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How long does it take? Reliable personality assessment based on common behaviour in cotton-top tamarins (*Saguinus oedipus*)

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1 **Title: How long does it take? Reliable personality assessment based on common behaviour**
2 **in cotton-top tamarins (*Saguinus oedipus*).**

3 Running head: Personality assessment method

4

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26 **Highlights**

- 27 • Coding of common behaviours represents reliable method of personality assessment.
- 28 • Behaviour coding is not necessarily time-consuming personality assessment method.
- 29 • Five observational hours per individual were sufficient for personality evaluation.
- 30 • Two personality components were described for cotton-top tamarins.

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Abstract

Individual variation in behaviour has been shown to have important ecological and evolutionary consequences. Research on animal personality has therefore received considerable attention, yet some methodological issues remain unresolved. We tested whether assessing personality by coding common behaviours is as time-consuming method as some researchers believe it to be. Altogether, 300 hours of observation were collected on 20 captive cotton-top tamarins (*Saguinus oedipus*). We first examined the repeatability of behavioural indices that represented the behavioural repertoire of cotton-top tamarins. We then compared the personality structures, based on different lengths of observation time, of these behavioural indices. The minimum observational time necessary to obtain a stable personality structure was 5 to 7 hours per individual. This stable structure included two components: Extraversion and Confidence, which were similar to those described in great apes, Old World monkeys, and other New World monkeys. Our findings suggest that, at least in the case of cotton-top tamarins, behavioural coding over relatively short periods of time can be used to assess personality and that longer observation periods may yield diminishing returns.

Keywords: animal personality; behavioural observation; Callitrichidae; consistency; continuous focal recording

74 **1. Introduction**

75 Personality traits have been described in species throughout the animal kingdom
76 (reviewed in Bell et al., 2009; Freeman and Gosling, 2010; Gosling, 2001) and have far-
77 reaching ecological and evolutionary consequences (reviewed in Réale et al., 2007). However,
78 methodological issues relating to personality assessment remain unresolved (e.g. Carter et al.,
79 2013).

80 Despite personality in animals having been studied since the 1970s (e.g. Chamove et al.,
81 1972; Huntingford, 1976; Stevenson-Hinde et al., 1978) and earlier (reviewed in Whitham and
82 Washburn, 2017), currently animal personality research is pursued predominantly by
83 behavioural ecologists and comparative psychologists. Although there is overlap between these
84 disciplines, they differ in how they conceptualise animal personality, which species they study,
85 and which methods they use (Carter et al., 2013; Koski, 2011a; Weiss and Adams, 2013). To
86 summarise, behavioural ecologists typically measure individual variation in a single trait and
87 so assess narrow aspects of personality; their study subjects are usually small mammals (Kanda
88 et al., 2012), birds (Carere and van Oers, 2004), fish (Wilson et al., 2010), or invertebrates
89 (Stanley et al., 2017), all of which are easily subjected to experimental tests of personality, such
90 as the open field test (Perals et al., 2017). The personality traits that behavioural ecologists
91 study most often include activity, aggressiveness, boldness, exploration and sociability (Réale
92 et al., 2007; Sih et al., 2004). Comparative psychologists, on the other hand (like human
93 personality psychologists) tend to examine multiple, structured traits (e.g. Garai et al., 2016).
94 The resulting models, derived from data reduction techniques, such as factor analysis (FA) or
95 principal components analysis (PCA), reflect latent constructs that describe patterns of
96 covariation among these traits (Digman, 1990). The human Five-Factor Model or “Big Five”,
97 consisting of personality dimensions labelled Agreeableness, Conscientiousness, Extraversion,
98 Neuroticism, and Openness (Digman, 1990), has been a useful framework for comparing

99 species (Gosling and John, 1999; Weiss, 2017), especially when applied to nonhuman primates,
100 to humans and one another (e.g. Weiss et al., 2011).

101 There are several methods of personality assessment (see Freeman et al., 2011 and
102 Vazire et al., 2007 for reviews). One method is to gather ratings of traits by knowledgeable
103 informants. Another method is to conduct behavioural tests and to record (or code) the
104 behaviours performed by the animals in the experiments (hereafter “experimental coding”). A
105 third method is to record naturally occurring everyday behaviours (hereafter “common
106 behaviour coding”). These three methods overlap to a certain degree and have been used to
107 validate one another as in, for example, a study of hanuman langurs (Konečná et al., 2008).
108 These methods also can complement one another as in a study of common marmosets
109 (*Callithrix jacchus*) where behavioural coding revealed a “Neuroticism” that did not emerge
110 from trait-ratings in the same sample (Iwanicki and Lehmann, 2015).

111 Common behaviour coding is based on methods used in classical ethology. It therefore
112 involves recording frequencies and durations of behaviours that are predefined in ethograms by
113 means of different methods of observation, such as continuous focal recording, instantaneous
114 sampling, or scan sampling (Martin and Bateson, 2007). By recording a broad range of
115 everyday, naturally occurring, behaviours and subjecting them to data reduction analyses one
116 can identify how behavioural traits within a species are organised by seeing how they “cluster”
117 in the same components or factors (Itoh, 2002; Koski, 2014). Therefore, this method is
118 potentially useful for studying personality structure and conducting cross-species comparisons.
119 Moreover, common behaviour coding is an ecologically relevant method as the behaviour of an
120 individual is measured in its natural environment and in natural social settings (Koski, 2011a).
121 Yet, so far, not many animal personality studies have involved common behaviour coding in
122 personality model assessment (some exceptions include Anestis, 2005; Freeman et al., 2013;

123 Garai et al., 2016; Iwanicki and Lehmann, 2015; Konečná et al., 2008; Neumann et al., 2013;
124 Pederson et al., 2005; Robinson et al., 2018; Sussman et al., 2014, 2013).

125 Assessing personality variation via observations of behaviours can benefit both
126 behavioural ecology and comparative psychology. For example, behavioural observations can
127 be used to validate other measures such as personality questionnaires (Konečná et al., 2008) or
128 experiments (Neumann et al., 2013). Behavioural observations can also be used to measure
129 personality in species that are difficult to study in laboratory settings (e.g. large or endangered
130 species), species that are not found in sufficient numbers in the field (e.g. solitary species), or
131 species that are prone to stress when separated from conspecifics for the purpose of individual
132 testing (e.g. group-housed laboratory animals). Common behaviour coding can also be used to
133 study personality in captive or wild individuals when there are no potential raters available.

134 Although it has been shown that common behaviour coding can contribute to animal
135 personality research, the perception that long periods of time need to be devoted to gathering
136 these observations (Freeman et al., 2011; Itoh, 2002) may have led some researchers to prefer
137 trait rating or behavioural experiments. However, it is not clear how much time needs to be
138 devoted to behavioural observations if one is to obtain representative data for constructing
139 stable personality models. Indeed, the length of behavioural observations reported for
140 personality studies varies substantially from 2 (Vazire et al., 2007) to 66 hours (Neumann et al.,
141 2013) of mean observation per individual. In some studies, the observation time can be highly
142 variable as it depends on the visibility of focal individuals. For example, Neumann et al. (2013)
143 reported between 0.6 and 130 hours of observation time per individual. Observation time that
144 is too short might miss meaningful but rare behaviours and may be susceptible to bias arising
145 from temporal fluctuations in an animal's state, its environment, or in the situations in which it
146 finds itself (Freeman et al., 2011; Vazire et al., 2007). Extensive observational hours, on the
147 other hand, might be an unnecessary investment of scientific resources. Ideally, then,

148 researchers need to spend enough time to obtain an adequate sample of behavioural data but
149 not spend time or scientific resources that could be invested elsewhere.

150 The present study sought to determine how much sampling effort was needed to derive
151 stable personality traits and individual variation in each trait from common behaviours in
152 captive cotton-top tamarins, a cooperatively breeding primate species from the family
153 Callitrichidae. Although evidence for the existence of consistent personality traits has been
154 already demonstrated within this clade (Addessi et al., 2007; Day et al., 2003; Franks et al.,
155 2013; Koski and Burkart, 2015; Šlipogor et al., 2016), personality structure based on common
156 behaviour coding has so far only been examined in common marmosets (Iwanicki and
157 Lehmann, 2015). In our study, we tested the repeatability of each behaviour within our dataset
158 and then proceeded subject reliable behaviours to data reduction analyses (PCA and REFA) to
159 derive a personality structure for our subjects. We then compared how this personality structure,
160 i.e., the number and characteristics of the components or factors, differed as a function of
161 varying levels of observation length.

162 **2. Methods**

163 *2.1. Subjects*

164 Subjects were 20 captive-born cotton-top tamarins that lived in five zoos located in the
165 Czech Republic and Slovakia: Zoo Bojnice, Zoo Bratislava, Zoo Jihlava, Zoo Ostrava, Zoo Ústí
166 nad Labem. The subjects included eight females (mean age in months \pm *SD* = 75.7 \pm 46) and
167 12 males (mean age in months \pm *SD* = 59.4 \pm 54.5). With the exception of the tamarins in
168 Ostrava, each group consisted of a breeding pair and their offspring (see Table 1 for group
169 composition and demographic data). Only adults and subadults were observed as focal
170 individuals.

171 All facilities are members of the European Association of Zoos and Aquaria and meet
172 the conditions of animal welfare (Bairrão Ruivo and Stevenson, 2017). Tamarins were housed

173 in indoor enclosures equipped with branches, ropes, shelves, sleeping boxes and other sources
174 of enrichment. One group (Zoo Ostrava) also had access to an outdoor enclosure at the time of
175 data collection. Tamarins were fed a mixture of commercial prepared food and fresh food two
176 to four times each day. Water was always available.

177

178 **Table 1**

179 Composition and demography of observed groups.

Zoo	Adult	Subadult	Juvenile	Infant
Bojnice	1F, 1M	2M	2F	2F
Bratislava	1F, 1M, 1M			1F
Jihlava	1F, 1M	1F, 1M	1M	1F,1M
Ostrava	1F, 1F, 2M			
Ústí nad Labem	1F, 1M, 2M	1F		1M

180 *Note.* Breeding individuals are shown in bold. F = female, M = male. Adults > 21 mo,
181 subadults 14–21 mo, juveniles 7–14 mo, infants < 7 mo (Cleveland and Snowdon, 1984).

182

183 *2.2. Behavioural data collection*

184 For the common behaviour coding, we created an ethogram consisting of a broad range
185 of behaviours previously described in tamarins (Coates and Poole, 1983; Edwards et al., 2010;
186 Knox and Sade, 1991; Peñate et al., 2009; Price, 1991; Vogt, 1978). The complete ethogram of
187 122 items with the 47 behaviours selected for the analyses in bold is presented in Supplementary
188 materials (Table S1).

189 A combination of focal continuous recording with 30-minute periods and focal
190 instantaneous sampling with 2-minute intervals was used to collect behavioural data (Martin
191 and Bateson, 2007). This enabled us to obtain frequencies from continuous recording and

192 proportions from instantaneous scans. During focal observations, all behaviours of the focal
193 individual were recorded, including the identity of social partners, which included infants, and
194 the direction of social interactions. In instantaneous samples, the location (type of substrate)
195 was also recorded. Not all of the study groups included infants, and as such any interactions
196 with infants were omitted from the analyses. The order of focal individuals was counterbalanced
197 so that focal periods for individuals were distributed evenly throughout the day and the study
198 period. There were 12 focal sessions per day with each focal animal being observed from 2 to
199 4 times depending on the group size. Each individual was observed for 15 hours in total within
200 8 to 13 days.

201 Altogether, 300 hours of observation were collected from July 2011 to February 2012
202 by MM using a voice recorder (Olympus VN-8700PC Digital Voice Recorder). The
203 observations were conducted from an area for visitors. Each group was given 2 days to
204 acclimatise to the presence of the observer. MM identified individual tamarins using distinct
205 facial or body features, such as body size, face shape, the presence of scars or warts, the size
206 and shape of white head tufts and the shape of the tail.

207 2.3. *Behavioural indices*

208 Twenty-three behavioural indices (see Table 2) representing behaviours ranging from
209 activity to social interactions were created from recorded behaviours. Using behavioural indices
210 to assess personality provides a more detailed account of behaviour than simple behaviours as
211 they take relations between different behaviours into account and correspond more to the use
212 of questionnaire items (Konečná et al., 2008) (for examples, see Tables S19–S20). Indices
213 based of frequency, proportions and diversity indices (Shannon and Weaver, 1963) were
214 computed. The selection of indices was based on previous studies (Anestis, 2005; Garai et al.,
215 2016; Iwanicki and Lehmann, 2015; Konečná et al., 2008) and on the frequency of the observed
216 behaviours. The latter was important to demonstrate interindividual variation, especially when

217 dividing the observation times into relatively short periods (see section 2.6. *Time-constrained*
 218 *models*). The indices were transformed into z-scores for all analyses.

219

220 **Table 2**

221 List of behavioural indices and their definitions used in principal components analysis.

Behavioural category	Index	Type of observation	Calculation
activity	<i>Resting</i> ^P	I	(rest + look + watch + sit + lie) / (move + jump + cling + hang)
	<i>Activity diversity</i> ^S	I	Shannon diversity index of activity types
	<i>Substrate diversity</i> ^S	I	Shannon diversity index of substrate types
self-directed	<i>Self-grooming</i> ^F	C	self-groom/hour
	<i>Scratching</i> ^F	C	scratch/hour
surroundings	<i>Object sniffing</i> ^F	C	object sniffing/hour
dirrected	<i>Exploration</i> ^F	C	(exploration + object manipulation + search)/hour
	<i>Vigilance</i> ^F	C	alert/hour
	<i>Monitoring</i> ^P	I	watch/sample
socio-positive	<i>Affiliation</i> ^P	I	[contact + proximity + social play + groom(in) + groom(rec)]/hour
	<i>Passive affiliation</i> ^P	I	(contact + proximity)/[contact + proximity + social play + groom(in) + groom(rec)]
	<i>Grooming(in)</i> ^F	C	groom(in)/hour
	<i>Grooming(rec)</i> ^F	C	groom(rec)/hour
	<i>Invite grooming(in)</i> ^F	C	groom invite(in)/hour
	<i>Invite grooming(rec)</i> ^F	C	groom invite(rec)/hour

	<i>Approaches(in)^F</i>	C	approach(in)/hour
socio-negative	<i>Contact aggression(in)^F</i>	C	(general aggression + bite + beat + grab + grasp + chase + fight + face + push + displace)/hour
	<i>Threats(in)^F</i>	C	(facial threat + open mouth display + headshake + body display + tongue flick)/hour
dominance	<i>Scent marking^F</i>	C	scent marking/hour
	<i>Carrying food away(in)^F</i>	C	carry food away(in)/hour
	<i>Terminate grooming^F</i>	C	terminate grooming(in)/hour
	<i>Grimace^F</i>	C	grimace/hour
	<i>Departures(in)^F</i>	C	departure(in)/hour

222 *Note.* P = based on proportion of time, S = computed as Shannon diversity index measuring
223 and explaining the variation in diversity of a particular variable with higher values indicating
224 higher variability (Shannon and Weaver, 1963), F = calculated as frequency, (in) = behaviour
225 initiated by focal individual, (rec) = behaviour received from an individual, C = continuous
226 recording, I = instantaneous sampling.

227

228 2.4. Repeatability

229 Consistency of behaviour over time (e.g. whether an individual is consistently more
230 aggressive than others) is a fundamental aspect of animal personality (Gosling, 2001; Réale et
231 al., 2007; Sih et al., 2004). To examine the consistency of behaviour in time, and thus
232 appropriateness of the behaviour for personality analyses, we determined the repeatability of
233 each behavioural index. Repeatability is the proportion of behavioural variation that is due to
234 interindividual differences compared to within individual variation (Bell et al., 2009). High
235 repeatability estimates imply that individuals behave differently from each other and at the same
236 time behave consistently over two or more observation periods (Bell et al., 2009). To do so, we

237 divided the observation into 3 5-hour time blocks and computed the behavioural indices for
238 each time block. The reasoning for dividing observations into 3 time blocks was two-fold. First,
239 we wanted to test the repeatability of behaviours collected over several time periods long
240 enough to enable reasonable data aggregation within each period. Second, the time blocks
241 enabled us to cover several days of observation (3–5 days per block) and so to reduce
242 measurement error (Epstein, 1983). The repeatability was analysed using linear mixed-effects
243 models (Nakagawa and Schielzeth, 2010). The 95% confidence intervals and p -values were
244 calculated by means of 1000 bootstrap runs and 1000 permutations, respectively. As
245 recommended by previous studies (Schuster et al., 2017), we interpreted the estimates of
246 repeatability regarding both the confidence interval and p -values simultaneously.

247 *2.5. Data reduction*

248 To determine the number of components to retain for personality models, we performed
249 a parallel analysis (Dinno, 2012; Horn, 1965) and examined the scree plot (Cattell, 1966).
250 Parallel analysis compares eigenvalues derived from observed data to eigenvalues of randomly
251 generated matrices with the same numbers of variables and subjects as the observed data.
252 Eigenvalues of data that exceed the 95th percentile of eigenvalues derived from parallel analysis
253 are retained (Zwick and Velicer, 1986).

254 Given our small sample size, to examine personality structure, we performed a PCA and
255 a regularised exploratory factor analysis (REFA; Jung and Lee, 2011), as recommended for
256 samples below 50. To improve interpretability of the component or factor structure, we applied
257 a promax (oblique) and varimax (orthogonal) rotation. The oblique rotation produces
258 components that are correlated with one another, whereas the orthogonal rotation provides
259 components that are independent. To interpret the structure, we defined absolute loadings of
260 indices $\geq |0.4|$ as salient. In the case of cross-loadings, indices were assigned to the component
261 or factor with the highest absolute loading.

262 *2.6. Time-constrained models*

263 To estimate the minimum number of observational hours needed to obtain a stable
264 personality structure, we split our data, which was based on 15 hours of observation, into 14
265 subsets based on various amounts of observation time. Each subset contained one hour of
266 observation per individual less than the previous subset, therefore observation times for subsets
267 ranged from 14 hours to 1 hour per individual. For each subset, we used the data reduction
268 methods described above. This resulted in generating 14 time-constrained personality models.

269 *2.7. Comparison of models*

270 We first compared the personality structure of the full 15-hour model based on PCA and
271 REFA to assess whether our sample size was satisfactory to obtain a stable structure (Jung and
272 Lee, 2011). Second, we compared the promax and varimax solutions of the full model to
273 determine whether we should interpret the correlated or independent dimensions. Third, we
274 compared all 14 time-constrained models to full model based on 15 hours of observation to
275 determine the minimal length of observation needed to get a stable personality structure. We
276 then interpreted the personality structure identified in the full model.

277 To compare the models' loadings and structure we used targeted orthogonal Procrustes
278 rotations (McCrae et al., 1996), which yield Tucker's congruence coefficients for each factor
279 and for the entire loading pattern (Lorenzo-Seva and ten Berge, 2006).

280 *2.8. Individual variation assessment*

281 To evaluate how well the individual personality scores on each component based on
282 time-restricted models describe the behavioural variation in comparison to full model, we
283 computed three sets of unit-weighted scores for each individual. These scores were computed
284 using time-restricted personality models based on 5, 10, and 15 hours of observation. We then
285 used Pearson's correlation coefficients for those scores to compare whether the rank orders of

286 scores were consistent, making sure to adjust p -values for multiple tests using a procedure
287 described by Holm (1979).

288 All statistical analyses were performed in R (version 3.3.3, 2017) using the psych
289 (Revelle, 2017), paran (Dinno, 2012), and rptR (Stoffel et al., 2017) packages. REFA was
290 computed using MATLAB (version 9.4., 2018).

291 **3. Results**

292 *3.1. Repeatability of behavioural indices*

293 The repeatability of the behavioural indices ranged from 0.25 for *Invite grooming(rec)*^F
294 to 0.93 *Approaches(in)*^F and *Departures(in)*^F with a mean repeatability of 0.62 (SD = 0.23)
295 (Table S2). These values were in the range of repeatability reported for other species (Bell et
296 al., 2009). Five indices, however, had lower repeatability, and although the p -value indicated
297 significance, the confidence interval included zero. We conducted the same analyses without
298 these indices and the results (personality models, the recommended length of observation) did
299 not change considerably (data not shown). Therefore, we decided to consider all indices as
300 acceptable for further data reduction analyses (Freeman et al., 2013).

301 *3.2. Model comparison*

302 Parallel analysis and the scree plot indicated that there were 2 components in the full
303 data set. The component solution derived from PCA was equal (congruence coefficients 1.00
304 for both components) to the REFA solution (see Table S3). Therefore, we decided to interpret
305 the PCA structure as it is reported more frequently in the literature (Konečná et al., 2012). Since
306 the correlations between components were negligible, and the structure of components from
307 both solutions were nearly identical, we retained component solution from varimax rotation.
308 For the promax-rotated solution see Table S4.

309 In subsets based on 2 to 14 hours of observation, parallel analyses and scree plots
310 suggested retaining 2 components. In the subset based on 1 hour of observation per animal, the
311 parallel analysis and scree plot indicated that there was 1 component. Given this result, we
312 considered 1 hour of observation as insufficient and did not examine it further. Time-
313 constrained personality models are provided in Tables S5–S18.

314 Congruence coefficients comparing the loadings of 14 time-constrained models to
315 loadings from the model derived from 15 hours of observation are presented in Table 3. The
316 structure of time-constrained models based on 2 to 3 hours of observation did not replicate the
317 structure of the full model. At 4 hours of observation, only 1 of the components replicated. The
318 components derived from data based on 5 or 6 hours of observation time, however, replicated
319 those derived from the full data set (all congruence coefficients > 0.89). From 7 hours onward,
320 both components and the structure can be considered equal to full model (congruence
321 coefficients > 0.97). It took less observation time to replicate the second component, which we
322 labelled Confidence, than it took to replicate the first component, which we labelled
323 Extraversion. Specifically, a stable Confidence dimension was obtained after 4 hours and was
324 replicable at 6 hours; to derive a stable and replicable Extraversion dimension required 1
325 additional hour (Fig. 1).

326 Although the overall model structure of datasets based on shorter observation periods
327 was replicable, there were minor inconsistencies with respect to assignment of certain indices
328 to dimensions. *Monitoring^P* for example, only had a salient loading in models based on ≥ 10
329 hours. For *Vigilance^F* this was true only with ≥ 6 hours of observation time. Only three indices
330 were assigned to different components (*Grooming(rec)^F*, *Invite grooming(in)^F*, *Resting^P*) in the
331 models based on 6 and 5 hours in comparison to the full model.

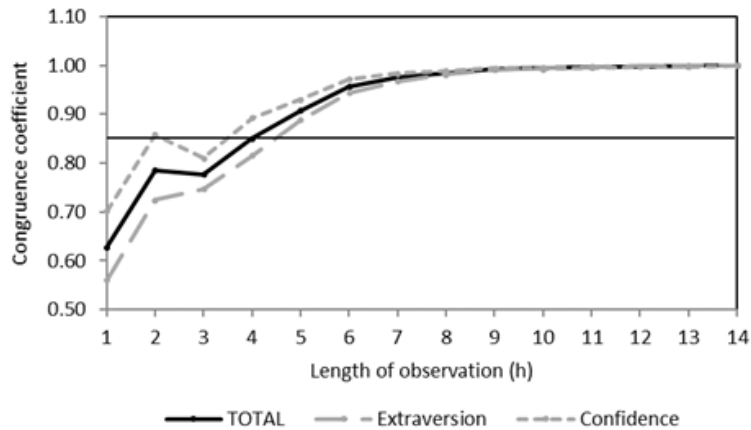
332

333 **Table 3**

334 Congruence between models based on different length of observation and full model based on
 335 15 hours of observation.

Observation length (h)	Congruence coefficient		
	Extraversion	Confidence	Model total
1	0.86	0.61	0.74
2	0.72	0.86	0.79
3	0.75	0.81	0.78
4	0.82	0.89	0.85
5	0.89	0.93	0.91
6	0.94	0.97	0.96
7	0.97	0.98	0.98
8	0.98	0.99	0.98
9	0.99	0.99	0.99
10	1.00	0.99	0.99
11	1.00	1.00	1.00
12	1.00	1.00	1.00
13	1.00	1.00	1.00
14	1.00	1.00	1.00

336 *Note.* >0.95 models are equal, 0.85 – 0.94 models display fair similarity, <0.85 no similarity
 337 (Lorenzo-Seva and ten Berge, 2006).



338

339 **Fig. 1.** The relationship between congruence coefficients and the length of observation
 340 (hours). Reference line refers to threshold of fair similarity.

341

342 *3.3. Individual variation*

343 Table 4 shows the correlations of unit-weighted scores for each component of three
 344 time-restricted models. Correlations between scores based on 5 and 10 hours and between 5
 345 and 15 hours are slightly lower but still reasonably high and significant ($p < 0.01$). Thus, 5
 346 hours of observation is sufficient for description of individual variation on personality
 347 components (Fig. 2).

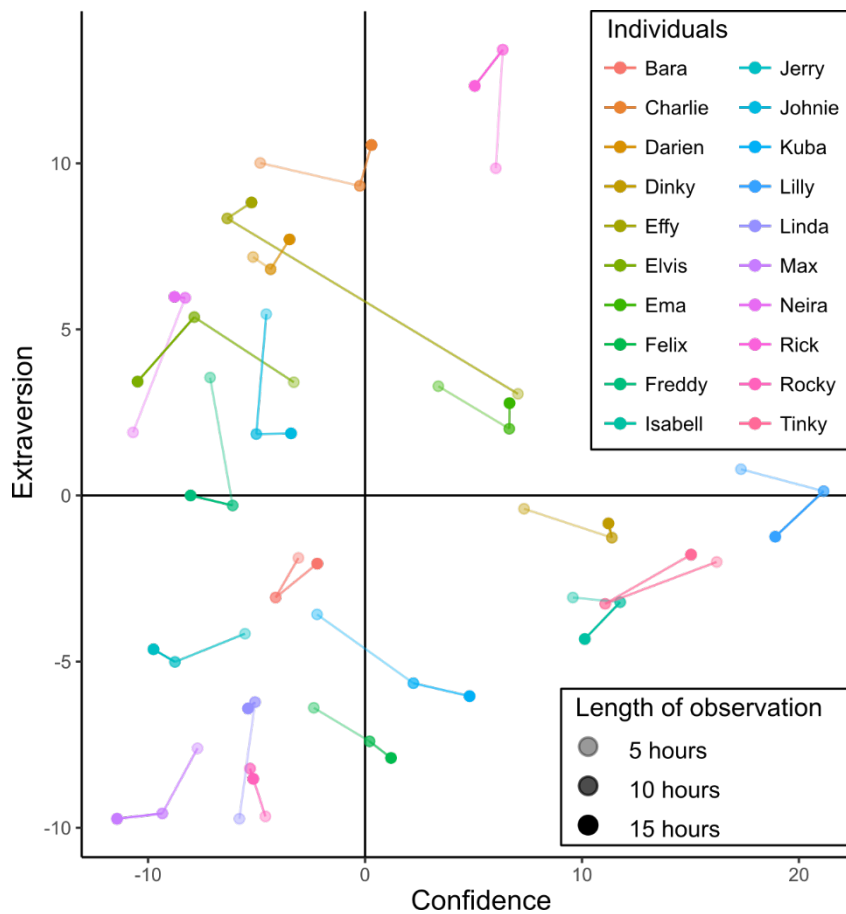
348

349 **Table 4**

350 Pearson's correlations of individual personality scores for each component of three time-
 351 restricted models.

Observation length (h)	Extraversion (95% CI)	Confidence (95% CI)
15 vs 10	0.98 (0.95, 0.99)	0.99 (0.98, 1.00)
15 vs 5	0.87 (0.70, 0.95)	0.93 (0.82, 0.97)
10 vs 5	0.87 (0.70, 0.95)	0.92 (0.81, 0.97)

352



353

354 **Fig. 2.** Individual PCA scores based on the components Extraversion and Confidence for 5,
 355 10 and 15 hours of observation. Scores of each individual are represented by 3 dots connected
 356 with a line. Shading indicates the length of observation. See online version for the figure in
 357 colour.

358

359 3.4. Full personality model

360 The full personality model with the two components is presented in Table 5. The
 361 components explained 54% of the variance. Only one index (*Scent marking^F*) did not load on
 362 any component. The indices *Vigilance^F*, *Terminate grooming^F*, and *Resting^P* loaded on both
 363 components. The first component loaded on indices related to physical and social activity.
 364 Individuals who scored high on this component performed a wide range of behaviours (*Activity*
 365 *diversity^S*) and preferred active affiliation, such as grooming and social play, to sitting in contact

366 or proximity with conspecifics (*Grooming(in)^F*, negative *Passive affiliation^P*). This component
 367 consisted also of indices related to exploration and active interest in surroundings
 368 (*Exploration^F*). Therefore, we labelled this component “Extraversion”.

369 The second component was characterized by dominance-related behaviours. Individuals
 370 scoring high on this component were confident in their interactions with others (*Approaches*
 371 *(in)^F*, *Contact aggression(in)^F*) and could acquire resources (*Carrying food away(in)^F*,
 372 *Grooming(rec)^F*). Furthermore, *Scratching^F*, which is often identified as an indicator of anxiety
 373 and stress in callitrichids (Caperos et al., 2011), loaded negatively on this component. Given
 374 these features, we labelled this component “Confidence”.

375

376 **Table 5**

377 Personality model of cotton-top tamarins. Varimax rotated solution of principal components
 378 analysis.

Behavioural index	Component		Communalities
	Extraversion	Confidence	
<i>Activity diversity^S</i>	0.89	0.29	0.87
<i>Passive affiliation^P</i>	-0.88	0.09	0.79
<i>Exploration^F</i>	0.88	0.00	0.77
<i>Threats(in)^F</i>	0.88	-0.06	0.77
<i>Vigilance^F</i>	0.72	-0.42	0.69
<i>Grooming(in)^F</i>	0.71	0.35	0.62
<i>Invite grooming(rec)^F</i>	0.68	0.04	0.46
<i>Terminate grooming^F</i>	0.64	0.41	0.58
<i>Resting^P</i>	-0.63	-0.44	0.59
<i>Grimace^F</i>	0.59	-0.12	0.36

<i>Object sniffing</i> ^F	0.49	-0.34	0.36
<i>Monitoring</i> ^P	0.43	-0.09	0.19
<i>Self-grooming</i> ^F	0.40	-0.22	0.21
<i>Departures(in)</i> ^F	-0.17	0.92	0.88
<i>Approaches(in)</i> ^F	-0.07	0.85	0.72
<i>Scratching</i> ^F	-0.12	-0.84	0.72
<i>Affiliation</i> ^P	-0.25	0.80	0.70
<i>Contact aggression(in)</i> ^F	-0.05	0.76	0.58
<i>Carrying food away(in)</i> ^F	-0.17	0.65	0.45
<i>Grooming(rec)</i> ^F	0.05	0.62	0.38
<i>Substrate diversity</i> ^S	0.30	0.58	0.42
<i>Invite grooming(in)</i> ^F	0.21	0.45	0.25
<i>Scent marking</i> ^F	0.34	0.10	0.12
<hr/>			
Explained variability	29%	25%	

379 *Note.* N = 20. Salient loadings are in boldface. P = index based on proportion of time, S =
380 index computed as Shannon diversity index, F = index calculated as frequency, (in) = behaviour
381 initiated by focal individual, (rec) = behaviour received by focal individual.

382 **4. Discussion**

383 A PCA of commonly observed behaviours that had moderate to high repeatability
384 unveiled two personality components, Extraversion and Confidence, in cotton-top tamarins.
385 Comparisons of the personality structures based on different lengths of observation indicated
386 that 5 hours of observation time per individual were sufficient to obtain a replicable personality
387 structure and a stable description of individual variation.

388 *4.1. Common behaviour coding method*

389 Behavioural coding has often been considered time-consuming and thus has not been
390 used as often as other methods of collecting personality data (Freeman et al., 2011; Itoh, 2002).
391 Our results, however, indicate that long observations might not be necessary for assessing
392 personality. In cotton-top tamarins, stable personality structure was revealed after 5 hours of
393 observation per individual. After 7 hours of observation time, both components and the overall
394 structure were nearly identical to the full model.

395 The minimum length necessary to obtain stable personality assessment might differ
396 across personality dimensions. Our results indicate that Confidence takes less time to assess
397 than Extraversion. Similarly, research on humans reported that some traits are more “visible”
398 and thus easier to judge than others (Funder, 2012). Behaviours related to Confidence could
399 have been easier to observe due to their higher frequency, as these behaviours are important in
400 social animals that have to cope with complex individualised social relationships on a daily
401 basis. Confidence-related behaviours also play a crucial part in callitrichid social groups, where
402 reproductive suppression can impose intense competition (Digby et al., 2006).

403 For this study, we analysed behaviours that occurred more frequently which could have
404 also contributed to significant reduction of the overall sampling effort. Recording rare but
405 species relevant behaviours, such as food sharing in tamarins, would probably extend the length
406 of observation. Age-sex classes should also be considered as certain behaviours might be more
407 prevalent in males or females or in different age categories. For example, severe aggression is
408 more common among male cotton-top tamarins (Snowdon and Pickhard, 1999). Similarly,
409 individuals in larger groups might have more opportunities to express social behaviours than
410 individuals in smaller groups or pairs of individuals, thus the behaviour is more rapidly
411 accumulated. The effect of those variables on data accumulation in the context of animal
412 personality, however, remains to be tested.

413 The overall sampling effort in terms of observation length can also be influenced by the
414 selection of the sampling method and the design of observation. In our study, we used a
415 combination of continuous and instantaneous focal sampling methods, which together enabled
416 us to record different types of information and thus collect the data more efficiently. Scan
417 sampling of the group could further reduce the workload of observers as it allows one to
418 measure behaviours in several animals within one period (Martin and Bateson, 2007).
419 Furthermore, the length of the focal observational period or scan interval can influence how
420 fast the data accumulate, with shorter periods and intervals possibly accumulating data faster
421 (Edwards et al., 2010; Kawanaka, 1996). Scheduling the focal periods across several days (in
422 our study the minimum of 5 hours was accomplished within 3 to 5 days) eliminates the influence
423 of unexpected situations (such as severe fights or management intervention in captivity) that
424 may affect the behaviour of an animal on a particular day. The effects of the distribution of
425 focal periods over time, the length of focal period, and the sampling method on personality
426 assessment remain to be tested as well.

427 It is important to emphasize, however, that the minimum length of observation might be
428 specific to nonhuman primates, New World monkeys, callitrichids, cotton-top tamarins or even
429 just captive populations of cotton-top tamarins. A study on wild chimpanzees, for example,
430 reported 25 hours of observation as the critical length of observation needed for reliable scoring
431 of behaviours and social relationships (Kawanaka, 1996). On the other hand, results from a
432 study on rhesus macaques in captivity suggested that 6 hours of data collection per group were
433 sufficient to provide a reliable group time budget (Nyström et al., 2001). Given that callitrichids
434 are small bodied, active, and have a relatively high metabolism rate, behaviours in this species
435 might accumulate more quickly compared with larger, less active species that have a relatively
436 slow metabolism (Careau and Garland, 2012). Furthermore, the type and quality of a species'
437 diet as well as feeding habits can be directly connected to activity patterns (Baldwin and

438 Baldwin, 1978; Masi et al., 2009), and thus affect the accumulation of different behaviours. For
439 instance, “energy minimising” folivores, such as howler monkeys (*Alouatta* sp.), spend up to
440 80% of their daily activities resting (Estrada et al., 1999), compared with the frugivorous-
441 insectivorous black-handed tamarins, which spend only 10% of the day resting (da Silva and
442 Ferrari, 2007). However, more data is needed from a wider variety of species in order to
443 determine whether body size or feeding ecology, indeed influence the rate of accumulating
444 behaviours related to personality.

445 Finally, depending on group size, 5 hours of observation per individual can be
446 considered time-consuming and requiring more effort compared to other methods. However,
447 preparation of experiments, from designing an apparatus, habituating animals, conducting the
448 experiments to necessary pauses between tests, can also take up a considerable amount of time,
449 in particular when researchers seek to evaluate several personality dimensions. Using
450 questionnaires for trait rating might seem to be the quickest method, however, it is only shorter
451 if well-acquainted raters are available. In other cases (e.g. Konečná et al., 2008), raters must
452 spend several months observing individuals before they can even begin rating. Moreover, long
453 forms (e.g. HPQ with 54 adjectives; Weiss et al., 2009) can take considerable time to complete.
454 Interestingly, the time demands of different personality assessment methods have only been
455 discussed but not empirically examined (Freeman et al., 2011; Vazire et al., 2007).

456 4.2. Repeatability of behaviours

457 The majority of behavioural indices used in the current study were either highly or
458 moderately reliable across three observation periods, representing a short time span. Still, there
459 was some variation. Indices with lower repeatability included those related to grooming
460 interactions, namely *Grooming(rec)^F*, *Invite grooming(rec)^F*, *Grooming(in)^F*, *Terminate*
461 *grooming^F*, and self-grooming (*Self-grooming^F*). One possible explanation of lower stability
462 estimates is that social grooming indices are, by definition, a function of the social environment.

463 Therefore, the lower stability of social indices might be attributable to the fact that their
464 occurrence is dependent on the behaviour of the focal individual and its social partners at the
465 same time. Some studies have found that grooming-related indices were repeatable (Blaszczyk,
466 2018; Koski, 2011b; Neumann et al., 2013), although the indices based on received social
467 interactions were less repeatable than the indices based on initiated social interactions
468 (Blaszczyk, 2018; Koski, 2011b). Alternatively, grooming behaviours might be context specific
469 and therefore represent several different traits (Carter et al., 2013; Gosling, 2001). Grooming is
470 most often thought of as an affiliative action but in cooperative breeders it can also be used to
471 induce helpers to stay in the group (pay-for-help strategy) (Ginther and Snowdon, 2009) or to
472 reduce the tension of these helpers (Caperos et al., 2011).

473 Other indices that could have been influenced by context are *Scent marking^F* and
474 *Monitoring^P*. *Scent marking^F*, which did not have a salient loading on any component in our
475 study, has been suggested to be a contagious behaviour in marmosets (Massen et al., 2016) and
476 so it is not possible to determine whether this behaviour was spontaneous, or triggered by the
477 behaviour of others. Moreover, scent marking might have several functions (Roberts, 2012) and
478 might be affected by sex (French and Cleveland, 1984) or breeding position (Heistermann et
479 al., 1989). *Monitoring^P* could have merged several types of scanning as social scanning,
480 curiosity or alertness (Gosselin-Ildari and Koenig, 2012). Therefore, we recommend using
481 indices related to scent marking and monitoring with caution. The context specificity and the
482 true motivation of an animal, however, is not always possible to record during focal behavioural
483 coding (for discussion see Freeman et al., 2011; Iwanicki and Lehmann, 2015; Vazire et al.,
484 2007). To overcome the effect of context it would be necessary either to record the context they
485 occurred in or aggregate those behaviours sufficiently in time by means of longer observation
486 periods (Epstein, 1983).

487 4.3. Cotton-top tamarin personality model

488 One set of behaviours that defined Extraversion in tamarins included indices related to
489 physical and social activities. Extraversion in this sense has been described in great apes (Weiss
490 et al., 2009, 2006) and as part of the human Five-Factor Model (McCrae and John, 1992). A
491 second set of behaviours defining cotton-top tamarin Extraversion included indices related to
492 individuals' tendencies to explore their environment. In this way, tamarin Extraversion partly
493 resembled common marmoset Inquisitiveness (Koski et al., 2017) and Openness dimensions
494 (Iwanicki and Lehmann, 2015) identified by questionnaires (for details see Table S19), and
495 Exploration-Avoidance (Koski and Burkart, 2015; Šlipogor et al., 2016) measured by
496 experimental coding. There are three possible reasons why exploratory behaviours were
497 subsumed under cotton-top tamarin Extraversion. First, exploratory behaviours that we
498 observed might be those more connected to physical activity and thus loaded on the same
499 dimension. Second, exploratory behaviour might be rare in stable predictable captive conditions
500 where animals do not have to forage and do not encounter novel stimuli as often. Third, the
501 species-specific socioecology might also play a role. Marmosets live in more diverse habitats
502 than tamarins, and so a distinct Openness dimension in marmosets could reflect an evolved
503 response to spatial variation in habitats (Digby et al., 2006).

504 Confidence included dominance-related behaviours, low levels of scratching and
505 indices connected to using the space and resources. Tamarin Confidence corresponded to the
506 Assertiveness dimension in one ratings-based study of common marmosets (Koski et al., 2017).
507 It also corresponded to a dimension labelled "Extraversion", which mainly comprised of
508 dominance-related traits, as described in another study (Iwanicki and Lehmann, 2015) (Table
509 S20). Our results therefore support the general interpretation of dimension, usually labelled as
510 Confidence, Dominance, or Assertiveness as an important part of primate personality that
511 reflects the individuals' need to cope with social interactions and relationships in highly
512 complex social groups.

513 Many studies have demonstrated that behaviour-based personality models correspond
514 to questionnaire-based models (Garai et al., 2016; Iwanicki and Lehmann, 2015; Konečná et
515 al., 2008; Murray, 2011). This suggests that both methods assess the same underlying
516 constructs. However, the resulting cotton-top tamarin personality model remains to be validated
517 against other personality measures, underlying physiological indicators (e.g. hormones), or
518 other outcomes (e.g. survival or reproductive success).

519 The fact that we did not obtain further personality dimensions does not necessarily imply
520 that only two personality dimensions characterise tamarin behaviour. Using trait ratings,
521 Iwanicki and Lehmann (2015) and Koski et al. (2017) identified a Conscientiousness dimension
522 in marmosets, which appears to be connected to the advanced socio-cognitive skills necessary
523 for cooperative breeding and therefore it might be an important domain to callitrichids. It is
524 possible that we might have omitted behaviours relevant to Conscientiousness, such as infant
525 care (Delgado and Sulloway, 2017) and other traits otherwise present in questionnaires.
526 Similarly, using controlled experiments it might be possible to assess reactions to novelty or
527 other exploratory tendencies in more detail. For the identification of the whole personality
528 model of a species, we recommend the utilisation of the broader behavioural spectrum and a
529 selection of behaviours relevant to species typical socio-ecology.

530 **5. Conclusion**

531 We described a personality model of cotton-top tamarins, consisting of Extraversion and
532 Confidence. The model corresponds with results of previous studies in primates and can serve
533 as a basis for future comparative personality research in callitrichids. Our findings suggest that
534 common behaviour coding is a useful tool for assessing complex personality structure and may
535 be less time-consuming than previously believed. For cotton-top tamarins, stable personality
536 structure was obtained only after 5 hours of observation per individual. The recommended
537 length of observation in this species can be used as a guide not only in personality studies but

538 also in studies assessing individual variation in behaviour in general. The minimum length of
539 observation recommended in this study for personality assessment should, however, be treated
540 as species-specific before data from other species differing in body size and feeding ecology
541 are tested.

542

543 **Conflict of interest**

544 Declarations of interest: none

545

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555

556 **Appendix A. Supplementary data**

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Supplementary data for: How long does it take? Reliable personality assessment based on common behaviour in cotton-top tamarins (*Saguinus oedipus*)

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Table S1. Ethogram of cotton-top tamarin (*Saguinus oedipus*)

Behavioural category	Behaviour	Description
<i>Continuous focal sampling</i>		
Locomotion	Move	horizontal or vertical movement of more than 50 cm; including walking running and climbing; excluding chasing and playing
	Jump	focal individual jumps to overcome gaps between substrates in the enclosure (i.e. branches, trunks, shelves, walls, ...); including change of substrate
	Resting	sitting or lying in relaxed position with closed eyes; individual may be in proximity or contact with other individual
Food interactions	Eating	handling, chewing and active ingestion of food by swallowing it
	Drinking	ingestion of liquids by drinking from water bowl/dispenser, licking wet surfaces or hands dipped in water
	Floor scanning	visual inspection of ground in order to find food; individual might be on the ground or on substrate above the ground
	Prey catching	catching invertebrates moving freely in the enclosure
	Prey catching - attempt	unsuccessful attempt to catch invertebrates moving freely in the enclosure
	Taking food from keeper	individual takes food from the zookeeper's hand
	Approach – food	oriented approach towards individual possessing food item
	Contact - food	initiation of contact with individual possessing food item
	Follow – food	individual follows the movement of another individual that possesses food to its proximity
	Co-feeding	joining other individual eating from the same feeding bowl
Carrying food away	taking food away from feeding bowl where other individual is eating	

	Begging	scrounging the food from individual that is eating by fixing the food item with sight; may involve characteristic vocalization (squeak), touching or attempting to take the food item
	Sharing food	voluntary sharing of food item with other individual resulting in eating together the same food item the possessor holds in hand or yielding the food item; often after begging
	Stealing food	taking food from other individual's hand or mouth
	Stealing food - attempt	unsuccessful attempt to steal food from hand or mouth of other individual
Object interactions	Attention	individual fixes its stare to the object of interest to examine it; usually followed by moving in direction of object
	Surface licking	individual licks surface of substrate
	Substrate searching	sitting on the ground and looking for the food in the substrate by using hands
	Object manipulation	manipulation with object (e.g. twigs, leaves, bark; excluding food) using hands or mouth; including looking at, sniffing and biting into the object
	General exploration	manipulative investigation of objects, enrichment or equipment of enclosure using hands or mouth
	Approach - object	oriented approach towards individual possessing object of interest
	Contact – object	initiation of contact with individual possessing object of interest
	Follow - object	individual follows the movement of another individual that possesses object to its proximity
	Stealing object	taking an object (e.g. twig, leaf, bark) from individual possessing it
	Stealing object - attempt	unsuccessful attempt to possess an object that is hold by other individual
Comfort	Scratching	rapid rubbing of body using the claws of hand or foot; individual does not have to be visually focused on the scratched area
	Face scratching	rubbing muzzle with hand

	Self-grooming	using claws of hands or mouth to pick through its own skin or fur; including removing of particles; individual is visually focused on the groomed area
	Stretching	stretching of entire body or limbs
Olfactory	Object sniffing	smelling the surface of substrate, objects, scent marks or food
	Sniffing individual	smelling the body, face or anogenital region of other individual
	Muzzle rubbing	pressing the oro-facial region onto the substrate and rubbing it with movements of head
	Scent marking	rubbing the anogenital area against the substrate in a sitting position or the suprapubic pad or sternal area either by pulling itself forward with hands or pushing with legs; may be accompanied by urine discharge
	Allomarking	scent marking over the body of another individual that can carry infants
	Urine tasting	individual licks urine drops of another individual either left on substrate or while the individual is urinating or scent marking
Play	Solitary play	repeated jumping and falling from one branch to another, swinging and bouncing on branches; excluding play with object
	Play with object	manipulation or biting into an object in the context of play
	Social play	non-aggressive and active interaction of 2 or more individuals, including play chasing, play wrestling, displaying, repeated jumping/ falling from one branch to another together with others
	Joining the play	individual engages in ongoing social play of other individuals
	Solicit play	attempt to attract the attention and involve other individual in playing; including tongue flicking, staring, pushing the individual or jumping in front of the individual
Affiliative	Proximity	individual is in the distance of max. 30 cm from other individual
	Contact	individual is in body contact with another or in the comfortable reach of arm (<9 cm)

	Allogrooming	individual picks slowly through the fur or skin of other individual using the claws of 1 or both hands or mouth; including removing particles
	Invite grooming	individual lowers its body or stretches out on its back or side requesting grooming
	Nuzzling	individual gently rubs its muzzle against other individual; may be accompanied by sniffing and licking
	Kiss	muzzle-muzzle contact of 2 animals; may involve tongue flicking
	Arm over	placing arm around other individual's upper body or shoulders
	Waist clasping	placing both arms from behind around other individual's waist
	Huddling	animal lies across or sits or lies next to other individual in tight body contact; limbs can be intertwined
Sexual	Copulation	male mounts a female, including penile insertion and thrusting, sometimes accompanied by tongue flicking
	Mounting	individual gets on back of other individual with arms around its waist; may include pelvic thrusts and tongue flicking
Infant care	Climb on	infant climbs on the back or side of potential carrier (from substrate or another carrier); limbs of infant are not in the contact with substrate; initiative of infant
	Climb off	infant climbs from the carrier to substrate or another carrier
	Solicit carrying	infant approaches potential carrier trying to climb on its back squeaking; potential carrier is not interested
	Invitation to carry	potential carrier attempts to entice the infant in order to carry it; including tongue flicking or lowering its body
	Taking infant on	potential carrier gathers infant from substrate or back of current carrier in order to carry it; initiative of potential carrier
	Taking infant on – attempt	unsuccessful attempt of potential carrier to gather infant from substrate or back of the current carrier in order to carry it; infant refuses to climb on or the carrier refuses to transfer the infant; sometimes resulting in aggression between caretakers

	Infant rejection	caretaker dislodges infant clinging to it or prevents infant to climb on by using scratching, biting, pushing, pulling infant's extremities or rolling the infant against substrate
	Infant rejection - attempt	unsuccessful attempt to dislodge infant from back or prevent infant to climb on
	Nursing	infant is from the ventral side of the female suckling; infant's mouth is on the nipple of female
Dominance	Grimace	lip corners are pulled back, lower lip is retracted so the mouth is slightly open revealing dentition with pressed jaws; accompanied by vocalization
	Avoiding	individual while travelling changes the direction of its move in order to avoid another individual
	Grasp	individual places its arm over the other individual's shoulder, head, upper body or touches other individual's face in dominant manner while slightly raising its body or head
	Displacement	individual chases other individual away from potential source, e.g. food, water, sleeping box
Agonistic non-contact	Facial threat	staring and frowning at other individual, may involve tongue or ear flicking
	Open mouth display	individual stares at another with mouth widely open exposing its teeth
	Headshake	rapid turning of head from side to side; might be accompanied by teeth chattering
	Body display	individual stares at other individual, limbs flexed, vertebral column bent into high arch, fur piloerected; often accompanied by facial threat; individual might be moving or vocalizing
	Chase	chasing other individual that is fleeing and trying to hide; rapid locomotion
Agonistic contact	Face pressing	individual grabs the head of other individual and presses its open mouth to oponent's mouth
	Bite	individual bites another individual with its teeth; teeth may or may not penetrate the skin
	Push	individual aggressively hits other individual using its hand; may push the other animal away

	Grab	individual grabs hair of other individual; may pull out strand of hair
	Beating	repeated pushing and hitting other individual using arms; other individual usually beats back
	Fight	aggressive physical confrontation of individuals; short fast struggle involving biting, wrestling, hitting, scratching, kicking; victim may scream
	General aggression	any fast aggressive act of behaviour that observer was not able to register in detail
Other	Alert	vigilant observing of environment; individual is stationary and may turn its head from side to side
	General alarm	individual vocalizes (Type E or H chirp) when startled or frightened
	Vomiting	throwing up, usually after eating insect
	Head twist	stereotypic behaviour when individual stretches its head by tilting it back
	Out of sight	individual disappears from sight of observer to the box or separate part of enclosure
Other social	Approach	individual comes in proximity to other individual
	Departure	leaving from contact or proximity of other individual; excluding fleeing or displacement
	Following	individual follows the movement of other individual to its proximity
	Attention to other	fixed gaze at individual of interest; in context of hostility or curiosity
	Tongue flick	protrusion and rapid rhythmical movements of the tongue tip up and down; in sexual, aggressive or infant care context
	Teeth cleaning	individual uses its hands to open mouth of other individual and clean its teeth by using tongue; does not usually last long as groomee tries to recoil; often followed by aggression from groomee
	Terminate grooming	individual ends the allogrooming

Instantaneous focal sampling

Substrate type	Branch	branch or stem of a tree or bush; excluding vertical stems
	Trunk	vertical trunk or stem of any diameter
	Sleeping box	nesting box providing shelter
	Shelf	horizontal surfaces wider and longer than 10 cm, e.g. shelves, top of sleeping box
	Ground	floor of the enclosure
	Wall	vertical wall (wire mesh, artificial rockwork) of enclosure enabling clinging and locomotion
	Ceiling	roof or ceiling of enclosure enabling hanging or moving
	Other	other equipment of enclosure, e.g. ropes, pipes, toys, enrichment
Locomotion/ postures	Move	
	Jump	
	Sitting	individual is in stationary position sitting on horizontal substrate
	Lying	individual places its body in horizontal position, with both limbs hanging down or rested; on horizontal or slightly inclined substrate
	Clinging	individual hangs on tightly to vertical substrate using claws of both hands and feet (i.e. wire mesh, wall, large tree trunks)
	Hanging	individual is suspended from wire mesh ceiling of enclosure or branch holding on using all limbs or legs
	Resting	
Food interactions	Eating	
	Drinking	
	Co-feeding	
Object interactions	Substrate searching	
	Object manipulation	

	General exploration	
	Play with object	
Social interactions	Social play	
	Allogrooming	
	Proximity	
	Contact	
Other	Solitary play	
	Self-grooming	
	Looking	individual is stationary and calmly looks around
	Watching	individual observes particular object, place, animal or person
	Alert	

Table S2. Repeatability estimates of behavioural indices across three time blocks

	R ± SE	95% CI	<i>p</i>
<i>Approaches(in)^F</i>	0.93 ± 0.04	[0.83, 0.96]	0.001
<i>Departures(in)^F</i>	0.93 ± 0.03	[0.85, 0.97]	0.001
<i>Substrate diversity^S</i>	0.88 ± 0.05	[0.75, 0.94]	0.001
<i>Affiliation^P</i>	0.84 ± 0.06	[0.67, 0.92]	0.001
<i>Scratching^F</i>	0.82 ± 0.07	[0.64, 0.91]	0.001
<i>Scent marking^F</i>	0.79 ± 0.08	[0.60, 0.89]	0.001
<i>Exploration^F</i>	0.77 ± 0.08	[0.57, 0.88]	0.001
<i>Object sniffing^F</i>	0.77 ± 0.08	[0.57, 0.88]	0.001
<i>Contact aggression(in)^F</i>	0.76 ± 0.09	[0.54, 0.88]	0.001
<i>Carrying food away(in)^F</i>	0.73 ± 0.10	[0.47, 0.86]	0.001
<i>Resting^P</i>	0.73 ± 0.09	[0.51, 0.85]	0.001
<i>Activity diversity^S</i>	0.69 ± 0.10	[0.44, 0.83]	0.001
<i>Grimace^F</i>	0.69 ± 0.10	[0.43, 0.82]	0.001
<i>Monitoring^P</i>	0.63 ± 0.12	[0.35, 0.79]	0.001
<i>Threats(in)^F</i>	0.60 ± 0.12	[0.32, 0.77]	0.001

<i>Vigilance</i> ^F	0.51 ± 0.13	[0.19, 0.71]	0.001
<i>Passive affiliation</i> ^P	0.45 ± 0.14	[0.15, 0.67]	0.002
<i>Invite grooming(in)</i> ^F	0.37 ± 0.14	[0.07, 0.62]	0.004
<i>Grooming(in)</i> ^F	0.29 ± 0.14	[0, 0.54]	0.02
<i>Self-grooming</i> ^F	0.28 ± 0.14	[0, 0.55]	0.02
<i>Grooming(rec)</i> ^F	0.26 ± 0.15	[0, 0.55]	0.03
<i>Terminate grooming</i> ^F	0.26 ± 0.14	[0, 0.53]	0.03
<i>Invite grooming(rec)</i> ^F	0.25 ± 0.14	[0, 0.52]	0.04

Note. P = index based on proportion of time, S = index computed as Shannon diversity index, F = index calculated as frequency, (in) = behaviour initiated by focal individual, (rec) = behaviour received by focal individual.

Table S3. Full model. Varimax rotated solution of REFA

Behavioural index	Component		Communalities
	F1	F2	
<i>Activity diversity</i> ^S	0.86	0.28	0.81
<i>Passive affiliation</i> ^P	-0.85	0.09	0.73
<i>Threats(in)</i> ^F	0.84	-0.05	0.72
<i>Exploration</i> ^F	0.84	0.00	0.71
<i>Vigilance</i> ^F	0.69	-0.40	0.64
<i>Grooming(in)</i> ^F	0.68	0.33	0.57
<i>Invite grooming(rec)</i> ^F	0.65	0.04	0.43
<i>Resting</i> ^P	-0.61	-0.42	0.54
<i>Terminate grooming</i> ^F	0.61	0.39	0.53
<i>Grimace</i> ^F	0.57	-0.11	0.33
<i>Object sniffing</i> ^F	0.47	-0.32	0.33
<i>Monitoring</i> ^P	0.41	-0.08	0.17
<i>Self-grooming</i> ^F	0.39	-0.21	0.19
<i>Scent marking</i> ^F	0.32	0.09	0.11
<i>Departures(in)</i> ^F	-0.16	0.88	0.80
<i>Approaches(in)</i> ^F	-0.06	0.81	0.66
<i>Scratching</i> ^F	-0.11	-0.80	0.65
<i>Affiliation</i> ^P	-0.24	0.76	0.64
<i>Contact aggression(in)</i> ^F	-0.05	0.73	0.53
<i>Carrying food away(in)</i> ^F	-0.16	0.62	0.41
<i>Grooming(rec)</i> ^F	0.05	0.59	0.35
<i>Substrate diversity</i> ^S	0.29	0.55	0.39

<i>Invite grooming(in)^F</i>	0.20	0.43	0.23
Explained variability	27%	23%	

Note. N = 20. Factor loadings $\geq |0.3|$ are considered salient and indicated in bold-face.

Table S4. Promax rotated solution of PCA and the component correlation: full model

Behavioural index	Component		Communalities
	PC1	PC2	
<i>Activity diversity^S</i>	0.90	0.22	0.87
<i>Exploration^F</i>	0.88	-0.07	0.77
<i>Passive affiliation^P</i>	-0.88	0.16	0.79
<i>Threats(in)^F</i>	0.88	-0.13	0.77
<i>Grooming(in)^F</i>	0.72	0.29	0.62
<i>Vigilance^F</i>	0.70	-0.47	0.69
<i>Invite grooming(rec)^F</i>	0.68	-0.02	0.46
<i>Terminate grooming^F</i>	0.65	0.36	0.58
<i>Resting^P</i>	-0.65	-0.39	0.59
<i>Grimace^F</i>	0.58	-0.16	0.36
<i>Object sniffing^F</i>	0.48	-0.38	0.36
<i>Monitoring^P</i>	0.42	-0.12	0.19
<i>Self-grooming^F</i>	0.39	-0.25	0.21
<i>Scent marking^F</i>	0.34	0.07	0.12
<i>Departures(in)^F</i>	-0.13	0.93	0.88
<i>Approaches(in)^F</i>	-0.03	0.85	0.72
<i>Scratching^F</i>	-0.15	-0.83	0.72
<i>Affiliation^P</i>	-0.22	0.81	0.70
<i>Contact aggression(in)^F</i>	-0.02	0.76	0.58
<i>Carrying food away(in)^F</i>	-0.14	0.66	0.45
<i>Grooming(rec)^F</i>	0.08	0.61	0.38
<i>Substrate diversity^S</i>	0.32	0.55	0.42
<i>Invite grooming(in)^F</i>	0.23	0.43	0.25
Explained variability	29%	25%	

Note. The correlation of components was 0.04. Tables S4 – S18: N = 20. Salient loadings $\geq |0.4|$ are in bold-face.

Table S5. Varimax rotated solution of PCA: 14-hour model

Behavioural index	Component		Communalities
	PC1	PC2	

<i>Activity diversity</i> ^S	0.89	0.27	0.86
<i>Exploration</i> ^F	0.87	0.00	0.76
<i>Passive affiliation</i> ^P	-0.87	0.12	0.78
<i>Threats(in)</i> ^F	0.87	-0.05	0.76
<i>Vigilance</i> ^F	0.72	-0.41	0.69
<i>Grooming(in)</i> ^F	0.72	0.33	0.63
<i>Invite grooming(rec)</i> ^F	0.71	0.07	0.50
<i>Terminate grooming</i> ^F	0.66	0.38	0.58
<i>Resting</i> ^P	-0.61	-0.43	0.56
<i>Grimace</i> ^F	0.58	-0.12	0.35
<i>Object sniffing</i> ^F	0.49	-0.31	0.34
<i>Self-grooming</i> ^F	0.47	-0.21	0.27
<i>Monitoring</i> ^P	0.44	-0.14	0.21
<i>Scent marking</i> ^F	0.35	0.09	0.13
<i>Departures(in)</i> ^F	-0.17	0.91	0.86
<i>Scratching</i> ^F	-0.11	-0.86	0.75
<i>Approaches(in)</i> ^F	-0.09	0.82	0.68
<i>Affiliation</i> ^P	-0.24	0.80	0.70
<i>Contact aggression(in)</i> ^F	-0.08	0.74	0.56
<i>Grooming(rec)</i> ^F	0.09	0.62	0.40
<i>Carrying food away(in)</i> ^F	-0.19	0.62	0.42
<i>Substrate diversity</i> ^S	0.29	0.59	0.43
<i>Invite grooming(in)</i> ^F	0.20	0.49	0.28
Explained variability	30%	24%	

Table S6. Varimax rotated solution of PCA: 13-hour model

Behavioural index	Component		Communalities
	PC1	PC2	
<i>Activity diversity</i> ^S	0.89	0.25	0.86
<i>Threats(in)</i> ^F	0.88	-0.07	0.78
<i>Exploration</i> ^F	0.88	-0.06	0.77
<i>Passive affiliation</i> ^P	-0.87	0.08	0.76
<i>Vigilance</i> ^F	0.72	-0.41	0.68
<i>Grooming(in)</i> ^F	0.70	0.36	0.63
<i>Invite grooming(rec)</i> ^F	0.65	0.09	0.44
<i>Resting</i> ^P	-0.63	-0.41	0.56
<i>Terminate grooming</i> ^F	0.63	0.45	0.59

<i>Grimace</i> ^F	0.55	-0.14	0.32
<i>Object sniffing</i> ^F	0.51	-0.28	0.34
<i>Self-grooming</i> ^F	0.47	-0.20	0.26
<i>Monitoring</i> ^P	0.46	-0.16	0.24
<i>Scent marking</i> ^F	0.33	0.09	0.12
<i>Departures(in)</i> ^F	-0.19	0.91	0.87
<i>Scratching</i> ^F	-0.10	-0.87	0.76
<i>Approaches(in)</i> ^F	-0.09	0.83	0.69
<i>Affiliation</i> ^P	-0.26	0.79	0.70
<i>Contact aggression(in)</i> ^F	-0.07	0.74	0.56
<i>Grooming(rec)</i> ^F	0.02	0.63	0.39
<i>Carrying food away(in)</i> ^F	-0.20	0.61	0.42
<i>Substrate diversity</i> ^S	0.28	0.59	0.43
<i>Invite grooming(in)</i> ^F	0.15	0.47	0.25
Explained variability	29%	25%	

Table S7. Varimax rotated solution of PCA: 12-hour model

Behavioural index	Component		Communalities
	PC1	PC2	
<i>Activity diversity</i> ^S	0.89	0.24	0.86
<i>Passive affiliation</i> ^P	-0.88	0.08	0.78
<i>Exploration</i> ^F	0.88	-0.07	0.78
<i>Threats(in)</i> ^F	0.88	-0.03	0.77
<i>Grooming(in)</i> ^F	0.74	0.36	0.67
<i>Vigilance</i> ^F	0.71	-0.41	0.67
<i>Terminate grooming</i> ^F	0.66	0.45	0.64
<i>Invite grooming(rec)</i> ^F	0.64	0.09	0.42
<i>Resting</i> ^P	-0.61	-0.40	0.54
<i>Grimace</i> ^F	0.54	-0.13	0.31
<i>Object sniffing</i> ^F	0.51	-0.26	0.33
<i>Self-grooming</i> ^F	0.48	-0.19	0.26
<i>Monitoring</i> ^P	0.48	-0.13	0.24
<i>Scent marking</i> ^F	0.30	0.09	0.10
<i>Departures(in)</i> ^F	-0.19	0.92	0.88
<i>Scratching</i> ^F	-0.12	-0.84	0.73
<i>Approaches(in)</i> ^F	-0.09	0.83	0.70
<i>Affiliation</i> ^P	-0.26	0.79	0.70

<i>Contact aggression(in)^F</i>	-0.06	0.75	0.57
<i>Grooming(rec)^F</i>	0.07	0.64	0.42
<i>Substrate diversity^S</i>	0.25	0.57	0.39
<i>Carrying food away(in)^F</i>	-0.21	0.56	0.36
<i>Invite grooming(in)^F</i>	0.16	0.48	0.25
Explained variability	29%	25%	

Table S8. Varimax rotated solution of PCA: 11-hour model

Behavioural index	Component		Communalities
	PC1	PC2	
<i>Activity diversity^S</i>	0.89	0.25	0.85
<i>Threats(in)^F</i>	0.88	-0.02	0.77
<i>Exploration^F</i>	0.85	-0.03	0.72
<i>Passive affiliation^P</i>	-0.83	0.08	0.70
<i>Grooming(in)^F</i>	0.70	0.41	0.66
<i>Vigilance^F</i>	0.69	-0.42	0.66
<i>Resting^P</i>	-0.64	-0.37	0.55
<i>Invite grooming(rec)^F</i>	0.62	0.13	0.40
<i>Terminate grooming^F</i>	0.62	0.51	0.64
<i>Object sniffing^F</i>	0.57	-0.24	0.38
<i>Grimace^F</i>	0.49	-0.14	0.26
<i>Monitoring^P</i>	0.46	-0.10	0.23
<i>Self-grooming^F</i>	0.46	-0.19	0.25
<i>Scent marking^F</i>	0.35	0.10	0.13
<i>Departures(in)^F</i>	-0.19	0.92	0.88
<i>Approaches(in)^F</i>	-0.10	0.84	0.71
<i>Scratching^F</i>	-0.11	-0.83	0.70
<i>Affiliation^P</i>	-0.28	0.78	0.68
<i>Contact aggression(in)^F</i>	-0.07	0.75	0.56
<i>Grooming(rec)^F</i>	0.07	0.67	0.45
<i>Substrate diversity^S</i>	0.25	0.56	0.38
<i>Carrying food away(in)^F</i>	-0.18	0.56	0.34
<i>Invite grooming(in)^F</i>	0.19	0.51	0.29
Explained variability	28%	25%	

Table S9. Varimax rotated solution of PCA: 10-hour model

Behavioural index	Component		Communalities
	PC1	PC2	
<i>Activity diversity</i> ^S	0.89	0.24	0.85
<i>Threats(in)</i> ^F	0.85	-0.03	0.72
<i>Passive affiliation</i> ^P	-0.83	0.09	0.69
<i>Exploration</i> ^F	0.79	-0.04	0.63
<i>Grooming(in)</i> ^F	0.74	0.39	0.70
<i>Terminate grooming</i> ^F	0.66	0.49	0.67
<i>Vigilance</i> ^F	0.65	-0.45	0.62
<i>Invite grooming(rec)</i> ^F	0.62	0.22	0.44
<i>Resting</i> ^P	-0.60	-0.36	0.49
<i>Object sniffing</i> ^F	0.54	-0.30	0.38
<i>Grimace</i> ^F	0.50	-0.15	0.27
<i>Self-grooming</i> ^F	0.48	-0.11	0.24
<i>Monitoring</i> ^P	0.42	-0.07	0.18
<i>Scent marking</i> ^F	0.37	0.05	0.14
<i>Departures(in)</i> ^F	-0.22	0.91	0.88
<i>Approaches(in)</i> ^F	-0.13	0.82	0.70
<i>Scratching</i> ^F	-0.16	-0.81	0.67
<i>Affiliation</i> ^P	-0.25	0.75	0.63
<i>Contact aggression(in)</i> ^F	-0.12	0.71	0.52
<i>Grooming(rec)</i> ^F	0.13	0.67	0.46
<i>Carrying food away(in)</i> ^F	0.10	0.60	0.37
<i>Invite grooming(in)</i> ^F	0.20	0.56	0.35
<i>Substrate diversity</i> ^S	0.25	0.56	0.37
Explained variability	28%	24%	

Table S10. Varimax rotated solution of PCA: 9-hour model

Behavioural index	Component		Communalities
	PC1	PC2	
<i>Activity diversity</i> ^S	0.88	0.27	0.85
<i>Passive affiliation</i> ^P	-0.80	0.11	0.66
<i>Exploration</i> ^F	0.80	0.04	0.65
<i>Threats(in)</i> ^F	0.79	-0.03	0.62
<i>Grooming(in)</i> ^F	0.72	0.45	0.72

<i>Terminate grooming</i> ^F	0.64	0.54	0.70
<i>Invite grooming(rec)</i> ^F	0.62	0.24	0.45
<i>Vigilance</i> ^F	0.60	-0.42	0.53
<i>Object sniffing</i> ^F	0.56	-0.30	0.40
<i>Resting</i> ^P	-0.56	-0.42	0.49
<i>Grimace</i> ^F	0.52	-0.10	0.28
<i>Self-grooming</i> ^F	0.45	-0.17	0.23
<i>Monitoring</i> ^P	0.36	-0.06	0.14
<i>Scent marking</i> ^F	0.34	0.05	0.12
<i>Departures(in)</i> ^F	-0.27	0.90	0.88
<i>Scratching</i> ^F	-0.16	-0.82	0.71
<i>Approaches(in)</i> ^F	-0.18	0.82	0.71
<i>Affiliation</i> ^P	-0.23	0.78	0.65
<i>Contact aggression(in)</i> ^F	-0.17	0.73	0.57
<i>Carrying food away(in)</i> ^F	-0.07	0.62	0.39
<i>Grooming(rec)</i> ^F	0.16	0.59	0.37
<i>Substrate diversity</i> ^S	0.17	0.58	0.36
<i>Invite grooming(in)</i> ^F	0.16	0.51	0.29
Explained variability	26%	25%	

Table S11. Varimax rotated solution of PCA: 8-hour model

Behavioural index	Component		Communalities
	PC1	PC2	
<i>Activity diversity</i> ^S	0.89	0.18	0.82
<i>Grooming(in)</i> ^F	0.82	0.29	0.76
<i>Threats(in)</i> ^F	0.80	-0.01	0.65
<i>Passive affiliation</i> ^P	-0.80	0.20	0.68
<i>Exploration</i> ^F	0.76	0.06	0.58
<i>Terminate grooming</i> ^F	0.75	0.39	0.71
<i>Invite grooming(rec)</i> ^F	0.67	0.28	0.53
<i>Grimace</i> ^F	0.54	-0.08	0.30
<i>Vigilance</i> ^F	0.54	-0.45	0.50
<i>Resting</i> ^P	-0.53	-0.38	0.43
<i>Object sniffing</i> ^F	0.51	-0.28	0.34
<i>Self-grooming</i> ^F	0.41	-0.19	0.20
<i>Scent marking</i> ^F	0.36	0.07	0.13
<i>Monitoring</i> ^P	0.27	-0.09	0.08

<i>Departures(in)^F</i>	-0.25	0.90	0.87
<i>Scratching^F</i>	-0.18	-0.83	0.72
<i>Approaches(in)^F</i>	-0.18	0.81	0.69
<i>Affiliation^P</i>	-0.15	0.79	0.65
<i>Contact aggression(in)^F</i>	-0.19	0.74	0.58
<i>Substrate diversity^S</i>	0.23	0.59	0.40
<i>Carrying food away(in)^F</i>	0.03	0.58	0.34
<i>Invite grooming(in)^F</i>	0.14	0.58	0.35
<i>Grooming(rec)^F</i>	0.25	0.54	0.35
Explained variability	27%	24%	

Table S12. Varimax rotated solution of PCA: 7-hour model

Behavioural index	Component		Communalities
	PC1	PC2	
<i>Activity diversity^S</i>	0.87	0.22	0.80
<i>Grooming(in)^F</i>	0.87	0.22	0.80
<i>Passive affiliation^P</i>	-0.80	0.21	0.69
<i>Terminate grooming^F</i>	0.79	0.33	0.73
<i>Threats(in)^F</i>	0.77	-0.01	0.59
<i>Exploration^F</i>	0.73	0.09	0.54
<i>Invite grooming(rec)^F</i>	0.64	0.28	0.48
<i>Grimace^F</i>	0.61	-0.06	0.38
<i>Resting^P</i>	-0.49	-0.44	0.44
<i>Vigilance^F</i>	0.49	-0.42	0.42
<i>Object sniffing^F</i>	0.48	-0.25	0.29
<i>Self-grooming^F</i>	0.43	-0.18	0.22
<i>Scent marking^F</i>	0.36	0.12	0.14
<i>Monitoring^P</i>	0.18	-0.08	0.04
<i>Departures(in)^F</i>	-0.28	0.89	0.88
<i>Scratching^F</i>	-0.20	-0.83	0.74
<i>Approaches(in)^F</i>	-0.21	0.81	0.70
<i>Contact aggression(in)^F</i>	-0.19	0.79	0.66
<i>Affiliation^P</i>	-0.09	0.78	0.62
<i>Substrate diversity^S</i>	0.24	0.60	0.42
<i>Invite grooming(in)^F</i>	0.17	0.58	0.36
<i>Carrying food away(in)^F</i>	0.03	0.53	0.29
<i>Grooming(rec)^F</i>	0.33	0.47	0.33

Explained variability	27%	23%
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Table S13. Varimax rotated solution of PCA: 6-hour model

Behavioural index	Component		Communalities
	PC1	PC2	
<i>Grooming(in)^F</i>	0.88	0.01	0.78
<i>Passive affiliation^P</i>	-0.88	0.14	0.79
<i>Activity diversity^S</i>	0.85	0.19	0.76
<i>Terminate grooming^F</i>	0.83	0.10	0.70
<i>Threats(in)^F</i>	0.80	-0.02	0.64
<i>Invite grooming(rec)^F</i>	0.68	0.22	0.51
<i>Exploration^F</i>	0.65	-0.08	0.43
<i>Grimace^F</i>	0.61	-0.11	0.38
<i>Grooming(rec)^F</i>	0.52	0.40	0.44
<i>Object sniffing^F</i>	0.50	-0.33	0.36
<i>Self-grooming^F</i>	0.49	-0.19	0.27
<i>Resting^P</i>	-0.48	-0.44	0.42
<i>Scent marking^F</i>	0.28	0.03	0.08
<i>Departures(in)^F</i>	-0.25	0.87	0.82
<i>Scratching^F</i>	-0.19	-0.83	0.72
<i>Affiliation^P</i>	0.04	0.80	0.65
<i>Approaches(in)^F</i>	-0.20	0.79	0.67
<i>Contact aggression(in)^F</i>	-0.19	0.78	0.64
<i>Substrate diversity^S</i>	0.14	0.67	0.47
<i>Carrying food away(in)^F</i>	0.10	0.55	0.32
<i>Invite grooming(in)^F</i>	0.32	0.44	0.29
<i>Vigilance^F</i>	0.35	-0.40	0.29
<i>Monitoring^P</i>	0.19	-0.21	0.08
Explained variability	28%	22%	

Table S14. Varimax rotated solution of PCA: 5-hour model

Behavioural index	Component		Communalities
	PC1	PC2	
<i>Grooming(in)^F</i>	0.87	-0.10	0.77
<i>Terminate grooming^F</i>	0.85	-0.03	0.73
<i>Passive affiliation^P</i>	-0.84	0.26	0.77

<i>Activity diversity</i> ^S	0.81	0.20	0.70
<i>Invite grooming(rec)</i> ^F	0.72	0.13	0.53
<i>Threats(in)</i> ^F	0.67	0.09	0.46
<i>Grooming(rec)</i> ^F	0.65	0.20	0.46
<i>Self-grooming</i> ^F	0.55	-0.11	0.32
<i>Grimace</i> ^F	0.53	-0.06	0.28
<i>Object sniffing</i> ^F	0.52	-0.38	0.42
<i>Invite grooming(in)</i> ^F	0.51	0.23	0.31
<i>Exploration</i> ^F	0.45	0.00	0.20
<i>Scent marking</i> ^F	0.33	-0.01	0.11
<i>Departures(in)</i> ^F	-0.21	0.89	0.84
<i>Approaches(in)</i> ^F	-0.17	0.84	0.73
<i>Scratching</i> ^F	-0.29	-0.79	0.71
<i>Contact aggression(in)</i> ^F	-0.19	0.78	0.64
<i>Affiliation</i> ^P	0.14	0.72	0.54
<i>Substrate diversity</i> ^S	0.21	0.67	0.50
<i>Carrying food away(in)</i> ^F	0.17	0.56	0.34
<i>Resting</i> ^P	-0.41	-0.54	0.46
<i>Vigilance</i> ^F	0.05	-0.35	0.13
<i>Monitoring</i> ^P	0.10	-0.33	0.12
Explained variability	27%	21%	

Table S15. Varimax rotated solution of PCA: 4-hour model

Behavioural index	Component		Communalities
	PC1	PC2	
<i>Grooming(in)</i> ^F	0.87	-0.01	0.75
<i>Terminate grooming</i> ^F	0.85	0.04	0.72
<i>Invite grooming(rec)</i> ^F	0.81	0.05	0.66
<i>Passive affiliation</i> ^P	-0.81	0.17	0.68
<i>Grooming(rec)</i> ^F	0.74	0.08	0.56
<i>Activity diversity</i> ^S	0.67	0.37	0.59
<i>Object sniffing</i> ^F	0.64	-0.34	0.53
<i>Grimace</i> ^F	0.58	0.06	0.34
<i>Threats(in)</i> ^F	0.57	0.25	0.39
<i>Invite grooming(in)</i> ^F	0.54	0.05	0.30
<i>Self-grooming</i> ^F	0.45	-0.09	0.21
<i>Scent marking</i> ^F	0.40	0.01	0.16

<i>Exploration</i> ^F	0.29	0.21	0.13
<i>Departures(in)</i> ^F	-0.29	0.85	0.80
<i>Approaches(in)</i> ^F	-0.26	0.82	0.74
<i>Scratching</i> ^F	-0.22	-0.80	0.68
<i>Contact aggression(in)</i> ^F	-0.28	0.79	0.70
<i>Substrate diversity</i> ^S	0.10	0.72	0.53
<i>Affiliation</i> ^P	0.13	0.63	0.41
<i>Resting</i> ^P	-0.30	-0.61	0.47
<i>Carrying food away(in)</i> ^F	0.16	0.55	0.33
<i>Monitoring</i> ^P	0.10	-0.35	0.14
<i>Vigilance</i> ^F	-0.09	-0.26	0.08
Explained variability	26%	21%	

Table S16. Varimax rotated solution of PCA: 3-hour model

Behavioural index	Component		Communalities
	PC1	PC2	
<i>Terminate grooming</i> ^F	0.89	-0.11	0.80
<i>Grooming(in)</i> ^F	0.87	-0.15	0.79
<i>Grooming(rec)</i> ^F	0.81	-0.11	0.67
<i>Invite grooming(rec)</i> ^F	0.78	-0.08	0.61
<i>Passive affiliation</i> ^P	-0.75	0.27	0.63
<i>Threats(in)</i> ^F	0.68	0.00	0.47
<i>Activity diversity</i> ^S	0.56	0.35	0.44
<i>Invite grooming(in)</i> ^F	0.55	-0.13	0.32
<i>Grimace</i> ^F	0.49	0.22	0.29
<i>Vigilance</i> ^F	-0.32	-0.11	0.12
<i>Scent marking</i> ^F	0.19	0.03	0.04
<i>Departures(in)</i> ^F	-0.18	0.87	0.79
<i>Approaches(in)</i> ^F	-0.14	0.82	0.70
<i>Scratching</i> ^F	-0.42	-0.78	0.79
<i>Contact aggression(in)</i> ^F	-0.10	0.72	0.53
<i>Substrate diversity</i> ^S	0.08	0.66	0.45
<i>Resting</i> ^P	-0.21	-0.60	0.40
<i>Carrying food away(in)</i> ^F	0.22	0.58	0.39
<i>Affiliation</i> ^P	0.39	0.57	0.49
<i>Object sniffing</i> ^F	0.35	-0.50	0.37
<i>Self-grooming</i> ^F	0.17	-0.37	0.17

<i>Monitoring</i> ^P	0.15	-0.33	0.13
<i>Exploration</i> ^F	0.00	0.22	0.05
Explained variability	24%	21%	

Table S17. Varimax rotated solution of PCA: 2-hour model

Behavioural index	Component		Communalities
	PC1	PC2	
<i>Terminate grooming</i> ^F	0.88	-0.15	0.80
<i>Grooming(in)</i> ^F	0.88	-0.22	0.82
<i>Invite grooming(rec)</i> ^F	0.83	0.12	0.71
<i>Grooming(rec)</i> ^F	0.80	0.09	0.64
<i>Passive affiliation</i> ^P	-0.65	0.39	0.57
<i>Invite grooming(in)</i> ^F	0.64	0.08	0.41
<i>Threats(in)</i> ^F	0.63	0.00	0.40
<i>Activity diversity</i> ^S	0.51	0.34	0.37
<i>Object sniffing</i> ^F	0.34	-0.30	0.21
<i>Grimace</i> ^F	0.33	0.12	0.12
<i>Scent marking</i> ^F	0.29	0.06	0.09
<i>Self-grooming</i> ^F	0.22	-0.22	0.10
<i>Departures(in)</i> ^F	-0.33	0.85	0.83
<i>Scratching</i> ^F	-0.29	-0.84	0.80
<i>Approaches(in)</i> ^F	-0.29	0.75	0.64
<i>Contact aggression(in)</i> ^F	-0.10	0.73	0.54
<i>Substrate diversity</i> ^S	0.15	0.59	0.37
<i>Affiliation</i> ^P	0.35	0.58	0.46
<i>Resting</i> ^P	-0.16	-0.55	0.33
<i>Carrying food away(in)</i> ^F	0.18	0.43	0.22
<i>Monitoring</i> ^P	0.26	-0.29	0.15
<i>Vigilance</i> ^F	-0.21	-0.26	0.11
<i>Exploration</i> ^F	-0.07	0.21	0.05
Explained variability	23%	19%	

Table S18. Varimax rotated solution of PCA: 1-hour model

Behavioural index	Component	
	PC1	Communalities
<i>Grooming(in)</i> ^F	0.77	0.60

<i>Terminate grooming</i> ^F	0.73	0.54
<i>Departures(in)</i> ^F	-0.72	0.52
<i>Scratching</i> ^F	0.65	0.42
<i>Approaches(in)</i> ^F	-0.62	0.39
<i>Contact aggression(in)</i> ^F	-0.59	0.35
<i>Monitoring</i> ^P	0.59	0.35
<i>Substrate diversity</i> ^S	-0.58	0.34
<i>Object sniffing</i> ^F	0.53	0.29
<i>Passive affiliation</i> ^P	-0.51	0.26
<i>Resting</i> ^P	0.51	0.26
<i>Exploration</i> ^F	-0.44	0.20
<i>Scent marking</i> ^F	0.42	0.18
<i>Grooming(rec)</i> ^F	0.42	0.18
<i>Invite grooming(in)</i> ^F	0.36	0.13
<i>Invite grooming(rec)</i> ^F	0.31	0.10
<i>Carrying food away(in)</i> ^F	-0.28	0.08
<i>Threats(in)</i> ^F	0.26	0.07
<i>Affiliation</i> ^P	-0.23	0.05
<i>Self-grooming</i> ^F	0.21	0.04
<i>Activity diversity</i> ^S	-0.19	0.04
<i>Vigilance</i> ^F	0.01	0.00
<i>Grimace</i> ^F	0.00	0.00
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Explained variability	23%	
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Table S19. Comparison of cotton-top tamarin behaviour-based Extraversion with common marmoset questionnaire-based dimensions

Cotton-top tamarin		Common marmoset (Koski et al., 2017)		Common marmoset (Iwanicki and Lehmann, 2015)	
Index	Formula	Adjective	Definition	Adjective	Definition
Extraversion		Inquisitiveness		Openness	
(-)Resting ^P	(rest + look + watch + sit + lie) / (move + jump + cling + hang)	(-)Lazy	“Monkey has inexpressive reactions, is inactive and slow.”	Active	“Spends considerable time moving around or engaging in some energetic behaviour”
Activity diversity ^S	Shannon diversity index of activity types	Active	“Monkey seeks physical activity, and is fast and agile.”		
Exploration ^F	(exploration + object manipulation + search)/hour	Exploratory	“Monkey is seeking new objects in its environment and seems eager to learn about them as much as possible.”	Curious	“Readily explores new situations, seeking out or investigating novel situations”
Object sniffing ^F	object sniffing/hour				
(-)Passive affiliation ^P	(contact + proximity)/[contact + proximity + social play + groom(in) + groom(rec)]	(-)Solitary	“Monkey prefers to spend considerable time alone not seeking or even directly avoiding contact with others		
Grooming(in) ^F	groom(in)/hour				
Monitoring ^P	watch/sample	Alert	“Monkey pays attention to other monkeys’ behavior and its environment. Monkey does not seem to be tense; it is keeping an eye on the general situation.”		
Vigilance ^F	alert/hour			Vigilant	“Attentive, watchful, notices with special attention; not oblivious to surroundings”
				Extraversion	
Threats(in) ^F	(facial threat + open mouth display + headshake + body display + tongue flick)/hour			Dominant	“Able to displace, threaten, or take food from other animals”

Note. (-) negative loading on component

Table S20. Comparison of cotton-top tamarin behaviour-based Confidence with common marmoset questionnaire-based dimensions

Cotton-top tamarin		Common marmoset (Koski et al., 2017)		Common marmoset (Iwanicki and Lehmann, 2015)	
Index	Formula	Adjective	Definition	Adjective	Definition
Confidence		Assertiveness		Extraversion	
Contact aggression(in) ^F	(general aggression + bit + beat + grab + grasp + chase + fight + face + push + displace)/hour	Dominant	“Monkey easily gets its own way, is able to control others and decisively intervenes in social interactions.”	(-)Submissive	“Gives in readily to others”
		(-)Vulnerable	“Monkey is prone to be physically or emotionally hurt as a result of aggression or assertive behavior by another individual.”	Effective	“Gets own way; can control others”
		(-)Sympathetic	“Monkey seems to be considerate and kind towards others as if sharing their feelings or trying to provide reassurance.”	Bold	“Daring and fearless, not restrained or tentative. Not timid, shy, or coy.”
Substrate diversity ^S	Shannon diversity index of substrate types	(-)Cautious	“Monkey avoids risky behaviors and situations.”	(-)Cautious	“Exhibits a careful, measured approach to investigations; avoids risky behaviors”
		(-)Timid	“Monkey lacks self-confidence, is easily alarmed and is hesitant to venture into new social or non-social situations.”		
(-)Scratching ^F	scratch/hour	(-)Anxious	“Monkey often seems distressed, troubled, or in a state of uncertainty.”		
Carrying food away(in) ^F	carry food away(in)/hour	Selective	“Monkey tries to select the best food or place if having chance to do so, seems picky.”	Stingy	“Excessively covetous of favored resources(food, etc.); unwilling to share”
Affiliation ^P	[contact + proximity + social play + groom(in) + groom(rec)]/hour	Agreeableness		(-)Solitary	“Prefers to spend considerable time alone; avoids contact with other animals”
Invite grooming(in) ^F	groom invite(in)/hour	Sociable	“Monkey seeks, enjoys and keeps the company of other monkeys.”	Confident	“Behaves in a positive, assured manner; not restrained or tentative”
Approaches(in) ^F	approach(in)/hour	Affectionate	“Monkey has a warm attachment or closeness with others. Monkey’s behavior expresses the positive relationship to others.”		

Confidence	Agreeableness	Extraversion
Grooming(rec) ^F groom(rec)/hour	Popular “Monkey is often sought out as a companion by others”	(-)Depressed “Often appears isolated, withdrawn, has reduced activity; socially unresponsive”

Note. (-) negative loading on component