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BRIEF REPORT

Measuring Physical Traits of Primates Remotely: The Use of Parallel Lasers

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Physical traits, such as body size, and processes like growth can be used as indices of primate health and can add to our understanding of life history and behavior. Accurately measuring physical traits in the wild can be challenging because capture is difficult, disrupts animals, and may cause injury. To measure physical traits of arboreal primates remotely, we adapted a parallel laser technique that has been used with terrestrial and marine mammals. Two parallel lasers separated by a known distance (4 cm) and mounted onto a digital camera are projected onto an animal. When a photograph is taken, the laser projections on the target provide a scale bar. We validated the technique for measuring the physical traits of identifiable red colobus monkeys (*Procolobus rufomitratus*) in Kibale National Park, Uganda. First, we photographed the tails of monkeys with laser projections and compared these with measurements previously obtained when the animals were captured. Second, we manually measured the distance between two markers placed on tree branches at similar heights to those used by monkeys, and compared them with the measurements obtained through digital photographs of the markers with parallel laser projections. The mean tail length of the monkeys via manual measurements was 63.3 ± 4.4 cm, and via remote measurements was 63.0 ± 4.1 cm. The mean distance between the markers on tree branches via manual measurements was 13.8 ± 3.59 cm, and via remote measurements was 13.9 ± 3.58 cm. The mean error using parallel lasers was 1.7% in both cases. Although the needed precision will depend on the question asked, our results suggest that sufficiently precise measurements of physical traits or substrates of arboreal primates can be obtained remotely using parallel lasers. Am. J. Primatol. 70:1–5, 2008.

Key words: remote measurements; laser metrics; photogrammetry; morphometrics; morphology; field measurements

INTRODUCTION

Accurate measurements of inter and intraspecific phenotypic variation are critical for understanding the key aspects of life history and behavioral ecology. For example, variation in growth rates represents a potentially significant source of intraspecific variance in fitness, such as age at first reproduction and fecundity [Altmann & Alberts, 2005]. Differences in body size and the size of individual features (swellings, tail length, head breadth, limb length, etc.) may indicate mate quality and be an important factor in sexual selection, thus influencing reproductive success. For example, female squirrel monkeys (*Saimiri oerstedi*) preferentially chose to mate with males that attain a larger body size during the breeding season [Boinski, 1987], and the size of sexual swellings of female baboons (*Papio anubis*) and chimpanzees (*Pan troglodytes*) appear to be an honest signal of reproductive value [Domb & Pagel, 2001; Emery and Whitten, 2003].

Remotely projected parallel lasers have been used to measure the physical traits of marine and terrestrial animals [Bergeron, 2007; Durban & Parsons, 2006]. The method is based on the principle that parallel lasers project light that is equidistant regardless of the distance from the origin. Two

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parallel lasers separated by a known distance are mounted on a digital camera and the beams of the lasers are projected onto the subject. A digital photograph is taken and the laser projections on the image provide a scale bar that can be used to measure the size of physical traits in the image. Although the remote measurement of physical traits of primates is not new [e.g. Breuer et al., 2007; Caillaud et al., 2008; Domb & Pagel, 2001; Emery & Whitten, 2003] to our knowledge the parallel laser technique has not previously been applied to primates.

Here, we describe validation of the parallel laser method and its application in measuring traits in wild, arboreal primates. Validation of the method took place in two ways. First, we measured the tails of identifiable red colobus monkeys (*Procolobus rufomitratus*) using digital photographs taken with laser projections; these measures were then compared with direct measures of tail length of the same anesthetized, immobilized monkeys. Second, we manually measured the distance between two markers placed on tree branches that were at similar heights to those used by monkeys, and compared them with the measurements obtained through digital photographs with parallel laser projections.

METHODS

Laser Apparatus and Technique

We adapted our technique from the method described by Bergeron [2007, personal communication]. Like Bergeron [2007], we designed an L-shaped aluminum frame to hold a camera and two laser pointers, with the lasers separated by a known distance of 4 cm (Fig. 1a). We used green lasers (Module AGLM2, Apinex, Montreal) as they are more visible in the canopy than standard red lasers. The lasers are standard and commercially available similar to those used in classroom situations. The lasers were fixed into two aluminum holders that were adjustable with small set screws. They were adjustable as we followed Bergeron's design and aluminum can expand or contract with temperature. Slightly turning the screws with a hex key allowed fine-level adjustments to ensure the two lasers were parallel before and after each photo session. To power the laser projections, we attached a simple switch encased in plastic that held two AAA batteries. Any camera can be attached to the apparatus using a simple bolt to the tripod attachment; we used a digital Canon Rebel XT/18–55 mm with a Canon EF 75–300 mm lens.

To ensure parallel orientation of the lasers before their use on animals, the laser beams were projected and photographed perpendicular to the ground (i.e. vertical alignment or one on top of the other) onto on a flat surface (i.e. side of a building, or on the base of a tree), with the distance between the laser projections manually measured at intervals up to 20 m. The positions of the lasers were finely adjusted until the laser beams were 4 cm when measured at any distance of 0–20 m.

The parallel lasers were projected onto the animal horizontally (0°) or vertically (90°) depending on the trait of interest. Because the distance between the lasers when vertical will vary with the angle to the monkey in the tree, we attached a clinometer to the laser apparatus. This allowed us to measure the angle (θ) between the lower laser beam while

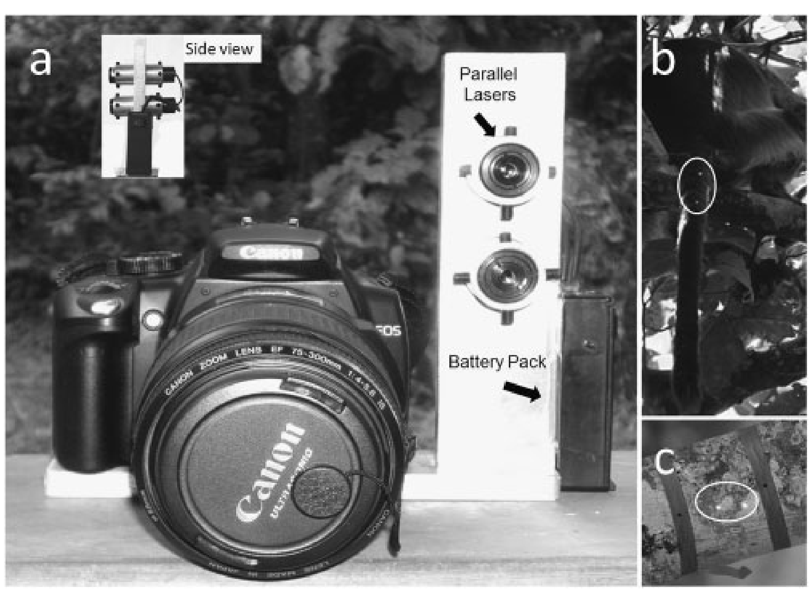

Fig. 1. Photographs of the apparatus used to perform the parallel laser technique, which includes an aluminum frame with two parallel lasers set at a known distance (4 cm). The frame is attached to a digital camera (**a**). The technique was validated using laser projections on red colobus tails (**b**), and laser projections on tree branches (**c**).

projected on the subject and the ground or horizontal. To confirm the parallel orientation of the lasers when vertical, a skilled tree climber measured the distance between the lasers when projected onto surfaces in a tree at different angles up to 60°.

Validation

As a part of a health assessment and ongoing study of behavior and conservation, C. A. C., T. L. G., J. E. L. and colleagues captured and collared red colobus monkeys in Kibale National Park, Uganda in June 2006. Kibale is a moist, mid-altitude evergreen forest located in western Uganda (0° 13′–0° 41′ N and 30° 19′–30° 32′ E). Details of the study site [Chapman et al., 2005], and red colobus immobilization [Goldberg et al., 2008] are outlined elsewhere. During immobilization, the tail lengths of 13 animals were measured by hand using a tape measure. The tail was measured from the first point at which it emerged from the torso (base) to the distal tip of the last caudal vertebrate.

We validated the parallel laser technique in two ways during February 2008. First, we projected the lasers onto the tails of monkeys whose tails were previously measured ($n = 13$), photographed them, and calculated tail length from the laser points in the photograph. We compared the results with tail lengths measured during capture (to the nearest mm); the same individuals were measured manually and photographically, using the same measurement criteria. The lasers were projected along the long axis of the tail when hanging vertically (Fig. 1b), so we adjusted for projection angle (see Equation (2)).

Second, with the help of a skilled tree climber, we manually measured the distance (to the nearest mm) between two markers placed on tree branches ($n = 30$) at similar heights to those used by monkeys. These measurements were then compared with those obtained through digital photographs with horizontal parallel laser projections (Fig. 1c).

In both the horizontal and vertical laser placements, a digital photo was taken of the target with the laser projections from 10 to 20 m away using a Leica DISTO D3 Laser Distance Measuring Device (Leica Geosystems AG, Heerbrugg, Switzerland). The laser projected from the observer to the animal; the angle (θ) to the animal was not more than 45° above the observer. For this method to be accurate, the target must be perpendicular to either the laser beams if the sources are horizontal or the ground if the surfaces are vertical. Although it is difficult to accurately determine this in the field, the use of a digital camera allows for multiple photos of the same subject to be taken quickly in sequence so that any photos where the target was not perpendicular by visual examination were immediately discarded. When it was not clear that the target was positioned perpendicular to either the lasers or the ground (e.g. if the tail was bent), the longest calculated length was considered the most accurate estimate, as any deviation from the perpendicular would always decrease the inferred length of a morphologic feature [Bergeron, 2007].

Photographs were downloaded to Adobe® Photoshop Version 5.02 (San Jose, CA) and the measure tool was used to measure either tail or tree branch length on the photograph. First, if multiple photographs were taken of the same animal or tree branch, we selected the best one for use based on the position of the lasers relative to the target, sharpness of the photo, and visibility of the target. Then, as the lasers were fixed at a known distance (4 cm), the laser projections in the horizontal position provided a scale bar that was used to measure the unknown distances using the following formula:

$$T_{\mathrm{a}} = (T_{\mathrm{r}} \times L_{\mathrm{a}})/L_{\mathrm{r}} \quad (1)$$

where T is the target measurement and L is the distance between the two lasers and the subscripts r and a represent the remote and actual hand measurements, respectively.

When the lasers were positioned vertically, the path of the top beam was longer than that of the lower beam, which altered the actual distance between the two laser projections on the target. To correct this, we used the following formula:

$$D_{\mathrm{x}} = \left[\left(\frac{D_{\mathrm{f}}}{\cos[90-\theta]}\right) \times \tan\theta\right] \quad (2)$$

where D is the distance between the two projected lasers, θ is the angle of the projected lower laser beam on the subject with the ground (the horizontal), and the subscripts x and f represent the unknown distance of the lasers when projected on the subject, and fixed distance (in our case, 4 cm) between the two laser beams, respectively (Fig. 2).

To compare the remote measurements of tail or branch lengths with the actual tail or branch lengths, we present descriptive statistics, a paired t-test and used linear regression forced through the origin; a slope of one indicates that the parallel laser technique is similar to hand measurements. A correlation analysis was used to test for bias in error owing to branch or tail size.

All of the research conducted during this study and that of the capture complied with animal care protocols and was approved by the Animal Care Committee at McGill University. We obtained permission from the Uganda Wildlife Authority and the Uganda National Council for Science and Technology; all research adhered to the laws of Uganda and Canada.

RESULTS

We compared the photographic estimates of the distance between two markers placed on branches

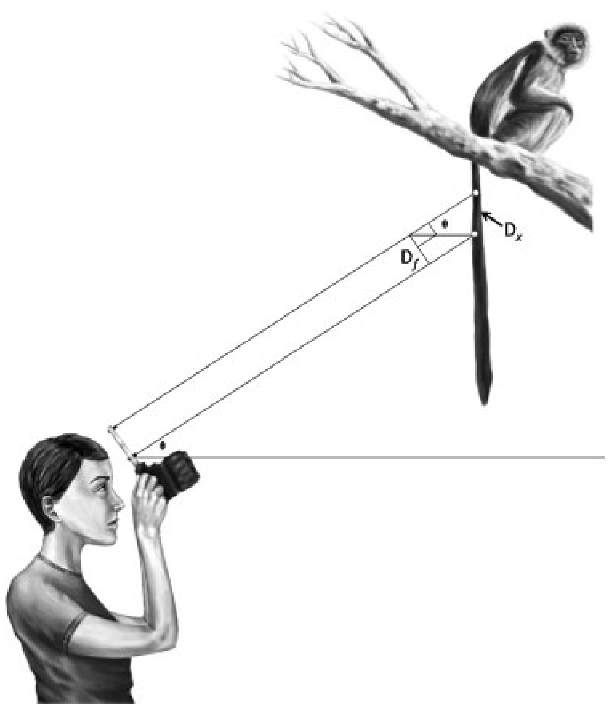

Fig. 2. A diagram demonstrating the use of parallel lasers in the field to measure the physical traits of arboreal primates, and the angles used to calculate the distance between the two projected lasers on the subject: θ = the angle between the lower laser and the horizontal, which is measured using a clinometer, D_f = fixed distance between the two lasers, D_x = distance between the two projected lasers. The diagram is not drawn to scale.

and tail lengths of red colobus monkeys, and manual measurements. The mean tail length of the monkeys using manual measurements was 63.3±4.4 cm (range: 56.9–69.1), and using the parallel laser projection measurements was 63.0±4.1 cm (range: 56.4–72.5). The mean error was 1.1±1.02 cm (range: 0.09–3.4 cm); the average error was 1.7%, and the largest error in a single measurement was 5.0%.

The mean distance between the markers on tree branches using manual measurements was 13.8±3.59 cm (range: 8.5–22.2), and using the parallel laser projection measurements was 13.9±3.58 cm (range: 8.5–22.2). The mean error was 0.24±0.25 cm (range: 0.01–0.87 cm); the average error was 1.7% of the mean length, and the largest error in a single measurement was 6.4%. The distance between markers on tree branches, or tail length was not correlated with the percent error in measurement (markers: Pearson's $r = -0.16$, $P = 0.42$; tails: Pearson's $r = 0.30$, $P = 0.33$). There was no difference between the same branches measured photographically or manually ($t = -0.64$, $P = 0.53$).

In both cases the slope of the regression line of the lengths of the hand measurements vs. the photographic measurements approached one (marker measurements: $b = 1.002$, SE = 0.005, $r^2 = 0.999$; tail measurements: $b = 1.006$, SE = 0.006, $r^2 = 0.999$), and a paired t-test revealed no differences ($t = -0.86$, $P = 0.40$), indicating that the laser measures were very similar to manual measurements.

DISCUSSION

The average error of our measurements using the parallel laser technique compared with manual measurements was just 1.7%, indicating that for many research questions this simple parallel laser technique will provide a sufficiently precise method of remotely and noninvasively measuring physical traits of arboreal primates. This technique has wide application as the measurement of physical traits has important implications for understanding primate life history patterns, sexual selection, measuring limb segments (arm/forearm/trunk, etc.), and other aspects of primate behavior and ecology. We envision that applications might include examining the size of sexual swellings, measuring the dimensions of food items, comparing sizes of competitors, defining growth rates and patterns, and measuring declines of health or body condition after an injury or period of food scarcity. Measuring substrate size might be another application.

Primatologists working in field conditions have used photogrammetry as a measurement tool in the past, but the calibration for this technique is difficult, and the measurement of photographs not only can be very time consuming, but also needs to be accurate with respect to distance [Breuer et al., 2007; Caillaud et al., 2008], which are a significant limitations in the case of arboreal primates. When lasers are projected horizontally, the parallel laser method does not require any correction factors, and when used vertically, a clinometer can be attached to accurately measure angle and correct for parallax. Our photos were taken within 20 m of the subjects, as we could not reliably identify individuals in the forest canopy at greater distances. However, in areas of better visibility, the laser beams used here will travel much further, and could be observed at distances of over 200 m in daylight. Our largest error in measurement was 6.4%. If repeated measurements of the same monkey or tree branches were taken on different days, it is possible this would have decreased measurement error.

There are some limitations to the method. First, the laser projections must be on a flat surface; if the target surface is curved or bumpy, the distance between the lasers may be altered with no reliable correction factor. Second, the projected lasers must be in the same plane as the target. Third, care must be taken to avoid the laser contacting the primate's eye. Although the lasers are classified as IIIA and there are no risks of injury associated with short exposure to human eyes, the effect on other primates is not known. Therefore, all care should be taken to minimize contact between the laser beam and the primate's eyes. Finally, to have a precise measurement, it is important that parallel orientation of the lasers be preserved. Like the apparatus designed by Bergeron [2007], the distance between our two lasers was adjustable with small screws. Although the small screws allowed adjustments, as the lasers were not fixed permanently at 4 cm, they could inadvertently move during fieldwork, thus great care was taken to ensure that the lasers were immobilized and regularly calibrated. During this study we did not see any reactions to the lasers by the monkeys; however, we are currently using this method to measure the thigh length of immature monkeys. On occasion, our subjects touch the laser projections when they are apparent on their body, or their supportive tree branch with an apparent attempt to groom themselves or chase the laser projections. Improvements to the apparatus we used could be made for future application: the apparatus could be constructed from a lighter metal or a hard plastic that did not expand and contract as much as the aluminum, the clinometer could be permanently fixed to the apparatus, and the lasers could be permanently fixed at a distance of 4 cm on a substrate that does not expand or contract with heat.

Our results indicate that precise measurements of physical traits and substrates of arboreal primates can be obtained remotely using parallel lasers. Using this simple method it is possible to take repeated measurements of individuals noninvasively, enhancing our ability to more fully understand primate ecology, behavior, growth, and habitat use.

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