White-nosed Coati Learning and Problem-solving Behaviour
Cloudbridge Nature Reserve, Costa Rica

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White-nosed Coati (*Nasua narica*). Photo: Jennifer Powell

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ACKNOWLEDGEMENTS

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ABSTRACT

The White-nosed Coati is a mammal very common in Costa-Rica, it can easily be seen in natural parks or close to human habitations and roads. At Cloudbridge Nature Reserve, numerous records of coati were captured by camera trap, moreover, Cloudbridge staff often see coatis near the houses. At the reserve, coatis break into food storage areas and compost bins, and eat the food on birdfeeders, despite increasingly complex ways to prevent them, which is troublesome, but also shows a certain amount of intelligence on the part of the coatis. During 5 months, the learning and problem-solving behaviour of one coati was observed, on the same site, every day. The observation time began at 9 AM and ended around 6 PM. On the site, two wooden boxes with a hinged lid were installed. Two bananas were placed in the boxes every morning to encourage the coati to open the boxes. During the study, different lock systems were fixed on the boxes in order to test the coati's capacity to learn techniques and his physical abilities. In addition to the box tests, at two sites we observed if the introduction of bananas every day in the same place had an impact on coati foraging behaviour. We could conclude that: coatis can remember specific actions, positions, events and location. Moreover, they are able to memorize a chain of actions, however it seems that there is a limit in the number of actions that they can memorize in sequence. We could clearly see that the introduction of bananas in the same place every day resulted in the coatis coming to the site more often. Finally, coatis have agile handling thanks to their fingers and claws, which allow them to manipulate small objects. Coatis can pull with their arms and mouths, and can push something with their noses.

1 INTRODUCTION

The White-nosed Coati (*Nasua narica*), called Pizote in Spanish, is a very common mammal in Costa-Rica (Gonzalez-Maya, J. 2008 ; cited by IUCN, 2016). They can be found on roads and near houses in some cities. Coatis are very well know at Cloudbridge Nature Reserve, they are often seen near Cloudbridge habitations and on camera trap, however no studies about coati have been carried out at Cloudbridge. They have regularly broken into the outdoor pantry, forcing Cloudbridge staff to repeatedly strengthen and try new lock systems. They also like to eat what is in the compost bins, despite attempts to prevent them from opening the bins by putting a cover and heavy stone on them. Moreover, they eat the food on any birdfeeders put up in the reserve. Numerous systems have been tested to stop them, but until now, no solution have been found. This shows that this mammal species is endowed with problem solving abilities. For all of these reasons, the Cloudbridge team wanted to know more about coatis and how they think, in the hopes that some effective locking mechanisms could be discovered.

While some studies about coati behaviour have been done before, I could not find any about the problem solving abilities of this animal, and as such, this research is a preliminary study into this subject.

My three objectives were:

- Determine if the introduction of banana at the same place every day will induce a change in their food scavenging process.
- Evaluate learning and memorizing skills
- Determine physical abilities and limitations

Two sites among three were choose as study sites. The first site (Site C, Figure 3) was located on a quiet trail, far from human habitation and close to the primary forest. Two bananas were placed there every morning between 7:00 and 8:00 AM at the same location, in front of a camera trap. Thanks to the camera trap, which had been in place on the site for a long time, the frequency of coatis visits before and after the introduction of bananas could be determined. The second site (Site A, Figure 3) was located just few meters up from a Cloudbridge staff house and close to the main trail. On this site, over about 4 months, I observed a coati's problem-solving behaviour. Two boxes were fixed on this site. Every morning between 8:00 and 9:00 AM, two bananas were placed in each box, and then the observation period began. During the study, the lock systems changed and became more and more difficult.

I faced some challenges during this study as I was not able to control the number of tests that occurred per day, the number of coatis participating in the study, or the hour of the coati visits. Generally, cognitive tests are conducted in zoos, which allows the repetition of the same experiment with the same individual several times a day and the selection of the number of individuals needed. In my case, one coati participated in the study. Moreover, the observation time began at 9:00 AM and ended at 6:00 PM, so I missed some visits because the coati visited the boxes out of this time period. Finally, I could only collect one to two results per day because the coati only visited the site once to twice a day.

However, it was interesting to study the coati in his natural environment. It allowed me to not limit the study to cognitive and physical capacities, but also to explore his behaviour when he encountered unusual situations (an object built by humans, presence of food at the same place regularly, change of lock systems).

2 MATERIALS AND METHODS

2.1 STUDY SUBJECT

One male, White-nosed Coati participated in this study. He always came alone to the study site, except one time when he was accompanied by three other coatis: one adult and two young. Twice, I saw another male coati at the study site, but he never tried to open the boxes. Once a group of five coatis came and they smelled, and walked on the boxes, but did not try to open the boxes.

2.2 MATERIALS

Testing materials consisted of two wooden boxes with a hinged lid. The boxes were different sizes: the first was a little one (47.5L x 19.0W x 21.0H cm) and the second a big one (72.5L x 34.5W x 40.5H cm). A wire mesh was fixed on the lid and on the two large side of the little box, and the large back side of the big one. Both boxes opened on the top and the lock systems were located on the same side.

The big box. Three different lock systems were added one-by-one during the study on the big box. The first was a stone on the door, the second an elastic cord around the whole box, and the third a rigid string latch around a piece of wood (see Fig. 1).

The little box. Two lock systems were installed on the little box. Both lock systems on this box were tested independently of each other: when the test with the first one finished, it was removed and replaced by the second one. The first lock system was a 5.9 cm wooden latch (short latch) and the second was a 7.9 cm wooden latch (long latch) (see Fig. 2).

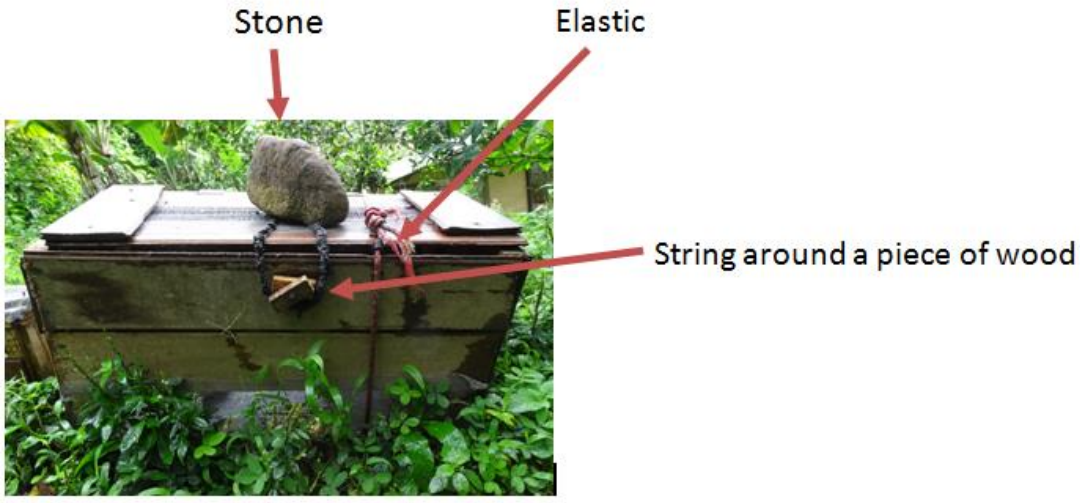

FIGURE 1: Big box and the three lock systems.

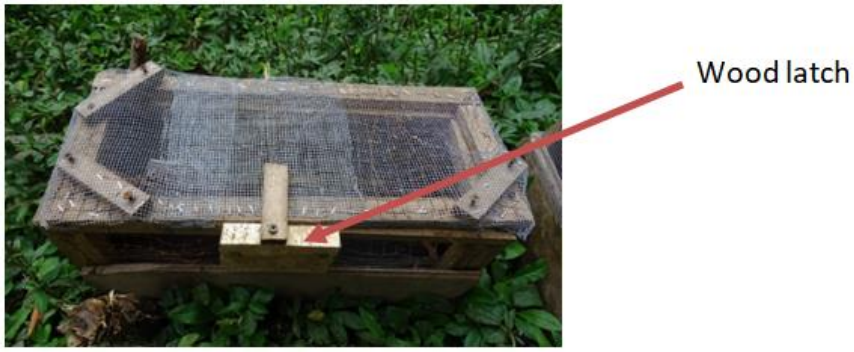

FIGURE 2: Little box and the wood latch lock system.

2.3 PROCEDURE

2.3.1 SELECTION OF THE STUDY SITE AND COATI HABITUATION

Three sites were selected as potential study sites, due to known or suspected coati presence. The study was run from April 23rd to July 18th, 2017 at study Site A, from March 21st until April 24th, 2017 at study Site B, and from March 21st to May 5th, 2017 at study Site C.

Site A was close to human habitation (single dwelling) and a few meters above an Art Gallery. Moreover, the main hiking trail was not very far. Every day, people passed close to Site A to go to the Art Gallery, the house, or just to follow the main trail. From the study site we could see and hear noise from people visiting the Art Gallery. Sites B and C were situated on a trail reserved for Cloudbridge staff or for hiking with a reserve guide. The frequency of human visits at Site B was very low (nobody or one/two people per day, maximum). Site C was further from human habitation and closer to the primary forest. Human visits to Site C fluctuated from around 6 persons to 1 person per day.

Two bananas were placed at each site every morning between 7:00 and 9:00 AM, depending on the site (see Fig. 3), in order to attract coatis to the site and habituate them to regular food availability. The bananas were placed on a tree at about 1 meter from the ground for the lower site and 2 meters for the higher sites to protect the bananas from other animals, like peccary.

After 21 days, the site next to the Art Gallery (Site A) was selected to conduct all tests, as there was a coati that visited the area regularly to eat the bananas, and engaged with the testing boxes. There were also a few practical reasons Site A was chosen. It was close to the living quarters making it easier to arrive early in the morning, and the deck of the Art Gallery provided a good view of the boxes and surroundings, while being far enough from the boxes to avoid disturbing the coati. At Site C, when the box was placed at the site, the coatis were first afraid and did not want to open it. Eventually, they smelled it and shook it a little, but were never successful in opening the door, even without any locking system (the box was left for 25 days). Site B was abandoned as a potential site sooner because it was uncertain that the bananas were being eaten by a coati. Before the study, the coati which participated in the study at Site A, was often seen around the Cloudbridge buildings trying to eat the compost. At Site A, the coati opened the box from the start of the study. This suggests that the coati that visited Site A was used to the presence of humans, unlike the coatis at Site C. However, as there was a camera trap installed at Site C, as well as regular coati activity, Site C was used to observe coati behaviour without a testing box.

2.3.2 SET UP OF THE TEST AND OBSERVATION

The big box was placed at the site first, then the little box was added two weeks after. Two bananas were placed in each box every morning between 8:00 and 9:00AM. The observation time began at 9:00AM and continued until the coati came. If he came before 3:00PM, two new bananas were placed in each box and the observation ended at 6:00PM. On days when no observations were made, two bananas were still placed in each box every morning, to maintain the reliability of the food source for the coati. A camera trap (Bushnell, model 119436) placed in front of the two boxes allowed a view of what the coati did on the other side of the boxes, and also provided a record of when the coati came to the site when an observer was not present. Once triggered, the camera trap began to record after 1 second and recorded 10 second videos. Due to the short recording time, it was not possible to use the camera trap to record the coati's attempts to open the boxes. Moreover, the reliability of the camera was not absolute, but it provided additional information observations were not possible.

The big box. No lock systems were installed for the first 18 days, in order to habituate the coati to the box. The first test (the stone on the lid) was installed after 18 days. Twenty-one (21) days later, the second test was added (the elastic cord), and 21 days after that, the third test was added (the rigid string latch).

The little box. No lock system was installed for the first 10 days to allow for habituation. The first system was left in place for 37 days (5.9cm latch), and the second (7.9cm latch) for 27 days. The first system was left in place for longer because of repairs which had to be carried out several times during the study, and which slowed down, and distorted the experimental results.

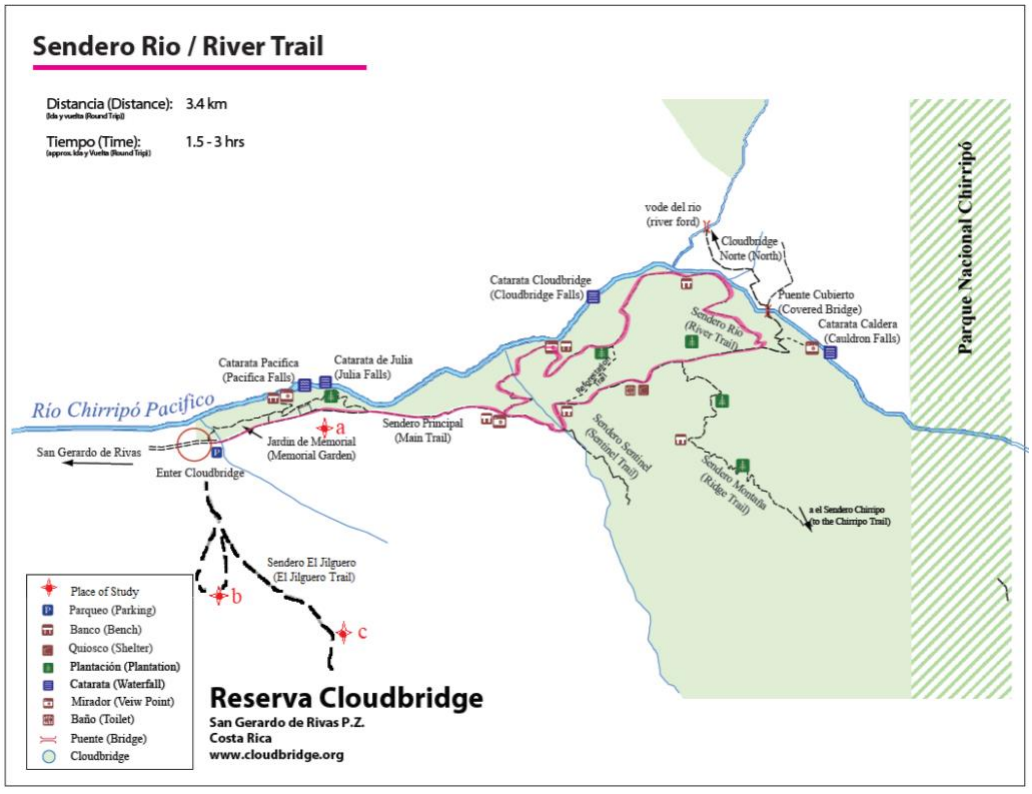

FIGURE 3: Cloudbridge Nature Reserve map. Potential study sites: (a) Art Gallery, (b) El Jilguero loop, and (c) El Jilguero Camera Trap.

2.3.3 CODING AND ANALYSES

Four different types of response were studied: frequency of visits, persistence, learning, and physical ability.

Frequency of visits was measured different ways at Site A and Site C. At the main study site (Site A), the hourly distribution of visits throughout the day was calculated for the duration of the study. In order to be scored as a visit, the coati had to come within at least 2 meters of the boxes. If the coati came in and out of range in a 10 minute period, then it was scored as one visit. To increase the reliability of the data, only the days where there was physical observation in addition to camera trap data were scored. The time of the coati's daily visits was graphed to determine if the coati's visiting schedule was at a similar time every day and whether or not it showed regularity.

At Site C, frequency was measured a different way. For this component of the study, the individuals included in the study were more numerous. At this site, a camera trap (Bushnell, model 119874C) had been in place months before the beginning of the study. This allowed measurement of the gap between visits before and after the bananas had started being placed. Coati visits for a 44-day period before, and 37 days after, were calculated from the camera trap images. When a coati was filmed by the camera trap, it counted as one visit. Every image recorded in a 10 minute period with the same individual counted as one visit. The mean between the time of the first and the last image was used for measuring the time-gap. Results were graphed to determine if the introduction of the bananas decreased the time between visits.

Persistence was measured as the total time in seconds that the coati spent trying to open one box. The timer was started when the coati touched the box with his body and stopped when the coati had his head in the box. When the coati failed to open the box, the timer was stopped when the coati left the box. The total time spent trying to open the boxes each day was calculated and the successes and failures were added together. Results were graphed to determine if the persistence of the coati changed as the tests changed and as time progressed.

Learning was measured as the change in time spent to open a box. The time was recorded the same way as for persistence. However, only the successful attempts were used, and each successful attempt was used as an individual data point, meaning that the times were not added. Results were graphed to see if there was a correlation between the time spent to open the box, and the number of times an attempt was made. The capacity to learn can also be shown by the evolution of behaviours, which is why the analysis included statistical tests combined with behavioural observations.

Physical skills were observed throughout the study to better understand the behaviour of the coati by gaining insight into why he would choose some actions over others.

Frequency of visits and persistence data did not follow the assumption of normality. Therefore, nonparametric tests were used for analysis. The Mann-U-Whitney test was used to compare the frequency of visits before and after the bananas were placed. This test was also used to compare the persistence of the coati on the first and second lock system on the little box. To compare the persistence on the three s of the lock system on the big box, Kruskall-Wallis was used. Linear models were used to interpret the learning data (linear regression and quadratic regression). However, for some tests, no linear models correlated with the data.

3 RESULTS

3.1 FREQUENCY OF VISITS

3.1.1 DISTRIBUTION OF DAILY VISITS AT SITE A

Figure 4 shows the distribution throughout the day of all visits to the boxes at Site A during the study period. For each hour, how many times the coati came throughout the study were tallied, helping to determine if the coati had a random schedule, or if he always came always at the same times. The highest number of visits occurred between 10:00 and 12:00 and between 16:00 and 17:00.

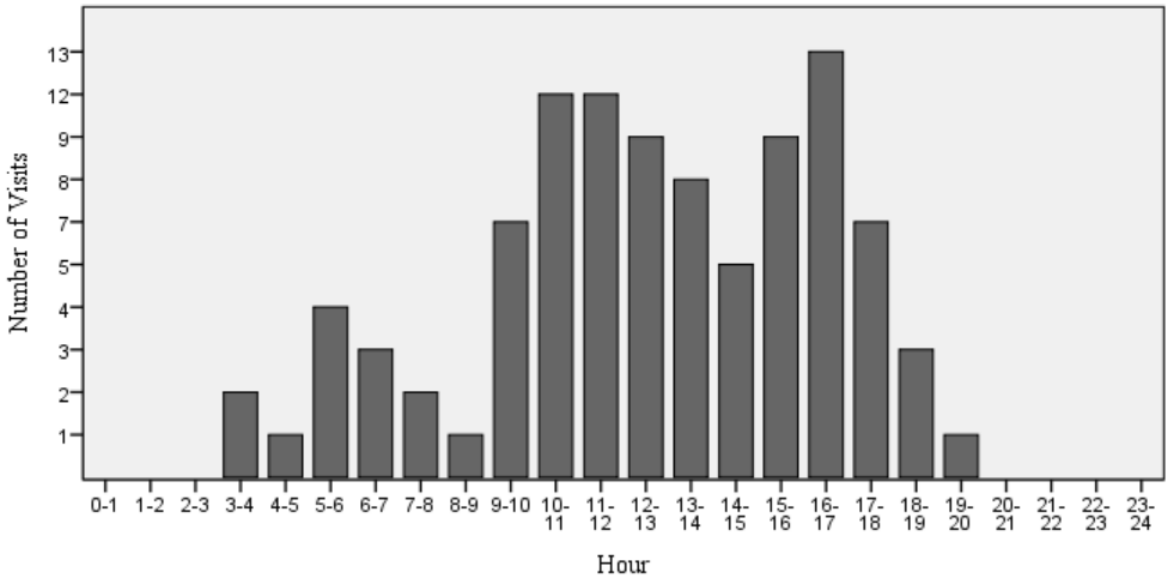

FIGURE 4: Distribution of visits throughout the day at Site A.

3.1.2 FREQUENCY OF VISITS AT SITE C BEFORE AND AFTER INTRODUCTION OF BANANAS

Figure 5 shows the interval between each coati visit at Site C, with the red line indicating the introduction of the bananas. Thirty-seven (37) days of data were collected at Site C after the introduction of the bananas, while 44 days of data before the introduction of the bananas were used for analysis. This was done because the interval between visits was so large prior to the banana introduction that, if 37 days were used, there would have only been 12 data points. To improve the reliability of the analysis with the Mann-U-Whitney test, an additional week of data was included before the banana introduction. February 11th (the date 37 days before the banana introduction) is included in the 4th interval shown by the red arrow on Figure 5. There was a significant difference between the frequency of visits before and after banana introduction: coatis came more often after the introduction of the bananas ($W = 643.50$, $N_{before} = 16$ intervals, $N_{after} = 42$ intervals, p-value $= 0.003$).

Looking at the just the number of visits, there were 13 visits in 37 days before and 43 visits in 37 after. The introduction of the bananas had a clear positive impact on the number of visits.

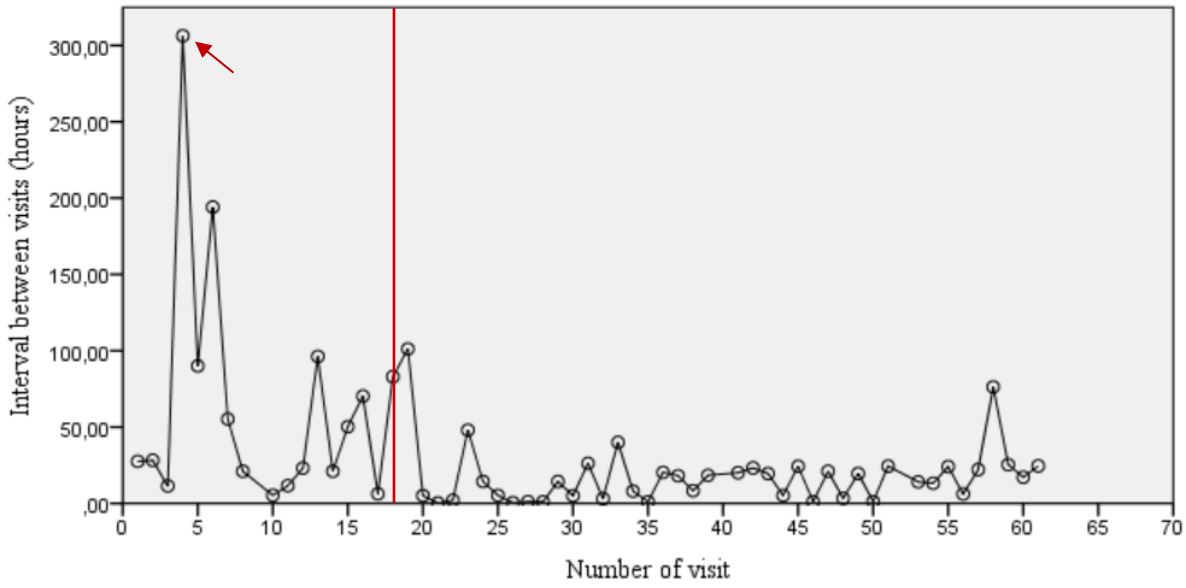

FIGURE 5: Interval between visits before (44 days) and after (37 days) introduction of bananas at Site C. The introduction of the bananas is indicated by the red line. The red arrow shows the interval that includes February 11th, the date 37 days before the introduction of the bananas.

3.2 PERSISTENCE

Figure 6 shows the persistence of the coati in attempting to open the big box, with the red lines dividing the three tests of the study. There were significant differences between the 3 tests. The coati spent less time to succeed at the first test (stone), than at the second test (stone and elastic). He needed a significantly larger amount of time to succeed at the third test (stone, elastic, and string latch) than the first and second ($H = 15.69$, $N_{test1} = 8$ data, $N_{test2} = 13$ data, $N_{test3} = 12$ data, p-value = 0.000).

Figure 7 shows the persistence of the coati in attempting to open the little box, with the red line dividing the first (short latch) and the second test (long latch). There was no significant difference between the first and the second test. The time spent to open the box with the first and the second lock system can be considered as the same ($W = 233.00$, $N_{test1} = 19$ data, $N_{test2} = 8$ data, $p = 0.084$).

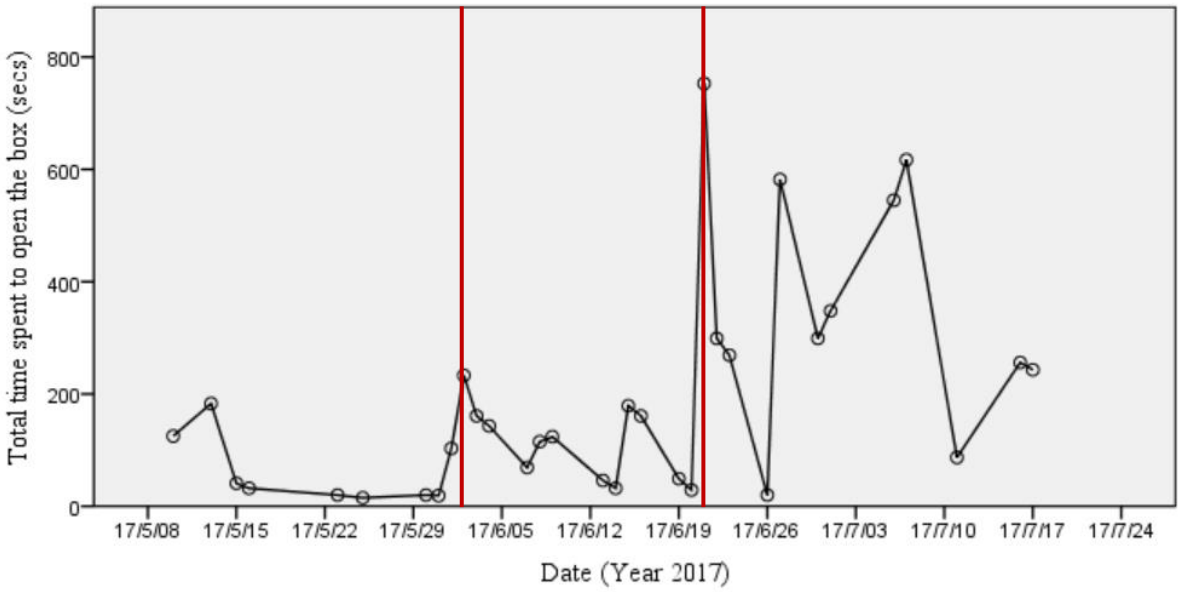

FIGURE 6: Persistence for the big box. The red lines indicate when additional locking mechanisms were added to the box. First section = stone on lid; second section = stone and elastic; third section = stone, elastic, and string latch.

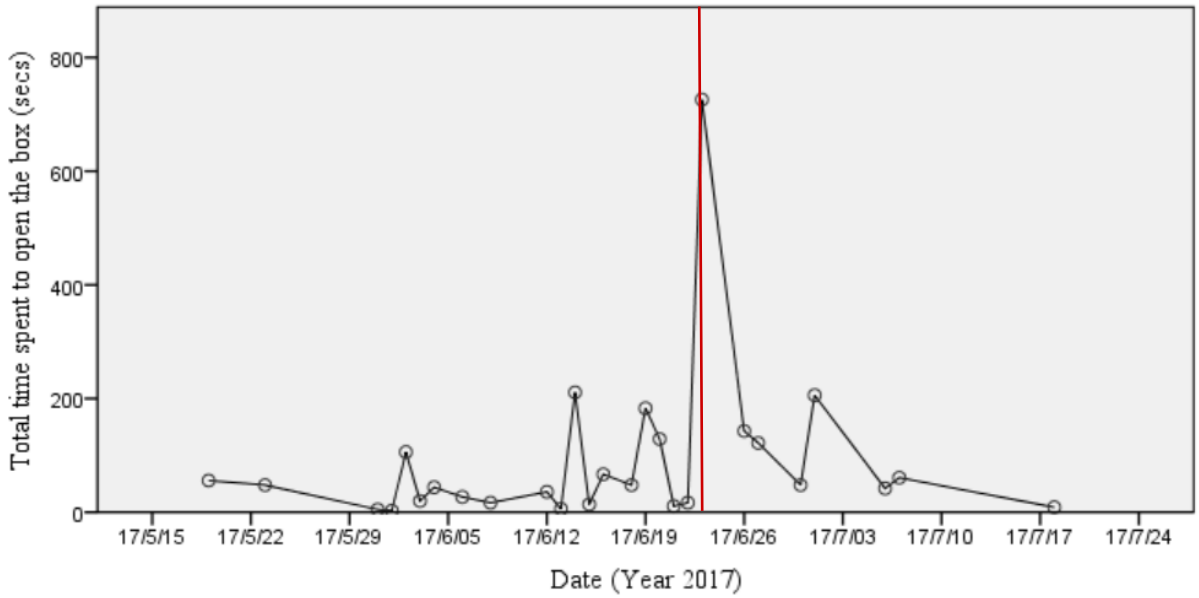

FIGURE 7: Persistence for the first and second lock system on the little box. The red line indicates when the locking mechanism was changed. First section = short latch; second section = long latch.

3.3 LEARNING

3.3.1 THE BIG BOX

For the first test (stone on lid) a quadratic regression explains the variation of the data really well, $R^2 = 91.27\%$ (see Fig. 8). Moreover, a significant negative relationship between the number of attempts and the time spent to open the box was found ($p = 0.002$). Moreover, around the fifteenth try, we can observe that the time needed to open the box stopped decreasing and stabilized. By using a quadratic regression, the time seems to increase again at the end of the test. However, more data would need to be collected to be sure whether the time increase continues or continues to remain relatively stable.

For the second test (stone and elastic) a weak, but significant ($p=0.016$), negative linear relationship was found ($R^2 = 42.2\%$) (see Fig. 9). As the number of attempts increased, the time to open the box tended to decrease ($r = -0.65$). However, this model is weakened by some extreme values of data.

For the third test (stone, elastic, and string latch), no model matches the data well (see Fig. 10). No clear trend can be identified, the time spent to open the box did not decrease consistently and showed a lot of peaks, and was generally a lot higher than for the second test.

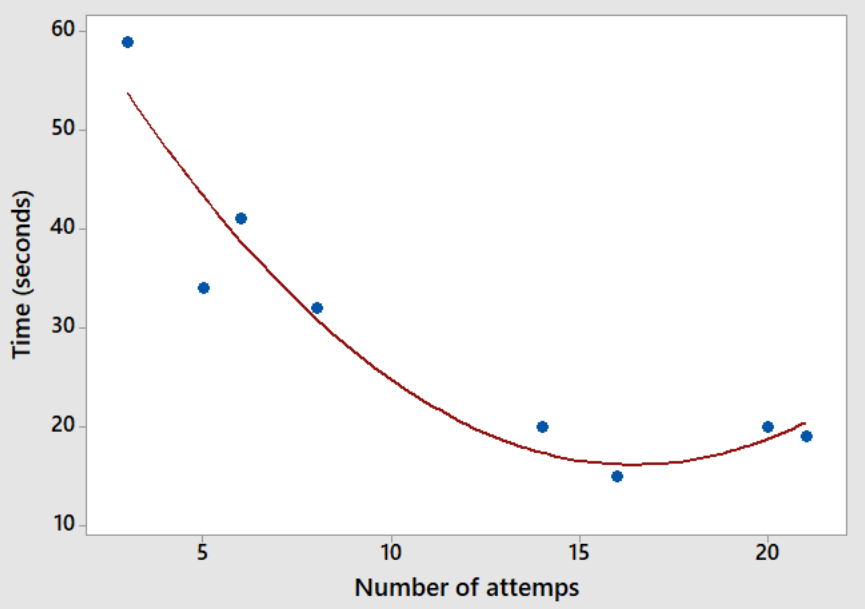

FIGURE 8: Test 1 (stone on lid) on the big box. Change in the time spent to open the box vs the number of attempts. $R^2 = 91.27\%$.

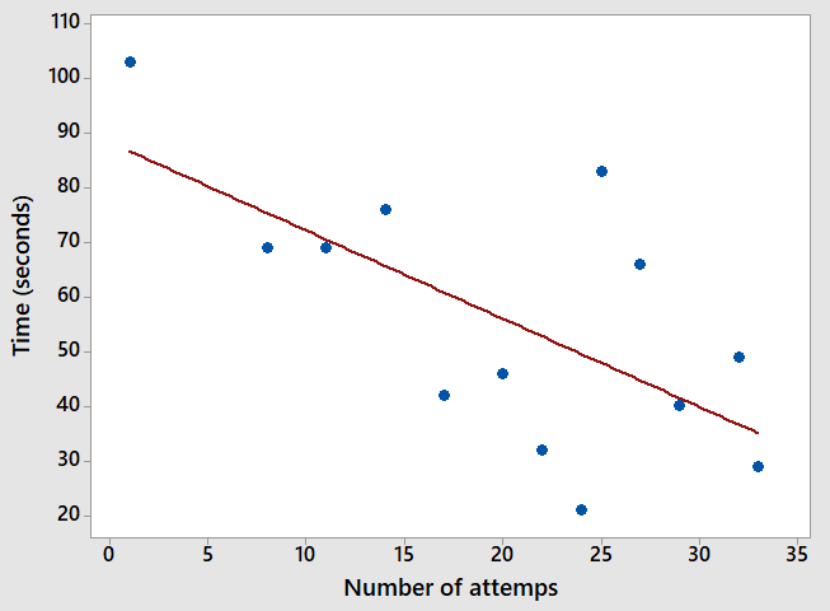

FIGURE 9: Test 2 (stone and elastic) on the big box. Change in the time spent to open the box vs. the number of attempts.

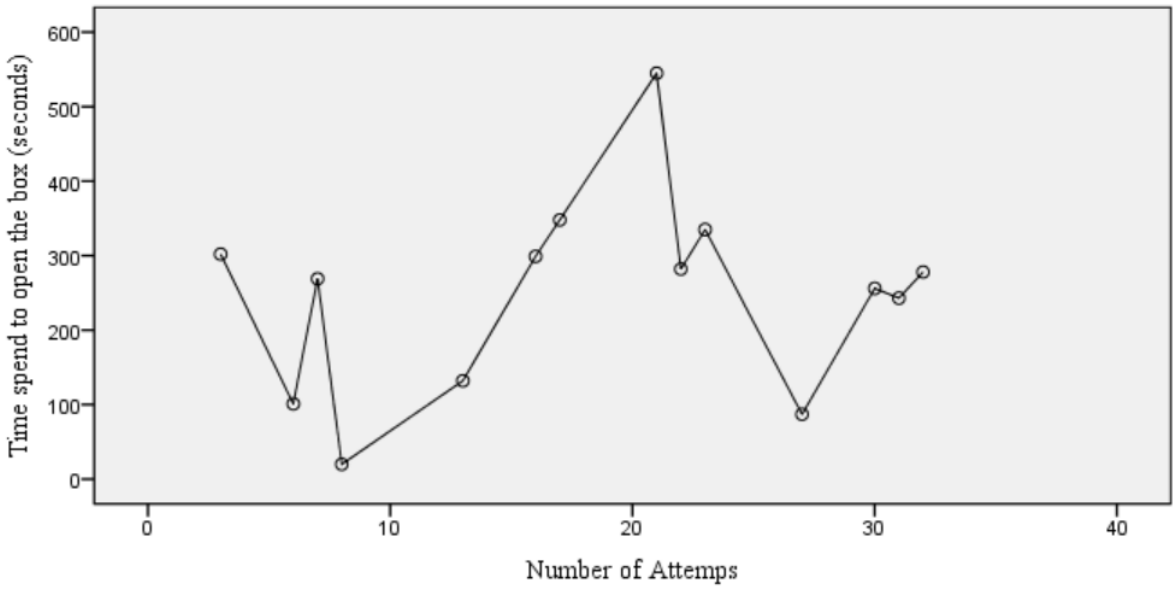

FIGURE 10: Test 3 (stone, elastic, and string latch) on the big box. Change in the time spent to open the box vs the number of attempts.

3.3.2 THE LITTLE BOX

For the first test (short latch), no model matches the data well (see Fig. 11); no decreasing trend can be seen. If we exclude the two outliers at the end of the study (34th and 35th) all the data ranges between 3 seconds and 56 seconds. The peak at the 34th and 35th were caused by repairs to the box, which made the box more difficult, and therefore more time consuming, to open.

For the second test (long latch), a weak, but significant (P=0.044), negative linear relationship was found (R^2 = 46.12%) (see Fig. 12). As the number of attempts increased, the time spent to open the box decreased (r = -0.68). Here again, the model is weakened by some extreme values.

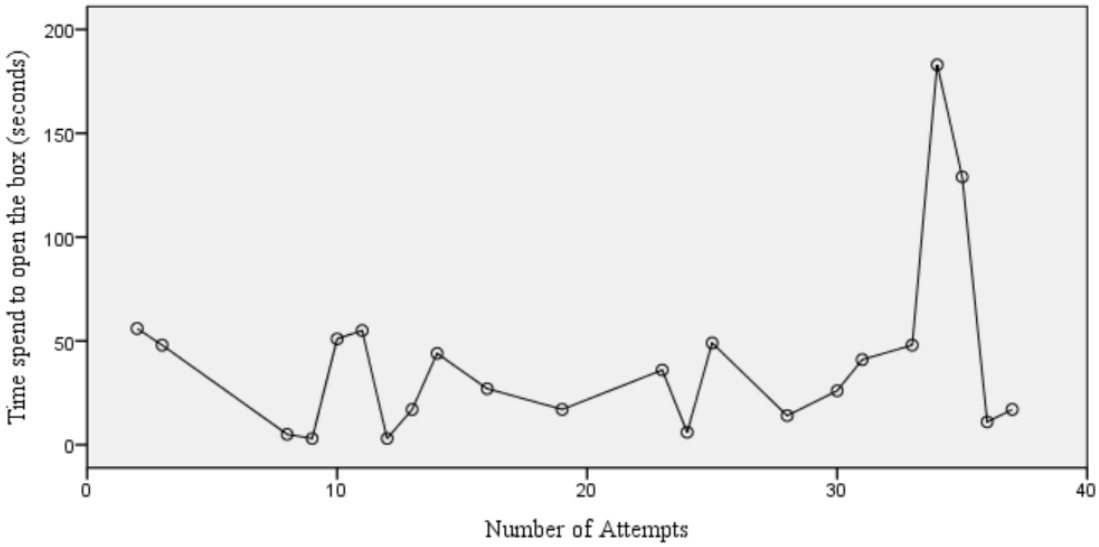

FIGURE 11: Test 1 (short latch) on the little box. Change in the time spent to open the box vs. the number of attempts.

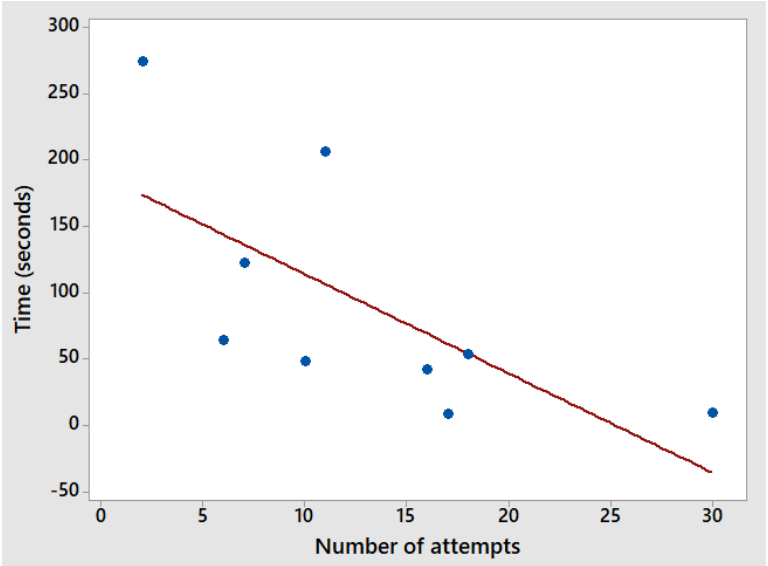

FIGURE 12: Test 2 (long latch) on the little box. Change in the time spent to open the box vs. the number of attempts. R^2 = 45.12%.

4 DISCUSSION

4.1 BEHAVIOUR AROUND FOOD

At Site A, the distribution of visits on one day (see Fig. 4) shows that the coati came mostly during day time (sunrise around 5:30AM and sunset around 5:55PM (Time and Date 2017)) which is consistent with the literature (Marceau 2001, Gompper 1997). The hour the coati visited each day varied, although it mostly came between 10:00-12:00 (around 24% of the daily visits) and 16:00-17:00 (about 13% of the daily visits). This is probably due to the almost daily rains, which, during the study period, typically began around 12:00 and saw the heaviest rains between 13:00 and 14:00 until around 16:00 (Cloudbridge Nature Reserve 2017).

The coati came almost every day: over 71 study days, he only did not come 3 days. The coati seemed to have a kind of 'food research' routine, which consists of daily visits to places where he typically finds food. The frequency of the visits before and after introducing bananas to Site C (see Fig. 5) shows that consistently placing bananas at the location resulted in coatis coming more often to the site. This shows their 'food research' routine can change if they find a new place where food is present.

At Site A, another coati came to the site twice, but never tried to come near the boxes. He seemed to be young (smaller size that the study coati), so may have been more wary of an unknown object. In fact, the study coati was often seen around the Cloudbridge buildings, eating the compost, was not scared by human presence or sounds, and was generally habituated to humans.

The lack of presence of other coatis besides the study coati at Site A may also be explained by coatis' territorial behaviour. Once a group of 5 coatis, composed of 2 adults and 3 young, came to Site A and approached and smelled the boxes, but did not try to open them. At Site C, the most frequent visitors were 2 coatis who came separately. The first was smaller and darker with a ball of hair at the end of his tail, and the second had a circle of damaged hair on the right thigh and a straight tail. Some groups of two coatis were also observed occasionally. The two main coatis did not seem to change their behaviour if the other had visited the site before them. Both walked on the same stone, along the same path, and I did not observe a difference in behaviour (e.g. smelling more, more cautious, etc.). In this instance, the coatis did not seem to defend and mark Site C even though they were including the site in their food research routine.

Adult male coatis use scent-marking to mark their territory and indicate their reproductive state. They establish ranges that they mark by spraying urine or dragging their abdomens on a surface and spreading anal secretions, called penile dragging (Macdonald 1985b, cited by Marceau 2001). However, I never observed these behaviours at either of the two sites. This may be because they use a very small volume of urine for marking so I could not detect it (Macdonald 1985a, cited by Norberg 2014). While adult males will mark their territory, bands of females with their young (occasionally accompanied by males) often travel and forage together, and their ranges can overlap with single male territories. This might explain why the crew of 5 coatis dared to come up to the boxes while the single male did not, as only adult male ranges do not overlap (Marceau 2001). If my observations are right, and no coati marked these places, it could be because coati mark a territory around their home, but the study sites could be located outside of their home territory. This could explain why the two coatis at Site C did not fight or mark the site.

In terms of the number of daily visits, the study coati at Site A came one time per day, 27 times; two times per day, 20 times; and three times per day, 11 times. When after the first visit some bananas were still left, the coati always came a second time, and sometimes, a third. If there was a banana left, he would always come back. Even the times when he did not manage to open any of the boxes, he came back a second and third time to try again and only stopped coming when all the bananas were eaten. This shows memory as well as persistence.

4.2 PERSISTENCE

With each test, I tried to increase the difficulty of the locking mechanism on the 2 boxes. For the big box, the time to open the box increased at each test, however this is likely due to the fact that there were additional locks to open so it is expected that it would take more time to open it (see Fig.6).

For the little box, no significant difference was found between the first and the second test (see Fig. 7). This could be because the type of test did not change, only the size changed. If the coati was able to learn how to open the first latch, we would assume that the coati could then reproduce this technique on the second latch. However, as it will be explained in the learning section, it seems that the coati never learned how to operate the first latch. When he was successful at opening the little box, he opened it because he shook it, walked on it, twisted the door, or destroyed the box. Meaning without turning the latch, he was able to open the box. This also explains the lack of trend in the time to opening the box and the number of attempts we see for test 1 on the little box (see Fig. 11), as he successfully opened the box through a failure in the structure of the box, rather than opening the latch.

However, for the second test, the structure of the box was strengthened and he had no other choice than to learn to turn the latch to open the box. The longer latch also made it easier for the coati to manipulate the latch, usually by pushing it with his nose or with his hand. This is likely why we see a similar negative relationship between the time to opening the box vs the number of attempts for the long latch (see Fig. 12) as was seen for test 1 (rock) (see Fig. 8) and test 2 (rock and elastic cord) (see Fig. 9) on the big box. Because of the coatis' ability to open the little box without turning the latch during the test with the short latch, we cannot conclude that it was because of the learning during the first test period that the coati was able to reduce the time it took to open the latch during the second test.

For the third test of the big box there is no negative relationship between the time to opening the box vs the number of attempts for the string latch (see Fig. 10). Moreover, the time is more variable than for the other tests. During the third test the coati was more disorderly. For example, he would forget to undo all the locks before trying open the box, or focus on one lock system for a long time even after having opened it. He always finished by opening the box even if it took him more time (mean of time needed far higher than for the first and second test) and often to came back several times to the study site before he was successful. This shows that even if the coati did not establish a routine for the resolution of the third test, and had to think about it each time, he continued to come every day and sometimes several times per day until he got the banana. The coati is quite persistent and spent up to 12 minutes (all time cumulated on one day) working on the boxes in order to get food. It could be interesting to test what is the maximum time that the coati is willing to spend at one site while foraging for food.

In terms of the difficulty of the tests, it is not possible to compare the two boxes as, for the little box, the second test was not added to the first one like the big box. For the big box, as the tests were cumulative instead of being separate tests, the increased time to open the box at each test does not mean that the successive tests were more difficult, but just a reflection of adding additional locking mechanisms. It was not possible to divide the time it took the coati to defeat each lock system on the big box. In future, it could be interesting to do the same experiment, but replace each lock system one by one instead of adding them together.

4.3 PHYSICAL ABILITIES

Observing how the coati manipulated the boxes to resolve the different tests provided information on the physical abilities of the coati. First, the coati used different parts of his body and different techniques to pull something toward him and to push something. To make the stone fall, the coati chose to shake the box by pulling the box, little by little, towards him. To do this, he used his hands and the weight of his body to pull the box. Using the weight of his body allowed him to have more strength and more range. The coati's arms are short and do not allow large movements. However, by swinging his body backwards when he pulled something, this allowed him to pull it further. We also observed this behaviour when he tried to turn the latch of the little box. To pull something toward him, the coati would also use his mouth. To break the elastic around the box, the coati grabbed it with his mouth, placed his hands on the elastic, and pulled with little sharp movements, also using his body weight. I observed the coati push with his arms just one time; he typically used his nose to push things away from him. He did this when he wanted push up the door of the boxes, and the string around the piece of wood. The coati could also grab small objects with his fingers. He used his hand to catch the latch, the string, and the elastic. He could also grab the wire mesh of the lid with his claws. However, to grab the banana in the box he always used his mouth. In each box there were at least 2 bananas, he always took the bananas one at a time.

4.4 LEARNING

According to the Britannica Online Encyclopedia (Mackintosh 2017) animal learning is "the alteration of behaviour as a result of individual experience. When an organism can perceive and change its behaviour it is said to learn".

During this study, 2 phases of learning have been identified. First, a phase where the coati tries different solutions to get the bananas: phase A. Second, a phase where the coati applies methods that were previously successful: phase B. The observations of the coati's behaviour around the boxes throughout the study provides insight into these phases.

At the beginning of the study, no lock systems were put on the boxes. The big box was in place for 16 days already when the little box was added. On the first day that the 2 boxes were in place, the coati smelled the little box first, then opened the big box, ate the bananas, and then opened the little box after it was finished eating all the bananas from the big box. After that first day, the coati tried to open the little box first all the time. I suspect that as the little box is smaller, it looks less impressive and easier. Furthermore, the bananas are closer to the lid in the small box which may entice him to open the little one first. During the first 2 days of the study, when only the big box was in place, the coati took time to smell all the way around the box and walk on top of the box. It took less than 20 seconds each time. Then he went to the right corner and passed his nose between the door and the sides of the box to open it. For the little one, he smelled the box quickly and tried immediately to pull the box toward him. He used his hands more than his nose to open the little box. As it says in the physical skills section, the coati can pull toward him, but not push. That is why to open the box he placed himself on the side of the box and pulled the door. Without locks, he could open the boxes in a few seconds.

4.4.1 FOR THE BIG BOX

The first test was the stone on the door. At the first visit the coati quickly smelled the wire mesh parts and moved fast to the right corner to try several times to put his nose between the door and the sides of the box. He reproduced the same movement that he did when no lock systems were in place. This is phase B: trying to reproduce the method that worked previously. He could not open the box so he began turning around the box, smelling the wire mesh and the edges of the door. Then he shook the box from a different spot which made

the stone move a little. It seems this made him aware of the stone on the box, because then he began to smell the stone. He went on the box numerous times to continue to smell. Then he took position on the right corner of the box and shook the box. This action made the stone move toward him little by little. He regularly pushed up on his back legs to smell the stone. I think this is a way to measure the distance between him and the stone. He did this until the stone fell. When the stone fell he immediately stopped shaking the box and tried to open it with his nose. This entire behaviour was reproduced during the 5 first days of the stone test: it is phase A, researching ways to open the box. After five days, the coati directly positioned himself at the right corner, quickly smelled the wire mesh and the corner, and then shook the box until the stone fell. He would keep alternating between shaking, and smelling the stone. This is the phase B, application of the methods previously learned. We can see clearly the time to open the box reduced significantly between the first and the last day of the first test. At about the fifteenth try, a stabilization phase seems to have been reached. The coati had certainly seemed to have reached the minimum amount of time that he needed to open the box with this lock system. However, a longer study should be carried out to confirm this.

The second test was the stone and the elastic around the box. The first day, the coati tried to open the box like in test 1. He came to the right corner, shook the box, made the stone fall, and tried to open the door with his nose (phase B). When he tried to put his nose between the door and the edge of the box the pressure of the elastic made it harder for him. He tried many times to open the door, but without success. So, he began to smell, shake, turn around, and go up on the box. He tried several times to pull the elastic without success (phase A). He gave up and came back later. When he came back, he used more force to put his nose between the door and the edge of the box. He managed to get his head and a part of his body into the box, but his back legs stayed on the edge of the box. However, this allowed him to take a banana. Although there were two bananas in the box, he only managed to open the box once, and so took only one banana.

The next two days, he came several times (3 and 2 times, respectively) shook, went on, smelled the box and passed his head numerous times inside the box, but he never reached the bananas and gave up. The next 3 days (4^{th}, 5^{th}, 6^{th} day) like the previous days he made the stone fall first, then he began to shake, smell and climb on the box (phase A). Even if he moved all around the box to try all these actions, he still focused more on the right corner. He would then pass his head and the upper part of his body inside the box and quickly catch one banana that he ate outside the box. After eating the first banana, when he would enter the box a second time to take the other banana, he would come directly to the right corner and force it open to enter in, with almost no smelling or hesitation. Meaning, for the second banana, he did not reproduce phase A again. It seems he could remember how he opened the box few minutes ago.

The seventh day after the beginning of the study, the coati smelled the box, particularly the right corner, for a long time, but did not turn around or climb on the box. When he finished smelling the box, he shook the box quickly and with force, which made the stone fall quickly and he entered into the box completely. He seemed not to show any hesitation to put his nose between the door and the side of the box. Phase A almost completely disappeared and only phase B was implemented. Since day 7, he entered into the box completely and ate the bananas inside the box. After the next day (the 8^{th} day), phase A was completely absent and he implemented only phase B. Throughout the stage of the study when the elastic was present, the coati never tried to open or remove the elastic.

While overall there was a significant decrease in the time it took the coati to open the box between the first and the last day of the second test (see Fig. 9), the twenty-fifth and twenty-six tries took a lot of time and were anomalous. For the twenty-fifth try, the coati spent a long time smelling all over the box. It may have been that another coati or animal came before and left an odor on the box, causing it to delay opening the box in order to investigate the smell. However, I did not observe another animal visiting the box during my observation time, nor was another visit recorded by the camera trap, so this cannot be confirmed. Moreover, during this try, the coati tried to lift the door to enter the box before making the stone fall, which was impossible, and

caused some of the delay entering the box. The next day (the twenty-sixth), he tried again to enter the box without first making the stone fall. He tried to pull the elastic several times before finally shaking the box to make the stone fall.

There is no clear explanation for the different behaviour observed for these 2 tries. A decrease in the coati's health was considered as a possible explanation, but that was rejected as no abnormal results were found for the little box for the same two days. The change in behaviour is even more surprising given that the day before and the day after, did not show any difference with the regular behaviour. It seems that for these 2 days, the coati became fixated on the 2nd test (pull the elastic and lift the door of the box) and either 'forgot' about the rock, or might have been trying to get to the bananas with less effort by skipping the rock test. When the coati realized it could not skip the rock test and still get to the bananas, it went back to the old behaviour. It may have returned to phase A for a couple of days to see if it could improve the process. When that did not work, it reverted back to doing the previously learned behaviour.

For test 2, we did not see a stabilization in the time the coati took to open the box, and the test may have needed more time to reach the minimum time needed to complete test 2. The first test was left for 17 days and the second for 20 days. During the first test, the coati seems to have been reaching a plateau in the time it took to open the box. Because the second test is more difficult, it is reasonable to assume that more time would be needed to reach this plateau. We can see evidence of this in the number of days after which phase A was completely absent: after 5 days for test 1, and after 7 days for test 2.

The third and last test was the stone, elastic, and string around a piece of wood. On the first day, the coati tried to open the box as before (phase B): approached the right corner, shook the box, and put its nose between the door and the side of the box. As he did not get into the box, he began to look for other solutions, phase A began. He smelled, climbed on, and turned around the box, and pulled the elastic. For the third test, I noticed a difference in phase A compared to phase A during the first and second tests. This time, he focused more on the place where he was used to getting into the box, the right corner. As well, this time, he pulled on the elastic until it broke. Directly after having broken the elastic, the coati tried to open the box. He forced the door hard with his nose, which made the string slip off of the piece of wood and the coati was able to enter into the box entirely. It is not possible to determine if the coati noticed the piece of wood with the string because he did not pay attention to it.

The second day, the coati smelled the right corner for a long time, but he did not turn around or get onto the box. It was not a real phase A. After having smelled the box, he applied the same actions that he used the day before: shaking the box to make the stone fall, trying to open the door with his nose, and pulling the elastic until it broke. This day as well, forcing the door with his nose was enough to make the string slip.

The third day, the coati removed the string around the piece of wood first with his teeth before even smelling the box. This was the first confirmation that he had noticed the string. Then a real phase A began: he smelled all the way around the box, went on the top of the box and pulled the elastic until he broke it. Then he tried to open the box, even though he did not make the stone fall yet. He finished by making the stone fall, and then entered into the box.

The next two days, no phase A was observed. The coati came directly to the right corner, shook the box, and forced with his nose to open the box without opening the elastic. This could mean that he remembered that he did not need to open the elastic in order to enter the box. He passed his nose between the door and the side of the box, which pulled the string off the piece of wood without needing to use his mouth or hands. The third lock system was not strong enough to force the coati to find another method to open the box.

Because of this, a bigger piece of wood was installed to reinforce the lock. The first day after the reinforcement, the coati first tried to use the same method as before (phase B): shake the box to make the stone fall, and try

to force with his nose. He could not open the door, so phase A began. Here again he focused principally on the right corner. He then alternated between pulling on the elastic, and trying to put his nose between the door and the side of the box. He was eventually able to get the string off using this method, and he was able to get into the box without breaking the elastic. The next day, without hesitation, the coati shook the box to make the stone fall and then began a phase A. This phase was shorter. He continued pulling the elastic even though he was able to enter the box the previous 3 days without breaking the elastic.

I hypothesized two possible explanations for this behaviour: he did not understand he did not need to open the elastic to enter the box or, he thought that to open the door he had to pull on the elastic and whether or not the elastic broke had no bearing on his entering the box. In fact, during the previous 3 days, he tried to pull the elastic even though he did not break it, so he could think that pulling on the elastic was one of the reasons he was able to enter the box. By pulling on the elastic, and passing his nose between the door and the side of the box he was able to enter the box.

The next 4 days, the same series of actions were repeated: shake the box to make the stone fall, pull the elastic until it broke, and then try to enter the box. When he saw that he could not immediately enter the box, he moved toward the string. He then tried to open the string with his hand and his mouth. From this we can conjecture that he understood he needed to pull the string off the piece of wood to enter the box. After have done these three actions, he directly positioned himself on the right corner and entered the box. During these 4 days, he seemed to have memorized that if the stone fell, the elastic was open, and the string not around the piece of wood, he could enter the box.

However, during the following week, the coati did the same 3 actions, but not in a fixed order. This was a kind of phase B, the coati using the same method every day, even though the actions were not in the same order every day. In the third week, phase B changed again: he only shook the box to make the stone fall, and then pulled the string off the piece of wood, he did not try to break the elastic. However, we cannot confirm that this was because he remembered the previous times when he was able to enter without opening the elastic.

For the third test, the time spent to enter the box did not generally decrease over time and correspond to a linear model like the first and second tests (see Fig. 9). We can notice however some interesting results on try number 8 and 21. For try number 8, the time spent was very short: this corresponded to the first time the coati did not break the elastic. A peak was observed on the 21st try: this day the coati broke the elastic first, then make the stone fall quickly, but then spent a long time trying to open the door with his nose and shaking the box, before pulling the string around the piece of wood. Moreover, after having finally pulled off the string from around the piece of wood, he usually went directly to the right corner and opened the door, but this time he spent a lot of time pulling the string again and again with his nose. These two extreme points are not correlated with the coati's health, because similar results in entering the box were not observed for the little box on the same days.

Some of the techniques that the coati acquired during Phase A, he continually reproduced throughout the study once he had learned them. For example, from the first test until the last, the coati kept shaking the box and checking the distance between the stone and himself until he made the stone fall. This allowed him to anticipate and to move quickly when the stone fell. Since test 2, he entered entirely into the box and ate the bananas inside, even when, during the third test, he broke the elastic and would have been able to get in and out of the box more easily, like in the first test. It can be argued that the coati needed to reproduce the same technique several times before a technique would become habit and be included in his regular routine. An example of this can be seen during the third test. Two times the coati entered the box without opening the elastic, but then the next day, he still opened the elastic. It was only after the third time that he entered the box without breaking the elastic that he reproduced that behaviour every time thereafter.

4.4.2 FOR THE LITTLE BOX

It was difficult to identify two learning phases with the little box like those that were identified for the big box. This was because the little box was more fragile and, as it was smaller, the coati was able to exert more force to open it. The little box was broken several times, which biased the study.

The first test was the little latch. The coati smelled the box, particularly the wire grid part, and positioned himself on a side. He pulled the box toward him, changed his position to another side, and pulled again until he succeeded in opening the door. He pulled the latch several times toward himself, but he did not seem to pay attention to this. In fact, every day he just pulled the box toward himself from each side, without especially trying to turn the latch. For test one, it is difficult to really separate a phase A (research of solution, learning) and a phase B (application of previously learned methods) from his behaviours. From the first day, the coati kept pulling from different sides of the box and using force to twist the door and open the box.

We can however notice an evolution of his behaviour. After 10 days, the coati spent a very short time smelling the box. He took position always in the same place, on the corner of the front side (side with the latch), which allowed him to twist the door a little and open it, without opening the latch. It seemed that he remembered every day the position he should be situated at and where to pull on the box to open it more easily. We can associate this period to the phase B. The data did not show a decreasing trend in the time it took to open the box. The time to open the box peaked on the 34th and 35th tries, because on the day of the 34th try, the box was strengthened, making it more difficult to twist the door. I think that the time needed to open the box after this peak decreased quickly, because the coati shook the box very hard during the first few days after the box was strengthened, and so weakened the box again. As well, after the two long tries (34 and 35), the box was more securely fixed to the ground, which allowed the coati to exert more force on the box, making his movements more efficient, and speeding up the time it took to open the box.

The coati turned the short latch with his hand several times, but never consistently reproduced this method. I thought that perhaps this was because the coati found it easier to shake the box from a corner and twist the door, than turning the latch. Or perhaps, it is because he did not associate the action of turning the latch with opening the box. To help resolve this, I chose to put a longer latch on the little box, which prevented the box being opened by twisting the door. This would leave the coati with no choice but to turn the latch to open the box.

As for the first test, the results from the second test were difficult to interpret because the coati broke the box numerous times. During the first three days, the coati took position at the same spot as before - on the left corner on the same side as the latch side - and tried to pull the door like before. After several tries, he pulled the door from each side, he smelled, turned around, and climbed on the box. This represents phase A. During these three days, the solution found by the coati was to make a hole in the wire grid of the door and pass his head inside to take the banana. So after three days of phase A, he did not try to shake the door for long and directly climbed on the box to make a hole in the wire grid (phase B). Each day the box was repaired and strengthened. Finally, after five days (3 days of phase A, and 2 of phase B) the door of the box was completely lined and it was impossible to make a hole. During the next five days, the coati pulled the door by alternating principally between the two longer sides (latch side and the opposite side). He would always start with the latch side, like he had since the beginning of the study. He spent a lot of time, walking around the box and smelling it. He tried many times to pull the wire grid on the door where he used to break it previously. The latch was placed on the middle of the long side, but the coati always pulled the door from the extremities of each side and so spent a lot of time pulling on the door without even touching the latch. He ended by pulling the latch, but it seems that he did not make the link between pulling the latch and successfully opening the box, because each time, the next day he tried as before to pull from the extremities of the side. We can designate these 5 days as a new phase A.

After those five days, a change in his behaviour was noted. The coati stopped alternating between pulling the doors on the two longer sides, and stayed on the side of the latch. He would only pull on the door from the extremities for a short time, and then quickly moved toward the latch. He tried to move it with his hand or his nose, and immediately after having moved the latch, he would pass his nose between the door and the side of the box and attempted to open the door. This appears to confirm that he understood that if he moved the latch, he could open the door. These behaviours correspond with phase B.

The data for test 2 showed a negative linear regression, showing that the time to open the box decreased with the number of tries, similar to tests 1 and 2 for the big box. What is particularly important is that there is a great difference between the time before and after the 15th try. Before the 15th try is the period where the coati broke the wire grid to take the banana (up to try 10, when the wire grid was strengthened) and when he turned the latch by chance (new phase A) and the time it took to enter the box was very high. After the 15th try, the coati had begun to focus on the latch quickly (phase B) and the time needed to open the box was considerably lower.

Tests on the little boxes produced less reliable and obvious results that the tests on the big box. Although for the first test we cannot consider that the coati learned how to open the latch, he still learned a way to open the box. However, for the second test it seems that the coati understood the relationship between the latch and the opening of the door as he would apply the same movements and techniques to open the door. It would have been useful to be able to extend this test to have more reliable results and confirm the learning of this test.

It is interesting to note that even though it was the same individual coati opening both boxes, he did not use the same techniques on the two boxes. This was probably due to the different sizes of the boxes. The strength and weight of the coati are more important on the little box proportionally to the size and weight of the box. Several times he broke the strings which fixed the box to the ground and turned the box over. He could also see the whole of the little box by staying at the same place. To walk around the big box and change sides to shake it, took more time and energy, but this was easier on the little box. One of the techniques used to open the little box was to shake alternately between the two large sides. However, the coati never tried this method for the big box. In fact, he almost always tried to pull and shake the big box from the same place.

5 CONCLUSION

To learn, individuals have to be able to remember previous experiences, which was evident during this study: several times the coati remembered a location, movement, position or event. At Site C, we saw that coatis came more regularly to the site after having found bananas at the site. The coati came every day to Site A, and when he did not open the box, or left bananas in it, he always came back later the same day. Therefore, coatis are able to remember significant features (like food availability) of locations and return to those locations. Finding food in a location can make them modify their food research routine and, as for Site A, it can become part of a daily routine.

In order to get food, the coati is persistent. At Site A, he always came back when he left bananas in the box. He stayed at the study site sometimes for several minutes in order to open the box and get the banana. However, at Site C, the visits of the coatis became more frequent when the bananas were placed regularly, but visits did not become daily. Moreover, several times the coatis came and did not open the box, and did not return for a second attempt. It shows that the persistence of the coatis at Site C was far lower than the coati at Site A. The variation seen in persistence between the two sites may depend on the availability of food resources available at the two sites, or variations in the character of the coati's present in the two areas. A study in the same conditions with more than one individual could determine if the sex or the character (e.g. amount of fear response, general curiosity, etc.) of the coati can have also an impact on their persistence in getting food.

At Site A, the coati was able to remember the movements it did the previous day that resulted in opening the box, and so he was able to reduce the time needed to open it. It showed that the coati was able to memorize movement over a one-day period. For the big box, the coati had to enact different movements successively in order to open the box. He could remember several actions and distinguish between them, which allowed him to know when it was possible to open the box. His memory of the sequence of the actions seemed to start to break down during the 3rd test, when he began to do actions out of order, or skipped steps. While this made the amount of time it took for him to open the box erratic, he was always able to eventually remember, and enact all the actions necessary to open the box.

Finally, the coati always visually measured the distance between him and the stone which allowed him to know when the stone was about to fall. The first time when the stone fell, he seemed surprised and afraid: he got back very quickly, ran three or more meters away and smelled the stone before trying to open the box again. However, after a few tries he seemed to remember and anticipate the stone falling. When the stone was close to the edge of the box, he shook the box a little and then stepped back, and so on, until the stone fell and he did not run away or smell the stone when it fell. This study shows the coati was able to remember and repeat actions based on his previous experiences.

However, it seems that before the actions became a habit, he had to repeat them several times. For example, during the third test on the big box, the first days the coati broke the elastic to open the box even if in the previous he understood that he did not need to break it to open the box. After some days he opened the box without breaking the elastic, however 3 days after he broke the elastic again to enter into the box. Finally, after 4 days he stopped breaking the elastic to open the box. During this test, several times the coati entered the box without breaking the elastic, but the next day he tried again to break the elastic even though it was not necessary. One explanation of this is that he did not remember that he does not need to open the elastic to enter in the box and so, even if he entered in the box the previous day without breaking the elastic, he tried again to break the elastic the days after. It appears that to memorize or learn something, the coati needed to do it a number of times by chance. We can see in figure 10 that there are a lot of peaks which correspond to the time when he broke the elastic again to open the box. However, this explanation should be tested again because, as it was said before, during the third test the coati seemed to have difficulty remembering all the actions that he had to do.

A possible explanation for the coati trying to open the box without breaking the elastic during the third test of the big box, is that he wanted to improve the process of opening the box. For the second test on the big box (the stone and the elastic around the box), the coati was able to remember the movements required to open the box. In spite of this, during two days he tried to open the box without undoing all the locks (stone on the door) and just focused on the last movement that he learned (pull the elastic) which resulted in opening the box taking more time (see Fig. 9). Just pulling on the elastic he was unable to open the box, and therefore reverted back to his first chain of movements right after. I hypothesize that during these two days he tried to reduce the time needed to open the box by trying to skip one movement, failed, and so reverted, without improvement, to his first method of opening. We could so suppose that the coati was looking for solutions to reduce the time needed to get the food by trying to remove some actions in the chain of movements.

To finish, this study revealed different physical abilities of the coati. In short, the coati can pull with his arms and his mouth and he can push something with his nose. He has agile handling thanks to his fingers and craws which allow him to catch the string and the latch and to move them (lift the string from the piece of wood, turn the latch). His physical abilities explained some actions and choices during the study. For example, during the second on the big box once the coati climbed on the door (top of the box) and pushed the rock with his arms. Even if it seemed easier and quicker, he never did it again. Pushing with his arms was a movement only seen once during the entire study. We can conclude that even if it looks easier, it is not for the coati. His physical abilities determined which methods he used to resolve the tests.

This study will gain more reliability if these tests could be conducted over a longer time period with more than one individual.

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