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Cultural transmission of ethnobotanical competence: An empirical analysis from a society of foragers and farmers

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Abstract

Researchers have hypothesized that cultural transmission could occur through at least three different, not mutually exclusive, paths: from parents (vertical), from age-peers (horizontal), and from elders (oblique). In this study, we use data from 313 adults from a forager-horticulturalist society in the Bolivian Amazon to estimate the relative weight of the vertical, horizontal, and oblique paths in the transmission of ethnobotanical competence. We estimated the association between a person's knowledge and skills and the knowledge and skills of a) the person's parents (vertical), b) individuals born ±4 years from the subject's year of birth who spent childhood in the same village (horizontal), and c) individuals from the parental generation (excluding parents) (oblique). We found possitive associations between the subject's knowledge and skills and the knowledge and skills of the parental generation. We also found that the knowledge of age-peers is associated with a person's knowledge (especially among women). We found a weak association between parental skills and a woman's skills. Our results suggest that during adulthood the horizontal and oblique paths might supersede the importance of the vertical path in the transmission of ethnobotanical knowledge and skills.

Key words: Ethnobotanical knowledge, cultural transmission, Tsimane' (Bolivia), oblique transmission.

Introduction

Cultural transmission refers to the process of social reproduction in which the culture's technology, knowledge, behaviors, language, and beliefs are communicated and acquired (Cavalli-Sforza et al 1981; Hewlett et al 1986). Researchers have hypothesized that, unlike biological transmission, which is largely vertical, cultural transmission in pre-industrial settings occurs through at least three distinct, but not mutually exclusive, paths: 1) from parent-to-child (vertical transmission), 2) from any two individuals of the same generation (horizontal transmission), and 3) from non-parental individuals of the parental generation to members of the filial generation (oblique transmission) (Cavalli-Sforza and Feldman 1981).

The modeling of cultural transmission is of great importance for understanding the maintenance, erosion, and spread of cultural traits and innovations. Quantitative data on the mechanisms of transmission of cultural traits could be useful in predicting within-group variability, stability of cultural traits over time and space, and the evolution of culture (Cavalli-Sforza and Feldman 1981). For example, vertical transmission is highly conservative and may maintain individual variation. Innovations would spread slowly in a society where transmission of knowledge is done mainly through vertical transmission. By contrast, horizontal transmission might lead to fast difussion of new cultural traits if contact with transmitters is frequent. Horizontal and oblique transmission involving many transmitters to one receiver tend to generate the highest uniformity within a social group, while allowing for generational cultural change (cf. Cavalli-Sforza and Feldman 1981 for a discussion on the effects of different ways of transmission on the spread of cultural traits). Because cultural transmission can occur through different mechanisms, and because the mechanisms through which cultural transmission occur affect the stability of cultural traits over time and space, it is important to assess the relative weight of each mechanism.

In this article we estimate the relative weight of vertical, horizontal, and oblique transmission of an important cultural trait in a pre-industrial society: ethnobotanical competence, defined as ethnobotanical knowledge and skills. To do this, we estimated the association between a *(i)* person's knowledge and skills and *(ii)* the knowledge and skills of the person's a) parents (vertical transmission), b) age peers (horizontal transmission), and c) member's of the person's parent's generation, excluding the parents (oblique transmission). From the many domains of cultural knowledge, we focused on ethnobotanical competence because researchers have outlined the benefits that ethnobotanical knowledge confers to people in small-scale societies (McDade et al 2007; Johns 1996). For the empirical analysis, we drew upon a unique body of primary data collected from adults (≥16 years of age) in 13 villages of a society of foragers and farmers in the Bolivian Amazon (Tsimane'). Data include individual-level information on ethnobotanical knowledge and skills for a sample of adults related by both kinship (parents and their offspring) and spatial and temporal proximity (birth date and village of residency during childhood).

Previous studies on the transmission of folk biological knowledge

Below we review the literature on the transmission of folk biological knowledge, with special attention paid to studies on the transmission of ethnobotanical competence. We focused on 1) the acquisition of folk biological knowledge in indigenous and rural societies, and 2) the empirical evidence for the horizontal, vertical, and oblique transmission of folk biological knowledge.

Learning. The literature on how people learn the everyday skills and tasks that shape their interactions with the environment has reached three main conclusions: 1) cultural learning occurs through a temporal sequence that spans from childhood to adulthood, 2) people learn from others, but knowledge acquisition is faster if people can experiment on their own, and 3) people need to come in direct contact with nature to accumulate folk biological knowledge.

First, previous research suggests that people learn most about folk biology during childhood. Children in subsistence societies master great quantities of empirical knowledge about their natural environment and subsistence-related skills before 12 years of age (Stross 1973; Zarger 2002). Simple skills, such as the ability to identify and prepare medicinal plants, are mastered before adolescence. For instance, primary school children in rural and indigenous societies have been shown to self-medicate with local herbs (Geissler et al 2002; Sternberg et al 2001). By the time these children reach adolescence, their ability to name plants and describe their uses peaks and remains largely unchanged for the rest of their life (Hunn 2002; Stross 1973; Zarger et al 2004). However, complex skills that require years of experience to be done well, such as hunting or craft production, may not be mastered until later in life (Gurven et al 2006). Because cultural tasks vary in their complexity and in the years they take to learn and to master, the mechanisms of cultural transmission will naturally vary. Simple tasks, such as the ability to name objects (including plants), can be learned early in life and are most likely learned from parents and immediate kin. As the cultural tasks grow in complexity – hunting, craft production, reciting and interpreting myths – so does the role of experience in learning the task. As experience grows in the importance of learning and performing a task, so does the possibility that one learns from people beyond one's immediate kin.

Second, learning in pre-industrial societies is typically experimental and unlikely to occur in schools (Atran et al 1991). Qualitative studies on children's acquisition of folk biological knowledge suggest that children acquire most of their folk biological knowledge through hands-on-experience, play, and direct observations (Zarger 2002), rather than through organized and verbal instruction. Furthermore, parents and other elders do not see their duty towards children as primarily one of education, although interactions with parents, siblings, and other adults matter in the transmission of folk biological knowledge (Zarger 2002; Ruddle et al 1977). Research also suggests that children must practice tasks to learn folk biological knowledge (Chipeniuk 1998; Ohmagari et al 1997). For example, Ruddle and Chesterfield (1977) examined the traditional system of knowledge transmission on Guara Island, in the Orinoco Delta of Venezuela. They concluded that learning occurs through repeated practice over time, rather than through simple observation of adults' performance.

Third, research suggests that contact with nature is of pivotal importance for the acquisition of folk biological knowledge (Atran et al 2004; Nabhan et al 1993; Zent 1999; Chipeniuk 1995; Ross et al 2003; Atran, Medin, and Ross 2004; Wolff et al 1999; Baileson et al 2002). For example, in a cross-cultural study, Ross and colleagues (2003) administered the same task to groups of rural and urban children from the US. They found that urban children generalized less in terms of biological affinity than even the youngest rural children due to their impoverished experience with nature.

<u>Paths for the transmission of folk biological knowledge.</u> In the rest of this section, we review quantitative research that supports the three proposed paths that explain the transmission of folk biological knowledge.

Vertical transmission: Anthropologists have stated that folk biological knowledge is mainly transmitted from one generation to the next by parents to offspring (Lancy 1999).

The intuition that folk biological knowledge is transmitted directly from parents is consistent with evolutionary theory (Cronk 1991) and finds support in several empirical studies (Hewlett and Cavalli-Sforza 1986; Lozada et al 2006). For example, in a study of the transmission of cultural traits and skills among Aka in the tropical forest of Africa, Hewlett and Cavalli-Sforza (1986) found that parents were singled out as the transmitters of 81% of the studied skills, followed by "watching others" (10%), and grandparents (4%). Similarly, in a study of a rural population in Argentina, Lozada and Ladio (2006) analyzed the transmission of knowledge of medicinal and edible plants. They concluded that family members (especially mothers) were the most important source for the acquisition of knowledge, followed by experienced non-familial traditional healers. Ohmagari and Berkes (1997) also found that parents, especially mothers, were cited as the principal teachers of bush skills.

Horizontal transmission: Some anthropologists, sociologists, and development psychologists have argued that parent-child transmission might not be the dominant mode of cultural learning (Henrich 2002), at least when a person's total lifespan is considered (Aunger 2000). Several authors have argued that there are also social and evolutionary reasons to expect intra-generational transmission of cultural knowledge beyond the parent-offspring dyad (Harris 1999; Boyd and Richerson 1985). Observational studies suggest that, in some domains, children learn a considerable amount from age peers (Boyd et al 2005; Lancy 1999; Zarger 2002). Sociological research suggests that children even develop their own forms of culture that greatly impacts the acquisition of social skills and knowledge (Corsaro et al 1990). For example, children regularly teach each other tasks and skills during the course of their daily play (Lancy 1999). Zarger (2002) showed that siblings pass along extensive information to one another about plants, including where to find them, their uses, or how to harvest or cultivate them. Research also suggests that, later in life, young adults turn to age peers rather than to parents for information. As adults, people might turn to age peers for information because age peers are highly similar in their social positions. Thus, if there is a change in the social or ecological environment, age peers are the individuals most likely to have tracked such changes and should provide the best information under current conditions (Boyd and Richerson 1985). The new information provided by age peers might allow the person to update the information previously acquired from parents (Aunger 2000). Furthermore, asking peers is less socially questionable than asking parents because, at certain ages, parents might reproach offspring for their inability in certain skills.

The importance of age-peers in the transmission of cultural knowledge has only been sparsely tested in relation to ethnobotanical knowledge, but dovetails with studies in developmental psychology and in cultural anthropology. Studies in developmental psychology stress the importance of age peers in the acquisition of knowledge and socialization, even in school (Vygostky 1978; Shaeffer 1996). Cultural anthropologists have conducted time allocation studies with children to show that children spend large portions of time with siblings and age peers (Whiting et al 1975; Weisner et al 1977). Time spent together gives children the opportunity to share knowledge. Time spent together also allows for staggered learning because it allows children to learn from someone who knows just a little more than themselves and is not necessarily an expert. It might be easier to learn from these individuals than it would be to learn from an adult because the adult might be less accessible, might move quickly over things because of their expertise, and be less willing to deal with the naïve learner.

Oblique transmission of knowledge: Oblique transmission can take the form of (a) one-to-many, when one person (e.g., a teacher) transmits information to many people of a younger generation or (b) many-to-one, when the person learns from older adults other than the parents (Cavalli-Sforza and Feldman 1981). Quantitative studies on oblique transmission of ethnobotanical knowledge are scarce and focus on the transmission of knowledge from one-to-many. For example, Lozada and Ladio (Lozada, Ladio, and Weigandt 2006) found that experienced traditional healers outside the family are important in the transmission of ethnobotanical knowledge. Hewlett and Cavalli-Sforza (1986) found that non-parental older family members contributed only 1.4% to the transmission of bush skills among the Aka in the tropical forest of Africa. In a previous study with the same population (Reyes-García et al 2007a), we found a weak association between prestige and ethnomedicinal plant knowledge. The association found might support the hypothesis that an important source of bias in the acquisition of culturally-transmitted information are prestige processes (Henrich et al 2001), which mainly occur through oblique transmission.

Recent theoretical research on the evolution of psychological tendencies to imitate parents and non-parent adults shows that neither vertical nor oblique mode of transmission should be expected to dominate the other across all domains (McElreath et al 2007). Vertical learning is expected to be more adaptive in stable environments and when the behavior being learned affects fertility. Oblique transmission might be more adaptive when the learned behavior affects survival to adulthood.

In sum, previous empirical research has outlined the importance of the vertical path in the transmission of ethnobotanical competence. However, all the studies reviewed in this section have relied on self-reports, where researchers asked informants to report who was the main teacher of a given cultural trait. A large body of literature shows that reports typically contain many types of bias (Bernard et al 1984). Specifically, in a study comparing the reported to estimated cultural transmission in the same population, Aunger (2000) suggests that self-reports concerning where cultural information was learned are subject to normative response bias for parental influence. There are theoretical reasons and empirical evidence from other fields of study to suggest that the importance of vertical transmission may be overstated, and that horizontal and oblique transmission of cultural knowledge may play important, but underappreciated, roles.

Tsimane': Social organization and acquisition of ethnobotanical competence

The Tsimane' number ~8,000 people and live in the rainforests and savannahs at the foothills of the Andes, mostly in the Department of Beni, Bolivia. Relatively isolated until the mid-twentieth century, they started to engage in more frequent and prolonged contact with Westerners after the arrival of Protestant missionaries in the late 1940s and early 1950s (Daillant 2003; Huanca 2007). Like many native Amazonians, the Tsimane' practice a mix of slash-and-burn farming, hunting, fishing, and plant gathering (Vadez et al 2004).

Ethnographic observations suggest that, as with other hunter-gatherer societies, cultural knowledge among Tsimane' is transmitted orally and through informal means. The Tsimane' have been exposed to schooling since the 1950's, but despite nearly five decades of exposure to schools, Tsimane' adults have little formal schooling (avg= 1.99 years of schooling; S.D. = 2.41) (Godoy et al 2007). Given the limited levels of literacy among the Tsimane', it is accurate to say that cultural transmission requires personal interaction, either through oral communication or imitation of observed behaviours.

In previous articles and books, we provide ethnographic details of the Tsimane', including descriptions of Tsimane' ethnobotanical knowledge (Huanca 2007; Godoy et al 2005; McDade, Reyes-García, Leonard, Tanner, and Huanca 2007; Reyes-García et al 2007b). In this article, we focus on describing Tsimane' social organization and acquisition of ethnobotanical competences. We focus on social organization because it might be central to understanding the potential paths for the transmission of cultural knowledge.

Tsimane' social organization: Until recently, the Tsimane' were a highly autarkic and egalitarian society (Ellis 1996). The villages included in this study contain an average of 24 nuclear households (S.D. = 10.88). Polygynous in the past, most Tsimane' presently practice monogamy and live in nuclear households run jointly by a wife and a husband. Each household contains an average of 6.23 people (S.D. = 2.85) including 2.66 adults (S.D. = 1.10) and 3.59 children (S.D. = 2.31), defined as people under the age of 16. Although nowadays most Tsimane' households are nucleated, households related by kin are usually organized in village clusters and situated at a short distance one from another.

The Tsimane' kinship system is Dravidian and functions as Tsimane' social organization (Daillant 2003). The Tsimane' practice cross-cousin marriage, meaning that a man weds the daughter of his mother's brother or of his father's sister. This preferential system of marriage generates a thick network of relations and multiple alliances (Daillant 2003). The Tsimane' call each other "*chatidye*" (relative) and they apply the term liberally to any Tsimane'.

The Tsimane' visit each other frequently. Social visits within the village occur on a daily basis and visits to family and friends in other villages are also frequent, sometimes lasting several weeks and even months. Ethnographers have stressed the importance of visiting for the transmission of cultural knowledge among the Tsimane' (Ellis 1996).

The learning process: In previous research, we found that, like other indigenous groups, the Tsimane' acquire most of their ethnobotanical knowledge during childhood. The increase of ethnobotanical knowledge is slow after adolescence and is more important for skills than for the acquisition of theoretical acquisition (Reyes-García et al 2007; Godoy et al 2007).

From ethnographic observations, we also know that Tsimane' learning is based on observation and direct experience. Children are free to play, explore, and interact with the natural world with little or no restriction or supervision. Children as young as five years of age have the freedom to perform some activities alone or with their age peers. Children above five years of age usually spend a good portion of each day solely in the company of brother, sisters, cousins, and friends carrying out daily activities, such as household chores, baby-sitting, playing, bathing, or looking for edible snack foods. As in other subsistence societies (Lancy 1999; Zarger 2002), Tsimane' play and work activities are frequently intertwined. For example, boys organize and go on fishing expeditions by themselves. Girls are requested to perform household tasks and accompany mothers and older siblings to agricultural fields where they often play with, and take care of, younger siblings.

The early acquisition of ethnobotanical knowledge and skills is important for Tsimane' youngsters. The skills of young unmarried Tsimane' boys and girls seeking partners are typically evaluated by their potential in-laws as well as by their own parents, who worry about their children's ability to meet their expected duties in their future homes. The Tsimane' stress the need to acquire competence in sex-specific tasks before marriage, and many of these tasks require a certain domain of folk biological knowledge. For example, boys must know how to hunt and fish. A boy needs to go on a hunting expedition alone and hunt with his bow and arrow before being able to form a new household. Similarly, girls must know how to prepare fermented beverages, farm, and weave. Excelling in subsistence-related activities (some of them highly dependent on ethnobotanical knowledge) is a source of social status for the Tsimane' (Reyes-García et al. 2007a).

In sum, the process of knowledge acquisition among the Tsimane' is almost exclusively oral and based on hands-on experimentation. Tsimane' social organization and kinship provide children and adults with ample opportunities to interact with same age kin and friends, facilitating the exchange of information across age-groups.

Estimation strategy

The goal of this article is to estimate the relative weight of parents, age peers, and parental cohort in the transmission of ethnobotanical competence. For the empirical estimation, we assessed the association between *(i)* two outcome variables (ethnobotanical knowledge and ethnobotanical skills), and *(ii)* ethnobotanical knowledge and skills of the (a) parents, (b) age-peers, and (c) parental cohort. We used parent's knowledge to test for vertical transmission of knowledge, age-peer's knowledge to test for horizontal transmission of knowledge, and parental cohort's knowledge to test for oblique transmission of knowledge.

We differentiated between ethnobotanical knowledge and ethnobotanical skills because the two dimensions of ethnobotanical competence might be transmitted through different paths. For example, ethnobotanical knowledge might be learned early in life and, therefore, be more influenced by parents, but skills that require untangling more complex tasks and are more susceptible to be transmitted over a longer time may be learned from other sources.

We use the following expression to model the association between ethnobotanical knowledge (Y) of oneself and covariates:

[1]. $OK_{ijv} = \alpha + \beta PK_{ijv} + \gamma SK_{ijv} + \theta CK_{ijv} + \varphi D_{ijv} + \varepsilon_{ijv}$

The term OK_{ijv} refers to a persons' ethnobotanical knowledge, where *i* is the participant, *j* the household, and *v* the village. We use ethnobotanical knowledge for ease of exposition, but the expression also applies to ethnobotanical skills. PK_{ijv} captures the average ethnobotanical knowledge of a person's parents. SK_{ijv} captures the average ethnobotanical knowledge of the subject´s age-peers (excluding the subject´s own knowledge). We defined age-peers as people who were born within ± 4 years of the subject's year of birth and who reported spending their childhood in the same village as the subject. Because we do not have kinship data, we can not conduct a separate analysis for siblings, and the measure of same age-peers might include some, but not all of the subject's siblings. CK_{ijv} captures the average ethnobotanical knowledge of the elder generation, or parental cohort, defined as the people who were born 20 to 45 years before the subject and who lived in the subject's village during the subject's childhood (excluding the parents). D_{ijv} is a vector of variables that captures the demographic attributes of the participant (e.g., age, sex, school attainment), and ε_{ijv} is a random error term with standard properties.

By including the ethnobotanical knowledge of parents, age peers, and parental cohort in the same equation, we can evaluate and compare the relative weight of the three paths for the transmission of ethnobotanical knowledge. If transmission of ethnobotanical knowledge occurs mainly from parents-to-offspring, then the coefficient β should be positive and larger than γ and θ. If transmission of ethnobotanical knowledge occurs mainly through contact with age peers, then the coefficient γ should be larger than the coefficients β and θ. If transmission of ethnobotanical knowledge occurs mainly through contact with the parental cohort, then the coefficient θ should be larger than the coefficients β and γ. If the three paths of transmission have a similar weight, then the three coefficients, γ, β, and θ, should be positive, statistically significant, and of similar magnitude.

To estimate the parameters, we used ordinary least square regressions with robust standard errors. We ran regressions with clustering of individuals by contemporary households because individuals are nested in households and because individuals from a household are more likely to be similar in their ethnobotanical competence than individuals from different households.

Potential biases: Potential biases in our estimations relate to 1) omitted variables, 2) small sample size, 3) random measurement error of dependent and explanatory, and 4) possible reverse causality.

First, our estimations might be biased by the role of omitted variables. The underlying assumption of the econometric model is that a person acquires cultural knowledge through vertical, horizontal, or oblique transmission only. However, there might be other paths for the transmission of cultural knowledge. For example, people might acquire ethnobotanical knowledge and skills from people outside their own villages. Or knowledge within a cohort might be correlated because the cohort had a good role model in the village. The role model might have shaped the knowledge of the target participants, but might have also shaped the knowledge of the older cohort. Failure to control for other variables that might influence transmission of knowledge will bias our estimations in an unknown magnitude and direction.

Second, data for this article was collected among adults, but since we lack data for many of the subject's parents, our sample size is small. A small sample size weakens the statistical significance of our results. Furthermore, our sample might be biased because of the lack of information from people over 50 years of age, whose parents are not alive.

Third, we might have random measurement error in our proxy measures of ethnobotanical knowledge and skills. For example, we relied on reports rather than on objective measures of ethnobotanical knowledge and skills. People might have given random answers about whether they mastered a particular skill. Random measurement error in outcome variables would inflate standard errors. Random measurement error in the explanatory variables would produce an attenuation bias and make our estimates more conservative.

Fourth, we do not have convincing instrumental variables to control for the potential two-way causality in the transmission of knowledge. For example, it is possible that parental knowledge contributes to children's knowledge, but causality could also run the other way because children can transmit knowledge to parents (Harris 1999). As a result, our estimates do not indicate the direction of the transmission, but only show association between the variables explored.

Materials and Methods

Data came from a panel study among the Tsimane' (1999-present). Four experienced interviewers and translators, who had been part of the panel study from the beginning, did the 2005 survey. The study protocol was approved by Northwestern University and Brandeis University Review Boards for research involving human subjects. The Tsimane' Grand Council also approved the study and individual consent was obtained before enrollment.

<u>Sample:</u> We collected data through a survey that took place during June-September 2005 among nearly all households (n=252) in 13 Tsimane' villages straddling the Maniqui river. The villages surveyed differed in their proximity to the market town of San Borja (pop ~ 19,000) (mean=25.96 Km; SD=16.70). Our initial sample included every person over 16 years of age (or younger if they headed a household) willing to participate. Because we could not interview all the parents of people in our sample, the total sample with complete information included 313 adults, 146 men and 167 women, from 182 households in 13 villages.

<u>Own ethnobotanical knowledge:</u> To measure traditional knowledge of plants we mentioned the Tsimane' name of 15 local plants selected at random from a list of 92 plants that we developed in an earlier study done in 1999-2000 (Reyes Garcia et al 2006). For the tests, participants were asked whether they knew each plant. If subjects said they knew the plant, we coded the answer as one; otherwise, we coded the answer as zero. We added subject's answers to the 15 questions to obtain a total score for the subject. Knowledge scores were transformed using a natural log function to ease the reading of the coefficients. When outcome and explanatory variables are in logarithms, coefficients can be read as elasticity (%Δ in Y/1% Δ in X). No subject received a score of zero on the test of ethnobotanical knowledge. Thus, taking logarithms did not reduce the number of observations.

<u>Own ethnobotanical skills:</u> To capture the practical dimension of ethnobotanical competence, we also used a measure that focuses on empirical, rather than on theoretical knowledge: self-reported ethnobotanical skills. To measure ethnobotanical skills, we asked subjects whether they had ever used 12 plants for a specific purpose

(e.g., "Have you ever used coyoj (*Zantedeschia sp.*) for medicine?"). None of the questions were purposefully false. If participants had used the plant, we coded the answer as one; otherwise, we coded the answer as zero. We summed the answers to the 12 questions to obtain a total score of ethnobotanical skills for each participant. Twenty-five people (women=16, men=9) or 8% of the sample had scores of zeros in the test of ethnobotanical skills, so we left the data in raw form for multivariate analysis.

Parents' ethnobotanical knowledge and skills. During interviews, we asked informants to provide their father's and mother's name and village of residency. We used the information to match the data from the participant with the participant's parents, but only if the parent was part of the panel study. We did not attempt to find and interview parents who resided in villages outside our sample. We used the same tests of ethnobotanical competence for a subject and his/her parents. We then used parental measured ethnobotanical knowledge and skills as explanatory variables in the regressions. From the 642 adults who answered the survey, only 313 had one or both parents in the sample. Pair-wise Pearson correlation coefficients of spouses in our sample were 0.62 ($p<0.0001$) for ethnobotanical knowledge and of 0.48 ($p<0.0001$) for ethnobotanical skills. Thus, in regression analyses, we used the average parental ethnobotanical knowledge and skills as explanatory variables. To avoid further reduction in our sample, and due to significant correlation between spouses knowledge, we took the mother's ethnobotanical knowledge as a proxy of parental ethnobotanical knowledge if information from the father's ethnobotanical knowledge was missing and vice versa.

Age peers' knowledge and skills. We asked informants to report their village of residency during childhood. Because the wording of the question was ambiguous (i.e., we did not define childhood) the variable might contain measurement error. We also asked participants their birth date. We asked informants who did not know their date of birth to estimate their age in years. We used the subject's reported age to group them into cohorts. For each individual, we generated a group of age peers, defined as people who spent childhood in the same village as the subject and who were born during a period of ± four years from the subject's year of birth. We then calculated the average ethnobotanical knowledge of a person's age peers using their direct measures of ethnobotanical knowledge. We excluded the individual's knowledge for the average measure of age peers' knowledge. We followed the same procedure to calculate age peers' ethnobotanical skills.

Parental cohort knowledge and skills. To define parental cohort, we first estimated the average difference between a subject and their parents. The average difference in age between a women and her mother was 31.5 years (SD=12.5) and 36.0 (SD=12.4) between a woman and her father. The average difference between a man and his mother was 30.7 (SD=12.0) years and 35.4 (SD=12.4) between a man and his father. We defined parental cohort as people who were born between 20 and 40 years before the subject and who lived in the village where the subject spent childhood, excluding the subject´s parents. To calculate parental cohort ethnobotanical knowledge and skills, we averaged the measured ethnobotanical knowledge of informants in each group, but excluded the ethnobotanical knowledge of the subject's parents.

Controls: Controls for the regression analysis include age, schooling, and walking distance from the village to town.

Results

Table 1 contains a definition and summary statistics of the variables used in the regression analysis.

INSERT TABLE 1 ABOUT HERE

Table 2 contains the regression results for ethnobotanical knowledge (part A) and ethnobotanical skills (part B). In column [1], we include only men (n=146) and in column [2], we include only women (n=167).

INSERT TABLE 2 ABOUT HERE

A. Ethnobotanical knowledge (Table 2). The analysis of the possible transmission of ethnobotanical knowledge among men (column [a]) suggests that a man's ethnobotanical knowledge bears a statistically significant association with the average knowledge of the parental cohort and a statistically non-significant association with the knowledge of his parents and his age peers. A 1% increase in the average ethnobotanical knowledge of the parental cohort is associated with a 0.79% increase in the ethnobotanical knowledge of the man (p=0.001).

The analysis of the possible transmission of ethnobotanical knowledge among women (column [b]) suggests a different pattern. A woman's ethnobotanical knowledge bears a positive and statistically significant association with the knowledge of her age peers, a low association with the knowledge of her parental cohort, and a statistically non-significant association with the knowledge of her parents. A 1% increase in the average ethnobotanical knowledge of a women's age peers is associated with a 0.64% increase in the ethnobotanical knowledge of the woman (p=0.001). A 1% increase in the average ethnobotanical knowledge of a women's parental cohort is associated with a 0.50% increase in the ethnobotanical knowledge of the woman (p=0.05).

In column [c], we present results from the pooled sample. We found that the strongest association was between an individual's knowledge and the knowledge of the individual's parental cohort, both in statistical and real terms. Doubling the average knowledge of the person's parental cohort would be associated with a 62% increase in the person's ethnobotanical knowledge (p=0.001). Doubling the average knowledge of a person's age peers would be associated with a 39% increase in the person's knowledge (p=0.018).

B. Ethnobotanical skills (Table 2). Results for the paths of transmission of ethnobotanical skills differ from results for the transmission of ethnobotanical knowledge. We found that a man's ethnobotanical skills were strongly associated with the average skills of the parental cohort, but not associated with the skills of his parents or the skills of his age-peers. An increase of one point in the skills of a man's parental cohort would be associated with an increase of 0.67 points in a man's ethnobotanical skills (p<0.0001). A woman's ethnobotanical skills were associated with her parent's skills and weakly associated with the average skills of her parental cohort. An increase of one point on the skills of a woman's parents would be associated with an increase of 0.21 points in the woman's ethnobotanical skills (p=0.06). An increase of one point in the skills of a woman's parental cohort would be associated with an increase of 0.22 points in the woman's ethnobotanical skills, but this result only approaches statistical significance (p=0.10).

Results from the transmission of ethnobotanical skills with the pool sample (Table 2, Section B, column [c]) suggest an association between the skills of an individual and the skills of the parental cohort of the same individual. An increase of one point in the skills of a person's parental cohort would be associated with an increase of 0.42 points in the person's ethnobotanical skills (p<0.001)

In sum, we generally found that (a) the knowledge and skills of the parental cohort are associated with a person's knowledge or skills, (b) the knowledge of age-peers is associated with a person's knowledge; the association is stronger for women's than for men's knowledge, and (c) parental knowledge is not associated in a statistically significant way with offspring's knowledge or skills, and parental skills are weakly associated with a woman's skills.

Robustness. In Table 3, we present results from a series of sensitivity analyses to assess how well the results of Table 2 held up. The first column in Table 3 contains a description of the changes made to the core model.

INSERT TABLE 3 ABOUT HERE

In model [2] we ran regressions similar to those presented in Table 2, but changed parents, age peers, and parental cohort knowledge by parents, age-peers and parental cohort skills as explanatory variables for own ethnobotanical knowledge (Section A). In Section B, we include parents, age peers, and parental cohort ethnobotanical knowledge as explanatory variables for own ethnobotanical skills. We found that parental cohort's ethnobotanical skills were associated with a man's ethnobotanical knowledge and that age peer and parental cohort skills were associated with woman's ethnobotanical knowledge. A one point increase in parental cohort skills would be associated with a 5.6% increase in a man's ethnobotanical knowledge. An increase of one point in age peer's skills was associated with a 6.7% increase in a woman's ethnobotanical knowledge ($p<0.001$). A point increase in the skills of the parental cohort was associated with a 3.5% increase in a woman's ethnobotanical knowledge ($p=0.005$).

Age peer's knowledge was associated both with men's and women's skills. An additional point in the age-peers skills would be associated with a 314% increase in a man's and 555% increase in a woman's knowledge ($p= 0.07$ and $p=0.002$). We also found a positive association between parental cohort knowledge and men's skills. An additional point in the skills of the parental cohort would be associated with a 482% increase in men's knowledge. Parent's skills were not associated in an statistically significant way to own knowledge.

In model [3], we included decade of birth dummies to separate the collinearity between the cohort and age effects (Borjas 2005). In model [4], we ran the same regression, clustering by village where the person spent childhood, rather than clustering by contemporary households. Clustering by village of childhood allows one to control for fixed-effects related with intragroup correlation during an important time for the transmission of knowledge, childhood. Results from models [3] and [4] closely resemble those presented in model [1].

Last, in model [5], we include a set of village dummy variables to control for a subject´s village during childhood. When we analyzed the paths of transmission of ethnobotanical knowledge and skills, including village dummies, most of the associations discussed so far lost their statistical significance. We only found one statistically significant variable. The knowledge of a man's parental cohort is associated in a statistically significant way with a man's knowledge. A 1% increase in the ethnobotanical knowledge of a man's parental cohort would be associated with a 0.84% increase of the man's knowledge (p=0.005).

Discussion

We organize the discussion around findings from the three analyzed paths to explain the transmission of ethnobotanical knowledge and skills. Results from our research suggest that, for Tsimane' adults, the relative importance of the horizontal and oblique paths of transmission of ethnobotanical knowledge and skills may be greater than the putative importance of the vertical path of transmission. Specifically, we found that 1) the ethnobotanical knowledge of age-peers is associated to the subject's ethnobotanical knowledge; the association is stronger for women's than for men's knowledge, 2) the knowledge and skills of the parental cohort is generally associated with the subject's ethnobotanical knowledge and skills, and 3) parental knowledge is not associated in a statistically significant way with offspring's knowledge, with parental skills being only weakly associated with woman's skills.

Our findings contrast with previous empirical findings on the transmission of ethnobotanical knowledge, which suggests that parents are the most important actors in the transmission of cultural knowledge (Ohmagari and Berkes 1997; Hewlett and Cavalli-Sforza 1986; Lozada, Ladio, and Weigandt 2006). However, our findings are consistent with the expectations of cultural evolution theorists (Henrich 2002; McElreath and Strimling 2007) and dovetail with previous empirical findings on the transmission of cultural knowledge based on direct measures (Aunger 2000).

A possible explanation for the difference between our finding and previous findings lies on the method used for data collection. As Aunger (2000) noticed, previous research has mostly relied on informants' self-reports to analyze the paths of transmission of knowledge. When relying on self-reports, it is possible that informants did not exactly know where their knowledge came from and answered that they learned from their parents, thus overemphasizing the role of parents on the transmission of ethnobotanical knowledge and skills. It is also possible that people acquire ethnobotanical knowledge from their parents during childhood, but then modify that knowledge as they acquire new knowledge from other sources. People might then answer that they originally learned from their parents, without realizing that knowledge learned latter in life from other sources supersedes parental knowledge.

Cultural transmission is a process that occurs over a life-time and the sources of learning later in life may be different from those of the early years. Research shows that, despite strong parental influence during childhood, children are also highly exposed to age peers (Corsaro and Eder 1990). Constant interaction with age peers might facilitate the transmission of information among children. During adulthood, the process of cultural learning continues as individuals assume new social and familial responsibilities (i.e., work, maternity). At that point, age peers might become increasingly significant sources of reference because age peers share the subject's social environment and parents might not be easily available, providing information that is more relevant to the subject than information that parents might provide. Thus, the importance of information transmitted from age peers during childhood, added to the information transmitted from age peers during adulthood, might end up obliterating the importance of information transmitted from parents among adults.

The importance of the parental cohort in a person's ethnobotanical knowledge and skills might be mediated by the parent's themselves. If, as we just discussed, individuals rely on age-peers when they become adults and parents themselves, it is not surprising to find an association between parental cohort and individual knowledge. As Aunger (2000) pointed out, if an adult's knowledge is strongly influenced by age peers, children might not learn what their parents learned when they were children, but rather what their parents learned later from their corresponding age peers. If true, then a person's knowledge might be highly associated with the parental cohort. Thus, a plausible explanation for the lack of association between own and parental knowledge relates to the fact that the two variables are collinear. When including parental and parental cohort knowledge in multivariate analysis, we do not find a positive association between a person's knowledge and the knowledge of the person's parents because parental cohort knowledge picks up the entire effect of the association.

We also found some differences in the paths of transmission for ethnobotanical knowledge and ethnobotanical skills. Our results suggest that horizontal and oblique paths are important in the transmission of ethnobotanical knowledge, whereas only the oblique path is important in the transmission of ethnobotanical skills. The associations are robust for most of the regression models tested, including the model that controls for decade of birth. Why would ethnobotanical knowledge and skills be transmitted through different paths? A possible explanation might be related to the different characteristics of ethnobotanical knowledge and skills. Research shows that ethnobotanical knowledge, such as names or traits used for recognition, is easier to acquire than ethnobotanical skills and is mainly acquired during childhood. Knowledge relies on cumulative memory and individuals can learn quickly and effectively through relatively few interactions; therefore, individuals can acquire ethnobotanical knowledge from many sources. Learning skills might require higher investment by the learner. Acquiring skills is more costly in time and requires a number of direct observations and repetition within a particular ecological context. Individuals might be more conservative in selecting models for the transmission of skills and place more weight on information acquired from older informants or informants with more expertise than their peers.

Our data also suggest that there might be differences in the transmission of ethnobotanical competencies among men and women. We find a stronger association between age-peers and own knowledge among women than among men, and a stronger association between parental cohort and own knowledge among men than among women. We also find that only women's ethnobotanical skills are associated with the parent's skills. Differences in the paths for the transmission of ethnobotanical knowledge skills among Tsimane' men and women might reflect differences in time allocation and sexual division of labor among the Tsimane'. For example, as we have seen before, from a young age, Tsimane' girls are requested to perform household tasks and accompany mothers and siblings to agricultural fields. Such close interaction could facilitate the transmission of skills from mother-to-daughter and among age peers. In contrast, Tsimane' fathers are reluctant to take young children to the forest with them because of the dangers of the forest for young children and because children might make noise, thus spoiling hunting opportunities. This could result in boys having fewer opportunities to directly interact and learn from their fathers. Thus, it is possible that Tsimane' men's learning from parents is of a more indirect nature than Tsimane' women's learning from mothers. Because men's learning from parents is more indirect, it could be superseded more easily by parental cohort knowledge.

The last finding that deserves discussion is the importance of village-level attributes in explaining the pathways for the transmission of ethnobotanical knowledge and skills. When we include village dummies in the regression analysis, most of the associations presented lose their statistical significance. The results suggest that village-level attributes might be of pivotal importance in explaining the pathways for the transmission of ethnobotanical knowledge and skills. For example, it is possible that the transmission of ethnobotanical knowledge and skills in a village is affected by its given ecological context, or by the presence of a charismatic or knowledgeable person who lives (or lived in the past) in the village and from whom all the people learned. The results, however, should be read with caution because we do not have enough degrees of freedom to calculate the model with confidence. Given our relatively small sample size, future research is needed to confirm the importance of community level effects on the transmission of ethnobotanical knowledge and skills.

In conclusion, results from this research point to the need for a better understanding of the relative weight of the different paths of cultural transmission at different points in time. If ethnobotanical knowledge and skills are acquired across the life span, then different paths of transmission might play a different role through time. In the study presented here, we analyze associations between members of an adult population, under the strong assumption that their ethnobotanical knowledge has stabilized. Further empirical research on the transmission of cultural knowledge should address the longitudinal dimension of knowledge acquisition. Further research should follow children into adulthood to provide a better understanding of how knowledge and behaviours are first acquired and latter changed as individuals age and are exposed to other sources of information.

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Table 1

Definition and descriptive statistics of variables used in regression analysis (n=313)

Variable	**Definition**	**Mean**	**Stand dev**
	I. Outcome variable		
Ethnobotanical knowledge	Score in test of plant knowledge; subjects asked if they new names of 15 wild and semi-domesticated plants. In regression entered in natural logarithms.	11.55	2.80
Ethnobotanical skills	Reported use of 12 wild and semi-domesticated plants.	4.36	2.65
	II. Explanatory variables		
Parental ethnobotanical knowledge	Average of subject's father and mother measured ethnobotanical knowledge score.	16.22	5.72
Age peers ethnobotanical knowledge	Average ethnobotanical knowledge score of people born the same or ± 4 years apart from the subject's year of birth and who lived in the same village during childhood (excluding subject's knowledge).	12.18	2.03
Parental cohort ethnobotanical knowledge	Average ethnobotanical knowledge score of people born between 20 and 40 years before the subject and who lived in the subject's village of childhood, excluding parental knowledge.	13.11	1.66
Parental ethnobotanical skills	Average of subject's father and mother measured ethnobotanical skill score.	6.36	2.44
Age peers ethnobotanical skills	Average ethnobotanical skills score of people born the same or ± 4 years apart from the subject's year of birth and who lived in the same village during childhood (excluding subject's knowledge).	4.45	1.59
Parental cohort ethnobotanical skills	Average ethnobotanical knowledge score of people born between 20 and 40 years before the subject and who lived in the subject's village of childhood, excluding parental knowledge.	6.20	1.63
	III. Control		
Schooling	Maximum school grade achieved by subject	2.64	2.06
Age	Age in years	26.27	9.20
Male	Sex of the subject, Male=1	0.46	0.49
Walk access	Walking time during the dry season from the village to the closest town or road, in hours	2.58	2.74

Table 2

Regression results: Paths of the transmission of ethnobotanical knowledge and skills, Tsimane' adults

	Dependent Variables						
	A. Ethnobotanical knowledge (log)				B. Ethnobotanical Skills (raw)		
	[a] Male	[b] Female	[c] Pool		[a] Male	[b] Female	[c] Pool
Explanatory variables							
Parent's knowledge (log)	.002	.039	0.036	Parents' skills (raw)	-.098	.211*	.070
Age peers' knowledge (log)	.105	.649***	0.393**	Age peers' skills (raw)	.179	.273	.237
Parental cohort knowledge (log)	.794***	.506*	0.627***	Parental cohort skills (raw)	.678***	.227*	.425***
Control variables							
Male	^	^	0.115***	Male	^	^	.663**
Schooling	-.02***	-.03**	-.025***	Schooling	-.20***	-.266*	-.23***
Age	.008***	-.0008	.004**	Age	.051**	.017	.029
Walk access	.009**	.009	.009	Walk access	.086	-.033	.019
Constant	-.031	-.619**	-.409*	Constant	-.728	.397	-.315
R^2	0.49	0.45	0.47		0.35	0.22	0.25
N	146	167	313		146	167	313

Note: ***, **, and * significant at ≤1%, ≤5%, and ≤10%. Regressions are ordinary-least squares. Robust standard errors used when probability of exceeding χ^2 value in Breusch-Pagan test <5%. ^=variable intentionally left out. For definition of variables see Table 1.

Table 3: Sensitivity analyses

	Dependent Variable						
	A. Ethnobotanical Knowledge (log)			B. Ethnobotanical Skills (raw)			
		[a]	[b]	[c]		[a]	[b]	[c]
		Male	Female	Pool		Male	Female	Pool
[1] Core model, as in Table 2	Parental knowledge	.002	.039	0.036	Parental skill	-.098	.211*	.070
	Age peers knowledge	.105	.649***	0.393**	Age peers skill	.179	.273	.237
	Parental cohort knowledge	.794***	.506*	0.627***	Parental cohort skill	.678***	.227*	.425***
[2] Skill as explanatory variable for knowledge and viceversa	Parental skill	.006	.008	.009	Parental knowledge	-.906	.033	-.253
	Age peers skill	.015	.067***	.042***	Age peers knowledge	3.14*	5.55***	4.49***
	Parental cohort skill	.056***	.035***	.045***	Parental cohort knowledge	4.82**	.290	2.18
[3] With decade of birth dummies	Parental knowledge	-.008	.047	.041	Parental skill	-.107	.216*	.066
	Age peers knowledge	.024	.462**	.315**	Age peers skill	.151	.273	.238
	Parental cohort knowledge	.885***	.664**	.674***	Parental cohort skill	.720***	.210	.422***
[4] With clustering by village during childhood	Parental knowledge	.002	.039	.036	Parental skill	-.098	.211**	.070
	Age peers knowledge	.105	.649**	.393**	Age peers skill	.179	.273	.237
	Parental cohort knowledge	.794***	.506*	.627**	Parental cohort skill	.678***	.227*	.425***
[5] With village dummies	Parental knowledge	-.024	.030	.021	Parental skill	-.113	.097	.042
	Age peers knowledge	-.336	.214	-.054	Age peers skill	.074	-.147	-.110
	Parental cohort knowledge	.847***	-.058	.093	Parental cohort skill	.356	-.381	-.004

Note: Regressions as in Table 2 with changes indicated in first column. See notes in Table 2.

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