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Brief Report

Who Needs a Forelimb Anyway? Locomotor, Postural and Manipulative Behavior in a One-Armed Gibbon

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Given the predominance of brachiation and other forms of suspension in gibbon locomotion, we compared the locomotor, postural, and manipulative behaviors of a captive, juvenile, one-armed gibbon to the behavioral profiles of his family members. We expected Kien Nahn, whose arm was amputated in response to an untreatable injury approximately 1 year before observations began, to avoid suspensory locomotion, to spend more time immobile, and to be less likely to exhibit postures involving forelimb suspension. Data were collected using scan sampling to record the behaviors and postures of Kien Nahn, his younger brother, and his parents. Additional postural and manipulative behaviors were recorded ad lib. Kien Nahn and his younger sibling had similar activity levels, and although differences in postural profiles existed, they were surprisingly few. Specifically, Kien Nahn spent significantly less time in motion and in non-suspensory forms of locomotion than his brother. When compared to his parents, Kien Nahn was found to be both active and in motion more often, but was less likely to exhibit the forelimb suspension posture. Despite the increased energetic demands associated with one-armed brachiation, Kien Nahn preferred suspensory locomotion to other forms of locomotion. Furthermore, he found unique solutions for foraging and locomoting, often making use of his feet and teeth, and he was generally the first to approach and manipulate enrichment objects. We found no evidence to suggest that Kien Nahn's injury has altered his activity levels. Although the one-armed gibbon displayed slightly different locomotor, postural, and manipulative behaviors than his family members, he seems to have adapted well to his injury. Zoo Biol 26:215–222, 2007. © 2007 Wiley-Liss, Inc.

Keywords: brachiation; suspensory locomotion; amputation

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INTRODUCTION

The purpose of this study is to assess the behavioral differences between a captive, juvenile white-cheeked gibbon (*Nomascus leucogenys*) whose right arm was amputated just above the elbow in response to an untreatable injury approximately 1 year before the initiation of observations, and his family members. Of particular interest is his locomotor and postural behavior. Most primates, including gibbons (family Hylobatidae), are arboreal [Nowak, 1999]. Gibbons, however, have developed a highly specialized form of suspensory locomotion (brachiation) to obtain fruit and leaves from the thin, terminal branches of trees, using their hanging weight to draw a desired branch closer and to exploit an underused food niche [Grand, 1972]. Gibbons spend approximately 50% of their time locomoting, 80% of which involves brachiation [Bertram, 2004].

Although brachiation is a two-armed motion, both captive and wild gibbons have been observed to use a single arm to traverse branches. Both forms of brachiation are structurally similar in limb and trunk movement, however one-armed brachiation is more energetically expensive and consequently, generally limited to situations in which gibbons are carrying food [Gibbons and Lockwood, 1982]. However, this modified form of brachiation may help an individual cope with injury, which is surprisingly common in gibbons. Schultz [1939, 1944] reported that 42% of gibbons sampled had healed fractures, 37% of which were brachiation-related, indicating that wild gibbons fracture their arms, yet survive into adulthood. The ability to locomote via one-armed brachiation would allow an injured gibbon to function in his natural environment with minimal adjustments to his lifestyle, although some deficit in locomotor and manipulative abilities would be likely.

The present study investigates the behavioral profile of four captive white-cheeked gibbons to examine the impact of the loss of an arm on a juvenile male gibbon. Despite the available information on one-armed brachiation in gibbons, the injury was expected to impact the activity and postural behavior of this individual and we expected that his behavioral profile would be markedly different from his family members. We predicted that he would be in motion less often, prefer other forms of locomotion to suspensory locomotion, and be more likely to exhibit postures that did not include a component of forelimb suspension.

MATERIALS AND METHODS

The subjects were four white-cheeked gibbons, *Nomascus leucogenys*, living at Lincoln Park Zoo in Chicago, Illinois. The gibbons comprised a single family with one adult female, Burma (17 years), one adult male, Caruso (16 years), and two offspring, brothers Kien Nahn (almost 5 years), and Sovann (18 months). The animals were housed in an indoor/outdoor exhibit. All were captive born and parent-raised except for Caruso who was hand-reared. On April 9, 2005 Kien Nahn sustained an injury that ultimately led to the amputation of his right arm just above the elbow. He was reunited with his family on May 4, 2005.

Scan sampling at 1-min intervals for 30-min blocks was used to observe all four animals [Altmann, 1974]. The posture and behavior of each individual was noted as described by the ethogram in Table 1. Motion was included as one of several postural categories and specific locomotor patterns were further broken down in the

TABLE 1. Ethogram for study

Postures	Sit (S)	Animal is stationary with buttock firmly planted on some surface
	Posture w/forelimb suspension (F)	Animal is stationary with at least one forelimb above the head and engaged with a substrate used for support or balance; animal may or may not be grounded
	Other posture (O)	Animal is stationary but not in the sit or forelimb suspension posture (i.e., standing, crouched)
	Motion (M)	Any continued postural movement by the animal
	Out of view (X)	Animal is not visible
Scan behaviors	Suspensory locomotion (SL)	Any movement by the animal involving forelimb suspension
	Other locomotion (OL)	Any movement by the animal not involving forelimb suspension
	Forage (F)	Animal searches for, moves or handles, or eats food or water
	Groom (G)	One animal runs its fingers or teeth through the fur of another or itself
	Inactive (I)	Animal sits, stand or lies immobile with eyes open not doing any other activity—this behavior includes social inactivity
	Play (P)	Moving objects or apparently "purposeless" and non-threatening movement that may involve another animal
	Swinging (S)	Hanging on substrate by arms and moving body in a rhythmic swaying motion or latched onto rope and moving the rope like a pendulum with no attempt to locomote
	Other (O)	Any behavior not listed above
	Out of view (X)	Animal is not visible
All occurrence behaviors	Throw food (TF)	Animal repeatedly throws and catches food with hand
	Hanging by feet (F)	Animal is suspended from substrate only by hind limbs
	Boost (B)	Kien uses stump to assist him with maneuvering

activity budget. For example, if an animal were brachiating, we scored the posture as "motion" and the activity as "suspensory locomotion." Additional postural and manipulative behaviors were recorded ad lib for all animals (Table 1). Data were collected in 15 sessions, on 11 days during April and May 2006 for a total of 24.5 hr.

To provide some basis for comparison of Kien Nahn's behavior before the injury, we used behavioral monitoring data collected regularly by keepers from November 2004–December 2006 [Atsalis et al., 2005], with data divided into pre- and post- injury periods. Although the ethogram for behavioral monitoring was not identical to that used here, the value of having data for at least a cursory comparison is substantial. Thus, we were able to qualitatively compare activity levels before and after the injury. Given our small sample size and differing ages and genders of subjects, we chose to present descriptive statistics and graphic interpretations of the data.

RESULTS

The gibbon behavioral time budgets are summarized in Figure 1, excluding inactivity, which comprised over 45% of the time. Kien Nahn was noticeably less inactive than his parents. There were no differences in the amount of time that Kien Nahn and his brother Sovann spent inactive, playing, swinging, or engaged in suspensory locomotion. However, Kien Nahn was observed in other locomotion less often than Sovann and more often than Caruso. Finally, Kien Nahn was observed to groom others more than Sovann and Caruso.

The gibbons' postural behavior is summarized in Figure 2. Kien Nahn spent less time in motion than Sovann, but more than Burma and Caruso. He was observed to be sitting more often than Sovann and Caruso.

Each gibbon's postural behavior when not in motion was analyzed to determine individual preferences for forelimb suspension, sitting, or other postures. The results are shown in Figure 3. Based on this analysis, Kien Nahn and Sovann spent similar amounts of their immobile time in forelimb suspend postures, but Kien Nahn spent less time in this posture compared to Burma and Caruso. Similarly, Kien Nahn and Sovann did not differ in the amount of their immobile time spent sitting, but Kien Nahn sat immobile more than his parents.

Behavioral monitoring data covering the period November 2004–December 2006 is presented in Figure 4. Although quantitative assessment is not possible given the differing methodologies, it is apparent that the injury did not greatly affect Kien Nahn's behavior.

Ad lib observations of manipulation indicated that although Kien Nahn did not differ from the other gibbons in amount of time spent foraging with enrichment items (browse balls), he was generally the first to approach and use the object, removing the majority of the food items before moving onto the next. On most occasions, Kien Nahn foraged with the browse ball by holding it with his foot and

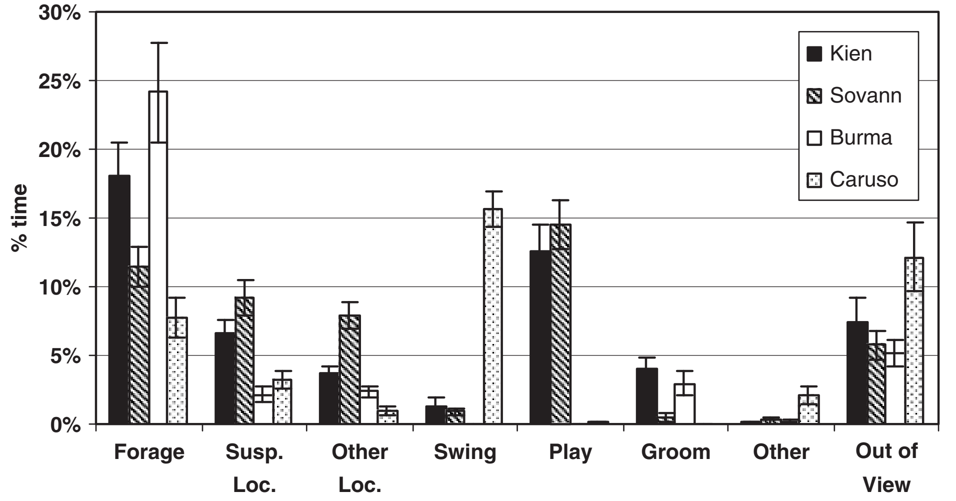

Fig. 1. Activity budgets for four gibbons, excluding % time inactive which accounts for >45% of observation time (mean ± SE).

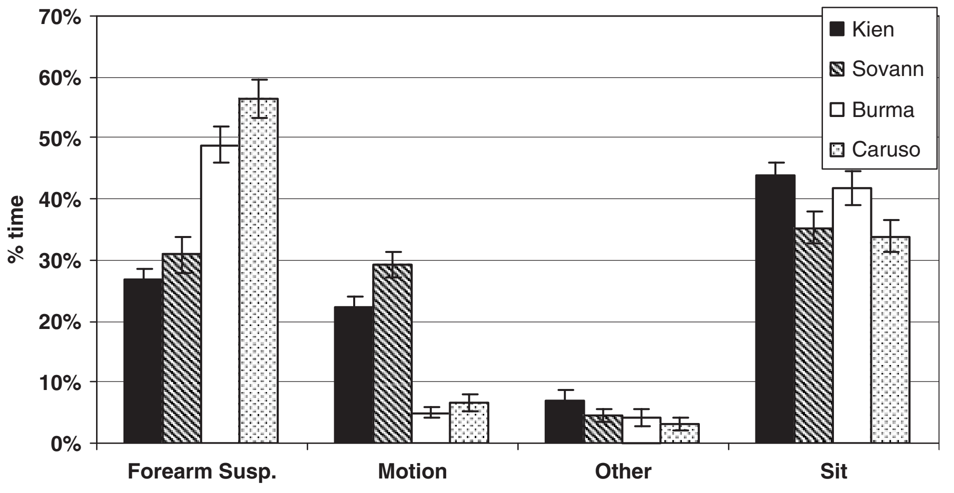

Fig. 2. Gibbon postural behavior (mean % time ± SE).

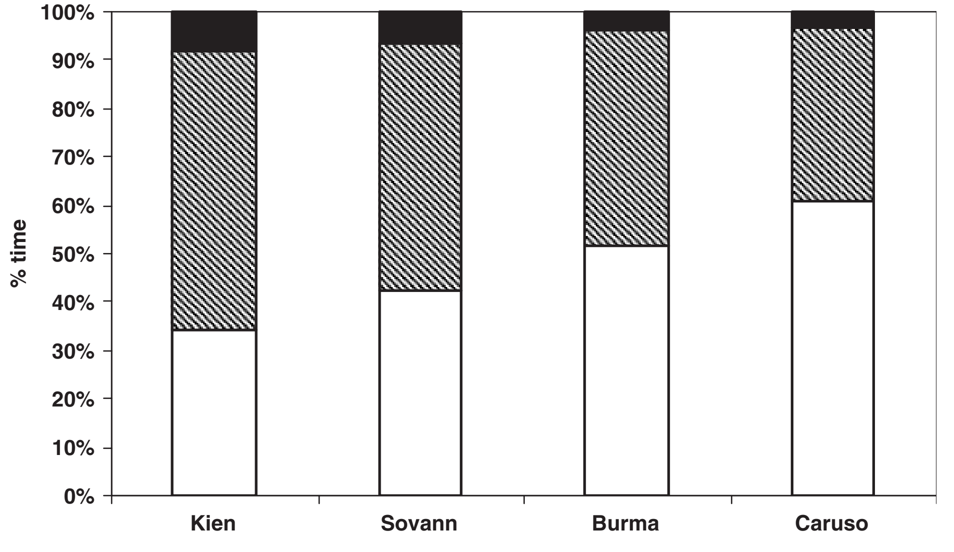

Fig. 3. Breakdown of postural behavior during immobile time for each gibbon, based on an average for each observation session. Open bars, forelimb suspend; hatched bars, sit; solid bars, other.

using his hand or teeth to remove its contents. Burma used one hand to carefully dig out food, and Caruso used two hands, one to hold the object and one to remove its contents. Sovann rarely removed the food from enrichment objects; rather he manipulated the empty browse balls.

Kien Nahn found unique solutions for problems that arose while locomoting and foraging, making use of his arm, stump, and feet. When locomoting, Kien Nahn would hold food in his foot, in his mouth, and on two occasions, under his stump. In one instance, he held a food item in one foot and hopped on the other foot to

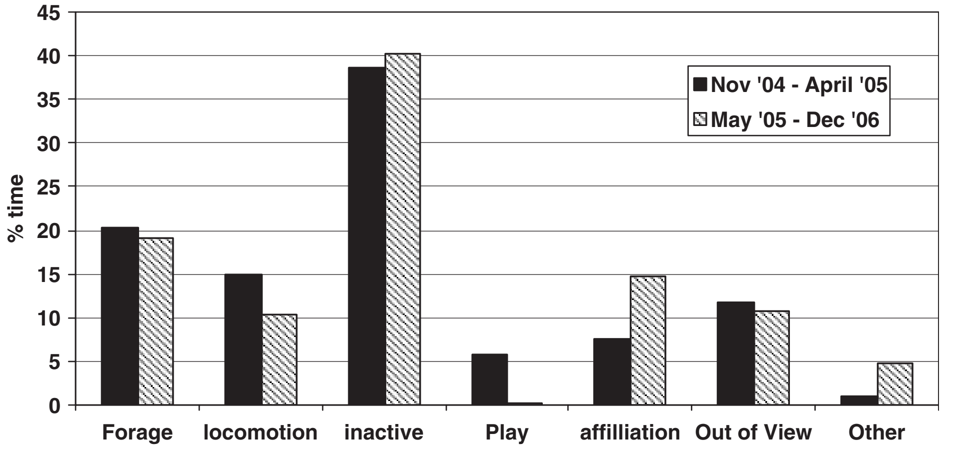

Fig. 4. Comparison of Kien Nahn's activity budget during/pre-post injury time periods, using behavioral monitoring data. Data are broken down based on the timing of the injury, which occurred in early April 2005.

traverse the floor of the enclosure. When substrates were available below the superstrate he was traveling on, Kien Nahn locomoted frequently by alternating weight from his single arm, to one foot, and back to his arm. In sections of the habitat where substrates were unavailable below him, Kien Nahn would travel via one-armed brachiation. Finally, Kien Nahn also engaged in the ''hang by feet'' behavior, and did so more often than Sovann.

DISCUSSION

This study aimed to understand the impact of Kien Nahn's injury on his behavior. Due to the composition of the group (two adults, one younger sibling), it is not possible to draw any definitive conclusions given that age and gender may also affect activity levels. Nevertheless, it is striking that Kien Nahn was, on average, less inactive than the other gibbons. Thus, we find no evidence to suggest that Kien Nahn's injury has reduced his activity levels.

Our results show that both Kien Nahn and Sovann preferred suspensory locomotion to other forms of locomotion. While in suspensory locomotion, Kien Nahn would travel via one-armed brachiation unless sufficient substrate existed below him, allowing for alternate hand-foot travel, which presumably conserves energy. Although one-armed and two-armed brachiation involve similar limb and trunk movement, the former is more energetically expensive [Gibbons and Lockwood, 1982]. Although gibbons generally use suspensory locomotion to travel [Byron and Covert, 2004], Burma traveled via some other form of locomotion more often. Because Burma was foraging or inactive for nearly 90% of her behavioral time budget, her use of other locomotion (namely bipedal locomotion) suggests that it was not especially energetically taxing nor physically challenging and thus, Kien Nahn could have easily adopted a non-suspensory form of locomotion. The fact that he prefers suspensory locomotion indicates that despite the increased energetic demands associated with one-armed brachiation, Kien Nahn has adapted well to his injury. The zoo environment may have contributed to this finding, as the energetic demands experienced by a wild gibbon are largely absent in the zoo.

Although immobile postural behavior was analyzed independent of time in motion, it is possible that Kien Nahn and Sovann's comparatively low levels of forelimb suspend postures may be attributed to their frequent bouts of motion. If their immobile postures were often interrupted by short periods of motion, they may not have had the time or the need to use an overhead branch for comfort and balance. It also should be noted that Sovann is much younger than Kien Nahn and still spends a large portion of time affiliating with or in contact with his mother, thus limiting his opportunities for forelimb suspend postures. Based on age and size, we might expect Kien Nahn to spend a comparable amount of time in forelimb suspend postures as his parents, but this was not the case. Perhaps Kien Nahn's lack of a limb disrupted his weight balance and ability to change his center of gravity, limiting him to more suspensory types of locomotion. Indeed, Kien Nahn's stump was generally extended horizontally, perhaps to accommodate his weight imbalance.

Byron and Covert [2004] studied captive white cheeked gibbon postural behavior and found that adults spent 44.8% of their time in forelimb suspend postures. Burma and Caruso spent over 44.8% of their time in postures that involved forelimb suspension, whereas Kien Nahn and Sovann spent less. In the wild, forelimb suspend postures may be adaptive to facilitate quick locomotion in case of a predator attack. Juvenile gibbons may be less aware of this potential threat as they are still dependent on their parents for protection and warning.

The ad lib observations showed that Kien Nahn used his feet substantially more than the other gibbons. He was the only gibbon to repeatedly use his feet to hold and manipulate objects. The observed behavioral changes are minor, and did not impact his activity levels or social interactions. Kien Nahn engaged in high levels of use of enrichment objects, allogrooming, and participation in play, suggesting that he has effectively adapted to his injury.

Kien Nahn's experiences as a one-armed gibbon cannot be generalized for all gibbons. His age at the time of his injury and the presence of his brother certainly influenced his behavior. As a young but largely independent juvenile, Kien Nahn was at the best possible age to recover from such a traumatic and potentially debilitating injury. Old enough to be socially competent, but young enough to still be to be flexible and adaptable, Kien Nahn seems to have made a full recovery both physically and socially.

CONCLUSIONS

1. We found little difference in activity levels between a one-armed juvenile gibbon and his younger sibling.
2. The one-armed gibbon used slightly different postural and manipulative behaviors than did his family, however he showed no obvious deficits as a result of the injury.

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