

# MEASUREMENT FORCES DURING MANIPULATION IN NON-HUMAN PRIMATES

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## INTRODUCTION

Dexterous manipulation of objects is most highly developed in primates and requires precise control of the forces applied to objects held between two or more digits. Scientific study of control of these digit forces has been limited by measurement difficulties. Most studies involve simple gripping and lifting of an object instrumented with load cells that require placement of the digits in specific locations to permit accurate force measurements (e.g., Flanagan et al. 1999, Brochier et al. 1999). Training monkeys to perform such a task requires considerable time and effort. We aimed to develop a method to record forces applied by the hand and digits during a behaviourally relevant task that requires precise control. Such a method should provide a very sensitive measure of hand motor coordination because skilled movements would result in low applied forces while clumsiness would be reflected in high force application, even when the object is successfully acquired.

## PROCEDURES

We modified the automated monkey movement assessment panel developed by Gash and colleagues (Gash et al. 1999) to permit measurement of forces applied by the digits and hand during complex food acquisition tasks. This device (Fig. 1) attaches to the monkey's cage and requires the monkey to place one hand (depending on which port is open) into a food acquisition chamber. There are three levels of difficulty

in the task as the monkey lifts food from a flat plate or threads a lifesaver (or other suitable food) over a straight or curved bar (Fig. 1B). We modified the original design (see Gash et al. 1999) to incorporate a 6 degree of freedom load cell (JR3, Inc. model 30E12A 25L) below the food acquisition chamber (Fig. 1A) that supported circular Plexiglas plates on which the food was placed (Fig. 1B). The plates are interchangeable and are rigidly attached to the load cell with a central screw. Thus, the system recorded forces and torques applied to the Plexiglas plate and the bar as the food was acquired.

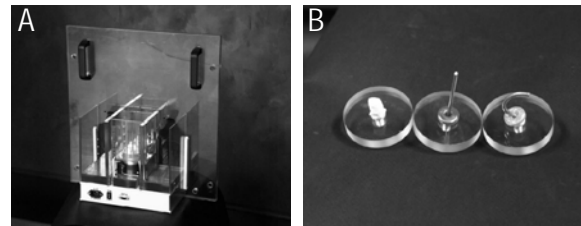


Figure 1: A – modified monkey movement assessment panel with JR3 load cell. B - 3 Plexiglas plates (one flat and two with embedded bars) with treats to be lifted.

Three adult rhesus monkeys performed the food acquisition tasks with both hands. During early testing we found that the monkeys were quickly satiated by the lifesavers and were not highly motivated to perform despite 24 hours of food deprivation before the experiment. Thus, we used carrot chips (a preferred food of these monkeys) prepared using a punch device that created chips from whole carrots that were of the same thickness and diameter with equal


sized central holes. Forces recorded while acquiring the carrot chips were similar to those recorded from lifesavers. The monkeys attempted to perform the food acquisition six times for each of the three levels of difficulty and with each hand for a total of 36 trials. They were allowed up to one minute to acquire the food on each attempt. Order of performing with the left and right hand and the different levels of difficulty was varied on different testing days for each monkey.

Forces and torques from the load cell were recorded at 100 samples/s (16 bits resolution). Duration of force application, peak forces and number of force peaks exerted in each of the six directions (+/- X – left/right, Y – forward/backward, Z – up/down) were recorded along with success (food acquired or not) on each trial. These data were used to assess progress of learning the task and quality of performance by the left and right hands.

## RESULTS & DISCUSSION

During initial attempts the monkeys were usually successful when acquiring the food from the flat surface with low forces (1 N or less) applied for less than 1 s. They were also usually successful in the straight bar task, but much higher forces (over 5 N) were often applied for several seconds with multiple force peaks. With additional training the peak forces were typically less than 5 N applied for 2 s or less with fewer force peaks. In the curved bar task the monkeys were usually unsuccessful on initial attempts on the first training day and applied very large forces (up to 20 N) with many force peaks. Within a few sessions these forces decreased to about 5 N or less and were applied for only 1-3 s. Fig. 2B shows force patterns recorded from a monkey who was experienced with the task but had not performed it for several months. She was unsuccessful in acquiring the food with the right hand on all attempts with peak

forces of about 4 N (e.g., Fig. 2B). With her left hand she was always successful within a few seconds and applied forces lower than 4 N (fig. 2A). Similar results were obtained from other monkeys.

In conclusion, the task appears quite sensitive to motor skill and hand preference in monkeys. Clearly, the force records provide a highly sensitive measure of hand coordination during food acquisition. Such measures could be used to examine cerebral dominance of motor skill and the effects of brain trauma on hand/digit coordination. 

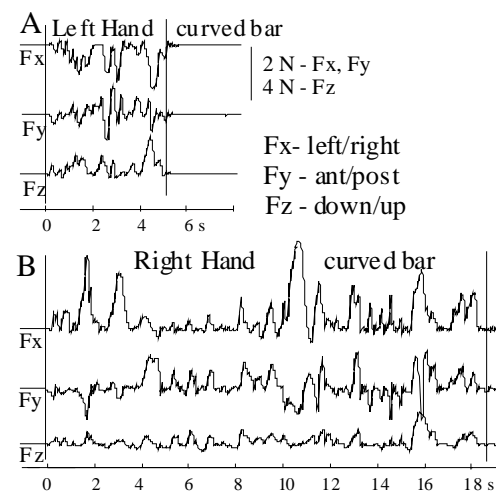


Fig. 2: Forces exerted while threading a lifesaver over the curved bar.

## References

- Brochier, T. et al. (1999). *Exp Brain Res.* **128**(1-2): 31-40.  
 Flanagan, J.R. et al. (1999). *J. Neurophys.* **81**(4): 1706-17.  
 Gash, D. M. et al. (1999). “ *J. Neurosci. Meth.* **89**(2): 111-7.

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