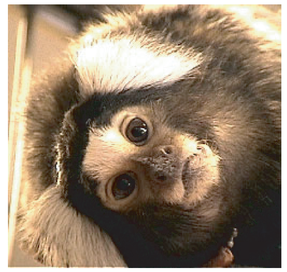
Quantity discrimination in two callitrichid primate species

Jeffrey R. Stevens and Marc D. Hauser

Primate Cognitive Neuroscience Lab
Dept. of Psychology, Harvard University

Email: jstevens@wjh.harvard.edu
WWW: http://wjh.harvard.edu/~jstevens



Introduction

Weber's law states that the ease of detecting small differences between stimuli is proportional to their magnitudes. For instance, discriminating the weight of one from two marbles in a bag is much easier than discriminating eleven from twelve marbles, even though the difference between the two is the same in both cases. Work on non-human animals suggest that their quantitative abilities follow Weber's law as an approximate method of tracking large amounts (Brannon and Terrace 1998, Emmerton 2001, Hauser et al. 2000). A more precise system (object-file system) may track small amounts, representing the numbers 1-3 (Hauser et al. 2000).

Here we assess the quantitative abilities of cotton-top tamarins (*Saguinus oedipus*) and common marmosets (*Callithrix jacchus*) by varying differences in reward amounts (numerical distance) for different amounts of reward (magnitude). The goal of this project is to address three questions:

1. Do tamarins and marmosets conform to Weber's law?
2. Do tamarins and marmosets use an object file system at small magnitudes?
3. Do tamarins and marmosets possess different quantification abilities?

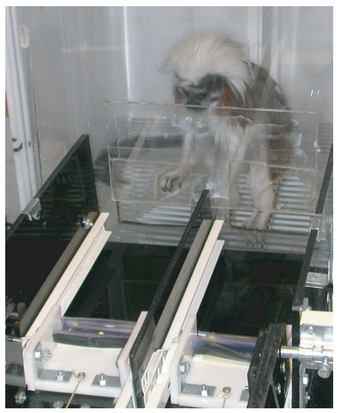


Figure 1: Experimental apparatus. Linear arrays of primate pellets were placed in food bins. Subjects could only draw one of the bins close enough to consume the pellets.

Methods

We allowed five tamarins and six marmosets to chose between two linear arrays of food pellets by pulling a food bin forward (Figure 1). We tested the subjects with three different numerical distances (1-3) and four magnitudes (1-4) using the following sets of reward pairs:

		Magnitude 1	2	3	4
Numerical Distance	1	(1,2)	(2,3)	(3,4)	(4,5)
	2	(1,3)	(2,4)	(3,5)	(4,6)
	3	(1,4)	(2,5)	(3,6)	(4,7)

Each subject experienced a daily session of the 12 randomly ordered test trials, plus four (0,1) trials to verify motivation and attention to the sets. The subjects experienced 12 replicates for each of the 12 numerical pairs.

Results

- Both species performed better at *large numerical distances* (ANOVA: $F_{2,18}$=15.3, p<0.01) and *small magnitudes* (ANOVA: $F_{3,27}$=10.5, p<0.01). There was no interaction between distance and magnitude (Figure 2).
- Both species performed better as the ratio between the large and small reward amounts increase (linear regression: R^2=0.40, $F_{1,97}$=65.2, p<0.01).
- There was a trend for marmosets to perform better than tamarins (ANOVA: $F_{1,9}$=3.8, p=0.08) and a trend for a species by ratio interaction (ANOVA: $F_{11,99}$=1.8, p=0.07; Figure 3).

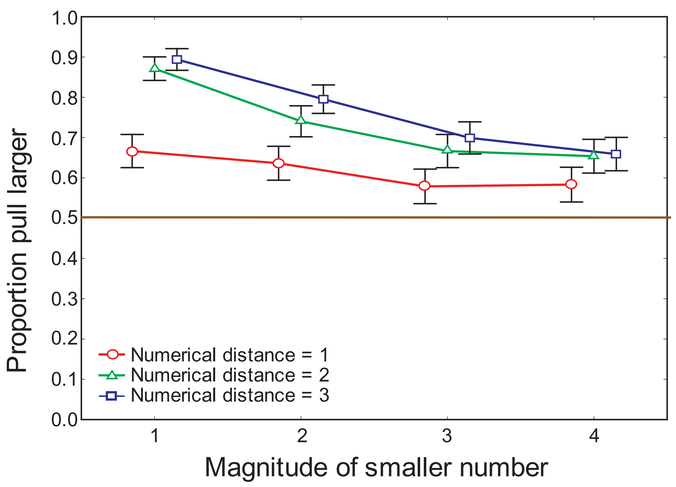


Figure 2: Numerical distance × magnitude interaction. Both species chose the larger reward more often at larger numerical distances and at smaller absolute magnitudes.

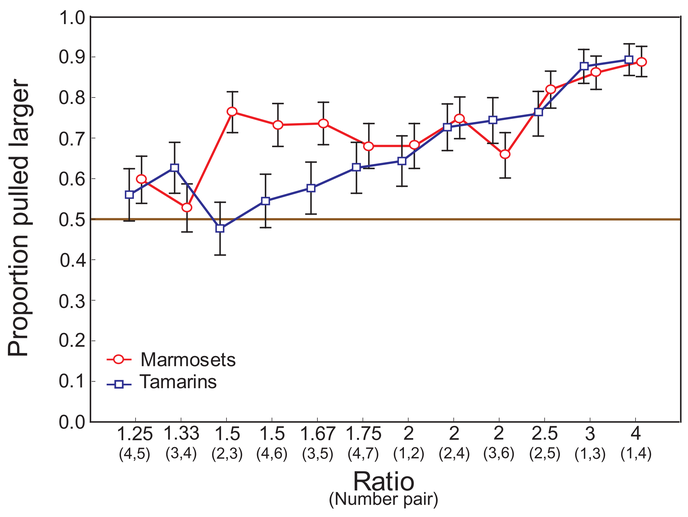


Figure 3: Ratio × species interaction. Marmosets tend to perform better than tamarins, and there is a trend for a species by ratio interaction. Marmosets discriminate at a ratio of 1.5, whereas tamarins do not discriminate until a ratio of 2.

Conclusions

- Both marmosets and tamarins appear to *conform to Weber's law* because they discriminate small differences in reward amounts better if the magnitude of the amounts is small rather than large.
- They *do not appear to use the object-file system* at small magnitudes. In this experiment, however, the monkeys can use other cues of quantity without representing number.
- *Marmosets tended to discriminate better* than tamarins overall, but the difference is fairly small. Interestingly, it appears as though marmosets may discriminate ratios of 1.5, whereas tamarins do not discriminate until ratios reach about 2.

References

Brannon, E.M. & Terrace, H.S. 1998. Ordering of the numerosities 1 to 9 by monkeys. *Science* 282:746-749.

Emmerton, J. 2001. Birds' judgments of number and quantity. In: Avian Visual Cognition (Cook RG, ed). [On-line]: www.pigeon.psy.tufts.edu/avc/emmerton/.

Hauser, M.D., Carey, S. & Hauser, L.B. 2000. Spontaneous number representation in semi-free-ranging rhesus monkeys. *Proceedings of the Royal Society of London, Series B* 267:829-833.

Acknowledgments

We thank Ian Goh, Sarah Heilbronner, Jeff Lau, and Amy Tao for assistance in data collection. We appreciate funding from an NIH National Research Service Award to JRS and an NSF-ROLE grant to MDH.