

Social learning across the life cycle: cultural knowledge acquisition for honey collection among the Jenu Kuruba, India[☆]

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Abstract

Accounting for age-dependent patterns of knowledge transmission is critical for understanding cultural evolution in age-structured populations. Cultural evolution theory predicts which social learning biases we expect people to use, but much less often when—during a person's life cycle—different social learning biases will be used. By measuring knowledge and skill variation among age cohorts, it is possible to infer how people socially acquire different types of knowledge at different ages. We use this strategy among the Jenu Kuruba, a tribal community in South India. We document the accumulation of local knowledge required for collecting wild honey among 71 children and 125 adults from five communities. Combining quantitative measurements of knowledge with measures of four honey-collecting skills and self-reported data on learning age, we infer patterns of social learning across the lifecycle. We find that (1) most knowledge related to honey collecting is acquired by the early 20s, and later social learning mainly functions to update information; (2) the eldest cohort has the highest average explicit knowledge, although the most knowledgeable or skilled individuals do not always belong to the most elderly cohort; (3) length of learning can be affected by age-dependent trade-offs of costs and benefits to learners; and (4) children tend to learn from parents, but individuals use other demonstrators later in life. These results have implications for current models of cultural evolution.

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1. Introduction

Humans are characterized by our unique penchant for cumulative cultural evolution and the consequent adaptations for social learning like psychological learning heuristics and an extended juvenile period (Bogin, 2001; Boyd & Richerson, 1985; Kaplan et al., 2000). Overlapping generations in human populations are the key to a social structure which can promote such a successful system of nongenetic information inheritance. Because the right measure of fitness in age-structured populations is not simply reproductive

success, but rather comparison to the success of current and previous age cohorts (Schaffer, 1974), we expect individuals to optimize the timing of learning for different domains of knowledge acquired during the life cycle. Additionally, any behavior dependent on adaptations to different points in the life cycle results in a phenotype that reflects a combination of evolutionary forces (Ozgul et al., 2009). Since knowledge is age relevant, the age structure of a population will influence the cultural demonstrators and information available to naive individuals and the efficiency of various learning pathways as they age. Different learning pathways have consequences for the transmission of knowledge and its rate of change over time (Boyd & Richerson, 1985).

Age-dependent patterns of knowledge acquisition are not taken into account in current models of cultural evolution, and there is a shortage of empirical data, especially from non-Western populations. Carotenuto, Feldman, and Cavalli-Sforza (1989) produced an unpublished working

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paper on age-structured transmission and found that a greater number of age groups lead to stronger effects of nonparental transmission. Cavalli-Sforza and Feldman (1981) infer elements of age structure with their vertical–horizontal–oblique terminology, but most social learning models do not make assumptions, less so predictions, about age structure and timing of learning. They average across the development of adult beliefs with probability statements (Boyd & Richerson, 1985; Cavalli-Sforza & Feldman, 1981; Henrich, 2009; McElreath, 2004). And while valuable, more general theories about the timing of learning in the life cycle, such as embodied capital, fall short of testing the effects of age structure on cultural transmission because they cannot predict specific learning pathways, only that learning will occur during certain periods.

Empirically, knowledge about the effects of the life cycle on cultural transmission is piecemeal. Previous research has shown that children know a lot about the identity, behavior, and location of animals in their habitat before adolescence (Lee, 1979; McDonald, 2007; van Beek, 1987). In contrast, hunting skill has been observed to peak around the age of 40 (Gurven et al., 2006; MacDonald, 2007; Walker et al., 2002). Some researchers have documented learning periods after which individuals have greater difficulty acquiring skills (Hannon & Trehub, 2007; Oyama, 1976; Omaghari & Berkes, 1997). Aunger (2000) looks at the acquisition of food taboos across the life cycle and finds that parents are important demonstrators mainly at early ages. Peers become more important at later ages, and different categories of demonstrators are emphasized for different skills (Aunger, 2000; Hewlett & Cavalli-Sforza, 1986; Hewlett et al., 2011).

Our study attempts to connect social learning pathways with patterns of knowledge acquisition across the life cycle to tie the population-level evolution of a body of knowledge to the mechanisms that transmit that knowledge between individuals of different ages. We present data from empirical work with the Jenu Kuruba, a tribal group living in the state-protected reserve forests of Karnataka, South India. The Jenu Kuruba pursue a mixed strategy of foraging and wage labor and are experts in wild honey collection (Misra, 1975). Our sample of individuals aged 6–65+ years participated in (1) a multidimension interview about their honey-collecting knowledge and social learning experiences and (2) practical measures of honey-collecting skills to demonstrate knowledge and skill not easily verbalized, like tree climbing. By combining quantitative measures of local ecological knowledge associated with honey collecting with self-reports of social learning patterns, we infer age-dependent transmission pathways at different stages in the life cycle. We expect patterns of physical development to condition learning patterns, and we expect to see differences for explicit and tacit knowledge. Similarly, as individuals age, we expect that changes in social context affect transmission pathways with changes in cultural settings (Whiting, 1980). Finally,

we expect that age can affect length of learning and accuracy of knowledge.

2. Background

Researchers suggest that the greatly lengthened adolescence period in our life history is meant for cultural learning so individuals can acquire the skills and knowledge needed to live in a great diversity of habitats with an intensely complex social order (Bogin, 2001; Kaplan et al., 2000). Social learning streamlines the interpersonal transmission of knowledge and skills required to exploit a local ecology—saving time and effort over pure individual learning (Boyd & Richerson, 1985). Because humans can acquire information from individuals other than parents, we can access a cumulative, evolved body of knowledge (McElreath, 2010). Cultural transmission balances the costs of access to demonstrators and potentially unreliable information with the benefits of a greater sample size and intragenerational transmission (Richerson & Boyd, 2005). Learning from kin can reduce learning costs, but copying nonrelatives increases the potential for sampling adaptive cultural variants (Henrich & Boyd, 2002; Richerson & Boyd, 2005; Henrich & Boyd, 1998).

Training in economic activities can be age, gender, sequence, location, and teacher specific (Ruddle & Chesterfield, 1977; Ruddle, 1993). Among the Tsimane', children's ethnobotanical knowledge is positively associated with age (Martinez-Rodriguez, 2009). In the Orionoco delta of Venezuela, tasks are taught sequentially—age, strength, skill, and experience determine advancement to successive levels (Ruddle & Chesterfield, 1977). For example, explicit knowledge which can be verbalized—like naming bees in the forest—might be learned before tacit knowledge which cannot be verbalized—how to cut honey combs (Nonaka, 1998). MacDonald (2007) provides a cross-cultural review of the acquisition of hunting skills across the life cycle. Children begin practicing hunting skills at around age 5–6, mostly with their fathers. They start participating in hunting activities at around puberty, usually with older kin. Experience, skill, and rates of return seem to peak at around 40 years of age. Learning hunting skills occurs throughout the life cycle, and MacDonald concludes that, “a wide range of people are involved in different parts of a child's hunting education, and there is considerable variation from group to group in the people concerned” (MacDonald, 2007: 397). Because theoretical development of this topic is nascent, we begin with an exploratory analysis of field data.

3. Study site

We collected data from an indigenous population of honey collectors living in a dry deciduous forest in the Western Ghats of South India. The Jenu Kuruba are a small-

scale society who supplement wage labor on local coffee estates with the sale of minor forest products, including honey collected from two wild honey bee species. Classified as a Scheduled Tribe, the Jenu Kuruba number about 30,000 and mostly live in the district of Kodagu, Karnataka state (Census of India, 2001). They are nominally Hindu, patrilineal, and monogamous with a flexible preference for cross-cousin marriage (Mutharayappa, 1993). Historically, honey collecting has been an important spiritual and economic activity for the Jenu Kuruba—whose name translates as honey collectors in Kannada (Richter, 1870; Misra, 1975; Singh, 1994). Nowadays, Jenu Kuruba can sell honey for about US\$2 a liter to local shops or to the Large scale Adivasi Multi-Purpose Society (LAMPS), a cooperative funded by the state government.

We collected data on ecological knowledge and skills needed for collecting wild honey in a cluster of five villages located inside the Reserve (state controlled) forest. A full account of the village and household organization would be out of the scope of the paper, but we detail here the basic elements that will help putting the results in perspective. The villages contain 26 households on average and are spaced 1–2 km from one another in a star-shaped pattern, with a school as one of the points. The two large villages average a population of 161 individuals, and the three smaller villages average 49 individuals. The public school located in the forest is free for Jenu Kuruba children (first to seventh standard, ~6–13 years of age). Households generally have at least a small garden space separating them, but kin groups sometimes form clusters of two or three houses with a shared patio for related nuclear families. Fig. 1 shows the age structure of the Jenu Kuruba population living in the villages where we collected data. Currently, none of the villages have access to electricity or running water. During the rainy season, two are unreachable except by foot. The Karnataka

Forest Department has jurisdiction over the Reserve Forest and resents efforts of the Jenu Kuruba to take advantage of forest products, even after the passage of the Forest Rights (Restitution) Act in 2006 which allows the Jenu K-uruba to legally extract honey, tree moss, and other nontimber forest products for consumption and sale.

According to our ethnographic observations, children begin learning about honey collecting between 6 and 8 years of age, when they are old enough to accompany friends and older siblings into the forest during play or tag along after adults on honey-collecting trips. Younger children are kept near the household and play within the confines of the village. At around 6 years of age, they start learning skills like climbing trees, and many begin collecting some easily accessible honey for personal consumption. The two smallest bee species, nasarajenu (*Trigona* spp.; stingless bee) and koljenu (*Apis florea*), make their hives in tree branches and bamboo stands that can be found on the outskirts of the village, some of which children can access for the small amount of honey inside. By the age of 10–12 years, girls no longer play away from the household, and boys begin to collect honey from the next largest bee species—thudujejenu (*Apis cerana*, which resembles the Western honey bee). Around this age, the boys also start accompanying older relatives and friends to collect thudujejenu.

After their strength has increased and limbs have lengthened, at around the age of 18 years, the boys begin collecting hejjenu—honey from the large Asian bee (*Apis dorsata*). Because hives are located on exposed tree limbs or rocks often more than 40 m above the ground and because there can be a large quantity of honey, men usually collect hejjenu in groups of three to eight people. They divide the labor into various jobs such as cutting the honey comb, holding a basket to catch the honey, and making smoky torches to subdue the bees. Smoke is necessary to collect any kind of honey because it reduces stings, but special torches are made to collect hejjenu because they must produce continuous and heavy smoke when hoisted into the tree to protect the individual cutting the honey combs. Various assistants help where needed, and honey is divided evenly between all present at a collection event reflecting a cooperative atmosphere. Honey-collecting songs are traditionally sung before and during a honey-collecting event for the largest honey bee to ensure success and pacify the bees. These songs are sung together as a group and are an easily measured aspect of ritualistic honey-collecting knowledge. Groups often collect at night when the honey bees are less aggressive. Between the ages of 40 and 50 years, men usually stop collecting honey, but some continue to go on collecting trips as advisors.

Social influences and a culturally constructed environment can affect variation in individual learning. Schooling, for example, is often cited as having negative effects on local ecological knowledge acquisition, although the results are mixed and vary between locations (Reyes-García et al., 2010). Jenu Kuruba children in these villages

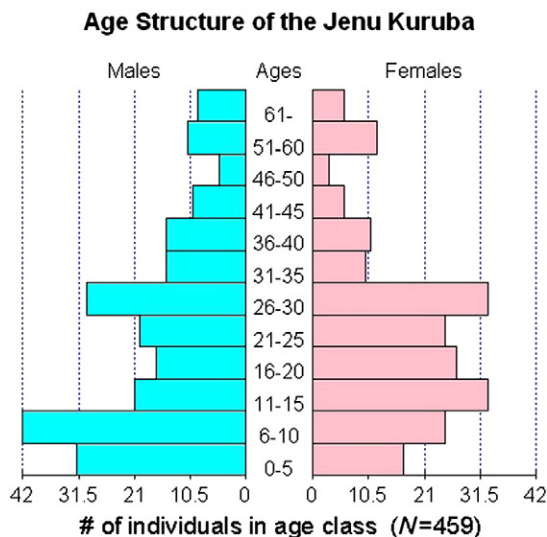


Fig. 1. Age structure from census data of the five study villages.

begin attending school between the ages of 6 and 7 years, and 92% of the boys and girls in our sample had at least 1 year of schooling. Most children attend school 6 days a week until they approach the age of 15 years, when they can begin working on the coffee estates. Additionally, gender roles prohibit females from collecting honey once they begin to approach puberty. Caste does not affect variation in individuals' learning patterns because everyone in this population is of the same tribe; being a member of a forest-dwelling Scheduled Tribe allows continued access to the forest and honey collecting. Even so, while every man has the opportunity to learn to collect honey, not all learn this skill, and most skew a mixed economic strategy towards wage labor or cultivation to supplement seasonal collection of forest products. Many dilettantes in honey collection will still forage opportunistically or accompany others for social purposes. Bragging about ability is neither encouraged nor discouraged; more data are needed to conclude whether or not this behavior could be considered costly signaling.

4. Methods

Research was conducted from January to December 2009 and included an ethnographic and an interview phase. K.D. spent 9 months completing ethnographic research on honey collecting (including in-depth interviews and participant observation). We visited 28 villages to choose a location that had an appropriate size, was located inside a reserve forest where individuals were allowed to collect honey, and contained enough villages close together for an intersite comparison. We visited the LAMPS office and several non-governmental organizations which buy and distribute the honey sold by the Jenu Kuruba. We timed the ethnographic research to occur during the major honey season just before the monsoon and conducted our interviews and skills tests during the minor honey season at the beginning of the dry season. We pre-tested interview questions with an independent sample to ensure two-way understanding. The multi-dimensional interview included three sections: (a) Explicit knowledge, (b) Social learning, and (c) Sociodemographic characteristics, namely, age. To this, we added skills tests to gauge individuals' tacit knowledge. Data collection was helped by translators fluent in Kannada and English. The English translation of the interview questions is available in the supplemental material.

4.1. Sample

We conducted interviews about honey-collecting knowledge with 196 individuals from a cluster of five villages. We included ~90% of adult males who had collected honey ($n=91$) and boys ($6 < \text{age} < 16$ years; $n=56$) in the villages, as well as a random sample of 25% of the women and girls ($n=34$ and $n=15$, respectively). Since gender roles prevent women from participating in honey collection,

knowledge scores from women and girls were included to create a baseline from which to compare the different age cohorts of males. This enables us to make inferences about knowledge acquisition across the life cycle using a cross-sectional data set. Except where noted, all data analysis is done for males only.

4.2. Explicit knowledge for honey collection

The questions for the interviews were designed to assess a variety of types of knowledge regarding bees and honey from a range of respondent ages. We divided responses into two categories of explicit knowledge which individuals could verbally express about bees and honey: bee ecology and medicinal knowledge. Each response was coded as 1 or 0, right or wrong, depending on the ecological and cultural information collected during the ethnographic phase. We combined these measures to create a theoretical knowledge score with a maximum of 14 points. Interviews occurred in a private setting, with every attempt made to interview the informant alone.

4.2.1. Bee ecology

This part of the interview included a free listing (Puri, 2011) of types of honey bees in the forest (up to four species), two multiple-choice questions about which plants the bees prefer to forage from, and seven open-ended questions on bee behavior and hive composition.

4.2.2. Medicinal knowledge

We also asked people for a recipe for a medicine made with honey that would cure a cough or cold. We scored responses by evaluating answers as correct (1 point) when the response given reflected an agreement with the rest of the community on a "correct" recipe.

4.3. Social learning

At the end of the interview, we asked at what age the informant first learned each skill listed in the tacit knowledge section below, at what age they mastered it, how they learned it, and from whom they learned it. Skill mastery is roughly defined by community members as being very good at something. To ensure two-way understanding, we pre-tested this set of questions with 14 individuals from five villages outside our sample, and we began this section of the interview with a throw-away question about a ubiquitously familiar activity (cooking rice) to introduce the response structure. Categories for demonstrators for social learning were developed from free response answers to the question "How did you learn this skill?" Individuals responded in three categories: learned themselves, observed, or were taught. If they responded as observed or taught, we asked from whom. We were unable at this time to cross-check learning patterns between learner and teacher.

4.4. Age

We determined ages through self-reports from adults combined with school records and genealogical data. Because there may be some remaining errors or biases in this information, we also analyzed the data by age cohorts. We distinguished adults as being 16 years of age or older, at which time individuals begin to take on adult roles such as marriage and self-support.

4.5. Tacit knowledge for honey collection

To measure tacit knowledge, we scored people's performance during a day of competitions—a sort of “Jenu Kuruba olympics”—of skills necessary for a successful honey-collecting event. We invited all people in the sample to climb a tree and to make a torch. We used self-reports of skill level for two skills difficult to test in situ: cutting honey combs and singing honey-collecting songs.

4.5.1. Tree climbing

For the tree-climbing competitions, we used two different trees: one for men and one for boys. For safety reasons, we limited the height of the trees to 12 m for men and 9 m for boys. The men's tree was about 60 cm in diameter at the base with smooth bark, and the boy's tree was about 25 cm in diameter at the base with rough bark; both were straight with no branches. We measured total height achieved and round-trip climbing time.

4.5.2. Smoky torch

Sticks and leaves from a single plant species were made available to construct torches in a common area under the observation of a research assistant. Individuals were not given any limitation in the length or girth of their torch and had to construct their torch without help or instruction. The research assistant, a French ecologist, ranked each torch on a scale of 1 to 10 when the owner decided it was at the smokiest (1=no smoke, 10=completely opaque).

4.5.3. Cutting honey combs

We were unable to test cutting the honey combs because it was impossible to achieve uniformity or ensure safety, so we used the information gathered in the interview. We validated responses on age at learning with reports on age of honey-collecting experiences previously reported.

4.5.4. Singing the honey song

We asked people if they knew a song, and then prompted them to recall as much as they could. If they could recall at least one line of a song, we coded them as possessing the knowledge.

4.6. Data analysis

We summed the two measures of explicit knowledge into a single score, which we plot against age (Fig. 2). We compared Akaike Information Criterion (AIC) weights between the candidate models of monotonically increasing

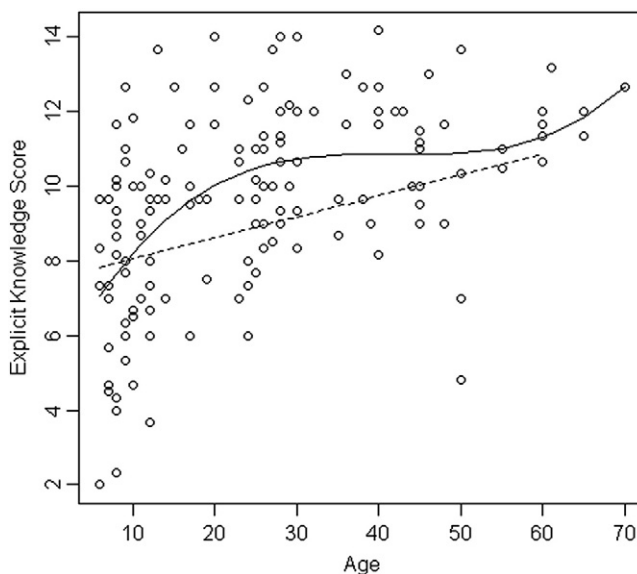


Fig. 2. Explicit knowledge score for males, including all boys aged 6–15 years and adults 16 years and older who have reported honey-collecting experience ($n=147$). The solid line represents a cubic polynomial for male knowledge scores across age. The dashed line represents a spline of female knowledge scores (points not plotted here $n=39$).

functions, and linear, quadratic, and cubic polynomials (Akaike, 1975). AIC estimates the distance between each candidate model to the pattern underlying the data, while correcting for overfitting, which allows us to choose the shape of the linear model that best explains the trend in the data (Anderson et al., 2000).

In Fig. 3, we show the trend of age by height achieved in climbing trees. Because the potential of some climbers was censored due to the imposed height limit, we used a Gibbs sampler algorithm (Geman & Geman, 1984) to infer the actual potential of those who might have climbed higher than measured. The real, positive relationship between climbing height and time, including error, allows us to use a Seemingly Unrelated Regressions model to infer what the climbers who reached the limit could have done. Using the uncensored data to impute the censored heights thousands of times, each time updating the model, we can estimate the potential heights of the censored individuals. The estimates we report are summary statistics based on 10,000 realizations from the posterior distribution generated by the Gibbs sampler using a burn-in period of 2000. We used a vague prior for the regression coefficients with mean zero and a covariance matrix of 100 times the identity matrix and an inverse Wishart for the error variance covariance matrix.

In Fig. 4, we present comparisons of ages reported at first learning a skill and at which the informant reported mastering the skill. Results for social learning patterns are displayed in the mosaic plots in Fig. 5 with sample sizes. Column widths reflect number of informants who report social learning for each category. Very narrow columns

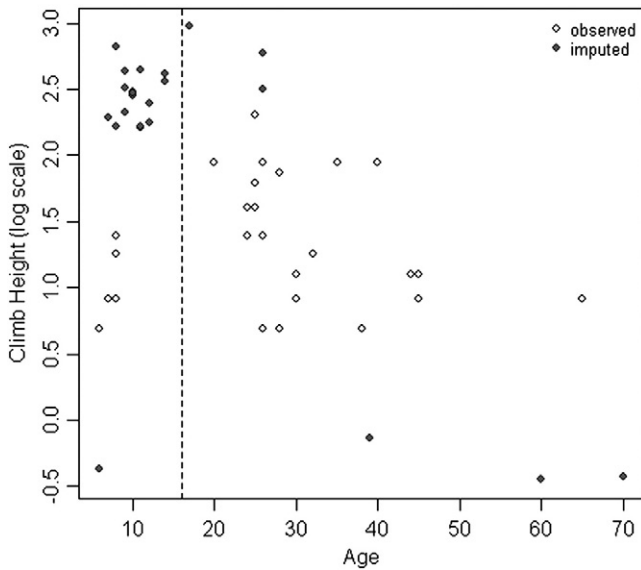


Fig. 3. A plot of tree-climbing ability, recorded as maximum height achieved by age ($n=66$). Points representing boys (ages 6–15 years) are left of the dashed line, and points representing men (16+ years) are right of the dashed line. Black dots represent imputed heights because these individuals reached the height limit for their tree. Black dots below zero are individuals who tried to climb, but achieved no height. Data were analyzed on the log scale.

may represent a sampling bias, as the limited number of individuals who learned in that cohort might not reflect the true variability.

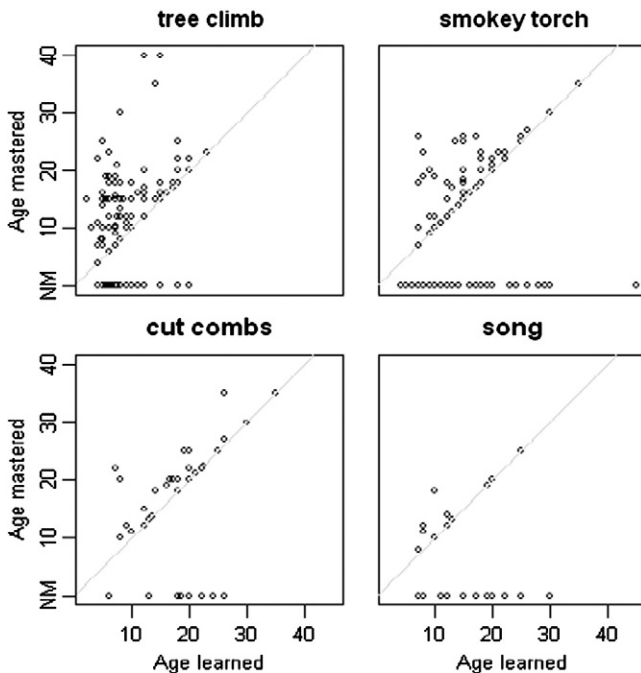


Fig. 4. Comparisons between reported age at first learning a skill and reported age of mastering that skill. The bisecting gray midline represents where age of learning and age of mastery are equal—the greater the distance between a point and the midline, the greater disparity between age at first learning and at mastery. Points along the x-axis represent individuals who report learning the skill, but never mastered it (NM).

4.7. Potential biases

We acknowledge that measures of knowledge and skills collected in different ways might make it hard to compare between categories for some of our analyses. We also recognize that our measurement instruments do not have enough precision to capture more subtle variations in specialized knowledge. For example, we were able to separate good smoky torches from poor ones using a rough scale of opacity, but were unable to distinguish finer variation in craftsmanship. We hope to improve this method in the future. We also wish to confirm informants’ reported learning patterns and skill level with third-party emic data. Data collection time did not permit cross-checking responses about learning patterns or degree of mastery, although we included several questions in the multidimensional interview that would ensure internal consistency within informants.

5. Results

5.1. Age variation in knowledge acquisition

Each type of knowledge or skill has a private learning trajectory across age cohorts. In Table 1, we list the percentage of the age cohort that demonstrates explicit knowledge or self-reports the tacit knowledge learned. Contrary to expectations, explicit knowledge (bee ecology and medicinal use) does not appear to be learned in earlier age cohorts than tacit knowledge (tree climbing, torch making, cut honeycombs, singing a song). For instance, tree climbing and medicinal use both appear to peak in the late 20s at 100% and 92%, respectively.

Explicit knowledge by age shows an s-shaped upward trend (Fig. 2). Among men, we observe a general increase across cohorts between the ages of 10 and 40 years. After middle age, knowledge acquisition levels off to the baseline—calculated by a spline representing women’s knowledge by age. The maximum distance between explicit knowledge scores and the baseline occurs during the mid-30s, although average knowledge reaches a maximum in the eldest age cohort. We were surprised to see a constant increase in women’s explicit knowledge with age. We are fairly certain that cohort affects are not responsible for this. Since women have never specialized in honey collecting, we find it hard to believe that older women would have greater knowledge because they learned to collect honey in the past.

The nearly empty lower right quadrant of Fig. 2 is partly due to a reduction in variance with age. We tested three models to the data in Fig. 2, with the result that an increasing cubic polynomial which accounts for a reduction in variance by age provides the best fit. This reduction in variance across the life cycle is observed for all our measures and derives from individuals on the lower end of the spectrum scoring higher with age and individuals on the higher end of the spectrum scoring slightly lower.

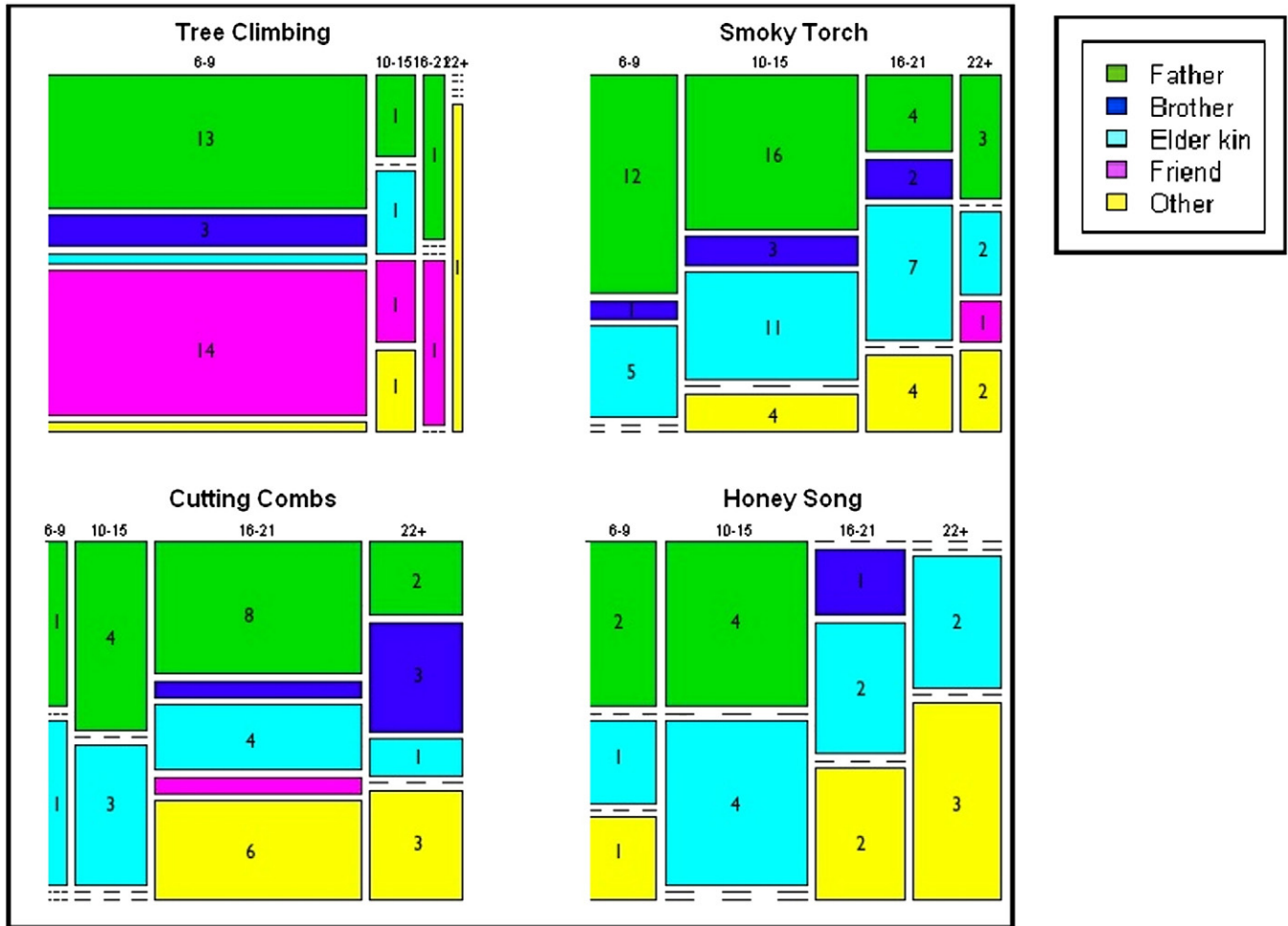


Fig. 5. Mosaic plots representing comparisons between social learning strategies for different skills by age cohort. Sample sizes marked for each category; a dashed line indicates zero responses; present but not labeled had one response.

Fig. 3 compares age with height climbed in the tree-climbing competition. The peak at around age 20 years is most likely understated because the men’s tree was much more difficult to climb than the boys’ tree, essentially handicapping the young men’s climbing. We fit several curvilinear models to this data set, with limited success. There is a strong positive trend for boys and a negative trend for men. But a small sample size ($n=66$) and clustering of points at some ages mean we cannot distinguish these two trends from the noise with statistical confidence.

We also measured an individual’s ability to make a smoky torch. Unlike tree climbing, this type of tacit knowledge is not strength dependent and shows a linear trend positively associated with age when comparing linear and quadratic models for a binomial regression (not displayed here).

5.2. Length of learning and time to mastery

The graphs in Fig. 4 suggest an age-dependent lag between first learning and mastering for some honey-

Table 1
 Percentage of males in each age cohort who demonstrated or reported the knowledge listed ($n=147$)

Domain of knowledge	Age group (years)						Adult average
	6–10 ($n=37$)	11–15 ($n=18$)	16–23 ($n=15$)	24–32 ($n=35$)	33–49 ($n=25$)	50+ ($n=17$)	
Bee ecology	63%	70%	81%	86%	92%	86%	86%
Medicinal use	38%	61%	41%	92%	73%	85%	73%
Tree climbing	84%	88%	93%	100%	92%	83%	92%
Smoky torch	22%	71%	73%	89%	88%	83%	83%
Cut honeycombs	3%	0%	33%	64%	65%	67%	57%
Honey song	5%	18%	13%	25%	19%	28%	21%

collecting skills. Cutting the honey combs has the oldest average age of learning because it is sequentially dependent on learning to climb trees. Once learned, it is quickly mastered though, as we can see by the closeness of the data points to the midline. Learning to sing the honey song shows the same trend. However, time between learning and mastery of tree climbing and torch making decreases as individuals get older. This can be seen by the triangular shape of data points above the midline for tree climbing and smoky torch. Skills also vary in the proportion of people who report mastering them once they have started learning: 73% of learners master tree climbing, 64% master making smoky torches, 77% master cutting honey combs, and 54% master singing a honey song. Upon a reviewer request, we examined characteristics which might correlate with degree of mastery. We found that the number of individuals reporting mastery across all skills increased when they report at least one honey-collecting experience.

5.3. Age variation in social learning patterns

Sources of social learning vary across skills and age cohorts, as seen in Fig. 5. Each graph represents a different honey-collecting skill, where columns are divided by age cohorts, and the different shades reflect the relation to the person from whom the skill was reportedly learned. For tree climbing, the column for 6–9 years old is widest because most individuals report learning at these ages. Only one person reportedly learned after the age of 22 years. For making the smoky torch, ages 10–15 years appear to be most common for social learning; for cutting honey combs, it is 16–21 years. Learning the honey song is fairly evenly distributed across age cohorts.

Across the life cycle, fathers decrease in importance (though most knowledge is acquired at young ages, as we have seen above). The role of brothers varies widely depending on the skill. Between the ages of 10 and 21 years, elder kin become important. Friends seem to be important mainly for learning tree climbing, with many children reporting learning through playing a tree-climbing game. “Other” individuals become increasingly important as men age, and this is dominated by individuals reporting learning from a successful person but also includes co-workers teaching tree climbing.

6. Discussion

We find that social learning patterns are a function of age and vary across the life cycle by type of knowledge. Learning at different ages entails different physical and social costs and benefits. Traits for social learning have been previously regarded as adaptive during a snapshot of adulthood, but considering interactions of evolutionary forces across the life span brings a new perspective on social learning patterns. Because very little is known about

age-structured social learning, we begin by describing learning patterns for different types of knowledge and skills at different ages. We then explore the consequences for social learning and cultural transmission strategies dependent on these patterns.

Our first finding is that, in the studied population, most of the basic honey-collecting knowledge is gained by the early 20s. Across all honey-collecting skills, very few people learned or mastered a skill after the age of 30 years, and none after 40 years. This is most abrupt for learning to climb trees—no one who collects honey learned tree climbing after the age of 26 years. Finite practice time and limited observational opportunities mean that individuals who forgo learning at young ages might never make up that deficit later in life. Other researchers have observed that attending school during childhood can affect the quantity and quality of ecological knowledge among students (Atran, Medin, & Ross, 2004; Reyes-García et al., 2010; Sternberg et al., 2001). Ohmagari and Berkes (1997) found that girls who spend diminished time in the bush and who do not learn traditional knowledge between 13 and 15 years of age have difficulty acquiring it later in life. It appears that something akin to a sensitive learning period might be occurring here—either culturally or psychologically. There is some evidence that the phase of adolescence functions as a period for cultural learning and that individuals might be less able or motivated to acquire new skills, knowledge, and belief once they reach their 20s (Bogin, 2001). If learning slows once individuals reach adulthood, future opportunities for cultural acquisition are pruned down through canalization and specialization.

Among the Jenu Kuruba, tree-climbing ability increases sharply to peak in the early 20s and then decreases gradually as men age. This is due to changes in physiology and temperament and contributes to a decrease in new learners after this age; older individuals are no longer as fit or as risk prone as the younger men. One 25-year-old honey collector told us that he is “the only one crazy enough to climb the big trees to cut the honey combs.” Other researchers have identified a linear increase in ability during young adulthood leading to a peak in skills like hunting around the age of 40 years (Bock, 2005; Gurven et al., 2006). When combining the pattern we observe in Fig. 3 with the positive linear increase with age of other types of knowledge (like making smoky torches), we see a gestalt in overall competence at subsistence activities as has been observed in many other societies.

Our second finding is that the most elderly cohort does not always contain the most knowledgeable individuals, although it can contain the highest average explicit knowledge score. The data here show that one should exercise caution when assuming that elders are a store of expertise for cultural knowledge. In the oldest cohorts, declines in mental and physical abilities probably contribute to the decline in maximum knowledge scores as individuals age. Also conceivably, the elder cohort may be less knowledgeable

due to a sampling bias of individuals who have survived to old age, for reasons uncorrelated with the domains of knowledge we were testing. And as much as we try to account for cohort effects, there may have been a greater emphasis on learning honey-collecting skills in the past. Even so, these processes generate variation between cohorts, which is why it is essential to understand the effects of age structure and learning between overlapping generations.

Some authors have argued against cultural evolutionary theory as a model of information inheritance because social learning can be error prone and particles of cultural knowledge might lack fidelity of transmission (Dawkins, 1982). While some social learning patterns, like conforming to the majority, can solve the problem of error-prone transmission (Henrich & Boyd, 2002), we also observe here that variation in amount of knowledge is reduced in older age cohorts across all of the knowledge domains we examine. Learning can be a repetitive process, as individuals correct previous transmission errors to improve their knowledge base throughout the life cycle. The linear increase in female honey-collecting knowledge with age (Fig. 2) leads us to think that costs of learning have heretofore underspecified life cycle effects. The percentage of knowledgeable individuals generally plateaus in the age cohorts following the mid-20s.

Our third finding is that people make a trade-off between age and duration of learning for some skills. We have found it useful to structure our thinking about aging and its affect on cultural transmission in three ways: (1) ability, (2) location, and (3) previous experiences. Mental and physical maturity occurs against a backdrop of developmental organization which sets the context and pace of learning. As children grow, they are physically and mentally able to handle different skill sets and knowledge, some of them based on previously acquired skills and knowledge (Bock, 2002; Feldman & Cavalli-Sforza, 1986; Gurven et al., 2006; Kaplan et al., 2000; MacDonald, 2007). Children acquire almost all of their theoretical knowledge about bees and honey collecting before the age of 12 years, but physically cannot begin to collect hejjenu from the giant honey bee until they are large enough and strong enough. At this point, they are able to learn new skills, such as cutting hejjenu honeycombs. Likewise, Martu children's foraging ability is dependent on height and walking speed, and children will switch to a better type of patch once they can forage efficiently enough to achieve higher rates of return more consistently (Bird and Bleige Bird, 2005).

Location involves the placement of individuals—who is around a learner at different ages, and which cultural demonstrators are available. Location also refers to the setting and context of learning (both of which can be affected by cultural norms) (Whiting, 1980). One must be around bee trees and cultural demonstrators to learn to collect honey. Young boys learn tree climbing mostly from family members and practice with age group peers with whom they spend time playing in the forest. Singing a

honey-collecting song generally only occurs at the site of honey collecting, so learning is delayed until adolescents are included on hejjenu honey-collecting trips. Not only do interactions occur between skills and knowledge acquired at different ages, but other cultural traits and norms structure the setting of social learning opportunities.

Likewise, past experience affects the acquisition of skills and knowledge that requires previous training. The average age for learning to climb trees is earlier than the average age for learning to cut the honey combs. Learning to cut honeycombs is dependent on being able to climb trees. In this case, acquiring a particular cultural trait does not occur in a vacuum. Schniter (2009) observes that, for strength-based skills, those who go on to become experts are young adults who achieve expertise in fewer years after first learning (compared to skill-based knowledge). In our sample, greater mastery of honey-collecting skills correlates with reporting at least one honey-collecting experience. Some individuals may learn a skill, but not devote the practice required to perfect and maintain it. Complex culture might be dependent on specialists to maintain and improve the knowledge for future generations (Henrich, 2004).

The last finding which deserves discussion relates to pathways for the transmission of knowledge. There is a long-running debate about the importance of vertical transmission from parents vs. horizontal transmission from peers vs. oblique transmission from older individuals besides parents (Cavalli-Sforza & Feldman, 1981). Reyes-García et al. (2009) found that, among the Tsimane', skills and knowledge are learned primarily obliquely from older, nonparental models. Auger (2000) by contrast found that parents are important demonstrators for children and adolescents, but later in life, peers are the major source for socially learned information like food taboos. The Aka, Bofi, and Tsimane' also show a heavy reliance on vertical transmission via close kin at young ages and diversify their social learning strategies later on (Hewlett et al., 2011; Schniter, 2009). Language learning in the US occurs along the same lines; early vocabulary and grammar are generally learned from parents, with children updating their lexicon and eventually acquiring their dialect from teenage peers (Eckert 1988, Kerswill 1996).

Different learning pathways should be important in different contexts, depending on information type, environmental stability, and the strength of selection (Strimling & McElreath, 2008). Each skill observed here contains an age cohort more common for learning than the rest, although all age cohorts are represented on each graph. Fathers are generally the most prevalent category of reported teachers, but their importance declines with age of learner. We accept the biases of self-report data towards overrepresenting parents with the caveat that these data contain reports from individuals across many ages, many of whom could be recalling very recent learning experiences. An analysis of variation in learning style (teaching, observation, individual practice) with extensive ethnographic information is

forthcoming (Demps et al., submitted). We observe that vertical transmission from parent to child is important but not dominant (Puri, 1997; MacDonald, 2007). This is probably part of what makes culture adaptive (Richerson & Boyd, 2005). Individuals are motivated to learn from and to teach kin because of inclusive fitness benefits and cost reduction in the learning process, but expanding the sample of potential teachers gives an individual a greater chance of acquiring better or more updated information. Not every father is going to be an expert at making smoke.

The sample size of potential teachers is important to this process. Ritualistic knowledge is generally maintained by a limited number of individuals, and therefore, it is unlikely to be possessed (and therefore taught) by one's parents. Tree climbing shows the opposite pattern. This is the only skill where learning from friends is the predominant category even at young ages. Tacit knowledge like climbing trees must be learnt and practiced on-site, and social learning patterns are reflected by the availability of demonstrators when they encounter the activity site (and therefore a learning opportunity). For the Jenu Kuruba, learning patterns are generally reflected by social groups, but for other societies, learning may be more directed with a father or teacher specifically bringing the naive individual to the site with the intent of teaching (MacDonald, 2007; Ruddle & Chesterfield, 1977).

7. Conclusions

We have included several types of honey-collecting knowledge in our examination of the transmission of this cultural domain with the hope that the patterns we observe can be generalized. There is variation in social learning patterns, and age is an important factor creating that variation. Despite great cross-cultural diversity in socialization, all humans are constrained by the same life-history structure. Age affects what people are able to do, who they are around to learn from, and how accumulated knowledge affects current learning opportunities. Models of knowledge transmission, social learning, and cultural evolution must begin to account for the variability in teaching patterns across ages, across skills, and across cultures for a better understanding of the processes which affect the ebb and flow of knowledge at the population level.

Supplementary Materials

Supplementary data to this article can be found online at doi:10.1016/j.evolhumbehav.2011.12.008.

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