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Personality assessment of headstart Texas horned lizards (*Phrynosoma cornutum*) in human care prior to release

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ABSTRACT

The study of animal personality is a growing field that has applications for welfare of animals living in captive settings. We measured personality traits (activity, exploration, and neophobia) in Texas horned lizards (*Phrynosoma cornutum*) living in human care before they were released to their natal habitat as part of a headstart program. We found evidence of consistent inter-individual differences in activity and exploration, but not neophobia. We also identified a positive correlation between activity and exploration, such that more active lizards were also more likely to explore a novel environment. These results suggest that Texas horned lizards have individual differences in response to their environment, which can inform husbandry decisions. Extensions of this work could also have implications for conservation of Texas horned lizards and for headstart programs focused on reptiles.

1. Introduction

Integrating knowledge about animal behavior into routine care and welfare assessments is crucial for monitoring and maintaining excellent animal welfare. However, caretakers sometimes lack empirical criteria for assessing animal welfare of reptiles in human care, partially because reptiles have been historically understudied with regard to their welfare (Melfi, 2009). Recent work into reptile welfare has shown promising applications for husbandry and care in captive settings (e.g., pets, zoo specimens, etc.). For instance, providing enrichment has been shown to reduce escape behavior in captive turtles (Bannister et al., 2019) and increase welfare for leopard geckos (Bashaw et al., 2016). Moreover, snakes have shown preference for enriched over non-enriched habitats (Hoehfutner et al., 2021). As research progresses, we continue to gain insight into reptile behavior and the important implications of these datasets for improving husbandry programs for reptiles moving forward.

The burgeoning field of animal personality research has applications for advancing welfare science for reptiles in zoos (Moszuti et al., 2017; Tetley and O'Hara, 2012). In fact, personality has already been shown to relate to many animal behavioral responses that are relevant to life in captive environments, including how animals learn to avoid certain dangers, whether they participate in self-harm behaviors (such as feather-plucking), and whether they possess the ability to acquire food for growth (van Oers and Naguib, 2013). There have been recent calls for more research into personality in reptiles (Waters et al., 2017), since individual animals differ consistently in their behavioral tendencies (i.e., have personality) (Sih et al., 2004; Reale et al., 2007). Here we use "personality" to refer to among-individual variation in average behavior across repeated observations (Dingemanse and Wright, 2020). Recent work has already shown evidence of personality in reptiles (e.g., Cote et al., 2010; Horvath et al., 2016, 2017, 2019; Michelangeli et al., 2021; Galliard et al., 2013), and personality could have welfare implications in captive settings. For instance, Aldabran giant tortoises showed inter-individual variation in preferences when given the choice among

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different stimuli, demonstrating the importance of considering choice and control for reptile welfare in captivity (Learmonth, 2020). Using knowledge of individual differences, caretakers can tailor their husbandry approaches to offer opportunities to the animals in their care for choice and control.

Beyond leveraging individual differences for welfare purposes, personality studies are critically needed for captive reptile conservation programming, including headstarting initiatives where reptiles are bred and/or raised in captivity before being released into the wild to bolster native populations or prior to translocation (Hammond et al., 2021; Kelleher et al., 2018; Homberger et al., 2021). Personality assessments of reptiles living in human care until reintroduction into the wild may help predict traits correlated with increased survivorship of headstarted animals post-release (Allard et al., 2019; de Azevedo and Young, 2021; Bremner-Harrison et al., 2004). Beyond predicting or selecting candidates for reintroduction, it is also important to evaluate personality in headstart programs to help managers make decisions about headstart initatives, such as whether any behavioral training (e.g., antipredator training) or exposure to novel stimuli or live predators (Alberts, 2007; Tetzlaff et al., 2019; Watters and Meehan, 2007) is needed (though this was not a goal of the current study). Here, we leveraged animal personality assessments to determine if Texas horned lizards (*Phrynosoma cornutum*) in a headstart program varied in their behavioral responses and maintained consistency across time while they were living in human care.

Historically, Texas horned lizards were distributed broadly across the southwestern United States and northern Mexico, but populations are believed to be declining across this range (Price, 1990; Carpenter et al., 1993; Donaldson et al., 1994; Vesy et al., 2021). Currently, *P. cornutum* is listed as vulnerable in Arizona, Colorado, and Texas, and imperiled in Arkansas and Missouri, as well as in Oklahoma where it is considered a Tier I species of greatest conservation need (Vesy et al., 2021; Oklahoma Department of Wildlife Conservation, 2016). As such, Texas horned lizards are now the focus of several headstart programs in Texas and Oklahoma, where lizards are bred and/or raised in captivity until they reach a target age or weight and then are reintroduced to native habitat to increase the chance of their survival. Although personality may be an important factor in explaining success of lizards in headstart programs, and has significant implications for lizard welfare, nothing is known about personality in *P. cornutum*. If individuals of this species exhibit repeatable behavioral responses, assessments could be used by caretakers to measure personality in their own collections and make more informed management decisions for headstarting programs. Here we address this gap in understanding personality of Texas horned lizards in captivity.

In this study we tested whether a group of Texas horned lizards, originally collected as eggs in the wild before being hatched and raised in human care, exhibited consistent inter-individual differences across two time periods (four trials per each of the three tests). We next asked if personality traits were related, thereby forming a behavioral syndrome, which would indicate that traits coevolved or are associated via pleiotropy (Sih et al., 2004; Sih and Bell, 2008). We predicted that more active lizards would be less neophobic and more explorative (Sih et al., 2004).

2. Methods

We assessed the personalities of 15 lizards that were native to Tinker Air Force Base in Oklahoma City, Oklahoma, United States but had been living in human care at the Oklahoma City Zoo and Botanical Garden's Lizard Lab in Oklahoma City, Oklahoma for approximately 22 months. The subjects were collected as eggs between 14 and 16 July in 2019 from Tinker Air Force Base and incubated in human care. Eggs were incubated at 83 degrees and ~80% humidity, with an incubation period of ~60 days from egg laying to hatching. Lizards were housed individually in 75.71-liter (20-gallon) glass aquariums (~76.20 cm × 33.02 cm × 33.02 cm) with an ambient end of the environment at roughly 24 °C and basking end at 37 °C (home enclosure). Basking lamps were on for eight hours daily (09:00–17:00) while over-head UVB fixtures facilitated calcium metabolism and provided additional light (and negligible heat) for 11 h (8:00–19:00) daily. Home tanks all had similar setups; each contained a heat lamp with a Fluker's 100w Basking Bulb, an overhead fixture with a Reptisun 10.0 UVB bulb, rocks, a tunnel, a water dish, and a hide structure. The lizards were maintained on a diet of fruit flies and pinhead crickets and generally fed every other day at irregular time intervals (i.e., sometimes in the morning and sometimes in the afternoon, but always after test trials concluded each day to ensure that lizards were always hungry for testing) as part of their pre-release protocol, which attempted to mimic natural conditions they would face post-release and sought to avoid habituation. These food items were dusted with Repashy Calcium Plus powder which included pre-formed vitamin A.

Lizards received one trial per day in June 2020 (for a total of six trials per lizard, two trials per each of the three tests) and November 2020 (for a total of six trials per lizard, two trials per each of the three tests), and all trials took place in the morning (09:00–11:00) (Fig. 1). No animals were food deprived prior to testing (Bajer et al., 2015).

Starting in June 2020, first, all lizards received a one-hour general activity test in their home enclosure. From the one-hour trial, we scored 30 min as three 10-minute intervals (e.g., minutes five to 15, minutes 25–35, and minutes 45–55 of the one-hour trial), and we recorded time spent moving and number of movements (Horvath et al., 2016, 2019) (Video S1).

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Next, all lizards received an exploration trial for which we placed them inside an 11.43 cm long, opaque PVC tube, and then placed the tube in the center of a novel 75.71-liter (20-gallon) aquarium with a grid-marked floor and a patterned wallpaper (e.g., wrapping paper) on the outside of the glass (Fig. 1). After a two-minute habituation period, we opened the tube at one end for five minutes and recorded latency of the head (to the base of the skull) and latency of the body (to the cloaca) to emerge from the tube (following Horvath et al., 2016). If lizards emerged, they had five minutes to explore the tank, during which we recorded the number of grids each lizard entered (Bajer et al., 2015).

Fig. 1. A lizard explores a novel, wallpapered environment.

Following the observation that some individuals being tested were not emerging from the tube, lizards in close proximity to the tube edge after five minutes, but not yet emerged, received two additional minutes. We cleaned the tube and novel environment between individuals to remove scent. Lizards received a different wallpaper for each trial, and all lizards received the same order of wallpaper (Video S2).

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Last, following personality assessment methods used in other taxa (reviewed in Greggor et al., 2015) and adapted from novel object tests used with reptiles (e.g., Siviter et al., 2017), we tested object neophobia by presenting each lizard with a novel toy/figurine (such as a small rubber duck or a hair curler; SI Fig. 1). We divided lizard home enclosures into four quadrants and placed the novel object in the quadrant opposite that of the lizard, then measured lizard movement within each quadrant of their home enclosure for ten minutes (Video S3). Lizard starting position was not standardized across individuals. Objects were similar in size but differed in color and texture (Appendix A), and all lizards received the same order of presentation of objects. For both general activity and neophobia tests, we considered lizards to be in locomotion if they lifted a leg off the ground and their body position moved. The general activity, exploration, and neophobia tests were repeated one week later.

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Prior to retesting all lizards again in November 2020 (Fig. 1), six lizards were moved to an outdoor enclosure for 70 days as part of a secondary experiment investigating the effects of enrichment before release into the wild (*L.P.B., unpublished data*). After the November 2020 assessment, the lizards were assessed two more times: once in the lab (April 2021) and once while in an outdoor, soft release enclosure (June 2021) (Fig. 2; *L.P.B., unpublished data*). The lizards were released into their natal habitat in July 2021 and are currently being tracked to monitor their survival (*L.P.B., unpublished data*).

All trials were video recorded for subsequent coding. Videos were coded by K.L.A. after achieving reliability > 85% with L.P.B. using pearson correlations on 10% of trials (i.e., 10% double-coded) in each test (Activity: r = 0.98; Exploration: r = 0.99; Neophobia; r = 0.99). We could not reliably ascertain the presence/absence of fruit flies from video footage, so we retained data where a fruit fly could have been present.

2.1. Data analysis

All analyses were conducted in R version 1.4.1717 (R Core Team, 2021). To evaluate the consistency of personality traits across time, we used the 'rptR' package (Stoffel et al., 2017), with each behavioral measure as the response variable and ID as a random effect (for estimated repeatability), as well as trial as a fixed effect (for adjusted repeatability). For activity, time spent moving was rounded to a whole number, and we used a Poisson distribution; we also used a Poisson distribution for number of movements. For exploration, we used a binomial distribution. To explore whether traits were correlated (akin to a behavioral syndrome), we used Pearson correlations.

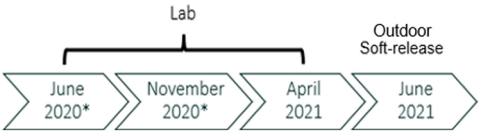

Fig. 2. Timeline of personality assessments and their locations. Asterisks indicate data included in present study.

2.2. Ethical approval

This study was conducted according to the guidelines of the Scientific Review Committee at the Oklahoma City Zoo and Botanical Garden (Approval #2020–009).

3. Results

Our two measures of general activity level differed in repeatability when considering all trials in June and November: time spent moving was significantly repeatable across all four trials (r_{adj} = 0.233, p = 0.024; r_{est} = 0.229, p = 0.026), but the total number of movements was not significantly repeatable (r_{adj} = 0.178, p = 0.065; r_{est} = 0.168, p = 0.077). We also investigated repeatability within each assessment across one week in June and in November. Lizards were repeatable in time spent moving and number of movements across trials in June (Time: r_{adj} = 0.514, p = 0.019; r_{est} = 0.574, p = 0.008; Movements: r_{adj} = 0.522, p = 0.021; r_{est} = 0.269, p = 0.014) but not in November (Time: r_{adj} = 0.113, p = 0.343; r_{est} = 0.059, p = 0.416; Movements: r_{adj} = 0.086, p = 0.382; r_{est} = 0.015, p = 0.479).

Due to a lack of variation among lizards in number of grids explored, we converted our measure of exploration to a binary variable (whether or not lizards explored the novel environment). Whether or not lizards explored the novel environment was significantly repeatable across trials in June and November (r_{adj} = 0.282, p = 0.0351; r_{est} = 0.169, p = 0.079). We could not determine repeatability within each assessment due to a lack of variation in responses.

For the novel object tests, there was not enough variation in boldness responses (time spent in quadrant with the object) to test for repeatability, because many of the lizards did not move during the trials.

Since we found consistent behavioral responses of activity and exploration, we correlated these traits to determine if they were related. Activity (time spent moving) was positively related to whether or not lizards explored in their novel environment (r = 0.301, p = 0.017; Fig. 3).

Lastly, we conducted a correlation of risk-taking tendency (measured as latency of the body to emerge from the tube) and exploration

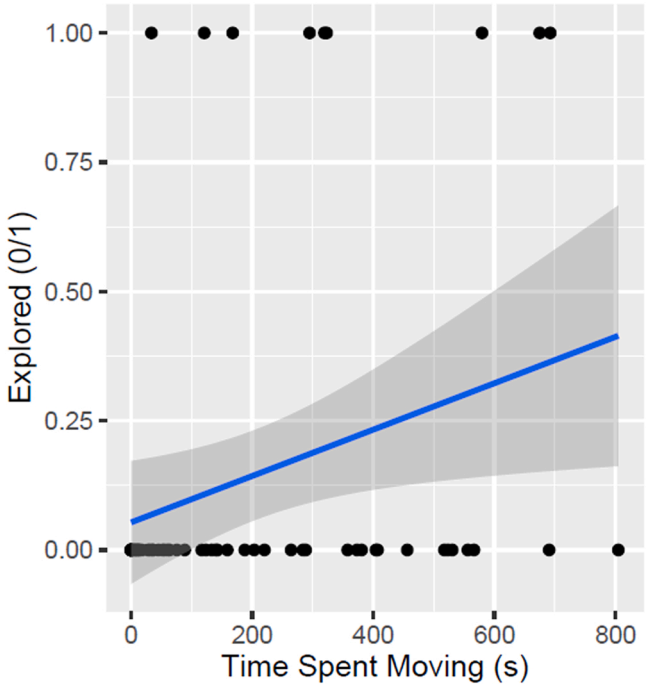

Fig. 3. Correlation between time spent moving (activity) and whether lizards explored the novel environment (exploration).

(measured as the number of grids explored), based on previous work with European green lizards (*Lacerta viridis*) (Bajer et al., 2015). We found that less risky lizards were also less explorative ($r = -0.796$, $p < 0.001$). We did not assess repeatability of risk-taking tendency due to the fact that some lizards received more time than others to emerge from the tube.

4. Discussion

Overall, we found some evidence of personality (activity and exploration) in Texas horned lizards for the first time. Due to a lack of variation in movement during novel object testing and risk taking, we did not see evidence of consistency in these traits. Although it is unlikely, the slight variation in our feeding times may have affected repeatability of behavior of the lizards, but feeding each day took place after testing. The lizards we tested were juveniles, which could represent a transitional time in personality formation as it is for other vertebrates (e.g., cattle during puberty, Neave et al., 2020; but see: European green lizards, Bajer et al., 2015), and could explain the observed lack of repeatability. Future work could investigate ontogenetic differences in personality in Texas horned lizards.

We found some evidence that the lizards were less consistent in activity levels in their November trials. This could be because wild Texas horned lizards brumate during colder temperatures, and although these headstart lizards experienced constant temperatures around 24 °C and no natural daylight in captivity, they may have nevertheless been reducing their activity levels. Indeed, mean activity levels were higher in June (e.g., time spent moving [seconds]: $\bar{x}_{trial\ 1} = 242.842$ s; $\bar{x}_{trial\ 2} = 262.095$ s) than in November ($\bar{x}_{trial\ 3} = 200.752$; $\bar{x}_{trial\ 4} = 106.294$ s), with lowest activity occurring during the second November trial. Moreover, some individuals were observed brumating upon release onto Tinker Air Force Base in October 2021 (Eliades et al., 2022). Future studies of personality in Texas horned lizards should consider this when choosing intervals for retesting behavior. Additional studies could also determine if measuring latency to feed near the novel object or using a novel food test or response to predation threat might be a more ecologically relevant way to test for neophobia or risk-taking tendency in this species. Also, although we found consistency in exploration, the lizards' behavior may have been affected by other factors like whether or not they received an additional two minutes in the tube, or by sex or snout–vent length (which we did not measure here).

Beyond consistent personality, we also found evidence that traits (activity and exploration) are related to one another in Texas horned lizards. Lizards that were more active in their home tanks during activity testing were also more likely to be explorative in a novel environment tank. This matches our prediction that more active individuals would be more explorative and has significant implications for welfare of reptiles living in captivity, because more active Texas horned lizards may require more environment enrichment and more space than that of their less active counterparts.

Although not a prediction we initially planned to explore, we investigated the relationship between risk-taking (measured as latency of the body to emerge from the tube) and exploration (measured as the number of grids explored). A previous study of European green lizards found that adults that took longer to emerge from a refuge (a measure of risk-taking tendency) also explored more of the novel environment, whereas there was no relationship between latency to emerge and exploration for juveniles (Bajer et al., 2015). Unlike this previous study, we found a negative relationship between emergence from a refuge and exploration, in which juvenile Texas horned lizards that took longer to emerge explored less of the novel environment.

Our findings on personality contribute to what is already known about reptile behavior. Recent work, for instance, has shown that reptiles experience pleasure and anxiety (Lambert et al., 2019) and exhibit complex cognitive abilities including problem solving, learning, quantity discrimination, social learning (reviewed in: de Meester and Baeckens, 2021; Szabo et al., 2020), and some form of self-recognition (Burghardt et al., 2021). There is evidence that reptiles living in human care (e.g., pets, zoo animals, etc.) require environmental enrichment (Burghardt, 2013) and welfare assessment to minimize stress (Silvestre, 2014), like other taxa. This is also true for headstart/release program reptiles that will, ideally while living in captivity, develop antipredator behaviors, social competency, and become familiar with biotic and abiotic cues they will use in the wild (Alberts, 2007). Caretakers of reptiles can therefore benefit from incorporating information about responses to novel objects and environments for enrichment protocols, especially considering that caretakers may be least familiar with reptiles' enrichment preferences compared to preferences of other taxa (Mehrkam and Dorey, 2015). Based on our findings, there are individual differences in responses to environmental change and novel objects, and consistency of traits may differ depending on the response measure recorded. Thus, like welfare of other taxa commonly housed in captivity, welfare of captive reptiles should be assessed at the individual (animal) level within a species, and future work should incorporate this knowledge into developing reptile welfare measures.

Besides bolstering captive reptile welfare, more behavioral research on reptiles can inform headstart initiatives, although this was not a focus of the current study. Program managers can glean information about which behavioral traits result in individual survival upon reintroduction into the wild as has been found in birds (e.g., Smetzer et al., 2021; Harmange et al., 2021) and mammals. Bolder swift foxes, for instance, were more likely to die post-reintroduction compared to their shyer counterparts (e.g., Bremner-Harrison et al., 2004). There has been very little work on personality and reintroduction in reptiles and amphibians, however (e.g., Kelleher et al., 2018; but see Allard et al., 2019). Personality predicts how animals interact with potential threats, disperse, and find mates to reproduce, which are integral for successful reintroduction (de Azevedo and Young, 2021). We therefore recommend expanding on the current work done in captivity by leveraging personality assessments as a tool to identify certain candidates for release and/or target and encourage development of certain optimal traits over others within the population (de Azevedo and Young, 2021). However, it is important to note that a single behavioral phenotype will not always be best, due to fluctuating selection across environmental contingencies (Watters and Meehan, 2007). Nevertheless, with knowledge of individual personality in their headstart program, program managers could make decisions about length of time in captivity before release, type of release (soft vs. hard), and whether any behavioral training (e.g., antipredator training) or exposure to live predators (Alberts, 2007; Tetzlaff et al., 2019; Watters and Meehan, 2007) is necessary in captivity.

4.1. Conclusions

We measured personality of Texas horned lizards living in human care and found evidence of activity and exploration as consistent traits. This is the first investigation of personality in this species. Personality assessments such as those used here are critically needed to improve welfare of captive lizards (e.g., in zoos, as pets, etc.) and animals in headstart programs. More work is needed to expand the efforts of the field of conservation behavior to more species in headstart programs, especially those with lesser studied reptiles, like Texas horned lizards.

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CRediT authorship contribution statement

Lisa P. Barrett: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Project administration, Funding acquisition. **Kelsea L. Anthony:** Methodology, Data curation, Writing – review & editing. **Samuel J. Eliades:** Conceptualization, Resources, Writing – review & editing, Funding acquisition. **Cameron D. Siler:** Conceptualization, Resources, Writing – review & editing, Supervision, Funding acquisition. **Brad Lock:** Conceptualization, Resources, Writing – review & editing, Supervision. **Rebecca J. Snyder:** Conceptualization, Resources, Writing – review & editing, Supervision. All authors have read and agreed to the published version of the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.applanim.2022.105690.

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