

*BaYaka adolescent boys nominate accessible adult men as preferred spear hunting models*

Article

Accepted Version

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Kiabiya, Broesch, Tanya and Kline, Michelle A. (2021) BaYaka  
adolescent boys nominate accessible adult men as preferred  
spear hunting models. *Current Anthropology*, 62 (5). pp. 631-  
640. ISSN 1537-5382 doi: <https://doi.org/10.1086/716853>  
Available at <https://centaur.reading.ac.uk/102634/>

It is advisable to refer to the publisher's version if you intend to cite from the work. See [Guidance on citing](#).

Published version at: <http://dx.doi.org/10.1086/716853>

To link to this article DOI: <http://dx.doi.org/10.1086/716853>

Publisher: University of Chicago Press

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1 **Title:** BaYaka adolescent boys nominate accessible adult men as preferred spear hunting  
2 models

3  
4 **Short title:** BaYaka adolescents nominate accessible spear hunting models

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37 **Main text and references:** 6,443 words

38

39 **Abstract:**

40 Humans are selective social learners. In a cultural landscape with many potential models,

41 learners must balance the cost associated with learning from successful models with learning

42 from accessible ones. Using structured interviews, we investigate the model selection biases of

43 Congolese BaYaka adolescent boys learning to hunt with spears ( $n=24$ ,  $m_{age}=15.79$  years,

44 range: 12-20 years). Results from Social Relations Models suggest that adolescents nominated

45 accessible adult men (closely related kin and neighbors) as preferred spear hunting models.

46 Direct cues for success were not strong predictors for adolescent nomination in the statistical

47 models, despite learners justifying model selection according to teaching and spear hunting

48 skill. Indirect cues including Body Mass Index, age, and cross-domain prestige, were weak

49 predictors for adolescent nomination. We interpret these findings as suggesting that BaYaka

50 spear hunting knowledge is widely shared in the community, with all adult men participating

51 in spear hunting, and therefore having the requisite experience to transmit this skill. This  
52 supports previous findings that in egalitarian societies, with low rates of role specialization,  
53 prestige has limited importance for cross-domain learning.  
54

55 **Résumé:**

56 Les êtres humains sont des apprenants sociaux sélectifs. Dans un paysage culturel comportant  
57 de nombreux modèles potentiels, les apprenants doivent trouver un équilibre entre le coût  
58 associé à l'apprentissage à partir de modèles qui ont fait leurs preuves et celui à partir de  
59 modèles accessibles. À l'aide d'entretiens structurés, nous étudions les biais de sélection de  
60 modèles des adolescents congolais BaYaka qui apprennent à chasser à la lance (n=24, âge  
61 moyen=15,79 ans, intervalle: 12-20 ans). Les résultats des Modèles de Relations Sociales  
62 suggèrent que les adolescents désignent des hommes adultes accessibles (parents proches et  
63 voisins) comme modèles préférés de chasse à la lance. Les indices directs de réussite ne  
64 constituaient pas des prédicteurs forts de nomination par des adolescents dans les modèles  
65 statistiques, bien que les apprenants justifiaient la sélection du modèle en fonction des habiletés  
66 d'enseignement et de la chasse à la lance. Les indices indirects, dont l'indice de masse  
67 corporelle, l'âge et le prestige inter-domaines, constituaient de faibles prédicteurs de la  
68 nomination par les adolescents. Ces résultats suggèrent que la connaissance de la chasse à la  
69 lance des BaYaka est largement partagée dans la communauté, puisque tous les hommes  
70 adultes participent à la chasse à la lance et ont donc l'expérience requise pour transmettre cette  
71 compétence. Ceci confirme les résultats de recherches antérieures selon lesquels dans les  
72 sociétés égalitaires, qui ont de faibles niveaux de spécialisation des rôles, le prestige a une  
73 importance limitée dans l'apprentissage inter-domaines.  
74

75 **Data availability:** Data is available upon request. The code used in the analysis can be found  
76 in the supplementary files.  
77

78 **Key words:** hunter-gatherers; model selection biases; adolescence; spear hunting  
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84 Humans are selective social learners: through model selection biases, children and adults  
85 preferentially attend to, and learn from, individuals who are most likely to have adaptive  
86 information (Henrich and Broesch 2011; Henrich and Mcelreath 2003; Henrich and Gil-  
87 White 2001). Learners must balance the costs associated with learning from preferred models  
88 against the potential benefits (Henrich and Broesch 2011). If skills are widely shared within a  
89 community, or if they are easily observable, learners should focus on accessible models  
90 (Henrich and Broesch 2011). Accessible models include kin, who may recoup inclusive  
91 fitness costs from transmitting knowledge to genetically related learners (Hamilton 1964;  
92 Kline, Boyd, and Henrich 2013). Neighbors are also accessible models, as proximity offers  
93 more opportunities for learning through observation and copying, and for assessing model  
94 skill (Corriveau and Harris 2009; Henrich and Gil-White 2001). Once learners have acquired  
95 baseline competencies from accessible models, they may learn specialized, complex, difficult  
96 to learn, and hard-to-observe skills from individuals who exhibit cues for success (Reyes-  
97 García, Gallois, and Demps 2016; Henrich, Boyd, and Richerson 2008; Kline, Boyd, and  
98 Henrich 2013).

99       Models may be selected based on direct success cues, including domain-specific  
100 knowledge and skill (Henrich and Broesch 2011; Koenig and Harris 2005), and from  
101 individuals who are good teachers (Dira and Hewlett 2016; Hewlett 2013, 2016, 2021). If  
102 direct success is difficult to interpret, learners may pay attention to indirect cues, such as  
103 cross-domain prestige, under the premise that an individual who is successful in one domain,  
104 and whom others turn to for learning, is likely to be successful in other domains (Henrich and  
105 Broesch 2011, 1140; see also Chudek et al. 2012). Learners may selectively learn from older  
106 individuals (Wood, Kendal, and Flynn 2012; Henrich and Henrich 2010), presumably  
107 because they have had more years to accrue knowledge (Henrich and Broesch 2011). Health  
108 may be an indirect cue of success, demonstrating that the model has fitness-enhancing

109 knowledge (Henrich and Mcelreath 2003). Because indirect cues of success are noisy and  
110 open to deception, learners should attend to direct success cues whenever possible (Jiménez  
111 and Mesoudi 2019; Henrich and Gil-White 2001).

112         Hunting, especially of larger game with lethal weapons, is a domain in which learners  
113 may preferentially attend to models who demonstrate direct or indirect success cues (Dira and  
114 Hewlett 2016). This is because such hunting usually occurs away from camp, where younger  
115 children cannot directly observe it (Lancy 2016), and because it is a complex skill requiring  
116 extensive experience (Walker et al. 2002; but see Bird and Bliege Bird 2005). Assessing  
117 hunter skill based on returns is difficult because variation may also be due to prey type  
118 targeted or environmental fluctuation (Hill and Kintigh 2009). Spear hunting, defined here as  
119 hunting with spears without the use of nets or traps, is particularly difficult because hunters  
120 must get relatively close to prey. Because body height and mass may correlate with effective  
121 spear use (Coppe et al. 2019; Milks, Parker, and Pope 2019), some growth must occur before  
122 learners can successfully target larger game, suggesting that regular *in situ* learning likely  
123 starts in adolescence. Only one study previously examined model selection biases among  
124 adolescent spear hunters: Dira and Hewlett (2016) found that Chabu forager adolescent boys  
125 from highland Ethiopia preferred to learn from attachment figures including close kin,  
126 successful hunters, and good teachers.

127         The present study contributes to our understanding of model selection biases by  
128 testing a series of hypotheses among BaYaka forager adolescent boys learning to spear hunt.  
129 We examine accessibility biases by positing that **(H<sub>1</sub>) kinship**: adolescents will preferentially  
130 learn from kin rather than non-kin, and **(H<sub>2</sub>) proximity**: adolescents will preferentially learn  
131 from models living in closer proximity to them. We examine biases related to direct cues of  
132 success by hypothesizing that **(H<sub>3</sub>) teacher quality**: adolescents will preferentially learn from  
133 good teachers, and **(H<sub>4</sub>) hunting skill**: adolescents will preferentially learn from good spear

134 hunters. Finally, we investigate indirect cues for success by hypothesizing that **(H<sub>5</sub>) health:**  
135 adolescents will preferentially learn from healthier adults, **(H<sub>6</sub>) age:** adolescents will  
136 preferentially learn from older adults, and **(H<sub>7</sub>) cross-domain prestige:** adolescents will  
137 preferentially learn from prestigious individuals.

138

### 139 **Ethnographic Background**

140 BaYaka<sup>1</sup> inhabit the dense tropical rainforest of the Congo Basin. Data for the present study  
141 were collected in a village along the Motaba river in the Likouala department of the Republic  
142 of Congo. Approximately 32 villages, home to BaYaka foragers and Bantu farmers, line the  
143 banks of the river (Kano and Asato 1994). While these villages vary in terms of market  
144 integration, travel and migration between them is frequent (Boyette et al., under review).  
145 Hunting, gathering, and gardening continue to be the main modes of food production in the  
146 village where the present research took place. Women focus on collecting wild yams, nuts,  
147 mushrooms, and greens. Men primarily collect honey, hunt with spears, and set traps and  
148 snares. Both men and women participate in tending low-maintenance forest gardens, collect  
149 liana fruit and caterpillars, and fish (Kitanishi 1995). Approximately six months of the year is  
150 based in a multi-ethnic village where BaYaka work for Bondongo Bantu farmers and  
151 participate in daily and overnight foraging excursions (Boyette et al. 2020). The remainder of  
152 the year is spent in forest camps during fishing and caterpillar seasons.

153 While BaYaka men regularly hunt with guns owned and provided to them by  
154 Bondongo, meat is given back to the owner of the gun in exchange for market goods. Spear  
155 hunting is a primary method by which BaYaka hunt for direct consumption. Spear hunting  
156 occurs throughout the year, and varies from a solitary to a group activity, depending on prey  
157 type and season (Kitanishi 1995). Hunting forays can last a single day, or several days from

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<sup>1</sup> BaYaka surveyed in the present study are most closely related to the Mbendjele BaYaka (Lewis 2002)

158 men-only hunting camps. Spear hunters primarily target brush-tailed porcupine, blue duiker,  
159 red duiker, red river hog, and historically, elephant (Lupo and Schmitt 2005; Kitanishi 1995;  
160 Lewis 2002). Among Congo Basin foragers including BaYaka, children as young as three  
161 begin learning to hunt with spears by playing target practice games, in pretense play, and by  
162 hunting rats (Figure 1) (for Mbendjele, see Lewis 2002; for Aka, see Hewlett 1991). Children  
163 learn the mechanics of spear hunting during other types of hunts, such as when checking  
164 traps, as spears are often used to kill prey in these settings. When children are old and strong  
165 enough, they accompany fathers and other adult men on hunts for larger prey (for Aka, see  
166 Hewlett and Cavalli-Sforza 1986; for BaYaka, see Lew-Levy et al., 2021; Kitanishi 1995).  
167 Because spear hunting is an activity primarily—though not exclusively—conducted by men,  
168 the present paper focuses on the model selection biases of adolescent boys.

169

## 170 **Methods**

171 Fieldwork took place in July and August 2019. Ethical approval was obtained from Simon  
172 Fraser University (2019s0187), and in-country permission from the Institut de Recherche en  
173 Sciences et Exactes et Naturelles (IRSEN). Community, adult, and parent/guardian consent,  
174 and unmarried adolescent assent, was obtained prior to the start of research.

175

### 176 *Sample*

177 All adult men and adolescent boys inhabiting the larger of two BaYaka village  
178 neighborhoods at the time of data collection were invited to participate in the study.  
179 Following BaYaka views on maturity, older adolescents (<20 years) who were married were  
180 categorized as adults (n=3), and young adults (20 years) who were not married (n=2) were  
181 categorized as adolescents. One adult declined to participate, stating that he was preoccupied



182 with other work activities. In total, 24 adolescents ( $m_{age}=15.79$  years, range: 12-20 years) and  
183 47 adults ( $m_{age}=37.06$  years, range: 17-70 years) participated in the research.

184

#### 185 *Adolescent Interviews*

186 During a free list task, adolescents were asked “*who would you like to learn to spear hunt*  
187 *from?*” [“*Odinga bane ayekodje we botamboli na gongo?*”]. We focused on prospective  
188 models rather than retrospective self-reports in order to avoid recall biases which  
189 overemphasize vertical transmission (Aunger 2000; Henrich and Broesch 2011). When  
190 participants stopped listing names, we asked them who else they would like to learn from  
191 until they indicated that their list was complete.

192 We did not instruct adolescents to restrict their listing to adults, but all did.

193 Adolescents named an average of 3.33 adults (range: 1-9; Figure S1). In 21% of cases,  
194 adolescents named adults who did not live in the community at the time of data collection.  
195 These nominations are discussed qualitatively, but are excluded from the statistical models  
196 because additional information (e.g. health, hunting skill, prestige) regarding these  
197 individuals was not available. Two of these external nominations came from one adolescent  
198 who lived in a forest camp full-time, but was visiting village kin during data collection, and  
199 was enthusiastic to participate in our study. We include his responses in the qualitative  
200 analysis but excluded him from the statistical models described below.

201 To examine the attributes attended to in preferred models, we revisited the free list,  
202 and asked adolescents why they nominated each model. We also asked adolescents about  
203 their experience with spear hunting, what makes a good spear hunting teacher, who had  
204 taught them previously, and what they felt they still had to learn. Finally, to estimate when  
205 children begin to learn to hunt with spears, we asked adolescents to name a child in the  
206 village who was as old as they were when they started learning this skill.

207

208 *Peer Rankings*

209 To assess model skill, we asked a subset of adult men in our sample (n=37) to participate in a  
210 peer ranking task. Interviewees were shown pictures of all participating adults, excluding  
211 themselves. Each picture was pulled from the deck, handed to the interviewee, and the person  
212 depicted was named by the researcher. Once the interviewee recognized the participant, the  
213 picture was placed on a table. This was repeated until all pictures were placed in three to four  
214 rows. In the interest of identifying the most skilled community members and of keeping  
215 interviews short, interviewees were asked to select up to five individuals from the spread  
216 whom they felt surpassed others in each of four attributes; overall hunting skill, spear hunting  
217 skill, teaching skill, and welcoming (Table 1). Once they had selected five individuals or  
218 stated that no other individuals demonstrated the attribute in question, we replaced the  
219 selected pictures on the table, in a different spot. Unselected pictures remained in the same  
220 place. The deck of pictures was shuffled once before each interview, and all interviewees  
221 ranked their peers on all four attributes, which were alternated such that each interviewee  
222 began the ranking task with a different attribute than the previous interviewee. Most  
223 participants ranked the maximum of five peers per question (78-84%). Interviewee responses  
224 were internally consistent (Table 1).

225 Participants who were selected as demonstrating a particular attribute received a score  
226 of 1. These were then summed, such that if Participant A was selected as being a top spear  
227 hunter by five peers, he received a rank-score of 5 in this attribute category. Since some adult  
228 men were on month-long hunting trips during the start of the research period, their pictures  
229 were missing for part of the ranking task. Thus, we divided each participant's attribute-  
230 specific rank-score by the number of times they appeared in the deck. Distributions show that

231 ranks are skewed towards zero, meaning that few participants were highly ranked (Figure  
232 S2).

233

#### 234 *Demographic Data*

235 Kinship relationships between adolescents and adults were determined from yearly  
236 genealogical interviews, starting from 2017 (Boyette et al. 2020). Using the package *kinship2*  
237 version 1.8.4 (Therneau et al. 2015) in R version 4.0.3 (R Core Team 2013), we estimated the  
238 degree of relatedness between adolescents and adults in our sample. We categorized kinship  
239 relationships as fathers and brothers ( $r=0.5$ ), other kin ( $0.125 \leq r < 0.5$ ), and non-kin  
240 ( $r < 0.125$ ). While these  $r$  values are based on genealogical distance, they reflect BaYaka  
241 kinship relationships. One of the central responsibilities of BaYaka fathers is transmitting  
242 subsistence knowledge to their children (Boyette et al. 2020). According to interviews and  
243 structured observations, both parents and siblings play a prominent role in the transmission of  
244 subsistence knowledge (Lew-Levy et al. 2021; Lew-levy et al. 2020). While less so than  
245 fathers, uncles also have a special duty of care to their brother's children, especially in the  
246 event of their brother's death.

247         Because BaYaka do not track their age in years, a neighborhood-wide age ranking  
248 task was conducted in 2018. Age was assigned using a Bayesian approach outlined in  
249 Diekmann et al. (2017, 8209) in which “ranking and prior age distributions are processed to  
250 generate a probability distribution of age per individual.” Mean estimates were adjusted for  
251 parent-child age differences of a minimum of 16 years. For individuals absent in 2018, we  
252 asked their family members to identify someone born in the village around the same time,  
253 and considered both individuals to be the same age.

254         To identify prestigious individuals, we developed a list of men who were on the  
255 village council and/or were healers. Those on the council act in the same capacity as

256 traditional camp spokespeople (*mokonji* or *kombeti*), who can influence camp movement and  
257 subsistence activities (Hewlett 1987). *Nganga* are traditional healers who provide healing to  
258 BaYaka and Bantu farmers, usually in exchange for payment. These positions are strong  
259 contenders for prestige-biased social learning because councilmen and healers are considered  
260 highly skilled within their domains, are turned to for advice across domains such as in  
261 solving interpersonal disputes, deference is freely-conferred to them by community members,  
262 and because they are remunerated for their services (Henrich and Gil-White 2001). *Tuma*—  
263 master hunters, usually of elephants—also maintain a position of prestige in BaYaka  
264 communities (Lewis 2002), but none inhabited the village at the time of data collection. A  
265 total of eight (17%) adult participants were identified as holding a prestigious community  
266 position.

267         We collected GPS points for each house in the village. Using *geosphere* version 1.5-  
268 10 (Hijmans 2019), we estimated the distance between all adolescent and adult households  
269 from front doors, measured in meters. To calculate adult Body Mass Index (BMI), we  
270 measured height using a Seca stadiometer, and weight using an electronic bathroom scale.  
271 BMI is an easily implemented measure of nutritional status (Bailey and Ferro-Luzzi 1995). In  
272 energetically demanding ecologies, such as those inhabited by BaYaka, higher BMI is an  
273 indicator of better physical health. Note that our entire sample's BMI range was classified as  
274 'normal weight' as outlined by the World Health Organization (Weir and Jan 2019).

275

## 276 *Analysis*

277 The dependent variable was binary and dyadic, as it measured whether adolescent *i*  
278 nominated adult *j* as a preferred spear hunting model. Since each adolescent could  
279 theoretically name any or all adults, and all adults could theoretically be named by any or all  
280 adolescents, both adolescents and adults are repeated in the dataset. We therefore analyzed

281 our data using the binary logistic multilevel Social Relations Model (SRM) (Kenny and La  
282 Voie 1984; Koster and Aven 2018; Koster and Leckie 2014). A type of network analysis,  
283 SRM considers interpersonal interactions to be dyadic. By decomposing dyadic relationships  
284 into their component parts (e.g. actor, partner, relationship), and estimating the effects of  
285 these components on the outcome, SRMs allow for the simultaneous modelling of behaviors  
286 operating on multiple levels (Kenny and La Voie 1984). The data structure for the present  
287 analysis can be considered a half-block design because nominations were unidirectional;  
288 while adolescents could nominate adults, adults could not nominate adolescents (Malloy  
289 2018).

290 We fit five models to the data. Details regarding each variable can be found in Table  
291 2. **Model 1 (*intercept-only*)** served as a baseline comparison for subsequent models, and  
292 included random effects for adolescent learners and adult models. These random effects were  
293 included in Models 2-5. **Model 2 (*accessibility*)** assessed whether adolescents nominated  
294 accessible adults as preferred models, and included dyadic-level fixed effects of kinship  
295 (father/sibling, other kin), and inter-household distance. **Model 3 (*direct success*)** examined  
296 whether learners nominated adults who were skilled spear hunters and teachers, and included  
297 adult peer ranks for spear hunting skill and teaching skill. **Model 4 (*indirect success*)**  
298 examined whether learners attended to indirect cues of success, including cross-domain  
299 prestige, model age, and BMI. To examine the relative importance of access, direct success,  
300 and indirect success, **Model 5 (*full model*)** included all variables from Models 1-4.

301 Continuous variables were z-score standardized to facilitate estimation. While ideally  
302 all four peer ranking variables would be included in the model, these were highly correlated  
303 (Table S1), resulting in high Variance Inflation Factors ( $VIF \geq 4$ ). We excluded peer ranks  
304 for 'welcoming' and 'overall hunting skill' from the analysis because these were least  
305 relevant to our hypotheses, resulting in lower VIFs across the independent variables.

306 Models were fit using the Hamilton Monte Carlo estimation in *rstan* (Stan  
307 Development Team 2016) via *brms* version 2.14.4 (Bürkner 2017). Each model was fit on 4  
308 chains of 3000 iterations each, half of which were warmup iterations. All R-hat Gelman and  
309 Rubin convergence diagnostic statistics were smaller than 1.01, and there were no divergent  
310 iterations, suggesting good mixing across all models. We compared model fit using Widely  
311 Applicable Information Criteria (WAIC). We expand on the model with the lowest WAIC  
312 because it has the highest probability of making the best predictions with new data  
313 (McElreath 2015). As a measure of effect size, we report Relative Risks, computed by  
314 dividing the posterior probabilities associated with and without exposure to each variable.  
315 Exploratory correlations were calculated using *BayestestR* version 0.8.2 (Makowski, Ben-  
316 Shachar, and Lüdtke 2019) and *BayesFactor* version 0.9.12-4.2 (Morey and Rouder 2018).

317

## 318 **Results**

319 All adolescent boys had previously participated in spear hunting (4 participated daily; 8  
320 weekly; 5 monthly; 7 rarely), and all but three had successfully speared an animal.  
321 Participants reported starting to learn to spear hunt between the ages of 10 and 20 ( $m_{\text{age}}=13$ ).  
322 Adolescents reported successfully spearing on average 5.96 animals—primarily small- and  
323 medium-sized prey—with or without adults present, though these numbers are skewed by  
324 two participants who reported harvesting 23 and 68 animals. While these reports are likely  
325 slightly inflated, both participants were older (16 and 19 respectively), and often went on  
326 hunting expeditions. Participants reported wanting to learn to kill larger animals, to hunt  
327 (with headlamps) at night, and to hunt (through tracking and trailing) in the day.

328 Excluding adolescents who did not respond to the question, participants primarily  
329 explained their model selection according to the potential for receiving teaching (60%),  
330 opportunities to gain experience (e.g. “to look for animals”, “so I can kill an animal”—22%),

331 and the model's hunting skill (16%). A breakdown of justifications in Table 3 shows that  
332 receiving teaching was the primary reason for selecting preferred models irrespective of  
333 kinship relationship. Adolescents reported that hunting skill was an important attribute of a  
334 good teacher (78% of responses; Table 4). Good teachers were also noted to teach through  
335 instruction ("he tells you [how] to go hunt"), scaffolding ("A good teacher takes you to hunt,  
336 he gives you the spear, he gives you the headlamp"), and demonstration ("He walks with  
337 spears often and shows me how").

338         There was no association between adolescent age and number of nominations  
339 ( $r_{median} = -0.03$ , 95% Credible Intervals (CI)[-0.35, 0.33], Bayes Factor (BF)=0.45). Of the  
340 17 nominations for adults who lived outside the community, five were fathers, one was a  
341 stepfather, five were uncles, and six were non-kin. When considering nominations from  
342 within and outside the community, there was a weak but positive association between  
343 adolescent age and the proportion of non-kin nominated to total nominations ( $r_{median}=0.31$ ,  
344 95% CI[-0.04, 0.62], BF=1.85). In total, 27 adult community members were nominated as  
345 preferred models at least once by adolescents. Of these preferred models, 63% had previously  
346 taught the nominating adolescent to spear hunt, and only four had not previously taught any  
347 adolescent in our sample. The number of adolescents taught (range: 0-3) by each nominated  
348 adult was not correlated to their peer ranked spear hunting skill ( $r_{median}= 0.19$ , 95% CI[-  
349 0.15,0.50], BF=0.75), and was weakly but positively correlated to teaching skill ( $r_{median}=  
350 0.24$ , 95% CI[-0.10,0.55], BF=1.03). Adult age, prestige, and BMI positively predicted peer  
351 ranked spear hunting and teaching skill (Table S2).

352         All model results can be found in Table 5. A comparison of WAICs suggest that  
353 while both Models 2 (*accessibility*) and 5 (*full model*) were comparable in their fit to the data,  
354 Model 5 had the lowest WAIC. Thus, we expand on the results from the latter model. In  
355 support of H<sub>1</sub>, kinship relationship was a strong predictor for nominations, with adolescents

356 16.68 times more likely to nominate fathers/siblings and 7.16 times more likely to nominate  
357 other kin, when compared to non-kin. Note that with fewer observations of father/sibling  
358 dyads, CIs for this kinship category are large (Figure 2). In support of H<sub>2</sub>, inter-household  
359 distance was a strong predictor for nomination, with adolescents 1.87 times less likely to  
360 nominate an adult as a preferred model with every standard deviation (45.06m) increase in  
361 distance between their households (Figure 3). H<sub>3</sub> was not supported; adolescents were only  
362 1.08 times more likely to nominate an adult as a preferred model with every standard  
363 deviation increase in peer ranked teaching skill. There was weak (i.e. 95%CI crossed 0)  
364 support for H<sub>4</sub>; hunting skill was a positive predictor for nomination, with adolescents 1.28  
365 times more likely to nominate an adult as a preferred model with every standard deviation  
366 increase in their peer ranked spear hunting skill. Figures 2 and 3 show that while CIs for  
367 spear hunting skill are wide, being a highly ranked spear hunter increases the probability of  
368 nomination for close kin and neighbors. There was weak support for H<sub>5</sub>; BMI was a positive  
369 predictor for nomination, with adolescents 1.33 times more likely to nominate an adult as a  
370 preferred model with every standard deviation increase in their BMI. Contrary to H<sub>6</sub>, adult  
371 age was a negative and weak predictor for nomination, with adolescents 1.25 times less likely  
372 to nominate an adult as a preferred model with every standard deviation increase in their age.  
373 Contrary to H<sub>7</sub>, adult prestige was a negative and weak predictor for nomination, with  
374 adolescents 1.50 times less likely to nominate a prestigious vs. non-prestigious adult as a  
375 preferred model. We also note wide CIs associated with the effect of low and high prestige on  
376 the probability of nomination (Figure S3). While the data were sparse (63 nominations for  
377 1081 dyads), our results are supported by additional analyses (Tables S4-5).

378

379 **Discussion**



380 Using data collected among BaYaka foragers, the present paper investigated the model  
381 selection biases of adolescent spear hunters. That Models 2 (*accessibility*) and 5 (*full model*)  
382 had comparable WAICs, and that kinship and inter-household distance were the strongest  
383 predictors for nomination, suggest that accessibility was an important factor in adolescent  
384 model selection. While a fifth of nominations were from outside the study community, the  
385 exclusion of external nominations is unlikely to bias our results towards accessible models  
386 because more than half of external nominations were fathers or uncles, and because many of  
387 the external models lived with adolescents in forest camps for part of the year. Since our  
388 sample was small, our statistical analyses likely could not confidently detect effects for  
389 model selection biases based on direct and indirect cues of success. Still, we found weak but  
390 positive support for the hypothesis that adolescents would preferentially nominate good spear  
391 hunters as models. Our findings are consistent with Dira and Hewlett (2016, 80), who found  
392 that Chabu adolescents named both attachment figures and good hunters as preferred spear  
393 hunting models, and that “they preferred to learn from their fathers and friends because they  
394 knew how to hunt well.”

395         That adolescents preferentially learned from accessible models reflects the fact that  
396 spear hunting knowledge is widely shared by nearly all adult BaYaka men in the studied  
397 community. Indeed, peer rankings for spear hunting skill were the most evenly distributed of  
398 the four peer ranked attributes (Figure S2). Further, one adolescent explicitly stated that a  
399 good teacher was any Mwaka, because “all BaYaka know how to hunt with spears” (Table  
400 4). In a previous study, we found that all BaYaka adult men reported knowing how to hunt  
401 with spears (Lew-Levy et al. 2021). These findings echo reports from neighboring Aka  
402 (Hewlett and Cavalli-Sforza 1986). Spear hunting skill may be widely shared because this  
403 type of hunting is an efficient method for capturing small- and medium-sized game;  
404 alongside snaring, spear hunting yields “the highest post-encounter rate as scaled by prey

405 size” (Lupo and Schmitt 2005, 6). Also, spear hunting is not season-specific, but rather,  
406 conducted throughout the year (Lupo and Schmitt 2005; Kitanishi 1995). Because spear  
407 hunting is a widely practiced and reliable method for collecting game, learners have ample  
408 opportunity to participate in this activity, and thus, less incentive to seek out higher-skilled,  
409 but potentially costlier, models. Nonetheless, adolescents did state that they selected models  
410 based on spear hunting skill, and this effect was picked up, though weakly, in our model.  
411 Learners may pay closer attention to model attributes such as skill when learning about  
412 specific aspects of spear hunting, including how to hunt large or dangerous game, rituals,  
413 supernatural beliefs, sharing norms, and taboos regarding hunting, because not all adults hold  
414 this information (Lewis 2002). Model attributes may also be more important when acquiring  
415 innovations because these skills are not yet shared by the wider community (Hewlett 2013;  
416 2016; 2021; Lewis 2015).

417         Receiving teaching was the most frequently mentioned reason for selecting a model,  
418 and most nominated adults had taught adolescents to hunt with spears previously. Teaching  
419 may be especially important for the acquisition of hard-to-observe and complex skills (Kline  
420 2015; Boyette and Hewlett 2017; Csibra and Gergely 2011). The importance of learning from  
421 good teachers was mentioned by Chabu adolescents learning to spear hunt (Dira and Hewlett  
422 2016), and both Chabu and Aka adolescents from the Central African Republic seeking to  
423 learn innovations (Hewlett 2013; 2016; 2021). BaYaka adolescents in the present study  
424 reported that good teachers taught by scaffolding, demonstration, and instruction. Hewlett  
425 (2013, 192) also reports that Aka adolescents view good teachers as “those who were patient,  
426 taught slowly, gave directed instruction and ensured the student correctly performed the new  
427 task.” In other words, good teachers are those who facilitate the accurate transmission of  
428 cultural knowledge by calling attention to relevant stimuli (Kline 2016). As in Hewlett  
429 (2013), BaYaka adolescents in the present study reported that hunting skill was also an

430 important attribute of a good teacher. While adult teaching skill was not a strong predictor for  
431 nomination in the statistical models, this variable was based on peer rankings. Adolescents  
432 may pay attention to different aspects of teacher quality than adults. Adolescent rankings may  
433 have better captured perceived teaching skill, representing a limitation of the present study.

434         Prestige-biased transmission has been found in ethnographic accounts, primarily  
435 among Fijians who maintain age-sex and clan-based social hierarchy (Henrich and Henrich  
436 2010; Henrich and Broesch 2011). However, we did not find that prestigious individuals were  
437 nominated as preferred models in the present study. Our findings echo those of Garfield et al.  
438 (2016) whose survey of hunter-gatherers found limited evidence for prestige-biased  
439 transmission. Similarly, while peer nominations for mentor salience were positively related to  
440 leadership rankings among Chabu, it was not a better predictor than other variables (e.g.  
441 likability), suggesting that prestigious leaders do not have a specialized role for knowledge  
442 transmission in this society (Garfield and Hagen 2019). Tightly-knit settlements that provide  
443 learners with opportunities to observe and assess the skill of many cultural models (Hewlett  
444 et al. 2019), prestige-avoiding cultural norms (Boehm et al. 1993; Wiessner 1996) and low  
445 rates of role specialization (Jiménez and Mesoudi 2019) may limit the importance of prestige  
446 on cross-domain learning in egalitarian societies.

447         It is important to note that, because of our small sample size, we were unable to  
448 examine the interaction between learner age and model attributes on the probability of  
449 nomination. Several studies have shown that whom individuals learn from changes across the  
450 life course, reflecting development in skill, social status, and access to models (Demps et al.  
451 2012; Lew-levy et al. 2020; Reyes-García, Gallois, and Demps 2016; Henrich, Boyd, and  
452 Richerson 2008; Kline, Boyd, and Henrich 2013). For example, Demps et al. (2012) working  
453 with Indian Jenu Kuruba, found that the importance of fathers to the transmission of honey  
454 collection knowledge declined with learner age, while learning from successful individuals

455 increased with age. Like other hunting types (Koster et al. 2020; Ohtsuka 1989; Walker et al.  
456 2002), the development of spear hunting skill continues into adulthood (see Figure S2 in  
457 Lew-Levy et al., 2021). Thus, it is possible that learning from models who exhibit direct and  
458 indirect cues of success is more common among adult spear hunting learners than  
459 adolescents. Beyond age-related learning patterns, more general indirect cues, such as overall  
460 intelligence or likability, may be better signals for model selection biases than the variables  
461 selected in this paper (Jiménez and Mesoudi 2019). Despite these limitations, the results of  
462 the present study add to our understanding of cross-cultural variability in model selection  
463 biases by demonstrating that BaYaka adolescent spear hunters select accessible adults as  
464 preferred models.

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470 **References**

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673

674 **Acknowledgements:** Special thanks to all participants in the study. Funding for this research  
675 was provided by awards from the Wenner-Gren Foundation (#9789) and the Leakey  
676 Foundation to SLL and AM. Research was also supported by a Social Sciences and Humanities  
677 Research Council of Canada Postdoctoral Fellowship (#756-2019-0102) to SLL. Thanks to  
678 Prof. Clobite Bouka-Biona from the Institut de Recherche en Sciences Exactes et Naturelles,  
679 who facilitated the acquisition of research permits and infrastructure, DZABATOU Moise,  
680 who served as a community liaison, DZABATOU Ardain, who provided additional contextual  
681 information, and our field assistants, MEKOUNO Paul. Thanks to Zachary Garfield, Bonnie  
682 Hewlett and Barry Hewlett for feedback on this manuscript, and to Jeremy Koster and Erik  
683 Ringen for answering questions about model formulation and results. Finally, thanks to Bret  
684 A. Beheim and two anonymous reviewers for their helpful suggestions.

685 **Author contributions:** SLL and AM designed the study. SLL collected the data with help  
686 from FKN. SLL conducted analyses and wrote the text. All authors gave critical feedback and  
687 approved of the final version of the manuscript.  
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## Tables

**Table 1.** Questions asked in the peer ranking task, and inter-rater reliability.

Attribute	Question: Of all the people you see here...	Cronbach's $\alpha$
Overall hunting skill	Who brings home the most animals?	0.86
Spear hunting skill	Who is the best spear hunter?	0.80
Teaching skill	Who is the best teacher?	0.88
Welcoming	Who is the most welcoming to newcomers?	0.93

Following the steps outlined in Weller (2007), we estimated the internal consistency of interviewees' peer rankings using *psych* version 2.0.12 (Revelle 2019) in R 4.0.3 (R Core Team 2013), with missing values imputed.

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**Table 2.** Descriptions of variables in the models.

Variable	Description	Variable Type	n	Mean	SD
Adult age	In years	Integer (z-score)	47	37.06	13.94
Adult Body Mass Index	Kg/m <sup>2</sup>	Continuous (z-score)	47	21.69	1.63
Adult status	Sits on village council or is a healer	Binary (ref=not prestigious)	47	0.17	0.38
Adult teaching skill	Peer rank	Proportion (z-score)	47	0.10	0.13
Adult spear hunting skill	Peer rank	Proportion (z-score)	47	0.10	0.10
Father/Sibling	Kinship relationship of $r=0.5$	Binary (ref=non-kin)	1081	0.01	0.12
Other kin	Kinship relationship of $0.125 \leq r < 0.5$	Binary (ref=non-kin)	1081	0.06	0.23
Inter-household distance	Meters	Continuous (z-score)	1081	84.41	45.06

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**Table 3.** Frequency table showing adolescent justifications for preferred models by learner-model kinship relationship.

	Father/Sibling	Other Kin	Non-Kin	Total
Receiving teaching	8	9	21	38
To gain experience	2	1	11	14
Spear hunting skill	3	6	1	10
To keep the model company	0	0	1	1
Did not answer/didn't know	5	8	4	17
<i>Total</i>	18	24	38	80

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**Table 4.** Adolescent response to the question "what makes a good spear hunting teacher?" Note that six participants declined to answer or stated that they did not know the answer.

Category	Response
Hunting Skill	By his knowledge and will
Hunting Skill; Teaching	He walks with spear often and shows me how
Hunting Skill	A good teacher knows the forest

Hunting Skill	He goes hunting often
Hunting Skill	You know him based on how much time he spends in the forest
Hunting Skill	He kills animals
Hunting Skill	He goes on many hunting trips
Hunting Skill	He goes walking [in the forest], he gets things, so I think I have to follow him because he's a good hunter
Hunting Skill	He walks with dogs
Hunting Skill	He walks in the night. The way he kills the blue duiker, I also want to learn that
Hunting Skill	He's a master with the spear
Hunting Skill	He walks in the forest often
Hunting Skill	He kills many animals, he doesn't miss
Hunting Skill	He goes hunting a lot
Prosociality	By his behaviour [because] he shares food.
Teaching	A good teacher takes you to hunt, he gives you the spear, he gives you the headlamp, he tells you [how] to go hunt
Kinship	A good teacher is a father teaches who teaches his child forest knowledge
Ethnicity	He's Mwaka, all BaYaka know how to hunt with spears

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**Table 5.** Posterior means (95% Credible Intervals) for Models 1-5 investigating adolescent model selection. Values in bold represent 95% Credible Intervals which do not include zero.

	<i>Model 1</i> Intercept-only	<i>Model 2</i> Access	<i>Model 3</i> Direct success	<i>Model 4</i> Indirect success	<i>Model 5</i> Full model
Intercept	<b>-2.92 (-3.40, -2.54)</b>	<b>-3.52 (-4.07, -3.08)</b>	<b>-2.96 (-3.42, -2.57)</b>	<b>-3.09 (-3.56, -2.68)</b>	<b>-3.57 (-4.15, -3.05)</b>
Father/Sibling	--	<b>3.45 (2.42, 4.56)</b>	--	--	<b>3.47 (2.37, 4.60)</b>
Other kin	--	<b>2.13 (1.44, 2.82)</b>	--	--	<b>2.17 (1.45, 2.88)</b>
Household distance <sup>1</sup>	--	<b>-0.62 (-0.95, -0.31)</b>	--	--	<b>-0.65 (-0.98, -0.32)</b>
Model Teacher skill <sup>1</sup>	--	--	0.03 (-0.40, 0.44)	--	0.07 (-0.46, 0.60)
Model Spear skill <sup>1</sup>	--	--	0.28 (-0.13, 0.68)	--	0.26 (-0.22, 0.73)
Model Status	--	--	--	0.57 (-0.20, 1.37)	-0.40 (-1.43, 0.67)
Model Age <sup>1</sup>	--	--	--	0.04 (-0.30, 0.38)	-0.24 (-0.75, 0.25)
Model BMI <sup>1</sup>	--	--	--	<b>0.44 (0.15, 0.76)</b>	0.29 (-0.04, 0.65)
$\sigma_{learner}^2$	0.23 (0.06, 0.92)	0.36 (0.08, 1.13)	0.24 (0.05, 0.96)	0.23 (0.05, 0.96)	0.39 (0.14, 1.13)
$\sigma_{model}^2$	0.29 (0.04, 1.10)	0.23 (0.02, 1.07)	0.27 (0.03, 1.09)	0.20 (0.02, 1.00)	0.22 (0.02, 1.10)
WAIC	473.0	354.4	472.0	468.7	353.9

1. z-score standardized

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715 **Figures**

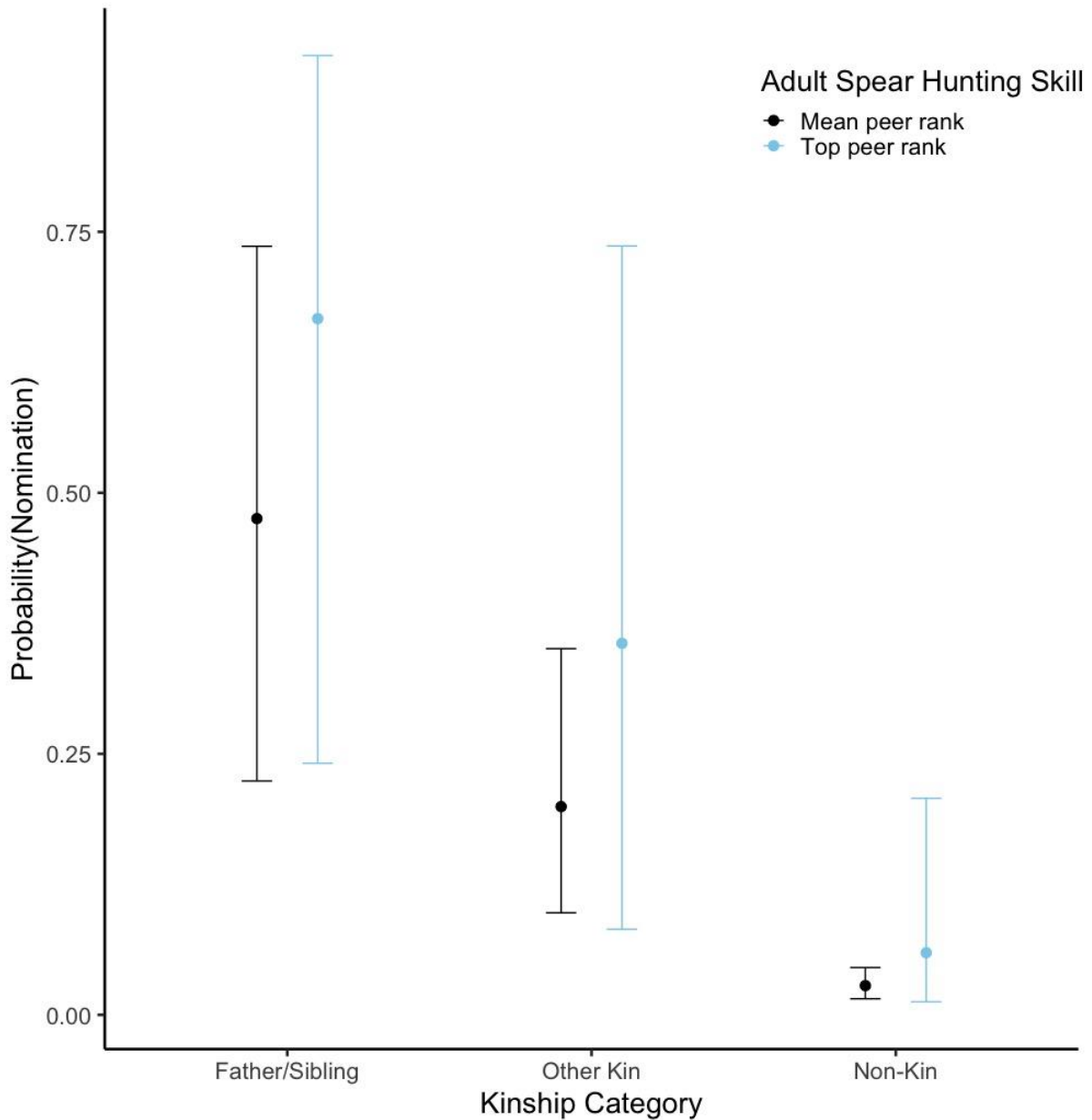
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**Figure 1.** Children hunting rats as part of work-play (a), and an adolescent prepares to go spear hunting with his dog (b).

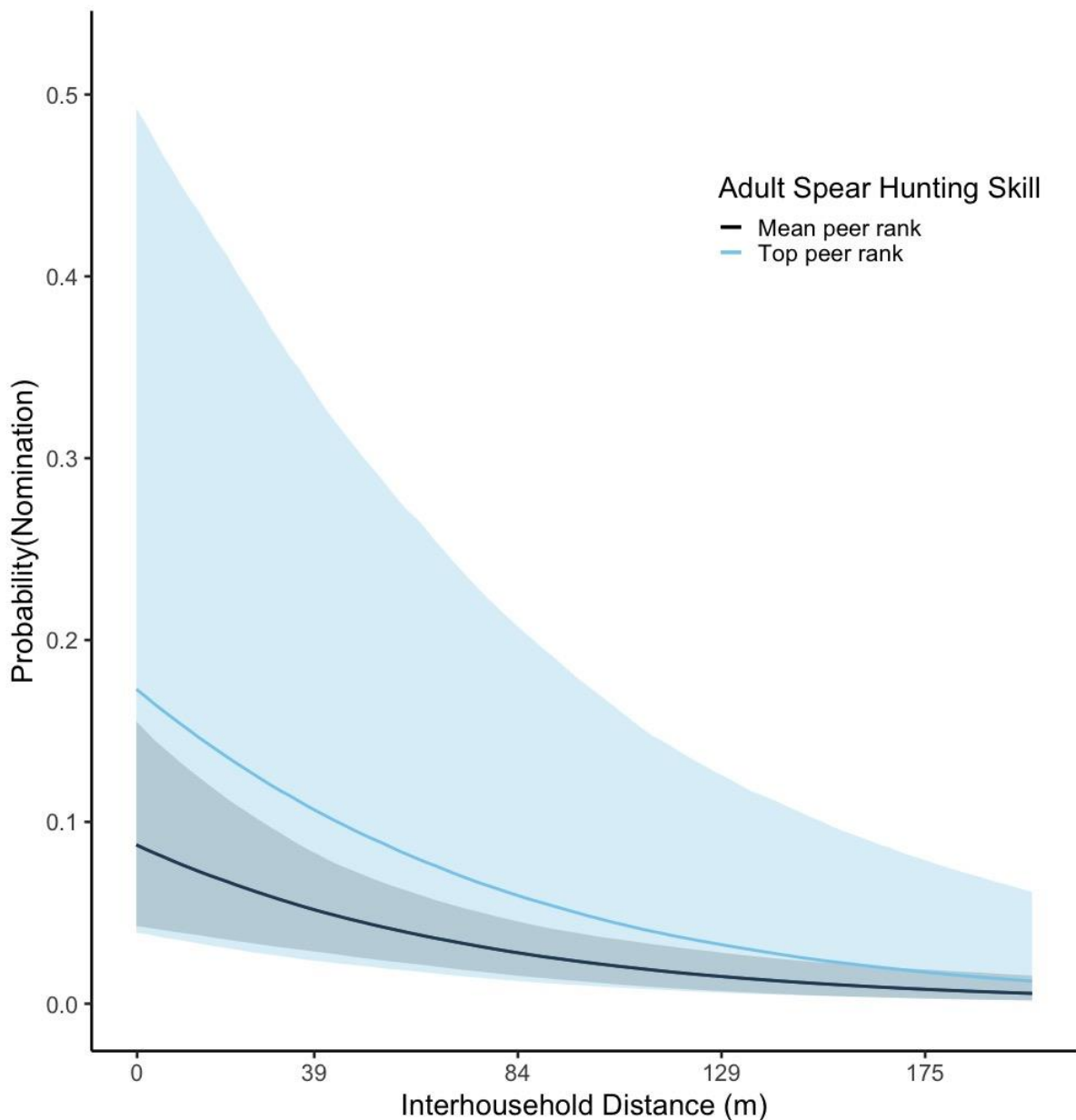




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**Figure 2.** Predictions from Model 5 showing the effect of adolescent-adult kinship relationship on the probability of an adolescent nominating an adult as a preferred spear hunting model. Predictions in black are for adults whose peer ranked spear hunting skill is at the sample mean (0.1). Predictions in blue are for adults whose peer ranked spear hunting skill is at the sample maximum (0.41). Other variables are held at their mean or reference value. Error bars depict 95<sup>th</sup> percentile Credible Intervals.

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**Figure 3.** Predictions from Model 5 showing the effect of adolescent-adult interhousehold distance on the probability of an adolescent nominating an adult as a preferred spear hunting model. Predictions in black are for adults whose peer ranked spear hunting skill is at the sample mean (0.1). Predictions in blue are for adults whose peer ranked spear hunting skill is at the sample maximum (0.41). Other variables are held at their mean or reference value. Shaded area depicts 95<sup>th</sup> percentile Credible Intervals.