Perceptual Concept Learning of Ecological and Artificial Stimuli by Rhesus Macaques

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Introduction

Concepts have long been of interest to psychologists because many theories hold them to be the basis for higher order cognition. Considerable research has focused on abstract concept learning (Katz, Wright, & Bodily, 2007); fewer studies have focused on perceptual concept learning (Vonk & MacDonald, 2002).

In animals, does the general ability to categorize rely on class-based concepts, those that process sensory inputs as perceptual gestalts, or on open-ended categories, which are grouped based on the similarities of their physical attributes (Herrnstein, 1990)? It has been very difficult to distinguish between these two possibilities with non-verbal experimental methods, because pictorial stimuli necessarily convey some physical information.

Main Questions

- How robust is the primate's ability to categorize?
- Are there distinct processes underlying the abilities to distinguish ecological and artificial stimuli?
- Is one of the above abilities superior?
- Can macaques form class based concepts without relying on perceptual features?

Materials and Methods

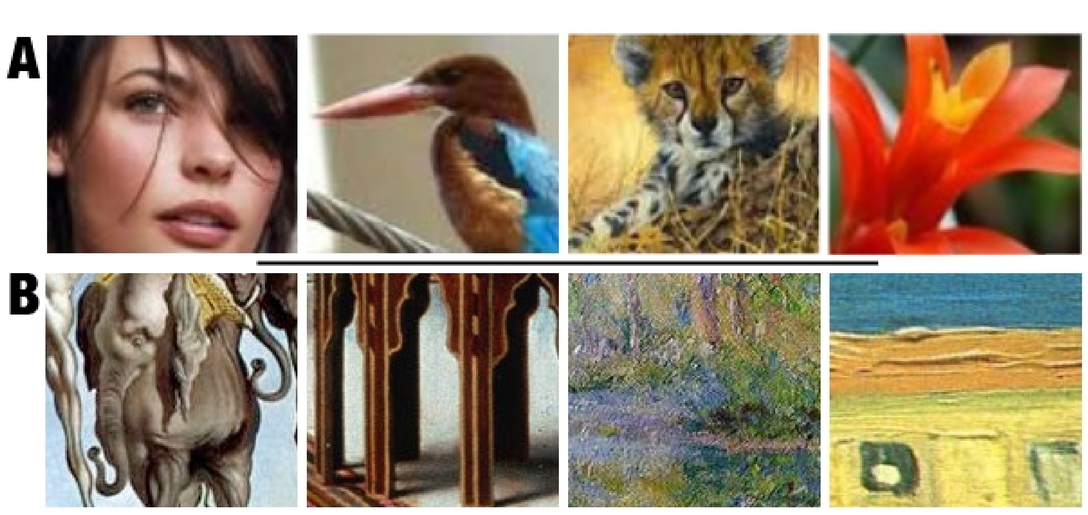

Figure 1: Sample stimuli used at test, representing **A.** ecological concepts, **B.** artifical concepts.

Subjects. 7 male Rhesus macaques - 3 learned ecological concepts, 4 learned artificial (Figure 1).

Procedure. Subjects were trained and tested using variations of the Simultaneous Chaining (SimChain) paradigm. Training was accomplished by presenting subjects with sequences in which the exemplars, drawn with replacement from very large stimulus banks, changed trial by trial. After learning the correct order of the concepts, performance was tested with 20 SimChains in which the stimuli were novel and did not change over the course of each session.

Results

At the end of ecological concept training, subjects were highly proficient at selecting never-before-seen trial-unique stimuli in an order prescribed by their categories, successfully earning a reward on 51.3% (Augustus), 58.8% (Coltrane), and 53.2% (Lashley) of trials. Chance performance on a 4-item SimChain gives a 4.16% reward rate.

At test, reward rates were significantly higher for concept ordered lists, than for lists composed of arbitrary stimuli:

Augustus - 13.7% arbitrary vs. 65.0% categorical (χ^2 =636, df=1, p<0.001).

Coltrane - 71.6% arbitrary vs. 86.0% categorical (χ^2 =63.1, df=1, p<0.001).

Lashley - 34.9% arbitrary vs. 65.4% categorical (χ^2 =148, df=1, p<0.001).

Additionally, performance in both tasks was characterized using a learning curve function (Thurstone, 1919). Model parameters significantly differed (p<0.001) between categorical and arbitrary performance curves (Figure 2).

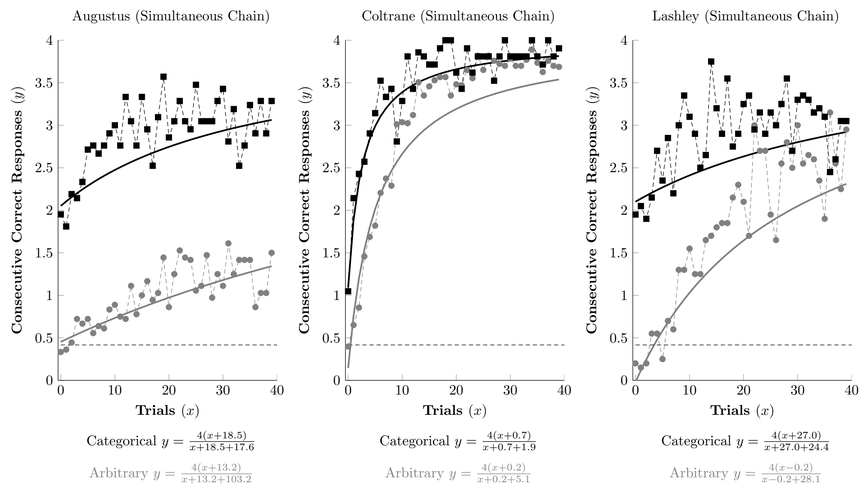

Figure 2: Learning curves of three macaques tested on 20 trials of a simultaneous chain using trial unique ecological concept stimuli.

The painting stimuli were considerably more difficult to train. Reward rates were similar across subjects: 28.3% (Benedict), 27.5% (Horatio), 33.5% (MacDuff), and 33.0% (Prospero), by the end of training.

Trial reward rates:

Benedict - 33.7% arbitrary vs. 50.2% categorical (χ^2 =74.2, df=1, p<0.001)

Horatio - 41.2% arbitrary vs. 44.4% categorical (χ^2 =2.59, df=1, p = 0.11)

MacDuff - 40.7% arbitrary vs. 31.7% categorical (χ^2 =16.14, df=1, p<0.001)

Prospero - 43.3% arbitrary vs. 35.5% categorical (χ^2 =15.50, df=1, p<0.001)

Comparable models were generated (Figure 3). Three of four subjects showed significant differences in model parameters (p<0.001), but one subject did not (Prospero).

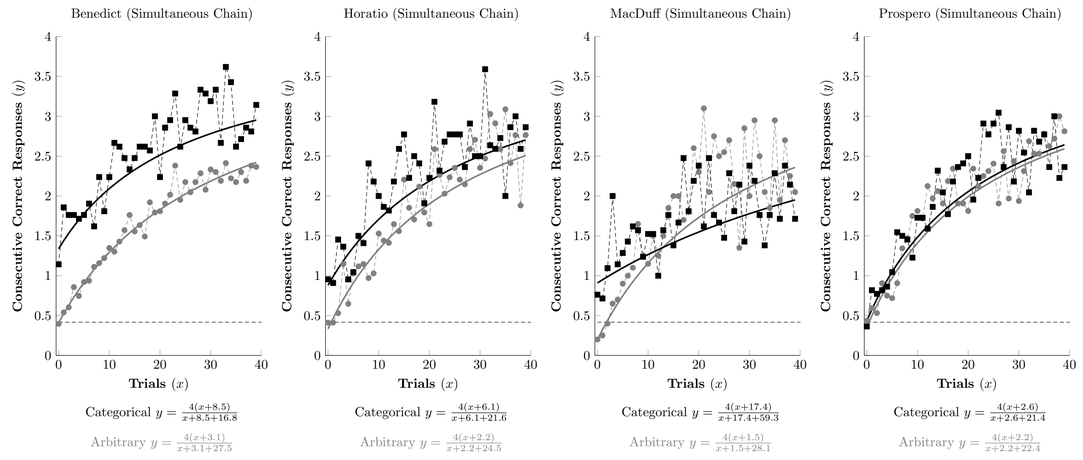

Figure 3: Learning curves of four macaques tested on 20 trials of a simultaneous chain using trial unique painting stimuli.

Summary

- With ecological stiimuli, macaques were proficient at classifying a large training set and novel exemplars.
- With artifical stimuli, macaques were able to classify a large training set.
- 3 out of 4 subjects displayed conceptual knowledge during transfer.
- Macaques appear able to classify stimuli based on gestalt properties, reflecting a generalizable ability to form abstract perceptual concepts.

Where to go from here

- Compare concept chaining performance to baseline SimChain performance and personality measures.
- Replicate in other species, notably humans, chimps.
- Explore the objective difficultly and attributes of painting stimuli.

References

Herrnstein, R. J. (1990). Levels of stimulus control: A functional approach. *Cognition*, *37*(1), 133–166.

Katz, J. S., Wright, A. A., & Bodily, K. D. (2007). Issues in the comparative cognition of abstract-concept learning. *Comparative cognition & behavior reviews*, *2*, 79.

Thurstone, L. L. (1919). The learning curve equation. *Psychological Monographs: General and Applied*, *26*(3), i–51.

Vonk, J., & MacDonald, S. E. (2002). Natural concepts in a juvenile gorilla (gorilla gorilla gorilla) at three levels of abstraction. *Journal of the experimental analysis of behavior*, *78*(3), 315–332.