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Article

Using Keeper Questionnaires to Capture Zoo-Housed Tiger (*Panthera tigris*) Personality: Considerations for Animal Management

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Abstract: Individual personalities affect animal experiences of zoo environments, impact on an animal's coping ability and have potential implications for welfare. Keeper assessments have been identified as a quick and reliable way of capturing data on personality in a range of species and have practical application in improving animal welfare on an individual level. Despite widespread recognition of the importance of animal personality within a zoo environment, there is a paucity of research into tiger personality and the potential impact of this on tiger experiences within zoos. This research investigated the personality of 34 tigers (19 Amur and 15 Sumatran) across 14 facilities in the UK using keeper ratings and identified changes keepers made in animal husbandry to support tiger welfare. Reliability across keepers (*n* = 49) was established for nine adjectives and a principal component analysis identified three personality components: 'anxious', 'quiet' and 'sociable'. When subspecies were combined, there was no relationship between tiger scores on the personality components and age or sex of tigers (*p* > 0.05). Subspecies of tiger was not related to scores on the 'quiet' or 'sociable' components (*p* > 0.05). Sumatran tigers scored more highly than Amur tigers on the 'anxious' component (mean ± SD, Sumatran: 3.0 ± 1.7, Amur: 1.8 ± 0.6, *p* < 0.05). Analysis within subspecies found that male Amur tigers were more sociable than females (mean ± SD, males: 5.5 ± 0.707; females: 4.15 ± 0.55). Amur tiger age was also negatively correlated with scores on the sociable personality component (R = −0.742, *p* < 0.05). No significant differences were seen in Sumatran tigers. Keepers reported a number of changes to husbandry routines based on their perceptions of their tigers' personality/needs. However, there was no significant relationship between these changes and tiger personality scores (*p* > 0.05). Despite significant evolutionary differences between Amur and Sumatran tigers, there are no subspecies specific guidelines for zoo tigers. This research has highlighted the potential for these two subspecies to display personality differences and we advocate further research into this area. Specifically, we highlight a need to validate the relationship between tiger personality, management protocols and behavioural and physiological metrics of welfare. This will enable a fuller understanding of the impact of personality on zoo tiger experiences and will enable identification of evidence-based best practice guidelines.

Keywords: Amur tigers; Sumatran tigers; personality; welfare; animal husbandry; keeper expertise

1. Introduction

Tigers, Asia's largest apex predator, are categorised as 'endangered' on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species. Occurring in a range of habitats including forest, shrubland and grassland [1], there is a paucity of information on tiger behaviour in-situ, predominantly due to their relatively secretive nature [2]. However, information suggests that their social organization is flexible and variable across regions [3], with interactions and movements shaped by habitat structure and

availability of resources [4]. There have been many taxonomic revisions of tiger subspecies in recent years, with scientists and researchers identifying four [5], eight [6], two [7] and six extant subspecies of tiger [8]. More recently, Armstrong et al. [9] identified at least four genetically distinct subspecies from around the world (Amur tigers (*Panthera tigris altaica*), Bengal tigers (*Panthera tigris tigris*), Malayan tigers (*Panthera tigris jacksoni*) and Sumatran tigers (*Panthera tigris sondaica*)).

Tigers are one of the most commonly exhibited species in zoos [10]. Within Zoological Information Management System (ZIMS) registered collections, there are 773 male and 900 female tigers held in 460 institutions around the world [11]. Of these, the most commonly housed subspecies are Amur tigers (232 male and 277 female at 212 facilities) and Sumatran tigers (119 male and 144 female at 108 facilities). Within European Association of Zoos and Aquaria (EAZA) zoos, Amur and Sumatran tigers are the only two subspecies of tiger recommended for holding and breeding [12]. Amur and Sumatran tigers are both genetically and morphologically distinct. The Sumatran tiger is much smaller and slighter than the Amur tiger. The Sumatran tiger lives in warm wet forests whereas the Amur tiger is adapted for the colder temperatures it experiences in Russia [8,13]. Subspecies, sex and age have been related to differences in captive tiger behaviour [14] and the differences between Amur and Sumatran tigers have been anecdotally highlighted [15]. Research to investigate whether tiger subspecies have different requirements within zoos, reflective of their differing life histories, has been advocated [16]. Currently, there are no subspecies-specific tiger management guidelines.

Zoo animals should be provided with environments in which they can thrive and not just survive [17]. Evidence-based approaches to animal management are important in providing environments for zoo animals which optimise welfare [18]. A key aspect of this is recognition of how individual differences between animals impact on how they experience their environment [19,20].

Animals may respond differently to one another within the same environment, a phenomenon described as 'behavioural syndromes' or 'personality' [21]. These individual differences have been reported across a wide range of species and contexts (e.g., aggressiveness, exploration, cooperativeness, response to novel stimuli) [22]. Animal personality should show individual differences, temporal stability and contextual consistency [23]. However, personality can be shaped by early environments [24] and adaptive needs for optimum fitness [25].

Personality can impact on physical and mental health of zoo animals and has therefore been identified as a key area for further research [26,27]. The development of animal personality in a zoological environment is also worthy of future research [26]. Behavioural plasticity is particularly prominent during early developmental windows, which enables adaptability to changing environments [28]. Animal personality can be assessed via three principle methods: behavioural coding, preference tests and trait rating by knowledgeable informants [19]. Within zoo animal research, trait rating by knowledgeable informants is most frequently used [19,29]. Using keeper ratings enables the opportunity to capture knowledge of people familiar with the focal animal in a standardised and repeatable manner [20]. Applying knowledge of animal personality profiles can be used to optimise welfare of zoo animals [19]. Within zoos it has been used to identify social group compatibility (e.g., [30–32]), predict friendships [33], and predict responses to management changes [34,35]. Understanding the impact of animal personality on their experiences enables the opportunity to take the 'guesswork' from zoo management decisions [20].

Early work into animal personality research focused on the five-factor model [36]. Originally based on measurements of human personality, this model consists of openness, conscientiousness, neuroticism, extraversion and agreeableness. Across felid species there are six personality components commonly identified: active, aggressive, curious, dominant, sociable, and timid/fearful/tense [27], with these being applied in variable combinations to create felid personality profiles based predominantly on three components (e.g., [37–39]).

Felid Personality in Captivity

Within felid species, animal personality has been advocated for use in a variety of settings. With cheetah (*Acinonyx jubatus*) it has been applied in relation to housing and husbandry considerations and investigated in relation to social behaviours [37,40]. In Asiatic lions (*Panthera leo*), personality traits have been associated with welfare states, with personality types (bold/shy) being linked to enclosure use, behavioural diversity and likelihood of expressing stereotypical behaviour [41]. Personality assessments have also been undertaken to increase understanding of behavioural responses to new environments in Asiatic lions [34] and help with enrichment management in cheetah and tigers [35]. In other felids, a relationship between age and personality has been identified; Scottish wildcats (*Felis silvestris*) become more agreeable as they age, clouded leopards (*Neofelis nebulosa*) become less agreeable and domestic cats (*Felis catus*) and snow leopards (*Panthera uncia*) become less impulsive [39]. There is a paucity of research into personality types of tigers and the impact of this on animal experiences [42]. However, tigers have been recognised as having individual personalities [34]. Amur tiger personality has been used to identify prey preferences and Sumatran tiger personality has been investigated in relation to enrichment [35,43]. Research in other felid species has identified correlations between keeper assessment of personality and behavioural coding [44,45] and preliminary research suggests keeper-ratings may be a reliable means of determining personality in tigers [34].

The aim of this study was to assess individual tiger personalities using keeper ratings and investigate whether there are any subspecies-level differences in personality between Amur and Sumatran tigers, and to understand whether this varied within males/females or age of tigers. A secondary aim was to consolidate information on current modifications to animal husbandry implemented by tiger keepers, to support tiger welfare based on keeper perceptions of tiger personality. Understanding whether common characteristics are seen in tiger subspecies, between males/females or as tigers age will be beneficial in optimising tiger management. Furthermore, understanding whether multiple facilities are making consistently similar modifications to animal husbandry based on individual personality will support sharing of good practice and enable continued development of evidence-based guidelines for zoo-housed tigers.

2. Materials and Methods

2.1. Ethics Statement

All research protocols and keeper surveys were favourably approved by Nottingham Trent University, School of Animal, Rural and Environmental Sciences School Ethics Group under a human ethics application (ARE1819860). Research support was given by the British and Irish Association of Zoos and Aquariums (BIAZA) Research Committee. Permission to conduct the study was granted by the participating zoos prior to commencement of data collection.

2.2. Keeper Assessment of Tiger Personality

Tiger personality was assessed using a trait rating method by keepers familiar with the tigers, via distribution of a questionnaire. The questionnaire was created using Bristol Online Surveys (now JISC) and distributed via email to research departments at 17 UK zoological institutions. The survey remained open for 5.5 months from July to November 2019.

Keepers ($n = 49$) from 14 zoological facilities ($n = 7$ housing Amur tigers and $n = 7$ housing Sumatran tigers) in the UK returned personality questionnaires for the tigers in their care. An additional three institutions were excluded (housing $n = 9$ tigers) due to incomplete questionnaires from $n = 10$ keepers. The questionnaire contained three parts (see Supplementary Material File S1). Part A consisted of general keeper information such as how long they had worked in the zoo industry and how long have they been working with the focal tiger. Part B consisted of tiger demographic information (species, age and sex), and any husbandry changes that were in place to accommodate the tigers' personality. Part C comprised 21 personality adjectives (Table 1). Ratings were made on a seven-point likert scale from 1 (does not describe the tiger) to 7 (accurately describes the tiger). Definitions of personality adjectives ensured clarity of each question. Questionnaires were accompanied

by instructions for completion to ensure they were filled out as accurately as possible. Keepers were asked to complete the questionnaires independently of one another, and to base their ratings on their own experience with the focal tiger.

Table 1. Adjectives and behavioural definitions included in the tiger personality questionnaires sent to the study zoos (*n* = 14) (adapted from [35,44]).

Adjective	Definition
Active	Moves frequently (e.g., paces, runs, stalks often)
Aggressive to people	Reacts in a hostile way or attempts to attack/threaten people
Anxious	Interested but fearful and uneasy; vacillates between approach and withdrawal
Calm	Not easily disturbed by changes in the environment
Cooperative	Is compliant; willingly behaves when asked to do something
Curious	Seeks out or investigates novel situations
Depressed	Failure to seek out or respond to social interactions (inactive, unresponsive, asocial)
Eccentric	Shows stereotypic or unusual behaviours
Excitable	Overreacts to changes in the environment
Fearful of people	Retreats readily from people
Friendly to people	Initiates proximity; approaches fence readily and in a friendly manner (e.g., purrs, rubs on fence)
Insecure	Seems scared easily; "jumpy" and fearful in general
Playful	Initiates and engages in play behaviour (seemingly meaningless, but nonaggressive behaviour) with objects
Self-assured	Moves in a seemingly confident, well-coordinated, and relaxed manner
Smart	Learns quickly to associate certain events, appears to remember for a long time
Solitary	Spends time alone; avoids company
Tense	Shows restraint in movement and posture
Timid/shy	Reluctance to approach other animals, novel objects, or new situations
Trusting	Not suspicious; approaches easily
Vigilant	Watchful, observant; spends a lot of time attending to its surroundings
Vocal	Frequently and readily vocalizes

2.3. Statistical Analysis

2.3.1. Inter-Rater Reliability

Once surveys were returned analyses to determine inter-rater reliability (IRR) were undertaken in R (Version 3.6.3) [46] using the 'irrICC' package [47]. Intra-class correlation coefficients (ICCs) were calculated for each personality adjective to determine inter-rater reliability for each adjective [48]. At facilities housing more than one tiger (*n* = 8), an ICC (3,k) was used to calculate rater reliability within facility. Facilities housing only a single tiger were combined and an ICC (1,k) was used to calculate reliability across sites. An ICC of >0.4 demonstrates an acceptable level of agreement between raters [48], therefore any adjectives with a mean ICC of <0.4 were excluded from further analysis.

2.3.2. Principal Component Analysis

Analyses were undertaken in R (Version 3.6.3, R Foundation for Statistical Computing: Vienna, Austria) using the 'psych' [49] and 'factoextra' [50] packages. A principal component analysis (PCA) was conducted to reduce the remaining personality adjectives into personality components. The component solution was rotated using varimax rotation and components with eigenvalues >0.9 were extracted. Suitability of data for the PCA was assessed using the Kaiser-Mayer-Olkin (KMO) Measure of Sampling Adequacy and the Bartlett's Test of Sphericity. Adjectives with salient loadings (>0.35) on more than one component were assigned to the component on which it had higher loading. Items with negative loadings on the components were reverse scored (e.g., 7 minus "score"). Cronbach's alpha was used to detect internal consistency within each component. Composite scores for each personality component (PC) for each tiger were calculated as the mean score of the adjectives within the component.

2.3.3. Relationship between Tiger Personality, Demographic Factors and Modifications to Husbandry Protocols

Analyses were undertaken in SPSS Version 26 (SPSS Inc., Chicago, IL, USA) and tests were undertaken based on whether data fitted a normal distribution (ascertained through a

Shapiro Wilk test). Data analysis was undertaken on all tigers combined and then within subspecies, to determine whether differences were present within subspecies in the study populations. Relationships between the identified personality components and tiger subspecies were assessed using an independent *t*-test. For all tigers combined, correlations between tiger age and personality component scores were undertaken using a Spearman's rank test (PC1) and a Pearson's correlation (PC2 and 3). Relationship between tiger sex and personality component scores were assessed using an independent samples *t*-test (PC2 and 3) and a Mann Whitney U test (PC1). Within subspecies, Pearson's correlations were used to determine relationships between tiger age and the three personality components, and independent samples *t*-tests were used to determine the relationship between tiger sex and personality component scores. Relationships between the modification of husbandry protocols (modifications present/absent) at the collection and the three personality components were assessed using an independent samples *t*-test.

3. Results

A total of 49 keepers (*n* = 31 female, *n* = 17 male, *n* = 1 not specified) from 14 zoological facilities across the UK completed the tiger personality questionnaire (Table 2). Each tiger (*n* = 34, 18 Amur tigers (4 males: 14 females) and 15 Sumatran tigers (7 males: 8 females)) was rated by two to six keepers (mean ± SD 2.7 ± 1.1). Years spent working with tigers ranged from 18 months to 26 years (mean ± SD 10.5 ± 7.2 years). Years spent working with the tiger they were rating ranged from 4 months to 8 years (3 ± 2.5 years). Tigers were housed in different social settings: solitary (*n* = 9), living with breeding partner (*n* = 4), living with another tiger of no relation but not breeding (*n* = 10), or living with relatives (*n* = 9). Amur tigers were aged 2 to 11 years (mean ± SD 7.8 ± 2.8 years). Sumatran tigers were aged 2 to 16 years (7.1 ± 4.6 years).

Table 2. Demographics of the study subjects across the study sites (*n* = 14).

Study Site	Species	Sex	Age	Number of Keepers Assessed by	Housed in a Social Group
Zoo A	Amur	Female	4	2	Y
	Amur	Male	2	2	Y
Zoo B	Amur	Male	7	3	Y
	Amur	Female	10	3	Y
Zoo C	Amur	Female	7	2	Y
	Amur	Female	7	2	Y
Zoo D	Sumatran	Female	11	2	Y
	Sumatran	Female	16	2	Y
Zoo E	Sumatran	Male	5	2	Y
	Sumatran	Female	6	2	Y
Zoo F	Sumatran	Female	13	6	Y
	Sumatran	Male	5	6	Y
Zoo G	Sumatran	Male	3	3	Y
	Sumatran	Female	12	3	Y
	Sumatran	Male	12	3	Y
Zoo H	Sumatran	Female	2	3	N
	Sumatran	Male	2	3	N
Zoo I	Amur	Female	11	2	N
Zoo J	Amur	Female	11	2	N
Zoo K	Sumatran	Female	2	2	N
Zoo L	Amur	Female	10	2	N
Zoo M	Sumatran	Male	5	2	Y
Zoo N	Amur	Female	9	2	N

3.1. Inter-Rater Reliability and Principle Components Analysis

Inter-rater reliability was assessed from the 21 personality objectives on the questionnaire. Nine of the 21 adjectives had mean ICC values of 0.4 and above and thus met statistically acceptable thresholds [48] (Table 3). These behavioural adjectives were entered into a principal component analysis (PCA).

Table 3. Intraclass coefficient (ICC) scores for each adjective included in the tiger assessment of personality. Adjectives with a mean ICC value of 0.4 and above (highlighted in bold in the final column) were entered into a principal component analysis (PCA).

Adjective	ICC * (3,k)								ICC (1,k)	Mean Score (1 dp)
	Zoo A	Zoo B	Zoo C	Zoo D	Zoo E	Zoo F	Zoo G	Zoo H	Mixed Facility *	
Active	0	0.9	0.5	0.8	−1	0.2	0.5	0.6	1	0.3
Aggressive	0	0.5	−1	1	0	1	0.6	0.9	0.5	**0.4**
Anxious	−0.1	0.3	−0.9	0.8	−0.8	0.8	NA	0.6	0.4	0.2
Calm	−0.8	−0.1	−0.8	0.9	0	NA	NA	−0.1	−0.3	−0.2
Cooperative	0	0	0	−1	0.6	0.5	0.1	0.9	0.5	0.2
Curious	0	0.3	0.8	0	0.9	0.3	NA	0.8	0.8	**0.5**
Depressed	0	0	0	0	0	−0.1	0	0	0.2	0
Eccentric	0	0.4	0	0	0.6	0	0.7	0.2	0.5	0.3
Excitable	0	0.8	−0.4	−0.6	0.8	NA	0.7	0.4	−0.2	0.2
Fearful of People	1	0.4	−1	0	1	0.9	0.0	0.7	0.7	**0.4**
Friendly of People	0.8	0.4	1	1	0	0.9	0.3	0.7	−0.1	**0.6**
Insecure	0	0.3	0	0	0.6	0.7	0.6	−0.1	0.7	0.3
Playful	0.8	0.4	1	1	0	0.4	0.6	0.7	0.9	**0.6**
Self-assured	0	0.3	0	−1	0	NA	NA	0.4	0.2	0
Smart	0.6	0.3	0.8	0	−0.6	0	NA	0.8	0.5	0.3
Solitary	0	0	1	NA	0.6	−0.2	0.3	0.8	NA	**0.4**
Tense	1	0.4	0	0	0.6	0.8	0	0.9	0.4	**0.5**
Timid	1	0.5	0	0	1	0.7	0	1	NA	**0.5**
Trusting	−1	0.5	0.6	1	0.9	0.8	0.7	0.1	0.2	0.3
Vigilant	0	−0.2	0	0	0.8	0.1	0.6	−0.2	0	0.1
Vocal	0	1	0.5	0	1	0.4	0.9	0.9	0.4	**0.6**

* Mixed facility sites: zoos I, J, K, L, M, and N. N/A: score could not be computed due to missing values.

The PCA yielded three components with eigen values >0.9, which accounted for 79.6% of the total variance. The KMO was 0.79 and Bartlett's test of sphericity was <0.001 (χ^2 = 120.542, df = 36, $p < 0.001$). Components were named according to the adjectives within them as 'anxious', 'quiet' and 'sociable'. The loadings of each trait onto the components are presented in Table 4. Cronbach's alpha revealed good internal consistency for each component.

Table 4. Factor loadings of the nine personality adjectives in the keeper questionnaire with intraclass correlation coefficient (ICC) scores of 0.4 and above.

Adjective	PC1—Anxious	PC2—Quiet	PC3—Sociable
Aggressive (people)	0.39		
Curious			0.38
Fearful (people)	0.36		
Friendly (people)	−0.36		
Playful	−0.36		
Solitary			−0.731
Tense	0.41		
Timid	0.38		
Vocal		−0.763	
Eigenvalue	5.08	1.18	0.94
Percent of variance	56.40%	13.10%	10.50%
Cronbach's alpha	0.913	NA	0.461

3.2. Relationship between Tiger Demographics and Personality Component Scores

Sumatran tigers had significantly higher ratings (mean ± SD, 2.96 ± 1.66) on the 'anxious' personality component than Amur tigers (1.84 ± 0.59) ($t = -2.248$, df = 16.010, $p < 0.05$). When all tigers were assessed, there was no relationship between sex or age of tigers and scores on the 'anxious' personality component. There were no significant relationships between PC2 (quiet) and PC3 (sociable) and any of the assessed demographic factors; subspecies, sex and age ($p > 0.05$). When this was further investigated 'within subspecies', no significant relationships between the personality component scores and tiger sex or tiger age were observed within the Sumatran tiger sample. Within the Amur tigers, there was no relationship between scores of 'anxious' or 'quiet' personality components and tiger sex ($p > 0.05$) or age ($p > 0.05$). Males (mean score ± SD, 5.5 ± 0.707) were considered to be more sociable than females (4.15 ± 0.55). Across both sexes there was a negative correlation between tiger age and their sociability score (R = −0.742, $p < 0.05$).

3.3. Changes to Husbandry Routines

Keepers from nine out of the 14 zoological facilities ($n = 22$ tigers) stated that they had made changes to their husbandry routines based on their perceptions of tiger personality (e.g., they made any changes to their husbandry routines to try to support tigers based on their perception of the tigers' personality). 50% of facilities housing Amur tigers and 50% of facilities housing Sumatran tigers reported making some changes to their husbandry routines (Figure 1). Changes to husbandry routines reported by keepers were grouped into seven categories: Feeding (e.g., separation of individuals at meal times to ensure equal access to resources), social management (e.g., moving tigers to different areas to avoid conflicts or aid social bonds, especially when introduced), desensitisation to keepers (e.g., habituation to human sounds via a radio), enclosure access (e.g., providing access to less disrupted areas), fear management, aggression management and specialised training (e.g., to support with medical examinations). Despite these modifications being made by keepers based on perceived tiger personality, there was no relationship between presence of husbandry modifications within a collection and the personality component scores for each tiger ($p > 0.05$).
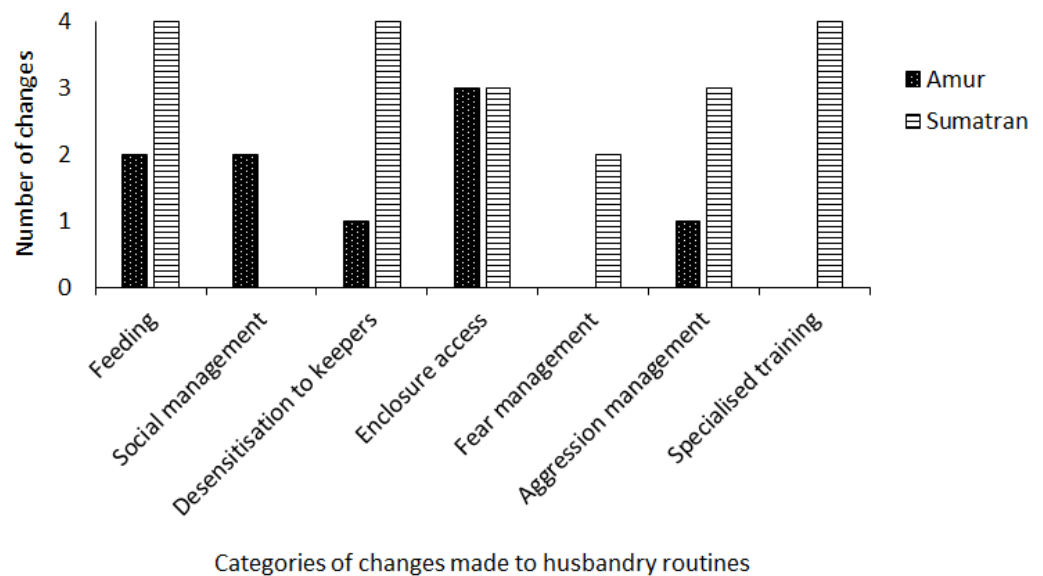
Figure 1. An overview of the changes keepers reported making to husbandry routines based on perceived tiger personalities. Reports were made by keepers at 9 facilities in the UK for their Amur (*n* = 10 tigers, *n* = 4 facilities) and Sumatran (*n* = 11 tigers, *n* = 5 facilities) tigers. Descriptively it is noted that more changes were reported to husbandry routines in relation to Sumatran tigers (*n* = 20) than Amur tigers (*n* = 9).

4. Discussion

The relationship between personality of Amur and Sumatran tigers and demographic factors (age, sex and subspecies) in 14 UK zoological collections was investigated. Reliability between keepers across the surveyed collections reached statistically acceptable thresholds and following a principle components analysis, three personality components were identified: 'anxious', 'quiet' and 'sociable'. Nearly 50% of the surveyed keepers reported making modifications to their husbandry protocols based on tiger personality; however, there was no relationship between tiger personality and presence/absence of specific husbandry protocols within facilities.

4.1. Identification of Relevant Personality Components

Two of the three personality components ('anxious' and 'sociable') identified from this sample of Amur and Sumatran tigers in UK zoological collections are generally comparable with components frequently identified in the wider felid literature [27]. Quiet (not vocal) is not commonly identified in the felid personality, however, in cheetahs vocal has been identified as a personality component that is linked to excitability, aligning with other similar constructs including playful, active, smart and aggression to people [45]. Tigers have an extensive and complex vocal repertoire which differ according to behavioural contexts [51]. The 'vocal' adjective in the tiger personality questionnaire did not consider the valence of the tiger vocalisations. It could thus be that in this study population being 'vocal' is more reliably rated than 'excitability' per se, but that one is a proxy for another, with the frequency of vocalisations or degree tigers are considered 'vocal' being related to responses to environmental conditions. It is also important to note that the labelling of personality components is subjective, and thus it is important to consider the adjectives (and their descriptors) within each component when comparing with other literature.

4.2. Investigation of Demographic Factors

There was no relationship between tiger age and sex across all of the study tigers, but some differences were observed between tiger subspecies. Sumatran tigers were considered to be more anxious than Amur tigers, scoring approximately 1.7× higher on the 'anxious'

personality component than Amur tigers. Within Sumatran tigers, perceived personality was not related to age or sex. Within Amur tigers, males were considered to be more sociable than female tigers, and a negative correlation was observed between tiger age and sociality.

The negative relationship between sociability scores and tiger age reflect research into tiger behaviour and indeed research into other species, which indicates that animals become less sociable with both conspecifics and keepers as they age (reviewed in [52]). Vaz et al. [53] described major age classes in captive tigers as: young (<5 years), middle aged (6–15 years) and old (>15 years). The majority of tigers in this study were in the young (*n* = 9) and middle aged (*n* = 13) age categories with the youngest tigers in this study being 2 years old. Behaviour patterns change and social interaction decreases between individuals as tigers mature [54]. Researchers have suggested that social partners are most important in younger tigers, with cubs (6 months old) and young tigers (up to 1 year old) engaging in higher proportions of interactions with one another [55].

The reasons for the reported difference in anxiety between the subspecies is not immediately clear. A number of factors (e.g., early life experiences, number of zoo moves, visitor interactions, zoo management, relationships with keepers) which were beyond the scope of this study could be causing these differences. The location of the tigers within the study sites (e.g., proximity to other felids), enclosure design (e.g., enclosure content or visitor viewing opportunities) and individual rearing history (e.g., captive born, wild born, hand-reared, parent-reared) were not captured during data collection but they could all impact on tiger experiences. Research by De Rouck et al. [56] found that tigers housed near other tigers showed an increase in stereotypic behaviour, and research into Amur tigers found increases in aggression and stereotypic behaviour in relation to visitor presence [57]. Factors contributing to the development of anxious personalities warrants further investigation, with appropriate management modifications (e.g., provision of space out of public viewing, or areas for separation between individuals if required) being considered. Furthermore, we advocate consideration of rearing history and past individual experiences on development of tiger personality, in order to identify whether it is possible to predict development of personality types from early life histories in zoo-housed tigers. Monitoring development of personality in zoo-housed tigers during their lifetime, to advance our understanding of the likely impacts as tigers age will enable appropriate management throughout tiger life cycles.

Despite perceived differences being reported across the subspecies the presence or absence of modified husbandry protocols was not related to any of the personality components. Keepers reported making changes such as altering how they approached tigers, to reduce potential stress. Descriptively it was noted that facilities with Sumatran tigers had more husbandry modifications than those housing Amur tigers. This may represent a genuine difference between these facilities, or it may be that respondents perceived changes in husbandry protocols in different manners, and what one may consider to be 'routine', others may consider to be a modification. Stockmanship, defined as management of animals in a manner which is safe, effective and low stress for both keeper and animals, can impact on keeper-animal dyads and has ramifications for animal experiences [58]. Indeed, the 'human dimension' of animal welfare has been recognised [59] and incorporated into the 2020 Five Domains of animal welfare model [60]. Previous research has indicated the potential for keeper personality to impact on interactions with zoo-housed tigers [38], and this could also impact on how keepers perceive and subsequently rate, tiger personality.

4.3. Study Limitations and Application of This Research to Tiger Management

Personality research in wild animals in-situ has shown strong evidence of the links between boldness and reproductive success in animals [61]. Within zoos, animal personality has been advocated for consideration in captive breeding programs and social management [29,42]. Breeding success has been closely linked to personality in a number of species (e.g., giant pandas (*Ailuropoda melanoleuca*) [62], and Black rhinoceros (*Diceros*

bicornis) [30]). Although research on felid personality is limited, in cheetahs, individuals described as being more 'tense' had reduced breeding success, which led to advocation for modifications to enclosure design, including more secluded and hidden areas to reduce stress [27]. The increased perception of anxiety in the Sumatran tigers surveyed here is interesting and may warrant further research. The Sumatran tiger breeding programme has historically been less successful than the Amur tiger breeding programme, with Sumatran tigers producing smaller litter sizes, having reduced female reproductive output and significant cub mortality in comparison to Amur tigers [63]. It was beyond the scope of this study to investigate breeding success in the observed tigers and the sample size was relatively limited. We do however recommend a larger study which looks more explicitly at tiger management, tiger personality and tiger reproductive success to determine whether any of these factors are linked, and whether management protocols can be developed which alleviate some of these issues if required. Understanding this has implications for success of breeding programmes and overarching tiger conservation.

The zoo environment is full of novel stressors [64] which animals may perceive differently [65]. Understanding the impact of these on animals is paramount in ensuring optimum welfare at an individual level. Previous research has highlighted the importance of management changes designed to support more anxious felids within zoological environments. For example, introduction of palm leaves as enrichment with the aim of reducing fear by eliciting rubbing behaviours has been shown to have a calming effect in various big cat species [35], as too has provision of hidden or more secluded areas within enclosures for Scottish wildcat [39]. Sharing knowledge in terms of new and innovative practices designed to alleviate the novel stressors experienced by zoo tigers has positive benefits for tiger welfare and facilitates advancement in tiger management. Work by Ward et al. [66] highlights the importance of knowledge exchange on a worldwide platform. Understanding the impacts of tiger personality and quantifying what facilities are doing to help to support individual tigers in their care has ramifications for zoo tiger welfare. Continued evolution of evidence-based best practice guidelines depends on work into new fields, of which felid personality is important [67]. Being able to quickly and accurately capture information on animal personality and apply this in animal management is important and consideration of the creation of 'behavioural profiles' has been advocated (e.g., [30,67,68]). Sharing areas of good practice based upon tiger personality will enable facilities to continue to improve zoo tiger welfare.

Previous research has validated the use of keeper assessments of personality against behavioural coding (see [29] for a review). However, the keeper assessments must be appropriate for the target audience and non-ambiguous in their nature to ensure appropriate understanding and subsequent interpretation by raters. Whilst the personality assessment used here was a replicate of other published research [35,44] there is the potential for confusion with some of the adjectives used. In future we would recommend developing a revised personality assessment in consultation with keepers, to ensure clarity of the questionnaire and thus accuracy. The use of ICCs to assess and identify reliability between raters went some way to overcome this limitation, but it is possible that keeper reliability would have been higher and considered acceptable for a greater number of behavioural adjectives if descriptors accompanying the adjectives had been more distinct. Identifying a suite of relevant behavioural adjectives which are reliably rated across collections enables development of tiger behavioural profiles. Using keeper assessment of personality questionnaires simultaneously alongside behavioural observations enables a holistic approach to understanding animal personality and its relationship with animal behaviour within zoological collections. Setting such research in the context of management routines is important in taking an evidence-based approach to animal management, which enables provision of environments in which animals can thrive. To the authors knowledge, in addition to this work, only two studies [35,38] have sought to investigate the relationship between keeper perception of tiger personality and tiger behaviour. Future research should seek to validate the relationship between tiger personality, management variables,

behaviour and physiological parameters of welfare in Amur and Sumatran tigers to determine the relationship between tiger personality and animal experiences. This will enable determination of whether subspecies-specific guidelines are necessary to ensure optimum welfare of these species within zoological facilities.

5. Conclusions

Individual personalities affect animal experiences of zoo environments, impact on an animal's coping ability and have potential implications for welfare. Understanding and applying knowledge of animal personality is an important area for consideration to ensure evidence-based zoological management. Despite widespread recognition of the importance of animal personality within a zoo environment and the development of this research area in a range of taxa, there is a paucity of research into tiger personality. This research identified three personality components, which align with the wider felid personality literature: 'anxious', 'quiet' and 'sociable'. Subspecies-level differences between Amur and Sumatran tigers were observed. Sumatran tigers scored significantly higher than Amur tigers on the 'anxious' personality component. In Amur tigers, sociability was related to sex and age of the tiger, with males being identified as more sociable and sociability decreasing as tigers aged. There are a number of factors (e.g., rearing history and past individual experiences) which can impact upon personality development of individuals. It is thus recommended that consideration is paid to the impact of these on development of zoo tiger personality, to determine whether personality development can be predicted from early life experiences in zoos. Monitoring development of personality in zoo-housed tigers during their lifetime, to advance our understanding of the likely impacts as tigers age will enable appropriate management throughout tiger life cycles. Furthermore, it is recognised that our understanding of the impact of personality on zoo tiger experiences and subsequent welfare are still limited. We highlight a need to validate the relationship between tiger personality and management protocols and behavioural and physiological metrics of welfare. This will enable a fuller understanding of the impact of personality on zoo tiger experiences and will enable identification of evidence-based best practice guidelines in the future.

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