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4	Behavioural examination of a successful introduction of a hand-reared white rhinoceros
5	Running title: Successful introduction of a hand-reared white rhinoceros
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Abstract: Introductions and familiarisations of captive animals are common in contemporary 11 zoos. To introduce hand-reared offspring to conspecifics can be challenging as they may lack 12 social skills and have rarely been investigated in non-primate mammals. A behavioural 13 assessment of these processes for hand-reared rhinoceros has not been previously reported. A 14 hand-reared southern white rhinoceros calf (Ceratotherium simum simun) was introduced to an 15 initially aggressive individual, the mother of another calf. Using continuous observations of 16 17 social interactions (agonistic, cohesive and play behaviour) and instantaneous sampling of four 18 routine behaviours (feeding, resting, locomotion, interaction environment) two weeks before and after the full introduction, the behaviour of five white rhinos was observed. The routine 19 20 behaviours were quantified as proportion of time and social interaction as frequency. Immediately following introduction, the frequency of agonistic behaviours increased but then 21 dropped quickly. Additionally, cohesive behaviours involved all individuals and elicited play 22 23 behaviour suggesting that previously used indicators for primates, as affiliative and play behaviour with all group members, may also be applied to other groups to assess a successful 24 introduction. Surprisingly, most social interactions and the closest bond of the hand-reared infant 25 occurred with the initially aggressive individual and her calf. This shows that even once 26 aggressive behaviour occurred, a successful introduction is still possible and the information 27 gained are relevant to guide similar future introductions and give valuable reference information. 28 Increased frequencies and greater behavioural diversity after the introduction indicated a welfare 29 benefit for the introduced individual, as well as the opportunity to learn species-appropriate 30 behaviour. 31

32 Keywords: animal welfare, integration, ungulates, hand-raising, alloparental, social enrichment

33 Introduction

In the wild animals can choose their group or companion conspecific, whereas in captivity 34 animals are allocated by humans and their choice is restricted due to limited space and a number 35 of conspecifics. Nowadays, many animals kept in zoos are transferred between facilities for 36 breeding to ensure species conservation and genetic diversity, or due to a lack of space or exhibit 37 38 considerations. Therefore group composition changes accompanied by introductions and 39 familiarisations of animals that are a necessary and a standard part in everyday zoo life (Guertler 2008). This also concerns animals of all age classes which should be socialised, as well as hand-40 reared offspring. Consequently, it is crucial to evaluate the ramifications of these processes for 41 the whole group, including introduced as well as individuals already present in the group. 42 Moreover, traits like health, and welfare of individuals, as well as the group, are affected by 43 44 social relations (Rose & Croft 2015). The introduction of an individual into an existing group can 45 pose a disruption and an alteration/intervention in the social framework which generates social stress and can, in turn, impair animal welfare (Patison et al. 2010). Introduction methods are 46 often reported, but scientific behavioural assessments are rarely presented, which are needed to 47 elucidate the current process status, determine special requirements, identify stressful aspects and 48 utterly incompatible individuals. Thus, there is a need for processes of introduction and 49 socialisation to be further investigated in non-primate mammals in a zoo or zoo-similar context 50 (Powell 2010). Despite their daily relevance and frequent occurrences, these processes are rarely 51 investigated with respect to their animal welfare consequences. 52

53 Most published literature on social introduction considers primates, many of them in a laboratory 54 environment. However, in order to facilitate the process, three introductory basic steps can be 55 adopted: sensory-, limited tactile- and full contact (Powell 2010). Essentially, an entirely new 56 situation should be avoided. Familiarisation with the area, other individuals and, as it would be usual in nature, first with the scent, sound or sight of the unfamiliar individual, are advisable 57 (Powell 2010). Familiarisation is the process of becoming acquainted with a new environment (K 58 Dictionaries 2013). After the non-tactile sensory contact has been established, the next step 59 should be limited tactile contact using a barrier. If in this stage aggression and anxiety signs of 60 the animals have ended, the next step can be initiated. For the physical introduction, clean 61 62 holding areas, where the animals can be controlled and if necessary easily separated, should be preferred. Furthermore, enrichment and distraction, perhaps encouraging of foraging throughout 63 the chosen enclosure, as well as an animal health-check, are advisable. However, the 64 65 implementation of these steps can vary, considering the respective characteristics of the species. Anyway, it is important to monitor, record, assess and readjust social introductions. Sometimes, 66 introductions aim for some level of socialisation, which is a development where an individual 67 68 acquires social skills, to live peacefully in a social group, or to be suitable to breed and rear offspring (Powell 2010). For example, familiarisation was measured as the level of agonistic 69 interactions between unfamiliar cattle (Bos taurus). Directly after an introduction, high numbers 70 of agonistic behaviours were reported, but over time, these interactions decreased (Kondo & 71 Hurnik 1990). This suggests a process of familiarisation between individuals. Other 72 ramifications accompanied with social stress of an introduction in cattle are more standing and 73 reduced lying (Gupta et al. 2008) and less affiliative interactions (von Keyserlingk et al. 2008). 74 Patison et al. (2010) examined social interactions and behaviour between familiar and unfamiliar 75 Brahman steer (Bos indicus) pairs for five days. They found that proximity, behaviour and 76 movement patterns are influenced by the level of familiarisation. The Initial distance between 77

unfamiliar individuals was larger for the first three days; they grazed more and they showedincreased locomotion as they moved more towards and away from another.

In zoos, it often happens that offspring will be hand-reared for a number of different reasons, 80 such as inappropriate maternal behaviour or neglect, injury concern, and insufficient breast-milk. 81 Especially in mammals, some adult species-appropriate behaviour is essentially influenced by 82 the mother-child bond (Powell 2010). Furthermore, certain behavioural patterns and 83 84 communication are necessary for social coexistence in groups (Cross 2007), though, hand-reared offspring might lack the opportunity to learn species-specific behaviours, which makes an 85 introduction particular challenging. In the introduction period, two hand-reared chimpanzee 86 offspring displayed stress-indicating behaviours and took part with all conspecifics in affiliative 87 interactions. Interestingly, an allomothering bond occurred with both infants; however, the hand-88 reared animals still engaged substantial less time in social behaviour than mother-raised 89 90 offspring. Furthermore, the two offspring' focused constantly few social behaviours on humans. The successful introduction of hand-reared offspring seems to be characterised by forming social 91 bonds with conspecifics but not by removing social contact to humans (Bashaw et al. 2009). 92 However, there is a lack of knowledge about the introduction of hand-reared non-primate 93 mammals to conspecifics. 94

An iconic species for many zoo visitors, the rhinoceros, is in the wild still threatened by poaching and the demand for their horns. As well as in captivity, a recent studbook analysis of the European southern white rhinoceros population revealed that the population size is on a negative trend by 1.19 times (Reid et al. 2012). Therefore, it is a vital topic to investigate the introduction of a hand-reared rhinoceros calf. In the wild, rhinoceros' form dynamic group compositions, usually they changed monthly and solely two rhinoceroses had a close 101 relationship. Nonetheless, also substantially longer lasting associations have been observed. Groups of southern white rhinoceros consisted of up to seven individuals, cows with and without 102 calves and sub-adults. Supposedly, the associations are based on mother-offspring relationships, 103 even formed with unrelated sub-adults or a bond of two sub-adults. Seldom two adult females 104 formed a group. (Owen-Smith 1973, Owen-Smith 1975, Shrader & Owen-Smith 2002). Group 105 members typically stayed in close distance, frequently less than 5m (Owen-Smith 1975). 106 107 However, at the time of parturition, cows ended associations (Owen-Smith 1975). The white rhinoceros is an exception among other rhinoceros species denoted by an increased sociality. 108 Although adult males become solitary and territorial (Shrader & Owen-Smith 2002). Cows 109 110 usually form overlapping home ranges, when they meet they either showed ignorance or approximate for "reciprocal nasonasal contacts" which might turn into "playful horn wrestling" 111 (Owen-Smith 1975). A snort understood as a slight distance vocalisation was also occasionally 112 113 perceived (Owen-Smith 1975). Subadults were often involved in "nasonasal contacts" and "horn wrestling" with each other or female adults (Owen-Smith 1975). A stronger defensive, distance-114 increasing display is the snarl (Owen-Smith 1975). In wild rhinos, space maintenance 115 vocalisation occurred fewer than once per hour (Owen-Smith 1973). Otherwise, for the majority 116 of the day, Owen-Smith (1973) reported that wild white rhinoceros fed 48.8% and rested 36.8%. 117 However, females with young calves vocalised more frequently towards approaching 118 rhinoceros', to maintain the distance, than other females (Owen-Smith 1973). Metrione et al. 119 (2007) confirmed these findings in a zoo environment and concluded they are spatially stressed. 120

Recently, Cinková & Bicík (2013) ascertained that social interactions were effected by group setups, because in a group of northern white rhinoceros after a segregation of one adult female the amount of play and agonistic behaviour raised, but cohesive behaviour did not show a 124 significant difference. The term cohesive behaviour was used as a surrogate for affiliative behaviour by Milkulica (1991) and carried further. Overall the individuals in this study displayed 125 behaviours relatively often which are rarely or not seen in wilderness, including cohesive, 126 playful and extreme agonistic interactions, such as "clash of horns". This might be a 127 consequence of confinement and the vicinity of individuals (Cinková & Bicík 2013). As well as 128 group alteration might be a chance to increase welfare (Cinková & Bicík 2013). Additionally, 129 130 Cinková & Bicík (2013) pointed out that to improve captive management, research how group composition affects the white rhinoceros' social behaviour is urgently required. 131

I investigated possible changes in social interactions and routine behaviours like feeding, resting 132 and locomotion in a group of five southern white rhinos following introduction and 133 familiarisation of a hand-reared calf. I also examined descriptively initiators of agonistic 134 behaviour towards the introduced individual. As there are no other behavioural examinations of a 135 hand-reared rhinoceros introduction available, this study is relevant to guide similar future 136 introductions. The aim is to investigate the processes of introduction and familiarisation in a non-137 primate mammal in a behavioural context and may, identify first assessment indicators of a 138 successful introduction and crucial aspects. Ultimately, to infer individual and group animal 139 welfare consequences. And to encourage facilities to introduce hand-reared rhinoceros thus, to 140 meet future decisions in terms of best possible welfare with the result of a further improved 141 captive management. 142

143

144 Materials and methods

145 Subjects and housing

The study's five white rhinoceros live in the Zoo Augsburg (Germany). The rhinoceros exhibit consists of two smaller pre-enclosures and the primary enclosure, the African Panorama (Figure 1). The two pre-enclosures have a size of 340 m² and 700 m², respectively, and the Africa Panorama is 11850 m². Keepers feed the rhinoceros every morning and evening, additionally outside grazing mainly in the Africa Panorama is possible, sometimes grass bunches were provided in the big pre-enclosure and Africa Panorama.

152 Table 1 gives an overview of details for the study animals and any further information. Two females of the established rhinoceros' group gave recently birth to Keeva and Kibo, thereafter 153 the group structure changed. The Zoo Augsburg participates in the European Endangered 154 Species Programmes (EEP) for rhinoceroses. In the past also two bulls were present, mainly kept 155 separate, though, however, they were transferred to other zoos before the birth of the calves. Yet 156 both offspring' have the same father. Kibo is hand-reared because his mother Kibibi refused to 157 158 suckle him and additionally injury concerns mattered. The hand-raising proceeded largely without any complications (White 2016), he was outside alone or with a keeper in one of the 159 enclosures. Chris did not tolerate any conspecifics in her environment and was thereupon 160 separated together with her offspring Keeva. Chris and Keeva were assigned to one enclosure as 161 well as Baby and Kibibi to another. Since the 26th and 27th of March 2016 Kibo and Chris and 162 Keeva, respectively, are grouped alternately with the two other adult females in one of the three 163 enclosures. 164

165

Swapping groups between the adjacent enclosures on different days allowed scent, auditory and visual contact between all individuals. Rhinoceros cannot only hear and communicate in the for humans audible frequencies but also in sonic and infrasonic ranges (Wiseman et al. 2014). 169 Approximately a month prior to the study, occasional attempts of limited tactile contact through bars had been conducted. Initially, Chris was very aggressive towards Kibo. Kibo was very 170 connected to humans and was not able to react species-appropriately to her signals to keep his 171 distance. Starting 24th May 2016, limited tactile contact was established every day until the full 172 physical introduction on the 2nd June 2016. For safety reasons, individuals stay inside boxes 173 overnight, only Chris and Keeva share boxes. Time spend outside depended on what keeper was 174 on duty, weather, number of visitors and the rhinoceros' behaviour. Sometimes, during heavy 175 rain or when they might have been exhausted, individuals stood outside in front of the door to go 176 inside. On the other hand, seldom the rhinoceros did not come inside long after the zoo closed. 177

178

179 Observations

In May and June 2016 I conducted 72 hours of observation before, during and after the 180 introduction of the hand-reared calf. The individuals could be identified using phenotypic 181 182 features. Twenty repetitions of each of the three group composition were observed; 1) Kibo together with Baby and Kibibi; 2) Keeva and Chris alone, and jointly with the two adults; 3) 183 Kibo, Keeva, Chris, Baby, Kibibi together resulting in a total sample size of n = 60. 184 185 Additionally, I observed 8 hours of limited tactile contact until the decision for the full physical introduction was finalised. Compositions 1) and 2), as control groups, ensure that observed 186 behaviours are truly caused by introduction. Keepers assigned the group compositions to the 187 three separate enclosures; however, some preferred to group composition 2) so that Kibo had 188 more time with conspecifics. Two different types of behaviour are distinguished, routine 189 behaviours and social interactions. The former are basic actions; I recorded feeding when an 190 individual grazed or suckled; resting when being inactive standing or lying, and locomotion 191

192 meant moving, little steps while feeding counted not as movement. The routine behaviour interaction environment combines different behaviours conducted alone such as rub body/horn 193 against trees, stones, tires, grid, taking a mudbath, play ball and interact with hanging branches. 194 The second type is social interactions, divided in agonistic, cohesive and play behaviour. A more 195 detailed subdivision and descriptions of these observed behaviours are listed in an ethogram 196 (Appendix 1). Although whine behaviour counts as cohesive behaviour, it is evaluated 197 198 separately, because Keeva usually directed it to her mother but also Kibo implemented this 199 vocalisation. Usually, two to four observation periods of circa one to two hours were conducted every day. Observations during midday were largely avoided since rhinoceros have been 200 201 reported as inactive at midday (Metrione et al. 2007) and were taken from good vantage points to get the best possible view. Following Martin & Bateson (2007), preliminary observation 202 empirically determined an appropriate objective sampling interval. I combined two approaches; 203 204 for the four routine behaviour (feeding, resting, locomotion, interaction environment) an instantaneous sampling design, using a 60 s interval. A 60 s interval was supported by the 205 calculation of 1.5 h of observation in group composition 1), there was no appropriate sampling 206 interval for social interactions (Appendix 2). Thus, the occurrence of rarer cohesive and agonistic 207 behaviours were recorded continuously. A new incident was reported when the behaviour 208 stopped, and the individual did something else. Further, I recorded the initiator and recipient of 209 each interaction. Additionally, similar to the utilisation in Metrione et al. (2007), the mean space 210 maintenance vocalisations (including snorts and snarls) in each group composition per hour was 211 212 calculated.

Apart from this, the daytime (start time of the observation), the enclosure, and the number of days since or to the full introduction, which mirrors the familiarisation process of Kibo, were also recorded; the latter is henceforth referred as familiarisation, day zero indicates the day of the
full introduction. Moreover, visitor numbers, provided by the zoo curator, are recorded because
Fernandez et al. (2009) concluded in their review that many loud visitors influence aggression
and activity in animals.

219 Data handling/processing

220 Prior to analyses, I summarised for every observation session; a frequency was calculated of 221 every routine behaviour and an event count was taken for the rare behaviours split into agonistic, cohesive and play behaviour. Calculations accounted for out-of-sight periods, all periods when 222 an individual or group was reported as NA were excluded from the calculations. Similarly, is the 223 utilisation for social behaviours, for example when two individuals were out of sight for 30 s, the 224 whole minute was recorded as NA. Number of social interactions are divided by the number of 225 226 rhinos present to account for different numbers of rhinoceros. The identity of the rhino was not considered as a random factor because of collinearity issues with group composition. The zoo 227 opens at 9 am and the rhino enclosures are far away from the entrance, and thus for observation 228 sessions starting before 8:30 am and 9:30 am, visitor numbers were reduced by 80% and 70%, 229 respectively (pers. observation), and visitor numbers were log-transformed. Daytime is R 230 compatible adjusted, e.g. 8:30 am is 8.5. Agonistic and cohesive behaviours towards Kibo were 231 analysed separately and specified what type they were and who initiated them. The observation 232 of the limited tactile contact through bars is not a part of the formal analyses due to 233 234 inconsistencies in implementation.

235

236 Statistical analysis

I conducted all following statistical analyses in R (R Core Team 2015 version 3.2.2) and used R
packages ggplot2 (Wickham 2009) and reshape2 (Wickham 2007) to present results.

At the start of the study, a power analysis for different mean distances between familiar and 239 unfamiliar pairs of Brahman (Bos indicus) steers ascertained an appropriate number of 240 241 observation replications. From each of seven movement vectors (values from Patison et al 2010) 242 an average effect size was calculated. The obtained effect size=0.70, the significance level=0.05 243 and the power=0.8, was applied in a Paired t-test power calculation. Paired because I observed the same individuals under different circumstances. The result justified the implementation of 19 244 repetitions of each group composition and ensures sufficient statistical power to show an effect 245 as found in another study. 246

247 Generalised linear models were used to analyse the following response variables: feeding; resting; locomotion; interaction environment; all agonistic behaviours; agonistic behaviour 248 249 towards Kibo, all cohesive behaviours; cohesive behaviour towards Kibo, whine and play behaviour. Group composition enclosure, log-transformed visitor number, daytime and 250 251 familiarisation were considered as explanatory variables. Further biologically relevant interactions were included between group composition and enclosure as well as group 252 composition and familiarisation. Beginning with a global model the best fitting model was 253 determined using a stepwise backwards elimination alongside Likelihood Ratio Tests (LRT's) by 254 testing the model with the effect in question against the model without it. 255

First, I examined the routine behaviours for differences among the groups. In case differences in routine behaviour between groups occurred, they would need to be considered for the modelling of social interactions. If I ended up considering too many explanatory variables, referring to the guideline that five to ten times as many cases (here n = 60) as explanatory factors are required 260 (D'Agostino 2005), I tried to reduce the number of explanatory variables. In these cases, 261 univariate tests determined the fixed effects that are ultimately considered in the global model for 262 each response variable, using p = 0.1.

Model assumptions are visually inspected and overdispersion considered using the residual 263 deviance in order to determine the best fitting model. All of the routine behaviours are modelled 264 using the normal distribution as error distribution. Furthermore, I used the Poisson distribution 265 266 for the analyses for the count data all agonistic behaviours, all cohesive behaviours and cohesive behaviour towards Kibo. For agonistic behaviour to Kibo the normal distribution fitted best. The 267 whine behaviour model using Poisson distribution were over dispersed and as well as for play 268 behaviour the negative binomial distribution was applied, using the package MASS (Venables & 269 Ripley 2002). 270

271 Ethical Consideration

Observations did not impair animal welfare because I solely choose locations accessible for visitors or keepers. If keepers felt the group composition during the beginning of the full physical introduction was too stressful, when individuals run around for an escape, and agonistic behaviour increased tremendously, a door opened to another enclosure, where animals could separate themselves from each other. According to the German Animal Welfare Act §7a, this research requires no special license.

278 Results

Before introducing the calf, no agonistic behaviour during limited tactile contact from theinitially aggressive individual was observed. Contrarily, Chris displayed much interest, she most

281 frequently approached Kibo and initiated nose meetings and moved her lips over Kibo and

allowed Kibo the same. None of the other females engaged as frequently with Kibo and allowed
Kibo to initiate interactions (Figure 2). However, these are anecdotal observations. This built the
base for the full physical introduction, though not statistically examined due to inconsistencies in
implementation.

286

287 Routine behaviours

288 Feeding

The interaction between group composition and familiarisation was significant (Table 2a). Figure 4 indicates the proportion of feeding was higher before full contact than after in group composition 1). But feeding increases with higher familiarisation in group compositions 2) and 3) compared to group composition 1) (Table 2a). Furthermore, start time and enclosure significantly correlated with the proportion of feeding (Table 2a). So there was less feeding in both pre-enclosures than in the Africa Panorama. Similarly, for later start times during a day the rhinoceros fed less.

The interaction between group composition and enclosure was not significant (LRT: n = 60; $\chi^2 = 3.93$, df = 2, p = 0.14), as well as the number of visitors (LRT: n = 60; $\chi^2 = 0.08$, df = 1, p = 0.78).

To explore the relationship between familiarisation and the group composition on feeding, two separate models for the periods before and after full contact were evaluated. For the period before full contact, only enclosure was significant (Table 2ai). Again, feeding occurred less in the big pre-enclosure than in the Africa Panorama. There was a tendency for an interaction between group composition and enclosure (LRT: n = 15; $\chi^2 = 3.30$, df = 1, p = 0.07) but that was not statistically significant. For group composition 2) in the big pre-enclosure feeding tended to decrease compared to group composition 1). The interaction between group composition and familiarisation (LRT: n = 15; $\chi^2 = 1.99$, df = 1, p = 0.16), visitor number (LRT: n = 15; $\chi^2 = 0.01$, df = 1, p = 0.93), familiarisation (LRT: n = 15; $\chi^2 = 0.29$, df = 1, p = 0.59), daytime (LRT: n =15; $\chi^2 = 0.57$, df = 1, p = 0.45), group composition (LRT: n = 15; $\chi^2 = 0.57$, df = 1, p = 0.45) were all not significant.

For the period after full contact, start time, enclosure, and familiarisation significantly associated 310 with feeding (Table 2aii). Similar to (2a), start time and both pre- enclosures correlated 311 negatively with feeding. However, the proportion of feeding increased with more familiarisation. 312 Additionally, there was a marginally significant interaction between group composition and 313 familiarisation (LRT: n = 45; $\chi^2 = 5.84$, df = 2, p = 0.054). Whereas, in group composition 2) and 314 3) with more familiarisation, feeding tended to increase more than in group composition 1). The 315 interaction between group composition and enclosure (LRT: n = 45; $\chi^2 = 0.48$, df = 1, p = 0.49), 316 visitor number (LRT: n = 45; $\chi^2 = 0.10$, df = 1, p = 0.76) and group composition (LRT: n = 45; χ^2 317 = 3.36, df = 2, p = 0.19) were all not significant. 318

319 *Resting*

Resting occurred significantly less in group composition 2) and 3) than in group composition 1) (Figure 4). Furthermore, resting increased later in the day (Table 2b). Both interactions; between group composition and familiarisation (LRT: n = 60; $\chi^2 = 4.76$, df = 2, p = 0.09); and between group composition and enclosure (LRT: n = 60; $\chi^2 = 1.13$, df = 2, p = 0.57) were not significant. Neither had visitor number (LRT: n = 60; $\chi^2 = 1.55$, df = 1, p = 0.21), enclosure (LRT: n = 60; χ^2 = 4.54, df = 2, p = 0.10), nor familiarisation (LRT: n = 60; $\chi^2 = 2.37$, df = 1, p = 0.12), a significant effect.

327 Locomotion

Table 2c shows the significant effects of group composition and visitor number. Movement was 328 higher in group composition 2) and 3) than in 1) (Figure 4). However, with increasing number of 329 visitors locomotion decreased. Later in the day (daytime (LRT: n = 60; $\chi^2 = 3.76$, df = 1, p = 330 0.053) locomotion tended to raise although that was only marginally significant. Both 331 interactions; between group composition and familiarisation (LRT: n = 60; $\chi^2 = 2.35$, df = 2, p =332 0.31); and between group composition and enclosure (LRT: n = 60; $\chi^2 = 3.78$, df = 2, p = 0.15) 333 were not significant. Moreover, the fixed effects enclosure (LRT: n = 60; $\chi^2 = 3.56$, df = 2, p =334 0.17), familiarisation (LRT: n = 60; $\chi^2 = 0.54$, df = 1, p = 0.46) were all not significant. 335

336 Interaction environment

Using interaction environment as response variable, no explanatory variable showed a statistical significant association; interaction between group composition and familiarisation (LRT: n = 60; $\chi^2 = 2.04$, df = 2, p = 0.36) and between group composition and enclosure (LRT: n = 60; $\chi^2 = 5.33$, df = 2, p = 0.07); visitor number (LRT: n = 60; χ^2 =1.09, df=1, p=0.30), enclosure (LRT: n = 60; χ^2 =2.18, df=2, p=0.34), daytime (LRT: n = 60; $\chi^2 = 0.17$, df = 1, p = 0.68), familiarisation (LRT: n = 60; $\chi^2 = 1.55$, df = 1, p = 0.21) and group composition (LRT: n = 60; $\chi^2 = 2.46$, df = 2, p = 0.29).

344

345 Social Interactions

The routine behaviours showed considerable differences between the three group compositions, thus, feeding, resting and locomotion are regarded as additional explanatory variables for the social interactions. Correlation tests clarified the use of locomotion and feeding as additional explanatory variables because resting correlated with locomotion. Furthermore, the effect of the
interaction between feeding and group composition on social interactions was examined. The
results are reported for those variables, which passed the univariate test.

352 *All agonistic behaviours*

The interaction between group composition and familiarisation showed a significant correlation 353 354 with agonistic behaviours (Table 3a). In group composition 2) these behaviours increased with 355 familiarisation. Contrarily, in group composition 3) the agonistic behaviours decreased with familiarisation. Initially, after the introduction of Kibo, the highest occurrence of agonistic 356 behaviours in the whole group have been observed (Figure 3). However, the frequency then 357 dropped very quickly. Taking snorts and snarls together, the mean rate of space maintenance 358 vocalisation per hour (\pm SE) is, in group composition 1) 15.14(\pm 1.64), group composition 2) 359 12.08(±2.70) and group composition 3) 24.47(±6.4). Furthermore, agonistic behaviours 360 depended on the type of enclosure. In both pre-enclosures, more agonistic behaviours occurred 361 than in the larger Africa Panorama. As well as, with a higher proportion of locomotion agonistic 362 behaviours increased (Table 3a). 363

The interaction between group composition and feeding (LRT: n = 60; $\chi^2 = 4.77$, df = 2, p = 0.09), between group composition and enclosure (LRT: n = 60; $\chi^2 = 3.49$, df = 2, p = 0.17) and visitor number (LRT: n = 60; $\chi^2 = 0.31$, df = 1, p = 0.58), feeding (LRT: n = 60; $\chi^2 = 2.02$, df = 1, p = 0.16) did not correlate with agonistic behaviours.

In the period before full contact there were significantly more agonistic behaviours in the big pre-enclosure than in the Africa Panorama (Table 3ai). The interaction between group composition and familiarisation (LRT: n = 15; $\chi^2 = 0.03$, df = 1, p = 0.86), between group composition and feeding (LRT: n = 15; $\chi^2 = 0.00$, df = 1, p = 0.96), between group composition and enclosure (LRT: n = 15; $\chi^2 = 2.94$, df = 1, p = 0.09), familiarisation (LRT: n = 15; $\chi^2 = 0.23$, df = 1, p = 0.63), feeding (LRT: n = 15; $\chi^2 = 0.26$, df = 1, p = 0.61) and group composition (LRT: n = 15; $\chi^2 = 2.30$, df = 1, p = 0.13) did not relate to agonistic behaviour.

After full contact, locomotion and enclosure showed a significant correlation. In both pre enclosures as well as with increasing locomotion more agonistic behaviours were present (Table 3aii). The interaction between group composition and familiarisation (LRT: n = 45; $\chi^2 = 5.21$, df = 2, p = 0.07) had a tendency towards a significant effect. With higher familiarisation, in group composition 2) was a tendency towards more agonistic behaviour. Contrarily, for group composition 3), there tended the agonistic behaviour to decrease with higher familiarisation.

The interaction between group composition and feeding (LRT: n = 45; $\chi^2 = 1.91$, df = 2, p = 0.38), between group composition and enclosure (LRT: n = 45; $\chi^2 = 0.05$, df = 1, p = 0.83), familiarisation (LRT: n = 45; $\chi^2 = 2.10$, df = 1, p = 0.15), visitor number (LRT: n = 45; $\chi^2 = 1.19$, df = 1, p = 0.28), feeding (LRT: n = 45; $\chi^2 = 3.09$, df = 1, p = 0.08), group composition (LRT: n = 45; $\chi^2 = 2.18$, df = 2, p = 0.34) were all not statistically significant.

386 Agonistic behaviour towards Kibo

The interaction between group composition and enclosure significantly correlated with agonistic behaviour towards Kibo (Table 3b). In the big pre-enclosure during group composition 3) more agonistic behaviours towards Kibo occurred than in the Africa Panorama containing group composition 3 or within group composition 1) in the big pre-enclosure (Figure 5). Only Keeva and her mother occupied the small pre-enclosure during observations, hence, this enclosure is not present in the current analysis. Consistently with all agonistic behaviours, agonistic behaviours towards Kibo increased with increasing locomotion (Table 3b). In group composition 1) Kibibi and Baby almost directed the same amount of snorts and snarls towards Kibo, and one time Baby
attacked Kibo (Figure 6a). However in group composition 3) Chris snorted, snarled and grunted
most to Kibo (Figure 6b). Baby initiated more physical attacks such as charging and advancing
steps.

The interaction between group composition and familiarisation (LRT: n = 60; $\chi^2 < 0.01$, df = 1, p = 0.95), between group composition and feeding (LRT: n = 60; ns; $\chi^2 = 0.01$, df = 1, p = 0.91), visitor number (LRT: n = 60; $\chi^2 = 0.17$, df = 1, p = 0.68) and familiarisation (LRT: n = 60; $\chi^2 = 42$, df = 1, p = 0.52), feeding (LRT: n = 60; $\chi^2 = 0.01$, df = 1, p = 0.94) were all not significant.

402 All Cohesive behaviours

Cohesive behaviours differed significantly between group composition and enclosure, and are 403 associated with locomotion (Table 3c). In group composition 2) and 3) more cohesive behaviours 404 were observed than in group composition 1) as well as in both pre-enclosures compared to the 405 Africa Panorama. And again, more cohesive behaviours were seen with increasing locomotion. 406 The interaction between group composition and familiarisation (LRT: n = 60; $\chi^2 = 2.35$, df = 2, p 407 = 0.31), between group composition and feeding (LRT: n = 60; χ^2 = 2.62, df = 2, p = 408 0.27), between group composition and enclosure (LRT: n = 60; $\chi^2 = 1.26$, df = 2, p = 0.53), visitor 409 410 number (LRT: n = 60; $\chi^2 = 0.79$, df = 1, p = 0.38) familiarisation (LRT: n = 60; $\chi^2 = 0.02$, df = 1, p = 0.90) and feeding (LRT: n = 60; $\chi^2 = 1.42$, df = 1, p = 0.23) were all not significant. 411

412 *Cohesive behaviours involving Kibo*

Interestingly, the interaction between group composition and enclosure as well as locomotion
significant correlated with cohesive behaviours, the same explanatory variables as for agonistic
behaviours towards Kibo (Table 3d). Moreover, the association shows a similar direction, group

composition 3) in the big pre-enclosure positively impacted cohesive behaviours involving Kibo
(Figure 5). More locomotion explained more cohesive behaviours involving Kibo significantly.
In group composition 1) Kibibi was involved in more cohesive behaviours with Kibo than Baby
(Figure 7a). In comparison to the first group composition, in the third group composition, the
behavioural diversity was greater in general. Keeva, followed by Chris, interacted most
frequently with Kibo (Figure 7b).

The interaction between group composition and familiarisation (LRT: n = 60; $\chi^2 = 0.67$, df = 1, p = 0.41), between group composition and feeding (LRT: n = 60; $\chi^2 = 1.45$, df = 1, p = 0.23), visitor number (LRT: n = 60; $\chi^2 = 0.01$, df = 1, p = 0.93), familiarisation (LRT: n = 60; $\chi^2 = 1.57$, df = 1, p = 0.21) and feeding (LRT: n = 60; $\chi^2 = 0.02$, df = 1, p = 0.87) were all not statistically significant.

427 *Whine*

Solely the two calves performed whine behaviour. Only the interaction between group composition and feeding showed a significant association, in group composition 2) and 3) the occurrences of whine behaviour decreased compared to group composition 1) with increased feeding (Table 3e). In both pre-enclosures whine behaviour tended (LRT: $\chi^2 = 5.84$, df = 2, p = 0.054) to take more place than in the Africa Panorama.

The interaction between group composition and familiarisation (LRT: n = 60; $\chi^2 = 2.33$, df = 2, p = 0.31), between group composition and enclosure (LRT: n = 60; $\chi^2 = 4.69$, df = 2, p = 0.10) also as familiarisation (LRT: n = 60; $\chi^2 = 2.09$, df = 1, p = 0.15), did not significantly correlate with whine behaviour.

437 *Play*

85.86 % of the play behaviour happened between the two calves. In group compositions 2) and
3) significantly more play behaviour occurred compared to group composition 1). Furthermore,
increasing familiarisation (Figure 3) and locomotion positively correlated with play behaviour
(Table 3f).

The interaction between group composition and familiarisation (LRT: n = 60; $\chi^2 < 0.001$, df = 2, p > 0.99), between group composition and feeding (LRT: n = 60; $\chi^2 = 0.42$, df = 2, p = 0.81), between group composition and enclosure (LRT: n = 60; $\chi^2 = 1.19$, df = 2, p = 0.55), visitor number (LRT: n = 60; $\chi^2 = 0.25$, df = 1, p = 0.62), feeding (LRT: n = 60; $\chi^2 = 0.01$, df = 1, p =0.94) and enclosure (LRT: n = 60; $\chi^2 = 4.37$, df = 2, p = 0.11) did not associate significantly with play behaviour.

448 **Discussion**

Over the study period, feeding differed between the enclosures and increased in group 449 450 composition 2) and 3) with increasing familiarisation. And in general after full contact feeding positively correlated with familiarisation. Likewise, the results of the rest of the routine 451 behaviours indicate that the rhinoceros in group compositions 2) and 3) had overall a higher level 452 of activity which may be linked to a higher amount of social interactions. Play behaviour; the 453 engagement in a wide behavioural spectrum of cohesive behaviours with all individuals; 454 reduction in agonistic behaviours following introduction, and the absence of serious physical 455 attacks indicate the success of the familiarisation/introduction of the hand-reared calf, maintained 456 at least until two months after the data recording. Surprisingly, most social interactions of the 457 hand-reared calf with adult female animals were with the initially aggressive individual. 458

Before making the final decision on the introduction of the hand-reared calf, the rhinoceros` behaviour during limited tactile contact was careful considered, no agonistic behaviour by the initially aggressive individual towards the hand-reared animal occurred, but frequent signs of individual identification and overall interestedness and calmness. Similarly, Souza et al. (2006) ascertained that unfamiliar piglets showed more social investigations (tactile contact, following) than familiar animals through a net.

465 First, the results of the routine behaviours reveal that the type of the enclosure significantly related to the amount of feeding but not effected resting, locomotion or the interaction with the 466 environment. The higher grazing possibilities in the large Africa Panorama explain these 467 findings for feeding. Besides, the rhinoceros' remaining routine behaviours seems to be not 468 related to the enclosure they are in. As well as, no variable explained the amount of time spent in 469 interaction with the environment, what either indicates that the rhinoceros perform it 470 471 independently from any conditions or that an appropriate indicator was not observed. Furthermore, feeding increased in group composition 2) and 3) with more familiarisation, yet not 472 473 in group composition 1). This increase likely represents the change of feeding in both calves. The older they get, the more they switch to grazing (for example in bison (Daleszczyk 2005), 474 which takes longer than suckle. Although Kibo is a bit older, he fed less than Keeva before 475 introduction; however, he presumably learned to graze properly from Chris and Keeva. This is 476 supported by the positive correlation of familiarisation in the analyses of feeding in the post-477 contact period. Meder (1989) came to the conclusion that apes study by imitation the use of 478 nests, because hand-reared gorillas did not use their nests in the same way than mother-reared 479 offspring, which might indicate that Kibo imitated Keeva and Chris more as he is more 480 connected to them than to the other individuals. It might be possible that Keeva caused the 481

increase in feeding because there is no significant result for group composition in the period after full contact, although contradictory to the keepers and my personal observations. Except for feeding, none of the routine behaviours changed over the study period, which might indicate that the introduction and the process of familiarisation are not detrimentally stressful for the individuals or the group.

487 The association between visitor numbers and locomotion is possibly confounded with weather. A 488 warm and sunny summer day attracts more visitors, but it might cause the rhinoceros' also to move less and to remain in shady areas provided by some big trees or a roof. A similar situation 489 found Giotto et al. (2013) in other ungulates, antelopes (Dorcatragus megalotis), which rested 490 particularly long and preferred foraging in shady areas during hot conditions. Furthermore, the 491 home ranges of the antelopes decreased in the hot season. This might explain the choice of the 492 rhinoceros to rest later in a day in favour of less feeding, and vice versa for earlier hours. Except 493 494 for locomotion, no behaviour was significantly affected by the number of visitors. This is consistent with a study finding that in white rhinoceros glucocorticoid concentrations were not 495 influenced by the level of exposure to visitors, whereas black rhinoceros were affected (Carlstead 496 & Brown 2005). 497

Generally, the results indicate that the rhinoceros in group composition 2) and 3) were in general more active and group composition 1) rather inactive, considering feeding and locomotion as active and resting as inactive (Figure 4). The higher proportion of active behaviours in group composition 2) and 3) than in group composition 1) might be linked to the higher amount of overall cohesive behaviour and agonistic and cohesive interactions towards Kibo in these groups. Similar a previous study determined a difference in activity, familiar pairs of steers grazed less and had a tendency for increased lying and standing (Patison et al. 2010). In group composition

505 1) Kibibi and Baby formed a very close bond for years (pers. communication). It might be argued that their close relationship was one reason for the hand-rearing, yet, I reject this 506 hypothesis because Kibibi acted appropriately until Kibo tried to suckle, and the keepers reported 507 elevated udder sensitivity to pain. Additionally, Baby performed the only attack in the study 508 period (Figure 6a), which possibly intimidated Kibo. Although wild rhinoceros cows would 509 terminate any relationship at the time of parturition (Owen-Smith 1975), Kibibi and Baby still 510 511 had a close bond (pers. impression and communication), and the motivation for locomotion and 512 grazing could be lower and therefore also the possibility of incidents of a closer encounter with Kibo are lower. Additionally, locomotion positively correlated with the occurrence of all social 513 514 interactions (except whine), which supports these findings. The proportion of feeding was also taken into account, but did not associate with social interactions, solely for whine behaviour in 515 an interaction with group composition. Whine mostly occurred before Kibo's feeding times and 516 517 similar Keeva whined when she was hungry and started to search her mother's udder. So whine behaviour do not need necessarily a mother to direct it. Suckle on her mother, or for Kibo the 518 519 flask is also counted as feeding, as well as the increasing proportion of feeding in group compositions 2) and 3) explain why whine decreased in these groups with more feeding. 520 It is notable that agonistic behaviours reached their maximum shortly after introduction in group 521 composition 3), however solely one attack happened, all remaining agonistic behaviours are 522 classified as defensive, and these behaviours dropped very quickly to a similar level seen in 523 group compositions 2) and 3). Yet, to the best of my knowledge, no criteria of a successful 524 introduction of rhinoceros' in a group of conspecifics exist. For primates, affiliative interactions 525 (Pazol et al. 1998), and play behaviour (Meder 1990) with all present conspecifics have been 526

527 considered as integration indicators.

528 Clearly, these criteria appear to be relevant also for other species, here for rhinoceros, both 529 criteria appear to be largely meet. The hand-reared calf was involved with all conspecifics and even part of more cohesive interactions after the introduction than before, especially with the two 530 unfamiliar individuals. The higher incidents of approaching Kibo by Chris and Keeva might be 531 caused by unfamiliarity. The first group composition already existed for approximately one and a 532 half month by the time the study started. Similarly, Patison et al. (2010) showed that unfamiliar 533 534 pairs of steers approached one other and also moved more frequently away than familiar pairs. 535 However, also two months after finishing data recording the relationships between Kibo and Chris and Keeva maintained. As usual in the wild (Owen-Smith 1973) play behaviour was 536 537 almost exclusively performed by the two calves. Chris allowed the performance of play behaviour and became the closest social relationship of Kibo to an adult female. In group 538 composition 3) Chris and Kibo engaged in frequent cohesive interactions, but also in the most 539 540 agonistic interactions. This is caused by proximity, Kibibi and Baby for comparison performed less of both behaviour types (Figure 6a, 7a). Because they were often not as close as it would be 541 542 necessary to use a distance increase vocalisation towards Kibo. The hand-reared calf even tried to suckle at the mother of the mother-raised calf, which solely snarled or went away. 543 Even though Kibo interacted not as frequent in group composition 1) with the two adult females, 544

than it was observed in the other group compositions, the two months of experience may

equipped him with the basic social skills and understanding he needed. As Pazol et al. (1998)

547

time to learn social skills in comparison to a longer period where infants were not together withthe whole group but only chosen females.

reported an integration in chimpanzees failed where hand-reared infants might had insufficient

550 An allomothering bound in primates is frequently reported (e.g. Bashaw et al. 2009, Pazol et al. 1998, Thunström et al. 2013), which compromises carrying, retrieval, nest-sharing and also 551 intervention to protect the offspring (Bashaw et al. 2009). Assigning these traits to rhinoceros in 552 a similar context, it could be interpreted as walking closely together (side by side, following, rub 553 side in passing), resting together while laying side by side or having tactile contact, and also the 554 intervention in critical situations. All of those manners were observed between Chris and Keeva, 555 556 but except for following and a few incidents of side by side, almost none involving the handreared calf. Although he seemed to stay in closer distance as he became more familiar, but for a 557 further evaluation distance measurements would been needed. Besides, it is unlikely that Chris 558 559 would intervene to defend Kibo as she is primarily concerned with Keeva.

As additional assessment criteria, Bashaw et al. (2009) hypothesised that young hand-reared 560 chimpanzees would show less social interaction to humans as the infants became more 561 562 comfortable interacting with conspecifics, which mirrors less interest in humans. For this last indicator no particular data have been collected; however, I suppose this criterion is also met. 563 Kibo formed a close bond with Chris and Keeva, as days went by he went further and longer 564 away from the bridge in the Africa Panorama and the edges in the smaller enclosures, where 565 keepers would go. Additional he stayed more frequently in closer proximity to the whole group. 566 Moreover, hand feeding of Kibo was continuously reduced. However, data for interactions with 567 humans or location/proximity data would be very helpful for a more systematic evaluation of the 568 role of the human caretaker. Because the behaviour directed to people did not decrease in the 569 chimpanzee young, Bashaw et al. (2009) concluded that it is relevant for a successful 570 introduction to add social relationship with conspecifics, but not to remove the interaction with 571 572 humans entirely.

573 Consistently, for both behaviours concerning Kibo, the same explanatory variables turned out to be significant, which substantiate their relevance. The highest occurrences of agonistic behaviour 574 towards Kibo and cohesive behaviour involving him were both in group composition 3) and 575 within the big-pre enclosure. And even though the Africa Panorama is considerable larger, Kibo 576 was in more cohesive behaviours involved in group composition 3) than in group composition 1) 577 in both enclosures, the Africa Panorama and the big pre-enclosure, underlining the success of the 578 579 introduction and Kibo's relationship with Chris and Keeva. Moreover, in the Africa Panorama 580 are less mean agonistic interactions towards Kibo in group composition 3) than in group composition 1) (Figure 5). As well as overall, more agonistic behaviours were recorded in both 581 582 smaller enclosures, which might be caused by spatial stress in the 700m² and 340m² enclosures. Metrione et al. (2007) found increased vocalisations (snorts and snarls) in female white 583 rhinoceros likely linked to spatial stress, the females in two different groups vocalised $6.19 \pm$ 584 585 0.199 or 1.90 ± 0.086 (mean number vocalisation \pm SE) per hour, respectively. These two groups had different compositions, the authors ascertained that cows kept with more calves in a smaller 586 area displayed more space maintenance vocalisations than cows without calves in a larger 587 enclosure. The authors used the rate of one space maintenance vocalisation/hour of wild rhinos 588 as criteria (Metrione et al. 2007). Comparably, the mean space maintenance vocalisations in the 589 three group compositions are all elevated referring to values of and the criteria Metrione et al 590 (2007) used. However, in this study, both enclosures were larger (0.033km², 0.65km²) than in the 591 current study, and introduction or hand-rearing were not an object, which possibly explain the 592 high observed values in the current study. 593

When interpreting the results further, possible limitations need to be considered, for
observations, it might be possible that I missed vocalisations if the individuals were far away.

596 However, a previous work conducted in the same zoo using recording equipment within the large enclosure also found more vocalisations in the smaller enclosures since rhinos can hardly avoid 597 each other (S. Linn pers. communication). Furthermore, the same individuals participated in 598 different group compositions which results in pseudo replication; therefore, it is difficult to 599 generalise the results. More individuals and groups would be required, yet, this is particularly 600 difficult with large mammals in zoos. The joint evaluation of two explanatory variables as 601 602 interactions prevented the analyses of the single effects in the model selection. The division of 603 the social interaction by rhino number caused a loss of individuality. It is likely that mother and daughter interact more often than two adult rhinos. As well as a more detailed statistical analyses 604 605 of selected behaviours might add valuable information. The high standard error values for group composition in the model for play behaviour indicate higher variability than expected and are 606 probably caused by the high occurrences of play behaviour almost exclusive in group 607 608 composition 3).

609 Animal Welfare implications

Introductions are particularly dangerous in rhinoceros due to potentially injury risk and even 610 death considering their horns and massiveness (Hutchins & Kreger 2006). However, for 611 offspring, it is crucial to study social behaviour from adults in a group (Jendry 1996) to develop 612 species-appropriate social skills for interactions with conspecifics (Meder 1990). This is of 613 particular importance for Kibo, because not only is he relevant for future breeding but in a nearer 614 615 future he has to go to a bachelor group. Therefore, it is vital that he learns species-appropriate behaviour, and the sporadical contact with Kibibi and Baby might have been insufficient. 616 Moreover, bulls determine their hierarchy using their horns (Owen-Smith 1973a) and playful 617 horn wrestling was just elecited with the contact of the calves. Besides, during the hand-rearing 618

619 Kibo was taught not to push with his horn and bodyweight to decrease the injury risk for keepers, so he had difficulties in implementing this behaviour properly. Furthermore, after the 620 introduction both the incidents and the behavioural diversity of cohesive behaviour in which 621 Kibo was involved increased. Behavioural diversity has previously been used to assess welfare 622 (of pigs: (Hirt & Wechsler 1994) and depressive-like primates (rhesus monkeys (Macaca 623 *mulatta*))) displayed less diverse behaviours than not depressed monkeys, among other criteria 624 for example stereotypic behaviour (Camus et al. 2014). Hoy et al. (2010) defined social 625 626 enrichment as "whereby the composition of a group is altered", and more diverse behaviours using environmental enrichment have been interpreted as increased animal welfare indicator 627 628 (Young 2013). More basically, referring to the Brambell Report (1965) the possibilities are increased for the hand-reared calf to display normal behaviour. Not only for the hand-raised calf, 629 but also for the mother-raised one, the introduction is a gain since play behaviour was especially 630 631 noted after the introduction in group composition 3). Although, it may be hard to infer, group animal welfare seems not to be strongly impaired. The spatial stress might be easily avoided 632 using larger enclosures. Moreover, the natural life history and previous research suggest that 633 group composition change is a natural and possible beneficial circumstance for white rhinoceros. 634

Therefore it might be a beneficial approach to introduce hand-reared rhinos, especially to a mother, raising an (older) calf, or in general in a more age diverse group. Although wild rhinos with young calves separated themselves from associations and have usually only one calf, it may be possible that they are in captivity with sufficient resources' more flexible than thought and as well as in the wild, cows with older calves have been observed to be associated with conspecifics (Owen-Smith 1975). Dinerstein et al (1988) reported a particular case of association and adoption in greater one-horned rhinoceros *(Rhinoceros unicorns)*. The orphan calf (3-4 months old) associated with different adults, among them a female with a calf and a bull, until it wasnursed and adopted by a cow, which possibly lost its infant before.

644 Conclusion

Conclusively, even after serious aggressive attempts, a peaceful and successful introduction is 645 possible; furthermore, it appears to be no concern to reintroduce a hand-reared infant to its 646 647 mother in white rhinoceros. As determined by previous research, the base should be ideally the steps of sensory contact, limited tactile contact and after careful consideration of the behaviour 648 of the animals the full physical introduction. After the introduction, the shortly raised frequency 649 of agonistic behaviour dropped fast to a level similar to group 2) and 3) and the introduced 650 animal engaged with all especially the unfamiliar individuals and the criteria defined by the 651 introduction of primates seem to endure also for other species/rhinoceros. Although 652 653 allomothering occurs frequently in primates, here the conditions tend to be insufficiently met. Because part of the definition is it compromises maternal behaviour (Bashaw et al. 2009), which 654 seems not to fit in this study because the female has her own infant and showed not the same 655 behaviours towards the hand-reared calf. Furthermore, a larger enclosure might be preferable to 656 avoid spatial stress. This study is relevant to guide similar future introductions and give valuable 657 reference information. Once quantified results from other rhinoceros studies are available a more 658 generalised examination of when, to whom and what criteria to use for an introduction of a hand-659 reared calf should be used, ultimately to promote successful procedures. Pazol et al. (1998) 660 pointed out how important it is to make such findings available. Distance measurements between 661 individuals might also be useful in the future to assess introductions and to identify subgroups. 662

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Figure 1 Rhinoceros enclosures at Augsburg Zoo. The green shady areas indicate the three
rhinoceros enclosures and the grey marking is the house containing the rhinoceros' overnight
boxes.



Figure 2 Cohesive behaviours during limited tactile contact. The barplot shows the frequency

of different cohesive behaviours during limited tactile contact in 8 hours of observation

distinguished by the individual which interacted with the hand-reared calf.

Animal name	Sex	Birthdate	Birthplace	Additional
				Information
Kibo	ď	06.02.16	zoo-born	hand-reared
Kibibi	ę	~2005	wild-born	mother of Kibo
Keeva	ę	18.2.16	zoo-born	mother-raised
Chris	ç	~2005	wild-born	mother of Keeva
Babangiboni/Baby	ę	~1971	wild-born	-

Table 1 Overview study animals. Basic information about the study's white rhinoceros
(*Ceratotherium simum simum*).

Table 2 Overview significant results routine behaviours. Overview of significant results of generalised linear models for different routine behaviours (a) Feeding, (b) Resting, (c) Locomotion; whereas feeding is additionally divided in the time period before and after the full physical introduction. LRT is Likelihood Ratio Test, p means value, SE is standard error and estimate derived from the summary of the preferred model as indication of the direction of the effect.

	estimate	SE	LRT	Р
(a) Feeding $(n = 60)$				
Familiarisation*Group			$\chi^2 = 11.05, df = 2$	< 0.01
composition				
- Group composition 2) *	0.01	0.01		
Familiarisation	0.03	0.01		
- Group composition 3) *				
Familiarisation	0.06	0.06		
Group composition	-0.07	0.08		
- Group composition 2)	< -0.00	< 0.00		
- Group composition 3)	-0.02			
Familiarisation				
Start time	-0.17	0.01	$\gamma^2 = 5.90$, df = 1	0.02
Enclosure	-0.17		$\chi^2 = 13.39 \text{ df} = 2$	< 0.01
- big pre-enclosure		0.05	λ 10.09, α 1 2	
- small pre-enclosure		0.10		
(a)Feeding				
(ai) Feeding before full contact (n =			$\chi^2 = 5.91, df = 1$	0.02
15)	-0.21	0.08		
Enclosure				
- big pre-enclosure				
(aii) Feeding after full contact $(n = 45)$				
Start time	-0.02	0.01	$\chi^2 = 4.33$, df = 1	0.04
Enclosure			$\chi^2 = 28.95$, df = 2	<< 0.001
- big pre-enclosure	-0.29	0.05		
- small pre-enclosure	-0.19	0.09		
Familiarisation	0.01	0.01	$\chi^2 = 5.89, df = 1$	0.02
(b) Resting $(n = 60)$				
Group composition			$\chi^2 = 19.59$, df = 2	<< 0.001
- group composition 2)	-0.15	0.06		
- group composition 3)	-0.27	0.06		
Start time	0.02	0.01	$\chi^2 = 3.92$, df = 1	0.04(7)
(c) Locomotion $(n = 60)$				
Group composition			$\chi^2 = 8.07$, df = 2	0.02
-group composition 2)	0.03	0.02	*	
- group composition 3)	0.07	0.02		
Visitor numbers	-0.03	0.01	$\chi^2 = 11.13$, df = 1	< 0.001





Figure 3 Behavioural changes with ongoing familiarisation. The scatterplots show the time 781 spent feeding and the frequency of agonistic behaviours differed between the interaction of 782 group composition and familiarisation. Immediately after introduction (day 0) high incidents of 783 agonistic behaviours in group composition 3) occurred. Play behaviour was just elicit after the 784 introduction and happened almost exclusively composition 3). 785 in group



Figure 4 Boxplot routine behaviours. The proportion of time the rhinoceros spent in active,
feeding; locomotion, and inactive, resting behaviours differed among group compositions.



Figure 5 Boxplot of agonistic and cohesive behaviours. Both behaviours concerning the handreared rhinoceros calf (Kibo) differed between group compositions but only in the smaller
enclosure (big pre-enclosure) but not in the larger enclosure (Africa Panorama).

Table 3 Overview significant results social interactions. Overview of significant results of generalised linear models for different social interactions (a) all agonistic behaviours, (b) agonistic behaviour towards Kibo, (c) all cohesive behaviour, (d) cohesive behaviour towards Kibo, (e) whine behaviour, (f) play behaviour; whereas all agonistic behaviours are divided in the time period before and after the full physical introduction. LRT is Likelihood Ratio Test, p means value, SE is standard error and estimate derived from the summary of the preferred model as indication of the direction of the effect.

	estimate	SE	LRT	Р
(a) All agonistic behaviours $(n = 60)$				
Group composition* Familiarisation			$\chi^2 = 9.43$, df = 2	< 0.01
- Group composition 2) *	0.05	0.02		
Familiarisation				
- Group composition 3) *	-0.06	0.03		
Familiarisation				
Group composition				
- Group composition 2)	-0.22	0.22		
- Group composition 3)	0.57	0.26		
Familiarisation	< 0.00	0.01		
Locomotion	3.28	0.86	$\gamma^2 = 14.23$ df = 1	< 0.001
Enclosure			$\chi^2 = 36.74 \text{ df} = 2$	<< 0.001
- big pre-enclosure	0.98	0.17	λ 50.71, αι 2	
- small pre-enclosure	0.58	0.28		
(a) All agonistic behaviours				
(ai)before full contact $(n = 15)$			$\chi^2 = 4.02, df = 1$	0.04
Enclosure				
- big pre-enclosure	0.77	0.31		
(aii) after full contact $(n = 45)$				
Locomotion	4.22	0.67	$\chi^2 = 14.83$, df = 1	< 0.001
Enclosure			$\chi^2 = 41.61$, df = 2	<< 0.001
- big pre-enclosure	1.01	0.15		
- small pre-enclosure	0.62	0.26		
(b) All agonistic behaviours towards				
Kibo $(n = 60)$				
Group composition*Enclosure			$\chi^2 = 4.20$, df = 1	0.04
-Group composition 3) * big-	2.15	0.86		
pre-enclosure				
Group composition				
- Group composition 3)	-1.03	0.62		
Enclosure				
- big pre-enclosure	0.33	0.60		
Locomotion	9.09	2.29	$\chi^2 = 14.76$, df = 1	< 0.001
(c) All cohesive behaviours $(n = 60)$				

group composition			$\chi^2 = 49.24, df = 2$	<<0.001
- Group composition 2)	0.93	0.14		
- Group composition 3)	0.93	0.15		
Enclosure				
- big pre-enclosure	0.28	0.10	$\chi^2 = 10.20$, df = 2	< 0.01
- small pre-enclosure	0.35	0.15		
Locomotion	3.73	0.55	$\chi^2 = 44.30$, df =1	<<0.001
(d) Cohesive behaviour towards Kibo (n				
= 60)				
Group composition*Enclosure			$\chi^2 = 6.29, df = 1$	0.01
- Group composition 3)* big-	1.07	0.46		
pre-enclosure				
Group composition				
- Group composition 3)	-0.30	0.37		
Enclosure				
- big pre-enclosure	-0.40	0.38		
Locomotion	4.32	1.25	$\chi^2 = 12.66$, df = 1	< 0.001
(e) Wine behaviour $(n = 60)$			N	_
group composition*feeding			$\chi^2 = 6.00, df = 2$	0.049
- Group composition	-8.13	6.69		
2)*feeding				
- Group composition	-5.64	6.85		
3)*feeding				
Group composition				
- Group composition 2)	1.37	0.93		
- Group composition 3)	-0.44	1.21		
Feeding	6.53	6.26		
(f) Play behaviour $(n = 60)$				
familiarisation	0.12	0.05	$\chi^2 = 7.90$, df = 1	< 0.01
locomotion	14.51	2.54	$\chi^2 = 15.82$, df = 1	<< 0.001
Group composition			$\chi^2 = 19.06$, df = 2	<< 0.001
- group composition 2)	18.27	7366.99	· · · · · · · · · · · · · · · · · · ·	
- group composition 3)	20.72	7366.99		
/				









809 Figure 7 Cohesive behaviours involving Kibo. The barplots present the allocation of various

cohesive behaviours involving Kibo distinguished by initiators a) in Group composition 1) in

811 1318 observation minutes and b) group composition 3) in 993 observation minutes.

812 Appendix 1 White Rhinoceros Ethogram combined from Cinková & Bicík 2013 and Metrione et

al. 2007 (both are based on Owen-Smith 1973)

Category of	specific behaviour	behaviour description
·	Rubbing its head against another rhino	
	Acceptance of tactile contact	To strengthen bonds - Expression
	Whine	Calf seeking udder or adolescents
	Nasonasal meeting	Potentially for individual
	Rubbing its head and neck against the back of	
	Touch and/or rubbing its horn against another	
	Leaning its horn against another lying or standing	
Cohesive	Placing its head and neck from the side on the	
(affiliative)	Touch and/or moving its lips over a skin of	
behaviour	Pressing its hind part to another animal in T- or L-	
	Placing its head from behind between the hind	
	Raising the head of another animal with its	
	Approaching: the animal then remains in	
	Following another animal	
	Lying, standing or walking side by side: heads and	
	Rubbing its side against the side of another rhino	
Play	Play horn wrestling	

	Snarl	(More powerful distance-
	Grunt	a low frequency vocalization
Agonistic		
C	Snort	(Mild "keep-away" warning)
behaviour –		
	Protest turning head and/or body towards the	
defensive		
	Advancing steps	More powerful distance-
	Charge	approaches another animal at a
Agonistic	Chase	chases another rhino, which is
behaviour –	Attack	several successive horn jabbing
subdued		
subuucu	Fight	Opponents attempting to drive
aggressive		

Appendix 2 Determination of appropriate sampling intervals from preliminary observations. For
routine behaviours values are listed for Kibibi, exemplary, and for social interactions for the
most inactive and the least socially interacting group, 1).

Behaviour	Tested sampling	Discrepancy (~10%)
	interval (s)	
Locomotion	60	19%
	120	35%
	180	64%
Resting	60	16%
	120	14%
	180	48%
Feeding	60	6%
	120	9%
	180	4%
Approaching	30	66%
	60	33%
	120	33%
	180	50%
Side by side	30	75%
	60	50%
	120	25%
	180	25%
Following	30	70%

60	80%
120	100%
180	100%

818 For routine behaviours, a sampling interval below 60 s would not have been feasible throughout

and prone to error considering five participating individuals in group composition 3). I chose a

one minute sampling interval as a practically feasible compromise. For social interactions,

approaching side by side and following were the most frequent ones, however no appropriate

sampling interval was determinable. Thus, I implemented a continuous sampling design.