Number Discrimination in a New World Monkey Species: Assessment of Tamarins Across 3 Tasks, All Using a 2/1 Ratio

Julie Neiworth, Maren Sonstegard, Alison Lewis, Kate Whillock, Aisha Kudura, Elizabeth Gray
Dept of Psychology, Carleton College Northfield, MN email: jneiwort@carleton.edu

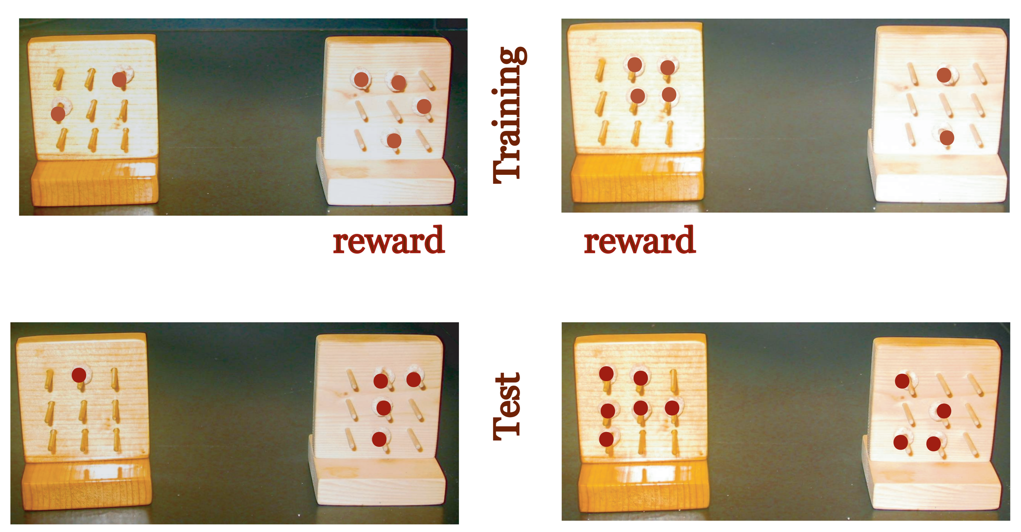
Introduction

Rudimentary numerical competence in the form of discriminating between numbers of items is widespread in the animal kingdom (i.e., for mammals, Boysen & Capaldi, 1993; for birds, Emmerton, 2001, and for amphibians, Uller, Jaeger, Guidry & Marten, 2003) and most likely serves as a phylogenetic precursor for higher, verbal-based numerical abilities in humans. Two nonverbal systems represent numerosity in animals, human infants and adults (Carey, 2001): 1) an object-file tracking system whereby small numbers of items (typically less than 4) are represented as distinct quantities, and 2) an analog magnitude system that obeys Weber's Law, wherein smaller amounts (i.e., 1 vs 2) are easier to discriminate from each other than larger amounts (11 vs. 12) are from each other (most likely due to ratio differences that are larger for small numbers and smaller when comparing large numbers to each other).

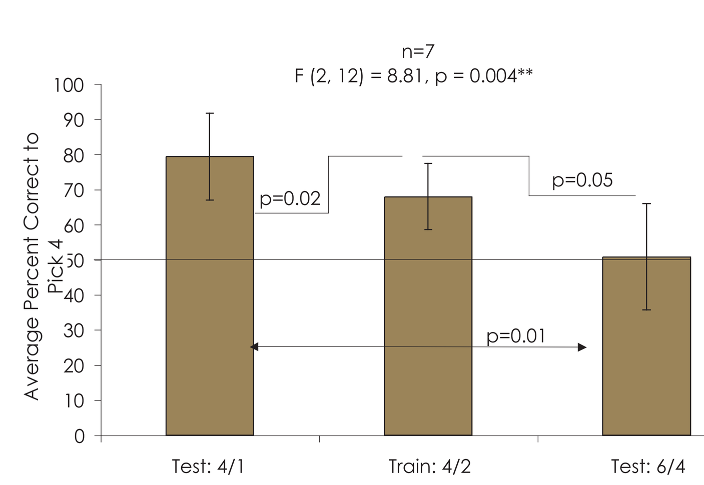
Monkeys have demonstrated a range of number discriminations, including greater than/less than judgments, ordinal relations (Brannon & Terrace, 1998), and simple additive and subtractive changes between small numbers of objects (Hauser, Carey and Hauser, 2000). The evidence is inconsistent, however, with regard to whether monkeys naturally have an object tracking system (or subitize) for small numbers of items, or whether relative judgments based on Weber's law seem the rule for most discriminations.

The present study used 3 different tasks to test whether tamarin monkeys show evidence of an object tracking system in which absolute values of small quantities are discriminated. The ratio between comparison amounts was kept at 2/1 for all training conditions, but the amounts themselves varied from small (2) to large (12) across the tasks.

Visual Task: 4 vs. 2 Matrices



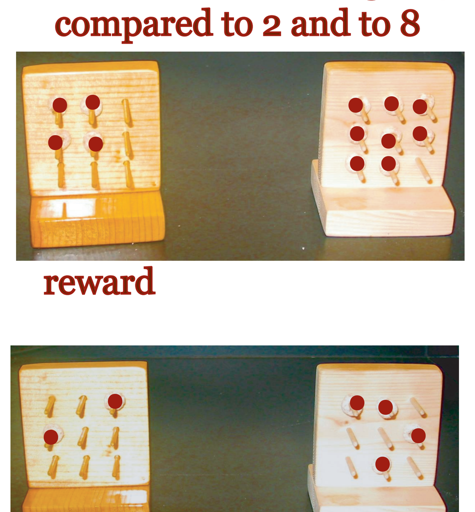
Each of 7 tamarins was trained to 80% criterion to select the matrix containing 4 cheerios. The response requirement was to pull a cheerio off the matrix, so it was a very clear and distinctive response. Two 3X3 matrices were presented for each trial, one showing 2 and the other, 4. The pattern comprising 2 and 4 varied from trial to trial, and the correct choice (4) was counterbalanced to occur on the left and right sides equally. Incorrect choices were not rewarded (i.e., the monkey was prevented from removing the cheerio from the matrix). Subjects took between 2 and 23 sessions to acquire 80% correct on this discrimination.



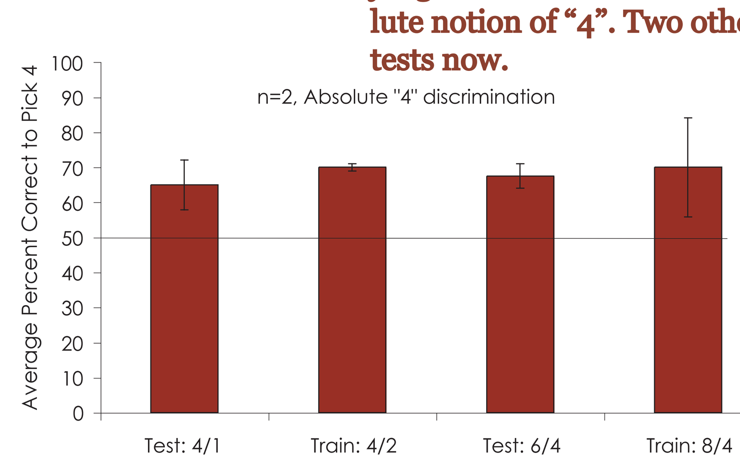
The tamarins chose 4 more often when it was compared with smaller numbers (i.e., with 1 or with 2) than when it was compared to a larger number (i.e., 6). Moreover, the preference to choose 4 seemed to obey a Weber function, in that larger ratio differences which occurred with smaller numbers produced more accurate discriminating than did smaller ratio differences when larger numbers were compared.

With more training in which the monkeys had to discriminate 4 from 2 and 4 from 8, the resulting test showed evidence of object-file tracking, in that the accuracy to pick 4 was consistent and no longer effected by the ratio comparison. However, only 2 monkeys acquired this discrimination thus far, in more than 100 sessions of training. Thus the more natural and automatic numeric judgment was based on analog magnitude, not an absolute notion of "4". Two other subjects are undergoing tests now.

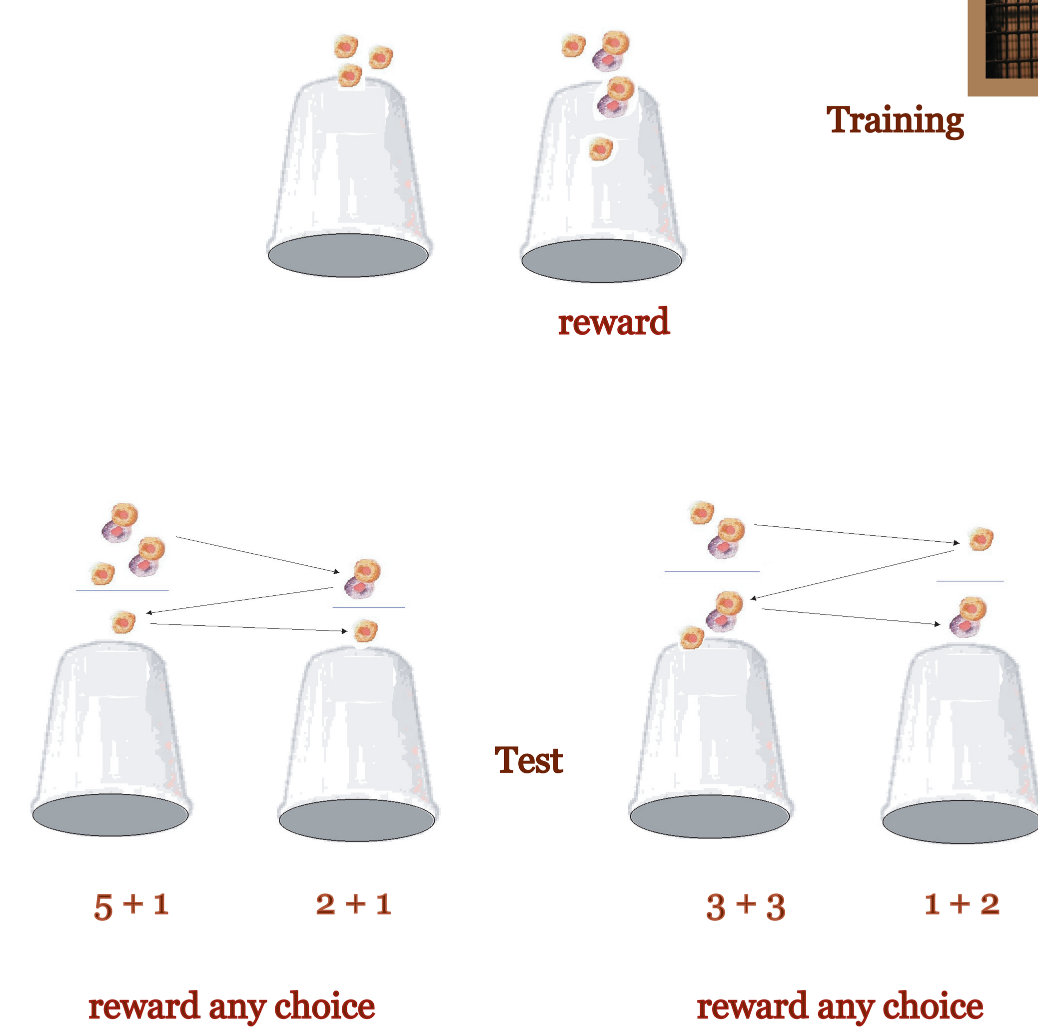
with further training of 4 compared to 2 and to 8



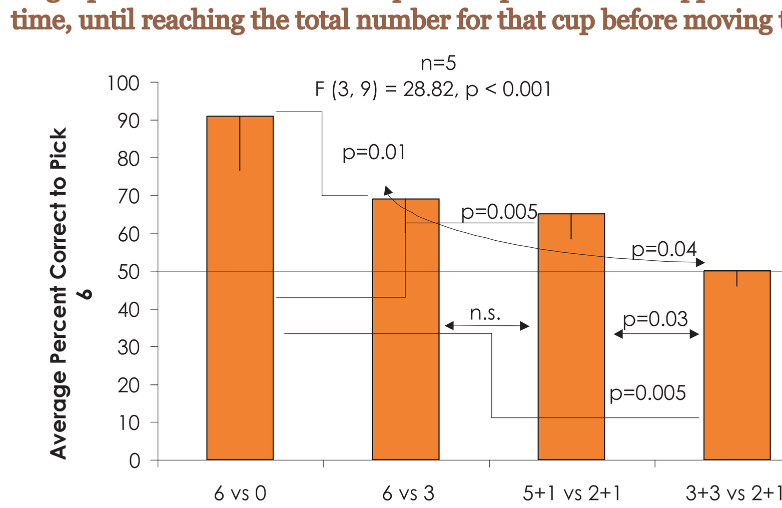
2 subjects reached criterion after > 100 sessions



Sequential Task: 6 vs. 3 in Cups



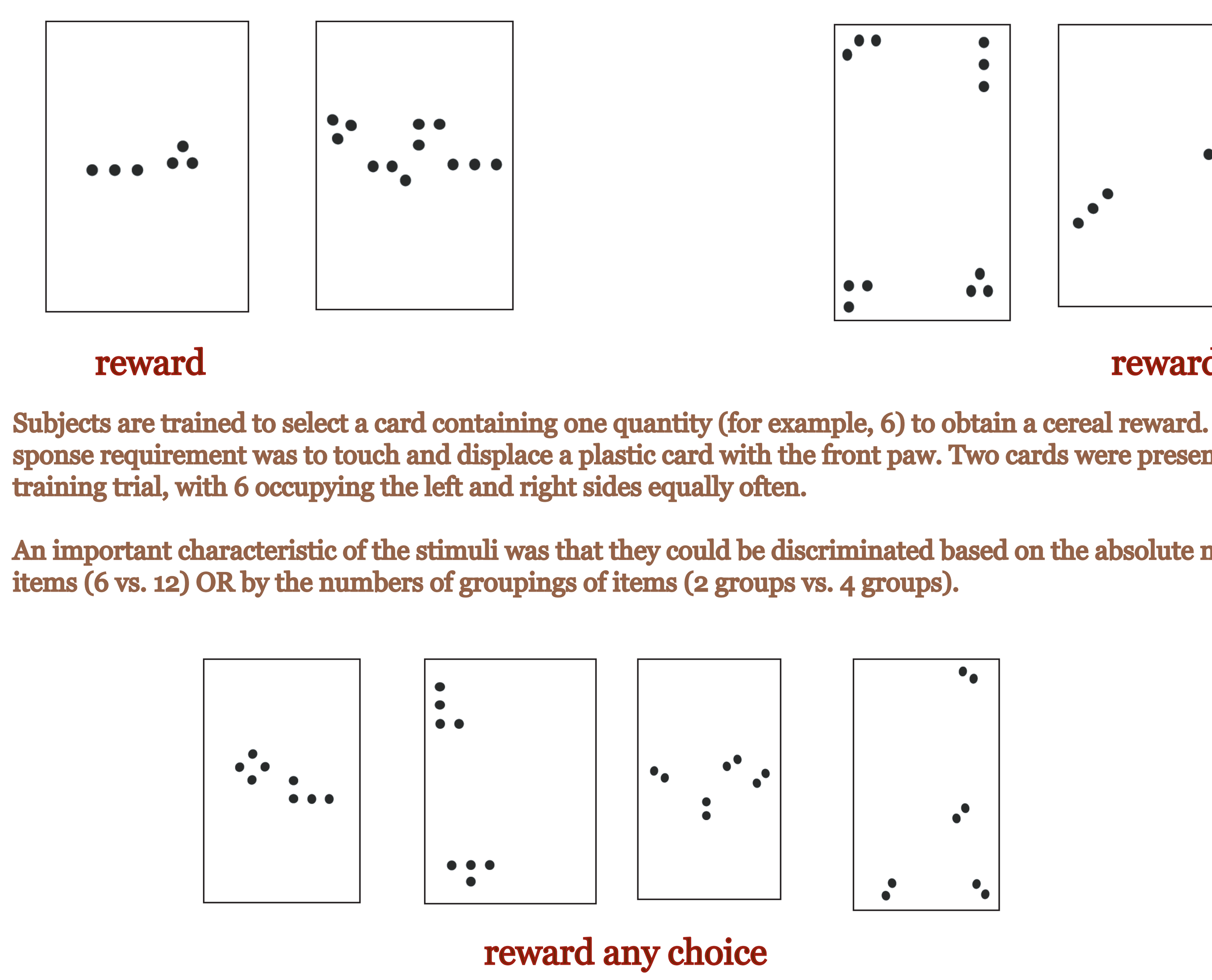
Each of 5 subjects were trained to 75% criterion to select 6 pieces of cheerios dropped in an inverted opaque cup, as compared to 3 pieces of cheerios in another opaque cup. The response requirement was for the subject to tip over the cup using his/her paw and remove one cheerio from the contents revealed by the tipping. The rewarded amount of 6 was presented equally often on both the left and right sides. Incorrect tipping was not rewarded. The subjects could not see the amounts contained in the cups, but could judge quantities by watching the experimenter drop single pieces of cereal in each cup. The experimenter dropped cereal in to one cup, one piece at a time, until reaching the total number for that cup before moving to the second cup.



It took subjects 4 – 32 sessions to learn the 6-3 discrimination. During the test, training trials were presented along with test trials in which each cup was visited 2 times, with multiple pieces of cereal dropped sequentially during each visit.

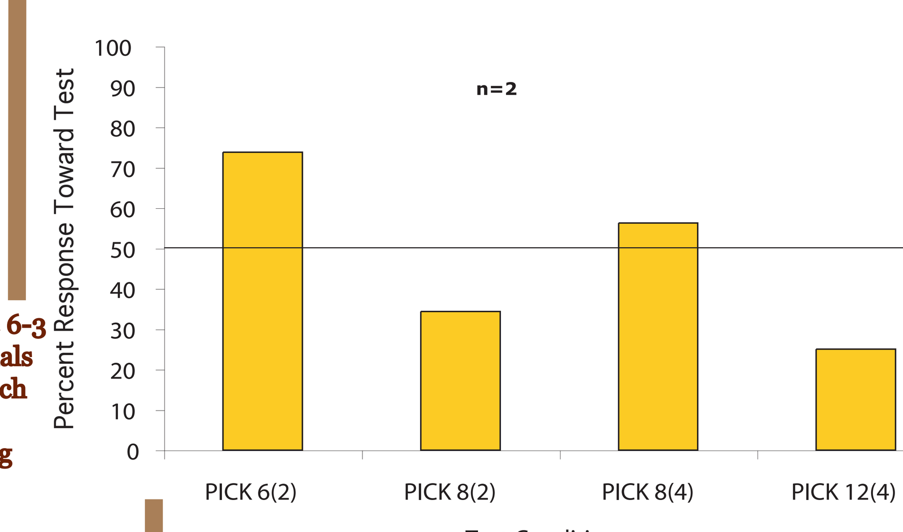
The results indicate that the tamarins discriminated the quantities based on the magnitude of the difference of the largest amounts observed through the sequential task. This is evident in the summed trials in which 5+1 was selected (as was 6) compared to smaller values. The sum 3 + 3 was not discriminated as a larger quantity than the other small amounts (1+2). The natural tendency was to discriminate based on analog magnitude, and items were not added across visits in the assessment of quantity.

Grouping Task: 6 (2 groups) vs. 12 (4 groups)



Subjects are trained to select a card containing one quantity (for example, 6) to obtain a cereal reward. The response requirement was to touch and displace a plastic card with the front paw. Two cards were presented on each training trial, with 6 occupying the left and right sides equally often.

An important characteristic of the stimuli was that they could be discriminated based on the absolute number of items (6 vs. 12) OR by the numbers of groupings of items (2 groups vs. 4 groups).



Once subjects reached 80% criterion, they were tested with various combinations of the training cards and cards containing the absolute value 8, grouped in 2 groups (to look more like the 6 cards in terms of grouping) and in groups of 4 (to look more like the 12 cards in terms of grouping).

Two subjects have completed training and testing thus far, and the results indicate that
a) the tamarins are discriminating based on the number of elements on the cards and
b) the groupings of elements are not exerting an influence on the discrimination.

Conclusion

In three different tasks involving visual simultaneous judgments, sequential judgments, and grouped or individual element judgments, tamarins demonstrate use of an analog magnitude assessment of quantity. When seeking a small number of items to choose to obtain reward, their discriminations are more accurate if the ratio between the two sets of items is 2:1 or greater, which often happens with smaller numbers of items. In all comparisons, monkeys' judgments suggest a Weber function, with smaller ratios generated by larger numbers leading to performance decline. Two interesting findings also emerged:
1) with intensive remedial training, monkeys could show absolute object-file discrimination of the number "4",but this certainly did not emerge easily or naturally, and
2) monkeys tend to see quantities of items as the total of individual elements, and ignore any grouping of items within the set. This latter finding is consistent with monkeys' tendencies to attend more to local than to global features in objects, a tendency also present in young children and people with autism.