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Research article

Preliminary model of personality structure in captive red pandas (*Ailurus fulgens*)

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Abstract

Animal personality is stable and contextually consistent and has an impact on an animal's physiology and psychological well-being. Personality, sometimes referred to as behavioural syndromes, personality dimensions, or temperament, impacts health, reproductive success and survival, and is thus an important factor to consider when assessing the welfare of captive animals. In this study, eight red pandas (*Ailurus fulgens*) from three institutions in New York City were observed to determine if personality dimensions can be assessed in this species using an ethological approach. Two personality dimensions were described: 1) "Active/Exploratory" and 2) "Maintenance". The "Active/Exploratory" dimension is consistent with several personality dimensions found in other mammalian species, while the "Maintenance" dimension may be related to "Tense" or "Fearful" dimensions found in other species. Both personality dimensions have ecological and welfare implications. Individual red pandas that score highly in the "Active/Exploratory" dimension may travel further and find more resources, and may require more enrichment in captivity to avoid frustration. Red pandas that score highly in the "Maintenance" dimension may have higher stress levels and require more areas of seclusion in captive environments. This study can serve as the start of a deeper investigation into personality dimensions in red pandas and the impact they have on the welfare of this species in captivity and possibly the wild.

Introduction

Research on non-human animal personality has become prevalent as a result of empirical and conceptual advances that demonstrate personality to be in fact stable, quantifiable and consistent (Sih et al. 2004a; Gosling 2008; Pennisi 2016). This is evident in a wide array of taxa (e.g. social spiders: Grinsted et al. 2013; Pruitt and Goodnight 2014; water striders: Sih and Watters 2005; great tits: Dingemanse et al. 2012; cockatiels: Fox and Millam 2014; domestic cats: Gartner and Weiss 2013; domestic dogs: Gartner 2015; cheetahs: Wielebnowski 1999; snow leopards: Gartner and Powell 2011; spotted hyenas: Gosling 1998; and giant pandas: Powell et al. 2008, Martin-Wintle et al. 2017). Scientists use several terms to discuss the concept of animal personality, including personality, behavioural syndromes and temperament (Gosling 2001). No comprehensive definition of animal personality exists across disciplines. For the purpose of this study, personality refers to suites of correlated behaviours that remain consistent within a given behavioural context and across time and ecological contexts (Sih et al. 2004b). Commonly, personality models in humans and non-human animals describe personality as comprised of discrete and non-overlapping dimensions, and each individual organism exists along a continuum in those dimensions that reflects their dispositions and internal motivating factors (Watters and Powell 2011).

Personality dimensions are variable between individuals (Gosling 1998; Wielebnowski 1999; Gartner and Powell 2011), heritable (Sih et al. 2004a; Dingemanse et al. 2012), and affect survival at both the individual and the group level (Bergvall et al. 2011; Grinsted et al. 2013), making these consistent individual differences an important factor in the evolution of a population. Personality serves an important ecological role, affecting species distributions and response to environmental change by maintaining individual variation in behaviour (Sih et al. 2004a; Sih et al. 2012). Broadly, personality can be a vital core of interdisciplinary studies that connect the ecological impacts of behaviour with the developmental bases of behaviour and

genetics due to their nature of variability, heritability, and their impact on survival, reproductive success and dispersal (Sih et al. 2004b).

Red pandas (*Ailurus fulgens*) are generally solitary, territorial mammals endemic to the Himalayan temperate forests (Hodgson 1847; MacClintock 1988). Mature individuals interact only briefly with conspecifics during the breeding season (mid-January to March), and at other times inhabit large, overlapping territories of about 2.5 km^2 (females) to 5 km^2 (males). Individuals generally travel over 25% of this range during the day to mark territory (MacClintock 1988). Red pandas are currently listed as endangered by the IUCN Red List. A Species Survival Plan exists in AZA-accredited zoos to maintain population genetic and demographic health in this species (AZA Small Carnivore TAG 2012; Glatston et al. 2015).

Personality is already a consideration in the rearing of captive red pandas, particularly in breeding and maternal care, but personality in these cases is based on keeper observations and impressions rather than empirical evaluation of individual personality. The AZA Red Panda Care Manual (2012) denotes two methods of management keepers may use for mothers and new cubs, and the manual states that the "personality of the dam will determine which management style or combination works best (AZA Small Carnivore TAG 2012)". The mother and cub may either access the exhibit before, during and after parturition, or be kept in the nest area until the cub is 2–3 months old (AZA Small Carnivore TAG 2012). The personality recommendation comes from the knowledge that red panda mothers may become intolerant of public disturbance when they have young cubs, and despite being used in red panda captive management, no work has been done to categorise personality in this species. A more detailed understanding of specific personality dimensions in this species and the effect they have on aspects of captive welfare may help improve their quality of life in captivity. Identifying behaviours that serve as major indicators of personality dimensions will aid in the analysis of individual personality, regardless of familiarity with the subject.

The goal of this study is to examine if a purely ethological approach can provide clear assessment of personality dimensions in a small sample of captive *A. fulgens.* Based on natural red panda behaviour, the authors anticipate isolating personality dimensions that pertain to activity or territoriality. Personality dimensions reflecting activity have also been found in a variety of other mammalian species (dog: Kubinyi et al. 2009; cheetah: Wielebnowski 1999; snow leopard: Gartner and Powell 2011; spotted hyena: Gosling 1998; giant panda: Martin-Wintle et al. 2017; sea lion: Ciardelli et al. 2017; chimpanzee: Weiss et al. 2007). This project can serve as a starting point for examining the structure of personality in captive red pandas and provide a foundation for further study.

Table 1. Ethogram of red panda behaviours.

Behaviour	Description
Lying-sleeping	Lying-sleeping (either curled in a ball or lying flat out); unresponsive to noise/activity
Lying or sitting-alert	Lying or sitting, head up, eyes open, reaction to surroundings in some manner (head, eye, ear or tail movement)
Standing	Standing on all fours or on back two paws
Locomotion/ Climbing	Using all four limbs running or bounding on ground, or moving along vertical or horizontal plane off of the ground.
Self-play	Purposeless activity with self (i.e. rolling, tail-chasing) but not repetitive
Pro-social interaction	Interaction with conspecific: grooming, social play, courtship, mating
Anti-social interaction	Interaction with conspecific: aggression
Carry object	Carrying an object in mouth or hand while locomoting
Grooming/ scratching self	Grooming or scratching own body, not repetitively
Eating	Eating provisioned food or browse in enclosure
Drinking	Drinking water in enclosure
Vocalisation	Quack-snort or grunt, any noise the animal emits from mouth
Exploratory	Territorial investigation of enclosure, can involve sniffing, digging, interaction with furnishings within enclosure
Approach-c	Approach keeper or other animal management staff without displaying any aggressive signals
Approach-a	Approach keeper or other animal management staff in aggressive manner
Marking	Rubbing genitals on an object, or frequent urination on objects
Out of sight	Believed to be active, but not visible to observer
Stereotypy	Purposeless, excessive and/or repetitive action (i.e. locomotion, grooming, body movement)

Methods

Subjects

This study includes eight red pandas (males: n=4) from the Bronx (n=4), Central Park (n=2), and Prospect Park zoos (n=2). Ages of subjects ranged from 3–9 years at the start of the study ($\bar{x}$=5.25 years, σ=2.43 years). All subjects were born in captivity and were housed with conspecifics. The Bronx Zoo group is comprised of a mated pair, their mature female offspring and an unrelated male. At the start of this study, the unrelated male was housed individually and the unpaired female was housed with her parents. Through the majority of the study, however, the unpaired female was housed alone and in a holding area adjacent to the unrelated male. The two underwent introductions and were given access to each other's holding areas periodically in the later part of the study. The Prospect Park and Central Park subjects are both mated pairs and were housed together.

Video Collection

This study consisted of 150 10-minute videos from two periods in 2012: spring (April–June) and winter (October–December). Animals were filmed using a Kodak PlaySport or Flip UltraHD Video Camera from the zoo visitor viewing areas at each institution using a continuous sampling method for individual subjects in order to capture durations of specific behaviours and interactions with conspecifics and/or the surrounding environment. The number of videos per subject was unevenly distributed, varying from 11 to 28 with an average of 18.75 videos per red panda, and a median value of 19.50 videos. The time of observation was randomised across videos to account for daily and weekly variations in behavior.

Table 2. Matrix of Pearson's correlation coefficients among consistent behaviours. "*" denotes significance at the p < 0.05 level, while "**" denotes significance at the p < 0.01 level.

Behaviour	Lying-sleeping	Lying or sitting-alert	Standing	Locomotion/ Climbing	Grooming/ scratching self	Eating	Exploratory	Marking
Lying-sleeping	1							
Lying or sitting-alert	-0.126	1						
Standing	-0.235**	-0.353**	1					
Locomotion/Climbing	-0.238**	-0.640**	0.307**	1				
Grooming/scratching self	-0.100	-0.023	-0.095	-0.138	1			
Eating	-0.142	-0.326**	-0.057	-0.032	-0.093	1		
Exploratory	-0.186*	-0.350**	0.267**	0.123	-0.012	0.052	1	
Marking	-0.144	-0.388**	0.131	0.568**	-0.057	-0.022	0.194*	1

Video coding

Videos were coded using GriffinVC, a free video coding software created by Shur V. Singh and Sonia Ragir (accessed from: http://svirs.github.io/griffinVC/). The analysis of red panda behaviours in this study is based on a comprehensive ethogram of 74 red panda behaviours compiled from 930 hours of observation (Jule 2008). In this study, a revised form of this ethogram consisting of 18 behaviours was used in order to focus on "higher-order behaviours" (Watters et al. 2009) (Table 1).

All videos were coded to determine the durations of each of the target behaviours. In order to test inter-rater reliability, a subset representing 10.67% of the total videos was also coded by a second person. The resulting paired observations were analysed using Cohen's (1960) Kappa. Kappa values are considered good between 0.40 and 0.75, and excellent if greater than 0.75 (Fleiss 1981). The Kappa value for this study was an acceptable κ=0.64.

Behavioural consistency

In order to assess personality dimensions, the relevant behaviours need to be consistent across different contexts. Consistency was assessed for each behaviour using an independent sample t-test between the spring and winter periods for each panda. A consistent behaviour in this case is defined as a behaviour where the mean duration time from the spring period and winter period were not significantly different, and therefore were displayed by the subject in relatively similar levels across a variety of times of day and environmental conditions.

Independent sample t-tests were used instead of paired sample t-tests despite the repeated measures nature of the data. Paired sample t-tests require equal pairs of data points between periods observed. In this study, however, data were collected randomly, no study variables were changed, and no modification or intervention was made to influence a change in behaviours in the subjects. Therefore, no such pairs exist, and the sample size of observations between periods was not equal for any subject. The goal of these observations was to examine natural behaviour across a wide array of contexts. As such, an independent sample t-test was sufficient to demonstrate which behaviours were consistent between the spring and the winter periods. Behaviours found to be significantly different between periods and behaviours that were not observed in any or most of the subjects were dropped from the analysis. Behaviours that were consistent in at least six of the eight subjects were used to assess personality dimensions.

Personality dimensions

This paper uses Principal Component Analysis, which has been used before to assess personality from consistent behavioural observations (Ciardelli et al. 2017), but with adjustments to account for the longitudinal behavioural observations. The purpose of running a PCA is to transform a large number of interrelated variables into a set of fewer variables (principal components) that are unrelated and preserve the majority of variation from the original variables (Jolliffe 2002). Typically, PCA assumes independence of the original variables; however, when the primary goal of the PCA is descriptive rather than inferential, non-independence does not severely impact results (Jolliffe 2002).

The PCA was performed using a varimax rotation because correlations were found between the consistent behaviours (Table 2). We performed the PCA within each subject and used the agreement between the individual subjects' results to account for the longitudinal nature of the data. The agreement in component loadings from the PCA between the eight subjects serves as evidence that the emergent factors adequately describe personality dimensions in this sample. Because of this methodological adjustment, we limited the PCA to load behaviours on only two components. PCA organises the resulting components in decreasing order based on how much variation of the original variables they explain (Jolliffe 2002). Attempts in this study to include more than two components greatly reduced the agreement between subjects on variables loading in the second component onward. A variable is said to load on a component if its loading is greater than 0.32 or less than -0.32 (Tabachnick and Fidell 1996). For each consistent behaviour, the direction and component upon which it loaded were tallied across subjects, and personality dimensions were constructed based on highest agreement between the individual subjects' results. For example, if six subjects had "Locomotion/Climbing" behaviour loading positively on Component 1, one subject had "Locomotion/Climbing" behaviour loading negatively on Component 1, and the final subject had "Locomotion/Climbing" loading positively on Component 2, agreement among subjects places "Locomotion/Climbing" behaviour loading positively on Component 1.

Table 3a. Consistency test between spring and winter periods. This table shows the results of an independent sample t-test showing consistency between spring and winter periods for four of the red panda subjects. "*" denotes significance at the P<0.05 level, and "**" denotes significance at the P<0.01 level. Behaviours that were not demonstrated by an individual subject are noted with a period (.).

Behaviour	Bamboozle			Elliott			MeiMei			Walter		
	t	P	DF	t	P	DF	t	P	DF	t	P	DF
Lying-sleeping	-1.688	0.112	15	0.823	0.422	16.53	-0.806	0.43	19	-1.708	0.16	4.15
Lying or sitting-alert	-0.436	0.666	25.91	0.702	0.491	20	-0.118	0.907	19	-0.86	0.405	13.78
Standing	2.025	0.062	14.16	0.536	0.598	20	0.695	0.495	19	0.993	0.338	14
Locomotion/Climbing	0.531	0.6	26	-1.336	0.208	11.14	1.914	0.076	14.02	0.795	0.44	14
Self-play	.	.	.	.	.	.	.	.	.	.	.	.
Pro-social interaction	.	.	.	.	.	.	-1.986	0.078	9	0.661	0.519	14
Anti-social interaction	.	.	.	.	.	.	-1	0.343	9	.	.	.
Carry object	.	.	.	-1	0.341	10	.	.	.	.	.	.
Grooming/Scratch self	1.294	0.22	11.75	-1.645	0.131	10.05	1.322	0.202	19	0.722	0.482	14
Eating	0.883	0.385	26	-0.128	0.9	20	-0.056	0.956	19	.	.	.
Drinking	.	.	.	.	.	.	-1	0.343	9	-1	0.374	4
Vocalisation	1	0.339	11	.	.	.	.	.	.	.	.	.
Exploratory	0.068	0.946	26	-0.836	0.418	13.43	2.161	0.05	13	1.699	0.12	10
Approach-c	.	.	.	.	.	.	.	.	.	.	.	.
Approach-a	.	.	.	.	.	.	.	.	.	.	.	.
Marking	-0.696	0.493	26	-1.658	0.128	10	1.647	0.127	11.27	1.482	0.169	10
Stereotypy	.	.	.	.	.	.	.	.	.	.	.	.

Table 3b. Consistency test between spring and winter periods. This table shows the results of an independent sample t-test showing consistency between spring and winter periods for four of the red panda subjects. "*" denotes significance at the P<0.05 level, and "**" denotes significance at the P<0.01 level. Behaviours that were not demonstrated by an individual subject are noted with a period (.).

Behaviour	Amaya			Biru			Beilei			Qin		
	t	P	DF	t	P	DF	t	P	DF	t	P	DF
Lying-sleeping	-0.755	0.461	17	-0.9	0.38	18	0.777	0.453	11	.	.	.
Lying or sitting-alert	1.293	0.228	9.05	0.909	0.376	18	2.539*	0.028	11	2.201	0.055	9
Standing	0.455	0.663	7.12	-0.973	0.343	18	-1.26	0.234	11	-0.735	0.481	9
Locomotion/Climbing	-3.147**	0.006	16.90	-2.245*	0.038	18	-1.815	0.139	4.26	-1.397	0.25	3.25
Self-play	.	.	.	0.221	0.827	18	.	.	.	.	.	.
Pro-social interaction	-0.755	0.461	17	-0.9	0.38	18	.	.	.	.	.	.
Anti-social interaction	.	.	.	.	.	.	-1.552	0.196	4	0.484	0.64	9
Carry object	.	.	.	0.023	0.982	18	.	.	.	.	.	.
Grooming/Scratch self	1.53	0.177	6.02	0.859	0.401	18	-1.202	0.291	4.33	-1.006	0.341	9
Eating	0.92	0.371	17	1.143	0.282	9.25	-0.761	0.463	11	-0.913	0.426	3.12
Drinking	1	0.356	6	-0.9	0.38	18	.	.	.	-1	0.391	3
Vocalisation	.	.	.	.	.	.	.	.	.	.	.	.
Exploratory	0.023	0.982	17	0.15	0.883	18	0.617	0.55	11	-0.112	0.913	9
Approach-c	.	.	.	.	.	.	.	.	.	.	.	.
Approach-a	.	.	.	.	.	.	.	.	.	.	.	.
Marking	-2.799*	0.016	11.73	-2.013	0.068	11.59	-0.29	0.777	11	-1.57	0.151	9
Stereotypy	-0.755	0.461	17	.	.	.	-1.674	0.17	4	0.739	0.479	9

Table 4. Consistent behaviours. Table is ranked from highest to lowest proportions. Proportions of 0.75 (six out of eight subjects) or higher were considered consistent for personality dimension analysis.

Behaviour	Proportion of subjects with non-significant results
Standing	1
Grooming/scratching self	1
Eating	1
Exploratory	1
Lying sleeping	0.875
Lying or sitting-alert	0.875
Marking	0.875
Locomotion/Climbing	0.75
Drinking	0.5
Pro-social interaction	0.375
Anti-social interaction	0.375
Stereotypy	0.375
Carry object	0.25
Self-play	0.125
Vocalisation	0.125
Approach-c	0
Approach-a	0

Results

Behavioral consistency and correlations

The results of the independent sample t-test for all behaviours between spring and winter periods are shown in Tables 3a and 3b for all subjects. The tables list the t-score and degrees of freedom of each behaviour per subject. Eight behaviours were consistent, and thus used in the assessment of personality dimensions. These behaviours are shown in Table 4.

Personality dimensions

Principal Component Analysis produced two components for each subject, shown in Tables 5a and 5b. Table 5a lists the varimax rotation factor loadings per panda on the first component, and Table 5b lists the loadings on the second component. The two components together explained between 50.8% and 67.6% of the variance for each subject. Table 6 shows the variance explained by each component, as well as the total amount of variance explained by both components, for each subject.

Seven of the eight consistent behaviours showed agreement among subjects for both components, representing personality dimensions. "Eating" behaviour loaded on Component 2 in three subjects, versus loading on Component 1 in two. Within Component 2, "Eating" behaviour loaded positively in one subject, and negatively in two subjects. Based on this lack of agreement, "Eating" was not included on either component. Component 1 is comprised of, "Standing", "Exploratory", "Locomotion/Climbing", and "Marking" behaviours loading positively, and "Lying or Sitting – Alert" behaviour loading negatively. This defines an "Active/Exploratory" personality dimension, wherein an individual scoring high in this dimension is characterised by increased movement or activity, exploration and territorial marking, while an individual scoring low in this dimension is primarily inactive. The second component is comprised of "Grooming/Scratching self" behaviours loading positively and "Lying-sleeping" behaviour loading negatively. This component seems to describe a personality dimension of "Maintenance". Individuals who score highly in this dimension frequently perform maintenance behaviours, such as grooming and scratching, while those who score low in this dimension are inactive or spend more time sleeping.

Table 7 shows subject age and personality scores. The "Active/Exploratory" personality dimension may be related to age, however the sample size in this study is too small to draw significant statistical conclusions.

Discussion

The ethological approach used in this study was successful in describing two personality dimensions in a small sample of captive red pandas. These personality dimensions have been labeled "Active/Exploratory" and "Maintenance", and are based on seven consistent behaviours commonly exhibited by red pandas in captivity. These personality dimensions explained more than half of the variance in the seven consistent behaviours used to calculate them. A larger sample size might allow for the isolation of additional personality dimensions. Furthermore, more personality dimensions may be assessed and more variance may be explained by combining the ethological approach with a test context or a with the trait survey approach (e.g. Gartner and Powell 2011; Ciardelli et al. 2017). The ethological approach is more objective, but trait ratings based on cumulative experience have been shown to be the most practical and reliable assessment method for personality dimensions (e.g. primates: Freeman and Gosling 2010). A combination of techniques would be more powerful and a test context or a trait rating survey would confirm the results of the ethological approach (Freeman and Gosling 2010).

As there has been no research done on the personality dimensions in red pandas, there is no previous research with which to compare our results. Therefore, we used the comparison methods described by Gosling and John (1999) and used by Ciardelli et al. (2017) to map the personality dimensions found in this study to those found in other species. Comparisons were based on mapping the behaviours that made up the red panda personality dimensions in this study to the core features comprising personality dimensions found in humans and other mammalian species. These comparisons are conceptualised in Table 8 and help interpret the results.

The behaviours observed in this study are similar to traits assessed in other mammals. "Locomotion/Climbing" is comparable to traits such as active, energetic, or excitable, while "Lying or Sitting – Alert" relates to traits like vigilant, calm and lazy. These traits loaded onto personality dimensions resembling "Dominance" in wildcats (Gartner et al. 2014), "Extraversion" in humans (McCrae and John 1992) and chimpanzees (Weiss et al. 2007), "Active/Vigilance/Excitability" in cheetahs (Wielebnowski 1999), snow leopards (Gartner and Powell 2011), spotted hyenas (Gosling 1998) and sea lions (Ciardelli et al. 2017), and finally "Clever/Playful" in giant pandas (Martin-Wintle et al. 2017). "Exploratory" behaviour is connected to traits such as curious, inquisitive and fearful. These traits were found in personality dimensions related to "Extraversion" in chimpanzees (Weiss et al. 2007), "Openness" in humans (McCrae and John, 1992), "Dominance" in dogs (Kubinyi et al. 2009) and sea lions (Ciardelli et al. 2017), and "Curiosity" in wildcats (Gartner et al. 2014), cheetahs (Wielebnowski 1999), snow leopards (Gartner and Powell 2011), spotted hyenas (Gosling 1998), giant pandas

Table 5a. Principal Component Analysis factor loadings for Component 1. This matrix shows the factor loadings of the Principal Component Analysis with varimax rotation for Component 1 for each of the 8 subjects. "*" denotes loading. Behaviours not exhibited by a subject are denoted by a "."

Component 1	Bamboozle	Elliot	MeiMei	Walter	Amaya	Biru	Beilei	Qin
Lying-sleeping	-0.227	-0.264	-0.243	-0.214	0.346	0.068	-0.27	.
Lying or sitting-alert	-0.852*	-0.584	-0.741*	-0.825*	0.864*	-0.875*	-0.439	-0.851*
Standing	0.758*	0.479*	0.188	0.727*	-0.152	0.182	0.819*	0.897*
Locomotion/Climbing	0.894*	0.854*	0.84*	0.874*	-0.907*	0.792*	0.041	0.18
Grooming/scratching	-0.062	-0.113	0.35	-0.136	0.408*	-0.517*	-0.108	0.053
Eating	0.294	0.775*	0.124	.	-0.108	-0.009	-0.519	0.48*
Exploratory	0.519*	0.912*	0.769*	0.571*	0.405	0.797*	0.679*	0.866*
Marking	0.542*	0.913*	0.72*	0.927*	-0.707*	0.687*	0.634*	0.141

Table 5b. Principal Component Analysis factor loadings for Component 2. This matrix shows the factor loadings of the Principal Component Analysis with varimax rotation for Component 2 for each of the 8 subjects. "*" denotes loading. Behaviours not exhibited by a subject are denoted by a "."

Component 2	Bamboozle	Elliot	MeiMei	Walter	Amaya	Biru	Beilei	Qin
Lying-sleeping	-0.818*	-0.88*	-0.092	-0.667*	-0.656*	-0.742*	-0.359*	.
Lying or sitting-alert	0.429	0.745*	0.4	-0.099	-0.162	0.062	-0.746*	-0.475
Standing	0.066	0.35	0.563*	0.049	0.69*	0.66*	0.309	0.058
Locomotion/Climbing	-0.013	0.009	0.385	-0.035	0.06	0.529	0.898*	0.978*
Grooming/scratching	0.579*	-0.111	0.393*	0.821*	0.406	0.213	-0.218	-0.227
Eating	-0.193	0.173	-0.901*	.	-0.108	-0.324*	0.779*	-0.015
Exploratory	0.131	0.244	-0.06	0.096	0.638*	0.115	0.004	-0.094
Marking	0.12	0.012	0.33	-0.025	-0.062	0.322	0.135	0.961*

Table 6. Variance explained by component in Principal Component Analysis.

Panda	Component 1	Component 2	Total
Bamboozle	35.1%	15.7%	50.8%
Elliot	46.3%	18.7%	65.0%
MeiMei	34.2%	19.7%	53.9%
Walter	46.2%	16.2%	62.4%
Amaya	32.0%	19.0%	51.0%
Biru	38.4%	15.9%	54.3%
Beilei	32.5%	21.8%	54.3%
Qin	43.7%	23.9%	67.6%

Table 7. Personality dimensions and demographic information for subjects.

Panda	Sex	Age	Exploratory	Maintenance
Bamboozle	F	3.5	-0.293	-0.546
Elliot	M	7.5	-0.658	-2.342
MeiMei	F	4.5	0.753	0.714
Walter	M	9.5	-1.780	-0.044
Amaya	F	5.5	1.795	0.560
Biru	M	3.5	0.630	0.104
Beilei	F	3.5	-0.108	0.482
Qin	M	8.5	-0.341	1.072

Table 8. Comparison of personality dimensions and associated behaviours among red pandas and other mammals. Across the top are broad personality dimensions found in other mammalian species. W – wildcat, D – dog; C – cheetah; L – snow leopard; Y – spotted hyena; P – giant panda; SL – sea lion; CH – chimpanzee; H – human. Studies referenced for this table are as follows – wildcat: Gartner et al. 2014; dog: Kubinyi et al. 2009; cheetah: Wielebnowski 1999; snow leopard: Gartner and Powell 2011; spotted hyena: Gosling 1998; giant panda: Martin-Wintle et al. 2017; sea lion: Ciardelli et al. 2017; chimpanzee: Weiss et al. 2007; human: McCrae and John 1992.

Red Panda Dimension	Behaviour	Extraversion	Active / Vigilant	Openness	Dominance / Tense / Fearful	Curious	Calm / Self Assured
Active / Exploratory	Lying/Sitting-alert	CH,H	D,L,Y,P,SL		W		W,D,C,L
	Loc/Climbing	CH,H	C,L,Y,P,SL		W		
	Exploratory	CH		H	D,SL	W,C,L,Y,P,SL	
	Marking				W,SL,CH		
	Standing		Y				
Maintenance	Lying-Sleeping		Y		C		W,D
	Groom/Scratch		Y		W,C,L, P,CH,H		D

(Martin-Wintle et al. 2017) and sea lions (Ciardelli et al. 2017). Finally, "Marking" behaviour is used in red pandas to define territory (MacClintock 1988), and therefore may be related to a "Dominance" dimension. "Dominance" dimensions have also been found in wildcats (Gartner et al. 2014), sea lions (Ciardelli et al. 2017) and chimpanzees (Weiss et al. 2007). These traits describe a personality dimension in which individuals who score highly show more movement and exploration, while those scoring lowly demonstrate less activity or interest in their environments.

The "Maintenance" dimension does not appear to map directly to personality dimensions in other species as it is comprised of behaviours involved in maintaining health ("Sleeping" and "Grooming"). The two behaviours present in this dimension may be related to "Tense" or "Anxious" personality dimensions. In particular, "Lying-sleeping" appears related to calm and lazy traits, which connect to an "Active/Vigilant" personality dimension in spotted hyenas (Gosling 1998), a "Calmness/Self-Control" dimension in wildcats (Gartner et al. 2014) and dogs (Kubinyi et al. 2009), and a "Tense/Fearful" dimension in cheetahs (Wielebnowski 1999). "Grooming", in turn, may denote tense, anxious or nervous traits as grooming behaviours have been shown to mitigate stress in primates (Boccia et al. 1989; Wittig et al. 2008) and rats (Kametani 1988; Sachs 1988). Therefore, "Grooming" may be related to "Tense/Fearful/Anxious" personality dimensions in cheetahs (Wielebnowski 1999), snow leopards (Gartner and Powell 2008) and giant pandas (Martin-Wintle et al. 2017), "Dominance/Neuroticism" in chimpanzees (Weiss et al. 2007) and humans (McCrae and John 1992), "Self-Control" in wildcats (Gartner et al. 2014), and "Calmness/Excitability" in dogs (Kubinyi et al. 2009) and spotted hyenas (Gosling 1998).

Understanding the personality dimensions present in red pandas is the first step to uncovering how personality impacts their welfare. This study is a basis for analysing personality dimensions ethologically from video data in this species. Identifying clear personality dimensions can help predict more accurately and efficiently how individual animals would interact with each other and how their environments could be designed to maximise welfare (Powell 2010; Wielebnowski 1999). Keepers can use this information to plan the space of an enclosure, predict how individuals will react to one another, provide enrichment and apply similar management strategies to reduce frustration and stress (Loeffler 2011). Eriksson et al. (2010) found that 30% of zoos in their study situated red panda exhibits adjacent to those of large carnivores. This could lead to chronic stress, which has been linked to poor reproductive and immune functioning (Terio et al. 2004; Mason and Rushen 2006). It has been established that personality influences judgements in the care of red panda mothers and young cubs (AZA Small Carnivore TAG 2012). Personality assessment for the mother could inform care for both mother and cub before the cub is born.

The red panda subjects in this study were kept in a variety of social conditions, which may impact the behavioural repertoire of the animals studied and thus impacted our assessments of personality. The Prospect Park Zoo pair and the Central Park Zoo pair were mated pairs housed together through the course of the study. The Bronx Zoo group had several different settings and pairings, with the female offspring (Bamboozle) undergoing introductions with the unrelated male (Elliot) during the study. The mated pair at this zoo (MeiMei and Walter) were housed separately during the study while the female cared for their newest cub. The enclosures varied moderately in size, but all contained similar furnishings, with elevated climbing and walking paths, trees, brush and food and water sources. However, these situations are similar to wild red panda social circumstances as red pandas are largely solitary and occupy overlapping territories (MacClintock 1988). Further research would be needed to address this potential confound.

This study serves as a foundation for further research into personality in captive carnivores. Next steps would include increasing the sample size, combining the personality assessment with trait rating surveys that will further allow comparison between species, and examine how personality impacts welfare. Additional in-depth examination can confirm the personality dimensions found in this study as well as describe other personality dimensions in red pandas. The behaviours seen in red pandas are common to many other captive mammalian species.

Understanding the role of personality dimensions in captive red pandas can provide a foundation for personality research in a variety of captive mammalian species.

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