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Research Article

Keeper-Dragon Behavioural Differences in Two Komodo Dragon (*Varanus komodoensis*) Brothers During Training

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Abstract

Personality in non-human animals is a vast area of research, yet many papers focus on that of mammals or bird species. Many reptile species show complex behaviour but have been historically overlooked in favour of mammal and bird studies. Due to this, reptile species have frequently not received behavioural management such as enrichment, including through training within captive settings, despite their potential level of cognition. Training sessions prepare animals for situations such as routine veterinary procedures in addition to acting as enrichment. To assess the use of training sessions in reptiles, it is important to understand their cognitive and behavioural capabilities. This small pilot study acts as a case study, examining the personality and cognition of two Komodo dragons (Varanus komodoensis) through video analysis of training sessions and personality questionnaires issued to zookeepers. We also assess the utility of personality questionnaires in a reptile species and the potential effect of intrinsic factors such as keeper personality and sex on their responses. The results display the plasticity of Komodo dragon behaviour and the utility of training through evidence of willing compliance with training regimes.

Keywords: Conservation; Enrichment; Komodo Dragons; Personality; Training

Introduction

Personality in non-human animals, or temperament, has been an area of research interest for some time and spans several topics including neuroscience, psychology and ethology. Personality has been investigated across domestic and non-domestic species and information about an individual's personality may be applied to resolve practical issues, for instance assessing suitability for training as working dogs [1-3] or predicting outcomes of conservation interventions such as reintroductions *in situ* and creating breeding pairs *ex situ* [4-9]. Assessment of personality can be conducted using methods such as scoring behaviours during direct observation (the 'coding method') and the use of questionnaires rating behavioural traits filled out by caregivers (the 'rating method') [10]. Often, results from these tests are highly correlated [11]. However, occasionally the rating method has been shown to be slightly more reliable with regards to inter-rater reliability and so is frequently the sole method used in personality research [10,12]. In non-domestic animals, much of this research has been conducted in captive populations, with some examples from *in situ* animals. A standard questionnaire has been adapted and validated across several mammalian and bird species, including lions (*Panthera leo*) [12-15], tigers (*Panthera tigris*) [16,17], great tits (*Parus major*) [18-20] and penguin species [21], with other taxa largely understudied.

This is not unique to personality research. Mammals have traditionally received more attention from researchers, conservation planners and zoo visitors than have other taxonomic groups [22-25]. The majority of the twenty animals ranked as the most charismatic, often defined as animals attracting the most public interest [26], are mammals, with only one reptile represented in the group and no reptiles in the top ten charismatic animals [26, 27]. Conversely, reptiles are underrepresented with regards to amount of both published literature and open access datasets [25,28]. This includes topics normally of high interest in mammalian species, such as cognition, temperament and welfare [29,30], despite an estimated one in five reptile species being threatened with extinction [31] and many reptile species showing behaviour similar in its complexity to mammals [29,32]. Reptiles have traditionally been considered unsuitable candidates for routine husbandry procedures implemented with mammalian species, such as target training [33]. Mammals have historically been regarded as possessing higher cognitive abilities and more distinct personalities than reptiles and, hence, as needing more enrichment and stimulation. However, this has begun to change in recent years, and the use of target training has been gaining traction as the importance of cognitive challenge as enrichment is being recognised in reptiles [34]. Additionally, understanding the differences between individual personalities or temperaments may lead to a positive impact on welfare through tailoring training or enrichment programmes.

The majority of research into reptile personalities or temperaments has taken place in lizards and snakes, with the common lizard (*Zootoca vivipara*) often used as a model organism [35]. The Komodo dragon (*Varanus komodoensis*) is a large reptile found on only five small islands in Indonesia [36] and, at its last assessment in 1996, was classified as Vulnerable [37]. As long-lived, alpha predators, Komodo dragons show complex behavioural traits and would be expected to show individual differences in temperament due to their large body size and life history. The behaviour and personality of individuals, and the differences between them, have been described previously in wild lizards on Komodo Island [38] and in captive Komodo dragons after a training experiment [39]. Research in this species is limited and there is little formal guidance as to their care in captivity, although many zoos employ enrichment and training programmes with their Komodo dragons.

To assess the use of target training in reptiles, it is helpful to have an understanding of cognition, memory and temperament in these animals. This allows us to analyse differences in their reactions to training and how they remember it. In this pilot study using two captive Komodo dragon brothers, we aim to explore differences in personality between individuals and the use of training enrichment in these animals. We utilised the coding and rating methods to provide a comprehensive overview of their behaviour and temperament, through video analysis of recorded training sessions and a personality questionnaire previously validated in big cat species. The aim of this study was to improve understanding of temperament in Komodo dragons and validate mammalian research methods for use in reptiles.

Materials and Methods

Ethical approval and informed consent

Full ethical approval for this study was obtained from Fondazione Bioparco di Roma and all institutional policies were followed during the study. Keepers received and signed consent forms prior to the commencement of data collection.

Subjects and housing

The subjects were two adult Komodo dragon brothers aged 9 years old at the time of study, housed at Bioparco di Roma Zoo, Rome, Italy (Figure 1). Four keepers, three male and one female, were in regular contact with both individuals, with one of the male keepers solely responsible for training the Komodo dragons.

Temperament assessment

In order to assess the temperament of the Komodo dragons, training sessions were video-recorded, and all keepers asked to complete temperament questionnaires for both individuals. 10-minute training sessions took place three times per week in the mornings due to lizard activity levels being higher earlier in the day. Training did not take place at the weekend to prevent the Komodo dragons becoming distracted by the public during the sessions. A 150cm cue with a white sphere on the end was used as a target: when the animal touched the sphere with its muzzle, a whistle was blown by the trainer and a reward offered. Rewards used were neck scratches administered by the keepers with a brush or food rewards, these being a mouse, chick or piece of beef. Sessions were ended by the trainer blowing the whistle three times.

The temperament questionnaire protocol followed that of a previous study [15]. The first part of the questionnaire collected demographic information about the keeper, their background and their experience in working with animals and specifically with reptiles. The second part of the questionnaire asked keepers to rate 31 traits on a scale of 1 (never exhibited) to 12 (always exhibited) for each Komodo dragon. All four keepers completed questionnaires for both individuals, although not every trait was rated by all four keepers (Table 1). Personality profiles were produced for each animal using the average score from the four keepers. Video

Figure 1: The Komodo dragon enclosure at Bioparco di Roma.

Traits	Raters
Active, Aggressive to familiar people, Aggressive to keepers, Aggressive to unfamiliar people, Aggressive to you, Attention span, Calm, Cooperative, Curious, Eccentric, Excitable, Fearful of familiar people, Fearful of keepers, Fearful of you, Friendly to familiar people, Friendly to keepers, Insecure, Self-assured, Smart, Tense, Timid, Vocal: aggressive	All
Fearful of conspecifics, Fearful of unfamiliar people, Friendly to conspecifics, Friendly to unfamiliar people, Playful, Solitary	2 male keepers
Friendly to you	2 male keepers, female keeper
Aggressive to conspecifics	None

Table 1: All traits included in the personality questionnaire and which keepers rated each trait.

recordings of training sessions were analysed to assess compliance of each individual with regard to keeper requests.

Statistical analysis

Data were analysed in RStudio version 1.4.1106 and Behavioral Observation Research Interactive Software (BORIS) version 7.13.8. Inter-rater reliability (IRR) was calculated for each personality trait from the questionnaire. The trait 'Aggressive to conspecifics' was excluded from analysis as the dragons were housed individually and had not had chance to display aggression to each other. IRR was calculated using intra-class correlation (ICC) or, where only 2 keepers reported ratings, Cronbach's alpha (CA). This was repeated for male keepers only, and non-training keepers. In assessment of non-training keepers, 6 traits ('fearful of conspecifics', 'fearful of unfamiliar people', 'friendly to unfamiliar people', 'playful', 'solitary') were only rated by a single keeper.

Traits were grouped into classes (Table 2) for analysis of differences between the Komodos. Differences between scores for traits and classes were calculated per Komodo dragon and with the data pooled. Differences between ratings given by keepers of different sexes, and the training keeper and non-training keepers, were analysed using both traits and classes to investigate whether the lizards reacted differently to male and female keepers and to the keeper involved in their training sessions or whether the animals' behaviour was interpreted differently by keepers of different sexes and their trainer. When testing individual traits, keeper scores for both Komodos were pooled. Descriptive statistics were first performed before the data were tested for normality using a Shapiro-Wilk test, and either a two-sample t-test or a two-sample Wilcoxon test applied. Scores given to both individuals through the personality questionnaire were tested by trait and class. Linear models were

used to assess the effect of animal, keeper sex and training keeper versus non-training keepers on assigning the scores given for each trait on personality questionnaires. Where linear model results showed a single significant factor, non-significant factors were removed from the model and the model run again.

Behavioural and compliance rating count data were calculated using BORIS and analysed in RStudio. Data were first analysed with descriptive statistics. Behavioural count data were totalled and calculated as a percentage of total behaviour and compared between the animals using a chi-square test. Compliance count data were totalled and calculated as a percentage of total keeper requests, and compared between Ivan and Richard using a chi-square test.

Results

Inter-rater reliability

IRR was generally poor across individual traits, with the exception of the 'excitable' (moderate agreement, ICC = 0.602, p = 0.0378) and 'playful' (excellent agreement, CA = 1) traits. Testing of IRR by class again showed poor agreement between keepers. Between male keepers, excellent agreement was seen for the 'friendly to you' (CA = 0.938) and 'playful' (CA = 1) traits, and poor agreement seen between male keepers when tested by class. Poor agreement was seen between non-training keepers when assessed by both individual traits and class.

Personality profiles

Differences in personality were explored through both the questionnaires completed by keepers and video analysis of recorded training sessions. The personality profiles of the two individuals constructed from questionnaire data show some differences dependant on trait (Figure 2).

Personality questionnaire

The temperament test scores given by the four keepers were analysed to examine the lizards' similarities to each other, and

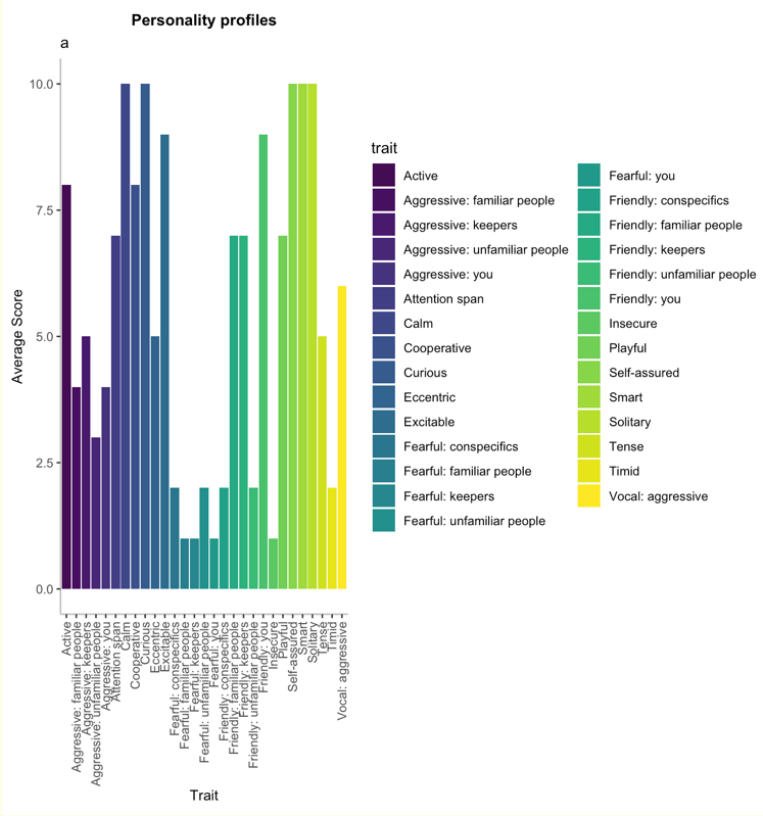

Figure 2: The Komodo dragon enclosure at Bioparco di Roma.

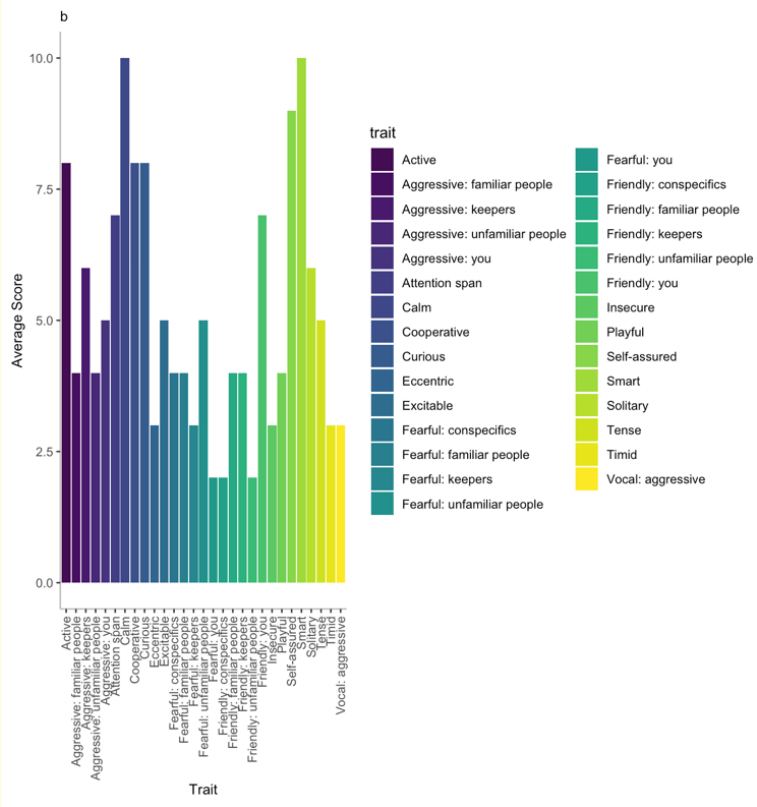

Figure 2: Personality profiles of the two lizards based on questionnaire data as reported by the surveyed keepers. A) Richard's personality profile. B) Ivan's personality profile.

whether reactions, or how the reporting keeper perceived their behaviour, differed depending on keeper characteristics. When keeper scores were analysed by individual behavioural trait, there was no significant difference in scores given for Ivan and Richard, except for the 'excitable' trait (t = -2.655, df = 6, p = 0.03778). When analysed in classes, a significant difference in scores between lizards was only seen for the Fearful class (Table 3).

Trait group	Result
Aggressive	W = 217, p = 0.6469
Confident	t = -0.40209, df = 18, p = 0.6924
Fearful	W = 380, p = 0.04107*
Friendly	W = 78.5, p = 0.1473
Interactive	W = 114, p = 0.1227

Table 3: A comparison of scores provided by keepers, comparing Ivan and Richard. * denotes a significance level of 0.05.

The difference between scores given by male and female keepers were analysed both as individual traits and as classes. Testing of individual traits showed a significant difference in scores given by male and female keepers in several traits (Table 4). When tested by class, both individuals received significantly different ratings from male and female keepers in the Aggressive class (Richard: W = 72.5, p = 0.001551; Ivan: W = 71, p = 0.003274; combined data: W = 288.5, p < 0.001), and Richard and combined data in the Interactive class (Richard: t = 3.0969, df = 16, p = 0.006925; combined data: W = 194.5, p = 0.001566).

When analysed by class, there was no significant difference in scores given by the keeper who trained the animals and other keepers. However, several individual traits received significantly different scores from training and non-training keeping staff (Table 5).

Trait	Result
Active	t = 1.7865, df = 6, p = 0.1243
Aggressive to familiar people	W = 12, p = 0.05393
Aggressive to keepers	t = 2.471, df = 6, p = 0.04839*
Aggressive to unfamiliar people	W = 12, p = 0.0357*
Aggressive to you	t = 5.9502, df = 5, p = 0.001915**
Attention span	t = 0.67082, df = 6, p = 0.5273
Calm	t = 0.16823, df = 6, p = 0.8719
Cooperative	t = 5.2588, df = 5, p = 0.003302**
Curious	t = 2.7617, df = 6, p = 0.03278*
Eccentric	t = 0.55456, df = 6, p = 0.5992
Excitable	t = 0.69944, df = 6, p = 0.5105
Fearful of familiar people	W = 3, p = 0.3397
Fearful of keepers	W = 2, p = 0.2108
Fearful of you	W = 5, p = 0.7728
Friendly to familiar people	t = 2.2854, df = 6, p = 0.06234
Friendly to keepers	t = 0.44909, df = 6, p = 0.6691
Friendly to you	W = 1, p = 0.2113
Insecure	W = 4, p = 0.5127
Self-assured	t = 2.7386, df = 5, p = 0.04086*
Smart	W = 9, p = 0.3397
Tense	t = -0.062582, df = 6, p = 0.9521
Timid	W = 7, p = 0.8609
Vocal: aggressive	t = 1.6327, df = 6, p = 0.1635

Table 4: A comparison of scores provided by keepers, comparing scores provided by keepers of different sexes. 'Fearful of unfamiliar people' and 'friendly to unfamiliar people' were omitted from this test as these traits were not rated by the female keeper. * denotes a significance level of p = 0.05, ** denotes a significance level of p = 0.01, *** denotes a significance level of p = 0.001.

Trait	Result
Active	t = 2.3905, df = 5, p = 0.06235
Aggressive to familiar people	W = 5, p = 0.8609
Aggressive to keepers	t = 2.8925, df = 5, p = 0.03409*
Aggressive to unfamiliar people	W = 9, p = 0.3397
Aggressive to you	t = 1.7037, df = 6, p = 0. 1393
Attention span	t = 0.67082, df = 6, p = 0.5273
Calm	t = 0.16823, df = 6, p = 0.8719
Cooperative	t = -0.69854, df = 6, p = 0. 511
Curious	t = 0.096523, df = 6, p = 0.9262
Eccentric	t = 0.55456, df = 6, p = 0.5992
Excitable	t = -0.43468, df = 6, p = 0.679
Fearful of familiar people	W = 1, p = 0.08571
Fearful of keepers	W = 1.5, p = 0.1526
Fearful of unfamiliar people	W = 0, p = 0.2207
Fearful of you	W = 7, p = 0.7728
Friendly to familiar people	t = 0.71693, df = 6, p = 0.5004
Friendly to keepers	t = -0.22177, df = 6, p = 0.8319
Friendly to unfamiliar people	W = 1, p = 0.6171
Friendly to you	W = 1.5, p = 0.3173
Insecure	W = 4.5, p = 0.6625
Playful	t = -1.4142, df = 2, p = 0.2929
Self-assured	t = 1.5, df = 6, p = 0.1843
Solitary	t = 1.5, df = 1, p = 0.3743
Tense	t = -0.18824, df = 6, p = 0.8569
Timid	W = 3, p = 0.381
Vocal: aggressive	t = -1.4741, df = 2, p = 0.2544

Table 5: A comparison of scores provided by keepers, comparing scores provided by the training keeper and non-training keepers. * denotes a significance level of p = 0.05, ** denotes a significance level of p = 0.01, *** denotes a significance level of p = 0.001.

Linear models showed significant effects of various factors in the traits 'Aggressive to familiar people', 'Aggressive to keepers', 'Aggressive to unfamiliar people', 'Aggressive to you', 'Cooperative', 'Curious', 'Eccentric', 'Excitable', 'Fearful of keepers' and 'Playful' (Table 6). The only significant factor in aggressive and 'Curious' traits was keeper sex, whereas other traits such as 'Cooperative' showed multiple significant factors.

Video analysis

The similarities seen in the animals' personality profiles were further illustrated from count data of behaviours extracted from analysis of training sessions (Figure 3). Additionally, no significant difference was found between the pair when tested ($p > 0.05$).

Trait	Significant factor(s)
Aggressive to familiar people	Keeper sex – female ($p < 0.001$)
Aggressive to keepers	Keeper sex – female ($p = 0.04839$)
Aggressive to unfamiliar people	Keeper sex – female ($p < 0.001$)
Aggressive to you	Keeper sex – female ($p = 0.01727$
Cooperative	Keeper sex – female ($p = 0.00157$) Training keeper ($p = 0.01200$)
Curious	Keeper sex – female ($p = 0.0151$)
Eccentric	Training keeper ($p = 0.0332$)
Excitable	Animal – Richard ($p = 0.03778$)
Fearful of keepers	Training keeper ($p = 0.03177$)
Playful	Animal – Richard ($p < 0.001$) Training keeper ($p < 0.001$)

Table 6: Linear model results. Where only one or two factor(s) was shown to be significant, other factors were removed and the model run again, with the results shown below.

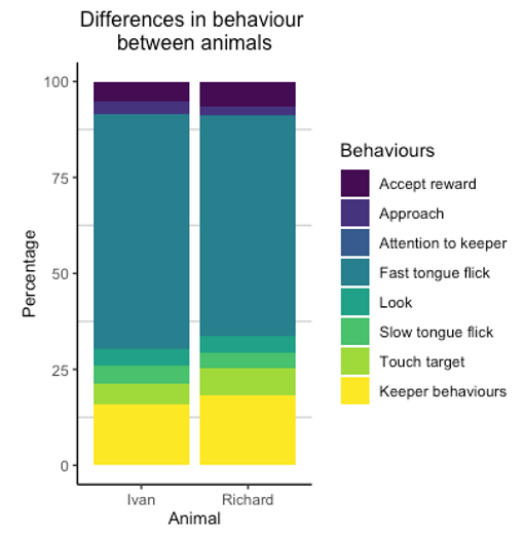

Figure 3: Differences in behaviour between Ivan and Richard from video analysis of recorded training sessions. The graph shows similar percentages of each behaviour in the individuals. 'Keeper behaviours' refers to behaviours performed by keepers in the training sessions (e.g., 'Target') and is included in the graph for completeness.

However, compliance data from video analysis shows differences between the pair. While the differences were not statistically significant ($p > 0.05$), there were visual differences in compliance rates (Figure 4).

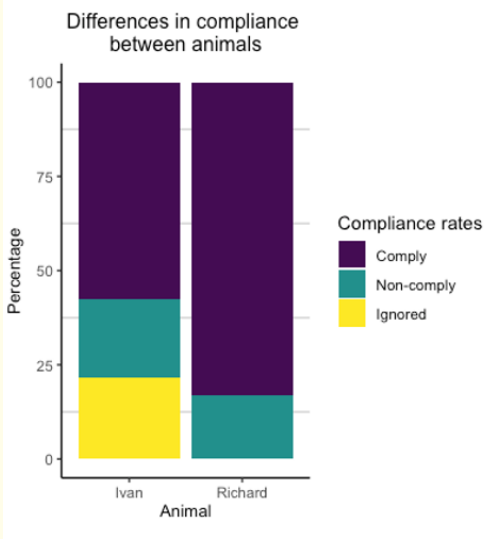

Figure 4: Differences in compliance rates with keeper requests. Both animals show similar non-compliance rates. However Richard shows a higher rate of compliance than Ivan, with Ivan ignoring the keeper at times.

Discussion

The results of this pilot study suggest some differences in personality between two Komodo dragon brothers, with statistical significance seen in select traits. Testing of different factors (animal, keeper sex and training keeper) with linear models within behaviour data sets also suggested differences in how keepers perceived or rated the lizards' behaviour. Personality profiles showed general visual similarities, with some differences seen in the traits 'Curious', 'Eccentric', 'Excitable', fearful traits, friendly traits, 'Playful', 'Self-assured' and 'Vocal: aggressive'. While testing of keeper scores by individual trait showed there were no significant differences between the animals, except for the 'Excitable' trait, the personality profiles illustrated some differences that would not be expected were the animals to show no 'personality'. One difference seen in the personality profiles between the animals was in the fearful traits, which showed significant differences when traits

were tested by class. Analysis of training videos show no significant differences between behavioural counts, with only slight differences seen in count data. However, in examination of compliance rates, non-significant differences were seen between the brothers, with Richard displaying more compliance than Ivan. These results suggest there are differences in the personality of the two brothers.

The testing of data when divided by keeper sex and training versus non-training keepers showed significant differences between keeper sex and non-training keepers. This could be due to different factors: the animals showing different behaviours towards keepers of different sexes or non-training keepers; keepers of different sexes or non-training keepers interpreting the animals' reactions differently; or the personality of the individual keepers themselves. Surveys have been shown to be a reliable method of assessing personality in non-human animals [15,41-44] but the method is not infallible. Keeper personality has been noted to impact on behaviour in tigers [16], black rhinoceros [45], and domestic species [46-48], with keepers more positive attitudes and behaviours to the animals they cared for more likely to experience positive relationships and interactions [49]. This, in turn, may impact on how they rate or interpret the animals' personalities. Keeper sex may also affect how the animals' behaviour is rated or interpreted. There were significant differences seen between the scores given by male and female keepers for several aggressive traits, including 'Aggressive to keepers' and 'Aggressive to you', as well as the 'Cooperative' trait, suggesting there is a sex effect in how keepers rate these traits. Notably, when tested with linear models, there was a significant relationship between keeper sex - female and all aggressive traits, further implying an influence of keeper sex on score assignment in aggressive traits. Whether this is due to keeper interpretation of the behaviours or the animals showing differing levels of aggression to each sex is a question that merits further investigation.

Additional differences in score assignment between groups of keepers were seen between training and non-training keepers, albeit at a much lower frequency. When tested with a t-test, only 'Aggressive to keepers' displayed a significant difference between keeper groups and, when tested with linear models, differences were seen in the 'Cooperative', 'Eccentric', 'Fearful of keepers' and 'Playful' behaviours. Divergences in these categories related to keeper group are potentially to be expected – the training keeper is likely to have a different relationship with the animals compared to non-training keepers, by virtue of the time spent training the animals. Therefore, they are likely to show a different perspective when rating these animals, and animal behaviour towards and around this keeper may be distinct.

This pilot study suggests differences not only between the Komodo dragon brothers, which merits further investigation to corroborate these findings, but diversity of keeper score related to sex and whether they were involved in training the animals. The study also confirms the utility of personality questionnaires in Komodo dragons, with some caveats. Keeper personality may also have affected how the animals' behaviour was seen, interpreted and scored by individual keepers. Further investigation of personality or temperament differences in Komodo dragons may include examination of the effect of keeper sex and training programmes in personality evaluation and widen the available data for reptile personality investigation.

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