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Cultural Transmission and the Role of Evolutionary Forces:
Empirical evidence for adaptive biases in learning and cultural transmission

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Doctor of Philosophy

Anthropology

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By

James Broesch

M.A., Emory University, 2009

Advisor: Joseph Henrich, Ph.D.

An abstract of
A dissertation submitted to the Faculty of the
James T. Laney School of Graduate Studies of Emory University
in partial fulfillment of the requirements for the degree of
Doctor of Philosophy
in Anthropology

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Abstract

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By James Broesch

Over the past 25 years, the application of evolutionary theory to understanding how natural selection may have shaped human psychological mechanisms for cultural learning has generated a wide range of hypotheses that together begin to lay the micro-level foundations of cultural evolution. Under this framework, cognitive biases for the acquisition beliefs and practices that are acquired socially (culture as defined here) can be broken down into two categories: 1) *Content biases*, which are specific to what is being learned, (e.g., selective retention of fitness relevant information over non-fitness relevant information) and 2) *Context biases* that pertain not to what is being transmitted, but rather to the context in which it is transmitted, including both who is transmitting and how this information is distributed across the population. Both analytical and simulation models have shown how these types of biases may produce adaptive change over time within populations, by increasing the likelihood that an individual acquires the variants of a cultural trait that are more likely to be adaptive on the whole. While these models have enhanced our understanding of the potential dynamics of different patterns of cultural transmission, and are supported by ethnographic observations from a variety of contexts as well as laboratory evidence, little detailed field data have directly tested the predictions from these models in real world settings. My dissertation is an attempt to bridge this gap, by directly examining several predictions from formal models among Fijian villagers. I accomplish this with 3 studies, each designed to explore a different area of the predictions from these models through the integration of experimental tools with quantitative ethnographic methods.

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Chapter 1-General Introduction

How is it that humans have gone from using stone tools 200,000 years ago, to landing on the moon and building super computers today? Why are humans able to live in almost every ecosystem on the planet? Why are we the only species on the planet to accomplish these things? These are some of the questions which have been at the center anthropological inquiry for the past 100 years. Potential explanations for species-specific human characteristics have included large brains, tool use, and culture. However, intensive research with non-human species over the past half a century has shown that these traits are not unique to the human species (Whiten, 2005). While this research increasingly suggests that humans are less unique than we had previously assumed, one would be hard pressed to make a case that there is not a qualitative difference in the cultural complexity exhibited by humans compared to other species. No other animal species on the planet has traveled out of our atmosphere, produced material artifacts with the same level of complexity as Acheulean stone tools or the computer, or colonized as many different ecosystems.

So what is unique to humans that can explain this discrepancy? Some have proposed that humans increased reliance upon social transmission of information between generations (cultural transmission) may explain this qualitative difference (Boyd & Richerson, 1996). For the remainder of this dissertation I will use an operational definition of culture as: information contained within individual minds that is acquired through social learning and social transmission (Boyd & Richerson, 1985). Theorists with various perspectives propose that culture functions as a second form of inherited information, similar to genetic information (dual-inheritance theory), which allows individuals to adapt to their environments (Boyd & Richerson, 1985; Cavalli-Sforza & Feldman, 1981; Durham, 1991; Lumsden & Wilson, 1981; Tooby & Cosmides, 1992). This perspective provides a theoretical construct under which we can begin to explore how culture, and the way that it is transmitted and shaped by natural selection, may shed light on these larger questions about human uniqueness.

This theoretical perspective also allows us to explore specific questions about the transmission of culture. For example, although culture appears to become increasingly complex over generational time in humans, and clearly allows individuals to adapt to their environments in unique ways, it also contains elements that seem counter to biological fitness (e.g., vows of celibacy, or delayed reproduction associated with the demographic transition). How is it that culture can have both adaptive and maladaptive consequences? Further, if we develop an understanding of the dynamics of how culture is transmitted, is it possible to use that information to disseminate knowledge more effectively (e.g., change the way we structure public health interventions)? These questions are the motivating forces of my dissertation research. Through this research, I hope to explore the dynamic patterns of cultural transmission and the role of evolutionary forces.

Introduction:

There are a variety of different approaches to understanding how culture may function as a second form of inheritance (dual-inheritance theory). One of the main differences in these approaches is the degree to which theorists claim that cultural inheritance is similar to biological inheritance and subject to the influence of natural selection. Some researchers have proposed the two systems of inheritance to be almost identical, suggesting that culture is composed of *memes* (the cultural equivalent of a gene) that are discrete replicators whose prevalence in the population is a direct reflection of their adaptive value (Blackmore, 1999). This approach has fallen out of favor more recently, as analytical and mathematical modeling have shown that many of the assumptions of the memetic approach are not necessary for cultural evolution to occur (J. Henrich, Boyd, & Richerson, 2008). Other approaches assume that while the two systems are not identical, there are strong parallels between the two (Lumsden & Wilson, 1981; Tooby & Cosmides, 1992). Under this perspective, human minds are composed of many cognitive modules that influence human culture and behavior directly (e.g., modules for cooperation, learning about animals, interactions with strangers, etc). One of the main questions that dual-inheritance researchers seek to answer is how cultural inheritance can produce adaptive change over generational time within a population. Theoretical perspectives such as sociobiology and classic evolutionary psychology propose that these evolved cognitive modules are largely the product of natural selection acting on genetic material that codes for cognitive structures, which over a long period results in adaptations to the environment in which selection is taking place, thereby producing adaptive change (Lumsden & Wilson, 1981; Tooby & Cosmides, 1992). When behavior appears to be maladaptive in the current context, it is assumed that the environmental conditions where selection took place were different and favored the types of behavior that are observed. For example, in the case of cooperation it is assumed that human minds evolved the propensity to cooperate with others when humans were living in small groups of closely related individuals. Under these conditions, cooperation would be favored for inclusive fitness benefits (N. Henrich & Henrich, 2007; Tooby & Cosmides, 1989). Therefore, when humans are observed to engage in behavior which is maladaptive from a genetic fitness perspective, it is proposed that corresponding cognitive modules are ‘misfiring’. For example, when humans choose to cooperate with anonymous others in present day societies, sociobiologists and evolutionary psychologists explain this by claiming that the ‘cooperation module’ makes the faulty assumption that we are still interacting with kin (see N. Henrich & Henrich, 2007 for a summary and counter arguments).

An alternative theoretical perspective, termed cultural evolutionary theory, proposes that while natural selection may have produced some domain specific biases in human minds, we should only expect to see these biases *(content biases)* in domains in which humans have a long evolutionary history (i.e., enough time for genetic selection to operate), where the costs and benefits to fitness are high, or when one variant of a cultural trait is inherently better than another at obtaining a desired result in a way that is salient to learners (Boyd & Richerson, 1985). However, because environments are noisy and the costs for assessing every possible cultural variant can be high, individuals are not always able to assess which behavioral variant is optimal. Therefore, cultural evolutionary theorists propose that natural selection has favored psychological biases which allowed individuals to use other individuals’(models) choices and outcomes in determining which traits to acquire (Boyd & Richerson, 1985 pg. 285). However, because individuals might not know exactly which traits produced the beneficial outcome of their chosen model, or because they only have access to information that is a proxy of fitness in their potential model (such as prestige), these more general biases may also give rise and maintain maladaptive behaviors in groups (Boyd & Richerson, 1985). In other words, individuals may copy characteristics of models that are irrelevant to their success in a given domain. For example, an individual may view Michael Jordan as prestigious because of his basketball skills, and may copy something irrelevant to his performance, like the kind of underwear that he wears. While copying prestigious individuals on the whole should lead to the acquisition of fitness enhancing behaviors, learners may copy other factors which can also favor the transmission of maladaptive practices as well.

There are several types of biases that are unrelated to the content of what is being transmitted (*context biases*) that have been proposed by cultural evolutionary theorists. For example, if individuals are able to assess potential models skills or success (*success bias)* they might preference their learning efforts toward those that they view as the most successful, and copy the behavior of those models. For example, if a learner is trying to decide what type of arrow to make for hunting, they might copy the technique used by the most successful hunter in their community. Assessing success is not always possible, nor is it always possible to determine which precise behaviors produce this success. In these situations, learners may use prestige in other domains as a proxy for skill, and copy others that they view as more prestigious (Boyd & Richerson, 1985; J. Henrich & Gil-White, 2001). Using this same hunting example, if learners were unable to assess hunting success of potential models, they might use other indicators like general health, and copy the techniques of models that are perceived to be the healthiest. However, the health of the model may have nothing to do with their hunting success, but rather due to some other factor (e.g., farming skill or hygiene related behaviors). Finally, learners might use the frequency of a cultural trait within the population as a proxy for the adaptive value of a trait, and copy the most frequently observed variant (*conformity bias)* (J. Henrich &

Boyd, 1998). For example, if a learner observes that 75% of the community uses arrows with 3 fletches, while 25% use arrows with 2 fletches, then conformity bias would favor the 3 fletch technique, and learners should be expected to copy it more than 75% of the time.

Theorists have used mathematical, analytical, and simulation based models to explore the consequences of transmission biases for cultural evolution. These modeling approaches in cultural evolutionary theory have shown that these types of context biases, are capable of producing adaptive change over time by allowing learners to obtain variants of a cultural trait that are better than the average population variant of the previous generation (Boyd & Richerson, 1985, 2005; J. Henrich & Boyd, 1998; J. Henrich & Gil-White, 2001; J. Henrich & McElreath, 2003). However, much of evolutionary psychology and sociobiology propose that these biases are unlikely, based on these theorists assessment of how much information is available to learners and their assumption that genetic selection plays a stronger role in the construction and maintenance of these biases (Tooby & Cosmides, 1992). Whether or not these types of biases operate in the real world is an empirical question. While there is ethnographic evidence, as well as laboratory based studies that support these biases (Birch, Akmal, & Frampton, 2010; Boyd & Richerson, 1985; Caldwell & Millen, 2009; McElreath et al., 2005; Alex Mesoudi, 2008), until recently there have been few direct empirical examinations of these predictions (see N. Henrich & Henrich, 2007; Reyes-García et al., 2009; Reyes-Garcia et al., 2008; Tehrani & Collard, 2009 for some exceptions).

The primary goal of my dissertation research is to bridge this gap and examine the way that both content and context biases operate in the real world settings. I seek to achieve this goal through two studies. In the first study, I explore the structure of local cultural transmission networks in three villages in Fiji. My examination of these networks focuses on the degree to which their structure is similar to what would be predicted by context biases proposed under cultural evolutionary theory. For example, do individuals report that they would go to others that they perceive as successful at fishing if the learner had a question about fishing? Do they tend to go to older individuals, as would be predicted by the models? Do they tend to go to others with whom they have strong social ties, and might be easier to observe? Are individuals who are perceived to be successful in one domain, say fishing, also likely to be solicited for advice in an unrelated domain such as growing yams? By analyzing several domains that are locally recognized as important skills and traits for adult members of Fijian villages to possess, I am able to assess the degree to which these network structures are similar or different depending on the domain as well. Since cultural evolutionary theory would propose that these biases generalize across a variety of domains, if the model predictions are accurate, then we would expect consistency in the general structure of cultural transmission networks.

In the second study, I use an experimental approach to examine if adults and children demonstrate a content biases in learning about animals. Humans have been living with animals, either being predated by them or predating them, for our entire evolutionary history. This, combined with the fact that there are high fitness costs to making mistakes about animals (i.e., assuming that a dangerous animal is safe), suggests that this may be a domain in which it would be likely that a content bias exists. I chose to explore the degree to which more fitness relevant information (e.g., if animals are dangerous or poisonous to eat) is preferentially retained over less fitness relevant information (e.g., habitat and diet). I conducted this study with both adults and children, which also enabled me to assess the degree to which there may be a developmental window in which content biases are present in children, but not adults. Combined, these two studies are direct empirical examinations of several predictions from cultural evolutionary theory, which will allow us to assess the degree to which the biases predicted by these models are observed in the real world.

A secondary goal of my dissertation research was to assess the degree to which culture beliefs, or cultural models, can influence individuals' behaviors and inferences in ways that can be both adaptive and maladaptive. To accomplish this goal, I build off of previous work by Joe and Natalie Henrich that explored food taboos for pregnant and lactating women in these communities in Fiji. Henrich and Henrich's work demonstrates that local taboos serve an adaptive function, by selectively targeting fish that also tend to possess dangerous levels of a reef toxin (ciguatera) found in Fiji (J. Henrich & Henrich, unpublished). With this project, I explore the degree to which this system of taboos shapes individuals inferences about species that they had no prior exposure to. In other words, does this system of taboos work on a one-to-one matching to local species, or does it allow individuals to make systematic and consistent inferences about species that they have no prior exposure to? If it does allow individuals to make inferences, what information about these species allows individuals to make these inferences, and how does that information correspond to a Western-scientific understanding of how the process of bioaccumulation works?

While the primary goals of this dissertation are specific to cultural transmission, and focused on empirical validations of predictions from models, there are practical and applied implications that also motivate this line of research. First, if the predictions from these models are accurate, then perhaps understanding how these biases operate can allow applied researchers to be more effective in their dissemination of knowledge, positive practices, or health interventions. To put it another way, perhaps we can use what we know about how culture is transmitted and acquired to get more ‘bang for our buck’ in health promotion. If there are already established networks that local individuals use to acquire knowledge and culture, then perhaps we can use these networks to create self-sustaining cycles of transmission of important public health information, among other things, that will persist after researchers or health workers leave. These implied implications are strongest for the first project of my dissertation, in which I explore the structure of cultural transmission networks in Fiji.

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Chapter 1b-Ethnographic Context

In this chapter, I will provide a brief description of the villages where this research took place. This is not intended to serve as a detailed ethnography of the Fijian way of life, but rather is intended to provide a short description of these communities and provide some ethnographic context for the subsequent chapters. As this research took place in two separate areas of Fiji, I will begin by describing the primary area of data collection, Yasawa, and in the process I will discuss several relevant aspects of the Fijian political, ecological and economic context. I will then conclude with a short description of how the other site, Totoya, differed.

Yasawa

The primary location for all data collection in this dissertation was on the island of Yasawa, in the north western corner of the Fiji Islands. There are six villages, each with 100-250 people per village, located on this island which is approximately 20km long and 2km wide. Ethnographic research, as well as most data collection occurred in 2 of these villages, Teci and Dalomo. While geographically separated from one another, Teci and Dalomo are densely connected through both political and kinship ties. These two villages comprise one *yavusa*, the largest kin-based political unit in the Fijian political system. Being one *yavusa*, these villages share a single hereditary chief, who is recognized as the traditional political leader of the villages. The *yavusa* is further subdivided into clans, *mataqali*, which are in turn headed by senior male members. The senior male members of the *mataqali*, along with the chief, govern the village and make important decisions regarding village projects, village development, and general issues that may arise in the village.

Villagers in Teci and Dalomo practice a primarily subsistence style of living and have limited contact with market economies. Being located in the tropics, Fiji experiences two primary seasons; a wet-hot season (October-March) and a dry-mild season (April-September). While there are many important associated changes associated with seasonal fluctuations (e.g., horticultural practices, increasing risk of hurricanes, increasing tourism presence in the country) for the most part, daily life is similar across the year. Villagers practice a mix of horticulture, marine/littoral gathering, and fishing and there is a strong division of labor by gender. Men tend to spend more time working outside the home, such as working in their plantations or fishing, while women tend to work closer to home, for example cooking or weaving mats. The primary food crops are root vegetables (cassava, yams, and taro), although coconuts, breadfruit, and bananas are also important food sources. Some market goods are also consumed (primarily flour, sugar, tea, and tined fish) depending on their availability and the financial means of the family.

The primary source of protein comes from marine resources that are obtained through gathering and fishing. Fishing techniques include: line-fishing (practiced by both men and women), net fishing, and free-dive spear fishing (practiced exclusively by men). The rich reef ecosystems that surround the Fijian islands are host to a great variety of species, and some form of fish is consumed at the majority of evening/afternoon meals. However, when inclement weather makes fishing difficult, it is not uncommon for families to eat primarily cassava or other root crops for several days at a time. Most foods are cooked over an open fire, although kerosene stoves are also used occasionally.

Occasionally, families also bake foods for larger meals (e.g., preparation for Sunday, or when visitors were present) using an earth oven, or *lovo*.

Religion is an important part of the lives of many Fijian villagers. In the villages where this dissertation research was conducted, the majority of villagers identified as Methodist while a smaller, but significant proportion of villagers identifying as being either Assemblies of God or Seventh Day Adventist. In all the villages that I worked in there was a prohibition of work on Sunday, in accordance with the religious beliefs of these Christian faiths. This often meant that a great deal of time was spent gathering and cooking food on Saturday to be prepared for Sunday.

The lives of indigenous Fijians are deeply embedded in a complex kinship system that defines relationships between genetic relatives, and non-genetic relatives. The nuclear family is extended to include same sex siblings of parents, who are called "mother" and "father" by what would be considered their nieces and nephews in the American kinship system. Further, all parallel cousins (e.g., mother's sister's children) are also referred to as siblings. Under this system of kinship, opposite-sex siblings (as defined by the Fijian system of siblings outlined above) are prohibited (*tabu)* from having social contact with one another. On the contrary, second degree same-sex cross-cousins maintain a joking relationship with one another, which sharply contrasts with these other *tabu* relationships.

The specific context of the island of Yasawa has several interesting details which merit mentioning. While the Yasawa Group (an archipelago of which Yasawa is the last island) is one of the more developed and tourist centric areas in Fiji, the island of Yasawa itself has limited contact with the tourism industry. The island of Yasawa is separated from the rest of the group by a passage that can become particularly treacherous in high winds that are frequent, which is one of the reasons it has not been more developed thus far. However, there is one luxury hotel on the island near by the village of Bukama, which employs some of the villagers from Bukama. The villages of Teci and Dalomo are less developed than villages in other parts of Fiji, including the village of Bukama, in part due to lack of opportunities for wage labor associated with tourism. While there are some modern houses, cement brick with tin roofs, many houses (*bures)* are constructed using traditional methods and thatch materials.

One of the things that did distinguish Teci village from the other villages on the island at the time of study was its abundance of drinking water. Yasawa experiences a dryer climate than the rest of Fiji, and most of the villages were reliant upon rain-water catchment systems, or well water. During long periods of drought, villages can exhaust their water supply and large container ships from the Viti Levu are filled with drinking water and sent for temporary relief. However, there is a small spring located just outside of Teci village which had been dammed and continually provided piped water to many households in the village. Since the study was completed, a development project successfully expanded access to drinking water and as of January 2010, Teci, Dalomo, and Bukama all have piped water from natural sources.

There is a primary school located in Teci, attended by children from both Teci and Dalomo for grades 1-8, while children in Bukama attend a separate school located there. Children that continue on with secondary education usually move to the main island, Viti Levu, where secondary schooling is available and often live with relatives in the area. This is in part responsible for an underrepresentation of children between the ages of 14-17 years old in the village. Schooling begins after breakfast in the morning. Children return home for a lunch break around noon and finish their classes in mid-afternoon. Upon returning home from school, most children play in or around the village and assist with household chores such as gathering firewood, gathering food, washing their clothes, or helping to prepare the evening meal. Parental supervision tends to be minimal and children spend a good portion of their time in the company of only other children in the afternoons. It is worth noting that children do supplement their dietary intake depending on the availability of certain food resources. For example, several mango trees began fruiting while I was living in the village, and most of the school age children could be found in and around these trees shortly after school let out. Children would usually eat their fill of mangos while playing in and around the trees before heading back for the village with several more in hand.

Totoya

While all of the data in chapter 2, and chapter 4 was collected in Yasawa, a portion of the data from chapter 3 was collected while I was living on the island of Totoya. This island, approximately 10 km in diameter and averaging 1.5 km in width, is located in the Moala group in the south western corner of Fiji. It is a collapsed volcanic caldera, horseshoe in shape, with a large lagoon in the located in the center. There are 4 villages located on the island, 3 of which are on the inside of the horseshoe and face the lagoon. While I visited all the villages, I worked primarily in Tovu and Ketei. These two villages are located in close geographic proximity to one another, about 15mins by foot, and between 100 and 200 people live in each village. While there are some important differences between Totoya and Yasawa, there are more similarities than there are differences. The day to day activities, modes of subsistence, and leisure activities were largely similar. Similar to Yasawa, primary schools are located on the island, but all secondary education occurs elsewhere. This is responsible for an under-representation of children between 14 and 17 years old.

Travel to the island is difficult, and at the time of study the island was only accessible via a cargo ship that would transport supplies monthly. However, during my stay on the island transportation became infrequent due to the high cost and limited benefit for the shipping company that serviced the island. The difficulty in getting to and leaving the island is in part responsible for the limited contact with the tourism industry. Villagers practice a primarily subsistence style of living, growing many of the same crops and living in much the same way as described above for Yasawa. However, an important difference is that large coconut plantations on the outside of the island are used to produce dried coconut (*copra)* which provides some economic revenue for villagers.

Hopefully, the descriptions above will provide the reader with an idea of the day-to-day lives of the people who participated in this dissertation research. With these descriptions in mind, I will discuss the first project of my dissertation research which explores the patterns of cultural transmission networks in Yasawa.

Chapter 2-Cultural transmission networks in Fiji: An empirical examination of predictions from cultural evolutionary theory

In recent years, there has been an increasing interest in understanding the role of evolutionary forces in the production, transmission, acquisition, and manifestation of cultural traits (Alex Mesoudi, 2008; Alex Mesoudi & Whiten, 2008). While early research on culture as a second form of inheritance was largely theoretical, based on analytical models or simulation (Boyd & Richerson, 1985; Cavalli-Sforza & Feldman, 1981), there have been recent efforts to empirically examine the predictions of these models (Caldwell & Millen, 2009; Efferson et al., 2007; McElreath, et al., 2005; Alex Mesoudi, 2008; A Mesoudi, Whiten, & Dunbar, 2006; Reyes-García, et al., 2009; Reyes-Garcia, et al., 2008; Tehrani & Collard, 2009). See (Flynn, 2008; Alex Mesoudi, 2008; Alex Mesoudi & Whiten, 2008) for recent reviews.

In this paper I aim to build on this growing body of research which empirically evaluates the patterns of cultural transmission based on existing models. Drawing on data collected in three Fijian villages, I will examine the relationship between several indicators which are thought to be important for context biases in cultural transmission (age, gender, perceived success, similarity between learners and individuals who serve as models (homophily), genetic relatedness, and social/geographic proximity) and cultural transmission networks (J. Henrich & Gil-White, 2001).

Introduction:

Research aimed at understanding the role of evolutionary forces in the transmission and acquisition of culture has become an increasingly important endeavor in the past decade (Flynn, 2008; Alex Mesoudi, 2008; Alex Mesoudi & Whiten, 2008).

Within this branch of research, two key areas of focus are: 1) how cultural transmission and evolution are similar to biological evolution, and 2) how social learning and cultural transmission can produce adaptive change over time. While early theorists shared many similarities in their perspective of how culture can operate as a second form of inheritance, they differed substantially in the degree to which they thought cultural evolution was similar to biological evolution (Boyd & Richerson, 1985; Cavalli-Sforza & Feldman, 1981; Durham, 1991; Lumsden & Wilson, 1981; Tooby & Cosmides, 1992). Some argued that these two systems of inheritance were subject to largely the same patterns of evolutionary forces (Lumsden & Wilson, 1981; Tooby & Cosmides, 1992). Others proposed there were parallels, but because culture is often transmitted between non-related individuals, there were important differences (e.g., possibility of maladaptive variants, absence of replicator units equivalent to genes (see J. Henrich, et al., 2008 for further discussion).

Depending on the perspective one adopts, the question of how culture can produce adaptive change over time has very different answers. Under the perspective exemplified by much of evolutionary psychology (Tooby & Cosmides, 1992), which suggests that human brains are made up of modules that have been directly shaped by natural selection and which in turn shape culture and behavior, adaptive change is the inevitable consequence. When behavior does not match with what would be adaptive, it is presumed to be the consequence of a discrepancy between the current environment and the environment in which the module evolved (N. Henrich & Henrich, 2007; Tooby & Cosmides, 1989).

An alternative perspective, exemplified by Boyd and Richerson (1985), is that human minds are composed of psychological biases for the acquisition of culture that have been shaped by evolutionary forces. These biases can be thought of as occupying one of two categories: 1) *content biases*, which are psychological biases related to the information that is being transmitted, and 2) *context biases* which are instead focused on the situational factors in which the transmission occurs (e.g., prestige, success, conformity). These psychological biases should on the whole favor the acquisition of adaptive cultural information, but can favor maladaptive variants as well (J. Henrich, et al., 2008).

Cultural transmission may produce adaptive change over time if individuals focus their learning on other individuals (termed *models* from this point forward) who are likely to possess better than average variants of a cultural trait. Such learning biases are just one way that this may be accomplished, through guiding individuals' learning efforts. However, even if learners were able to determine which models in their communities exhibited the optimum behavior to copy, they would still need to balance the costs of gaining access to that model with the potential benefits. To put it another way, if an individual who is learning to hunt needs to pay a high cost (e.g., in terms of social deference, direct monetary payment, or exchange of goods) to gain access to the best hunter in the community, they must also consider that there are others who may not be the best hunters but possess better than average hunting knowledge/skills and may be cheaper to gain access to for a variety of reasons (e.g., less demands on their time, or closer genetic relatedness to the learner and therefore more incentive for indirect fitness consequences) (J. Henrich & Henrich, unpublished).

Using this theoretical framework, it is possible to make testable predictions about who learners should select as models depending on the information available to the learner. Further, if these biases are truly applicable across domains, similar patterns should be observed in a variety of domains of learning. This general framework has been discussed in a variety of sources (Boyd & Richerson, 1985; J. Henrich & Henrich, unpublished; N. Henrich & Henrich, 2007 chapter 2), and here I present several key hypotheses that I will empirically evaluate with this project.

1) If there is a distribution in the quality of potential models (e.g., variation in skills, techniques, and success), patterns of nominations should be affected by this distribution. If there is a relatively uniform distribution of model quality, such that most community members possess the same skills, techniques, and levels of success, we would expect nominations to be more evenly distributed across all individuals in the community. In other words, these types of networks would be less centralized, such that most individuals would be seen as potential models by some individuals. However, if the distribution of model quality is more concentrated, such that only a few individuals possess high skill levels or are highly successful, then we would expect nominations to be more centralized. With this type of distribution we would expect that a relatively small number of individuals would be seen as potential models, while the rest of the community members would receive very few nominations.
2) Learners must balance costs of access and quality of information and holding skill level constant, therefore we should expect learners to differentially copy

from others that live in the same household, individuals who live close in geographic proximity, and with whom learners have strong social ties.

3) If there are divisions in the skill sets or specializations of community members based on individual level factors (e.g., gender), individuals should target their learning toward others that are similar to themselves. For example, we should expect that women should preferentially choose other women as models.
4) Since success is a key indicator of the potential adaptive value of the trait that is being acquired, learners should choose the model that is perceived to be the most successful when that information is available.
5) Success information is not always directly observable or accurate. For example, it may be impossible to determine the exact traits that are responsible for producing a desired outcome such as good physical health. When success information is not readily available, individuals should use other indicators that tend to be correlated with success or better than average knowledge/skills. In these situations we would expect the following:
    a. Age should be positively correlated with skill, as older individuals have had more time to acquire the most beneficial variants of a trait via social learning, and possibly improve on it via individual learning. Therefore, learners should preferentially target older individuals, when all else is equal. However, this effect may be non-linear since very old individuals may experience cognitive losses associated with aging.
    b. Because learners do not always have access to success information in the domain where learning is occurring, we might expect that

> perceived success or prestige in a domain that is seen as important by community members may confer prestige in other non-related domains. To put it another way, if an individual is seen as being prestigious in an important domain (such as fishing in Fiji), learners may choose them as models for other unrelated behaviors, (such as growing yams).

Boyd and Richerson acknowledge that while their models for cultural transmission were supported and informed by ethnographic observations, and experimental studies on human psychology, there is a need for direct empirical examinations of these predictions (Boyd & Richerson, 1985). In response to this gap, a growing body of research has been examining the degree to which individuals' behavior exhibit the biases predicted by the models put forth by Boyd and Richerson (1985). While most of this work comes from laboratory based studies with both adults and children, (Birch, et al., 2010; Caldwell & Millen, 2009; McElreath, et al., 2005; Alex Mesoudi, 2008), some have also focused on broader community/population studies (N. Henrich & Henrich, 2007; Reyes-García, et al., 2009; Reyes-Garcia, et al., 2008; Tehrani & Collard, 2009).

Here I present the results of an ongoing study in Fiji examining the structure of cultural transmission networks in Fijian communities. Within these networks, I evaluate the degree to which the structure of these networks match with the predictions from cultural evolutionary theory outlined above (Boyd & Richerson, 1985; J. Henrich & Gil-White, 2001).

Methods:

General Methods: This work was conducted as part of an ongoing research project on Fijian life and cultural transmission, initiated by Joe Henrich in 2003. The project combines in-depth ethnographic observation and participation with extensive interviews and experiments. The data used in the analysis presented here was collected at several different intervals between 2005 and 2008. The methods used to collect each of the measures will be discussed, but first I will present the general approach used in all data collection. All the data presented here were collected by trained Fijian interviewers (fluent in Fijian and English), who do not have kin or other ties to the communities where the research took place. Interviewers were initially trained by Joe Henrich or myself, and one of us would frequently accompany interviewers to ensure that proper protocols were being followed. Since all villagers above the age 7 are fluent in both standard Fijian and the local village dialect, interviews were conducted in standard Fijian. Survey and interview questions were developed using back-translation to ensure that important meaning was not lost in the process of translation. Interviews about advice and perceived success networks were conducted in a private setting with only the researcher and the participant present (with the exception of the occasional presence of babies and young children).

Demographic and Attribute Measures: One of the key components of the ongoing project in Fiji is maintaining an accurate and up-to-date database of who is present in the communities and their demographic information (e.g., gender, age, years of education, etc.) This allows us to assign a unique identifier to each member of the community that can link their responses across a wide variety of tasks and is essential for constructing the networks analyzed in this study. This demographic information is updated approximately every year. Researchers visit each house and ask questions about all the individuals that are currently living there. When possible, each member is questioned directly, but when not possible the male and/or female head of household is asked instead. The measures obtained from these surveys used in the analysis presented here are age, gender, and years of education.

Cultural Transmission Networks: This interview, conducted in 2008 with everyone in the communities over the age of 7, was used to construct the cultural transmission networks that serve as the primary dependent variables. These networks are estimated by asking whom individuals would go to for advice if they had a question in a given domain. Although these are not direct measures of actual cultural transmission, which would likely be infrequent events that would be difficult to observe, I make the assumption that 'who individuals would go to for advice' approximates the models that they would target for learning. Further, it is worth noting that while the question was "name anyone you would go to about…", participants self limited to individuals within their communities. This strengthens my confidence that their responses represent whom they would choose as models for cultural learning.

The questions that were administered were designed to elicit names of individuals whom the participant would talk to if they had a question in a given domain. For example, in the domain of medicinal plants, the question asked was: "Who would you go to if you had a question about using a plant as medicine?" Participants were allowed to free-list names, after which they were asked "Is there anyone else?" Participants had to respond that, “No, there was no one else” before the interviewer would move on to the next question. The individuals that a participant named (which were constrained to be a maximum of 5) were then matched to unique identifiers. This allows for the analysis of the network structure as well as merging with attribute data.

Teci-Dalomo Sample Networks: For two of the communities represented in this study (Teci and Dalomo), I used additional interview and survey data collected in previous years to explore other factors of interest. The measures discussed from this point forward will only apply to the sample labeled (*Teci-Dalomo Sample*).

Kinship Measures: In 2003, while updating the demographic database, the research team constructed kinship diagrams of genetic relatedness for each household in Teci and Dalomo. All of the kinship data collection was spear headed by Joan Silk while she was living in the village. In-depth interviews were conducted with heads of each household across the village, and researchers recorded parents, grandparents, and great-grandparents for every individual. This was then used to construct one large kinship diagram for the entire village. The data from this diagram was entered into a database in the computer program *Descent* (Hagen, n.d.). This program converts a list of each individual’s parents into a matrix, where cells represent the relatedness coefficient *(r)* between any two individuals in the communities (Hamilton, 1964; Wilson, 2005).

Time Allocation Measures: Since 2003, when researchers are present in the communities, a random sampling approach is used to obtain a variety of measures about how villagers spend their time. Each day, several individuals are randomly selected to be sampled at a random time during that day. It is important to emphasize that this is <u>not</u> a convenience sample, but rather a random number generator is used both for the selection of the individual to be sampled and selection of the time when the sampling will occur (Bernard, 2006). Researchers locate the selected individual at the specified time and document what that individual is doing, and who they are with. For the analysis presented here, I looked at all observations between 2003 and 2008. From this data, I generated a matrix where a cell in row *i*, column *j* would contain the proportion of times that individual *j* was present when individual *i* was sampled.

Perceived Success and Knowledge Measures: In 2006, the research team conducted an interview with all villagers over the age of 10 that was designed to measure the perceptions of community members about who were the most successful or knowledgeable individuals in a variety of domains. All of the questions followed a similar format as exemplified by the following question about fish knowledge: “Who knows the most about fish and fishing in this *Yavusa*?” (*Yavusa* is a Fijian term corresponding to the largest kin-based units in the Fijian political system. What is of relevance here is that both of the communities included in this sample, Teci and Dalomo, are members of only one *Yavusa*.) After they finished responding, participants were asked if they wanted to nominate any additional individuals and, if anyone else was mentioned, they were added to the list. Participants were then asked to look at the list and rank the individuals that they nominated, placing the best person first. Beyond giving us a general community perception as to which individuals were the most skillful or knowledgeable in these domains, this method also provides us with individuals’ perceptions of who was the most skillful or knowledgeable, which might not fit with the rest of the community’s perception. I then analyzed participant responses from the specific questions about: 1) who knew the most about fishing, 2) who the best line fishers were, 3) who the best spear fishers were, 4) who the best yam growers were, 5) who knew the most about growing yams, and 6) who knew the most about medicinal plants. From these data I constructed ‘perceived success/knowledge networks’ where a directed tie from individual *i* to individual *j* would be present if *i* nominated *j* as one of the best in a given domain. Using these networks as predictors allows a direct exploration of the effects of each individual’s perception, as opposed to simplifying these responses to general rankings for the community as a whole.

It is important to note that this interview was conducted 2 years prior to the cultural transmission network interview that serves as the primary dependent variable. If these surveys were conducted at the same time, or with a relatively short delay, it is possible that participants might be responding similarly to both sets of questions because they were thinking about their prior responses. However, given the long delay between interviews, it is unlikely that participants would recall their responses to the success/knowledge interviews when responding to the cultural transmission network questions.

*Method of Analysis***:** To statistically examine the relationship between the dependent and independent variables, I constructed exponential random graph (ERG) models using the *statnet* package in R (Goodreau, Handcock, Hunter, Butts, & Morris, 2008). A simplification of how ERG models are constructed and estimated will be presented here, but readers interested in the mathematical and statistical considerations are encouraged to consult: (Goodreau, et al., 2008; Handcock, Hunter, Butts, Goodreau, & Morris, 2003; Robins, Pattison, Kalish, & Lusher, 2007). In this case, the ERG models assume every tie between every possible pair of nodes (individuals in this case) in the network to be a random variable that can take a value of 1(if the tie is present) or 0 (if it is not). Under this assumption it is possible to construct all of the possible network configurations that have the same number of nodes as the observed network. If the process that generates the connections between individuals in the observed network was completely random, one would expect there to be exactly identical probabilities of a tie existing between every dyad in the network. However, if this process is not random, for example, if individuals are more likely to go to other individuals who are the same gender if they have questions, then the probability of ties between individuals of the same gender should be higher than ties between individuals of opposite genders. I placed further constraints on the networks that were considered to be possible, so that only networks with the same number of total ties and where the maximum number of nominations that one individual can give is 5, had a non-zero probability. If one specifies that a given set of variables should be used to estimate the probability of a tie existing between two individuals, it is possible to compare the observed network to the distribution of possible networks and estimate variable coefficients (parameter estimates) that maximize the probability of generating networks that are similar to the observed network (Robins, et al., 2007). The starting values for parameter estimates are obtained through a maximum pseudo-likelihood estimation (which is equivalent to the MLE in the case of the models discussed, which are dyad-independent). The estimation of the model fit and corresponding standard errors for each parameter estimate are derived through the use of a Markov Chain Monte Carlo Maximum Likelihood Estimation which simulates a probability distribution of the potential networks based on the starting parameter values, and then updates those parameter values to maximize the fit between the proposed model and the observed network (Goodreau, et al., 2008).

There are two categories of effects that I explore with this approach: 1) The relationship between individual level attributes (e.g., age, gender, years of education) and the number of times that an individual would be nominated as a potential model for learning by others (*Main Effects*); 2) If any two individuals in the network matched on a variety of attributes (e.g., given that two individuals were of the same gender or from the same household), was there a significant increase or decrease in the likelihood that there was a tie present between those individuals? Also, how other measured relationships between any two individuals in the network (e.g., being more closely genetically related to one another, or individual *i* nominating individual *j* as one of the best spear fishers in the village), was related to the likelihood of a tie being present those two individuals in the cultural transmission networks (*Dyad Effects*).

Results:

Before discussing the results of the statistical analysis of this data, it is beneficial to discuss the qualitative characteristics of these networks. The results will be discussed for two samples, which are not mutually exclusive. The *Full Sample* includes all participants for whom I collected measures of their cultural transmission networks. The *Teci-Dalomo Sample* includes only the participants, from the villages of Teci and Dalomo, for whom I have data on genetic relatedness, and perceptions of success or knowledge. Diagrams of the *Teci-Dalomo Sample* cultural transmission networks are presented in Figure 2.1 and Figure 2.2 for the *Full Sample*. First, we can notice that these networks do tend to be centralized, such that a few individuals receive many more nominations than the rest of the network. In Figures 2.1 and 2.2, these are the individuals with many lines pointing toward them, and are represented by objects of larger size (as size is proportional to in-degree centrality in these figures.) We can see that for the *Fishing* and *Yam Growing* transmission networks, men are more likely to be chosen as models than women (as evidenced by more large blue shapes in the network figure), while the opposite is true for medicinal plants. While these results are important, and support one of the key hypotheses from cultural evolutionary theory outlined in the introduction, a more detailed statistical approach is necessary to determine what the characteristics of these more central individuals are, as well as exploring more nuanced details of these networks.

I will describe the results from the statistical analysis for each cultural transmission network as follows. I begin with the *Teci-Dalomo Sample*, for which I have the most data. Crucially for this group of ~ 65 individuals (depending on the domain) there are direct measures of perceptions of success of other participants and genetic relatedness measures between all individuals. This allows for a fuller exploration of predictions outlined in the Introduction. I will then move on to discuss how these results compare with the full sample (~ 140 additional individuals for whom I have more limited data). Odds ratios for the *Teci-Dalomo Sample,* that are discussed bellow can be found in Table 2.1. ERG model summaries can be found in Table 2.2- Table 2.4, and Table 2.5 for the *Full Sample*.

These tables list the parameter estimates for the each of the ERG models that was run for each sample and in each domain. Multiple models were used to verify the robustness of the findings, and different predictor variables were included in each model.

With the exception of one of the models, the Non-Theoretical Predictors model, each of the variables was not highly co-linear with the other variables included in the same model. The first model, Theoretical Only, includes variables there were thought to be of key predictive value *a priori* based on existing theoretical work. In addition, these are also the variables which were collected for all participants *Full Sample)* and is of use when comparing parameter estimates between the samples. The second model, Non-Theoretical Included, includes homophily variables that were not thought to be of predictive value *a priori*, but were included to determine the extent to which homophily effects may influence the structure of these networks. However, this model is of limited predictive value as some of the variables are highly co-linear. The third model, Success in Domain, is the primary model used for comparison between networks. This model includes demographic homophily variables, main effects variables, as well as variables for perceptions of success or knowledge in the domain that is being investigated. The fourth model, Success in All Domains, includes these variables as well as perceptions of success in other domains. The subsequent 2 models, Kinship Only and Household Only, vary from the Success in Domain model as they include only one of the two measures for kinship effects (genetic relatedness for Kinship Only, and being from the same household for Household Only). The final model, Time Allocation, includes all variables from the Success in Domain model, as well as a variable for the proportion of time that two individuals were observed together.

Fishing Cultural Transmission Network -

The parameter estimates listed in Tables 2.2-2.4, are fairly consistent across all of the models that were run, with coefficients in all models falling within the 95%

confidence interval (CI) for the estimates of the Success in Domain Model, with the exception of inter-correlated predictors in the Non-Theoretical Predictors model. This indicates that the parameter estimates are statistically equivalent, when accounting for the certainty of the estimate. Therefore, the reported odds ratios are taken from the Success in Domain model unless otherwise noted.

Dyad Specific Predictors: The strongest predictor of ego nominating another individual as someone they would go for advice about fishing was if ego also mentioned that person as being one of the best spear fishers in the two communities. Individual *i* was 9.85 times more likely to go to individual *j* for advice if *i* also nominated *j* as one of the best spear fishers in the village. Perceived success at line fishing was also predictive of nominations, but to a lesser degree (OR=2.22). Individuals were 1.8 times more likely to go to someone else from their own village than someone from another village. Interestingly, ego's perceptions of others' fishing knowledge was not predictive of who they would go to for advice. There is evidence that perceived success in a domain not related to fishing, growing yams (from success in all domains model), was also positively correlated with who ego would go to if they had a question about fishing (OR= 2.19). Individuals were 1.6 times more likely to go to others of the opposite gender for advice. However, when this effect is split by gender (analyses not shown in the tables) it is evident that while women are significantly more likely to report that they would go to men (OR= 2.51, SE=.67 $p<.001$), men are no more likely to go to another man or another woman. Genetic relatedness and perceptions of being knowledgeable about growing yams were both negatively related to receiving a nomination. Proportion of times that individuals were observed together during random point samples (from Time Allocation

Model) was not significantly related to who individuals would go to for advice.

Main Effects: It is clear that fishing information networks are highly gender biased, with males being 3.5 times more likely to receive a nomination as a person someone would go to for advice about fishing than females. Years of formal education that an individual received is negatively correlated with being sought after for advice. If two individuals varied only in their level of schooling, one who completed 10 years of schooling would be 30 times less likely to be sought after for advice than an individual who had no formal schooling. Age was not significantly related to how many nominations an individual received.

Comparison with Full Sample: The results for the full sample were very similar. However, in the full sample, individuals were significantly more likely to go to other members of the same household for advice. This was a non-significant predictor for the Teci-Dalomo sample. There was also a significant positive correlation between age and the number of nominations an individual received, which was not observed in the Teci-Dalomo sample.

Yams Cultural Transmission Network-

Again the dyad level predictors were fairly consistent across all models (coefficients fall within the estimated CI of the Success in Domain model). However, being from the same village was not significant in this model, but it is in most other models. That same pattern is true for being of the same gender.

Dyad Specific Predictors: Like the fishing networks, perceived success in the domain in question, is strongly related to who individuals report that they would go to for advice. If ego reported a given person as being one of the best yam growers in the village, they were 7.25 times more likely to say that they would go to them for advice about growing yams. Perceived success at spear fishing was also positively correlated with who individuals would go to for advice about growing yams (OR=2.39), as was perceived knowledge about growing yams (OR=2.23), although to a lesser degree than perceived success at growing yams. Proportion of times that two individuals were observed together during random point samples (Time Allocation Model) was positively related, such that a 10% increase in the proportion of times individual *j* was observed with individual *i* would equal a 20% increase in likelihood of *i* going to *j* for advice. Difference in age, being from the same household, genetic relatedness and perceived fishing knowledge were not significantly related to who individuals report they would go to for advice about growing yams.

Main Effects: Who individuals would go to if they had a question about growing yams, like fishing, was highly gender biased, and men were much more likely to receive nominations (OR=2.62). Older individuals were also more likely to be sought after for advice. An individual who is 20 years older than another would receive 2.5 times more nominations on average. Education was strongly negatively correlated with nominations, with each year of schooling resulting in a 25% decrease in the number of nominations received. A person who attended school for 10 years would tend to receive 20 times fewer nominations than an identical individual who never attended school.

Comparison with Full Sample: The results for the full sample were very similar. The only significant difference in parameter estimates were for the main effects of gender and the main effects of age, which were of similar magnitude and direction but non-significant in the full sample.

Medicinal Plants Cultural Transmission Networks-

The dyad level predictors were fairly consistent across all models (coefficients fall within the estimated CI of the success in domain model). However, being from the same household was not significant when perceived knowledge is included as a predictor, but was significant in other models.

Dyad Specific Predictors: In the case of medicinal plants, I have no direct measure of perceived success at using medicinal plants. This is because it did not make cultural sense to ask individuals who were the best people at using plants as medicine. However, the research team did ask individuals who they perceived to be most knowledgeable about using plants as medicine. Ego's perception of which individuals knew the most about using plants as medicine was a very strong predictor of who ego said they would go to for advice in this domain. When individual *j* was nominated by individual *i* as being one of the most knowledgeable individuals about medicinal plants, *j* was 24 times as likely to also be named as a person that *i* would go to for advice. Although I could not include perceptions of fishing success, due to co-linearity, there was a positive relationship between perceived success at growing yams and cultural transmission networks for medicinal plants. The proportion of times *j* was observed in *i*'s presence during activity samples was positively correlated with nominations, such that a 10% increase would result in *i* being 1.5 times more likely to go to *j* for advice. Individuals also tend to go to other members of the same village (OR=2.76). Perception of knowledge about fishing, was negatively related to who individuals would go to with a question about using plants as medicine (OR=.21).

Main Effects: The network was highly gendered, such that a woman would receive 4.8

times as many nominations as a man, *ceteris paribus*. Age was positively associated with nominations, and a 20 year increase would roughly double the number of nominations received. Like the other two networks, there was a negative association between formal schooling and nominations. For each year of schooling individuals would tend to receive 25% fewer nominations. If two individuals were identical except one of them attended school for 10 years, and the other never attend school, the more schooled individual would receive 20 times fewer nominations on average.

Comparison with Full Sample: Like the previous two domains, I observed very similar results for the full sample compared to the Teci-Dalomo sample. The only substantive difference was that individuals were significantly more likely to go to someone of an opposite gender, which was not a significant predictor in the Teci-Dalomo sample. When we look at that effect separately for each gender in the Full Sample, I observed that the effect is significant for both men (OR= 1.82, SE=.22, $p<.001$) and women (OR= .28, SE=.09, $p<.001$). So while the effect is stronger for men (i.e., men are more likely to go to women than women are to go to men) it is significant for both. This suggests that men and women may have different skill sets when it comes to using plants as medicine.

Discussion:

Looking at the results across all models and samples, there is evidence that both supports and contradicts the predictions that I set out to evaluate. The strongest piece of evidence in support of the predictions is that, across all domains, perceived success/knowledge in the domain in question was the strongest predictor of who individuals would go to for advice in that domain. The effect sizes were substantially larger than all other predictors. This directly supports one of the main hypotheses, that individuals' perception of success should be the strongest predictor of whom they choose as models for cultural learning. With domains where I have measures of both perceived knowledge and perceived success, there are stronger effects for perceived success. Although I cannot definitively conclude why that may be the case, I hypothesize that it may be in part due to the way individuals assess success vs. knowledge.

There are two primary differences between success and knowledge that I believe may be relevant. First, assessing success can be accomplished by paying attention to outcomes (e.g., who brings home the largest catch of fish). It is my impression from ethnographic observations that not only are these outcomes salient to individuals, but they are also socially transmitted among community members. For example, when someone comes back to the village with a large fish catch, the rest of the community quickly finds out either by direct observation or by talking with others. This provides individuals with frequent, salient signals of success which can in turn lead to social and fitness benefits for more skilled individuals (Smith, Bird, & Bird, 2003). Another possibility is that knowledge is not as direct of an indicator of skill as success, and may in fact not be related to actual skill (Kightley et al., Unpublished). An individual can be very knowledgeable but unsuccessful, and what the learner should care about is success.

Another area where there was evidence supporting the initial hypotheses was in the relationship between proxies for success (age and success in another domain) and cultural transmission networks. In the full sample for all three domains, and in the Teci-Dalomo sample for yams and medicinal plants, there is a positive correlation between an individual's age and the number of community members that would go to that individual for advice. This is consistent with the predictions from models of cultural evolution (J.

Henrich & Gil-White, 2001). It is important to keep in mind that this relationship should be strongest when there are not other clear indicators of success available to learners, and thus we might expect this to be diminished in domains where learners are able to assess models' success. This may explain why there was not a significant relationship between age and the number of nominations that an individual receives for fishing advice in the Teci-Dalomo sample. It is my impression from living in these communities that fishing success is fairly easily observed and salient to learners, and may be more salient than the other two domains. However, this hypothesis would need to be empirically validated.

In the two domains where men received more nominations than women, fishing and yam growing advice, perceived success in either domain was predictive of being sought after for advice in the other. There are at least two reasons why this might be the case. The first, drawn from cultural evolutionary theory, is that in the absence of complete information, learners may use prestige in one domain as a cue for success in another domain. These cross-domain effects should be strongest when success information in the specified domain is unavailable or when signals of success are not clear indicators. An alternative explanation is that individuals that are successful at growing yams are also more successful at fishing, or vice versa. This could be because of related skills necessary for each task, or individuals who invest heavily in learning about fishing also invest heavily in learning about growing yams. I am unable to discern which of these two competing explanations may be correct. However, given that perceived success at growing yams also resulted in individuals being sought after for medicinal plant advice suggests that this may be a cross domain prestige effect. If I had direct measures of actual skill in each of these domains I could examine the degree to which skill in one domain was correlated with skill in another domain. If they were not correlated, then there would be support for the hypothesis drawn from cultural evolutionary theory.

An interesting result is that both samples and all three domains, there is a consistent negative relationship between years of formal schooling and the likelihood that an individual would be sought after for advice. While my initial hypotheses made no predictions about formal education per say, some readers may view formal education as a general proxy for knowledge/skills and, think that these results are inconsistent with the hypotheses related to prestige effects. While formal education may be equated with knowledge and skills in some domains (e.g., running a business), it is my perspective that, for the domains under study here, the inverse is true. As some anthropologists have noted, formal education does promote skills that are valued in market economies, the hours spent in school may result in fewer opportunities for learning other life skills that are not taught in schools (Galaty, 1989; Lancy, 1996). The hours that are spent in school are hours that would otherwise be spent observing other members of the community going about their daily life, and perhaps learning skills that are more typical of a traditional lifestyle (fishing, farming, using plants as medicines). For example, in a detailed study among the Maasai, John Galaty demonstrated that boys who attended school exhibited less mastery of Maasai cattle taxonomy (in terms of descriptive terms which are an important domain in Maasai culture and language) (Galaty, 1989).

Individuals who invest in obtaining formal education may envision themselves working in the market economy rather than living a subsistence lifestyle as an adult. In fact, during my time in these communities, this was frequently mentioned by villagers as something that does occur. Many individuals go to urban centers on the main island in Fiji (Viti Levu) for secondary education, with the intention of securing wage labor when they finish. However, due to lack of opportunities, among other factors, many individuals end up returning to their home communities where they live a primarily subsistence lifestyle. While formal education prepares them for wage labor opportunities, it may actually be detrimental for learning other skills that are important for a subsistence lifestyle. This is a potential explanation for our observed results in these domains, but further research is needed.

Finally, in the case of access costs to models, there were results that were both consistent and inconsistent with the hypotheses drawn from cultural evolutionary theory. Results that support the models are: 1) across all models, individuals report that they would go to other members of the same village more frequently than individuals from other villages and 2) for advice about growing yams and using plants as medicine, individuals tended to nominate others that they were frequently observed with in the time allocation surveys. While individuals reported that they would tend to go to other individuals who live in the same house for medicinal plants and fishing in the full sample, I did not observe this effect for the Teci-Dalomo sample when I included perceived skill as a predictor, contrary to the predictions from cultural evolutionary models. Further, genetic relatedness was either non-significant or negatively related to whom individuals go to for advice in the case of fishing.

The observed negative relationship between genetic relatedness and whom individuals go to for advice about fishing is the opposite of what is predicted from cultural evolutionary models. One possible reason for these disparate findings has to do with social norms surrounding interactions between related individuals in Fiji. In Fiji, there are social norms that specify the type of contact that is allowed between certain types of classificatory kin (e.g., a man should not speak his brother's wife) (Turner, 1991). It is highly plausible that emic kinship systems may bias whom individuals would choose as potential models in meaningful ways. Because I did not control for these factors, it is possible that this omitted variable influenced these results, particularly those for kinship. Future studies should attempt to control for these factors when possible. However, given that there are different patterns for the relationship between genetic relatedness and the cultural transmission networks depending on the domain in question, I think that there are likely other factors beyond emic kinship systems that explain these results. Another potential explanation is that for fishing, there is a wider range of skill levels and techniques used by different community members compared to growing yams or using plants as medicine. In other words, if everyone generally plants yams the same way and knows which plants can be used as medicines, individuals can target their learning to models that are easy to access and obtain the same end result as learning from someone that is harder to access. However, in the case of fishing, individuals may be willing to pay higher access costs because there is a greater disparity between the skill levels of low and high access cost models.

Conclusion:

From this project I obtained results that both support and contradict predictions from models of cultural evolution and cultural transmission. In support of the predictions, I found that: 1) perceived success in a given domain is the strongest predictor of whom individuals would go to for advice in that domain, 2) age and success in another domain are also positively correlated with whom individuals choose to go to for advice, 3) access costs also influence whom individuals go to for advice such that learners would tend to choose models from their own community, and in some domains, others with whom they spend more time with.

Contrary to the predictions, I found that 1) genetic relatedness is either non-significantly related or negatively related to whom individuals go to for advice and 2) formal education, which could be a general marker of knowledge, is negatively related to whom individuals go to for advice. In the case of formal education, I hypothesize that this effect would not be observed in domains where formal education is actually correlated with success in that domain (e.g., running a business), for the reasons outlined above.

The dependent measures used here, whom individuals reported that they would go to for advice, are self-report data which may be influenced by variation in memory, or systematic biases in whom individuals report that do not match their actual behavior. Future research that incorporates direct measures of learning events, or outcomes, may circumvent these potential confounds. For example, comparing the similarity in the production of a cultural trait between members of a community (e.g., arrows used for hunting, or techniques for processing plants for medicinal use), may be another promising avenue for studying patterns of cultural transmission.

These combined results indicate the need for further empirical examinations of patterns of cultural transmission in the real world, to validate the predictions from models of cultural evolutionary theory. This study provides evidence that both supports and contradicts predictions from previous modeling approaches. Further empirical studies of cultural transmission and social learning in the real world are necessary to determine the validity of proposed models and to refine models of cultural transmission and cultural evolution.

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Table 2.1: Teci-Dalomo Sample Odds Ratios

Fishing Advice-Teci Dalomo Sample

	Predictor Variable	Odds Ratio	Lower-95%CI	Upper-95%-CI
Dyad Effects				
	Same Gender	0.60	0.41	0.89
	Same Village	1.87	1.26	2.79
	Same Household	1.37	0.60	3.14
	Difference In Age	1.00	0.99	1.02
	Genetic Relatedness	0.10	0.05	0.20
	Proportion of Times Observed Together**	0.51	0.15	1.71
	Most Fishing Knowledge	1.30	0.94	1.81
	Most Yam Knowledge*	0.35	0.25	0.51
	Best Yam Grower*	2.19	1.71	2.82
	Best Spear Fisher	9.85	8.28	11.73
	Best Line Fisher	2.23	1.52	3.26
Main Effects on in-degree				
	Age(yr)	1.00	0.98	1.01
	Education(yr)	0.71	0.67	0.76
	Gender	3.49	2.12	5.76

*=Success in All Domains Model **=Time Allocation Included Model

Yams Advice-Teci Dalomo Sample

	Predictor Variable	Odds Ratio	Lower-95%CI	Upper-95%-CI
Dyad Effects				
	Same Gender	0.54	0.26	1.14
	Same Village	1.77	0.74	4.23
	Same Household	1.65	0.34	7.94
	Difference In Age	1.02	0.98	1.05
	Genetic Relatedness	0.49	0.12	2.01
	Proportion of Times Observed Together**	13.43	3.81	47.38
	Most Fishing Knowledge*	1.00	0.53	1.87
	Most Yam Knowledge	2.23	1.64	3.01
	Best Yam Grower	7.26	5.43	9.71
	Best Spear Fisher*	2.39	1.79	3.21
	Best Line Fisher*	1.03	0.73	1.44
Main Effects on in-degree				
	Age(yr)	1.05	1.01	1.09
	Education(yr)	0.75	0.66	0.85
	Gender	2.62	1.08	6.35

*=Success in All Domains Model **=Time Allocation Included Model

Medicinal Plants Advice-Teci Dalomo Sample

	Predictor Variable	Odds Ratio	Lower-95%CI	Upper-95%-CI
Dyad Effects				
	Same Gender	0.99	0.64	1.52
	Same Village	2.76	1.54	4.97
	Same Household	1.78	0.76	4.17
	Difference In Age	1.01	1.00	1.03
	Genetic Relatedness	0.54	0.11	2.58
	Proportion of Times Observed Together**	47.61	21.62	104.87
	Most Fishing Knowledge*	0.22	0.06	0.72
	Most Yam Knowledge*	1.56	0.93	2.63
	Best Yam Grower*	2.52	1.39	4.57
	Most Plant Knolwedge	24.46	19.63	30.48
Main Effects on in-degree				
	Age(yr)	1.04	1.02	1.05
	Education(yr)	0.73	0.66	0.81
	Gender	0.21	0.11	0.39

*=Success in All Domains Model **=Time Allocation Included Model

This table presents a summary of the odds ratio values and corresponding 95% confidence interval (CI) for the parameter estimates from the ERG models for the *Teci-Dalomo Sample* in all three domains. Parameters where the 95% CI includes 1 had no statistically significant relationship to whom individuals said they would go to for advice. Parameters where the 95% CI is less than 1 indicate a significant negative relationship with whom individuals would go to for advice. Parameters where the 95% CI is greater than 1 indicate a significant positive relationship with whom individuals would go to for advice. In the case of Gender, a parameter estimate that is greater than 1 indicates that men were more likely to receive nominations, while a parameter estimate less that 1 indicates that women were more likely to receive nominations. I ran multiple models, including different variables, to test the robustness of these estimates. The full results, including which variables were included in each model, can be found in Tables 2.2-2.4. Unless otherwise noted, these parameter estimates come from the *Success in Domain* model. However, as discussed elsewhere in the chapter, the parameter estimates for this model fall within the 95% CI for the corresponding parameter estimates in all other models that did not have co-linear predictors (*Non-Theoretical Included Model*).

Table 2.2: Teci-Dalomo Sample ERG Models-Fishing

		Fishing Advice Networks-Teci Dalomo Sample													
Variable	**Statistic**	**Theoretical Only**		**Non Theoretical Included**		**Success in Domain**		**Success in All Domains**		**Kinship Only**		**Household Only**		**Time Allocation Included**	
	Log-Odds	-0.511	<.01	-0.409	<.05	-0.505	<.01	-0.522	<.01	-0.515	<.01	-0.514	<.01	-0.504	<.01
Same Gender	SE	0.191		0.193		0.197		0.200		0.199		0.198		0.192	
	Log-Odds	0.716	<.001	0.934	<.001	0.628	<.01	0.657	<.01	0.638	<.01	0.610	<.01	0.630	<.01
Same Village	SE	0.194		0.204		0.204		0.206		0.212		0.202		0.202	
	Log-Odds	-0.029	>.05	-0.062	>.05	0.317	>.05	0.353	>.05			-0.317	>.05	0.402	>.05
Same Household	SE	0.426		0.416		0.423		0.417				0.421		0.408	
	Log-Odds	0.000	>.05	-0.019	<.01	0.003	>.05	0.003	>.05	0.004	>.05	0.004	>.05	0.004	>.05
Difference In Age	SE	0.006		0.007		0.006		0.006		0.006		0.006		0.006	
	Log-Odds	1.426	<.001	1.803	<.001	1.251	<.001	1.255	<.001	1.249	<.001	1.221	<.001	1.250	<.001
M.E. (in-degree) Gender	SE	0.247		0.269		0.255		0.257		0.252		0.248		0.249	
	Log-Odds	-0.001	>.05	-0.019	<.01	-0.001	>.05	-0.002	>.05	-0.002	>.05	-0.001	>.05	-0.002	>.05
M.E. (in-degree) Age(yr)	SE	0.007		0.007		0.008		0.008		0.008		0.008		0.008	
	Log-Odds	-0.306	<.001	-0.324	<.001	-0.341	<.001	-0.346	<.001	-0.340	<.001	-0.339	<.001	-0.341	<.001
M.E. (in-degree) Education(yr)	SE	0.032		0.033		0.034		0.033		0.033		0.033		0.034	
	Log-Odds			0.015	<.001										
M.E. (in-degree) Time in Village(yr)	SE			0.002											
	Log-Odds			-0.002	>.05										
Absolute Difference in Years in Village	SE			0.002											
	Log-Odds			-0.049	<.001										
Absolute Difference in Age	SE			0.003											
	Log-Odds					-2.317	<.001	-2.450	<.001	-1.867	>.05			-2.358	<.001
Genetic Relatedness	SE					0.373		0.412		1.081				0.380	
	Log-Odds					0.265	>.05	0.253	>.05	0.284	>.05	0.276	>.05	0.260	>.05
Most Fishing Knowledge	SE					0.167		0.176		0.173		0.216		0.160	
	Log-Odds					0.800	<.001	0.703	<.001	0.791	<.001	0.764	<.001	0.805	<.001
Best Line Fisher	SE					0.194		0.194		0.183		0.183		0.194	
	Log-Odds					2.288	<.001	2.311	<.001	2.303	<.001	2.305	<.001	2.286	<.001
Best Spear Fisher	SE					0.089		0.094		0.092		0.098		0.094	
	Log-Odds							-1.038	<.001						
Most Yam Knowledge	SE							0.184							
	Log-Odds							0.786	<.001						
Best Yam Grower	SE							0.128							
Proportion of Times Observed Together	Log-Odds													-0.668	>.05
	SE													0.614	

*Numerical values listed next to log-odds represent the corresponding p-value for the parameter estimate (see description of table in the text on page 31)

Table 2.3: Teci-Dalomo Sample ERG Models-Yams

		Yams Advice Networks-Teci Dalomo Sample													
Variable	Statistic	Theoretical Only		Non Theoretical Included		Success in Domain		Success in All Domains		Kinship Only		Household Only		Time Allocation Included	
	Log-Odds	-0.662	<.001	-0.569	<.01	-0.616	>.05	-0.628	<.01	-0.626	<.05	-0.619	<.05	-0.622	<.01
Same Gender	SE	0.191		0.196		0.382		0.245		0.323		0.274		0.231	
	Log-Odds	0.614	<.01	0.814	<.001	0.573	>.05	0.551	<.05	0.596	<.05	0.568	<.05	0.564	>.05
Same Village	SE	0.190		0.201		0.443		0.264		0.297		0.290		0.329	
	Log-Odds	0.561	>.05	0.579	>.05	0.502	>.05	0.371	>.05			0.296	>.05	0.111	>.05
Same Household	SE	0.408		0.404		0.801		0.579				0.537		0.577	
	Log-Odds	0.001	>.05	-0.034	<.001	0.016	>.05	0.016	>.05	0.018	>.05	0.018	>.05	0.017	>.05
Difference In Age	SE	0.006		0.007		0.017		0.010		0.010		0.014		0.015	
	Log-Odds	1.107	<.001	1.579	<.001	0.963	<.05	0.905	<.05	0.964	<.01	0.954	<.05	0.964	<.01
M.E. (in-degree) Gender	SE	0.250		0.284		0.452		0.356		0.366		0.381		0.333	
	Log-Odds	0.028	<.001	0.026	<.01	0.047	<.05	0.051	<.001	0.045	<.001	0.046	<.01	0.045	<.01
M.E. (in-degree) Age(yr)	SE	0.008		0.008		0.019		0.014		0.012		0.015		0.017	
	Log-Odds	-0.321	<.001	-0.350	<.001	-0.291	<.001	-0.297	<.001	-0.290	<.001	-0.290	<.001	-0.290	<.001
M.E. (in-degree) Education(yr)	SE	0.034		0.035		0.067		0.042		0.054		0.048		0.060	
	Log-Odds			-0.020	<.001										
M.E. (in-degree) Time in Village(yr)	SE			0.006											
	Log-Odds			-0.004	>.05										
Absolute Difference in Years in Village	SE			0.003											
	Log-Odds			-0.048	<.001										
Absolute Difference in Age	SE			0.002											
	Log-Odds					-0.717	>.05	-0.515	>.05	-0.032	>.05			-0.583	>.05
Genetic Relatedness	SE					0.722		0.375		1.401				1.006	
	Log-Odds					0.800	<.001	0.752	<.001	0.829	<.001	0.805	<.05	0.804	<.001
Most Yam Knowledge	SE					0.154		0.127		0.168		0.335		0.138	
	Log-Odds					1.982	<.001	1.882	<.001	1.979	<.001	1.980	<.001	1.981	<.001
Best Yam Grower	SE					0.149		0.091		0.118		0.099		0.176	
	Log-Odds							0.001	>.05						
Most Fishing Knowledge	SE							0.320							
	Log-Odds							0.025	>.05						
Best Line Fisher	SE							0.174							
	Log-Odds							0.872	<.001						
Best Spear Fisher	SE							0.149							
	Log-Odds													2.598	<.001
Proportion of Times Observed Together	SE													0.643	

*Numerical values listed next to log-odds represent the corresponding p-value for the parameter estimate (see description of table in the text on page 31)

Table 2.4: Teci-Dalomo Sample ERG Models-Medicinal Plants

	Medicinal Plants Advice Networks-Teci Dalomo Sample														
Variable	Statistic	Theoretical Only		Non Theoretical Included		Success in Domain		Success in All Domains		Kinship Only		Household Only		Time Allocation Included	
	Log-Odds	-0.060	>.05	0.016	>.05	-0.012	>.05	-0.008	>.05	-0.021	>.05	-0.011	>.05	-0.013	>.05
Same Gender	SE	0.194		0.193		0.221		0.233		0.204		0.253		0.223	
	Log-Odds	1.109	<.001	1.305	<.001	1.016	<.001	1.038	<.001	1.036	<.001	1.010	<.01	1.006	<.001
Same Village	SE	0.222		0.224		0.300		0.304		0.251		0.355		0.255	
	Log-Odds	0.763	<.05	0.820	<.05	0.578	>.05	0.514	>.05			0.404	>.05	-0.208	>.05
Same Household	SE	0.390		0.384		0.433		0.574				0.757		0.489	
	Log-Odds	-0.009	>.05	-0.046	<.001	0.013	>.05	0.014	>.05	0.015	>.05	0.016	>.05	0.011	>.05
Difference In Age	SE	0.006		0.006		0.009		0.009		0.012		0.015		0.008	
	Log-Odds	-1.757	<.001	-1.833	<.001	-1.559	<.001	-1.622	<.001	-1.551	<.001	-1.567	<.001	-1.575	<.001
M.E. (in-degree) Gender	SE	0.230		0.233		0.316		0.350		0.264		0.370		0.261	
	Log-Odds	0.030	<.001	0.024	<.01	0.036	<.001	0.035	<.01	0.034	<.01	0.034	<.05	0.035	<.001
M.E. (in-degree) Age(yr)	SE	0.008		0.008		0.009		0.012		0.012		0.015		0.009	
	Log-Odds	-0.329	<.001	-0.342	<.001	-0.313	<.001	-0.319	<.001	-0.311	<.001	-0.313	<.001	-0.316	<.001
M.E. (in-degree) Education(yr)	SE	0.043		0.042		0.055		0.057		0.055		0.066		0.052	
	Log-Odds			0.015	<.001										
M.E. (in-degree) Time in Village(yr)	SE			0.003											
	Log-Odds			-0.003	>.05										
Absolute Difference in Years in Village	SE			0.002											
	Log-Odds			-0.059	<.001										
Absolute Difference in Age	SE			0.002											
	Log-Odds					-0.625	>.05	-0.550	>.05	0.159	>.05			-0.262	>.05
Genetic Relatedness	SE					0.802		0.413		0.924				0.734	
	Log-Odds					3.197	<.001	3.229	<.001	3.216	<.001	3.190	<.001	3.265	<.001
Most Plant Knolwedge	SE					0.112		0.118		0.101		0.297		0.112	
	Log-Odds							-1.537	<.05						
Most Fishing Knowledge	SE							0.615							
	Log-Odds							0.447	>.05						
Most Yam Knowledge	SE							0.266							
	Log-Odds							0.925	<.01						
Best Yam Grower	SE							0.303							
	Log-Odds													3.863	<.001
Proportion of Times Observed Together	SE													0.403	

*Numerical values listed next to log-odds represent the corresponding p-value for the parameter estimate (see description of table in the text on page 31)

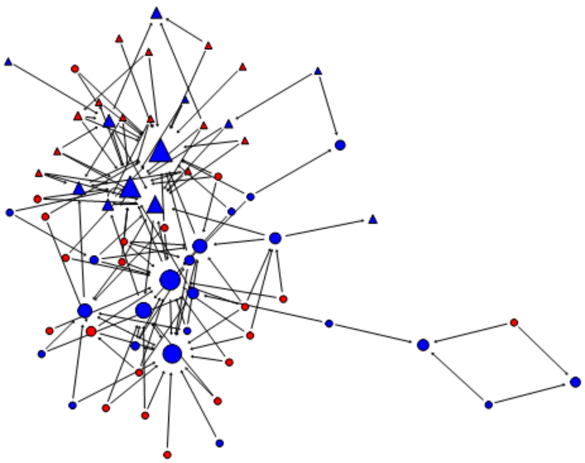
Table 2.5: Full Sample ERG Models

Full Sample- Advice Networks for All Domains							
		Medicinal Plants		Fishing		Yams	
Variable	**Statistic**						
Same Gender	Log-Odds	-0.801	<.001	-1.093	<.001	-1.131	<.05
	SE	0.168		0.110		0.531	
Same Village	Log-Odds	0.986	<.001	0.859	<.001	0.801	<.001
	SE	0.148		0.086		0.194	
Same Household	Log-Odds	1.228	<.01	0.994	<.001	1.322	>.05
	SE	0.384		0.202		1.139	
Difference In Age	Log-Odds	-0.007	>.05	-0.001	>.05	0.000	>.05
	SE	0.004		0.003		0.024	
M.E. (in-degree) Gender	Log-Odds	-2.532	<.001	0.283	<.01	0.273	>.05
	SE	0.157		0.106		0.535	
M.E. (in-degree) Age(yr)	Log-Odds	0.026	<.001	0.020	<.001	0.031	>.05
	SE	0.006		0.003		0.026	
M.E. (in-degree) Education(yr)	Log-Odds	-0.292	<.001	-0.223	<.001	-0.312	<.01
	SE	0.015		0.013		0.104	

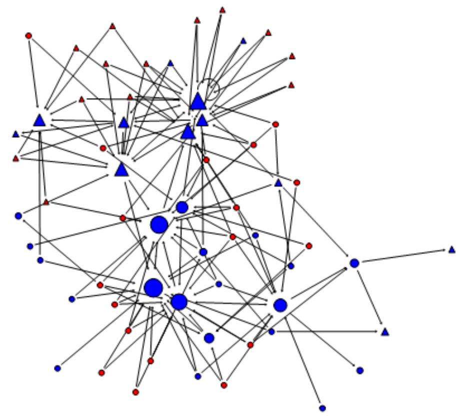
*Numerical values listed next to log-odds represent the corresponding p-value for the parameter estimate (see description of table in the text on page 31)

Figure 2.1-Cultural Transmission Networks for Smaller Sample

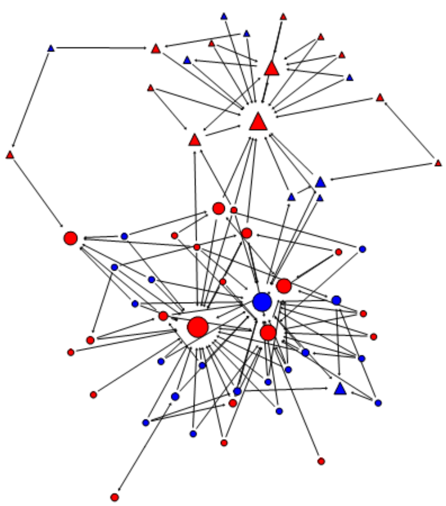
Fishing



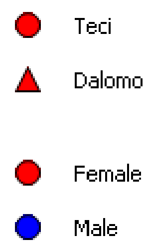
Yam Growing



Medicinal Plants

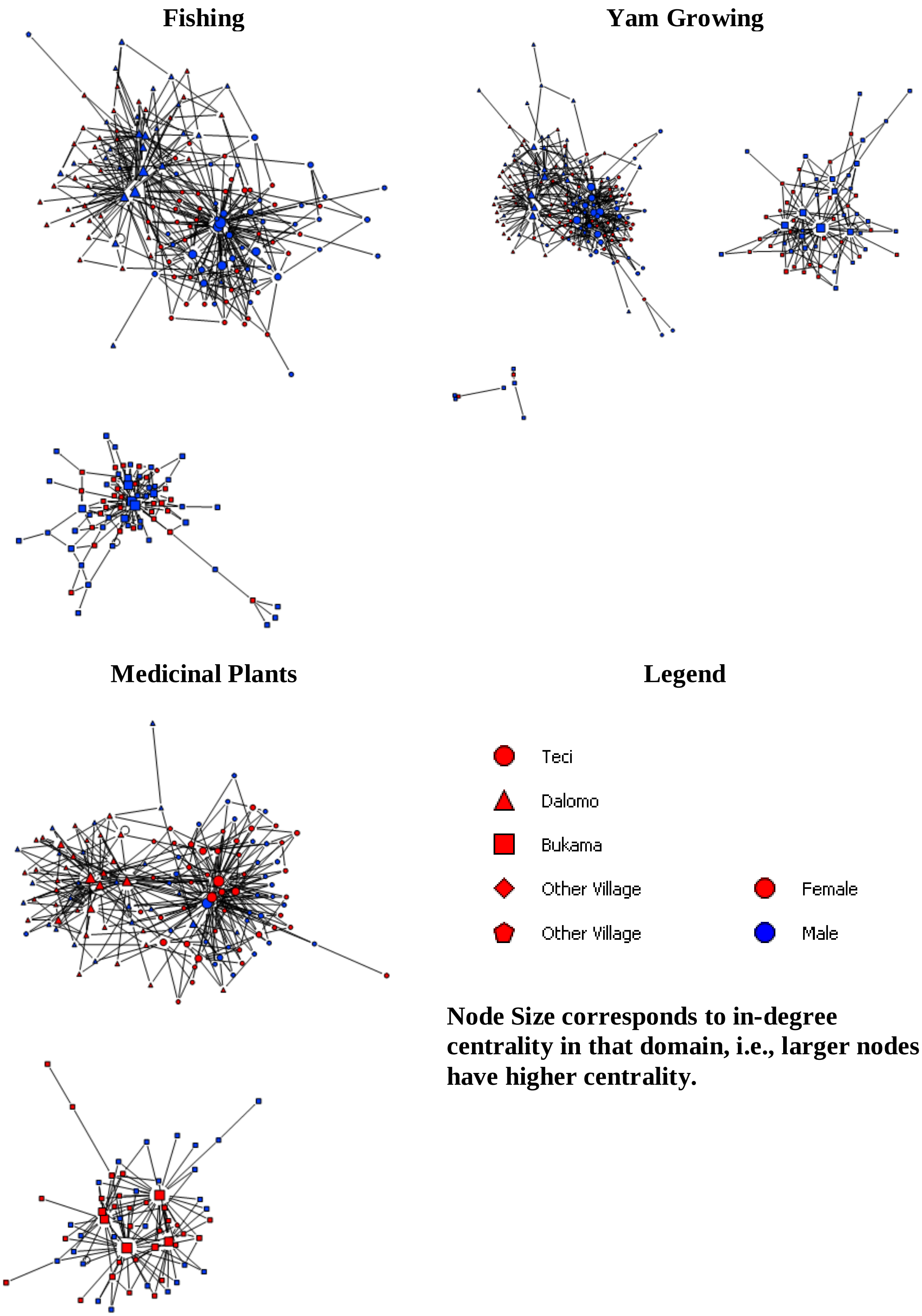


Legend



Node Size corresponds to in-degree centrality in that domain, i.e., larger nodes have higher centrality.

Figure 2.2-Cultural Transmission Networks for Full Sample



Chapter 2b- Interstitial Chapter

In the previous chapter, I explored one of the larger categories of biases proposed by cultural evolutionary theory (*context biases*). While there were some findings that were counter to the predictions from cultural evolutionary theory, I found more evidence that supports the key predictions from models from cultural evolutionary theory. If one is interested in understanding how patterns of human cultural transmission can lead to a “ratchet effect”(Boyd & Richerson, 1996; Tomasello, 2001), where cultural complexity increases over generational time, then the finding that individuals go to others that they perceive to be the most successful is crucial. If individuals’ perceptions of success are at all accurate, then this effect, which was observed across all the domains, would focus learners’ attention on models that are likely to possess better than average cultural variants (e.g., knowledge, skills, or techniques). This study demonstrates that individual level biases, that can produce this type of change, are in fact evident in individual decisions about whom they choose as models to learn from in the real world.

Knowing that this type of bias does operate in the real world provides researchers interested in spreading information and producing behavioral change with a theoretical framework that could be used as a starting point for the construction of effective interventions. Previous research has shown that artificially constructed social networks can aid in the dissemination of public health information (Kelly et al., 1997; Valente & Fosados, 2006). The study presented in chapter 2 shows that the intrinsic networks already present in these communities are highly influenced by perceptions of success, among other factors. Researchers could preferentially target those perceived to be knowledgeable about a health domain of interest, e.g., medicinal plants, and convince these central individuals that the intervention is really worthwhile. If the rest of the community is already looking to these central individuals for advice, then this would be an ideal starting point for producing the desired change. But even more broadly, seeing that these networks tend to be gendered toward women in the case of medicinal plants provides valuable information about who should be targeted for health promotions. For example, interventions aimed at convincing men are likely to have a much weaker effect if the rest of the community is looking to women for advice about health related practices.

It is important not to make overgeneralizations from one study in several Fijian communities to every other place in Fiji, or village communities in other parts of the world. What is important to recognize is that the same methodology employed here can be used elsewhere to determine if these same characteristics are observed in other communities. Using this approach provides a systematic method for determining who individuals tend to learn from in a given domain of interest.

The biases that were examined in the previous study, context biases, are only predicted under cultural evolutionary theory, as opposed to other dual-inheritance theoretical frameworks. However, the subject of the next study, content biases, are proposed by a variety of theoretical frameworks. Where these frameworks differ is the in the importance that they accord to content biases. Classic evolutionary psychology and sociobiology propose that they are pervasive, while cultural evolutionary theory proposes that content biases are likely to be relatively minor forces compared to context biases. Content biases are transmission biases that pertain to the information being transmitted, as opposed to the context in which it is transmitted. These biases privilege the transmission and retention of cultural variants that are more likely to produce adaptive consequences. Like context biases, they are another method through which individual level processes can lead to population level characteristics. If individual minds favor the acquisition or retention of certain cultural variants over others, we should expect that over generational time these variants will become more common. This in turn can lead to adaptive change over time.

I chose to explore if these biases are present in the domain of learning about animals for several important theoretical reasons. First, there are potentially very high fitness costs for making mistakes about animals. For example, falsely remembering that an animal is safe when in fact it is a dangerous predator could have very high negative consequences for fitness. Because of these potentially high fitness impacts, and the fact that humans have a long evolutionary history of interacting with animals (either as predators or as prey), we might expect that human minds would privilege the acquisition and retention of high fitness relevant information about animals over less fitness relevant information. For example, given the high fitness costs of mistaking a dangerous animal as being safe, we might expect learners to be more likely to remember this information than where the animal lives.

This study builds off of previous work by Clark Barrett that explored content biases in learning about animals among children in rural Ecuador and urban Los Angeles (H. C. Barrett, unpublished). Barrett found evidence for the preferential retention of danger information about animals compared to retention of information about their diet and habitat. However, because there was only one high fitness relevant domain, danger information, it is impossible to determine if it is danger information specifically that activates this content bias, or if it is because danger information is of high fitness relevance. To answer this question, I added an additional high fitness relevance domain, if animals are poisonous to eat. If the bias observed by Barrett is driven by fitness relevance, then we should expect to see a similar pattern of preferential retention in this domain as well.

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Chapter 3- Content Biases in Learning about Novel Animals

A little knowledge that acts is worth infinitely more than much knowledge that is idle.

Kahlil Gibran

Introduction

Every day, individuals are bombarded with information about the world they live in and the things that exist within it. It is impossible to attend to all the auditory, visual, and tactile information that exists in daily life; therefore, one must ignore extraneous information and attend to relevant information in the environment (Lavie, 2005). What information does make it through these perceptual filters is still potentially greater than what memory systems are capable of encoding. So which factors determine if information is encoded into memory, and if that information is likely to be retained for future use?

Content biases are biases that cause the preferential retention of certain behaviors or types of information over others, as a function of what is being transmitted. In this chapter, I will provide an overview of the theoretical foundations for biases in cultural transmission, and a brief description of the empirical evidence for content biases in a variety of domains. Building on this, I will then discuss a study which indicates that content biases may be operating when individuals learn about animals - a domain that would have clear evolutionary pressures. This study was conducted with indigenous Fijians living in a traditional context, to determine if information about novel animals that is fitness relevant (if an animal is dangerous or poisonous to eat) was preferentially encoded and remembered above non-fitness relevant information (diet and habitat).

Biases in Cultural Transmission:

In their discussion of cognitive mechanisms that influence social learning, Henrich and McElreath (2003) broadly distinguished between two types of biases that influence the transmission and acquisition of cultural information: *context* biases and *content* biases (Boyd & Richerson, 1985, 2005; J. Henrich & McElreath, 2003). *Context biases* reflect cognitive mechanisms that influence the salience and likelihood of transmission based on the contextual environment in which they are transmitted. These biases can be associated either with the model or teacher, or the distribution of the information within the population (frequency-dependent biases). For example, if a model is perceived to be skilled in the preparation of medicinal plants, individuals should seek out and preferentially encode information from these individuals regarding medicinal plants. This is largely intuitive given that learning involves some costs (time, effort, possibly monetary costs) so that individuals should seek to maximize their benefits by copying successful and skilled individuals (Boyd & Richerson, 1985; J. Henrich & McElreath, 2003).

While *context biases* are hypothesize to be a key force underlying the patterns of transmission of information and behaviors among humans, the *content* of what is being transmitted can also bias acquisition of information and practices. Not all cultural variants are created equal, and some may be inherently better than others. In their discussion of biases in cultural transmission, Boyd and Richerson use the following example. Consider the way that individuals hold a racquet for playing table tennis and imagine that there are two grips, a “pencil grip” and a “racquet grip”. Now, if the racquet grip allowed inherently more control over the direction of the ball and accuracy of the swing, there would be a content bias for individuals to adopt the racquet grip over the pencil grip (Boyd & Richerson, 1985 p. 135). It is possible that for certain individuals, the direction of the bias might shift; as the authors point out, individuals with larger hands might naturally do better with the pencil grip. The key point here is that the bias towards one behavior over the other is contingent on the behavior itself, not the dynamics of the situation in which it is transmitted.

Boyd and Richerson clearly demonstrate, through modeling approaches the conditions under which content biases would be favored by selection (Boyd & Richerson, 1985p. 137-157). Direct biases (termed content biases elsewhere) are favored when the cost of evaluating possible variants is cheap, or when the fitness consequences of traits are salient to the learner. Multiple coevolutionary theorists and evolutionary psychologists agree that content biases play a role in cultural transmission and behavioral expression (Boyd & Richerson, 1985; Durham, 1991; Lumsden & Wilson, 1981; Tooby & Cosmides, 1992). Although they do not specifically label them content biases, when Lumsden and Wilson, or Tooby and Cosmides discuss genetic factors that influence the acquisition of certain traits through their epigenetic expression, they are referring to what Boyd and Richerson (2005) or Henrich and McElreath (2003) term content biases. For example, certain stimuli might be more salient to learners because they appeal to an underlying cognitive predisposition to threat detection, and therefore might be detected more rapidly or recalled more frequently than non-threatening stimuli (see following section) (Ohman, Flykt, & Esteves, 2001). Evolutionary theory would predict that the costs of mistakenly ignoring a dangerous living or non-living stimuli in the environment would be potentially very high, and therefore humans should have a genetic predisposition that biases the development of our cognition to detecting and learning about these threats.

In order to understand how content biases work and their implications for learning, it is necessary to understand why they might be beneficial. As discussed above, one major reason for the existence of content biases is that certain behaviors or pieces of information are inherently better for obtaining resources or avoiding fitness costs, and are therefore transmitted at a higher frequency. The reader may be satisfied with this explanation for the acquisition of behavior but perhaps not for information. If two pieces of information are conflicting, it would explain why learning would favor the more accurate/beneficial of the two. However, what about non-conflicting information in different domains (e.g., if an animal is dangerous, and where it lives)? Would it not be better to know everything one can about a plant, tool, animal, etc.? While on the surface this may seem compelling, it is important to recognize the limitations on attention and memory encoding. Any resources devoted to perceive and encode information about an item means that those resources are no longer available to perceive/encode information about another item of the same object (Schaller, Park, & Kenrick, 2007). Attention is a limited resource, and therefore it has been proposed that it should be allocated to the most relevant features in order to maximize the adaptive capacities of cognition (Gigerenzer, Todd, & ABC Research Group, 2000; Schaller, et al., 2007).

Evidence for Content Biases in other domains:

Content biases may serve as one mechanism for directing attention to the most relevant features to structure learning in a way that optimizes fitness benefits, and there is some evidence for the existence of content biases in a variety of domains. For example, studies on visual detection of threats have indicated that there are both conscious and subconscious processes that make individuals more likely to detect fear-provoking stimuli than non-fear provoking stimuli (Ohman, et al., 2001). Such evidence argues for a possible genetic and cultural component in the construction of content biases in this domain. For example, individuals who have snake phobias are faster to detect snakes in a visual task than individuals that do not have a snake-phobia (Ohman, et al., 2001). The same biases are also observed in individuals who have spider-phobias in the detection of spiders. However, individuals who did not have particular phobias toward either organism were still quicker to detect these potentially threatening organisms than other non-threatening items in a visual task (Ohman, et al., 2001). This indicates that this bias is prior to conscious processing, but the fact that it is enhanced by phobias is evidence that conscious level processes can augment preconscious attention biases (Ohman, et al., 2001).

Ohman and colleagues (2001) also propose that the goals of an individual may influence their attention biases. For individuals that have a phobia, the primary goal is to detect the fear provoking objects so that they can be avoided. However, if an individual is in a situation of nutritional deprivation, their goal of obtaining food might cause them to be more attentive to stimuli that are likely to provide nutrition (Ohman, et al., 2001). This line of thinking implies that the conscious level biases in attention are malleable and should switch depending on the situational context of the individual. For individuals with phobias, attending to fear-inducing stimuli allows them to act in ways to avoid it, which the authors propose may be their primary goal. Ohman and colleagues propose that different goals may lead to different attention biases, which implies that certain information may be more important to act on given an individual's context. The observed effects of phobias, which are proposed to be enhanced by the authors due to personal relevance, illustrates that there may be individual variation in content biases. That is, content biases could be enhanced or suppressed by socially acquired cultural models that affect the relevance of certain types of information. However, the demonstration of a sub-conscious component also points to a more fixed type of content bias that is due to psychological predispositions.

The transmission of stories between individuals is another domain in where evidence exists with respect to the role that content biases have played in the preservation of certain stories over others. For example, a study by Barrett and Nyhof (2001) demonstrated that elements of stories that were counterintuitive were more likely to be retained after several retellings than entirely intuitive elements (J. L. Barrett & Nyhof, 2001). However, there does appear to be a crucial threshold as stories with many counterintuitive elements are less likely to be remembered (Boyer & Ramble, 2001). Taken together, these results indicate that stories that are "minimally counter-intuitive" are the most likely to be recalled and transmitted. Further work has confirmed this hypothesis, demonstrating that while participants show higher initial recall of lists that contain entirely intuitive concepts, they also show greater delayed recall on lists that are minimally counter-intuitive (i.e., containing mostly intuitive concepts but some counter-intuitive concepts) than entirely intuitive, or maximally counter-intuitive lists (Norenzayan, Atran, Faulknera, & Schaller, 2006).

Previously Studied Content Biases: Learning about Animals

Learning about animals is a domain where evolutionary theory would predict that content biases may be operating for several reasons. First, over our evolutionary history, humans have needed knowledge about other animals for obtaining food resources, and for avoiding potential fitness costs (i.e., being killed by dangerous animals). Because of this long evolutionary history, there may have been opportunities for the selection of psychological predispositions that favor acquisition and retention of fitness relevant information over non-fitness relevant information in this domain. Using an elegant experimental design, Barrett (unpublished) examined whether certain categories of knowledge about animals were preferentially acquired over others (H. C. Barrett, unpublished). Each of Barrett's two experiments was conducted in two different cultural contexts –urban U.S. and rural Ecuador, among the Shuar. The first set of experiments examined differences in knowledge about familiar animals. Barrett hypothesized that children should be more likely to know information about whether an animal was dangerous or safe over what the animal's name was or what it ate (because of the fitness relevance of those domains). The second set of experiments evaluated differences in the acquisition of knowledge about unfamiliar animals across different domains (danger, diet, name) (H. C. Barrett, unpublished).

The main hypothesis of these studies draws on hypotheses put forth by Boyd and Richerson (1985) regarding social learning. First, when the costs of individual learning are high, such as learning based on personal experience that an animal is dangerous, social learning will be favored over individual learning (Boyd & Richerson, 1985). Second, because of the differences in the potential fitness costs between knowing what an animal eats (low) and knowing if an animal is dangerous (high), content biases should favor the acquisition of danger knowledge over other types of knowledge. Barrett's findings from the studies on familiar animals indicate that children in both cultures have higher levels of knowledge about whether an animal is dangerous than about what it eats (H. C. Barrett, unpublished). Further, the direction of errors also indicate that children are more likely to misidentify a safe animal as dangerous, than a dangerous animal as safe; this fits with what would be expected based on the relative fitness cost of each of those types of errors (much more costly to identify a dangerous animal as safe).

In the second set of experiments conducted by Barrett (unpublished), children were presented with unfamiliar animals and told the species name, diet, and whether it was dangerous or not. After a week, participants were asked what they remembered about each animal. Children correctly recalled whether an animal was dangerous or not significantly more than the diet or name of the animal. This demonstrates that a single event was sufficient to learn information regarding the 'dangerousness' of an animal and that this information was preferentially retained over other information about the species (H. C. Barrett, unpublished).

This combination of experiments demonstrates a content bias in the acquisition of information about potentially dangerous animals. Barrett explains why this type of content bias may exist. He evokes the relative fitness benefits of acquiring this type of information and suggests that dangerous information is fitness relevant because individuals should prefer to avoid contact with these types of animals. Naming and diet information, however, is not as fitness relevant and therefore should be less likely to be retained. In addition, Barrett suggests that danger information is more emotionally evocative than the other categories and could appeal to fear based attention biases that were discussed in the studies by Ohman and colleagues (2001).

The present study follows directly from the study by Barrett regarding learning about novel animals. The goal was to replicate the results of Barrett as well as to validate the findings with another culture, across a broader age range, and with additional types of fitness relevant and irrelevant information. To accomplish these aims, I conducted this experiment with adults and children in Fiji to determine if these content biases are exhibited in adults as well as in children. In addition, I broadened the information that was presented to participants to include two more domains of knowledge: whether an animal is edible or poisonous (fitness relevant) and where an animal lives (less fitness relevant). The inclusion of information about if an animal is edible or not is intended to explore whether it is the fitness relevance of this information that explains the increased retention of danger information, or if it is something more specific to the danger domain itself, such as visual salience.

Methods:

Participants: The participants in this study come from 3 villages in the Fiji Islands. Informed consent from adults, parents of children, along with child assent was obtained for all participants prior to testing. The adult sample was composed of 92 individuals, 52 from the island of Totoya and 40 from the island of Yasawa. Within the Totoya sample, 11 individuals comprised a control group and 41 comprised an experimental group. Logistical constraints prevented the collection of the secondary recall data for 28 of the 41 participants in the experimental group in Totoya, leaving 13 who completed the entire experiment in this condition. All 40 individuals from the island of Yasawa were in the experimental group, and all completed both rounds of data collection. The child sample came entirely from the island of Yasawa, 13 in the control group 17 in the experimental group. All children were between the ages of 7 and 14.

Stimuli: Twenty animals were selected as exemplars, using a 5 X 4 design balancing scientific taxonomic categories with various levels of fitness threats. The taxonomic categories were: mammal, bird, reptile/amphibian, fish, and an additional category of animals that were taxonomically ambiguous based on physical appearance alone. Animals were selected to fill 4 different categories that varied in their fitness threats: 1) dangerous but not poisonous, 2) poisonous but not dangerous, 3) poisonous and dangerous, and 4) neither dangerous nor poisonous. It was possible to find species exemplars for all categories with the exception of a bird that is both poisonous and dangerous. All species chosen were non-native to Fiji. To control for order and fatigue effects, I randomized the order of presentation of the animals. To simplify the implementation of the experiment, this randomization was done by creating four versions of the stimuli and information presentation. Participants were presented with information using one version, and all subsequent interviews were done with another version.

Information Presentation: Participants were presented with a picture of the first animal and told information about it. For example, if the first species was a polar bear, the image would be placed in front of the participant and the experimenter would say, “This animal is a polar bear. It lives in open areas. It is dangerous. If you eat it, you can get sick. It eats only other animals.” Participants were allowed to inspect the image, and after they were finished, the experimenter moved on to the next species. This process was repeated until the participant had seen all 20 species.

Initial and Delayed Recall: To determine what information was encoded from the information presentation, participants were asked questions about each species immediately following the information presentation. The experimenter would begin by saying, “I would like to ask you a few questions about the animals I just told you about.” Participants were then shown an image of one of the 20 species (species were in a different random order than the version used in the information presentation) and asked the following questions: 1) What is this animal’s name? 2) Do you think this animal is dangerous? (yes/no) 3) Do you think this animal is poisonous to eat? (yes/no) (Literal translation: would you get sick if you ate it). 4) Where do you think it lives? (Forced choice from list of 10 options) 5) What do you think it eats? (Forced choice from list of 7 options). All forced choices are listed in the Table 3.4. These questions were then repeated for the remaining 19 animals. To determine what information participants remembered from the information that was presented, approximately one and one half weeks following the information presentation, participants were again asked to answer the questions outlined above.

Control Group: To determine what information might be present in the pictures, or if there was general prior knowledge that could explain participant performance on the task in the experimental condition, a subset of participants was not presented with any information and were instead directly asked the questions regarding each species outlined in the section above. Additionally, before the first question for each species, participants were asked: “Do you know this animal? (yes/no)”.

Results:

There are 4 main results which will be discussed in turn: 1) When adults and children in both the experimental condition and the control condition make mistakes in their attribution of whether an animal is dangerous, they err on the side of caution (e.g., significantly more likely to identify a safe animal as dangerous, rather than identifying a dangerous animal as safe). This pattern also holds for attributions of whether an animal is poisonous to eat for children in the experimental and control condition, but only for adults in the experimental condition; 2) adults and children in the experimental conditions exhibit higher performance across domains than in the control condition. This indicates that some learning is occurring due to the one time presentation of information; 3) when comparing how much was encoded and recalled immediately after information presentation across domains, there is some evidence for a bias towards higher encoding for fitness relevant information in children, and no evidence for a bias in adults; and 4) after ~1.5 weeks, we see evidence in children for preferential retention of information about whether an animal is dangerous or poisonous, over what it eats or where it lives. In adults this effect is weaker and not statistically significant, but there is some evidence that danger information is preferentially retained above the other domains.

Danger and Poison Attribution

First, I wanted to explore if there was any patterning to the direction of errors in participants' attribution of whether an animal was dangerous or poisonous to eat. If an individual misidentifies a dangerous animal as safe, it could be a potentially very costly mistake in terms of fitness (death or injury), while misidentifying a safe animal as dangerous would have much lower costs (avoiding a potential prey species). Therefore, evolutionary theory would predict that the cost benefit dynamics are such that individuals should err on the side of caution (e.g., should be more likely to identify a safe animal as dangerous, rather than identifying a dangerous animal as safe.)

I tested this prediction in two ways. First, I examined if there was a response bias toward saying animals were dangerous or poisonous on the whole. Binomial tests confirmed that both adult and child participants were significantly more likely to respond that an animal was dangerous rather than safe, and poisonous rather than edible for both the control and experimental conditions (all $p<.05$). (See Table 3.1) For the danger domain, I tested against expected probabilities of .45 (actual proportion of animals in stimuli that were dangerous), and .5 (probability based on random guessing). From this I conclude that there is a general bias that participants are more likely to say an animal is dangerous both without prior information (as evidenced by the control group) and with prior information (experimental group). For poisonous attribution, I observed the same general bias (i.e., participants were more likely to say an animal was poisonous rather than edible); however, it was not statistically significant for adults in the control group (see Table 3.1).

Secondly, I looked only at instances where participants made errors in their danger or poison attributions to see if the direction of errors was in line with the predictions from evolutionary theory. If errors were equally likely, one would expect participants to mistakenly identify safe animals as dangerous just as often as they mistakenly identified dangerous animals as being safe. Binomial tests confirmed that the direction of errors was as expected based on the predictions from evolutionary theory (see Figure 3.1). When adults and children made mistakes, they were significantly more likely to misidentify a safe animal as being dangerous, rather than mistaking a dangerous animal for being safe. The same trend held true for the errors regarding if an animal was poisonous or not; however, this was not significant in the control group adults.

The combined results of these analyses indicate that there is a general bias toward erring on the side of caution, which could be explained by a general bias toward saying that animals are dangerous or poisonous in the absence of other information (control group) or when participants were uncertain (experimental group-error bias). These results match those previously reported by Barrett (unpublished), who found a similar patterning of errors among Shuar and Ecuadorian children.

One Shot Learning

A key assumption of my experimental design is that participants are learning something as a result of being presented with information about these animals. However, it is possible that due to poor design, or high levels of prior knowledge, this may not occur. To evaluate this, I compared the performance of the control group to the immediate recall performance of the experimental group. To control for background knowledge or information that might be contained in the stimuli itself, I dropped any animals where more than eight percent of the control group responded correctly. With the remaining animals, I compared the mean proportion of correct responses in each domain between the control group and the experimental group's initial recall (Shown in Figure 3.2). All standard errors were clustered by participant to account for the fact that each participant responded for twenty different animals. Adults in the experimental group had significantly higher scores in every domain than the control group. The same was true for children, with the exception of the diet domain. These combined results indicate that individuals generally were learning something about these animals from a single presentation of information (except for diet information for children), validating the assumption regarding the experimental design.

Initial Encoding

The first test for content biases in learning was aimed at determining if certain domains of information were preferentially encoded. I tested for this by evaluating if there were any domains where individuals were more likely to respond correctly in the immediate recall. First, I eliminated any domains for a given animal if the control group responded correctly more than eighty percent of the time (to control for prior knowledge or visual cues). With the remaining animals, I performed four logistic regressions for each domain. The dependent variable was if the participant responded correctly (i.e., gave the response that they were told in the information presentation), and the independent variable was a binomial variable coding if individuals were or were not in the control group. Standard errors were clustered by participant, to account for the fact that there were multiple animals that participants were asked about. The coefficients for the independent variable indicate the increase in performance that can be attributed to being presented with information about the animals. Using these coefficients and standard errors, I performed Wald tests comparing the coefficients between domains (e.g., danger to diet domain, poison to diet domain, etc.). I adjusted the significance level to account for the fact that I was conducting multiple tests (alpha = .05/6 =.008; See Table 2.2). The only statistically significant differences observed were for children when comparing the diet domain to the other three domains. However, because there was no evidence for higher performance than the control group in this domain, this can be attributed to the fact that there was no learning occurring in children regarding diet information in the experimental condition. The magnitude of the coefficients indicated general trends in children for higher encoding in the danger domain above all others followed by poison information. For adults there were minimal differences between the magnitudes of the coefficients, indicating no evidence for preferential encoding in any domain. From these combined analyses I conclude that there may be slightly higher encoding of fitness relevant information in children, but there is no difference in the levels of encoding for adults.

Retention of Information

Next, I wanted to examine if there was evidence for a content bias in the information that was retained after some time had elapsed. To do this, I used a logistic regression approach, where the dependent variable was a participant answering a question regarding the animal correctly. The independent predictors were: dummy variables for the domain that was in question (danger, poison, diet, and habitat) and whether the participant responded correctly on the immediate recall (to control for guessing and lack of encoding). I clustered all standard errors to account for the fact that participants were answering these questions about 20 different animals. I compared the odds ratios for each of the dummy variables and their 95% confidence intervals to determine if any domain was significantly more likely to be remembered. The results of these regressions (see Table 3.3) indicate that for children there is evidence of higher retention of information in high fitness relevance domains, as their odds ratios are greater than that for diet and habitat, and the confidence intervals for these odds ratios in high relevance domains do not overlap with the low relevance domains. However, for adults there is much weaker evidence for a content bias in retention of high fitness relevant information. While the danger domain does have the highest odds ratio, the 95% CI's of the habitat and danger odds ratios overlap.

Discussion:

The results of this study broadly indicate the following: 1) Both adults and children exhibit a bias toward erring on the side of caution when attributing if an animal is dangerous or poisonous to eat, in the absence of other information or when they are uncertain. This finding matches with the previous work by Barrett (unpublished) and is in line with the predictions from evolutionary theory given the cost/benefit dynamics. 2) In adults and children, there is limited evidence for any preferential encoding of the information that they are presented with. That is, performance in both fitness relevant and fitness irrelevant domains increases in similar magnitudes, indicating that, given the way information was presented in this task, there is no bias toward initially remembering either fitness relevant or irrelevant information more than the other. However, when the same questions were asked of children approximately a week and a half later, there was less degradation in the information that was learned in the fitness relevant domains than in the less fitness relevant domains. This suggests that, for children, there may be a content bias in the retention of fitness relevant information about animals over less fitness relevant information. With adults, there is no statistical evidence of this bias; however, there is a trend toward danger information being retained at a slightly higher rate.

The results of this study largely confirm those of Barrett (unpublished) in that individuals err on the side of caution in attribution of whether or not an animal is dangerous or poisonous and I found evidence for content biases in retention of learned information about novel animals in children. However, with the expanded sample that included adults, I found limited evidence for this bias persisting in adulthood. I can make no definitive conclusions as to why this may be the case. A hypothesis is that there is a difference in relevance of this information for adults vs. children. Adults may have a higher degree of certainty that they will never encounter the novel animals presented in this task, given that they have had more extensive experience with their natural environment. Therefore, they may consciously or subconsciously judge all of the information regarding these animals to be irrelevant to their own survival. However, the relevance to children may be higher because they may not have the same level of certainty that the animals they already know about are the only ones that they will encounter in their own ecosystem or in other ecosystems that they may live in during their life-course. Therefore, children may be more attentive to learning about novel animals. If this is the case, this type of type of relevance judgment could be operating on a conscious level, or on a subconscious level via a developmental window where children are more attentive to information about animals generally (H. C. Barrett, 2004).

I tested the robustness of Barrett's hypothesis that these content biases are due to the fitness relevance of the information that is being transmitted by including another fitness relevant domain (if animals were poisonous to eat). I found that there is evidence for a content bias in this domain as well, adding support to this hypothesis. However, the effect appears to be stronger for danger information than for poison information. This may be explained by the differences in how potential fitness threats are experienced in these two domains. Individuals may encounter dangerous animals while isolated from other group members, whereas most food consumption occurs in the presence of others. In other words, when individuals consume food, there may be more opportunities for social transmission of what is safe and unsafe from other individuals, which might not be the case for making decisions about whether animals are dangerous or not.

Limitations

There are several limitations to this study design that are important to acknowledge. First, the study is limited for making generalizations outside of this sample population (Fijian village). It is possible that this type of bias is not present in other cultural groups because it is a culturally acquired bias. However, given that Barrett (unpublished) presents very similar results with both U.S. children and Shuar children, there is support for the hypothesis that this may be an innate cognitive bias due to humans' evolutionary history of living in other ecosystems with other animals.

Second, it may be possible that the study design itself is the reason that the observed biases are present. To attempt to control for this, I randomized the order that information was presented to participants and provided lists of multiple choice responses to aid in participant recall. It should be recognized, that the habitat and diet domains had more possible answers than the danger and diet domains. While the statistical analysis controls for these differences, it remains a nagging concern. However, in Barrett's (unpublished) study, there were equal numbers of choices for the dietary consumption domain (herbivore or carnivore) and for danger (dangerous/not dangerous), and similar effects were seen.

Conclusion

The human species has a long evolutionary history of sharing ecosystems with potentially dangerous or poisonous species. Given the high fitness consequences for encountering a dangerous animal, or consuming a poisonous animal, cultural evolutionary theory would predict that learning about animals would be a domain where content biases may privilege the retention of fitness relevant information about animals over other kinds of information. This study replicates the results observed by Barrett (unpublished), and adds strength to this hypothesis. However, the lack of the observed effect in the adult population indicates that there may be a developmental window for these biases. I hypothesize that this may be due to the relevance differences between adults and children in learning about novel animals, but further studies are needed to test this hypothesis.

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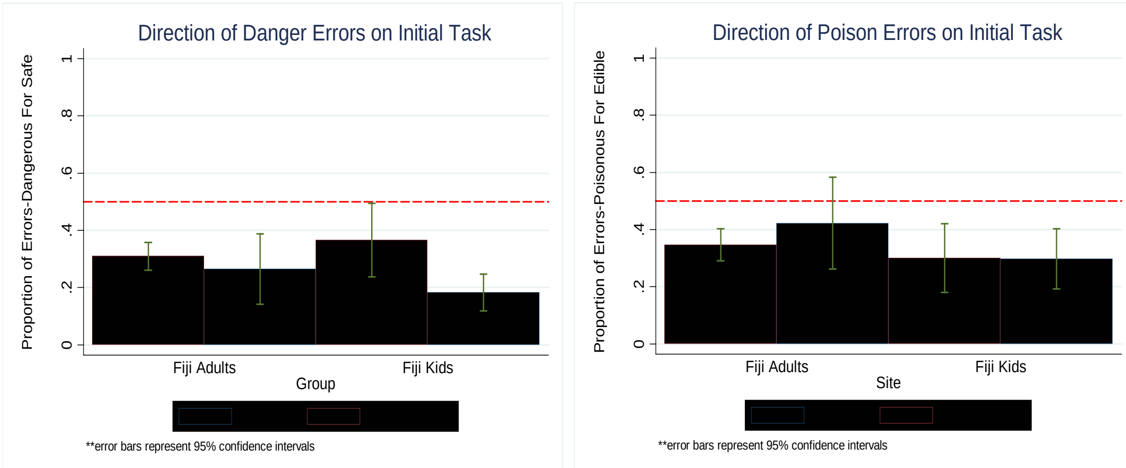
Table 3.1-Participant Attributions of Danger and Poison

Age Group	Condition	Domain	Observed Proportion Dangerous or Poisonous	Expected proportion	Siginificance
Adults	Control	Danger	0.66	0.5	0.000001
	Experimental	Danger	0.59	0.5	< 0.000001
	Control	Danger	0.66	0.45	< 0.000001
	Experimental	Danger	0.59	0.45	< 0.000001
	Control	Poison	0.56	0.5	0.034232
	Experimental	Poison	0.63	0.5	< 0.000001
Kids	Control	Danger	0.71	0.5	0.005349
	Experimental	Danger	0.57	0.5	< 0.000001
	Control	Danger	0.71	0.45	< 0.000001
	Experimental	Danger	0.57	0.45	0.000005
	Control	Poison	0.68	0.5	< 0.000001
	Experimental	Poison	0.68	0.5	< 0.000001

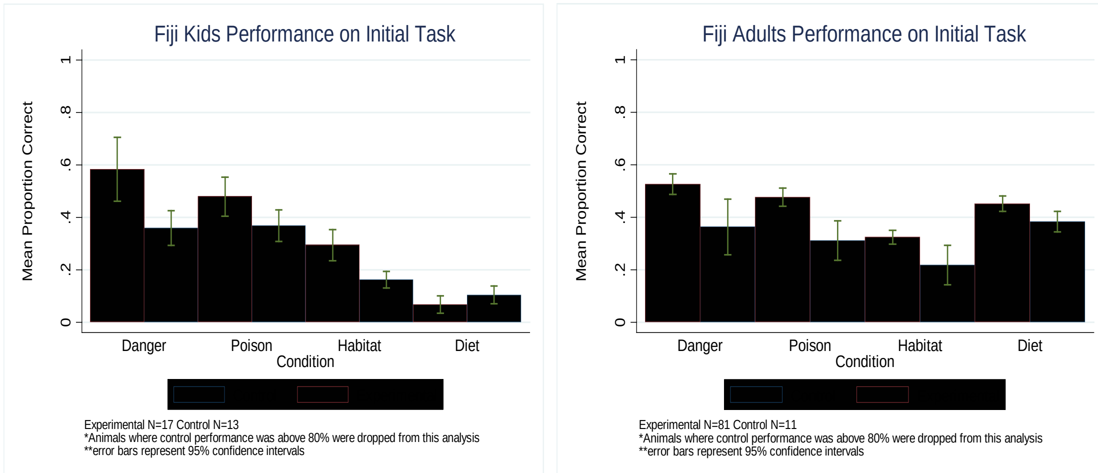
This table presents the results of binomial tests comparing participants' attribution of whether animals were dangerous or poisonous to what would be expected based on chance (50%), or based on the actual proportion in the stimuli (45% of animals were actually dangerous while exactly 50% were poisonous). All conditions, age groups, and domains exhibited a bias toward saying that animals were dangerous or poisonous, (all p <.05)

Figure 3.1-Direction of Errors in Attribution



These graphs illustrate the direction of errors that participants made in their attribution of whether animals were dangerous or poisonous. The red dashed line (.5) indicates what one would expect if participants were equally likely to mistake a dangerous animal as being safe, or a safe animal as being dangerous (and likewise for poison). The fact that the proportion of errors and their corresponding 95% confidence intervals for both adults and children in the control and experimental group are below this line indicates that they err on the side of caution (except adults in the control group for poison). That is, they are more likely to make the less fitness costly mistake.

Figure 3.2-Difference in Performance Between Control and Experimental Group



These graphs illustrate the mean performance, and corresponding 95% confidence interval (CI), for each domain on the initial recall task compared to the control group performance. Domains where the experimental group's 95% CI does not overlap and is greater than the control group's, indicates a significant increase in performance due to the information presentation. This is the case in all domains except for diet information for children.

Table 3.2-Initial Encoding Between Domain Comparison

	Danger to Diet					**Danger to Poison**		
	Difference between Coeff	Wald Stat	Significance			Difference between Coeff	Wald Stat	Significance
Fiji Kids	2.04	17.04	<0.01		Fiji Kids	0.55	1.30	0.25
Fiji Adults	0.20	0.29	0.59		Fiji Adults	-0.06	0.02	0.90
	Danger to Habitat					**Poison to Diet**		
	Difference between Coeff	Wald Stat	Significance			Difference between Coeff	Wald Stat	Significance
Fiji Kids	0.71	2.59	0.11		Fiji Kids	1.49	8.00	<0.01
Fiji Adults	-0.19	0.19	0.66		Fiji Adults	0.25	0.56	0.45
	Poison to Habitat					**Habitat to Diet**		
	Difference between Coeff	Wald Stat	Significance			Difference between Coeff	Wald Stat	Significance
Fiji Kids	0.16	0.12	0.73		Fiji Kids	1.33	14.54	<0.01
Fiji Adults	-0.14	0.10	0.75		Fiji Adults	0.39	1.35	0.24

This table presents domain by domain comparisons of performance on the initial recall for adults and children. The only domains where there are significant differences are for children when I compare the diet domain and all other domains. This is likely due to the fact that there is no increase in performance in this domain compared to the control group, indicating that children likely did not encode diet information from a single presentation of that information.

Table 3.3-Secondary Recall Between Domain Comparison

Age Group	Predictor	Odds Ratio	Lower 95% CI	Upper 95% CI
Kids	Correct on Initial Recall	10.98	6.20	19.42
	Danger	8.67	5.32	14.12
	Poison	6.69	4.42	10.13
	Habitat	2.92	1.94	4.39
Adults	Correct on Initial Recall	12.62	10.36	15.37
	Danger	2.38	2.02	2.81
	Poison	1.65	1.41	1.94

This table presents the results from the logistic regressions analyzing performance on the delayed (secondary) recall. For each age group the domain with the lowest performance was the dropped variable that all odds ratios are compared against (for kids it was diet, for adults it was habitat). For both adults and children, responding correctly on the initial recall is strongly predictive of also responding correctly on the secondary recall. However, beyond that, children demonstrate a significantly higher likelihood of also responding correctly (i.e., retaining) an animal's danger or poison status that what it eats or where it lives. This was not the case for adults, although there is a slight trend for danger information being preferentially retained.

Table 3.4-Forced Choice Options

Habitat Forced Choice Options	
English	**Fijian**
It lives in forests in trees	E bula ena vunikau e loma ni veikau
It lives in forests on ground	E bula e dela ni qele ena loma ni veikau
It lives in forests on trees and on the ground	E bula ena dela ni qele kei na vunikau ena loma ni veikau
It lives in in open areas	E bula ena vanua galala
It lives in in marshy areas	E bula ena vanua lolobo
It lives in on the edge of forests	E bula ena tutu ni veikau
It lives in in the ocean in deep water	E bula ena waitui titobu
It lives in in the ocean in shallow water	E bula ena waitui mamatia
It lives in in freshwater lakes	E bula ena waidrano
It lives in in fresh water streams	E bula ena wai drodro.

Diet Forced Choice Options	
English	**Fijian**
It eats only other animals and fish	E kani ira ga na manumanu kei na ika
It eats plant matter (fruit, leaves, seeds) and insects	E kania na vei tiki ni kau(vua-ni-kau, drau-ni-kau, sore-ni-kau) kei na manumanu somidi lalai
It eats only other animals	E kani ira ga e so tale na manumanu
It eats other fish and small molusks	E kani ira eso tale na ika kei na vivili
It eats plant matter (fruit, leaves, seeds), animals, and insects	E kania na vei tiki ni kau(vua-ni-kau, drau-ni-kau, sore-ni-kau), manumanu, kei na manumanu somidi lalai
It eats only insects	E kania ga na manumanu somidi lalai
It eats the flesh of other animals without killing it	E dau kania na lewe ni so tale na manumanu ia e sega ga ni vakamatei ira

Chapter 3b- Interstitial Chapter

The studies presented in the previous two chapters were designed to test predictions from cultural evolutionary theory about how culture is transmitted between individuals. In both cases, many of the predictions from models in cultural evolutionary theory are also observed in the real world. Both content and context biases can shape the social transmission of information between individuals in meaningful and important ways, but how does the information that is transmitted actually affect behavior? In both of the previous studies I make the assumption that cultural information does affect behavior (e.g., that if individuals know that a certain animal is poisonous, they will avoid eating it). However, in the case of the study on content biases, the reality is that the information is unlikely to actually produce any tangible benefits for the participants that are learning about those species, since they are not found in Fiji.

One can make the assumption that the same biases that are operating when individuals are learning about animals not found in Fiji in the experimental context, are also operating when they learn about animals that are present in their ecosystem in a more natural, day-to-day context. If this is the case, then it is likely that the biases observed in children will cause them to preferentially retain high fitness relevant information about local species, which in turn could influence their behavior. However, it quickly becomes clear that there are many assumptions that remain untested for how socially acquired information might actually shape individual behavior in meaningfully ways that could affect fitness. Likewise, for the study on context biases in chapter 2, because many of the factors predicted by cultural evolutionary theory were observed, we can assume that the results from analytical models of how those types of biases may affect fitness would also play out in the real world. However, there is no direct measurement of how the cultural information that is transmitted through these networks could produce different behavioral outcomes.

With these limitations in mind, we now turn our attention to the final study of my dissertation. In this study, instead of focusing on biases in the transmission of information, beliefs, or cultural models, I focus on how a system of cultural beliefs can shape individuals behavior and inferences which in turn may affect fitness. In Fiji, there are certain food taboos that pregnant and breastfeeding women are expected to follow regarding the consumption of marine resources. Previous work by Joe and Natalie Henrich has demonstrated that these taboos are preferentially applied to species that are likely to be bioaccumulators of ciguatera toxin, which can be hazardous to developing fetuses and breastfeeding infants at lower levels than would be toxic to an adult (J. Henrich & Henrich, unpublished). Henrich and Henrich show that these taboos are socially transmitted, primarily from older women to younger women. Following these taboos allows women to avoid potential fitness threats, demonstrating one way in which this system of taboo can impact behavior and fitness.

This study expands on the previous work not by looking at how this system of taboos influences behavior in relation to local species, but rather on how it might influence individuals inferences about species with which they have no prior experience. The process of bioaccumulation which allows ciguatera toxins to reach hazardous levels in top predator species is found in many other ecosystems with different toxins. For example, this same process explains why the effects of DDT were more profound on species at higher trophic levels when it was used as an insecticide from ~1940-1973 in the United States. What I wanted to explore with this study, was 1) do the villagers in these communities have some set of cultural beliefs (cultural model) that would allow them to make consistent inferences about a novel species bioaccumulation risk? and 2) if they do, what information about the species is necessary for that system of inferences to operate?

The western-scientific understanding of how bioaccumulation occurs proposes that species that are at high trophic levels and which live for a long time are the most likely species to contain toxins at hazardous levels. However, there are other species characteristics that can proxy for bioaccumulation risk as well. If Fijians have been dealing with this potential fitness threat for a long time, they may have learned how the process works and the characteristics of high risk species. Or they may have learned which local species are potentially hazardous and by looking at the similarity across these local species, determined the characteristics of high risk species. If this is the case, this information may be transmitted in the form of this system of local taboos from generation to generation. Another alternative explanation would be that there is no coherent concept of how this process works, but instead this system of taboos functions based on a one-to-one matching to local species. In other words, villagers learn what local species are hazardous and subject to taboos, but they would be unable to make any generalizations to other species not found in their ecosystem. Through an experimental approach, this study aims to determine which of these explanations is more likely.

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Chapter 4- Fijian Fish Taboos and Inference about Novel Fish Species

Anthropology has a long history of an interest in the patterns of taboo, and what their function might be in societies (Durkheim & Ellis, 1963; Fessler & Navarrete, 2003; Freud & Strachey, 1950; Meyer-Rochow, 2009). One particular domain of taboos that has received a great deal of attention, and is the main focus of this paper, is taboos surrounding the consumption of food. Explorations of food taboos have frequently focused on their utilitarian function in the local context (Meyer-Rochow, 2009), although some authors have also focused on their patterns across a wide variety of cultures (Fessler & Navarrete, 2003; Meyer-Rochow, 2009). Some of the proposed ultimate level explanations for their existence include serving as markers of group identity, to protect a valued resource, to monopolize a valued resource, as an expression of empathy, or to protect individuals from adverse health effects (Meyer-Rochow, 2009). This paper revisits the function of taboos in light of recent research in Fiji that has attempted to understand the function of taboos within the growing body of literature on cultural evolutionary theory. Henrich and Henrich (unpublished) showed that taboos on the consumption of marine resources by pregnant and lactating women may have a protective effect against negative consequences of ciguatera toxin for developing fetuses and breastfeeding children, who are more susceptible to the toxin at less concentrated levels. The authors show that these taboos are transmitted socially, frequently from older, highly knowledgeable women, which over time may have produced an accurate system for avoiding potential fitness threats. In this context, the fitness threat, ciguatera toxin, is scientifically known to be a bioaccumulated toxin (Friedman et al., 2008; Swift & Swift, 1993). The process of bioaccumulation causes toxins to become more concentrated as they move up trophic levels in the food chain (Gray, 2002). This same macro process occurs in many different ecosystems for a variety of chemical substances, e.g., PCB's, mercury, and DDT. (Gray, 2002). An understanding of how bioaccumulation works would allow individuals to make inferences about species that may be potential bioaccumulators based on their lifecycle characteristics.

This study expands on the work of Henrich and Henrich by exploring if the patterning of taboos in Fiji allows individuals to make inferences about novel species from North America that vary in their potential risk for having high levels of bioaccumulated toxins. If individuals are accurate in their identification of novel bioaccumulators, then it may be that the taboos in these communities allow individuals to develop an understanding of the lifecycle characteristics associated with bioaccumulators. In other words, the taboo system either directly or indirectly structures a cognitive inference system for identifying bioaccumulators which individuals have no previous experience with. By systematically varying the information that is presented and comparing levels of agreement and accuracy between different conditions, I am able to explore what factors participants are using to make inferences about these novel species (i.e., size, visual similarity, diet, habitat, and life duration).

*Previous work on taboo in Fiji***:**

This project is a continuation of work that our research team has conducted on the on food taboos for pregnant and lactating women in Fiji (J. Henrich & Henrich, unpublished). A previous study by Henrich and Henrich explored if the patterning of food taboos on the island of Yasawa could be explained by the relative threats that species posed in the way of fish poisoning, namely ciguatera poisoning. Ciguatera is a marine toxin, produced by dinoflagellates associated with macroalgae in marine reef ecosystems (Lewis & Holmes, 1993). The toxin accumulates in species as it moves up the food chain, often becoming most concentrated in the top predators in the food web (Friedman, et al., 2008; Swift & Swift, 1993).

This pattern of accumulation, bioaccumulation, is a common process by which many toxins can reach dangerous levels as they move up the food chain to higher trophic levels (Gray, 2002). This process can only occur when the rate at which species excrete or break down the toxin is slower than the rate at which it is taken in. In the case of ciguatera, the toxins are contained at low concentrations in the tissue of the herbivorous fish from eating the algae that contain the dinoflagellates. Those herbivorous fish are then consumed by predatory fish, which retain the toxin at higher concentrations than were present in the herbivorous fish because the concentration is higher in the herbivorous fish than it was in the algae. When those predatory fish are eaten by still larger predatory fish, the toxin becomes again becomes more concentrated in the flesh of these large predators, and may reach hazardous levels for humans (Friedman, et al., 2008; J. Henrich & Henrich, unpublished; Lewis & Holmes, 1993; Swift & Swift, 1993). From a scientific stand point, there are several characteristics that indicate potentially hazardous species in bioaccumulations systems. As the concentration of the toxins increases as it moves up the trophic levels, bioaccumulated toxins are at the highest levels in the top predators in the ecosystem. Also, the longer an individual animal or fish has been consuming the toxins, the more concentrated they become since the rate of intake is greater than the rate of excretion. Therefore, older fish are more likely to contain toxins at hazardous levels. Top predators tend to have longer lifecycles, and body sizes generally (Cohen, et al., 2003;

Simon, Pinnegar, Polunin, & Boon, 2001; Woodward et al., 2005) which explains why they can be particularly hazardous for bioaccumulated toxins and why size is generally positively associated with bioaccumulation risk. While most top predators have large bodies, not all species with large bodies are top predators. For example, large species that consume prey that occupy low trophic levels would not pose as great of a risk for containing high levels of bioaccumulated toxins.

Henrich and Henrich hypothesized that given the potential fitness risks that ciguatera toxin must pose given Fijian villagers dependence on reef fish for their primary source of protein, perhaps there were culturally transmitted practices to buffer these risks. Through the use of systematic interviews, Henrich and Henrich found several pieces of evidence that support this hypothesis. First, they demonstrated that ciguatera poisoning does appear to be a significant threat to health. Of a random sample of 60 adults, 58% reported having least one episode of fish poisoning in their lifetime where their physical symptoms matched with clinical diagnoses of ciguatera poisoning (J. Henrich & Henrich, unpublished). Second, only species that were bioaccumulators of ciguatera were reported by a majority of local women as being taboo for pregnant women to eat. Similar patterns were observed for breastfeeding taboos (J. Henrich & Henrich, unpublished). Finally, women reported learning these taboos from family members, elders in the community, and *yalewa vuku*, a Fijian term for women in the community who are respected for being knowledgeable about traditional medicines, and other health practices. Almost no women reported individual learning as the way they learned which fish to avoid while pregnant or lactating, suggesting that these taboos are socially transmitted beliefs that are often acquired from individuals that are recognized has prestigious and knowledgeable when it comes to health practices (J. Henrich & Henrich, unpublished).

The study presented in this chapter builds off of this work, and focuses on how these taboos may allow individuals to make inferences about other species, not present in the Fijian ecosystem. There are several competing hypotheses about how taboos may structure inferences about novel species that we examine with this study: 1) The local taboos may not provide individuals with any systematic method for making inferences about other species. Under this hypothesis, individuals acquire knowledge of local taboos, but that knowledge does not extend to making inferences about other species. The taboos only apply to local species and should not be generalized to other species regardless of their similarity to local species or other characteristics. 2) Individuals generalize taboos based on similarity to local species. Under this framework, individuals would make generalizations of taboos to novel species, but those generalizations should be due to similarity to local species that are tabooed (be it visual or something else). If this is correct, individuals' inferences about novel species should be limited by the degree to which they are able to identify local equivalents. 3) Local patterns of taboo provide individuals with a cognitive structure for making inferences about other species. Under this framework, individuals are able to use local patterns of taboos to infer the characteristics of species that are potentially hazardous to pregnant and lactating women, and would be able to make inferences about novel species based on their characteristics.

Methods:

Participants: The study discussed here was conducted between October and November 2008, in two neighboring villages on the island of Yasawa, in Fiji. Villagers practice a mix of horticulture, marine foraging, and littoral gathering, to support their primarily subsistence lifestyle, with some additional food resources coming in the form of purchased goods (e.g., flour, sugar, tea, tinned meat) (for further information see J. Henrich & Henrich, unpublished ESM). There were 65 adults living in these communities that participated in the study. One participant was dropped from the sample due to distractions during the testing period, leaving a total of 64 participants (32 men, 32 women) who were distributed approximately evenly across conditions. All participants have been part of ongoing ethnographic research project in the communities for the past 6 years, and informed consent was obtained prior to testing.

Stimuli: I selected nine species from North American fresh water ecosystems, not found in Fiji, that were matched on lifecycle, and ecological characteristics to species common in this area of Fiji. Of these nine species, there were three non-bioaccumulator species: bluegill (*Lepomis macrochirus)*, perch (*Perca flavescens)*, and crappie (*Pomoxis nigromaculatus*); three moderate bioaccumulators: largemouth bass (*Micropterus salmoides)*, sea-lamprey (*Petromyzon marinus*), hellbender (*Cryptobranchus alleganiensis*); and three high bioaccumulators: lake sturgeon (*Acipenser fulvescens)*, muskellunge (*Esox masquinongy*), snapping turtle (*Chelydra serpentina*). To control for order effects, four separate versions of the stimuli were used, each with a different random order in which the species were presented to the participant. Information about each species was told to participants (depending on condition) and was presented on a sheet of paper in large print for them to read if they chose to, but all choices were read aloud to control for literacy (see example in Table 4.1). Information included where the species lives (e.g., deep waters), what it eats (e.g., little fish), how big its maximum size is (e.g., between 1.5 and 11 kg, etc.), and how long it lives (e.g., between 7 and 15 years). *Conditions*: Participants were randomly assigned to one of four conditions (see Table 4.2). In the interest of clarity, I will first describe the procedure as if a participant were in condition 1 and then describe how the other three conditions varied. Participants were show an image of the species and then told the following information about the species: where the species lives, what it eats, its maximum size, and how long it lives. After being told this information, participants were asked the following series of questions: 1) Do you think this is dangerous? (yes/no), 2) Do you think you could get sick if you ate this? (yes/no), 3) If this was caught here, would it be taboo for pregnant women to eat it? (yes/no), 4) What local species is most similar to this one? (open-ended), 5) From a list of nine local species (presented to participant), choose the one that you think this is most similar to (forced-choice). After answering the questions the experimenter would say "Thank you, let's move on to the next one" and the process was repeated until all nine of the novel species were covered. Participants in condition 2 were shown an image of the species, not told any information about the species, and then asked the questions listed above. Participants in condition 3 were not shown any images and were presented with the all of the information about the species except its maximum size. Participants in condition 4 were not shown any images and were presented with all of the information about the species, including its maximum size (See Table 4.2 for a summary of the different conditions).

Results:

There were two main questions that I explored with the analysis of the data: 1) Was there more agreement (consensus) in some conditions over others? Does the patterning of agreement between domains and conditions indicate anything about how participants are making inferences? 2) Were participants in conditions there was some form of size information (either in an image, or being told directly) more accurate in their identification of potentially hazardous species (according to western scientific knowledge)?

Patterns of Consensus

I hypothesized that the presence or absence of information about species (which was varied by condition) would affect the amount of consensus within each condition. If individuals do not have access to information that allows for clear inferences based on cultural models, there should be low levels of agreement within the group, with responses being divided equally between all possible choices indicating random guessing. It should be recognized that in the evaluation of this hypothesis I make no claim on the accuracy of these inferences in relation to scientific knowledge, only that if there is a cultural model that allows for inferences to be made in the presence of certain information, we should observe high agreement between participants' responses when that information is present.

To evaluate this hypothesis, I used a variation of consensus analysis (Romney, Weller, & Batchelder, 1986; Weller, 2007) combined with quadratic assignment procedure (QAP) linear regression, which takes the non-independence of responses into account when looking at similarity of responses between pairs of individuals (Hruschka, Sibley, Kalim, & Edmonds, 2008; Hubert & Schultz, 1976; Romney, Moore, Batchelder, & Hsia, 2000). First, I performed a consensus analysis for each domain (questions about

9 species for each of the 4 domains (danger (true/false), poisonous (true/false), closest local species(multiple choice), taboo(true/false) with all conditions included to construct four person by person agreement matrices which indicate the similarity of responses between pairs of individuals in each domain. I then used these agreement matrices as dependent variables, for the QAP regressions. The independent variables, to explore condition effects, were four person by person matrices corresponding to each condition (e.g., the condition 1 matrix would contain values of 1 where pairs of individuals were both in condition 1, and 0 for all other pairs). To explore the effects of having some size information present in the stimuli, I created a person by person matrix where cells contained a value of 1 if both individuals were not in condition 3, and otherwise contained a 0. Additionally, I constructed person by person matrices for if an image was present (conditions 1 and 2) and if individuals were presented with full information about each species (conditions 1 and 4). Because I know *apriori* that the assumptions of the consensus model are violated (participants are non-independent because they were presented with different information in each condition), I did not include an individual by individual competence matrix as a predictor variable (Hruschka, et al., 2008).

The following three domains of questioning are important for explaining the broader effects of the different conditions, and will be discussed in relation to the interpretation of the data on taboo attribution. For participants attribution of danger, the only significant condition effect is the information minus size condition, where there is significantly less agreement between participants (Standardized Coeff -0.069, p =.014). There was also significantly higher agreement among participants who saw some image (Standardized Coeff 0.138, p =.0385). For participants attribution of whether species were poisonous to eat, I observed significant condition effects on agreement for both condition 1 (info and image) (Standardized Coeff -0.038 p =0.038) and condition 3 (info minus size) (Standardized Coeff -0.069, p =.003). The analysis also indicates significantly higher agreement between individuals in this domain in conditions where they saw an image (Standardized Coeff 0.203, p =.004). When evaluating participants' choices about what local species most resembles the novel species, there are several significant condition effects. Participants in condition 1 had significantly less agreement (Standardized Coeff -0.056, p =.001), while participants in condition 2 had significantly more agreement (Standardized Coeff 0.143, p =.009). Being presented with an image (conditions 1 and 2) was also associated with significantly higher agreement (Standardized Coeff 0.151, p =.034).

For the main domain of relevance to this paper, attribution of taboo, the only condition with a significant effect was condition 3 (info minus size), with decreased agreement between participants (Standardized Coeff -0.110, p =.004). This is directly in-line with the initial prediction, that the absence of size information prevents individuals from making clear patterns of inference. Also, there was a significant effect of increased agreement when individuals were presented with an image (Standardized Coeff .130, p =.025), and a trend for increased agreement between all conditions where individuals had access to either size information from images, or were told directly about species size (Standardized Coeff 0.105, p =.052).

Accuracy and Patterning of Inferences

To evaluate the accuracy of participants' identifications of potentially hazardous species, I constructed a binary variable that coded if they accurately identified one of the novel species as being potentially hazardous (identified bioaccumulator species, according to scientific knowledge, as one that should be taboo*)* or non-hazardous (non-bioaccumulators identified as one that should not be taboo). It should be noted, that I make no assumption that participants have a concept regarding how bioaccumulation work (they may or may not), instead I use their attribution of taboo as an indicator that they recognize it as a potentially hazardous species, or that these novel species should be subject to the same taboos as other local species. With this as the dependent variable, I used logistic regression to analyze the strength of the following predictors: dummy variables for each condition (except condition 3, which served as the comparison group for calculation of odds ratios), and participant sex. I clustered all standard errors by participant, to account for the fact that participants were asked about multiple species. The results of the regression (Table 4.3) indicated that participants in conditions 1, 2, and 4 were significantly more likely to correctly identify if the species were or were not bioaccumulators. Additionally, there is a statistically significant difference in performance by sex, with women being more accurate in their assignment of taboo to potential bioaccumulators.

To explore if there may be different effects depending on a species potential bioaccumulation threat, I repeated the regressions 3 times and restricted the species that were included in each. (i.e., separate regressions for only non-bioaccumulators, only moderate bioaccumulators, and only high bioaccumulators, see table 4.3). When I restricted the analysis to only the species that were non- bioaccumulators, participants in conditions 1 and 2 were significantly more accurate in identifying them as not subject to taboos. Individuals in condition 4 were not significantly better or worse than those in condition 3, and while sex is not a significant predictor, there is a statistical trend for men being more accurate. For species that were moderately likely to be bioaccumulators participants were significantly better at identifying them in conditions 1 and 4 than those in condition 3 or condition 2. Women also performed significantly higher. For species that were highly likely to be bioaccumulators, participants in condition 1 were significantly better than all other conditions. Again, women were significantly better at correctly identifying these species than men.

Discussion:

The results from the consensus analysis and QAP regressions on participant responses indicated significantly less agreement among participants in condition 3. While participants had lower agreement in this condition across domains, the effect was strongest in taboo attribution to the novel species. Additionally, participants in this condition also were significantly less accurate in their attribution of taboos to the novel species that are scientifically known to be potential bioaccumulators. This suggests that size information allows participants to make systematic inferences about novel species, and it is most important for making inferences about species that may be potential bioaccumulators. This hypothesis is supported by general ethnographic observations, and follow-up questions with participants. Upon completing the survey I asked participants "How do you know if a fish is dangerous to eat?" Responses were highly variable, and many indicated some folk methods that have been shown to be ineffective methods for detecting species with high levels of ciguatera toxin (e.g., if flies don't land on the flesh, it is poisonous) (Anderson & Lobel, 1987). However, one participant did mention that bigger fish are more likely to make you get sick. Henrich and Henrich also asked participants a similar question, and some of the participants mentioned large size (or fish that have to be cut with a cane knife, *na ika tavatava*, which is local category for large fish) as one of the characteristics of fish that should be avoided.

The size of a fish is a simple heuristic for identifying potential bioaccumulator species (Friedman, et al., 2008) (see Gigerenzer, et al., 2000 for a discussion of why simple heuristics are often highly effective). While size may also eliminate large species that do not bioaccumulate toxins because they do no occupy higher trophic levels, it is fairly accurate and clearly observable, where as other characteristics of the species may not be. In other words, while not all large bodied species are bioaccumulators, most bioaccumulators tend to be large bodied species. While I am unable to reconstruct the historic development of the patterns of taboo in Fiji, I can conclude that the system does allow individuals to make accurate inferences about potentially threatening species, which generalize outside of the individuals' particular ecological context.

The increased agreement in all domains among participants who saw an image indicates that there may be a second system of inference that participants use, based on similarity to local species. Participants who saw images also have increasing levels of agreement when forced to choose a local species that is most similar to the novel species. They may be using the visual similarity of these novel species to ones that they already know about to make a variety of inferences. An alternative explanation, that I cannot exclude, is that when an image is present participants are more engaged in the task generally, and the effects that are observed may be due to differences in levels of attention, or the way that information is encoded to memory in the presence of visual cues.

I evaluated the accuracy of participants inferences, by examining how often the species that they responded should be taboo were scientifically recognized as bioaccumulators. In condition 3, where participants had no access to information about the species size; they were significantly less accurate in their attribution of taboos. This directly supports the hypothesis that size is the primary mechanism by which individuals recognize potential bioaccumulator species. However, I am not able to definitively conclude if size information is the only mechanism by which these inferences are made. Individuals in condition 2, where they were shown only an image, could be using the image to infer the maximum size of the species, or be using visual similarity to local species to make these inferences. I think that is likely a combination of both, with support for the visual similarity coming from the increased agreement when they indentified what local species it was closest to than the other 3 conditions.

Finally, I found that women were significantly more accurate in the assignment of taboo to bioaccumulators than men. There are at least two possible reasons for this difference. First, women may be more attentive to these taboos generally, because they apply only to women. While men may know them, they themselves will never have to adhere to them, and may just have less knowledge about the local taboo. This may provide them with a weaker base by which to make inferences about the novel species. The second possible reason for the observed sex differences may be the difference in the relevance of the information that was presented for women and men. Local species that accumulate ciguatera at non toxic levels for adults are still a significant risk for fetuses and breastfeeding children. Because exposure happens as a direct consequence of the actions of the mother, knowing which species are safe to eat can be considered a highly fitness relevant domain for mothers. While men and women may have equal levels of knowledge about local taboos, women may be more attentive to the details about these novel species, because the relevance of this information is higher for them than for men. In other words, the observed difference in performance between men and women may stem from their differences in attention to the details of the task, rather than differences in their patterning of inferences.

Conclusion:

Henrich and Henrich (unpublished) showed that taboos on the consumption of marine resources for pregnant and lactating women are preferentially targeted toward bioaccumulator species that are likely to have higher levels of ciguatera toxin. The process by which ciguatera toxin reaches hazardous levels in top predator species, bioaccumulation, operates similarly in other ecosystems for other toxins, and species characteristics such as maximum size are accurate indicators of bioaccumulation risk. This study explored Fijian villagers' inferences about North American fish species that varied in their bioaccumulation risk to determine if villagers were systematic and accurate in their attribution of taboos to potential bioaccumulators. By varying the information that was presented to participants, I was able to demonstrate that without having access to size information about the species (either in the form of visual or direct presentation of size information) participants were less accurate and had less agreement about if these species would be taboo if caught in Fiji. These results indicate that local taboos may provide individuals with an accurate method for making inferences about novel species via a simple heuristic based on the size of the species. The accuracy of participants attribution of taboos indicate that they are effectively applied to species that are likely to be bioaccumulators and may contain toxins at levels that would be harmful to fetuses and breastfeeding children.

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Table 4.1-Sample Information Sheet

It lives between 7 and 15 years	It eats large fish
It lives in clear water and competes for habitat	Its maximum weight is between 1.5 kg and 11 kg

This table is the English equivalent of the sheet that would be presented to participants who were told information about the species.

Table 4.2-Summary of Experimental Conditions

Condition #	Name of Condition	Shown Image	Told Life Duration	Told Habitat	Told Diet	Told Size
1	Full Information and Image	X	X	X	X	X
2	Image Only	X				
3	Information Excluding Size		X	X	X	
4	Full Information Only		X	X	X	X

This table summarizes what participants in each condition were shown and/or told. For example, participants in condition 3, Information Excluding Size, were not shown an image, and were told each species life duration, habitat and diet, but nothing else.

Table 4.3-Accuracy in Identification of Bioaccumulators by Condition and Bioaccumulation Risk

	All Species			***Non-Bioaccumulators***			***Moderate-Bioaccumulators***			***High Bioaccumlators***		
Predictor	*Odds Ratio*	*Standard Error**	*Significance*	*Odds Ratio*	*Standard Error**	*Significance*	*Odds Ratio*	*Standard Error**	*Significance*	*Odds Ratio*	*Standard Error**	*Significance*
Told Full Information and Shown Image	3.147	1.026	<.0001	5.147	3.438	0.014	2.675	0.894	0.003	2.867	1.606	0.060
Shown Image Only	1.669	0.435	0.049	10.470	7.016	<.0001	0.991	0.290	0.975	1.074	0.504	0.879
Told Full Information Only	1.609	0.385	0.047	1.248	0.721	0.702	2.227	0.653	0.006	1.637	0.650	0.215
Gender (male=1)	0.640	0.125	0.022	2.460	1.174	0.059	0.370	0.089	<.0001	0.391	0.132	0.005

* All standard errors were clustered by participant to account for repeated measures

This table shows the results of logistic regressions where the dependent variable was if a participant correctly identified a species as being, or not being, a bioaccumulator. All odds ratios are compared to the reference category, which is being in the information minus size condition. Therefore, significant odds ratios greater than 1 indicate a higher performance than if a participant was in the information minus size condition.

Chapter 5-Conclusion

Let us return to some of the larger questions that this dissertation aimed to address. How do the results from these three studies inform our understanding of how culture is transmitted between people? What evidence do we have that evolutionary forces have and do influence the transmission of culture? How does culture as a second form of inheritance have both adaptive and maladaptive consequences? From the first study, we can conclude that many of the key predictions from cultural evolutionary theory about how context biases operate in the real world were confirmed. Individuals focus their learning attention on models who they perceive to be skilled in the domain where learning is occurring. There is evidence that perceived success in domains besides the focal domain also lead to individuals being more likely to be gone to for advice. Models from cultural evolutionary theory have shown that these biases would increase the likelihood that individuals acquire better than average cultural variants, and therefore are capable of producing adaptive change over time. However, the cross domain effects of prestige could also favor maladaptive variants as well. While some of the other predictions regarding access costs were not supported by the data, limitations in the study design, e.g., the failure to incorporate emic kinship categorizations, may explain the disparate findings.

In the second study, I explicitly examined if there were psychological biases that favor the retention of fitness relevant information about animals over non-fitness relevant information. When both adults and children make mistakes in their attribution of whether an animal is dangerous or poisonous, they are significantly more likely to make the less fitness costly mistake (i.e., mistaking a safe animal as dangerous) than the more fitness costly mistake. This finding indicates that both adults and children have cognitive biases that behave as one would predict if they were shaped by natural selection. However, when learning about animals, only children exhibit a cognitive bias that favors the retention of fitness relevant information. While previous work by Barrett showed similar results, the fact that I also observed this bias in the retention of information about if animals are poisonous to eat, in addition to danger information, indicates that the fitness relevance of this information is likely the force driving this bias. The fact that adults did not exhibit this same bias suggests that there may be a developmental window. Further work is needed to confirm this hypotheses and an expanded sample of children and adolescents may give sufficient resolution to see if this effect attenuates as children age.

In the third study, I moved away from focusing on how culture is transmitted, and instead focused on how culture can structure individuals' inferences in ways that in turn could lead to behavior that is both adaptive and maladaptive. The results of this study confirm that the system of food taboos in Fiji surrounding the consumption of marine resources by pregnant and breastfeeding women allows individual to make consistent inferences about species with which they have no prior experience. These inferences, based on size of the species and visual similarity to local species, are accurate in identifying potential bioaccumulator species that could have detrimental effects on fitness. Size is a simple heuristic that is easy to observe, which allows individuals to err on the side of caution, so while it has adaptive consequences in general, it also could cause females to underutilize potential protein sources. In other words, the inferences that are supported by the local system of taboo have both adaptive and maladaptive consequences.

Broadly, these studies confirm the predictions from cultural evolutionary theory and demonstrate that culture can impact behavior. However, they are only a first step in a rigorous evaluation of how culture is transmitted between individuals in the real world. It is my opinion, that the methodology used in the collection and analysis of the data is study 1 holds a great deal of promise for future research in this area. In study 1, I did not measure learning events directly, so a skeptic might critique this study by asserting that it falls short of actually measuring transmission. In other words, just because individuals say that these are the people that they would go to if they have a question, that doesn't mean that they actually have or would preferentially learn from those individuals. This is a valid critique. To address this concern, I hope to further pursue this line of research in a slightly different manner. In an ideal study, the dependent measure that I used here, who individuals would go to for advice, would instead be replaced with who they learned a given skill or technique from. Ideally, one would want to measure every event where learning may have occurred during the course of an individual's life time, and determine which of those learning events impacted on the current version of a cultural trait that they hold.

Unfortunately, this type of study is likely to be impossible as it would require almost continual monitoring of every individual in a community for a long period of time. However, an alternative may be to compare similarity in the cultural models held by two individuals. Take the construction of an arrow for example. Let us assume that there are many ways to make an arrow, e.g., different types of wood, different designs, different tips for the arrow, etc., and that there is variation in the techniques used by different members of a community. If one were to measure how each individual in the community constructed an arrow, and then compare the similarity in techniques between each different member of the community, e.g., how long was their arrow, what tip did they use, etc.; it would be possible to construct a matrix that represented similarity between any two individuals in the community. This matrix could then be used as the dependent measure in ERG models similar to those presented in study 1. This would allow one to assess what factors predict similarity in technique, which would serve as a proxy measure of who individuals actually learned the skills from. Further, one could also add additional independent variables that may be important to consider, e.g., emic kinship relationships, or geographic proximity. There are still flaws with this approach, such as failing to account for similarity due to individual learning, but it is one step closer to making the explicit link with cultural transmission as it operates in the real world.

There is another component of the social network approach that merits some further discussion. Much of the standard approach to statistical analysis relies on the assumption that individuals are independent of one another. While researchers often include variables to account for non-independence, e.g., village of residence, there is still a general underlying theme of independence between participants. However, we know from living in social groups that we as humans do not function independently of one another. The opinions, attitudes, and behaviors of our friends, family members, and co-workers, often influence our own opinions, attitudes and behaviors. Social network analysis not only assumes that individuals are non-independent, but that the nature of that non-independence matters and is important to measure. Advances in this methodological approach to studying the nature of that non-independence, which in many ways is made possible by advances in computing power, have enabled researchers interested in human behavior and the transmission of culture to study these processes in ways that were previously impossible.

Understanding who individuals learn from, and how culture is transmitted between individuals is important for reasons beyond explaining human cultural evolution as well. If we can understanding the psychological biases that structure who individuals look to for advice, or who they model their behaviors off of, then we can use that knowledge to construct education programs or public health interventions that use these biases to their advantage. The findings presented in this dissertation suggest that the models proposed under cultural evolutionary may serve as a great starting point for such campaigns.

I see these theoretical perspectives and the methodologies that I employed here as informing my future work in many ways. For example, one of my future research interests is in exploring the role of culture in the production of health disparities between different populations. While public health researchers acknowledge that culture is important, and likely plays a role in the production of health disparities, there have been limited attempts to actually measure its role. To do so would require first determining if proposed cultural groups each have a unified cultural model that impacts an outcome of interest, and second examining the degree to which these models differ between groups. Methodological tools such as consensus analysis, which was central to study 3, can be used to rigorously measure address both of these points.

Being able to determine if cultural factors are driving the production of a health disparity, as opposed to other factors such as the built environment or economic resources, is important because the path to alleviating the disparity is would be very different under each of these situations. For example, the rates of obesity are higher among Native American populations compared to every other ethnic group in the United States (Jernigan, Duran, Ahn, & Winkleby, 2010). If this disparity is due to factors such as the availability of healthy food options within the community (Morland, Wing, Diez Roux, & Poole, 2002) or lower economic resources which in turn lead to individuals purchasing high calorie-low cost foods (Cassady, Jetter, & Culp, 2007), then interventions aimed at promoting diets with more fruits and vegetables are likely to be ineffective. Likewise, if this disparity is driven by socially acquired practices or taste preferences, than interventions focused on changing the structural characteristics are not likely to produce the desired change either. Reducing disparities like this one first require researchers to definitively determine the causal factors producing the disparity, and rigorous methodological tools like cultural consensus analysis are one method for doing exactly that.

If cultural factors are driving the productions of health disparities, then understanding the structure of the networks through which culture is transmitted is essential to the alleviation of these disparities. For example, if children primarily learn about what a healthy meal is from slightly older peers, then interventions aimed at adults are unlikely to create self-sustaining changes. The same methodologies used in study 1, surveys and social network analysis, can be used to measure the structure of transmission networks and help researchers to determine who are the central nodes in these networks.

Targeting the interventions toward convincing those individuals and allowing the message to spread to their network alters, thereby using the structure of networks that are already present in these communities, may prove more effective than massive education campaigns. Further, constructing the intervention so that it is more likely to be remembered, by appealing to content biases (e.g., emotionally evocative messages), may make the intervention even more effective. This is not a new idea. Marketers readily use content biases in their advertising campaigns. For example, marketing studies have shown that slightly incongruent messages are more likely to be remembered by observers than entirely congruent ones (Moore, Stammerjohan, & Coulter, 2005). Interestingly, this matches with the research on the role of minimally counter-intuitive concepts that proposes why certain stories(J. L. Barrett & Nyhof, 2001; Norenzayan, et al., 2006) or religious concepts are more likely to be remembered(Boyer, 2002) .

In conclusion, this dissertation bridges a gap in the literature by testing predictions from cultural evolutionary theory in a real world setting. I found support for many of the predictions drawn from models of cultural evolution, but some evidence that does not support the model predictions and requires further examination. I also demonstrated that cultural models can shape behavior and inferences in ways that are both adaptive and maladaptive. These studies show that rigorous evaluations of how culture is transmitted between individuals are both important and feasible, and I look forward to many more years exploring these issues.

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