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From instinct to experience: understanding feeding behaviour in *Python regius* (Shaw, 1802)

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Abstract. Research on the cognitive abilities and behaviour of reptiles is quite limited, largely due to the challenges in accurately quantifying and interpreting observations made in both natural and controlled settings. This limitation is particularly notable in the study of snakes, where investigations into the cognitive skills of this suborder are scarce.

In this study, we focused on the feeding behaviour of young *Python regius* specimens to explore whether these behaviours are purely instinctual or if they involve learning and/or using previously acquired knowledge. We observed eight naive juvenile individuals to analyse their feeding behaviour. Our hypothesis proposed that as these snakes gained experience in the first month of their lives, their feeding efficiency would improve. We recorded and analysed the time allocated to various stages of their feeding behaviours during their initial four feedings.

The findings we obtained were unexpected and partially contradicted our initial assumptions. Ultimately, we concluded that the feeding efficiency in these reptiles presents a complex interplay of instinct, past experiences, and certain factors that remain challenging to explain within the framework of existing specialised literature.

Keywords: Ball pythons, feeding behaviour, feeding efficiency, snake learning, time budget.

Introduction

Historically, reptiles were regarded as a stimulus-bound, slow-learning group with a limited behavioural repertoire (Burghart, 1977). As they have a relatively small and simple brain compared to endotherms (Burghart, 1977), they were labelled as ”reflex machines” (Jerison, 1973), ”intellectual dwarfs" (Turner, 1892), or even completely inferior (Sagan, 1977; MacLean, 1985). However, new research into the cognitive abilities of reptiles is increasingly challenging these labels, as they reveal an impressive range of problem-solving, learning, and social skills (De Meester and Baeckens, 2021).

In their natural element, reptiles are actually far more than underperforming, pre-programmed robots. They show a high propensity for experience-based learning in areas such as homing behaviour, territoriality, formation of food preferences, and social dominance relationships (Burghart, 1973). Studying cognition under these natural conditions would be the preferred approach, as it makes the results more relevant, but reptiles are poorly suited to this type of experiment (Whiting and Noble, 2018). This seemingly rich behavioural palette may be responsible for the upsurge in reptile cognition research over the last decade (Wilkinson and Huber, 2012; Burghardt, 2013, Matsubara *et al*., 2017, De Meester and Baeckens, 2021); however, little experimental research has been conducted compared to other taxa in vertebrate phylogeny, particularly mammals and birds (Szabo *et al*., 2021).

The main reason for this, apart from the traditional reputation mentioned above, is the difficulty in designing a meaningful study, due to the lack of efficient reinforcers and motivators (e.g., food, which is commonly used as a motivator for cognitive tasks, is not very attractive to reptiles compared to other vertebrates - Burghart, 1977). In cognitive studies performed on snakes, these design difficulties become even greater. Their sedentary lifestyle in captivity, the difficulty of using food as a reinforcer, and the lack of limbs to press levers mean that this reptilian suborder is generally avoided.

Additionally, the total absence of parental care, which requires newborn snakes to find and capture prey without prior experience, suggests that instincts play a crucial role in their feeding behaviour. Newborn individuals can perform their tasks accurately without previous experience, but there is also evidence in the literature that the predisposition for a particular behaviour is not necessarily genetically determined (Suboski, 1992; Nafus *et al*., 2021).

Regarding the relationship between cognition and feeding, the literature is sparse and somewhat contradictory.

As far as initial chemosensory feeding responses are concerned, the reaction to a favoured prey item can be modified by experience (*Thamnophis sirtalis* to

Eisenia foetida and *Poecilia reticulata,* and *Drymarchon couperi* to mice), whereas in other cases it appears to be completely unaffected (*Thamnophis sirtalis* to tadpoles and frogs) (Fuchs and Burghardt, 1971; Arnold, 1978, Goetz *et al.* 2018).

The prey capture tactics described in the literature also appear to be prone to some experience-based learning. In a study on *Coleognathus helena*, concerning the response to different prey sizes, Mehta (2009) found that experience led to a better capture technique (forebody capture), a more complex prey restraint method, and an increase in the ingestion of dead prey versus still live prey. However, Mori (1993) found no effect of recent experience with large or small prey on subsequent capture and restraint behaviour in *Elaphe climacophora*. And, Ryerson (2020) found a decline in strike performance of *Python regius* over a three year time period.

Given this diversity of behavioural expressions, we were interested in testing whether neonate naïve constrictor snakes are able to improve the effectiveness of their feeding technique throughout their first four feeding sessions. More specifically, does experience promote an improvement in detection, constriction, and ingestion? We considered feeding behaviour to be more efficient if it led to a shorter duration of the time required for it (Bealor and Saviola, 2007). Based on the existing literature and anecdotal observation, we tried to answer the above question by formulating two starting hypotheses:

1. Feeding is not purely an instinct-driven behaviour.

2. There will be an improvement in the efficiency of feeding behaviour in the form of reduced time.

Materials and methods

The study was conducted in May 2024 at the herpetology laboratory of Babeș-Bolyai University's Vivarium. The experimental group consisted of eight neonate, naive *Python regius* (Shaw, 1802) (IUCN near threatened, number P1-P8), a constrictor species native to West and Central Africa (D'Cruze, 2020), obtained by captive breeding. Animal husbandry, management, and experiments were conducted in accordance with the ethical standards established by the World Association of Zoos and Aquariums (WAZA, 2023).

To have a more compact experimental group, we used only females with no significant variation in size and weight (initial measurements: 528.50 mm ± 12.78 mm SD average length, and 64.12 g ± 1.96 g SD average mass) and across experiment-time. The prey size used was approximately 15% of the snake's body weight. The animals were housed separately, in opaque Tupperware plastic containers (27 cm x 17 cm x 8 cm), which were equipped with bark mulch substrate, a hiding place, and a water bowl, illuminated with indirect sunlight, and had a temperature difference between day and night of 20/27 °C (Westhoff, 2005).

During the three-week experiment, we carried out four test feedings at one-week intervals. The first test feeding coincided with the very first feeding of the snakes and took place at the age of 2 weeks. To minimise handling stress in the snakes and obtain the best possible quality data, all test feedings were conducted directly in the housing containers. Preparations for the experiment began by replacing the opaque lid of the Tupperware container with a clear glass panel and positioning the container under the tripod-mounted camera. The experiments were filmed with a GoPro 7 camera placed 40 cm above the container. Playing back the videos (Windows Media Player), we measured the time budget (Brockman, 1994) of the following behavioural variables: 1) time to first strike, 2) constriction time, and 3) ingestion time.

The variables were measured in seconds and are defined as follows:

1) time to strike (S) was defined as the time between the insertion of the mouse in the housing container and the snake's strike.

2) constriction time (C) was defined as an interval starting with the strike and lasting until the experimental animal releases the initial bite or dislodges.

3) ingestion time (I) starts at the end of the constriction and also includes vomeronasal sniffing and adjustment of prey after constriction, not just the actual swallowing.

We also measured the total feeding time (T) that starts with the strike and is defined as a sum of the constriction time (C) and the ingestion time (I); and additionally, the time of the experiment in days after the start, with the first day of the experiment considered day 1, and the last, day 28.

To analyse the data, we first checked the distributions for each variable using a Shapiro-Wilk test (shapiro.test in RStudio, RStudio Team, 2025). Because the test results showed a non-normal distribution of the data in all cases ($P < 0.01$), we further used non-parametric tests to check for differences between trials accounting for repeated measures on individuals. For each variable (S, C, I, and T), we applied a Friedman test, treating individual identity as a blocking factor and feeding occasion as the within-subject factor. To maintain a complete block design, individuals that did not feed during the first trial, were excluded from these analyses. When the Friedman test indicated a significant effect of feeding occasion, post-hoc pairwise comparisons between trials were performed using Wilcoxon signed-rank tests with Holm correction for multiple comparisons. All analyses were conducted in R (RStudio Team, 2025). We also computed a correlation test with the method "Spearman's rank correlation" between the time of experiment in days and each variable (cor.test in RStudio, RStudio team, 2025).

Results

There were significant differences only between the trials regarding the time to strike – S (Tab. 1). The first trial had a higher value of S, which declined with time (Fig. 1). However, post-hoc pairwise comparisons using Wilcoxon signed-rank tests with Holm correction did not identify significant differences between individual feeding occasions (all adjusted $p \geq 0.19$).

Constriction time (C) varied slightly between trials, but had an overall lower median value on the fourth occasion (Fig. 2).

In the case of ingestion time, we can observe the tendency for a longer time in trial 3, and a similar median time with less variability in trial 4 (Fig. 3).

The median values of the total feeding time showed a tendency to increase, showing in the third and fourth trials longer and slightly longer times than those in the first two trials (Fig. 4).

Table 1. Results of the Friedman test comparisons between trials for all four variables measured (S – time to strike, C – constriction time, I – ingestion time, T – total feeding time). Significant values are underlined.

Parameters	chi squared	df	P value
S	9.600	<u>3</u>	0.022
C	4.627	3	0.201
I	5.000	3	0.172
T	3.800	3	0.284

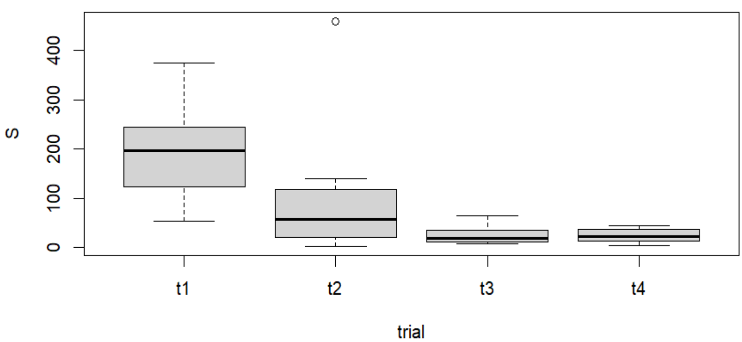

Figure 1. Time to strike values (S measured in seconds) for all *Python* juvenile individuals in the four feeding trials. Boxplots represent median values (thick line inside the box), interquartile range (the box), maximum and minimum values (whiskers), and outliers (empty circles).

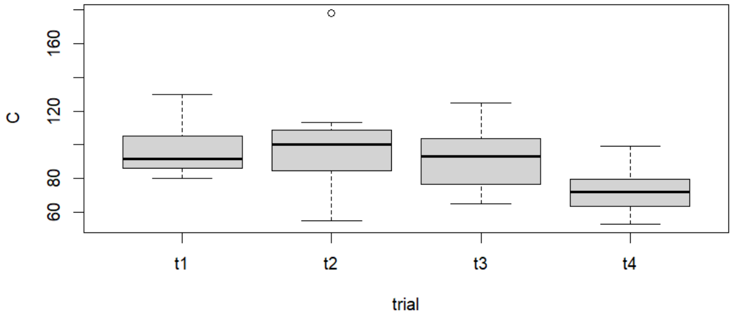

Figure 2. Constriction time (C measured in seconds) for all *Python* juvenile individuals in the four feeding trials. Boxplots represent median values (thick line inside the box), interquartile range (the box), maximum and minimum values (whiskers), and outliers (empty circles).

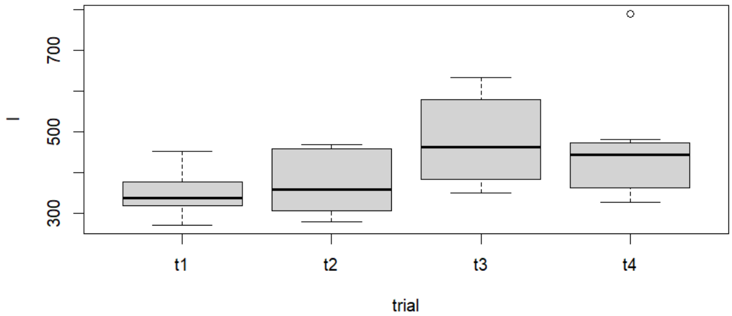

Figure 3. Ingestion time (I measured in seconds) for all *Python* juvenile individuals in the four feeding trials. Boxplots represent median values (thick line inside the box), interquartile range (the box), maximum and minimum values (whiskers), and outliers (empty circles).

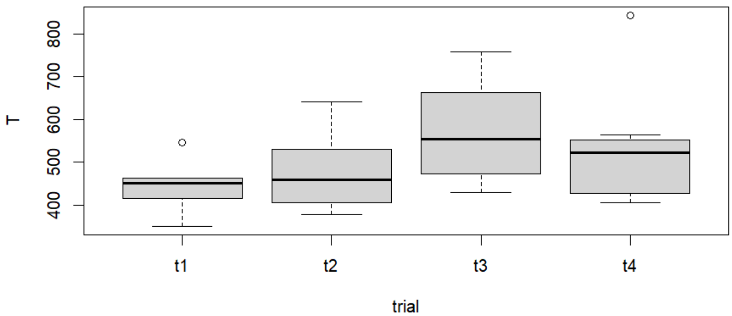

Figure 4. Total feeding time (T measured in seconds) for all *Python* juvenile individuals in the four feeding trials. Boxplots represent median values (thick line inside the box), interquartile range (the box), maximum and minimum values (whiskers), and outliers (empty circles).

The correlation analysis showed a strong negative correlation between time to strike (S) and time, and a more moderate negative correlation between constriction time (C) and time (Tab. 2). Another significant but only moderate positive correlation was between ingestion time (I) and time (Tab. 2). Total feeding time was not significantly correlated with time of the experiment (Tab. 2).

Table 2. Spearman rank correlation results for each variable (S – time to strike, C – constriction time, I – ingestion time, T – total feeding time) with experiment time.

S	C	I	T
Rho = -0.616, P < 0.001	Rho = -0.489, P = 0.006	Rho = 0.439, P = 0.015	Rho = 0.307, P = 0.099

Discussion

In this study, we tested whether the feeding behaviour of the Ball python is completely driven by instinct or whether it is subject to improvement in time and with experience. For this purpose, we measured the time budget invested in time to strike (S), constriction (C), ingestion time (I) and total feeding time (T) of a cohort of 8 newborn naive animals, throughout their first four feedings.

The results show a clear and linear improvement in some of these parameters, which is evidence of behaviour altered by experience. However, in the case of our second hypothesis regarding the decrease of the total feeding time, the result is quite different than expected, and suggests that there are other factors besides feeding efficiency that determine feeding time management.

The first parameter we measured was the time to strike. Here, our analysis showed a significant reduction in time, even though no particular pair of feeding occasions showed a dramatic contrast. This can be explained by the gradual trend this parameter displayed during all trials, rather than a steep change. The behavioural dynamics of the snakes were very close to what we hypothesised for this stage, namely, there was a clear, chronological improvement in the time budget as the prey was progressively more quickly and more eagerly attacked (Fig. 1, Tab. 1, Tab. 2).

We view these decreasing attack latencies as a form of associative learning in which the naive animals learn to associate two cues through positive reinforcement. More specifically, they have learned to associate the visual and chemical stimuli of the prey (conditioned stimulus) with the reward (unconditioned stimulus, the taste of the prey and post-feeding satiation).

The three other measured parameters (constriction time, ingestion time, and total feeding time) are interconnected and mutually dependent, i.e. total feeding time is the sum of the other two, so we will discuss the results accordingly.

In our experiment, we found that the animals showed a tendency to improve the ability to constrict the prey, expressed in a progressively shortened constriction time (Fig. 2, Tab. 2). Increased muscle efficiency could improve constriction patterns (Moon, 2000), but, at the same time, the snakes did not show significant dimensional gains during the three-week experiment. Consequently, we consider this progress as evidence of learning ability and subsequent utilisation of the acquired knowledge, and also a confirmation of our two initial hypotheses.

In contrast with our initial assumption, the ingestion time has shown a tendency to increase throughout the experiment (Fig. 3, Tab. 2). Despite an accelerated constriction rate, this caused the total feeding time to also increase from t1 to t4 (Fig. 4).

Thus, there was a clear difference in the overall feeding duration, with a linear relationship between time spent feeding and experience, which, however, proceeded in a direction contrary to our initial hypothesis. This outcome was not anticipated. The most obvious explanation was that the snakes at t4 were less skilled at ingesting their prey than at t1. However, such a circumstance is extremely unlikely, and the opposite is the most credible alternative. If we consider the first feeding as pure instinctual and the last feeding as the effect of a learning curve, it can be inferred that the protracted ingestion period must confer a certain benefit to the animals.

The biggest problem with the lengthened ingestion time is the unnecessary exposure to predation (Garland and Arnold, 1983). But what if the animals were never exposed to the smell or sight of a predator, and simply reacted to the consistent absence of stressors that overwrote their instinctual fearfulness, through learning? And, if so, is a longer ingestion time even beneficial for the animal? Does it increase ingestion efficiency? Why would they do it, anyway? The truth is that we found no mention of such a behaviour in the existing literature, so this takes us into the realm of speculation and educated guesswork. Nevertheless, we will attempt to make some inferences. Sometimes the snakes may exhibit more cautious or meticulous feeding behaviours, which can slow down the ingestion process. This could include repositioning the prey, adjusting its position, or needing more time to secure the prey within their jaws. If the snake is not fully hungry, it may take longer to swallow because it is not overly eager to consume its prey, or it simply has a lower energetic cost and a better energetic return. A slower swallowing process may reduce oesophageal abrasion by producing more saliva, and it could help with the kinematics of the jaw apparatus during prey handling and ingestion.

To summarise, our study highlighted a circumstance in which instinct, learning, and ecology interplay during the feeding process of the Ball python, with the unexpected outcome that the time spent ingesting prey tended to increase with gaining experience.

Furthermore, we hope that we have succeeded in debunking the stereotype that reptiles are merely "reflex machines" and confirming that cognition sometimes takes the road less travelled.

Authors contributions: Conceptualization, methodology, writing, and supervision was realised by Octavian Craioveanu; investigation, data collection and writing was realised by Vlad Stoicescu; data curation, data analysis, and writing was realised by Cristina Craioveanu. All authors have read and agreed the published version of the manuscript.

References

Arnold, S.J. (1978). Some effects of early experience on feeding responses in the common garter snake, *Thamnophis sirtalis. Anim. Behav. 26* (2), 455-462. https://doi.org/10.1016/0003-3472(78)90062-3

Bealor, M.T. & Saviola, A.J. (2007). Behavioural complexity and prey-handling ability in snakes: Gauging the benefits of constriction. *Behav. 144*(8), 907–929. https://doi.org/10.1163/156853907781492690

Brockmann, H.J. (1994). Measuring behaviour: *Ethograms, kinematic diagrams, and time budgets.* Technical document, Department of Biology, University of Florida, USA.

Burghardt, G.M. (1973). Instinct and innate behavior: Toward an ethological psychology. In J. A. Nevin & G. S. Reynolds, *The study of behavior: Learning, motivation, emotion, and instinct*. Scott, Foresman.

Burghardt, G.M. (1977). Learning processes in reptiles. In: *Biology of the Reptilia: Ecology and behaviour* (Gans, C. & Tinkle, D.W., eds). Academic Press, London. 555-681.

Burghardt, G.M. (2013). Environmental enrichment and cognitive complexity in reptiles and amphibians: concepts, review, and implications for captive populations. *Appl. Anim. Behav. Sci. 147*, 286–298. https://doi.org/10.1016/j.applanim.2013.04.013

D'Cruze, N., Harrington, L.A., Assou, D., Green, J., Macdonald, D.W., Ronfot, D., Segniagbeto, G.H. & Auliya, M. (2020). Betting the farm: A review of ball python and other reptile trade from Togo, West Africa. *Nat. Conserv*. 40, 65–91. https://doi.org/10.3897/natureconservation.40.48046

De Meester, G. & Baeckens, S. (2021). Reinstating reptiles: from clueless creatures to esteemed models of cognitive biology. *Behaviour. 158*(12-13), 1057-1076. https://doi.org/10.1163/1568539X-00003718

Fuchs, J.L. & Burghardt, G.M. (1971). Effects of early feeding experience on the responses of garter snakes to food chemicals. *Learn. Motivat. 2*, 271-279. https://doi.org/10.1016/0023-9690(71)90027-0

Garland, T. & Arnold, S.J. (1983). Effects of full stomach on locomotory performance of juvenile garter snakes (*Thamnophis elegans*). *Copeia. 4,* 1092-1096. https://doi.org/10.2307/1445117

Goetz, S.M., Godwin, J.C., Hoffman, M., Antonio, F. & Steen, D.A. (2018). Eastern indigo snakes exhibit an innate response to pit viper scent and an ontogenetic shift in their response to mouse scent. *Herpetologica 74*(2), 152-158. https://doi.org/10.1655/Herpetologica-D-17-00070.1

Jerison, H.J. (1973). Evolution of the brain and intelligence. *Academic Press*, New York, NY. https://doi.org/10.1126/science.184.4137.677

MacLean, P.D. (1985). Brain evolution relating to family, play and the separation call. *Arch. Gen. Psychiatry. 42*, 405-417. https://doi.org/10.1001/archpsyc.1985.01790270095011

Matsubara, S., Deeming, D.C. & Wilkinson, A. (2017). Cold-blooded cognition: New directions in reptile cognition. *Curr. Opin. Behav. Sci. 16*, 126-130. https://doi.org/10.1016/j.cobeha.2017.06.006

Mehta, R.S. (2009). Early experience shapes the development of behavioral repertoires of hatchling snakes. *J. Ethol. 27*, 143–151. https://doi.org/10.1007/s10164-008-0097-9

Moon, B. (2000). The mechanics and muscular control of constriction in gopher snakes (*Pituophis melanoleucus*) and a king snake (*Lampropeltis getula*). *J. Zool. 252*, 83-98. https://doi.org/10.1111/j.1469-7998.2000.tb00823.x

Mori, A. (1993). Does feeding experience with different size of prey influence the subsequent prey-handling behavior in *Elaphe climacophora*? *J. Ethol. 11*, 153–156. https://doi.org/10.1007/BF02350050

Nafus, M.G., Xiong P. X., Paxton, E.H., Yackel Adams A.A. & Goetz, S. M. (2021). Foraging behavior in a generalist snake (brown treesnake, *Boiga irregularis*) with implications for avian reintroduction and recovery. *Appl. Anim. Behav. Sci. 243*, 0168-1591. https://doi.org/10.1016/j.applanim.2021.105450

Ogle, D.H., Doll, J.C, Wheeler, A.P. & Dinno, A. (2025). *FSA: Simple fisheries stock assessment methods*. R package version 0.10.0, https://CRAN.R-project.org/package=FSA

RStudio Team. (2025). RStudio, 2025.05.1+513 "Mariposa Orchid" Release (ab7c1bc795c7dcff8f26215b832a3649a19fc16c, 2025-06-01) for windows

Ryerson, W.G., (2020) Ontogeny of strike performance in ball pythons (*Python regius*): A three-year longitudinal study. *Zool., 140*. https://doi.org/10.1016/j.zool.2020.125780

Sagan, C. (1977). The dragons of Eden: Speculations on the evolution of human intelligence. *Random House*, New York, USA. https://doi.org/10.1002/ajpa.1330500115

Suboski, M.D. (1992). Releaser-induced recognition learning by amphibians and reptiles. *Animal L&B 20*, 63–82. https://doi.org/10.3758/BF03199947

Szabo, B., Noble, D.W.A. & Whiting, M.J. (2021). Learning in non-avian reptiles 40 years on: advances and promising new directions. *Biol. Rev. 96*, 331-356. https://doi.org/10.1111/brv.12658

Turner, C.H. (1892). A few characteristics of the avian brain. *Science 19*, 16-17. https://doi.org/10.1126/science.ns-19.466.16

Westhoff, G. (2005). Expert report on the suitability of Geo Rack I systems (manufacturer: Lanzo Herp Cages) for species-appropriate husbandry and rearing of the ball python (*Python regius*). https://www.lanzo-herp.de/Gutachten/Expertises

Whiting, M.J. & Noble, D.W.A. (2018). Lizards - measuring cognition: practical challenges and the influence of ecology and social behaviour. In: *Field and laboratory methods in animal cognition* (eds N. Bueno-Guerra and F. Amici). 266–285. https://doi.org/10.1017/9781108333191.014

Wilkinson, A. & Huber, L. (2012). Cold-blooded cognition: reptilian cognitive abilities. In: *The Oxford handbook of comparative evolutionary psychology* (eds J. Vonk and T. K. Shackelford). 129–141. https://doi.org/10.1093/oxfordhb/9780199738182.013.0008

World Association of Zoos and Aquariums (WAZA). (2023). WAZA Code of Ethics [PDF document]. WAZA | World Association of Zoos and Aquariums.