



Left Hand Specialization for Reaching in 5-Month-Old Rhesus Monkeys: Evidence From 2-D Motion Analysis

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Background and Aims

- In a landmark paper, MacNeilage and colleagues (1987) outlined the postural origins theory of primate handedness evolution:
 - Early primates were arboreal and their main diet was insects. A division of labor occurred between hands such that the left hand was used for reaching ("smash and grab" strategy) and the right hand was used for postural support.
 - As primates became more terrestrial and diets diversified, the right hand was freed from posture and became specialized for manipulation (e.g., cracking nuts and other food processing).
- Monkeys may represent an intermediate group that retained a left hand preference for reaching from their primate ancestors, while developing a right hand preference for fine motor tasks.
 - A recent meta-analysis found a left hand preference for reaching in rhesus monkeys (Papademetriou et al., 2005)
 - Although frequency data lend support to the postural origins theory, there are no studies examining the quality of left and right hand reaching movements in any nonhuman primate.
- We tested the hypothesis that there are qualitative differences between hands for reaching in rhesus monkey infants using two-dimensional (2-D) motion capture analyses.
 - We predicted that left hand reaches would be ballistic, reflecting a residual specialization from earlier primates.
 - Ballistic movements, once started, continue uncorrected to a target and are carried by their own momentum. In the current study, the term "ballistic" was defined as having greater reach smoothness, higher peak speeds, and faster average speeds.

Subjects

- Data were collected from 16 nursery-reared rhesus monkey infants (*Macaca mulatta*) housed at the Laboratory of Comparative Ethology in Poolesville, MD. Monkeys were approximately 5 months old at the time reach quality was assessed ($M=138 \pm 5$ days).
- Hand preferences were measured on a prior reaching task. Monkeys with 65% or greater left hand use were classified as left-preferent. All other monkeys were classified as non-left-preferent (Table 1).

Procedure (Fig. 1)

- Reaching Task
 - An experimenter held the monkey in a fixed position that allowed the arms to move freely during the session
 - A small grape slice was presented on a testing platform in line with the left or right hand on different trials
 - Monkeys were given three blocks of 5 trials and all trials were videotaped for later analysis
 - Kinematic Analysis
 - A single point on the radial wrist was digitized in a frame-by-frame analysis (30 fps) for successful reaches using the 2-D motion analysis program MaxTRAQ Lite+
 - Reach onset was the first frame of arm movement to food and reach offset was the first frame of contact
 - Data were extracted with custom programs in Matlab for (1) overall reach, (2) early reach, and (3) later reach
- | Peak speed (reaches divided at peak) | Average speed |
|--------------------------------------|-------------------------|
| Duration | Straightness Smoothness |



Figure 1. Infant monkey reaching for a grape slice with the right hand.

Dot denotes point added to the radial wrist to track the movements of the hand.

Results

- In total, 181 reaches were examined. The average number of digitized reaches from each monkey was 12 ± 4 .
- There were main effects of hand on overall reach smoothness, early reach peak speed, and later reach average speed (Table 2).
- There were no effects of hand preference or sex on any variable.

Table 2. Effects of Hand on Reach Quality in Rhesus Monkey Infants

Variable	P-Value	Means
Overall Reach Smoothness (No. MUs)	0.010	Left=1.49 Right=1.93
Early Reach Peak Speed (mm/s)	0.036	Left=525 Right=428
Later Reach Average Speed (mm/s)	0.048	Left=274 Right=224

Data Analysis

- Linear mixed-effects models in R (Bates & Maechler, 2009) examined these factors on each dependent variable:
 - Hand (left or right hand)
 - Hand preference (preferred or non-preferred hand).
- Note: for non-left group, right hand was preferred hand*
- Sex (male or female)

Table 1. Distribution of Hand Preference Groups by Sex

	Left-Preferent	Non-Left-Preferent
Males	3	5
Females	4	4

Discussion

- As predicted, the left hand showed ballistic qualities: Smoother, higher early peak speed, faster later average speed.
- These data are the first systematic test of the postural origins theory as a function of kinematic differences in reach quality.
- Future work may expand on this technique to understand not only *how* but *why* the hands are used across the primate order.

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- Correspondence to: Eliza Nelson (elnelson@uncg.edu). References available upon request.