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Manipulation and Tool Use in captive Yellow-Breasted Capuchin Monkeys (*Cebus xanthosternos*)

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In this short report we test, at an individual level, the prediction that tool use abilities and manipulative tendencies should be correlated, derived from hypotheses in the literature which connect them at a cognitive and evolutionary level. We recorded manipulative events of six captive yellow-breasted capuchin monkeys and later compared these results to their performance in a tool using task. The frequency of time each animal was involved with manipulative events was not correlated to the number of tool-using events displayed by them, even when we analyzed the males only (the most frequent manipulators). This result goes against the idea that tool use in *Cebus* is a product of both manipulative propensities and tendency to use objects. Most likely, the evolution of tool use in *Cebus* was due to a complex combination of factors, belonging to various behavioral systems, not only to the foraging one.

In spite of the phylogenetic distance to the great apes and men, capuchin monkeys are capable of extremely versatile tool use, both in captivity (reviewed in Fragaszy, Visalberghi, & Fedigan, 2004; Tomasello & Call, 1997) and in the wild (Fragaszy, Izar, Visalberghi, Ottoni, & Gomes de Oliveira, 2004; Moura & Lee, 2004; Ottoni & Mannu, 2001). Capuchins have recently been shown to exhibit further behaviors formerly restricted to great apes; researchers found that they use anvil and stone pounding tools in the wild (Fragaszy, Izar, Visalberghi, Ottoni, & Gomes de Oliveira, 2004), besides showing, in at least one site, frequent, and quite diverse tool use, including the use of tool sets, that is, more than one tool for a single task (Mannu & Ottoni, 2006; Moura & Lee, 2004).

Additionally, capuchins deal with the environment in a vigorous and persistent way, harshly exploiting any potential food resource, so much so that this behavior was labeled as "destructive foraging" (Terborgh, 1983). Such aspect of their behavior allows them to exploit a variety of food resources not accessible to other sympatric monkey species, including the extraction of embedded foods.

Three decades ago, Parker and Gibson (1977) somewhat linked these two aspects of their ecology (tool use and extractive foraging), and argued that intelligent tool-use and complex object manipulation arose independently in the ancestors of *Cebus* monkeys, and the ape-man clade as a consequence of the evolution of tertiary sensorimotor intelligence (*sensu* Piaget) as an adaptation for extractive foraging on a number of seasonally available embedded foods.

Although their hypothesis is proposed at the evolutionary level, the authors suggest some lines of enquiry in terms of comparative studies in order to test predictions from it. Of particular interest to us here, they stress the need

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to investigate individual variation in complex object manipulation schemata. Admittedly, their main concern is with variety (of schemata, of contexts, and of objects employed), which would reflect differences in tertiary sensorimotor intelligence. Nonetheless, if there is such variation, one could expect that this be reflected in other aspects of complex object manipulation and tool use as well, such as the time devoted to it.

In a different view that bears some relation to the above, it has been suggested more generally that “tool use in captive capuchins arises from their strong tendency to interact with objects over an extended time in a variety of ways” (Visalberghi, 1993, p. 128), namely from their manipulative propensities (note, however, that Visalberghi strongly disagrees with the underlying cognitive basis of capuchin tool use suggested by Parker and Gibson). More recently, this view was reinforced and somewhat expanded in a comprehensive review of the genus (Fragaszy, Visalberghi, & Fedigan, 2004), in which the authors suggest that their “great variety of explorative and manipulative behaviors” (p. 177), as well as their persistent and interested manipulation of them is one of the two characteristics which are relevant to tool use.

However, these ideas (or parts of them) are not of universal acceptance, and some researchers have shown results which disagree with various aspects of the reasoning. King (1986), for example, has shown that there are various primate species which do not exhibit (or rarely do so) complex object manipulation, yet they do show extractive foraging. She argues that extractive foraging is linked neither to special cognitive skills nor to the evolution of intelligence.

Furthermore, Fragaszy and Adams-Curtis (1991) did not find an ontogenetic link between manipulation and tool use, thus rejecting a prediction from Parker and Gibson’s (1977) theory that both activities were indicative of cognitive abilities of the 5th and 6th stages of a sensorimotor intelligence scheme based on Piaget’s. However, the authors do propose a correlation between the generative aspects of manipulation and the tool using abilities of different species, regardless of underlying cognitive capacities. They supported such a view with a comparison between age classes, but did not extend their reasoning to the evolutionary origin of tool-using behavior. Lastly, Jalles-Filho (1995) found evidence that manipulative tendencies were not correlated to propensity to use tools in an experiment with captive *Cebus apella*.

Here we report the results of an experiment designed to test the hypothesis, expanded from Parker and Gibson’s central thesis and some hypotheses in the literature, that tool use in captive *C. xanthosternos* monkeys is a function of their overall manipulative tendencies. The particular prediction that will be tested here is that more manipulative animals should also be more frequent tool users. The underlying principle of this prediction is that both ‘tool use’ and ‘manipulative behaviors’ share a common basis. Note, however, that we treat this common basis as a black box and do not address its nature, if an expression of tertiary sensorimotor intelligence, of propensities to interact with objects, or any other factor.

Cebus xanthosternos is an endangered capuchin monkey species inhabiting some areas in a restricted region on Northeastern Brazil (Rylands, Kierulff, & Mittermeier, 2005), whose behavior and ecology are just starting to be known. As far as we know, no study on tool use has been conducted on this species, either in captivity or in the wild.

Method

Experimental subjects

Six (2 adult and 2 juvenile males, 1 adult and 1 juvenile female) captive yellow-breasted capuchin monkeys (*C. xanthosternos*) living in a single group. The group inhabited a small island (approximately 10 x 7m) within an artificial lake in a zoo setting (Parque Ecológico Municipal, Americana city, São Paulo state, Brazil). All individuals were wild born and reared in captivity. They came from a capture from IBAMA (Brazilian Institute for the Environment and Renewable Natural Resources). They had used tools before in previous experiments (unpublished data).

Observational phase

In this stage, the manipulative activities of the individuals were recorded through instantaneous scan sampling (Altmann, 1974). The manipulative events were registered at 1-minute intervals in sessions lasting 45 minutes each, along 19 days, with 8 sessions per day. The order of sampling the animals in the intervals was fixed for each day and varied between days in a pseudo-random fashion. Observations were conducted from 7:00 to 17:30. A total of 6120 data points were obtained due to the loss of some data points.

A behavioral category 'manipulative event' was operationally defined as any behavior that involved modification of an external object through two or more coordinated motor activities. For example, digging the soil as a necessary step to obtain a buried food item (e.g. grass roots) was classified as a manipulative event, but picking a food piece directly from the ground was not. In our category we included object-object manipulation instances, but only if the event could *not* be categorized as tool use (for example, if the animal hit a hard fruit against other substrates this was considered a manipulative event). Tool use, for the purposes of our work, was defined as any action of a deployed external object upon other object(s) that resulted in a modified state of the later, which was then subsequently used by the animal, e.g. hitting a stone on a nut and eating the edible parts inside it (similar to Beck, 1980). In terms of Parker and Gibson's (1977) scheme, our 'manipulative event' class encompasses the following categories: simple object manipulation (e.g. opening a closed leaf to reach a larvae inside it), object substrate manipulation (e.g. rubbing a twig on a hard surface) and complex object manipulation, but excluding tool use (e.g. banging two branches against each other).

Our behavioral category 'manipulative event' was defined in order to include those motor patterns sharing formal characteristics with the ones involved in tool use, which by necessity involves at least two manipulative events. Stereotyped or automatically-performed behaviors (auto grooming for example) were not included. 'Manipulative event' is a specific behavioral category, and does not function as a general activity index. At the end of the observational series, it was calculated the percentage of the total number of data points that each animal was recorded as performing manipulative events, which was used as a proxy for their manipulative propensities.

Experimental phase

After the end of the observational stage, the subjects were tested in a tool-using task. The apparatus consisted of a transparent 9 mm Plexiglas box with a transparent 3 mm Plexiglas lid and a couple of different sized quartzite stones to serve as potential hammers to break the lid. The Plexiglas box with a visible piece of food (maize) inside it was then secured to the ground, and two quartzite stones of different sizes were placed alongside. The only way for the animals to obtain the food was by breaking the lid.

Each subject was tested in a relative isolation from others. We prevented close approach with a small physical barrier and our presence. However, visual contact with the remainder of the group could not be prevented.

Each individual was given 10 different trials in succession. A trial began when a subject attempted to get the food inside the box, that is, when the subject approached and touched the box for the first time, in a clear movement to reach for the food placed within it. The trial ended when the lid was broken or if the box was abandoned for more than 5 minutes. In either case the box was replaced and a new trial began. Mere manipulation of the stones was not considered as a criterion for the beginning of the trial. Only trials that involved use of stones to break the lid were considered here (14 in total), in order to exclude from start the possibility of

breaking the lid with their teeth or hands only (something that happened before in experiments with another *Cebus* species). Every time a monkey attempted to break the lid with a stone, he/she was successful. Trials were conducted before the two regular feeding times of the animals (morning and at the end of the day) so as to keep their motivation high.

We then tested, through Spearman rank correlation test, if the percentage of the time the monkeys were involved with manipulative activities (in the observational phase) was correlated both to the number of tool use trials by them and to average trial duration, which can be considered a measure of the animal's efficiency in the use of tool.

Results

During the observational phase, all individuals performed a great number of manipulative behaviors, and were involved for a considerable amount of time on such activities, although there are marked individual differences (Table 1). When presented with the transparent box, all individuals, except one (Catriona), used the stones to break the lid (Table 2).

Table 1
Summary of the manipulative activities of the study group

Subjects	Number of manipulative events	Percentage of time spent in manipulative activities
Ahab (♂)	297	4.85
Ben Gunn (♂)	418	6.83
Moonstone (♂)	506	8.27
Smollet (♂)	473	7.73
Parthepone (♀)	424	6.93
Catriona (♀)	364	5.95
Average	413.67	6.76

Table 2
Summary of tool using activities of the study group

Subjects	Number of tool using events	Duration (s)
Ahab (♂)	3	270.51
Ben Gunn (♂)	5	163.59
Moonstone (♂)	3	273.22
Smollet (♂)	2	157.76
Parthepone (♀)	1	153.23
Catriona (♀)	-	-
Total	14	1018.31

The Spearman rank correlation between the frequency of time each animal performed manipulative events and the number of tool-using behaviors displayed by them (excluding Catriona, which did not use tools) proved to be non-significant: Spearman rank correlation coefficient $R = -0.31$; $t = -0.56$; $p > 0.6$ (Figure 1).

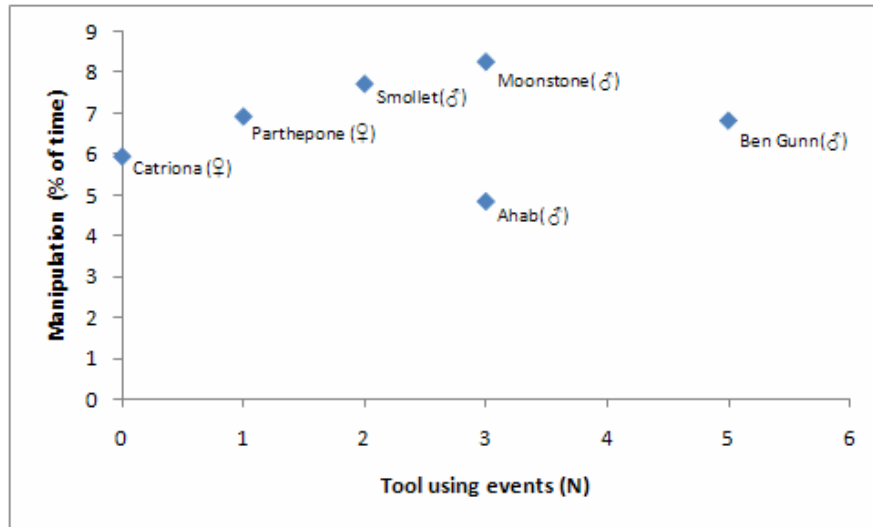


Figure 1. Relation between the time spent in manipulative activities and number of tool using events.

Since males were more manipulative than females (Goodness-of-fit test for different proportions $\chi^2 = 60.68$; $p < 0.001$), only one female used tools, and at a single occasion, we conducted another test, but excluding such female. The results were still non-significant: Spearman rank correlation coefficient $R = -0.37$; $t = -0.47$; $p > 0.68$.

The correlation with average trial duration was also non-significant: Spearman rank correlation coefficient $R = -0.1$; $p = 0.87$.

Discussion

The results show that the overall manipulative propensity of the monkeys is not correlated to the disposition and efficiency to use tools or in any way could be used to predict tool use. Thus, the present work does not support the contention that tool use in *C. xanthosternos* is a product of both overall manipulative propensities and tendency to use objects displayed by these animals, at least in an individual level.

Note that although Fragaszy and Visalberghi (1989) found out a correlation between exploratory behavior and tool use, exploration in their case involved the same tool and apparatus used in the experiments, and was not a measure of overall manipulative tendencies, such as the one used here. Thus, it may also be the case that manipulation/exploration with the tool itself or part of it may be necessary or a pre-requisite for correct tool use, as suggested by Visalberghi (1987; see also Fragaszy, Visalberghi, & Fedigan, 2004, p. 185) and also found by Fragaszy and Visalberghi (1989). Such result, however,

bears more significance to explain the ontogeny or emergence of tool-using behaviors in *Cebus*, than to its evolution.

A similar criticism might be raised in our case, that is, that the results at the individual level cannot be extrapolated to the evolutionary level. Nonetheless, note that the connection here is given by the common ground linking manipulative and tool use behaviors. If such factor has been selected for and is subject to individual variation, then we might expect to see such variation equally reflected in its consequences, both manipulation and tool use. It remains to be studied however, the alternative proposed by Byrne and Suomi (1996) that “individuals that are more diverse in their manipulative styles are more successful at tool use problems”. A similar proposal has been advanced by Frigaszy and Adams-Curtis (1991), who defend that differences in tool use between species are correlated to characteristics of generativity in manipulative behaviors, including the variety of acts towards a given object. Diversity, and other aspects of generativity, was not captured by our study design. If these aspects are found to be good predictors of tool using abilities, both at an individual and a species level, then they may provide a good foundation for hypothesis attempting to explain the origin of tool using capacities in the genus *Cebus*.

Thus, we are by no means stating that manipulation is completely uncorrelated to the emergence of tool use in evolutionary terms. What we are arguing is that one aspect of manipulation, namely, the tendency to perform the behavior, does not seem to be correlated to the tendency to perform tool using behaviors. The conclusions are by necessity preliminary, given the scope of the experiment and the limited group size. Nonetheless, we believe that it deserves attention, not only because it can lead to a more careful consideration of future studies (see below), but also because it replicates findings of another species of the genus (Jalles-Filho, 1995).

A possible confounding factor in our analysis is the potential influence of social factors in the access to the apparatus. Social influences have been argued before to influence manipulation (Byrne & Suomi, 1996) and possibilities for social learning (Fragaszy & Visalberghi, 1989). However, note that (based on *ad libitum* observations) Ahab was clearly the dominant male, but this did not prevent other males from using the tool at comparable frequencies. Nonetheless, one might still argue that social factors may play a role both in determining the fact that females almost did not use tools, and also in the anxiety of subordinate individuals when manipulating the apparatus or close to it. Thus, further studying the influence of social factors on tool use and performance, especially by testing the individuals separately, is a promising field of enquiry.

Having considered this potential caveat, our results are in line with other findings, all of which point to the need to expand and detail even further the test of the hypothesis that the evolution of tool use is somehow connected to manipulative tendencies. These tests should encompass other species of the genus, other measures of manipulation, and other kinds of tool use, in order to check which aspects of manipulation, if any, are correlated to tool use abilities. Then, we may be in a better position to propose and test theories about the evolution of tool use capacities in the genus that take into account ecological and/or social factors.

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