcortex overwhelms slower cortical plasticity
 - ▶ Brain has difficulties generalizing



Thank You!

