Exploring the relationship between personality and social interactions in zoo-housed elephants: incorporation of keeper expertise

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Abstract

Individual animal personalities affect experiences of zoo environments, and thus potentially welfare. Incorporating keeper knowledge of animal personality in a reliable way has great value in optimising welfare in zoo-housed animals. Assessment of animal personality has been used to predict group compatibility and social relationships in a number of species including rhinoceros, gorilla and chimpanzees, and there is potential to do the same with zoo elephants. This study identified elephant personalities using keeper ratings, and investigated the relationship between personality and social interactions in zoo elephants. Behavioural data were collected over a period of 12 months at seven study facilities (January 2016 – February 2017). Subjects were 10 African (1 male: 9 females) and 19 Asian (3 male: 16 female) elephants housed at zoos and safari parks in the UK and Ireland. Each subject was rated using an elephant personality assessment questionnaire, comprising 21 personality adjectives with a visual analogue scale. Personality assessments were completed by 27 keepers. Reliability across keepers was established for nine adjectives and a principal components analysis revealed three personality components: 'attentiveness', 'sociable' and 'engaged with the environment'. Correlations were observed between keeper scores of sociability and social interactions ($p<0.05$). Elephants considered more sociable by keepers interacted positively with a greater proportion of elephants in the herd than less sociable elephants ($p<0.05$). Current Secretary of States Standards of Modern Zoo Practice (SSSMZP) elephant management guidelines include the need for long-term management plans, including elephant behavioural profiles and herd compatibility assessments. The results show that sociability as identified by keepers relates to social interactions, illustrating the importance of inclusion of personality assessment in management plans. Future work should build on these findings; applying keeper ratings of elephant personality to a larger sample size, and exploring potential as a predictive tool in compatibility assessments. Such a measure would help to increase the chance of successful social group formation contributing to positive zoo elephant welfare.

1. Introduction

Personality is defined as 'individual differences in behaviour that are thought to be stable across time and situations' (Powell & Gartner, 2011). Personality is indicative of coping ability (Gartner & Weiss, 2018), and individual personalities affect how animals perceive and subsequently experience zoo environments (Hosey *et al*., 2013; Watters *et al*., 2017). Catering for individual personality and understanding group dynamics is important in social and enclosure management, in order to remove the 'guesswork' from management decisions (Gartner & Weiss, 2018) and optimise welfare of zoo animals (Racevska & Hill, 2017). Zoo animal personality is being increasingly investigated in a number of species, including chimpanzees (*Pan troglodytes*), black rhinoceros (*Diceros bicornis*), cheetah (*Acinonyx jubatus*) and giant panda (*Ailuropoda melanoleuca*) (Tetley & O'Hara, 2012). Keepers can use knowledge of individual personality to identify appropriate roles within a group for individuals e.g. identifying social compatibility or who to transport to a new facility (Horback *et al*., 2014). Personality traits have been used to predict pair or group compatibility and improve mating success (Carlstead *et al*., 1999; Fox & Millam, 2014; Martin-Wintle *et al*., 2017). Personality traits have also been used to successfully predict friendships in chimpanzees; friendships were more likely in individuals with similar sociability and boldness scores (Massen & Koski, 2014).

Zoo animal personality is most frequently assessed by 'rating' behaviour (Tetley & O'Hara, 2012; Watters & Powell, 2012). This method involves human observers (keepers) rating an animal's behavioural tendencies along a number of dimensions, based on their experience with the individual (Highfill et al., 2010). The use of keeper ratings to study personality in zoo animals makes it possible to measure traits and capture expert knowledge in a standardised and repeatable manner (Gartner & Weiss, 2018). Keeper ratings have been identified as a reliable and valid means of determining personality in zoo-housed African and Asian elephants (Grand *et al*., 2012; Yasui *et al*., 2013) and in wild African elephants (Lee & Moss, 2012). Elephant personalities demonstrate temporal stability (Horback *et al*., 2013). They have an underlying biological basis (Yasui *et al*., 2013) and are related to levels of serum cortisol (Grand *et al*., 2012). Capturing the knowledge of keepers is extremely

79 important when attempting to identify the needs of zoo animals (Chadwick *et al*., 2017); keepers
80 have an intimate knowledge of the individuals they work with and they can integrate knowledge
81 from a range of situations over a long period of time (Meagher, 2009). In elephants, keepers have
82 reliably predicted social bonds (when social bonds have been assessed using association data)
83 (Bonaparte-Saller & Mench, 2018) and play behaviour (Horback *et al*., 2013).

84 Social group cohesion is one of the most difficult aspects of zoo animal welfare and group
85 compatibility can play an important part in the success (or failure) of social groups (Williams *et al*.,
86 2018). Provision of choice in the zoo environment, including choice in social interactions, has been
87 identified as an important criterion to enhance welfare of social animals (Carlstead & Shepherdson,
88 1994; Chadwick *et al*., 2017; Williams *et al*., 2018). Group compatibility enhances physical safety but
89 can also create positive affective states (Mellor, 2015) and enhance psychological wellbeing of
90 individuals (Horback *et al*., 2014). In zoo elephants, appropriate social groups have been described
91 as one of the best forms of enrichment (Rees, 2000). Research has revealed individual differences in
92 tactile interactions in zoo elephants as well as preferences in social partners (Adams & Berg, 1980;
93 Garai, 1992; Makecha *et al*., 2012).

94 Assessment of personality for use in pending zoo transfers may have implications for animal
95 welfare. Researchers have suggested that assessment of personality can be used to increase success
96 and decrease risks when forming new groups of great apes (Gartner & Weiss, 2018). Being able to
97 predict potential social compatibility prior to moving individuals would enable zoo keepers to
98 minimise stress caused to individual animals and increase their long-term welfare. Thus, if keeper
99 ratings of personality can be used to predict social compatibility in elephants, as has been seen in
100 other species, it has value in the introduction of individuals into new groups.

101 A link has been established between keeper ratings of social bonds and social association
102 patterns in elephants in US institutions (Bonaparte-Saller & Mench, 2018). To date no work has
103 investigated the relationship between personality as rated by keepers and social interactions in UK
104 and Irish zoo elephants. The aim of this study was to assess individual zoo elephant personalities

using keeper ratings and investigate whether there is a relationship between personality and herd social interactions. It was hypothesised that social interaction frequency would be related to personality, and that some elephants would be more sociable than others.

2. Methods

2.1. Ethics statement

All research protocols were approved by the Nottingham Trent University School of Animal, Rural and Environmental Sciences School Ethics Group. Support for the study was obtained from the BIAZA Research Group and permission to conduct the study was granted by all of the participating zoos prior to the commencement of data collection.

2.2. Subjects and study sites

Subjects were 10 African (1 male: 9 females) and 20 Asian (3 male: 17 female) elephants housed at seven zoos and safari parks in the UK and Ireland (Table 1). Herd size ranged from 2 to 9. An additional three individuals housed at two of the study zoos (one at Zoo C and two at Zoo E) could not be included in the data set due to missing data.

2.3. Data collection

2.3.1. Video recording

Elephants were identified using visually discernible differences: height, size and shape of ears, length of tail and presence/absence of hair, scars and tattoos. Data were recorded via live and video observations. All live observations were conducted from public viewing areas during zoo visitor hours. Video footage was either provided by the study zoo from existing cameras (Zoo A, C and E), or cameras were temporarily installed on site (Zoo D, F and G). Where cameras were installed, video recordings were made of outdoor enclosures using high definition video cameras with infrared capability (Hikvision IR network camera, Model DS-2CD2632D-IS, Hikvision Europe, The Netherlands). Cameras had a 20m IR light range and recorded at 20FPS onto bespoke recording kits designed by Carnyx Wild (Carnyx Wild, UK). To comply with data protection laws no sound

recordings were made. A short pilot study was undertaken to determine the most appropriate data collection methods. The main data collection period ran from January 2016 to February 2017. Observations were undertaken by a single observer. Data were collected over a five day period with each day split into 12 x 2-hour periods. Within each 2-hour period data were collected for 1 hour. Observations were stopped whenever elephants were involved in keeper-initiated interactions (e.g. public feeding displays or training). There was a discrepancy in the hours of observations which were able to be undertaken across the study zoos due to external circumstances, e.g. failure of recording equipment, and it not always being possible to view all study elephants for the full duration of each observation period due to enclosure set-ups. Data were therefore analysed as a proportion of total possible observations, to enable comparisons to be made across the study zoos.

2.3.2. Social interactions

Scan sampling and instantaneous recording with a short inter-scan interval (30 seconds) was employed to reduce sampling bias, e.g. only recording the first elephant to take part in an interaction, or to limit introducing an error in interpretation of the context of the interaction. Social interactions were considered to be positive if they were non-aggressive contact or non-aggressive approaches (e.g. touching with the trunk), and negative if they were instances of aggression or a reaction to aggressive behaviour (e.g. walking away from another elephant) (Garai, 1992). Positive and negative social interactions were then further subdivided into physical and non-physical interactions (Table 2).

2.4. Keeper ratings of elephant personality

Elephant personality was assessed using the rating method by keepers familiar with the elephants. Following consultation with keepers, modifications were made to an existing questionnaire (Williams *et al*. 2015) to meet study aims. Modifications included removal of terms which may not be considered to be personality traits (e.g. dominant, subordinate) and inclusion of extra options for 'towards keepers' and 'towards elephants' for relevant terms (e.g. affectionate, calm, fearful and play). The final questionnaire comprised 21 adjectives (Table 3). Ratings were made

157 on a 10cm visual analogue scale with the anchors ‘disagree’ (0cm) and ‘strongly agree’ (10cm). An
158 exact score was determined by measuring the distance (in centimetres, to 1dp) along the line that
159 the rating was placed. Keepers were asked to complete the questionnaires independently of one
160 another. Rating bias was controlled by including a mix of positive and negative traits within the
161 questionnaire. Keepers were asked to state how long they had worked with elephants in general and
162 how long they had worked with the specific herd. Keepers who had worked with elephants or with
163 the specific herd for less than three months (n=1) were excluded from analysis as the assessment
164 required knowledge of the individual over time and in a range of contexts.

165 ## 2.5. Statistical analysis

166 ### 2.5.1. Social behaviour

167 None of the data were normally distributed (Kolmogorov-Smirnov test, $p<0.05$) therefore all tests
168 conducted were non-parametric. A Mann-Whitney U test was carried out to investigate the
169 difference in personality component scores and origin, sex, species and whether individuals were
170 related to others in the herd. Spearman’s rank correlations were undertaken to look at relationships
171 between the component scores and proportion of individuals in the herd interacted with (positive
172 and negative) and frequency of interactions (physical and non-physical positive and negative). Data
173 were also investigated in terms of dyadic interactions, to assess whether elephants were more likely
174 to spend longer interacting with an elephant to whom they had a similar sociable score. Sociability
175 was split, based on three equal sections, into low (0 – 3.3), medium (3.4 – 6.6) and high (6.7 – 10)
176 categories. A Kruskal Wallis test with a Dunn post-hoc test for multiple comparisons was used to
177 investigate whether there was a difference between sociability scores of givers/receivers in dyads
178 and frequency of interactions, i.e. whether there was a higher propensity for ‘givers’ of social
179 interactions to have higher, lower or equal sociability scores to the ‘receivers’ of the social
180 interactions.

181 ### 2.5.2. Keeper ratings of elephant personality

All data analyses were undertaken in SPSS version 21 (SPSS Inc., Chicago, IL). To determine inter-rater reliability, intra-class correlation coefficients (ICC (3,k)) were calculated for each personality adjective (Shrout & Fleiss, 1979). In general, an ICC (3, k) of >0.5 indicates a good level of agreement between raters (in this instance, keepers); therefore any adjectives with an average ICC of <0.5 were removed from further analysis. A single score for each personality adjective was calculated for each elephant by averaging scores across raters. A principal components analysis (PCA) was conducted to reduce the remaining personality adjectives into components. The component solution was rotated using varimax rotation and components with eigenvalues >1 were extracted. Sampling adequacy was assessed by examining the Kaiser-Meyer-Olkin (KMO) statistic and Bartlett's test of Sphericity. Adjectives with salient loadings (>0.4) on more than one component were assigned to the component on which it had the higher loading. None of the adjectives loaded negatively onto the components. Cronbach's alpha was used to detect internal consistency. Composite scores were calculated as the mean of the adjectives within each component.

3. Results

3.1. Social interactions

Social interactions accounted for a relatively small percentage of total activity (mean±SD, range): positive physical interactions 2.68+3.18% (0 – 11.54); negative physical interactions 0.04±0.05% (0 – 0.22); positive non-physical interactions 2.21±2.19% (0.03 – 8.4) and negative non-physical interactions 0.17±0.17% (0 – 0.75).

3.2. Keeper ratings of elephant personality

Personality assessments were completed by 27 elephant keepers across the seven study zoos for 30 elephants (4 males, 26 females. Elephants were rated by between 3 and 6 keepers (Zoos A, B and F: 4; Zoos C, D and E: 3; Zoo G: 6).

3.2.1. Inter-rater reliability and principle components analysis

Inter-rater reliability was assessed for 21 personality adjectives. Nine of the 21 adjectives achieved average ICC values of 0.5 and above (highlighted in bold in Table 4) and were entered into a PCA. The PCA yielded three components with eigenvalues >1 (Table 5), which accounted for 78.7% of the total variance. The KMO Measure of Sampling Adequacy was >0.5 and the Bartlett's Test of Sphericity was <0.001. The three components were named according to the adjectives within them as 'Attentiveness', 'Sociable' and 'Engaged with the environment'. The loadings of each trait onto the three components are presented in Table 5. Cronbach's alpha revealed good internal consistency for each component.

Component 1 was labelled 'Attentiveness' and had high positive loadings on the traits 'adaptable', 'calm in novel situations', 'active' and 'inquisitive'. Elephants scoring highly on this component were considered to be calm and adaptable. Component 2 had high positive loadings on 'sociable', 'affectionate with elephants' and 'playful with conspecifics', and was labelled 'Sociable'. Elephants who scored highly on this component were considered to be more sociable than individuals with lower scores, actively seeking interaction with other individuals or engaging in conspecific play. The final component, component 3, was labelled 'engaged with the environment'. This component had high loadings for 'affectionate with keepers' and 'playful with objects'. It also loaded highly for 'inquisitive', however as this personality adjective loaded higher on component 1 it was assigned to that component for consistency.

3.3. Component scores

3.3.1. Component 1: Attentiveness

Male elephants were considered by keepers to be more 'attentive' than female elephants ($Z=-2.136$, $p<0.05$) however there was no correlation between attentiveness component scores and any of the other variables (origin, species, relatedness to others or age). There was no correlation between attentiveness component scores and frequency of social interactions, nor with proportion of the herd interacted with in either a positive or a negative manner.

3.3.2. Component 2: Sociable

Elephants considered more 'sociable' by elephant keepers interacted positively with a greater proportion of elephants in the herd than did less sociable elephants (R_s=0.395, p<0.05). There was no correlation between personality and the proportion of the herd interacted with in terms of negative interactions. Sociable personality component scores decreased as the age of elephants increased (R_s=-0.714, p<0.001). There was no correlation between herd size and how sociable keepers perceived elephants to be. There was also no relationship between the sociable personality component and the origin of elephants so being born into a zoo was not reflective of keeper ratings of personality. There was also no relationship between personality and sex, species, relatedness to others in the herd or between individual elephants. There was a positive correlation between the sociable personality component score and physical positive interactions (R_s=0.627, p<0.001) and a negative correlation with the frequency of non-physical negative interactions (R_s=-0.505, p<0.01). There was no correlation between frequency of negative physical interactions or non-physical positive interactions and the sociable personality component score.

There was a positive correlation between the combined sociable personality component (i.e. where personality scores of both individuals were combined) and non-physical positive interactions (R_s=0.515, p<0.001) indicating that elephants with a higher combined sociable personality score engaged in a great number of non-physical positive interactions. There was a negative correlation between the combined sociable personality component score and non-physical negative interactions (R_s=-0.479, p<0.001) indicating that the higher the combined sociable personality score for the dyad (i.e. highly sociable giver and receiver), the fewer non-physical negative interactions were given/received. Analysis of the sociable personality component scores indicated that for positive non-physical interactions there was a significant difference between partner types (χ^2=17.461, df=4, p<0.01). A post hoc test revealed that highly sociable elephants (scoring >6.7) engaged in positive non-physical interactions with other highly sociable elephants more frequently than low scoring (<3.3) elephants engaged with medium scoring (3.4 – 6.6) elephants (χ^2=37.250, p<0.05), and medium scoring elephants engaged with each other (χ^2=-26.635, p<0.01). No interactions were

recorded for low – low, low – high, medium – low or high – low sociability combinations so these could not be analysed (Figure 1).

3.3.3. Component 3: Engaged with the environment

Individuals who scored higher on the 'engaged with the environment' component interacted negatively with a greater proportion of the herd than those who scored lower (R_s=0.388, $p<0.05$). There was also a positive correlation between engaged with the environment scores and positive non-physical interactions (R_s=0.385, p=0.002). However, there was no correlation between the 'engaged with the environment' component score and frequency of positive physical interactions, negative physical interactions or negative non-physical interactions. There was no correlation between the 'engaged with the environment' component score and origin, sex, species, relatedness to others in the herd or age.

4. Discussion

The relationship between keeper ratings of elephant personality in UK and Irish herds and social interactions were investigated. Reliability between keepers reached statistically acceptable thresholds and three personality factors were identified: 'engaged with the environment', 'attentiveness' and 'sociable'. It was hypothesised that social interaction frequency would be related to personality, and that some elephants would be more sociable than others. Sociable personality component scores were not related to elephant origin, sex, species or relatedness to others, but they decreased as the age of the elephant increased. There was a positive correlation between combined sociable personality scores in dyads and positive social interactions and a negative correlation with negative social interactions. Elephants considered to be more sociable by keepers interacted with a greater proportion of the herd. Elephants considered highly sociable interacted with other highly sociable elephants more than elephants of other levels of sociability.

4.1. Personality components and social interactions

There was no correlation with the 'attentiveness' component. There was a positive correlation between 'engaged with the environment' and positive non-physical interactions, however elephants who scored higher on that component interacted negatively with a greater proportion of the herd than those who scored lower. Playfulness and goal-directed behaviours are considered by the World Association of Zoos and Aquariums (WAZA) to be examples of positive experiences for animals (Mellor *et al*., 2015). Elephants that were engaging negatively with a greater proportion of the herd were considered to be playful (with objects). This is suggestive of positive welfare states and suggests some level of confidence in the environment. In order for zoo animals to experience good welfare they must be provided with environments that promote positive affective states (Mellor, 2016). The results of this study suggest that the welfare of these individuals is not comprised. The presence of positive social interactions, interaction with the environment and only low levels of negative social interactions suggest an overall positive affective state for the study herds.

Sociability personality component scoress were not related to origin of elephants, sex, species or relatedness to others in the herd. This suggests that being born into a zoo, or being a member of a naturalistic herd did not have an impact on the sociability of the study elephants. This finding is to be expected. Personality is defined as individual differences, stable across time and situations (Freeman & Gosling, 2010), but it is believed to be shaped by past experiences and environmental variations (Sachser *et al*., 2013). Individuals may respond differently to the same environments but the behavioural changes should change in relation to others in the group (Gosling, 2001).

Sociable personality component scores decreased as age increased in the study herds. This could be linked to development of young animals, settling into their adult personalities as they mature. The extent to which the zoo environment affects the development of personality is still unknown. Studies of laboratory rats have found that individual personality can be shaped by early environments (Rodel & Meyer, 2011). Powell and Gartner (2011) suggest that there is a need to

assess the impact of physical and social rearing environments on personality developments, because there may be the potential to steer personality development. How the zoo environment shapes the personality of young elephants is an area for future consideration.

4.2. Analysis of dyadic relationships

There was a positive correlation between combined dyadic scores and non-physical social interactions and a negative correlation with non-physical negative interactions. It was hypothesised that there would be a link between levels of sociability of individuals, with individuals who were highly sociable interacting more frequently with other highly sociable individuals and less frequently with individuals who were considered less sociable. A relationship between social personality component scores in dyads was found, but it was not linear. Elephants who scored highly on the sociable personality component engaged in more positive non-physical interactions with other high scoring elephants more frequently than low scoring elephants, and medium scoring elephants engaged most frequently with each other. These differences may be attributable to the relative hierarchical position of individuals or they may represent a lack of options in terms of sociability level of herd mates. In the wild, dominance interactions between African elephants were predominantly dyadic and were most frequent between group matriarchs (Wittemyer *et al*., 2007). Research into dolphins has also indicated links between personality and social rank, with the relationship being most apparent at extremes of the hierarchy (Frick, 2016).

Literature on the relationship between personality and social organisation is growing, particularly in zoo animal welfare studies where it is used to identify potentially more compatible social groups or appropriate partners for breeding (e.g. Carlstead *et al*., 1999; Wielebnowski, 1999; Massen & Koski, 2014; Martin-Wintle *et al*., 2017). There is still a paucity of literature on the relationship between personality and social behaviour in zoo elephants, despite recognition of their complex social relationships and needs. Indeed, for many species the relationship between personality and social relationships remains largely unclear. Personality and sociability are believed to be inherently related, with one factor influencing the other. Horback *et al*. (2013) suggested that

zoo elephant personalities, as rated by caretakers with an extensive knowledge of the individuals, could be used as a proxy for long-term behavioural monitoring. A recent study by Bonaparte-Saller and Mench (2018) was the first to use keeper surveys to assess social bond strength in zoo elephants, determining that keepers could reliably rate elephant social bond strength and ratings were related to proximity analyses of the study elephants. However, Bonaparte-Saller and Mench (2018) found no relationship between keeper ratings of social bond strength and social interactions. Makecha et al (2012) suggested that personality likely plays a critical role in frequency and types of social interactions in which elephants engage. Our findings support that assertion; keeper ratings of personality were related to social interactions in UK and Irish zoo elephant herds. Whilst it was beyond the scope of this study to assess the use of personality as a predictive tool in assessment of elephant compatibility, results highlight the potential use of keeper ratings in such an assessment.

Elephants are a social species and physical aggression in female wild elephant herds is minimal (Guthmann, 1970; Lee, 1987; Archie & Chiyo, 2012). Researchers have documented aggression in zoo elephant herds (Adams & Berg, 1980; Clubb & Mason, 2002; Wilson *et al*., 2006; Zoos Forum, 2010) but where details are provided the behaviours observed are those which could be considered low levels of agonistic interactions, such as displacement (Adams & Berg, 1980; Wilson *et al*., 2006). Most reports in wild elephants of physical aggression are from bull elephants, during musth, a point of heightened sexual activity when elephants have elevated levels of testosterone (Lincoln & Ratnasooriya, 1996). None of the herds in this study housed more than one bull elephant. Bulls were housed with females, or with family groups including calves of both sexes. The minimal aggression observed in this study may also be due to the pro-active management of social incompatibilities by the study zoos, to prevent escalation of aggression within the herds.

Results from this research have the potential for immediate application in industry. Current Secretary of States Standards of Modern Zoo Practice (SSSMZP) elephant management guidelines include the requirement for a long-term management plan for individual elephants, including a behaviour profile which can inform compatibility in the long term collection plan (Defra, 2017). An

individual's personality is an important component of a profile and it should therefore be incorporated into such a document. This study provides evidence for the reliability with which UK and Irish elephant keepers can rate personality of their animals. Incorporation of keeper ratings of personality is a simple means of incorporating individual personality into management decisions. This is not the first-time personality has been advocated for inclusion in welfare assessments, but it is the first time such a technique has been suggested for inclusion in the long term management plans of elephant herds and it deserves considerably more thought and discussion moving forward. Future work should seek to assess the reliability of personality assessment as a predictive social compatibility tool, for example, when individuals are moved to other herds as part of routine population management or when group structure changes due to births or deaths.

5. Conclusion

The importance of consideration of personality differences has been highlighted in a number of species both in the wild and zoos. Engagement in positive social interactions is indicative of positive affective states in zoo animals. The results from this study show that elephants exhibit unique personalities and that individuals show differing levels of sociability. Recognition of these differences is extremely important, and using a reliable assessment method which is unambiguous and repeatable is paramount for inclusion in welfare assessment. Keeper questionnaires were identified as a reliable means of assessing elephant personality and keeper ratings of personality were related to frequency of social interactions. Individual differences in zoo animals have previously been related to: breeding success, resting behaviour and social compatibility. Keepers and researchers have highlighted the importance of caring for elephants on an individual basis and recent changes to elephant management guidelines have expressed this sentiment. Current guidelines state that UK and Irish zoos should provide unique management plans for each animal and have a long-term management plan for each elephant exhibit (including individual behavioural profiles and details of herd compatibility). The ability to reliably document personality of zoo elephants is an important aspect to consider and include in individual management plans. Future

work should seek to build on the assessments undertaken here to investigate the potential for keeper ratings of sociability as a predictive tool in elephant compatibility assessments to optimise social management of elephants.

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515 Table legends

516 Table 1. Elephant and herd demographics for the study elephants at the onset of the study period
517 (October 2015)

518 Table 2. Elephant behaviour ethogram (based on Asher et al. 2015)

519 Table 3. Adjective and behavioural definitions included in the elephant personality assessment sent
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Table 1. Elephant and herd demographics for the study elephants at the onset of the study period (October 2015)

Zoo	Elephant	Species	Sex	Age	No. relatives in herd	Wild or captive born	If zoo born, at natal zoo?	Observation period (mins)	Proportion observations in sight
A	E1	African	F	45	0	Wild	N/A	5817	0.66
	E2	African	F	47	0	Wild	N/A	5817	0.98
B	E3	Asian	F	54	0	Wild	N/A	5842	0.89
	E4	Asian	F	44	0	Wild	N/A	5842	0.89
	E5	Asian	F	40	0	Wild	N/A	5842	0.85
C	-	Asian	F	49	0	Captive	N	-	-
	E6	Asian	M	15	1	Captive	N	5838	0.16
	E7	Asian	F	1	4	Captive	Y	5838	0.90
	E8	Asian	F	36	3	Wild	N/A	5838	0.78
	E9	Asian	F	19	3	Captive	Y	5838	0.87
	E10	Asian	F	13	3	Captive	Y	5838	0.87
D	E11	African	M	34	0	Wild	N/A	7666	0.20
	E12	African	F	35	0	Wild	N/A	7666	0.27
	E13	African	F	35	0	Wild	N/A	7666	0.67
	E14	African	F	31	0	Wild	N/A	7666	0.69
E	E15	Asian	F	32	8	Captive	N	3267	0.65
	E16	Asian	F	26	8	Captive	N	3267	0.66
	E17	Asian	F	13	8	Captive	N	3267	0.71
	E18	Asian	F	10	8	Captive	Y	3267	0.75
	E19	Asian	M	2	9	Captive	Y	3267	0.61
	E20	Asian	F	2	9	Captive	Y	3267	0.65
	E21	Asian	M	2	9	Captive	Y	3267	0.60
	-	Asian	F	<1	9	Captive	Y	-	-
	-	Asian	M	22	9	Captive	N	-	-
F	E22	African	F	14	1	Captive	Y	5031	0.79
	E23	African	F	30	0	Wild	N/A	5031	0.76
	E24	African	F	14	2	Captive	Y	5031	0.81
	E25	African	F	30	1	Wild	N/A	5031	0.80
G	E26	Asian	F	33	0	Wild	N/A	5016	0.69
	E27	Asian	F	22	1	Captive	N	5016	0.70
	E28	Asian	F	3	1	Captive	Y	5016	0.63
	E29	Asian	F	19	1	Captive	Y	5016	0.68
	E30	Asian	F	34	1	Wild	N/A	5016	0.67

The adult female at Zoo C was removed from the study for consistency between rating data, as her personality assessment was completed by only two keepers. The calf at Zoo E was not included as it was born midway through the study. The bull was rated for personality but no corresponding social behaviour data was available due to video camera quality from outside enclosures so was removed from the study.

553 Table 2. Elephant behaviour ethogram (based on Asher et al. 2015)

Behaviour			Description
Positive	Positive physical	Conspecific play	Engaging in active play with another elephant, including head-to-head sparring, trunk wrestling, mounting, chasing and rolling on one another. Does not include behaviours observed following an agonistic encounter or courtship.
		Touching (trunk to)	Touching another elephant with the trunk in a non-aggressive manner
		Touching (body to)	Touching/rubbing another elephant with the body
	Positive non-physical	Protecting	Standing over another elephant
		Huddling	Formation of a tight circle with calves at the nucleus. Calves hidden in the middle, adults surrounding them.
		Approach	Walking towards another elephant in a non-threatening manner. Recipient stays in position during and after the approach.
		Approach with trunk	Trunk outstretched towards another elephant. Not close enough to make physical contact.
		Walking with	Walking side by side with another elephant
		Following	Walking closely behind another elephant (within one elephant body length)
Negative	Negative physical	Pushing	One elephant forces or pushes against the body (usually the rump) of another elephant, resulting in the elephant that is being pushed moving at least two steps
		Pulling	Using the trunk to pull at another elephant in a non-playful manner. May pull at the trunk or an accessible body part such as tusks/tushes or the tail.
		Sparring	An escalation of a push/pull incident into more physical aggression
		Hitting/kicking	Aggressive physical contact with the trunk or leg, e.g. trunk strike or kicking out. A largely disciplinary behaviour.
	Negative non-physical	Displace	Movement of one elephant results in another elephant leaving its location (within 10 seconds) - usually occurs when a more dominant elephant approaches a more subordinate individual
		Approach	Walking towards another elephant in an aggressive or hostile manner (head held high, ears wide or flapping). Receiving elephant may either respond to this by standing as tall as possible, head raised, ears flapping or turning away from/walking away from the approaching elephant
		Walking/turning away from	Avoiding or shying away from elephants or people; the individual either walks forwards away from or backwards away from a particular elephant or person
		Frozen	Standing still and alert as another elephant approaches

	Charge/mock charge	Move towards another elephant with the head held high, pace usually quickens as individual gets closer to the target elephant. In the case of a mock charge the individual charging stops further away from the target elephant.
	Blocking	Blocking from food source or other resource (e.g. door)

Table 3. Adjective and behavioural definitions included in the elephant personality assessment sent to keepers (n= 27) at the study zoos (n=7) to assess the profiles of their elephants (n=30)

Adjective	Definition
Active	Has high motivation to be physically active
Adaptable	Quickly adapts to novel situations
Affectionate (keepers)	Seeks close relationships to keepers
Affectionate (elephants)	Seeks close relationships to elephants (please place two lines if there is a difference for related or un-related elephants)
Aggressive	Causes harm or potential harm to conspecifics, e.g. displays, chases, bites
Apprehensive	Seems anxious; fears or avoids risk
Calm (unfamiliar people)	Reacts to unfamiliar people in a calm and peaceful manner
Calm (novel situations)	Reacts to novel situations in a calm and peaceful manner
Confident	Behaves in a positive, assured manner
Curious	Shows interest in novel objects
Fearful (conspecifics)	Retreats readily from conspecifics
Fearful (disturbances)	Retreats readily from outside disturbances
Inquisitive	Explores new situations and tries to learn new things
Mischievous	Shows a fondness for causing trouble in a playful way, e.g. sand kicking or trunk grabbing
Playful (conspecifics)	Initiates or readily engages in play with conspecifics
Playful (objects)	Readily engages in play with objects
Placid	Reacts to conspecifics in an even, calm way; is not easily disturbed
Restless	Rarely relaxes, always walking or moving around the enclosure
Sociable	seeks companionship of conspecifics
Solitary	Spends time alone
Vigilant	Carefully watches or listens for possible dangers in the surroundings and easily becomes alerted

Table 4. Intra-class correlation coefficient (ICC*) scores for each personality adjective included in the keeper assessment of elephant personality. Adjectives with an average ICC value of >0.4 were entered into a PCA

Adjective	ICC* (3, K)							
	Zoo A	Zoo B	Zoo C	Zoo D	Zoo E	Zoo F	Zoo G	Average Score (1dp)
Active	0.95	0.86	0.67	0.96	0.51	0.79	0.73	**0.8**
Adaptable	0.92	-0.02	0.01	0.72	0.40	0.59	0.57	**0.5**
Affectionate (keepers)	-0.14	0.55	0.12	0.95	0.74	0.80	0.37	**0.5**
Affectionate (elephants)	0.95	0.76	0.30	0.69	0.62	0.52	0.40	**0.6**
Aggressive	0.47	-0.22	0.44	0.02	0.75	0.74	0.94	0.4
Apprehensive	0.96	0.08	-0.11	-0.01	0.42	0.15	-0.08	0.2
Calm (unfamiliar people)	0.18	0.7	-0.22	0.88	-0.30	0.75	-0.06	0.3
Calm (novel situations)	0.77	0.61	0.40	0.93	-0.02	0.47	0.36	**0.5**
Confident	0.95	0.56	-0.28	0.73	0.45	0.24	0.04	0.4
Curious	0.79	-0.08	0.28	-0.25	0.40	0.79	0.35	0.3
Fearful (conspecifics)	0.99	0.24	0.01	0.23	0.66	0.37	0.76	0.4
Fearful (disturbances)	-0.32	-0.26	-0.29	0.01	0.15	0.26	0.16	0.0
Inquisitive	0.92	0.01	0.58	-0.03	0.50	0.82	0.36	**0.5**
Mischievous	0.98	0.62	0.03	-0.13	0.21	0.41	0.63	0.4
Playful (conspecifics)	0.59	-0.18	0.69	-0.08	0.86	0.76	0.60	**0.5**
Playful (objects)	0.75	0.50	0.60	-0.07	0.74	0.55	0.42	**0.5**
Placid	0.85	0.36	0.08	0.47	0.52	-0.23	0.08	0.3
Restless	-0.18	0.17	0.27	0.28	0.42	-0.08	0.70	0.2
Sociable	0.96	0.71	0.74	0.76	0.08	0.18	0.73	**0.6**
Solitary	0.77	0.26	0.92	0.08	0.11	0.34	0.52	0.4
Vigilant	0.66	0.22	0.01	0.40	0.60	0.77	0.40	0.4

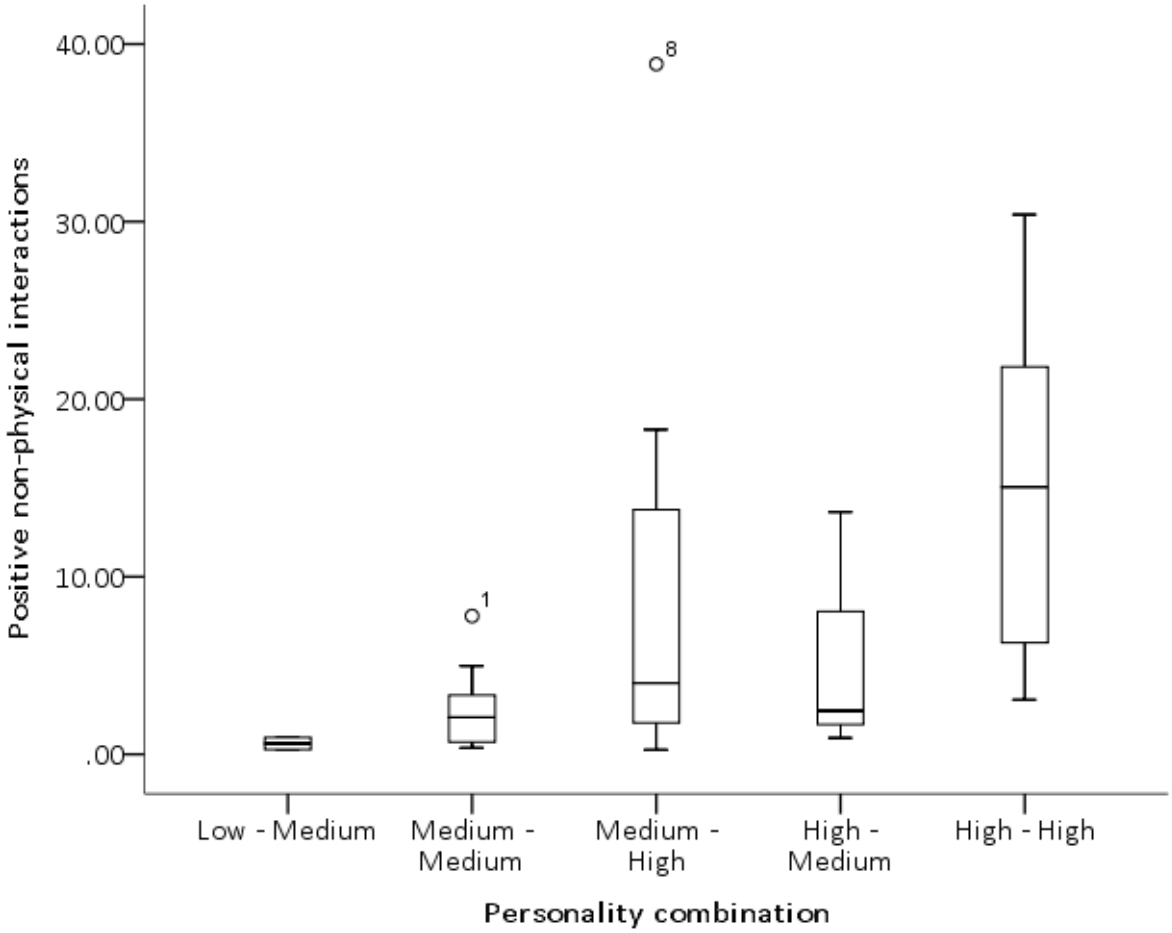
Values in bold indicate personality adjectives which were entered into a PCA

*ICC refers to an intra-class correlation coefficient, which is used as a measure of reliability between raters

Table 5. Factor loadings and communalities of the 21 personality adjectives in the keeper questionnaire with intra-class correlation coefficient (ICC) scores >0.4

Personality adjective	Component 1 (Attentiveness) α = 0.856	Component 2 (Sociable) α = 0.857	Component 3 (Engaged with the environment) α = 0.459	Communality
Adaptable	**0.910**			0.863
Calm – novel situations	**0.873**			0.778
Active	**0.735**	0.431		0.726
Inquisitive	**0.578**		0.568	0.801
Sociable		**0.925**		0.865
Affectionate – elephants		**0.878**		0.802
Playful – conspecifics	0.435	**0.697**		0.818
Affectionate – keepers			**0.838**	0.703
Playful - objects		0.447	**0.658**	0.730
Eigenvalue	4.623	1.387	1.076	
% of variance	51.4	15.4	12%	

Loadings of <0.4 are not shown. Factor loadings of less than 0.5 have been omitted. Only adjectives whose loadings are highlighted in bold contributed to the formation of the component scores. Cronbach's alpha scores for each component were as follows: component 1 = 0.856, component 2 = 0.857, component 3 = 0.459.



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