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1 ***Knowledge-sharing networks in hunter-gatherers and the***  
2 ***evolution of cumulative culture***

3

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## 18 **Summary**

19 Humans possess the unique ability for cumulative culture [1, 2]. It has been argued  
20 that hunter-gatherer's complex social structure [3–9] has facilitated the evolution of  
21 cumulative culture by allowing information exchange among large pools of individuals [10–  
22 13]. However, empirical evidence for the interaction between social structure and cultural  
23 transmission is scant [14]. Here we examine the reported co-occurrence of plant uses  
24 between individuals in dyads (which we define as their 'shared knowledge' of plant uses) in  
25 BaYaka Pygmies from Congo. We studied reported uses of 33 plants of 219 individuals from  
26 four camps. We show that 1) plant uses by BaYaka fall into three main domains: medicinal,  
27 foraging, and social norms/beliefs; 2) most medicinal plants have known bioactive  
28 properties and some are positively associated with children's BMI, suggesting that their use  
29 is adaptive; 3) knowledge of medicinal plants is mainly shared between spouses, biological  
30 and affinal kin; and 4) knowledge of plant uses associated with foraging and social norms is  
31 shared more widely among campmates, regardless of relatedness, and is important for  
32 camp-wide activities that require cooperation. Our results show the interdependence  
33 between social structure and knowledge sharing. We propose that long-term pair bonds,  
34 affinal kin recognition, exogamy and multi-locality create ties between unrelated families,  
35 facilitating the transmission of medicinal knowledge and its fitness implications.  
36 Additionally, multi-family camps with low inter-relatedness between camp members  
37 provide a framework for the exchange of functional information related to cooperative  
38 activities beyond the family unit, such as foraging and regulation of social life.

## 39 **Results**

40           Studies of cultural evolution have mainly focused on mechanisms such as fidelity,  
41 combination, innovation and modification [15], and rarely investigate how the content and  
42 function of cultural information affects knowledge-sharing mechanisms [16, 17]. Since  
43 human cumulative culture is diversified into functional domains [16–19], it may also  
44 require corresponding differentiation of knowledge-sharing mechanisms and underlying  
45 social structure [20]. Here we analyse the reported uses of 33 plants among the Mbendjele  
46 BaYaka pygmies from the Republic of Congo. We explored the effects of family and camp  
47 ties on the reported co-occurrence of plant use in dyads, which we define as the ‘shared  
48 knowledge’ between two individuals.

### 49 ***Uses of plants by BaYaka Pygmies.***

50           Our interviews showed that some plants were used mostly for medicinal purposes,  
51 and others for foraging or social beliefs and norms. Most reported medicinal uses were for  
52 treating digestive (35%) and respiratory disorders (25%; Table 1). The BaYaka use some  
53 plants for collecting caterpillars or honey, and as a poison for killing monkeys or fish; these  
54 were classified as foraging uses. Others were used to regulate social life and were classified  
55 as social norms and beliefs. For example, some plants are believed to be selectively  
56 poisonous to liars, while others are involved in sexual taboos (Supplemental Experimental  
57 Procedures, section S1; Table S1).

### 58 ***Medicinal properties of plants***

59           Use of similar medicinal plants across cultures would suggest that they have  
60 adaptive benefits and real medicinal properties [21–23]. Medicinal plants have already been  
61 shown to improve health in other traditional populations with limited access to modern

62 medicine [24]. Out of 33 plants cited by the BaYaka in our interviews, we successfully  
63 identified 31 species. Of these, 15 are also used by Baka Pygmies from Cameroon and Gabon  
64 [25, 26]. We found a positive correlation between the number of times each of the 15 plants  
65 was reported to be used for medicinal purposes by the BaYaka and Baka (Figure 1,  $n= 15$ ,  
66  $\beta= 0.81$ ,  $P< 0.01$ ). Moreover, 26 species in our sample are also used as medicine by at least  
67 one other Central African Pygmy population, including the Mbuti and Efe from Democratic  
68 Republic of Congo, the Aka from Central African Republic, and the Baka from Cameroon and  
69 Gabon [25–27]. Eight species are known to be used as medicine by gorillas [28–30]; and six  
70 by chimpanzees [29, 31, 32] (Table S1). Finally, 24 plants (77%) have known bioactive  
71 properties (Table S1). These findings indicate that medicinal plant knowledge by the  
72 BaYaka is likely to be adaptive.

### 73 ***Maternal knowledge of medicinal plants affects children's body mass index*** 74 ***(BMI)***

75 To examine potential health effects of medicinal plant uses, we investigated the 14 most  
76 frequently used medicinal species among BaYaka mothers of children aged 0-5 years. Seven  
77 plants were used primarily for treating respiratory diseases, and the other seven for  
78 digestive system disorders. We found that mothers with higher plant use scores (calculated  
79 as the number of plants used for medicinal purposes by each mother out of the seven  
80 possible plants) for treating respiratory system disorders had children with significantly  
81 higher BMI (Table 2). However, there was no effect of plant scores for digestive disorders  
82 on children's BMI (Table 2). These results indicate that certain medicinal plant uses may  
83 provide fitness benefits.

84

85 ***Medicinal plant knowledge is shared within families***

86 Mixed effect models revealed that dyads represented by biological or affinal kin ties  
87 had increased odds of reporting the same medicinal plant use (Figures 2A and S1A). A 0.25  
88 increase in the coefficient of relatedness within a dyad increased the odds of reported co-  
89 occurrence of medicinal plant use by 22% (Odds ratio (OR)= 1.22, 95% CI= 1.17, 1.27; Risk  
90 ratio (RR)= 1.19; Risk difference (RD)= 3%; Table S2). Breaking down the effects of kinship,  
91 dyads including mother and offspring had an increase of 57% in the odds of co-occurrence  
92 of medicinal plant use (OR= 1.57, 95% CI= 1.33, 1.84; RR= 1.46; RD= 6%; Figure S1A; Table  
93 S2). The effect was much smaller (28%), but still significant for father and offspring (OR=  
94 1.28, 95% CI= 1.04, 1.56; RR= 1.23, RD= 3%). Being siblings increased the odds by 40%  
95 (OR= 1.40, 95% CI= 1.18, 1.65; RR= 1.33; RD= 5%).

96 Affinal ties were also important in explaining co-occurrence of medicinal plant uses  
97 (Figure 2A, Table S2). The odds of co-occurrence of medicinal plant use increased by 61%  
98 between spouses (OR= 1.61, 95% CI= 1.32, 1.96; RR= 1.49; RD= 7%). Even distant affinal  
99 kin were more likely to report similar medicinal uses of plants (Figure 2A). The odds of co-  
100 occurrence of medicinal plant use increased by 41% (OR= 1.41, 95% CI= 1.26, 1.58; RR=  
101 1.34; RD= 6%) between an individual and their spouse's primary kin, and 24% (OR= 1.24,  
102 95% CI= 1.17, 1.31; RR= 1.20; RD= 3%) between an individual and their spouse's distant  
103 kin. We also observed spouses collecting medicinal plants and preparing medicines together  
104 (Supplemental Movie 1).

105 Unlike the large effect of family ties, camp ties (when the two individuals in the dyad  
106 reside in the same camp) increased odds of co-occurrence of medicinal plant use by only  
107 6% (Figure 2A; OR= 1.06, 95% CI= 1.04, 1.08; RR= 1.05; RD= 1%; Table S2). Dyads where  
108 individuals belonged to the same age group had increased odds of reporting the same

109 medicinal plant use by 36% (Figure 2A; OR= 1.36, 95% CI= 1.33, 1.39; RR= 1.30; RD= 4%;  
110 Table S2). Female-female dyads had increased odds of co-occurrence of medicinal plant use  
111 compared to female-male dyads, but the effect size (7%) was small (Figure 2A; OR= 1.07,  
112 95% CI= 1.05, 1.09; RR= 1.06; RD= 1%; Table S2).

113 ***Plant knowledge related to cooperative foraging and social beliefs is shared***  
114 ***among campmates***

115 Unlike medicinal plant knowledge, plant uses related to foraging and social  
116 norms/beliefs co-occurred more frequently among camp members, regardless of family ties  
117 (Figures 2B and S1B). Kin and non-kin effects on odds of reporting similar plant uses were  
118 similar in the two categories (Tables S3-4), which were therefore merged. Being from the  
119 same camp increased the odds of co-occurrence of plant use in foraging and social norms  
120 and beliefs by 84% (Figure 2B; OR= 1.84, 95% CI= 1.72, 1.97; RR= 1.83; RD= 0.3%; Table  
121 S3). In contrast, neither relatedness (Figure 2B; OR= 0.91, 95% CI= 0.78, 1.06; RR= 0.92;  
122 RD= 0%; Table S3) nor spousal ties had an effect on odds (Figure 2B, OR, RR= 0.82; RD=  
123 0.1%; Table S3). The odds of co-occurrence of plant use decreased by 26% between a  
124 person and his/her spouse's distant kin (OR, RR= 0.78, 95% CI= 0.64, 0.96; RD= 0.1%).  
125 Similarity in age group (OR, RR= 1.51; RD= 0.02%) and sex (for male-male dyads: OR= 1.13;  
126 RR= 1.12, RD= 0.01%; for female-female dyads: OR= 0.91; RR=0.92; RD= 0%) had  
127 significant effects, but the effect sizes for sex were small (Figure 2B and Table S3). Patterns  
128 of co-occurrence of plant use are similar for foraging and social norms and beliefs, as they  
129 both refer to camp wide activities. As an example, we observed multi-family groups fishing  
130 with plant poison (Supplemental Movie 2).

131 **Discussion**

132 Our results showed that family ties have a significant effect on variation in medicinal  
133 plant uses among BaYaka hunter-gatherers, while camp co-residence has the strongest  
134 effect on variation in plant knowledge related to foraging and social norms and beliefs. We  
135 suggest that this pattern is a consequence of two unique aspects of human social structure:  
136 pair-bonding with affinal kin recognition, and co-residence with unrelated individuals in  
137 camps. Joint-production of medicine by parents (Supplemental Movie 1) is consistent with  
138 the frequent co-occurrence of medicinal plant uses between spouses. Information exchange  
139 between families is also likely to be valuable since mothers with higher medicinal plant use  
140 scores had healthier children. We also observed grandmothers (maternal and paternal)  
141 preparing medicines, which creates additional opportunity for transmission of medicinal  
142 knowledge to grandchildren exposed to treatment.

143 We also show that co-residence of unrelated families in camps is associated with  
144 camp-specific plant uses in the domains of foraging and social norms and beliefs.  
145 Differences in foraging uses may reflect distinct levels of foraging activities in each camp  
146 [33, 34]. For example, people from the Minganga region (where camps one and two were  
147 located) are known as “children of the flowers” because they are known to be forest-  
148 oriented and good honey collectors [33]. Social norms and beliefs on the other hand help to  
149 regulate camp-wide processes, such as social conflict resolution, punishment of cheaters,  
150 and coordination of cooperation through rituals (Table 1). Camp-dependence on social  
151 norms and beliefs regardless of family ties (Figure 2B) may favour cultural drift in plant  
152 knowledge, exemplified by the distinct ritualistic ‘forest spirit’ dances across Pygmy groups  
153 [35]. A second example is that only people from the Ibamba camp are known as “people  
154 who can fly” due to their particularly rich rituals [33].



155 Overall, our results suggest that variation in plant knowledge across families and  
156 camps cannot be explained purely by ecological variation. If similar plant uses were a result  
157 of local variation in plant availability, camp co-residence would have an equal effect on the  
158 distribution of all types of plant knowledge. However, residing at the same camp had a very  
159 small effect on similarities in medicinal plant use. We propose instead that a multi-layered  
160 social structure provides underlying channels for cultural transmission and diversification  
161 of plant knowledge among the BaYaka. This is suggested by the correlations we found  
162 between social structure (family ties and camp ties) and plant uses. Attempts to detect  
163 patterns and direction of cultural transmission by asking people from whom they learned  
164 particular information (the 'retrospective method') are known to be problematic, as they  
165 are affected by memory biases and social norms [19, 36]. For this reason, assessing  
166 similarity of cultural knowledge among individuals is seen as a better way of mapping  
167 pathways of cultural transmission [18, 37]. By mapping dyadic correlations (or co-  
168 occurrence) in plant uses between individuals onto the underlying social structure, we  
169 could reveal the roles of biological kin, marriage and camp ties on the diversification of  
170 plant knowledge.

171 Social interactions create the conditions for cultural transmission through various  
172 modes of social learning [38]. Among the BaYaka, social learning predominantly happens  
173 through observation and imitation (a young woman observing her mother preparing a  
174 medicine), through being a recipient of actions relying on cultural knowledge (a child being  
175 treated with a particular medicine by parents), or through sharing experiences (co-  
176 participation in rituals). Active teaching is also present, although learning through  
177 observation, participation and practice is more common among African Pygmies [38, 39]. In  
178 this context, it must be noted that social learning and cultural transmission are not

179 exclusively human traits. Some African apes also use medicinal plants for similar diseases to  
180 humans, and may acquire plant knowledge through observation and imitation of other  
181 individuals [28, 29], as well as through asocial learning. The fact that eight plants are  
182 medicinally used by gorillas [28–30] and six by chimpanzees [29, 31, 32] makes it unlikely  
183 that learning happens solely through trial-and-error in those species. However, their  
184 medicinal plant uses are not comparable to the vast diversity of plants used by the BaYaka  
185 and other human populations. The close match between hunter-gatherer multi-level social  
186 structure and diversification of medicinal plant knowledge indicates that the complex  
187 structure of pair bonding, affinal kin recognition, and co-residence of multiple nuclear  
188 families created an environment for cultural transmission as well as knowledge  
189 specialisation and innovation exclusive to humans. In addition, co-residence of multiple  
190 families allows for the transmission and accumulation of plant knowledge related to group-  
191 wide activities such as foraging and rituals, which enhance group coordination. All these  
192 factors may have contributed to the adaptive differentiation of cultural domains and the  
193 diversity of human cumulative culture.

## 194 ***Experimental Procedures***

195 All experiments and procedures were approved by the UCL Ethics Committee  
196 (UCLEthicscode3086/003).

197 **Study population.** Mbendjele BaYaka hunter-gatherers are a subgroup of the BaYaka  
198 Pygmies whose residence spans across the rainforests of the Republic of Congo and Central  
199 African Republic. The BaYaka live in multi-family camps consisting of a number of huts in  
200 which nuclear families reside. Social ties among camp members affect food sharing patterns  
201 [40] and individuals' fitness [41, 42].

202 We visited four BaYaka camps in the Republic of Congo; three in the forest (Longa: n  
203 = 59, Masia: n = 22, Ibamba: n= 31), and one in a logging town (Sembola: n = 107;  
204 Supplemental Experimental Procedures, section S2).

205 **Measuring plant knowledge and use.** 15 adult informants (10 men, 5 women)  
206 were asked to list the names of plants they used for any purpose. We then chose a subset of  
207 33 plants that are used by the population and asked another 219 individuals (118 women,  
208 101 men) across four campsites whether they knew each of the 33 species, and if so,  
209 whether they used it for any purpose (Supplemental Experimental Procedures, section S1).  
210 Later, we classified plant uses into four categories: medicinal, social norms and beliefs,  
211 foraging, and other. Each category had sub-categories (Table 1). We used the Economic  
212 Botany Data Standard for sub-categories of medicinal uses [43].

213 **Dyadic sample.** From 219 individuals we obtained 23,871 dyads. Each dyad had  
214 responses for uses of 33 plants, resulting in possible 787,743 data points. In 151,038 data  
215 points (19%) neither individual used a given plant and these points were omitted, resulting  
216 in a sample of 636,705 data points and 23,868 dyads.

217 **Measuring co-occurrence of plant use ('shared knowledge').** For each dyad, if  
218 individual A and individual B reported the same use for a given plant, their dyadic response  
219 was coded as 1 ('shared knowledge'). For all other cases (when individuals reported  
220 different uses, or one of them did not report any uses), the dyadic response was coded as 0.  
221 When multiple uses were reported by the same individual, we only included the first use  
222 (which occurred in only 2% of the responses).

223 **Statistical analysis.** Because we had 33 responses for each dyad, we used mixed  
224 effects logistic regression to predict the reported co-occurrence of plant use in a dyad. Our

225 fixed predictors were biological kin ties (measured first as coefficient of relatedness, and  
226 subsequently as presence of a specific biological kin tie, e.g. mother-offspring; we analysed  
227 and described models based on each measure separately), affinal kin ties, camp ties  
228 (residing in the same camp), age group and sex. We used dyad id as a random effect. We  
229 performed separate analyses for three categories of plant use (medicinal, foraging, and  
230 social norms and beliefs).

231 **Maternal medicinal plant use and child BMI.** We calculated z-scores of BMI (body  
232 mass index) using 1-year intervals for children aged 0 to 5 to compare their health status.  
233 Plant use scores were calculated by summing the number of plants used by a mother, out of  
234 the seven most commonly used plants for treating respiratory or digestive system  
235 disorders. We used linear mixed-effects models for testing the effect of plant use score of  
236 each mother on offspring BMI (response variable), controlling for mother's age, camp  
237 residence, id (as there were 33 mothers and 42 children, random effect), and sex of the  
238 child (Table 2).

### 239 **Author contributions**

240 A.B.M. conceived the project; G.D.S designed the research and collected the data;  
241 G.D.S, A.B.M., R.M., N.C., J.T., M.D., A.P, D.S helped with protocol design and data collection;  
242 O.M.G and X.M.B identified the plant species and helped with the plant literature research;  
243 G.D.S. analysed the data with several contributions of A.B.M and L.V; J.L. assisted in  
244 fieldwork; G.D.S., A.B.M and L.V. wrote the manuscript with the help of all other authors.

245

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255 **References**

256

- 257 1. Tomasello, M., Kruger, A. C., and Ratner, H. H. (1993). Cultural learning. *Behav. Brain*  
258 *Sci.* 16, 495–552.
- 259 2. Dean, L. G., Vale, G. L., Laland, K. N., Flynn, E., and Kendal, R. L. (2014). Human  
260 cumulative culture: A comparative perspective. *Biol. Rev.* 89, 284–301.
- 261 3. Hill, K. R., Walker, R. S., Bozicević, M., Eder, J., Headland, T., Hewlett, B. S., Hurtado, a  
262 M., Marlowe, F., Wiessner, P., and Wood, B. (2011). Co-residence patterns in hunter-  
263 gatherer societies show unique human social structure. *Science* 331, 1286–89.
- 264 4. Dyble, M., Salali, G. D., Chaudhary, N., Page, A., Smith, D., Thompson, J., Vinicius, L.,  
265 Mace, R., and Migliano, A. B. (2015). Sex equality can explain the unique social  
266 structure of hunter-gatherer bands. *Science* 348, 796–798.

- 267 5. Chapais, B. (2013). Monogamy, strongly bonded groups, and the evolution of human  
268 social structure. *Evol. Anthropol.* 22, 52–65.
- 269 6. Chapais, B. (2008). *Primeval kinship: how pair-bonding gave birth to human society*  
270 (Cambridge, MA: Harvard University Press).
- 271 7. Foley, R., and Gamble, C. (2009). The ecology of social transitions in human evolution.  
272 *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* 364, 3267–3279.
- 273 8. Hamilton, M. J., Milne, B. T., Walker, R. S., Burger, O., and Brown, J. H. (2007). The  
274 complex structure of hunter-gatherer social networks. *Proc. Biol. Sci.* 274, 2195–202.
- 275 9. Marlowe, F. (2004). Marital residence among foragers. *Curr. Anthropol.* 45, 277–284.
- 276 10. Hill, K. R., Wood, B. M., Baggio, J., Hurtado, A. M., and Boyd, R. T. (2014). Hunter-  
277 gatherer inter-band interaction rates: implications for cumulative culture. *PLoS One*  
278 9, e102806.
- 279 11. Powell, A., Shennan, S., and Thomas, M. G. (2009). Late Pleistocene demography and  
280 the appearance of modern human behavior. *Science* 324, 1298–301.
- 281 12. Henrich, J. (2004). Demography and cultural evolution: how adaptive cultural  
282 processes can produce maladaptive losses: the Tasmanian case. *Am. Antiq.* 69, 197–  
283 214.
- 284 13. Derex, M., and Boyd, R. (2015). The foundations of the human cultural niche. *Nat.*  
285 *Commun.* 6, 1–7.
- 286 14. Derex, M., and Boyd, R. (2016). Partial connectivity increases cultural accumulation

- 287 within groups. *Proc. Natl. Acad. Sci.* *113*, 2982–2987.
- 288 15. Lewis, H. M., and Laland, K. N. (2012). Transmission fidelity is the key to the build-up  
289 of cumulative culture. *Philos. Trans. R. Soc. B Biol. Sci.* *367*, 2171–2180.
- 290 16. Mesoudi, A., Whiten, A., and Dunbar, R. I. M. (2006). A bias for social information in  
291 human cultural transmission. *Br. J. Psychol.* *97*, 405–23.
- 292 17. Reyes-García, V., Luz, A. C., Gueze, M., Paneque-Gálvez, J., Macía, M. J., Orta-martínez,  
293 M., Pino, J., and Team, T. B. S. (2013). Secular trends on traditional ecological  
294 knowledge: An analysis of changes in different domains of knowledge among  
295 Tsimané men. *Learn. Individ. Differ.* *34*, 206–212.
- 296 18. Reyes-García, V., Broesch, J., Calvet-Mir, L., Fuentes-Peláez, N., McDade, T. W., Parsa,  
297 S., Tanner, S., Huanca, T., Leonard, W. R., and Martínez-Rodríguez, M. R. (2009).  
298 Cultural transmission of ethnobotanical knowledge and skills: an empirical analysis  
299 from an Amerindian society. *Evol. Hum. Behav.* *30*, 274–285.
- 300 19. Henrich, J., and Broesch, J. (2011). On the nature of cultural transmission networks:  
301 evidence from Fijian villages for adaptive learning biases. *Philos. Trans. R. Soc. Lond.*  
302 *B. Biol. Sci.* *366*, 1139–48.
- 303 20. Díaz-Reviriego, I., González-Segura, L., Fernández-Llamazares, Á., Howard, P. L.,  
304 Molina, J. L., and Reyes-García, V. (2016). Social organization influences the exchange  
305 and species richness of medicinal plants in Amazonian homegardens. *Ecol. Soc.* *21*, 1.
- 306 21. Henrich, J., and Henrich, N. (2010). The evolution of cultural adaptations: Fijian food  
307 taboos protect against dangerous marine toxins. *Proc. Biol. Sci.* *277*, 3715–24.

- 308 22. Saslis-Lagoudakis, C. H., Klitgaard, B. B., Forest, F., Francis, L., Savolainen, V.,  
309 Williamson, E. M., and Hawkins, J. A. (2011). The Use of Phylogeny to Interpret Cross-  
310 Cultural Patterns in Plant Use and Guide Medicinal Plant Discovery: An Example from  
311 *Pterocarpus* (Leguminosae). *PLoS One* 6, e22275.
- 312 23. Saslis-Lagoudakis, C. H., Williamson, E. M., Savolainen, V., and Hawkins, J. a. (2011).  
313 Cross-cultural comparison of three medicinal floras and implications for  
314 bioprospecting strategies. *J. Ethnopharmacol.* 135, 476–487.
- 315 24. McDade, T. W., Reyes-García, V., Blackinton, P., Tanner, S., Huanca, T., and Leonard,  
316 W. R. (2007). Ethnobotanical knowledge is associated with indices of child health in  
317 the Bolivian Amazon. *Proc. Natl. Acad. Sci. U. S. A.* 104, 6134–9.
- 318 25. Betti, J. L. (2004). An ethnobotanical study of medicinal plants among the Baka  
319 pygmies in the Dja biosphere reserve, Cameroon. *Afr. Study Monogr.* 25, 1–27.
- 320 26. Betti, J. L., Yongo, O. D., Mbomio, D. O., Iponga, D. M., and Ngoye, A. (2013). An  
321 Ethnobotanical and Floristical Study of Medicinal Plants Among the Baka Pygmies in  
322 the Periphery of the Ipassa- Biosphere Reserve , Gabon. *European J. Med. Plants* 3,  
323 174–205.
- 324 27. AFlora Committee (2013). AFlora: The database of plant utilization in Africa. *Cent.*  
325 *African Area Stud.* Kyoto Univ. Available at: [http://aflora.africa.kyoto-](http://aflora.africa.kyoto-u.ac.jp/records/top)  
326 [u.ac.jp/records/top](http://aflora.africa.kyoto-u.ac.jp/records/top).
- 327 28. Cousins, D., and Huffman, M. A. (2002). Medicinal Properties in the Diet of Gorillas :  
328 an Ethno-Pharmacological Evaluation. *Afr. Study Monogr.* 23, 65–89.



- 329 29. Masi, S., Gustafsson, E., Saint Jalme, M., Narat, V., Todd, A., Bomsel, M. C., and Krief, S.  
330 (2012). Unusual feeding behavior in wild great apes, a window to understand origins  
331 of self-medication in humans: Role of sociality and physiology on learning process.  
332 *Physiol. Behav.* *105*, 337–349.
- 333 30. Huffman, M. A. (1997). Current evidence for self-medication in primates: A  
334 multidisciplinary perspective. *Am. J. Phys. Anthropol.* *104*, 171–200.
- 335 31. Krief, S., Hladik, C. M., and Haxaire, C. (2005). Ethnomedicinal and bioactive  
336 properties of plants ingested by wild chimpanzees in Uganda. *J. Ethnopharmacol.*  
337 *101*, 1–15.
- 338 32. Pebsworth, P., Krief, S., and Huffman, M. A. (2006). The role of diet in self-medication  
339 among chimpanzees in the Sonso and Kanyawara Communities, Uganda. In *Primates*  
340 *of Western Uganda*, N. E. Newton-Fisher, H. Notman, J. D. Paterson, and V. Reynolds,  
341 eds. (New York: Springer), pp. 105–133.
- 342 33. Lewis, J. (2002). PhD Thesis. Forest hunter-gatherers and their world: A Study of the  
343 Mbendjele Yaka Pygmies of Congo-Brazzaville and Their Secular and Religious  
344 Activities and Representations.
- 345 34. Salali, G. D., and Migliano, A. B. (2015). Future Discounting in Congo Basin Hunter-  
346 Gatherers Declines with Socio-Economic Transitions. *PLoS One* *10*, e0137806.
- 347 35. Lewis, J. (2015). Where goods are free but knowledge costs: the economics of ritual  
348 among forest hunter-gatherers in Western Central Africa. *Hunt. Gatherer Res.* *1*, 1–  
349 27.

- 350 36. Mesoudi, A. (2011). *Cultural Evolution* (University of Chicago Press, Chicago).
- 351 37. Aunger, R. (2000). The Life History of Culture Learning in a Face-to-Face Society.  
352 *Ethos* 28, 445–481.
- 353 38. Hewlett, B. S., Fouts, H. N., Boyette, A. H., and Hewlett, B. L. (2011). Social learning  
354 among Congo Basin hunter–gatherers. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* 366,  
355 1168–78.
- 356 39. Hewlett, B. S., and Roulette, C. J. (2016). Teaching in hunter – gatherer infancy. *R. Soc.*  
357 *Open Sci.* 3, 150403.
- 358 40. Dyble, M., Thompson, J., Smith, D., Salali, G. D., Chaudhary, N., Page, A. E., Vinicius, L.,  
359 Mace, R., and Migliano, A. B. (2016). Networks of Food Sharing Reveal the Functional  
360 Significance of Multilevel Sociality in Two Hunter- Gatherer Groups. *Curr. Biol.* 26, 1–  
361 5.
- 362 41. Chaudhary, N., Salali, G. D., Thompson, J., Rey, A., Gerbault, P., Stevenson, E. G. J.,  
363 Dyble, M., E. Page, A., Smith, D., Mace, R., et al. (2016). Competition for Cooperation:  
364 variability, benefits and heritability of relational wealth in hunter-gatherers. *Sci. Rep.*  
365 6, 29120.
- 366 42. Chaudhary, N., Salali, G. D., Thompson, J., Dyble, M., Page, A., Smith, D., Mace, R., and  
367 Migliano, A. B. (2015). Polygyny without wealth: popularity in gift games predicts  
368 polygyny in BaYaka Pygmies. *R. Soc. Open Sci.* 2, 150054.
- 369 43. Cook, F. E. M. (1995). *Economic Botany Data Collection Standard*. Prepared for the  
370 International Working Group on Taxonomic Databases for Plant Sciences (TDWG).

371 (Kew: Royal Botanic Gardens, Kew).

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374 **Figure legends and tables**

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376 **Figure 1. Cross Population Use of Medicinal Plants.** Percentage of Mbendjele BaYaka (n=  
377 219) that used a particular plant as a medicine and the number of times the same plant was  
378 used as a treatment by the Baka Pygmies from Cameroon (n= 37, data from Betti 2004 [23])  
379 and Gabon (n= 6, Betti et al. 2013 [24]). Each dot refers to a plant species (n= 15). The  
380 shaded area corresponds to 95% confidence interval. See also Table S1.

381 **Figure 2. Odds Ratios for the Predictor Variables.** Odds ratios are calculated based on  
382 mixed effects logistic regression models (Tables S2-3, full models). Response variable is  
383 reported co-occurrence of plant use for (a) medicinal purposes or (b) purposes related to  
384 foraging and social beliefs. The dots show the odds of co-occurrence of plant use when  
385 individuals in a dyad belong to the same camp; are genetically related (odds ratio calculated  
386 for a 0.25 increase in coefficient of relatedness); have one of the following affinal kin ties:  
387 spouse, spouse's primary kin, or spouse's distant kin; are females; are males; belong to the  
388 same age group. Error bars show 95% confidence intervals. \*\*\* $P < 0.001$ , \* $P < 0.05$ . See also  
389 Figure S1, Tables S2-4, and Movies S1-2.

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394 Table 1. Uses of plants by Mbendjele BaYaka Pygmies

Category	Sub category	% Percentage in all answers (219 individuals x 33 plants)
<b>Medicinal</b>	digestive	16.60
	respiratory	11.86
	pain and injuries	7.07
	infections	5.77
	wounds	3.27
	genitourinary	1.34
	pregnancy	0.75
	ill defined	0.32
	Skin	0.12
	poisonings	0.06
	circulatory	0.04
	<b>Subtotal medicinal</b>	<b>47.20</b>
	<b>Beliefs</b>	social norms concerning liars
social norms concerning sexual taboos		1.29
luck in finding a partner		0.35
luck in hunting		0.32
luck in fishing		0.32
better sing		0.06
better fight		0.03
for rain		0.03
better share		0.03
better work		0.03
<b>Subtotal beliefs</b>		<b>4.08</b>
<b>Foraging</b>	bee plants	0.73
	fish poison	0.62
	caterpillar tree	0.50
	monkey poison	0.48
	<b>Subtotal foraging</b>	<b>2.34</b>
<b>Other uses</b>	food	3.45
	mat	1.29
	food additives	0.35
	pirogue	0.32
	firewood	0.14
	uncategorised	0.12
	animal food	0.11
	axe	0.11
	hut	0.10
	avoid animal attacks	0.07
	drum	0.07
	basket	0.03

	<b>Subtotal other uses</b>	<b>6.14</b>
<b>Not available</b>		<b>0.10</b>
<b>Plant not used</b>		<b>40.14</b>
	<b>Total</b>	<b>100.00</b>

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396 **Table 2. Mixed-effects linear regression models.** Models 1-1 to 1-4: mothers' use score of  
397 7 plants for respiratory system disorders on children's (aged 0 to 5) z-BMI. Models 2-1 to 2-  
398 3: mothers' use score of 7 plants for digestive system disorders on children's z-BMI. Control  
399 variables: mother's age group, camp residence, and children's sex.

Respiratory uses								
	Model 1-1		Model 1-2		Model 1-3		Model 1-4	
	Coefficient (SE)	p-value	Coefficient (SE)	p-value	Coefficient (SE)	p-value	Coefficient (SE)	p-value
<b>(Intercept)</b>	-0.84 (0.67)	0.22	-1.24 (0.54)	0.03	-0.3 (0.31)	0.35	-0.37 (0.32)	0.26
<b>Use score</b>	0.21 (0.1)	<b>0.04</b>	0.2 (0.09)	<b>0.05</b>			0.1 (0.08)	0.21
<b>Age 25-35</b>	-0.28 (0.48)	0.56						
<b>Age 35-45</b>	-0.34 (0.51)	0.51						
<b>Age 45-55</b>	0.26 (0.79)	0.74						
<b>Forest camp 2</b>	0.61 (0.5)	0.23	0.55 (0.47)	0.25	0.73 (0.49)	0.15		
<b>Forest camp 3</b>	1.51 (0.54)	<b>0.01</b>	1.47 (0.54)	<b>0.01</b>	0.88 (0.49)	0.08		
<b>Town camp</b>	0.4 (0.4)	0.32	0.44 (0.38)	0.26	0.13 (0.37)	0.73		
<b>Sex- male</b>	-0.46 (0.3)	0.14						
<b>AIC</b>	119.83		117.64		120.36		120.17	
<b>N observations</b>	42		42		42		42	
<b>N groups</b>	33		33		33		33	

Digestive uses								
	Model 2-1		Model 2-2		Model 2-3			
	Coefficient (SE)	p-value	Coefficient (SE)	p-value	Coefficient (SE)	p-value		
<b>(Intercept)</b>	0.35 (0.65)	0.59	-0.3 (0.31)	0.35	-0.04 (0.34)	0.91		
<b>Use score</b>	-0.03 (0.13)	0.85						
<b>Age 25-35</b>	-0.51 (0.5)	0.32						
<b>Age 35-45</b>	-0.54 (0.54)	0.33						
<b>Age 45-55</b>	0.09 (0.89)	0.92						
<b>Forest camp 2</b>	0.9 (0.54)	0.11	0.73 (0.49)	0.15	0.7 (0.48)	0.15		
<b>Forest camp 3</b>	0.92 (0.52)	0.09	0.88 (0.49)	0.08	0.86 (0.48)	0.08		
<b>Town camp</b>	0.15 (0.41)	0.72	0.13 (0.37)	0.73	0.05 (0.36)	0.89		
<b>Sex- male</b>	-0.36 (0.34)	0.31			-0.46 (0.28)	0.15		
<b>AIC</b>	125.41		120.36		119.52			

<b>N observations</b>	42	42	42
<b>N groups</b>	33	33	33

400 The models were fit by maximum likelihood. Models 1-1 and 2-1 were the full models.  
401 For respiratory use score, the optimum model was Model 1-2 which included mother's use  
402 score for respiratory problems and her camp residence. Dropping the variable *Use score*  
403 from Model 1-2 significantly decreased the model's fit (for Model 1-2 and 1-3:  $P[\chi^2(1) >$   
404  $4.72] < 0.05$ ). For digestive use score, the optimum model was Model 2-2 which included  
405 mother's camp residence. Dropping the variable *Sex* from Model 2-2 did not affect the model  
406 fit (for Model 2-2 and 2-3:  $P[\chi^2(1) > 2.84] = 0.09$ ). Coefficient is the regression coefficient  
407 obtained from the model and SE is its standard error.

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