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SHORT COMMUNICATION

# Yes, they can! Three-banded armadillos *Tolypeutes* sp. (Cingulata: Dasypodidae) dig their own burrows

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ABSTRACT. It is believed that the two species of *Tolypeutes* Illiger, 1811are the only armadillos that do not dig their own burrows, and that these species simply re-use burrows dug by other species. Here, we show that *Tolypeutes matacus* (Desmarest, 1804) and *Tolypeutes tricinctus* (Linnaeus, 1758) dig their own burrows. We describe the burrows and three other types of shelters used by them, and provide measurements and frequency of use of the different types of shelter. We have studied free-ranging individuals of *T. matacus* in two locations in Central Brazil and individuals of *T. tricinctus* in semi-captivity in the Northeast of Brazil. Individuals of *T. matacus* were found primarily in small burrows (76%), straw nests (13%), shallow depressions covered with leaf-litter (7%) or in straw nests made on shallow depressions (4%). Adult males and females of *T. matacus* did not differ in frequency of use of different types of shelter. Sub-adults *T. matacus* used shallow depressions and nests more often (40%) than adults (22%) and nurslings (10%). Nurslings of *T. matacus* reused the shelters more frequently (66%), than sub-adults (46%) and adults (35%). Adult females reused burrows and other types of shelter more frequently than adult males. *Tolypeutes tricinctus* rested mainly in burrows and under leaf-litter, but did not dig depressions or build nests. *Tolypeutes tricinctus* occasionally used burrows dug by *Euphractus sexcinctus* (Linnaeus, 1758), but *T. matacus* never used burrows dug by other species. Nursling *T. matacus* always shared shelter with an adult female therefore, both used shelters with similar frequency. Adult females and nurslings of *T. matacus* reused shelters in higher frequency. That can be explained by the fact that adult females with offspring tend to remain for consecutive nights in the same burrow when cubs are recently born. Due to their smaller body size, sub-adult *T. matacus* used shelter strategies that require less energetic effort more frequently than adults and nurslings. The habit of covering the burrow entrance with foliage and the burrow's reduced depth, indicates that *Tolypeutes* use of burrows is more likely to be related to parental care behavior and thermoregulation strategies than to defense mechanisms. We are confident that the burrows used for resting were indeed dug by *Tolypeutes* because, besides the direct observation of armadillos digging burrows, the measures of the burrows are very distinctive from those presented as characteristic for the co-occurring burrowing species and are congruent with *Tolypeutes* size and carapace shape. The newly acquired knowledge that species of *Tolypeutes* dig burrows can be used to increase the well-being of individuals kept in captivity by adapting enclosures to enable their digging behavior. In addition, this information contributes not only to the study of the ecology and natural history of the species, but can shed new light on the study of the anatomy of specialized diggers. *Tolypeutes* spp. can comprise the least fossorial of all living armadillo species, but they can no longer be classified as non-diggers.

KEY WORDS. Digging behavior, ecology, Xenarthra.

It is believed that the two existing species of three-banded armadillos, *Tolypeutes* are the only ones among the twenty extant armadillo species that do not dig their own burrows. Even though both species have rarely been studied in the wild, the information that the species of *Tolypeutes* simply re-use burrows dug by other species is often repeated in the scientific literature (Guimarães 1997, Eisenberg & Redford 1999, Smith 2007, Wetzel et al. 2008, Medri et al. 2011).



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*Tolypeutes* comprises *Tolypeutes matacus* (Desmarest, 1804) and *Tolypeutes tricinctus* (Linnaeus, 1758), both species with the unique ability to roll into an almost perfect ball as a defense mechanism (Eisenberg & Redford 1999, Wetzel et al. 2008). These armadillo species have an average head plus body length of 25 cm and an average weight of 1.1 kg (Eisenberg & Redford 1999). The southern three-banded armadillo, *T. matacus*, is found primarily in the dry forests of the central region of South America, including western Brazil, eastern and southern Bolivia, western and northern Paraguay, and northern Argentina. The Brazilian three-banded armadillo, *T. tricinctus*, occurs exclusively in the semi-arid scrub forests and savannas of the northeastern and central regions of Brazil (Wetzel et al. 2008, Feijó et al. 2015).

Unfortunately, most of the scarce information on the ecology and habits of these species is derived from captive animals (e.g., Bernier 2003), dead animals (e.g., Bolkovic et al.1995) or occasional observations (e.g., Sanborn 1930, Marini-Filho & Guimarães 2010). Until now, only three comprehensive studies on the ecology of these species have been conducted in the wild, and only one of them has been published. Guimarães (1997) and Ilmar Bastos Santos (unpublished data) radio-tracked individuals of *T. tricinctus* in Cerrado and Caatinga areas, while Barrientos & Cuellar (2004) monitored individuals of *T. matacus* in the Bolivian Chaco (Cuellar 2002, 2008, Barrientos & Cuellar 2004, Noss 2013). However, these studies provide only scarce and fragmented information about the use of shelters by *Tolypeutes*.

Here, we describe four types of shelters used by free-ranging *T. matacus*, including burrows, and provide evidence that both species of *Tolypeutes* are able to dig their own burrows. In addition, we provide descriptions, measurements, and information on the frequency of use of these burrows.

## *Tolypeutes matacus*

We studied individuals of *T. matacus* in two locations. The first site is the Santa Teresa Ranch, located in the region of the Amolar Mountain Ridge, in the western limits of the Brazilian Pantanal, Corumbá, Mato Grosso do Sul state (18°17′51″S, 57°30′35″W). The second site is the Duas Lagoas Ranch, located in the Brazilian Cerrado, in Cáceres Municipality, Mato Grosso state (16°10′13″S, 58°11′12″W).

Animals were captured by hand during active searches performed by foot, horse, using ATV vehicles or using pickup trucks. From the 39 captured individuals of *T. matacus*, 13 males (12 adults and one sub-adult) and 13 females (eight adults, three sub-adults and two nurslings) were monitored. We defined adults as individuals with more than 1 kg and sub-adults as weaned individuals with less than 1 kg. Individuals were tracked by VHF (during 2 to 5 months) using the homing-in to the animal method (Samuel & Fuller 1994) and/or through GPS telemetry (during 5 to 27 days). Glue-on VHF radios and GPS tracking devices were attached to the posterior part of the pelvic carapace (using flexible cyanoacrylate super glue and/or epoxy resin), following a protocol commonly used for hard-shelled turtles (e.g., Seminoff et al. 2002). Eight individuals also had an intra-abdominal VHF radio tracking device surgically implanted in their abdominal cavity (Hernandez et al. 2010). Animals were tracked daily, at varying times between 6:00 and 22:00 h. During monitoring, camera traps (Bushnell® Trophy Camera Brown Model 119435) were set to video mode (30 seconds duration) and placed in front of shelters (n = 51) occupied by tracked animals (n = 17) in different occasions.

We were able to locate and visualize the monitored individuals at 445 occasions, and on 67% of them, they were found resting. Resting records were made mainly during daytime. On these occasions, *T. matacus* were found in four types of resting-sites: small burrows (76%), straw nests (13%), shallow depressions covered with leaf litter (7%) or in straw nests made in shallow depressions (4%) (Figs. 1-5). Adult males and females showed no difference in frequency of use of the different types of shelter, both using burrows in higher frequency than any other type of shelter. Different age-classes used the types of shelter differently (Friedman $\chi^2 = 6$, df = 2, p = 0.05). Sub-adults used shallow depressions and nests more often (40%), when compared to adults (22%) and nurslings (10%).

Burrows dug by *T. matacus* have a dome-shaped entrance, 11 ± 1.98 cm high and 12.8 ± 2.1 cm wide, with a depth of 35 ± 9.4 cm (Table 1), ending in a nearly conical shape. Both males and females of all age classes used burrows for shelter. Burrow sharing was observed only between mothers and their single offspring. Females sharing their burrow with their nursling dug deeper burrows than did single individuals of either sexes (mean difference = 14.9 cm, t = 9.2, df = 65, p < 0.01). The use of burrows was observed in both open and densely vegetated areas (i.e. all available vegetation types). Burrows were built at the base of trees, between thorny bromeliads and bushes, soil build-ups, leaf litter build-ups, and dense bushes located in the middle of open areas with tall grass.

Table 1. Measurements of *Tolypeutes matacus* burrows at Santa Teresa ranch, Corumbá, Mato Grosso do Sul, and Duas Lagoas ranch, Cáceres, Mato Grosso.

| | N | Height (cm) | Width (cm) | Depth (cm) |
|---|---|---|---|---|
| Male | 59 | 10.9 ± 1.8 | 12.8 ± 1.7 | 30.3 ± 4.7 |
| Female | 52 | 11.1 ± 2.1 | 12.7 ± 2.4 | 38.7 ± 10.5 |
| Female with nurslings | 26 | 11.6 ± 2.8 | 13.3 ± 2.9 | 45 ± 8.5 |
| Female without nurslings | 26 | 10.6 ± 1 | 12.2 ± 1.7 | 29.6 ± 4.9 |
| Male and Female | 111 | 11 ± 2 | 12.8 ± 2.1 | 35 ± 9.4 |

Burrows used by a single armadillo were deep enough to fit an "unrolled" adult individual, even though individuals were usually found resting on their side (half way curled) or almost completely curled into a ball. Sixty percent of the burrows where armadillos were found resting had inconspicuous entrances, covered with grass and/or tree leaves (depending upon its availability in the surroundings), and occasionally with dirt.

Figures 1-5. (1) An individual of *Tolypeutes matacus* (arrow) resting inside its burrow at Santa Teresa Ranch, Corumbá, Mato Grosso do Sul. (2-3) Straw-nest built by *T. matacus* in a pasture area at Duas Lagoas Ranch, Cáceres, Mato Grosso: (2) upper view of the nest (circle) and (3) close-up of the same nest (arrow indicates the entrance of the nest). (4-5) (4) An almost imperceptible individual of *T. matacus* resting in a depression under leaf litter at Santa Teresa Ranch, Corumbá. The arrow points to the only visible part of the carapace. (5) The same GPS-fitted animal resting in the depression after we manually removed some of the leaf litter to expose part of its carapace (circled).

Despite the occurrence of three other armadillo species – *Euphractus sexcinctus* (Linnaeus, 1758), *Cabassous unicinctus* (Linnaeus, 1758) and *Dasypus novemcinctus* Linnaeus, 1758) – and at least four other burrowing animals (iguanas, agoutis, pacas and the spiny rat) at our study sites, *T. matacus* was never found using burrows resembling those belonging to other species.

Nests and depressions were also used as shelters by *T. matacus*. The "nest" nomenclature has already been used by Barrientos & Cuellar (2004), for *T. matacus*, due to the resemblance of the structure to a bird nest. In the present study, nests were composed of a structured assemblage of dry grass and straw. Using camera traps set to video mode, we recorded individuals of *T. matacus* actively assembling dry grass and straw to repair their nests (Appendix S1*). Nests were usually conspicuous, being built at soil level (76%) or in depressions (24%), in the pasture, under fences and occasionally inside dense bushes (Figs. 2-3).

The main difference between nests and depressions is that the nest is a structured assemblage of grass and straw, while when resting in depressions armadillos simply cover themselves with any type of vegetation available in the surroundings, with no structured arrangement. In addition, nests are structured in a tri-dimensional way standing above ground, while the foliage assembled over depressions tends to lay flat over the animal and becomes inconspicuous among the rest of leaf litter on the landscape.

When using depressions, *T. matacus* were completely covered with leaf litter at the soil level, leaving almost no visible evidence of their presence (Figs. 4-5). Occasionally, the armadillos were resting within the leaf litter in places of difficult access, such as areas with dense coverage of thorny lianas, dense bushes, and near roots of trees or fallen logs. However, it was not uncommon to observe the use of depressions in grasslands. It was not always possible to determine if the depressions used were natural to the relief of the landscape or dug by the animals. However, the depressions were always deep enough so that the animal could lay down on its side, cover himself with leaf litter and those leaves would be at similar level to the soil compared to the leaf litter in the surroundings. Armadillos were observed using nests and depressions on both open and densely vegetated areas (i.e., all available vegetation types). Both males and females of all age classes used nests and depressions as shelters.

Individuals were observed changing resting places on consecutive nights, using the same burrow or nest for consecutive nights, and reusing the resting place after long periods of no use (up to 36 days). Our radio-tracking and camera trap data shows

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that no individual was ever recorded using burrows or nests previously used by another monitored individual. The reuse of shelters varied among age classes ($\chi^2 = 8.7$, df = 2, p = 0.01), being more commonly observed in nurslings (66% of the inactivity records of the individuals were made in shelters previously used), followed by sub-adults (46%) and then adults (35%). Adult females were recorded reusing burrows and other types of shelter more frequently than adult males ($\chi^2 = 3.4$, df = 1, p = 0.06).

We were able to record other animals visiting the burrows built by *T. matacus*. We have recorded small rodents, small lizards and teju lizards entering and/or exiting the burrow. Hence, three-banded armadillos burrowing habits could be potentially benefiting other species.

### *Tolypeutes tricinctus*

Two individuals of *T. tricinctus*, a male and a female, were encountered in the backyard of a private property at Buriti dos Montes Municipality, Piauí state, Brazil (5°18'33"S, 41°5'52"W). They had been kept in that property for a period between one to two years. At this locality, it was possible to record burrows covered by leaf litter, built near trees and in open areas (Figs. 6-7). Additionally, we were able to observe an individual actively digging a burrow, when we approached it during capture procedures (Fig. 8).

Both individuals were captured and relocated to a reserve, Reserva Natural Serra das Almas, Crateús, Ceará state, Brazil (5°8'30"S, 40°54'58"W), where they were kept for six months (July 2014 to January 2015). When the animals were taken to Serra das Almas, they were initially placed in a temporary enclosure. The animals were placed inside burrows that had been dug by the staff. However, the animals did not use these structures and immediately began digging their own burrows. After seven days, the animals were relocated to their permanent semi-captive enclosure. The enclosure was established inside the reserve, in an area of 93 $m^2$ of deciduous forest typical to the Caatinga eco-region, where the species naturally occurs. The animals were enclosed in a fine meshed-wire fence to prevent the access or outlet of small mammals and any other burrowing animal known to occur in the area. Two burrows, probably dug by yellow-armadillos (*E. sexcinctus*) prior to the establishment of the facility and the arrival of the three-banded armadillos were present in the enclosure. Despite the fact that the pre-existing burrows were initially used by the three-banded armadillos, they built and used four new burrows during the period in which the armadillos were kept in the enclosure (Fig. 9). The enclosure was monitored with camera traps and it was possible to record the animals digging and using the new structures. Nevertheless, the animals continued to use the yellow-armadillo burrows occasionally.

The burrows dug by *T. tricinctus* in semi-captivity (n = 4) were 10.5 ± 1.4 cm high, 14 ± 2.9 cm wide, with depth of 43.5 ± 12.8 cm (Table 2). These animals also rested under leaf-litter, but did not dig depressions or build nests. They rested in open areas and under leaf-litter amongst thorny bromeliads and lianas.

Table 2. Measurements of burrows of *Tolypeutes tricinctus* kept in semi-captivity at Reserva Natural Serra das Almas, Crateús, Ceará.

| Burrow | Height (cm) | Width (cm) | Depth (cm) |
|---|---|---|---|
| #1 | 9.4 | 11.1 | 47.0 |
| #2 | 10.0 | 13.0 | 60.0 |
| #3 | 12.5 | 18.0 | 32.0 |
| #4 | 10.0 | 14.0 | 35.0 |
| Mean ± SD | 10.5 ± 1.4 | 14 ± 2.9 | 43.5 ± 12.8 |

Predictably, nursling *T. matacus* used shelters with similar frequency of *T. matacus* adults, since nurslings always shared shelter with an adult female. Sub-adults have a smaller body weight, when compared with adults, and were not seen accompanied by any adult individual. Their smaller body size might make the burrow building activity even more challenging, making it more likely for these individuals to use shelter strategies that require less energetic effort, such as nests and depressions covered with leaves.

Six, out of the eight adult females of *T. matacus* monitored, had nurslings (of varied sizes/ages) with them. The higher rate of reuse of shelter by females and the nurslings can be explained by the fact that adult females with offspring tend to remain for consecutive nights in the same burrow when the cubs are recently born.

The reduced depth of the burrow of *Tolypeutes* compared to other armadillo species burrows (e.g., Abba et al. 2005) and the habit of covering its entrance indicates that the use of burrows by these species is more likely to be related to parental care behavior and thermoregulation strategies (Maccarini et al. 2015) than to defense mechanisms. The cover of burrow entrances could contribute to buffer the burrow temperature, as observed to be an important thermoregulation strategy to other armadillo species (Maccarini et al. 2015). Unlike other armadillo species, which have carapaces that can easily be perforated by predators (Carter & Encarnação 1983), *Tolypeutes* can roll into an almost perfect ball (Eisenberg & Redford 1999, Wetzel et al. 2008) and is likely to be predated only by top predators that have the strength to punch the carapace and/or a mouth big enough to fit the entire animal (e.g., jaguars, pumas and manned wolves, Hannibal et al. 2015). Hence, *Tolypeutes* may not rely as strongly on burrows as a protection against predators as other armadillo species do (Carter & Encarnação 1983). Alternatively, the reduced depth of *Tolypeutes* burrow compared to other armadillo species burrows (e.g., Abba et al. 2005), could be related to the very hard soil types of our study areas, that could make the burrowing activity for this small species even harder.

Usually, the shape of the cross section of a burrow entrance is in accordance with the shape of the cross section of the body of the burrower. Hence, besides the direct observation of animals digging, the width and the shape of the entrance of a burrow can allow the identification of a burrowing species (Krieg 1929 apud Abba et al. 2007). As shown in Table 1 and 2, the dimensions and the dome-shape of the burrows where

Figures 6-9. (6) Burrow of *Tolypeutes tricinctus* with entrance covered by leaves at Buriti dos Montes, Piauí. (7) Animal leaving the burrow after removal of the leaf litter cover. (8) An individual of *T. tricinctus* actively digging as an escape behavior at Buriti dos Montes. (9) Burrow dug by *T. tricinctus* in semi-captive conditions at Reserva Natural Serra das Almas, Ceará.

the individuals of *Tolypeutes* were found are congruent with the animal size and carapace shape. When observing animals entering and exiting the small burrows, the perfect congruence of the shape of the carapace and that of the burrow is evident (Appendices S2* and S3*).

In addition, the observed measures of burrows of *T. matacus* are very distinctive from those presented as characteristic for the co-occurring armadillo species that dig dome-shaped burrows, such as *E. sexcinctus* (W = 24 cm, H = 20 cm) and *D. novemcinctus* (W = 20 cm, H = 21 cm, Borges & Tomás 2008). The remaining co-occurring species of armadillo, *C. unicinctus*, is known to dig perfectly round burrows oriented vertically to the ground (Borges & Tomás 2008), presenting a very distinct pattern from the burrows where the *Tolypeutes* individuals were found resting. Finally, the spiny rat is known to dig long and complex tunnels and iguanas only dig burrows in close proximity of water bodies, during the breeding season (Z. Campos, pers. comm.). There is no reason to believe that *T. matacus* would be using or modifying other species burrows, since it is the smallest armadillo species occurring in the studied areas, using the shortest burrows found there. A species that uses another species' burrows could change its shape, but would not be able to make a burrow smaller than its original size. Finally, we were able to record free-ranging individuals actively digging burrows at Duas Lagoas ranch (Appendix S4*), leaving no further doubt on the ability of *T. matacus* to build the structures in which they had been recorded resting.

Vizcaíno & Milne (2002), based on anatomical features and the lack of direct behavioral observations in the field, misclassified *Tolypeutes* as a non-digger species. However, our direct observations demonstrate that, like all other armadillo species, *Tolypeutes* do dig their own burrows. These animals possess such long claws on the toes of their forefeet that they actually have to walk on their claws (Figs. 10-11, Eisenberg & Redford 1999). Such a remarkable apparatus is suitable for digging, and it is comparable with the same structure observed in other well-known, burrow-digging armadillo species. Yellow armadillos, for example, usually present body sizes two to three times larger than the three-banded armadillos, and their longest fore-claw is similar in size to that of the average *Tolypeutes* (N. Attias pers. obs.). Hence, three-banded armadillos do not seem to have any anatomical constraint that would impair them to be efficient

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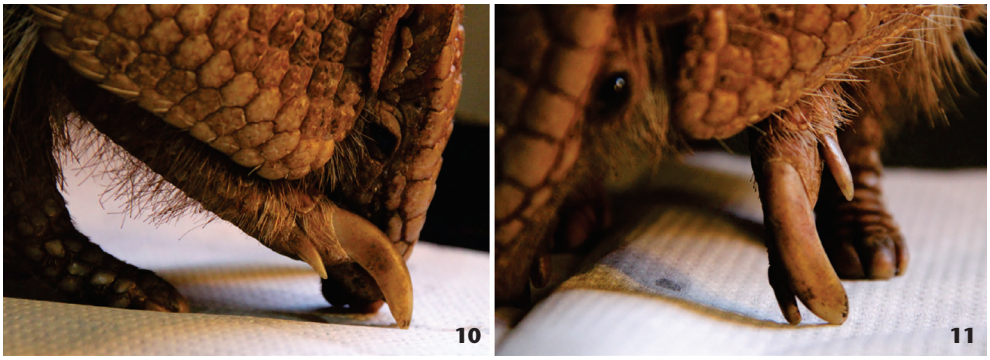

Figures 10-11. (10) Lateral and (11) frontal view of *Tolypeutes matacus* front claws.

diggers. Evolutionarily, it would be unexpected that such an apparatus evolved for foraging purposes alone, as opposed to serving a dual function, as is evident in all the other armadillos.

Eisenberg & Redford (1999) only recognized that "*Tolypeutes* can occasionally dig shallow foraging holes". Indeed, we have recorded *Tolypeutes* digging shallow foraging holes using their fore claws. Nevertheless, we have also seen those animals digging burrows up to 54 cm deep and using them as shelters. The individuals of *Tolypeutes* used their front claws to dig and their hind legs to push away the accumulated dirt, just like other armadillo species do when digging their burrows (Appendix S4*). Borges & Tomás (2008) previously described a specific pattern for *T. matacus* burrows. They were not able to record animals actively digging or using the assigned burrows, but relied on tracks in and out of burrows to state that *T. matacus* constructs burrows with almost circular entrances of 13 to 14 cm in diameter, which is similar to the pattern we documented at our study sites.

The newly acquired knowledge that these species dig burrows, might help to clarify some incongruence between anatomical aspects of the limbs of armadillos and their digging behavior, found by Vizcaíno & Milne (2002). It can also be used to increase the well-being of individuals kept in captivity by adapting enclosures to enable their digging behavior, especially during the breeding season. This new information on the behavior of *Tolypeutes* species contributes not only to the study of the ecology and natural history of the species, but can shed new light on the study of the anatomy of specialized diggers. *Tolypeutes* spp. can comprise the least fossorial of all living armadillo species, but they can no longer be classified as non-diggers.

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## APPENDICES

About the Online Supplementary Material (available with the HTML version of the article at http://www.scielo.br/zool):

Appendix S1. An individual of *Tolypeutes matacus* gathers straw to repair the nest it is currently using. The video is a compilation of several (30 sec.) videos captured by a camera trap set in front of the nest. The activity of gathering straw and bringing it to the nest was recorded for a period of one hour on July 21st, 2015 at Duas Lagoas Ranch, Cáceres, Mato Grosso. To enable the visualization of the complete behavior in a shorter time, the video was edited and its speed is four times the speed of the actual behavior.

Appendix S2. An individual of *Tolypeutes matacus* enters its burrow at Santa Teresa Ranch, Corumbá, Mato Grosso do Sul. In this video it is possible to observe the perfect congruence between the shape of the carapace of the animal and the burrow it builds.

Appendix S3. An individual of *Tolypeutes matacus* exits its burrow that had the entrance covered by leaf litter, at Santa Teresa Ranch, Corumbá, Mato Grosso do Sul. Again, in this video it is possible to observe the perfect congruence between the shape of the carapace of the animal and the burrow it builds.

Appendix S4. An individual of *Tolypeutes matacus* actively digging a burrow from scratch at Duas Lagoas Ranch, Cáceres, Mato Grosso. The recording of the digging behavior began at 21:14 h and ended at 21:18 h. The mid-section of the video had its speed doubled to enable the visualization of the behavior in a shorter time.