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

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Abstract:
Humans are selective social learners. In a cultural landscape with many potential models, learners must balance the cost associated with learning from successful models with learning from accessible ones. Using structured interviews, we investigate the model selection biases of Congolese BaYaka adolescent boys learning to hunt with spears (n=24, m_{age}=15.79 years, range: 12-20 years). Results from Social Relations Models suggest that adolescents nominated accessible adult men (closely related kin and neighbors) as preferred spear hunting models. Direct cues for success were not strong predictors for adolescent nomination in the statistical models, despite learners justifying model selection according to teaching and spear hunting skill. Indirect cues including Body Mass Index, age, and cross-domain prestige, were weak predictors for adolescent nomination. We interpret these findings as suggesting that BaYaka spear hunting knowledge is widely shared in the community, with all adult men participating

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

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

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

Key words: hunter-gatherers; model selection biases; adolescence; spear hunting

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

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

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

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

The present study contributes to our understanding of model selection biases by testing a series of hypotheses among BaYaka forager adolescent boys learning to spear hunt. We examine accessibility biases by positing that **(H_1) *kinship:*** adolescents will preferentially learn from kin rather than non-kin, and **(H_2) *proximity:*** adolescents will preferentially learn from models living in closer proximity to them. We examine biases related to direct cues of success by hypothesizing that **(H_3) *teacher quality:*** adolescents will preferentially learn from good teachers, and **(H_4) *hunting skill:*** adolescents will preferentially learn from good spear

hunters. Finally, we investigate indirect cues for success by hypothesizing that **(H_5) *health:*** adolescents will preferentially learn from healthier adults, **(H_6) *age:*** adolescents will preferentially learn from older adults, and **(H_7) *cross-domain prestige:*** adolescents will preferentially learn from prestigious individuals.

Ethnographic Background

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

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

[1] BaYaka surveyed in the present study are most closely related to the Mbendjele BaYaka (Lewis 2002)

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

Methods

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

Sample

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

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

Adolescent Interviews

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

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

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

Peer Rankings

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

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

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

Demographic Data

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

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

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

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

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

Analysis

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

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

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

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

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

Results

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

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

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

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

All model results can be found in Table 5. A comparison of WAICs suggest that while both Models 2 (*accessibility*) and 5 (*full model*) were comparable in their fit to the data, Model 5 had the lowest WAIC. Thus, we expand on the results from the latter model. In support of H_1, kinship relationship was a strong predictor for nominations, with adolescents

16.68 times more likely to nominate fathers/siblings and 7.16 times more likely to nominate other kin, when compared to non-kin. Note that with fewer observations of father/sibling dyads, CIs for this kinship category are large (Figure 2). In support of H_2, inter-household distance was a strong predictor for nomination, with adolescents 1.87 times less likely to nominate an adult as a preferred model with every standard deviation (45.06m) increase in distance between their households (Figure 3). H_3 was not supported; adolescents were only 1.08 times more likely to nominate an adult as a preferred model with every standard deviation increase in peer ranked teaching skill. There was weak (i.e. 95%CI crossed 0) support for H_4; hunting skill was a positive predictor for nomination, with adolescents 1.28 times more likely to nominate an adult as a preferred model with every standard deviation increase in their peer ranked spear hunting skill. Figures 2 and 3 show that while CIs for spear hunting skill are wide, being a highly ranked spear hunter increases the probability of nomination for close kin and neighbors. There was weak support for H_5; BMI was a positive predictor for nomination, with adolescents 1.33 times more likely to nominate an adult as a preferred model with every standard deviation increase in their BMI. Contrary to H_6, adult age was a negative and weak predictor for nomination, with adolescents 1.25 times less likely to nominate an adult as a preferred model with every standard deviation increase in their age. Contrary to H_7, adult prestige was a negative and weak predictor for nomination, with adolescents 1.50 times less likely to nominate a prestigious vs. non-prestigious adult as a preferred model. We also note wide CIs associated with the effect of low and high prestige on the probability of nomination (Figure S3). While the data were sparse (63 nominations for 1081 dyads), our results are supported by additional analyses (Tables S4-5).

Discussion

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

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

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

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

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

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

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

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

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687 approved of the final version of the manuscript.
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692 **Tables**
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Table 1. Questions asked in the peer ranking task, and inter-rater reliability.

Attribute	Question: Of all the people you see here…	Cronbach's ∝
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^2	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
Total	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

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.

	Model 1 Intercept-only	*Model 2* Access	*Model 3* Direct success	*Model 4* Indirect success	*Model 5* Full model
Intercept	**-2.92 (-3.40, -2.54)**	**-3.52 (-4.07, -3.08)**	**-2.96 (-3.42, -2.57)**	**-3.09 (-3.56, -2.68)**	**-3.57 (-4.15, -3.05)**
Father/Sibling	--	**3.45 (2.42, 4.56)**	--	--	**3.47 (2.37, 4.60)**
Other kin	--	**2.13 (1.44, 2.82)**	--	--	**2.17 (1.45, 2.88)**
Household distance[1]	--	**-0.62 (-0.95, -0.31)**	--	--	**-0.65 (-0.98, -0.32)**
Model Teacher skill[1]	--	--	0.03 (-0.40, 0.44)	--	0.07 (-0.46, 0.60)
Model Spear skill[1]	--	--	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[1]	--	--	--	0.04 (-0.30, 0.38)	-0.24 (-0.75, 0.25)
Model BMI[1]	--	--	--	**0.44 (0.15, 0.76)**	0.29 (-0.04, 0.65)
$\sigma^2_{learner}$	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)
σ^2_{model}	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

Figures

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

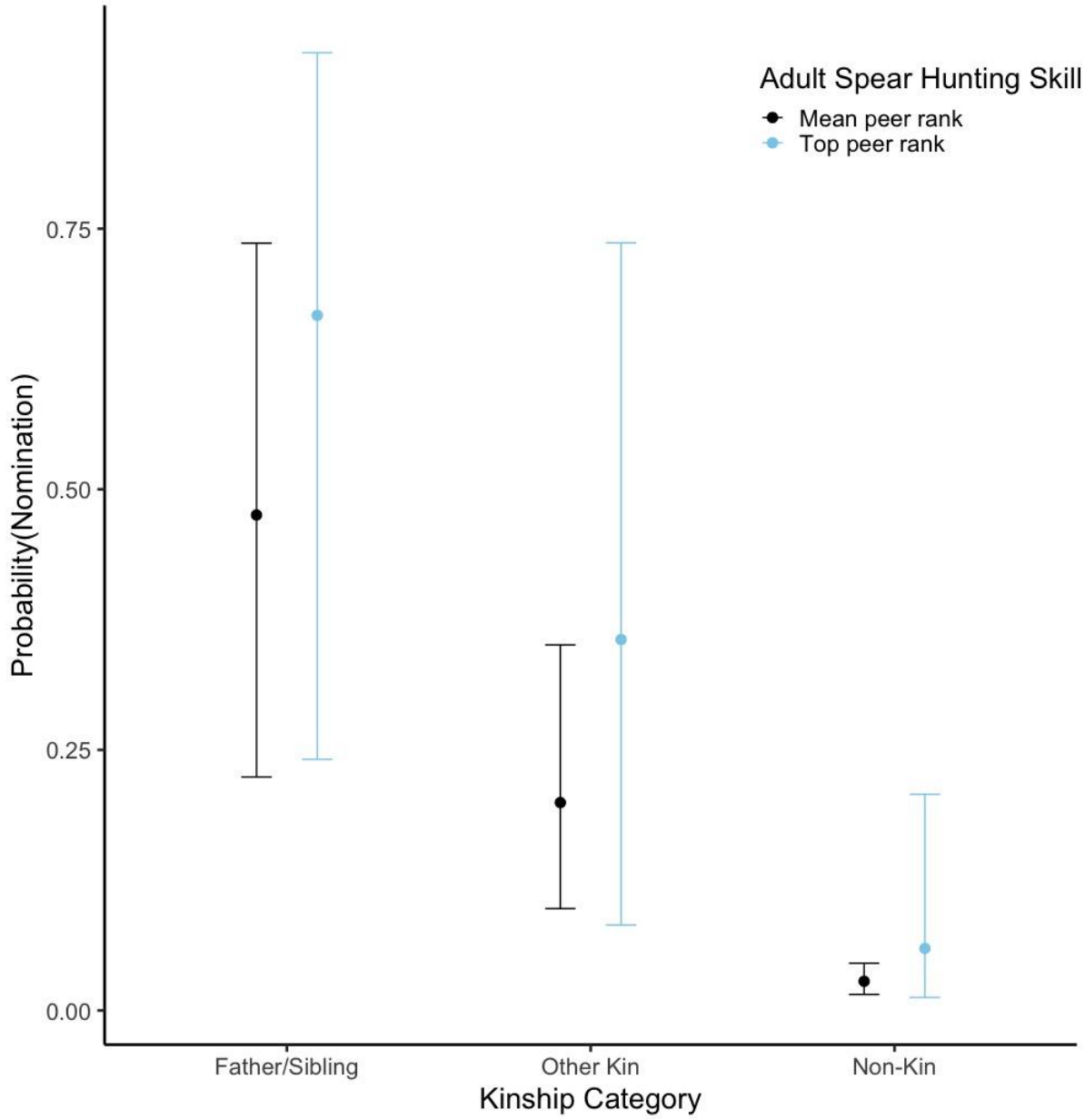

Figure 2. Predictions from Model 5 showing the effect of adolescent-adult kinship relationship on the probability of an adolescent nominating an adult as a preferred spear hunting model. Predictions in black are for adults whose peer ranked spear hunting skill is at the sample mean (0.1). Predictions 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 95th percentile Credible Intervals.

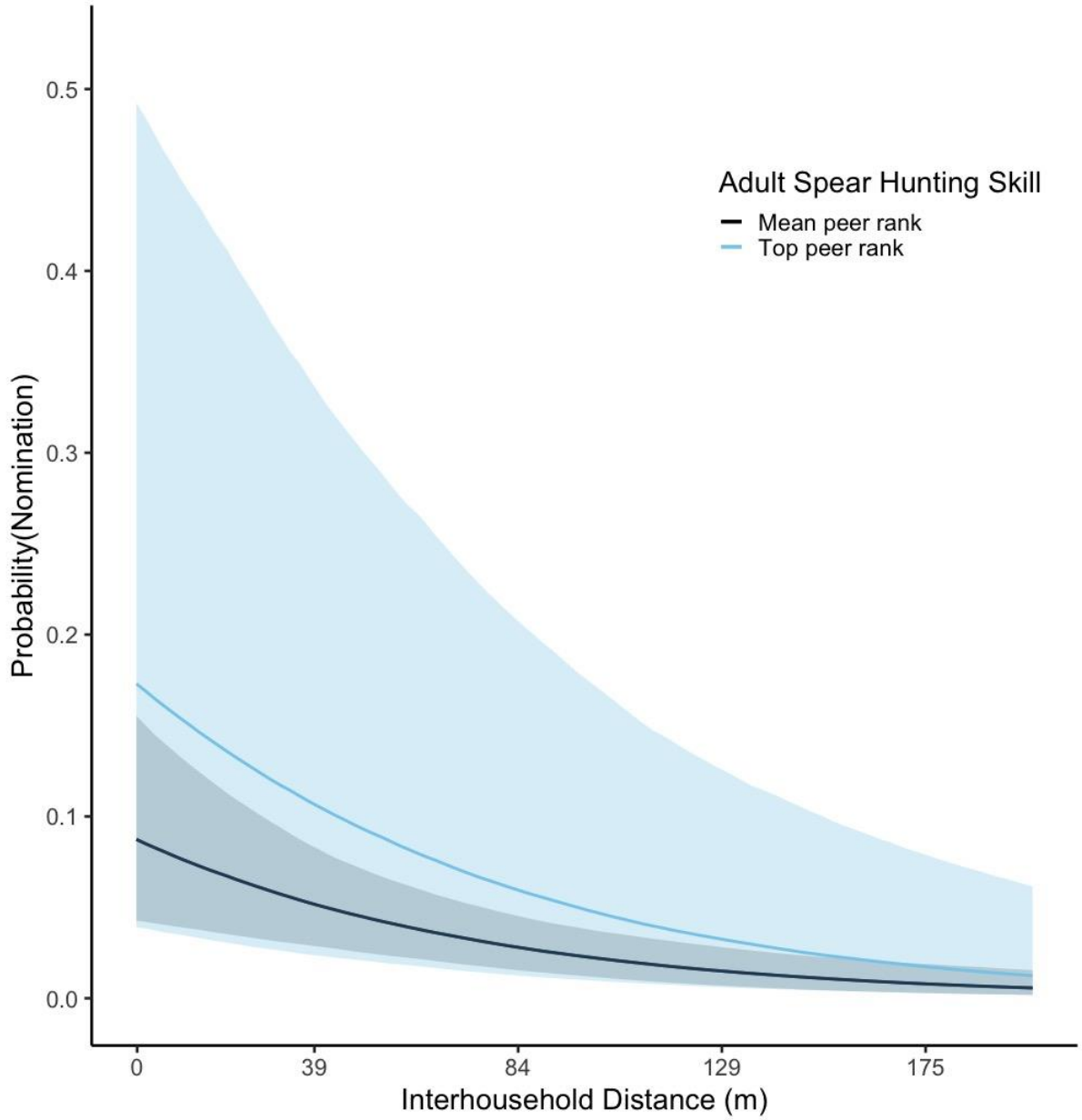

Figure 3. Predictions from Model 5 showing the effect of adolescent-adult interhousehold distance on the probability of an adolescent nominating an adult as a preferred spear hunting model. Predictions in black are for adults whose peer ranked spear hunting skill is at the sample mean (0.1). Predictions 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 95th percentile Credible Intervals.