Monkeys Count Up and Count Down: Conditional Numerical Ordering in Rhesus Monkeys
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Introduction
This research investigates the abstract nature of ordinal numerical concepts in non-human primates. Previous research has shown that rhesus monkeys can use ordinal rules to seriate numerosities. Subjects trained to order a subset of numerical values ordered novel numerical values with non-differential reinforcement (Brannon & Terrace 1998, 2000). Thus, rhesus monkeys learn ordinal numerical rules and represent numerosity as an ordered dimension. The level of abstraction at which subjects appreciate ordinal numerical relations, however, is still not known.

Here we address three questions regarding monkeys' ordinal numerical abilities:
1) Can monkeys learn to flexibly order numerosities with both ascending and descending ordinal rules?
2) Can subjects who are trained to perform a conditional ordinal rule on the numerosities 1 to 9 transfer the ordinal rule to larger numerical values?
3) To what degree do monkeys use density and perimeter as cues to discriminate and order numerosity?

Method
Subjects & Training Procedure
Two rhesus macaques (Feinstein and Mikulski)
Red background: respond ascending
Blue background: respond descending
Training Phase 1 (differed between monkeys)
Feinstein trained on 3-item subsets 1-3-5 and 2-4-6
Mikulski trained on 2-items subsets 1-9 and 9-1
Training Phase 2
Subjects trained on odd 2-item pairs between 1 and 9
Training Phase 3
Subjects trained on all 2-item pairs between 1 and 9

Stimulus Controls
After subjects learned to order the numerosities from 1 to 9, density, perimeter, and surface area were controlled.

Results
Acquisition
Accuracy on first sessions in which ascending and descending trials were randomized for a subset of numerical pairs.

Stimulus Controls
Accuracy on all odd pairs between 1 and 9 by ratio of perimeter:

Transfer
Pairwise test of large, novel numerical values (10-20, 10-30, 10-40, 20-30, 20-40, 30-40)
Pairs consisting of one or two novel values were non-differentially reinforced.

Discussion
1) Both monkeys were successful in learning to perform conditional ascending and descending ordinal rules.
2) After training on values ranging from 1 to 9, one subject was able to order the novel numerosities 10, 20, 30, and 40 consistent with the conditional ordinal rules.
3) Cumulative perimeter and density did not influence numerosity discrimination in this task.

This suggests that rhesus monkeys have a rich appreciation of numerosity and ordinality and that they appreciated large novel numerosities as a continuous extension of smaller, familiar numerosities.

References

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