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Evolution of Cooperation: Comparative Study of Kinship Behavior

DISSERTATION

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by

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DEDICATION

To Mom, Dad and Noyan Kalyoncu

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ABSTRACT OF THE DISSERTATION

Evolution of Cooperation: Comparative Study of Kinship Behavior

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Professor Douglas R. White, Chair

The focus of this dissertation research is to investigate the origins of cooperation in early human societies and its connection to kinship and marriage, more specifically its tie to what is known in the anthropological literature as in-law avoidance behavior. Humans are unique in that no other animal species can match the level of cooperation and altruistic behavior among humans. Examples closest to human cooperative behavior come from animals such as ants and bees; however, cooperation among these animals can be explained by kin selection, meaning the ants in an ant colony or the bees in a bee hive share the same genetic material and thus altruistic behavior serves to protect the common genetic material. However, in humans, altruistic behavior extends to those who are not genetically related and this unique ability to cooperate with strangers gave our species the evolutionary edge to survive and prosper.

At the core of human cooperation lies kinship and marriage. It is through marriage that human groups can extend their kinship network ties to groups other than their own and integrate new members to their core group. Rules of kinship determine the social relations between kin and affines. Such categorization of kin relations create rules for the society to function smoothly. In-law avoidance behavior is one of these crucial rules that organizes the relationship between wives or husbands and their in-laws. Mutual avoidance stemming

from mutual respect functions as a conflict aversion mechanism to facilitate the integration of affines to kinship groups. This in return increases jurisdictional hierarchies, political alliance formation and leads to increased levels of cooperation in human societies. As an early adaptation, in-law avoidance relations are observed in low-density societies across the world and they get dropped as societies get more complex and populations get denser.

Previous studies on in-law avoidances did not have any means to control for the diffusive effects of geography and common origin of societies and therefore they were prone to the Galton's problem. In this dissertation, we use a lagged network regression method to control for geographical and linguistic proximity and get unbiased and consistent results for the first time.

Chapter 1

Introduction

Cooperative behavior in humans presents itself as a puzzle as it extends beyond the close kin and reaches to distant relatives and even to total strangers. In present day societies we can observe examples of cooperative actions that include the contribution of millions of mostly unrelated strangers. Peter Turchin uses the term ultrasociality to refer to cooperative behavior at such a level and presents some immediate examples of ultrasociality in humans such as tax paying and voluntary military service [35]. In times of war, thousands of young men draft for the army to serve for their country even though death in war is not an unlikely event. Or similarly, most people voluntarily give some portion of their earnings back to the central government.

But what makes human ultrasociality a puzzle that scientists have spent their time to solve? Evolutionarily, it only makes sense for living beings to adopt behaviors that will increase their fitness. However, at the first glance, cooperative behavior does not seem to increase the evolutionary fitness of the individual who is exhibiting the cooperative behavior. At this point, it is crucial to distinguish and classify some of the types of cooperative behavior according to the fitness values to the individual acting cooperatively. Since there is no agreed upon consensus on this, I find the terminology used by Bowles and Gintis the most appropriate to follow in this introduction to the topic of cooperation. Following up on their definitions, a cooperative behavior is one where both sides engaged in the behavior get a benefit, i.e., a mutually beneficial activity whereas ”altruism” is the term used to describe the type of behavior where there is a net fitness loss for the person engaging in the said behavior [3]. The distinction between mutualistic cooperation and altruism is an important one since it is altruism alone that lies at the heart of the cooperation puzzle.

Altruistic behavior lies at the core of the cooperation puzzle and it begs an explanation since by definition it imposes a net fitness loss to those engaging in it and therefore such behavior is expected to be weeded out by evolution. But it is not, as we have given some present day examples from current societies like paying taxes and voluntary military service. So how is it that we have altruistic behavior persisting through time? There have been many models explaining precisely this question.

Some of these models that have been foundational in the research of the evolution of altruistic behavior are summarized below:

1.1 Kin Selection

The idea behind kin selection is that an organism will exhibit altruistic behavior, even one that can be as costly as death to the organism itself, if said behavior will increase the reproductive success of other organisms that are genetically related to the altruist. The origin of kin selection can be traced back to Darwin himself but the well-known mathematical formulation of it was developed by George Price [28] and the concept was made well-known by Hamilton and thus the well-known rule of kin selection goes by the name Hamilton’s Rule which is as follows:

$$rB > C \tag{1.1}$$

where r is the probability of genetic relatedness,

B is the benefit gained by the altruistic behavior by the recipients

C is the cost to the altruist. [13]

As long as the equation holds, the altruistic gene survives in the gene pool.

So kin selection is good at explaining why altruism may have persisted through time; however, the pivoting point to the model is in the parameter r for which some proportion of genetic relatedness is required. This model explains perfectly why ant colonies and bee hives are places in which altruistic behavior is observed among organisms that are genetically related but not so good when it comes to explaining why we observe altruism in human societies where in most cases the recipient of the benefit is not genetically related to the individual who is performing the altruistic behavior.

1.2 Multi-level Selection

Multi-level selection provides another mechanism that would allow the survival of altruistic genes through generations and unlike kin selection without making any assumption of genetic relatedness between the recipient and performer of altruistic behavior. The basic notion is realizing that evolution puts survival stress on two levels: one at the individual level but also at a group level where two groups that consist of related or unrelated individuals compete for a territory, food, other resources etc.

In this framework it is evident that within-group selection is not in favor of the altruists as their behavior puts a net cost on their survival; however, collectively as a group they can out-compete another group whose proportion of altruistic individuals is not as high. Here the problem boils down to whether the between group selection pressure is critically more important than the within-level group selection so that the altruistic genes can survive.

Hunter-gatherer bands of late Pleistocene and early Holocene shed light to the evolution of altruistic behavior in humans and thus an evolutionary explanation should start from how altruistic behavior might have emerged among our ancestors living during the Pleistocene.

Bowles and Gintis point to the fact that up until 20,000 ago, the population growth of humans was rather slow (at a rate about .002%) while these groups in theory are capable of sustaining a growth rate of about 2%. This tells us that there were dramatic population crashes facing our hunter-gatherer ancestors of Late Pleistocene[3].

Thus, it is likely that such an intense competitive environment may have prepared the necessary conditions for high between-group competition resulting in altruistic behavior being selected for.

The hunter-gatherer bands of Pleistocene mostly consisted of individuals who are not genetically related (i.e., not blood-related kin and even complete strangers) and these societies were egalitarian and cooperative [2] [16][4]. This kind of a social structure requires specific rules so that such a society can be maintained. Boehm lays out some of these rules of the hunter-gatherer societies. Mocking, shunning, ostracizing free-riders and moralistic gossiping are all traits of hunter-gatherers that help create a moralistic conscious and contribute to a cooperative egalitarian society [2]. In this regard, avoidance can be seen as one of the many ways of enforcing cooperation. It is a form of costless punishment since those who avoid a free-rider bear no cost while the free-rider who is avoided risks losing his access to fellow band members and the band's resources. With so much at stake for groups of free-riders, bands establishes cooperation in future interactions.

However, in societies of ethnographic present across the world we observe a structured behavior of avoidance relations which is quite different than the above-mentioned avoidance of free-riders. Structured avoidance behavior means certain people within the society do not speak with one another just due to the kin relation they have to one another. Such avoidance relations have various kinds and degrees and beg an explanation as to why they exist and what, if any, function they serve. We will show in this dissertation that avoidance relations are tightly related to cooperation and cohesion of societies especially those that lack institutions that control cooperation and cohesion. However, before doing this we will go over the theories in the literature on structured avoidance relations and how our hypothesis relates to these theories and at which points it differs from them.

1.3 Avoidance in Anthropological and Comparative-Studies Literature

In anthropological literature the topic of patterned avoidance behavior has been investigated from the perspective of maintaining the cooperative structure of the society. The two main theories regarding joking and avoidance relations (the two are not separate from one another on the contrary two different manifestations of the same principle) both have their origin in cooperation. First of these two main theories is Murdock's who believed that avoidances were a tool to control the disruptive effects of the sex drive [20]. The second major theory on avoidances is Radcliffe-Brown's, which says formalized/standardized avoidance relationships are conflict aversion mechanisms of a society [32]. Murdock defines an avoidance relationship as one in which there is complete avoidance of speech and physical contact. He also makes the important observation that such behavior is on a continuum where on the one extreme there is complete avoidance to marked restrained and he breaks up the spectrum into 5 categories where the other 4 categories are respect to moderate reserve, informality to intimacy, familiarity to privileged joking and finally obligatory joking to extreme license [20].

For Murdock, each society has to deal with striking a balance between free expression of the sex drive and the need to control it. This balance is maintained by the use of taboos, permission and injunctions [20] [8]. Patterned avoidance behavior that ranges from avoiding speech and contact to obligatory joking is one way some societies use to regulate sex relations between opposite sex kin. However, the very fact that there exist same-sex avoidance behavior makes it apparent that Murdock's views do not form a complete theory.

Murdock's hypothesis on avoidance is based on extended incest taboos. The immediate question is why is it that some societies have patterned avoidance relations while some do not when the incest taboo is almost always universal across societies (some exceptions like the noble families of Inca exist). To address this question Murdock posits the view that societies fall under two categories in terms of their approach to incest: those societies in which incest taboos are well internalized during socialization and those in which no such self-internalization exists. In the societies in which sex restrictions are internalized as incest taboos, a self-check mechanism takes care of possible problems that can arise due to having sex with close kin whereas in societies where no self-internalization of incest taboos exists, other mechanisms are required to ascertain that sex relations do not extend to close kin, namely patterned avoidance behavior [20] [9]. This explanation is not a satisfactory one as it basically makes an ad hoc claim in that after looking at the distribution of the absence and presence of avoidance behaviors across societies, it makes the claim that those societies that have kin avoidances are the ones that did not internalize sex restrictions. This does not allow room for understanding the dynamics associated with patterned avoidance behaviors. Murdock also believes behavior such as veiling and seclusion in harems are ways of enforcing incest taboo in societies that did not well-internalize the incest taboos [20] [10].

Another drawback of Murdock's extended incest taboo explanation of avoidances is that it is too particularistic. The structured avoidance behavior takes many forms, including Wife's Mother (WiMo), Wife's Father (WiFa), Husband's Father (HuFa), Husband's Mother (HuMo), Wife's Brother's Wife (WiBrWi) and many others in decreasing frequencies. The variety of avoidance behavior makes extended incest taboo hypothesis rather unlikely as for each kind of avoidance there should be an extension of a specific incest taboo between kin. This is a very particularistic approach and it does not really answer the questions of why the avoidances exist and what function they serve. If the answer is having a different extended incest taboo for each avoidance type, then this is far from providing a general answer to the underlying cause of avoidances.

Murdock's hypothesis derives from Freudian psychoanalytic theory. Levinson and Malone summarize the three steps of a hypothesis that was developed by Stephens and D'Andrade using Murdock's idea, which leads to a statement that can be empirically tested. Those steps are:

1. Long postpartum sex taboo intensifies the son-to-mother attraction
2. Which makes phobic attitudes toward incest more likely
3. Which contributes to the severity of kin-avoidances. [33][11]

Stephens and D'Andrade test whether postpartum sex taboo is correlated with son's wife, brother-sister and mother-in-law avoidances and find significant correlations, however; later retests do not show significant results [17].

Tylor puts forward the proximity hypothesis, which states that avoidances are tied with post-marital residence rules, his emphasis being on the relationship between mother-in-law avoidance and matrilocal residence [36][13]. Following up on Tylor, Witkowski further investigated the relationship between residence and patterned avoidance behavior. Witkowski distinguished between community residence and household residence [39]. In the former, in-laws live in the same community but not in the same household whereas in the latter they reside in the same household. The correlations (gamma values) however are not significant either for community and household coresidence cases with HuFa and WiMo avoidances [17].

Anthropologist Radcliffe-Brown presents the second main theory on structured kin avoidances and their function. For Radcliffe-Brown joking and avoidance relations are the two manifestation of the same mechanism that serves to maintain the social equilibrium in a given society [31]. In this regard, they are functional as a conflict aversion mechanism. Radcliffe-Brown writes

> The theory [...] starts from the position that the customs of avoidance or extreme respect towards the wife's parents, and of the privileged 'joking' with the wife's brothers and sisters, can be regarded as the means of establishing and maintaining social equilibrium in a type of structural situation that results in many societies from marriage[...] What is required for social equilibrium is that, as far as possible, he should not enter into conflict with his wife's group, but be obliged to maintain with that group or its members a 'friendly' relation [32].

In contrast to Murdock, Radcliffe-Brown believes that joking and avoidance behaviors are based on respect and do not have anything to do with sex taboos. However, they agree on a more fundamental level that these behaviors help maintain the cooperative structures of a society.

Radcilffe-Brown calls the formalized avoidance behavior one of 'friendliness' which begs more explanation. According to Radcliffe-Brown there are 4 modes of alliances. Namely, through intermarriage, through gift exchange, through blood-brotherhood or name exchange, or through joking (or avoidances as its polar opposite) [32]. Therefore for Radcliffe-Brown, just like jural relations that arise due to an individual's position in the structure of the society that he/she is born in, avoidance relations are also one of alliance which he calls a 'friendly' relation due to a lack of better term.

Our own hypothesis in this thesis is very similar in this regard to that of Radcliffe-Brown's in that we also believe avoidances help form alliances and increase cooperation by extending the networked relations to affines; avoidances help avoid conflicts and increase cooperation among distant members of a society and establish social cohesion at a broader level. More specifically, while joking relations bolster the ties among blood-related close kin, avoidance relations connect in-laws who are not previously connected through blood-relations and establish new and broader networks of cooperation.

That is the main reason why avoidance relations are not one of hostility as they may appear at a first glance but they are relations of 'friendliness' in the above-mentioned sense and of respect. Again, in Structure and Function in Primitive Society, Radcliffe-Brown mentions this one example in which he asked an Australian indigenous person the reason why he avoided his mother-in-law to which the response of the native was: "Because she is my best friend in the world; she has given me my wife" [32]. Andaman Islands presents yet another example demonstrating how avoidance relations stem from mutual respect. There, the in-laws (parents of the husband and the parents of the wife) avoid each other but quite frequently may send each other presents. This situation is explained by an Andaman Islander as follows: "They are great friends because their children have married" [32]. Summarizing, according to Radcliffe-Brown's theory of structured joking and avoidance relations, avoidances are not hostile relations, and have nothing to do with the sex drive. They are friendly relations that help bolster and/or form alliances and serve as conflict aversion mechanisms.

This idea of conflict aversion requires an in-depth analysis, as it is not self-evident. Radcliffe-Brown's theory is centered on the notions of conjunction and disjunction. Marriage by definition brings together people that are not related to one another and as a result the social structure in the community gets readjusted, new kin relations being defined as two families come together by means of marriage of a couple [31]. Radcliffe-Brown sees this as involving both attachment and separation, both social conjunction and disjunction [32]. He writes in his article published in Structure and Function in Primitive Society:

> Social disjunction implies divergence of interests and therefore the possibility of conflict and hostility, while conjunction requires the avoidance of strife. How can a relation which combines the two be given a stable, ordered form? There are two ways of doing this. One is to maintain between two persons so related an extreme mutual respect and a limitation of direct personal contact... In its most extreme form there is complete avoidance of any social contact between a man and his mother-in-law [32].

In summary, it has been proposed that avoidance relationships may have arisen from sex taboos, and may be related to residence or descent patterns in a society. As we will demonstrate in Chapter 2 and 3, we have not found any evidence to the hypothesis that sex taboos can be the reason behind in-law avoidances. As for descent and residence rules, we do not have evidence to their significance in the Old World sample. As for the New World Sample, we do see descent and marriage systems play a role in the in-law avoidance behavior but this role is only a secondary manifestation of the actual purpose of the behavior which is increasing cooperation across kin and affines and help build across-group-alliances. This hypothesis is of course is inspired from RedCliffe-Brown's theory which treats avoidance behavior as a respect relation and not as a relation of hostility. We take this a step further and hypothesize that out of this respect relations emerges an extended network of cooperative kin relations.

1.3.1 Hypotheses of this Thesis

Our first hypothesis is that patterned in-law avoidances are a unique human social feature that function as a conflict aversion mechanism and they help integrate groups that consist of kins and affines. This is an early adaptation and is a result of the strategic use of marriages for alliance formation. Therefore kin avoidances operate at the lowest levels of population density with a potential to shed light to our evolutionary past as a species.

$\mathbf{H_1}$ The population density of those societies in which in-law avoidances are observed is lower than that of those in which in-law avoidances are not observed.

Second, we hypothesize that as respect relations, avoidances serve as conflict resolution mechanisms in pre-industrial societies and help these societies integrate with groups outside of their own. This helps them form political and jurisdictional hierarchies at the community level; however, once social life gets more complex and beyond community level jurisdictional and political hierarchies emerge, avoidances become superflous and they dissipate. Similarly, the integration of affines from outside groups into the kinship network helps with the formation of political alliances. All of these are manifestations of an increased level of cooperation through kinship networks.

$\mathbf{H_2}$ Jurisdictional hierarchies at the local level and political alliance formation are expected to be higher with the existence of in-law avoidances. Jurisdictional hierarchies beyond community level is expected to have an inverse relationship with the existence of in-law avoidances.

The following hypotheses are made after looking at the distribution of avoidances on the maps across the globe and in North West America.

$\mathbf{H_3}$ The out-of-Africa migration theory for our species tend to show a similar distribution with the Wife's Mother avoidance indicating that integrating this behavior to the kinship network may have helped our ancestors move out of Africa and diffuse across the globe.

$\mathbf{H_4}$ The structure and distribution of in-law avoidances in the Western North American Indian societies show evidence towards a matrilineal origin for Wife's Mother avoidance as the root avoidance behavior and other forms (WiFa, HuMo, HuFa) are adopted only after descent and residence transitioned to bilateral/ambilocal or patrilineal/patrilocal descent and residence patterns.

1.4 Galton's Problem and DEf Functions

Driver, in his essay called Geographical-Historical Versus Pyscho-Functional Explanations of Kin Avoidances, visits the early and current kin avoidance theories of his time from the aspect of whether they use pyscho-functional explanations, which are the two main explanations mentioned in part 1.3 (a psychological one being that of Murdock's via Freud and the functional one being that of Radcliffe-Brown's), or whether they are geographical-historical explanations [6]. This second type of explanation, which we saved for this later part in the introduction, brings about one of the most fundamental problems in cross-cultural studies. Any theory including the one we are proposing in this thesis has to address how it tackles the problems of diffusion vs local invention and inheritance within a spreading language family before it can be taken seriously. In this part of the thesis, we will describe this problem in detail, called the Galton's problem, and then show our methods of addressing it.

What is known today in the field of anthropology as Galton's problem was first raised when Tylor presented his results on avoidance behavior: he correlated residence patterns with avoidance relations. Tylor postulated that the unilinear evolutionary track was flowing from matrilocality to patrilocality and husband's tendency to avoid wife's relatives was a remnant of the matrilocal evolutionary stage [36]. Today not only are the unilinear evolutionary theories definitely out of favor, but the statistically significant association Tylor found was very likely superfluous. When Tylor presented his results, statistician Sir Francis Galton pointed out the fact that the chi-square test he used for showing association between residence and avoidance assumes independence of the cases but the societies that the data were available for were not geographically nor historically independent from one another. Lowie pointed out that diffusion through intermarriage of neighboring peoples could explain the multiple occurrences of certain types of avoidance relations and thus it is more sensible to think of independent invention only for those societies with enough geographical distance as to not allow for diffusion. His solution was that one should only focus on certain areas to understand the context of the function of avoidances [19], which is not the best way to deal with avoidances especially if the goal is to understand the worldwide distribution of this phenomenon.

Murdock's solution to the problem of possible diffusion was to pick a sample of world societies that would constitute a close-to-independent sample of societies [23]. This is a good intention but not a real solution. The main problem is the anthropologist's subjective decision of what constitutes independent cases can never be accurate, no matter how educated the decisions are, in coming up with an "independent" sample as there are underlying networks of interactions such as common historical descent, language, migration, trade, war, etc., that are not necessarily discernible by looking at geographical distance alone.

Naroll in his '65 article addresses the issue of independent invention vs. diffusion extensively. There he mentions the two important approaches to cross-cultural studies. In one, the unit of study is a tribe, society or culture and in the other the focus is on controlling for associations of traits due to diffusion in a specific region. Our method combines the two in that it controls for diffusion due to geographical distance as well as other networks of possible diffusion and then studies associations across societies. However, in doing so, we do not treat diffusion networks as mere nuisances; on the contrary, we measure their individual effects on the dependent variable before going into the effects of other traits on the dependent variable.

This point will be clearer once we explain in detail the method we implement in our analyses [24].

Naroll also touches upon the issue of the effect of the environment on spurious associations. The example he gives is one about the natural environment of Chemehuevi, Mojave and Yuma. Chemehuevi lacks patrilineal clans whereas the neighboring societies Mohave and Yuma do possess patrilineal clan systems. These three societies do share the same natural habitat as far as the climate and other ecological factors are concerned yet if one goes out to establish an association between environment and matri versus patri-lineality, they would fail to do so. A closer look at these societies does reveal another important factor, which is that Mohave and Yuma are linguistically very close to one another while the Chemehuevi belong to a very distant language family than its neighbors [24]. This shows that ecology is not the only latent variable that can lurk in and cause spurious associations. The Dow and Eff functions method we utilize will help solve the problem of different sources of diffusion networks including language, ecology, geography and common history will each have their own effects accounted for before we establish a functional association between different independent variables and the dependent variable [9].

Finally Naroll's review of Galton's problem mentions how Driver approached this problem in North America Indian societies. We will pay some special attention to this example as it concerns avoidance relations in native North American tribes. Driver posits that there is an association between descent rules and avoidance behavior. To test this, being aware of the Galton's problem, he concludes that there is room for only a handful (3 or 4) independent inventions and the rest of the observed associations are due to diffusion [24].

Driver's North American data consists of 277 societies and he attempts to understand avoidance behavior in these societies by taking into account language and geographical distance of these societies to one another [6]. In his analysis Driver takes issue with Tylor's two conclusions. First, Tylor's hypothesis suggests a unilinear evolution in human history in that he believes the evolution flows from matrilocal to matri-patrilocal to patrilocal residence and avoidance of wife's kin by the husband is a residue of matrilocality. This imposes evolutionary dynamics to result in the same states for all world societies, which is not necessarily true. Second, Driver puts Tylor's data in cross classification tables and does chi square tests to demonstrate that the relation between kin avoidance and marital residence is not due to chance [6]. But as mentioned before the significance of the chi-square tests may be due to diffusion through distance or common history. Not only does Driver fail to take into account the underlying autocorrelation network structures in his data points, he also presents 4 different types of correlations with different groupings of the data without taking into account multiple testing. However, numerous tests lead to inflated group significant results so a Bonferroni correction should have been applied and Driver does not do that. Therefore, both Tylor and Driver fail to address the problem of inflated significance of their results.

Driver's attempt to control for distance and language is important but far from being adequate. He looks at the correlation coefficients of avoidance behaviors with cultural areas and language families as well as functional variables such as kin terminology and marital residence. By comparing the magnitude of the correlation coefficient he observes that historical factors such as language and geography have more effect than functional ones. This approach has some problems. First, it cannot look at the effect of functional variables after removing the effects of historical ones. Neither can it assign values to the single historical effects alone. Two-variable correlations by no means have the power of multivariate analyses.

The main problem with Driver's methodology is that it lacks the necessary tools to handle diffusion and functional traits at the same time. That is the reason why he resorts to tackling them one at a time. He looks at the presence and absence of all the possible causal traits that are required for avoidances to emerge such as residence and descent rules and determines which societies have the necessary conditions for avoidances. Then he looks at his maps to see if the ones that do not possess the causes but do have avoidances are close to others who have the causes and the avoidances therefore indicating possible borrowing. This approach is problematic because it lacks a certain generalizability and in the end it counts on the personal judgment of the researcher to decide whether avoidances are present due to invention or borrowing. In this thesis, we will make use of some of Driver's methods such as drawing maps to see distributions of variables on the globe and we use correlations as a first explanatory analysis step but we revisit the question of avoidances with a much better equipped tool that can handle networks of diffusion such as language and geography all at once and then look for functional associations separating them from the diffusive ones.

Chapter 2

Methods: DEf Functions, Multiple Imputation and a Solution to Galton's Problem

We use the functions developed by Dow and Eff for the R statistical analysis environment [7]. These functions which we call Dow and Eff functions (DEf) tackle the two main problems of cross-cultural studies. The standard datasets have many missing values and DEf functions make use of a multiple imputation method to solve the problem of missing values. Second, DEf functions use 2-stage ordinary least squares regression to solve the problem of non-independence across the units of study. In the following sections we explain these in detail so that the results of our models can be understood and interpreted from this general framework.

2.1 Missing Data and Multiple Imputation

In chapter 3 we analyze stereotyped kin avoidances in the Old World using the Standard Cross-Cultural Sample of Murdock and White and in chapter 4 we present the model results for the same type of avoidances coded by White from Driver's avoidance data for the New World societies of the Western North American Indians dataset of Jorgensen in an attempt to see to what extent the model is replicated across continents. One major problem that arises when using these standard datasets is the missing values problem. If not handled correctly missing values can lead to loss in statistical power and result in biased model estimates.

We will provide a detailed description of these two datasets in their corresponding chapters. In this section, we will only show how much missingness is present in the datasets and show that missing values indeed pose a serious problem for comparative studies, which is solved later in thesis.

The SCCS contains more than 2000 variables coded over the last 50 or so years from ethnographies published over previous centuries [23]. It covers 186 world societies and even though it is very rich in 2000 variables providing information on these societies, not all the variables are complete. Only a tiny 7.15 percent of the variables are complete; 82 % of the variables have 5 per cent missing; and 77 % of the variables have 10 per cent or more of their values missing. As for the WNAI, it is relatively better than the SCCS in terms of missingness but still far from being complete. WNAI covers only the Western North American tribes from Alaska to Mexico. The dataset has 440 variables on 172 native tribes. Out of these 440 variables 214 of them have complete data, i.e., all 172 tribes have values for these variables. However, 23 % of the variables still have 6 or more cases missing [8].

2.1.1 How Missingness Affects Results of Statistical Models

Statisticians define 3 types of missingness mechanisms possible in a dataset. Depending on the mechanism, the consequences of missingness on model results change and accordingly the success of the methods dealing with missingness vary. The following is a summary of mechanisms of missingness and possible shortcomings resulting from each of these mechanisms explained by Dow and Eff in their 2009 article [8].

Consider that we are focusing on the missingness of the dependent variable, Y. We have Y a single variable with missing values and $\mathcal{X}$ a set of complete variables that consists of the independent variables $\mathbf{X}$ in a model plus some auxiliary variables $\mathbf{Z}$ that can possibly explain the missingness in Y but will not be of interest in their own right and thus will not be used in the actual statistical model.

$$\mathcal{X} = [\mathbf{XZ}] \tag{2.1}$$

We create a new binary variable M whose values are 1 if the values of Y are present and 0 of they are missing. All 3 mechanisms make statements about the conditional probability of $P(M = 1|(Y, \mathcal{X}))$. That is to say, we look at whether the complete variables $\mathcal{X}$ and the dependent variable Y itself can explain whether a value is missing in Y or not.

1. Missing Completely At Random (MCAR): This mechanism assumes that neither $\mathcal{X}$ nor Y can explain the missingness in Y which translates in mathematical terms as

   $$P(M = 1|(Y, \mathcal{X})) = \mathbf{c} \tag{2.2}$$

   where c is a constant. So, if MCAR is the mechanism of missingness, it means that the missing values are independent of Y and $\mathcal{X}$. When MCAR is the case, the listwise deletion method, which is the most commonly used method in social sciences and comparative studies does not give biased results. However, it will still cause a decrease in the statistical power as we are throwing away data.

This being the case, in reality one can find variables that help explain the missingness in datasets such as SCCS and WNAI. Therefore, list-wise deletion is not a good method for handling missing data.

2. Missing At Random (MAR): In this missingness mechanism the conditional probability in equation 2.2 is not equal to a constant anymore but a function of $\mathcal{X}$, namely the set of variables that consists of the variables used in the model **X** plus the auxiliary variables **Z**:

$$P(M = 1|(Y, \mathcal{X})) = \mathbf{f}(\mathcal{X}) \tag{2.3}$$

This is a more realistic assumption for the cause of missingness in standard datasets such as SCCS and WNAI. If MAR is the underlying mechanism of missingness list-wise deletion will lead to biased model estimates as the complete subset of the dataset is not a random subset anymore.

3. Missing Not At Random (MNAR): This final missingness mechanism covers the case when the conditional probability is not only a function of $\mathcal{X}$ but Y as well.

$$P(M = 1|(Y, \mathcal{X})) = \mathbf{f}(\mathbf{Y}, \mathcal{X}) \tag{2.4}$$

The biggest issue with MNAR is that the function f can no longer be estimated as it would require us to use M equals 0 whenever Y has a missing value, meaning making a comparison of Y with observed and missing values is not possible.

In the light of the above mentioned missingness mechanism, it becomes easier to evaluate which method of imputation is better suited for cross-cultural data, what the advantages and disadvantages of each are.

List-wise deletion has often been used as a standard in the field of cross-cultural studies. It basically gets rid of all the societies in the sample that do not have values for the dependent variable of interest Y. This method has two obvious disadvantages: first, it reduces the sample size, which in turn reduces power of the statistical results. Second, if the missingness mechanism is not MCAR, list-wise deletion leads to biased model estimates. MCAR is an unrealistic and flawed assumption for social science data. If for example, cold climates are making it hard to collect data on certain variables, then the societies that do not have values for those variables are not a random subset of the whole dataset.

Mean substitution is another method where all the missing values are replaced by the mean of the observed values of the variable of interest. This causes the distribution of the variable to have more mass at the mean and also causes biased results even when the missingness is MAR or MNAR.

Regression substitution is yet another method where only a single imputation is done to replace missing values. In regression substitution the dependent variable Y is regressed against the set of complete variables and auxiliary variables $\mathcal{X}$ and then the regression coefficients are used to predict the missing values in Y. The problem with this method is that the predictions lie on the regression line whereas the observed values are scattered about the line. Therefore, the variability of the predicted values are underestimated. One can try to remedy this by adding noise but then the issue becomes choosing the distribution from which to generate the noise.

Due to these drawbacks, we utilized the Multiple Imputation method [18] in our analyses which comes as part of the Dow and Eff functions program in R. It uses the MICE algorithm in R, which is an iterative process whose steps are detailed below:

1. Let Y_1 to Y_k be the k variables with missing values and $\mathcal{X}$ be the matrix of variables with complete cases. $\mathcal{X}$ has both model independent variables and auxiliary variables whose relation to the dependent variable is not of interest as a confounder or precision variable but they help explain the missingness.

2. For j from 1 to k fill every missing value in Y_j with randomly chosen observed values in Y_j

3. for j from 1 to k regress the original non-missing values of Y_j with $U = (Y_1, ..., Y_{j-1}, Y_{j+1}, ...Y_k, \mathcal{X})$. Using the appropriate regression method for the scale of measurement of Y, i.e., linear regression for continuous, logistic for binary etc.

4. Replace the initial imputed missing values with the values coming from the regression in the previous step adding random disturbance both to the error variance and to the estimated regression coefficients following the steps described in Raghunathan et al.

5. Repeat this for a set number of times, c and save the dataset of the last (cth) iteration.

6. This completes the first round of the multiple iteration. Repeat the whole procedure for m times and obtain m different sets of imputed datasets.

7. Combine the m imputed datasets using Rubin's formulas. [8]

Multiple Imputation also assumes MAR [8] but as mentioned before this is not an unrealistic assumption for cross-cultural datasets such as SCCS and WNAI as it is quite feasible to believe that there are complete variables that can help explain the missingness in other variables. When MAR is a reasonable assumption the Multiple Imputation method becomes the obviously superior method to choose for handling missing cases.

Finally, there is one last issue that needs to be addressed and that is the choice of auxiliary variables. The set of variables $\mathcal{X}$ consists of complete variables to be used in the statistical model (i.e., the independent variables) and the auxillary variables that only help predict the missingness in the missing variables and will not be used in the statistical model itself. How do we decide which variables to include as auxiliary variables in SCCS and WNAI?

2.1.2 Choice of Auxiliary Variables in SCCS and WNAI

Some restrictions apply in choosing auxiliary variables.

1. The number of variables in $\mathcal{X}$ needs to be less than the number of observed cases in the variable we are imputing variables for, Y, since the coefficients needed for imputation cannot be solved for if the design matrix, $\mathcal{X}$ is not invertible.

2. There should not be collinearity between any two variables in the design matrix $\mathcal{X}$. In case of perfect collinearity the regression will not yield results at all and if there is a case of close to collinearity the standard errors will be inflated. Therefore we want to avoid collinear variables when choosing auxiliary variables.

3. The auxiliary variables may be good at predicting the observed variables when we test how well the imputation performs but may not be good at predicting out of the model cases, which are the actual missing cases. This is called over-fitting and we want to avoid over-fitting as well if we can.

The multiple imputation method we implement in our models deal with all three of these possible problems with one solution. It uses the principal components of a certain number of auxiliary variables with high explanatory power. Principal components by definition are perpendicular to one another and cannot be collinear. Using the principal components also reduces the dimension of the $\mathcal{X}$ matrix and therefore unless we impute for a variable with a lot of missing values, the regression for imputation does not fail. Each variable in each of the datasets (we use only SCCS and WNAI in this dissertation) has a certain number of auxiliary variables suitable for missing value imputation associated with them. The details of which variable has which auxiliary variables can be found in the *cov* matrices after loading the datasets in the DEf functions R program. Once the auxiliary variables are determined and the design matrix is set, data imputation is conducted and imputed data sets are combined following the steps described previously in section 2.1.1.

2.2 Dow and Eff Functions: Multiple Network Autocorrelation Effects

The models we use to analyze avoidances in chapter 3 and 4 take into account the network autocorrelation effects inherent in social science data and utilize a two-stage ordinary least squares estimation process to estimate model coefficients. In what follows we will specify the models and explain its steps in some detail.

There are two types of most common interdependencies in social science data. These are common history and geographical proximity. This suggests that the value of a society with regards to a certain variable depends on the values of other societies that are close by in terms of geography and history. Without accounting for those effects, we cannot tell apart functional effects of other variables from underlying network effects.

The multiple network autocorrelation effects model first requires creating a connectivity matrix C_{NxN} where the i, jth element of the matrix may carry a network effect between society i and society j. In order to make interpretation better, as a next step, we row-normalize matrix C by dividing every element in each row by the row sums and call this matrix W for autocorrelation weights. Doing so not only makes the elements of the W matrix more interpretible in comparison to the C matrix but also makes it so that the weight for i on j is not necessarily the same as the weight of j on i. This makes sense since the position of society i within the transmission network is not the same as the position of society j in the same network thus their respective weights on one another are also different. When the variable of interest, Y, is brought into model, and we multiply W matrix with Y we get the transmission effects on each society. A final comment on the W matrices is that, in order to avoid getting spurious results, one needs to specify the weights correctly respecting actual network effects [4].

2.2.1 The Problems with Ordinary Least Squares and Network Autocorrelation Model

The ordinary linear regression model is specified as follows:

$$y = \alpha + \mathbf{X}\beta + \epsilon \tag{2.5}$$

where $\mathbf{X}$ is the design matrix that contains the independent variables of interest, y is the dependent variable, α is the intercept, β is a vector holding the regression coefficients and ϵ is the error term such that $\epsilon \overset{iid}{\sim} I\boldsymbol{N}(0, \sigma^2 I)$

In (2.5), we make an assumption of independence thus not taking into account the network effects effectively risking to get either biased and inconsistent or unbiased but inefficient regression estimates [25].

Then, it is clear that one needs to incorporate the network effects into the model which means we need to model the networks effects first. A common way of doing it is as follows:

$$y = \alpha + \lambda \mathbf{W} y + \epsilon \tag{2.6}$$

In (2.6), without loss of generality we can force a 0 intercept, i.e., making the mean of y zero. Then λ can be interpreted like a correlation coefficient that shows the effect of the configuration of y in other societies on the level of y in society i for all i.

The biggest problem with this model in (2.6) is that $\mathbf{W}y$ is correlated with the error term ϵ making the estimate of λ biased and inconsistent [14].

The model can be improved upon and be made more realistic by adding other independent variables by the inclusion of a design matrix $\mathbf{X}$ as follows:

$$y = a + \lambda \mathbf{W} y + \mathbf{X}\beta + \epsilon \tag{2.7}$$

However, the problem remains, namely the error term and $\mathbf{W}y$ are still correlated. In what follows, we describe how the Dow and Eff functions model solves this problem of endogeneity. DEf functions use a method known as the 2 Stage Ordinary Least Squares to find an estimate for $\mathbf{W}y$ term so that it is no longer correlated with the error term. To accomplish this, in the first stage of this method we regress $\mathbf{W}y$ against what is called "instrumental" variables, which are basically variables that help explain $\mathbf{W}y$ but are not correlated with the error term itself. In other words, these instrumental variables are themselves independent variables that predict $\mathbf{W}y$. DEf uses $\mathbf{W}$ times all the independent variables in the design matrix $\mathbf{X}$, $\mathbf{WX}$, as instruments and we get the following equation 2.8:

A more detailed derivation of the following equations 2.8, 2.9, 2.10, 2.11 can be found at [9].

$$Wy = a + WXc + e \tag{2.8}$$

Using 2.8, we get the estimate for $\mathbf{W}y$, which we will call $\hat{y_w}$.

$$\hat{y_w} := \hat{\mathbf{W}}y = \hat{a} + \mathbf{WX}\hat{c} \tag{2.9}$$

Then substituting the uncorrelated estimate we have just created back into the model in 2.7, we get

$$y = \alpha + \lambda\hat{y_w} + \mathbf{X}\beta + \epsilon \tag{2.10}$$

(2.10) now yields to estimates that correspond to network effects (λ) and local effects (β). However, (2.10) makes use of one weight matrix $\mathbf{W}$ only. However, there is no reason to believe that there is only one network that needs to be considered; on the contrary, there are potentially many networks that are connecting the societies in a cross-cultural dataset such as geographical distance and common history. Ideally, we want to incorporate all these network effects in our model however adding estimates for each of these network effects

($\hat{y}_{Wlanguage}$, $\hat{y}_{Wdistance}$, and so on...) is problematic since it is very likely that these estimates are highly correlated and therefore will cause multicolliniarity. To address this issue DEf functions model combines all weight matrices into one matrix as such:

$$\mathbf{W}_{DLR} = \pi_D * \mathbf{W}_{Distance} + \pi_L * \mathbf{W}_{Language} + ... + \pi_n * \mathbf{W}_n \tag{2.11}$$

where,

$$\pi_D + \pi_L + ... + \pi_n = 1 \tag{2.12}$$

and,

$$0 \leq \pi_D, \pi_L, ..., \pi_n \leq 1 \tag{2.13}$$

This model takes into account n different network autocorrelation effects. In theory, the model can include as many **W** matrices as deemed appropriate but within the framework of this thesis we make us of only three such matrices (i.e., k=3) of geography, language and ecology.

One final point that needs to be explained is how to choose the weights of each **W**. In the case of 3 **W** matrices there are weights: π_D, π_L and π_E. The DEf procedure creates a set of different weights between 0 and 1 for each weight π with increments of 0.05 and forms the $\mathbf{W}_{DLR}$ matrix accordingly and fits the model. The weights that yield the highest R^2 are used as the final weights in creating $\mathbf{W}_{DLR}$.

Chapter 3

Stereotyped Kinship Avoidance Behavior in the Old World

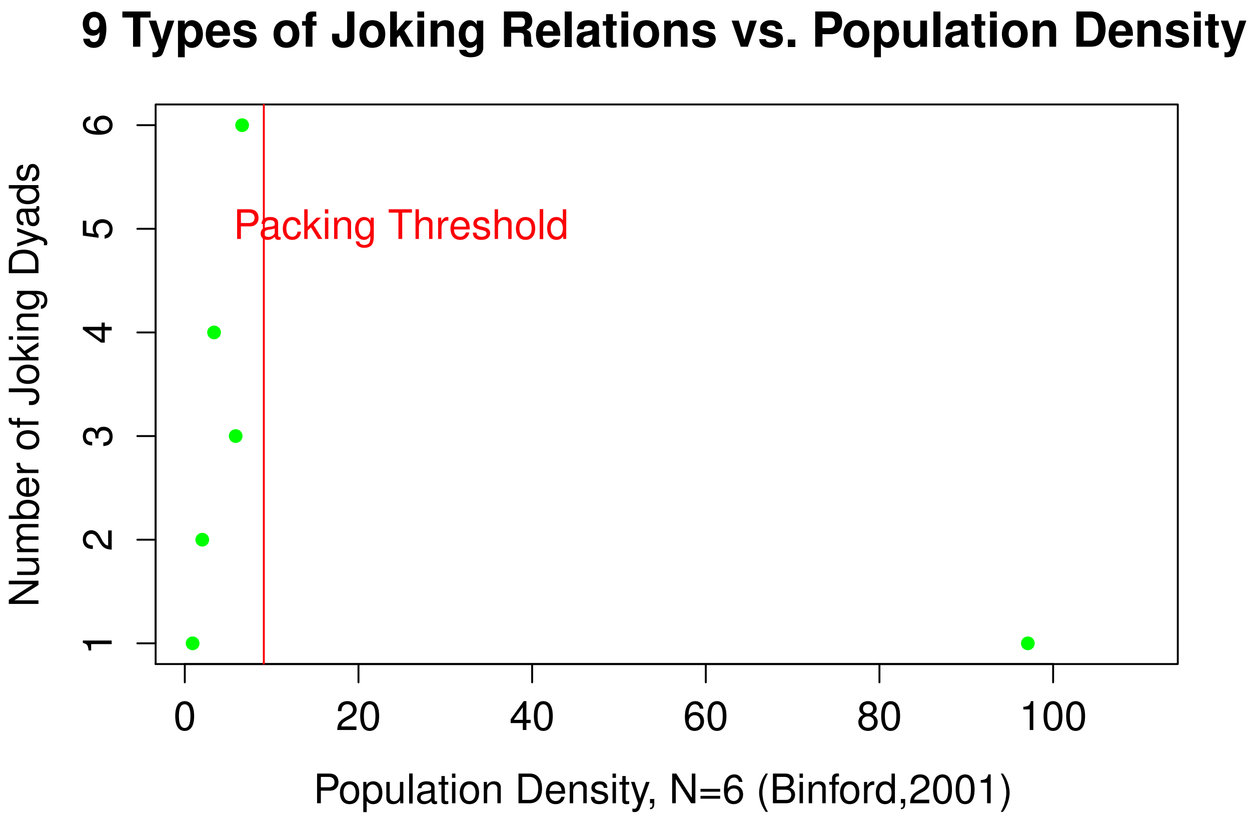
This chapter focuses on empirical results from the Old World societies using the Standard Cross-Cultural Sample [23] and later contributions to the dataset in an attempt to test our hypothesis on the link between stereotyped kin avoidance behavior and cooperation. Before getting into the details of the models on avoidance and cooperation it is important to touch upon the relationship between joking relations and avoidance behavior. Developing a fuller understanding of avoidances and joking is crucial for understanding at what population density levels and at what social complexities joking and avoidance behaviors operate.

Later in the chapter we will demonstrate how the cooperation on kinship networks extend to affines through marriage and how stereotyped avoidance behavior facilitates and secures such extending network ties in societies above the settlement threshold at 9.1 people/kmsq at which there is no longer unoccupied space into which mobile hunter-gatherers could move [1]. But first, we focus on our previous work that showed the relationship between joking relations and cooperation among hunter and gatherers who are below the settlement threshold and other early societies within a small network of close kin [38].

In a sample of 24 foraging societies with low population densities, joking dyads are frequently observed that help integrate small-scale societies through linking of close kin (e.g. wife's sister). Kin behaviors were coded by Murdock [21] and others respecting a scale ranging from 1 to 6 where 1 is avoidance, 2 is respect, 3 is informality, 4 is forbidden sex relations, 5 is joking and 6 is sex privileged relationship. We can see even in the coding of this variable that joking and avoidances are on the opposite sides of the same spectrum. They are the two sides of the same coin meaning these are different mechanism to reach the same end which is holding the group together and increasing its levels of cooperation. The difference is that joking helps increase cooperation within networks of close kin by reinforcing cross-cousin, siblings' spouses, spouses' siblings links; whereas, avoidances extend the cooperative kin networks to more distant affines and in-laws.

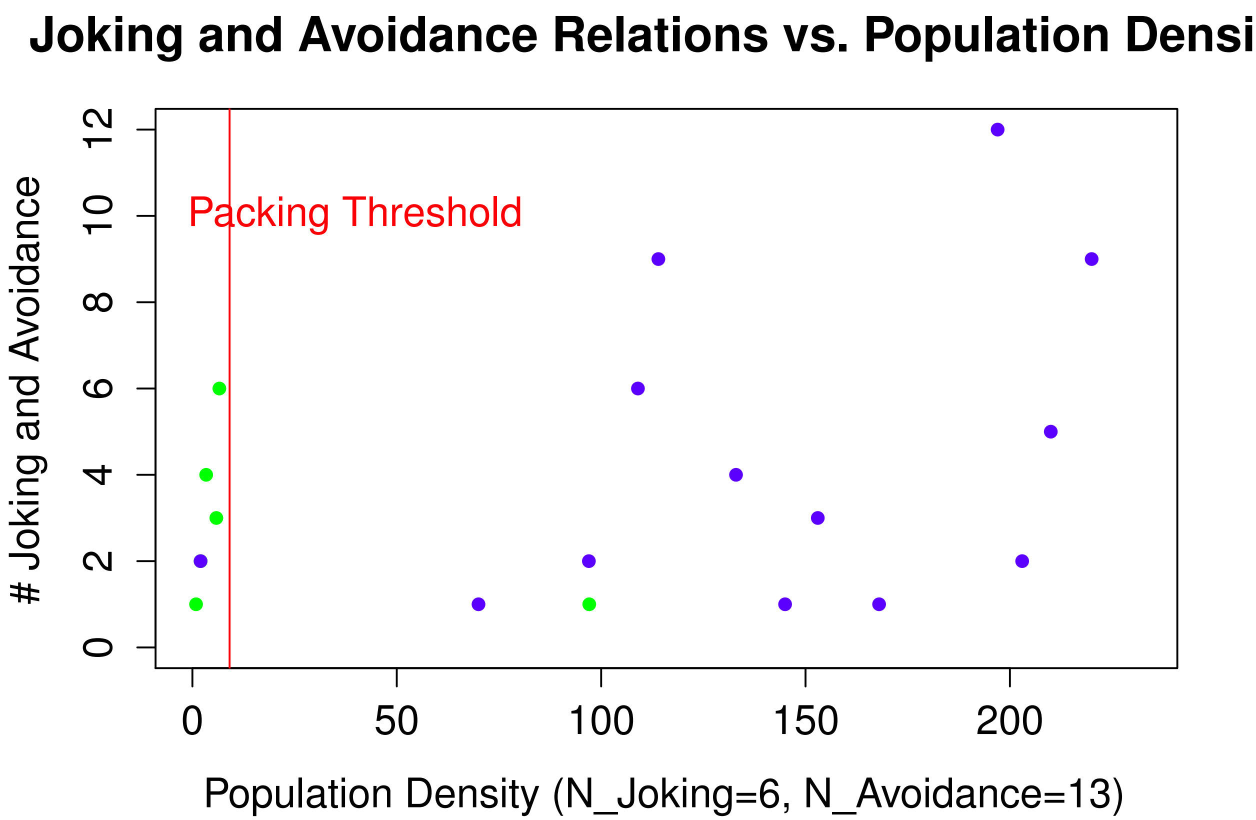
Drawing together data from Lewis R. Binford's [1] database and George P. Murdock's published [21] and unpublished (White n.d.) databases on kin-dyad behaviors, we demonstrate a critical relationship between the varying population density of forager bands with a packing density threshold at 9.1 people/kmsq at which there is no longer unoccupied space into which mobile hunter-gatherers could move [1], i.e., the settlement threshold, and the number of joking behaviors among relations in 26 societies (Figure 3.1). It is clear that joking relations mostly operate at density levels under the packing or settlement threshold of 9.1 people/kmsq. Five out of all six societies that have one or more type of joking relations have population densities less than 9.1 people/kmsq whereas those societies with population densities above the packing threshold do not have joking relations at all except for one. A one-sided Fisher's exact test suggests that the chances of the observed distribution being at random is 0.06584.

Figure 3.1: Joking Relations vs Population Density



In Figure 3.2 we juxtapose avoidance relations (blue dots) on top joking relations (green dots) to see how the distributions compare across population density. It is easily seen that most avoidance relations are present in those societies that are above the packing threshold and that there is only one society that is under the packing threshold and still has two kinds of avoidance relations present. The p-value for a one-sided Fisher's exact test is 0.09561 for avoidances and population density.

Figure 3.2: Joking and Avoidance Relations vs Population Density



Avoidances do not replace joking within particular dyads (the dyads in which they occur differ) as population density increases but they do increase in frequency in forager societies while joking declines. Population density rises with larger population ($R^2 = 0.374$, $p = e^{-16}$) and implies many more non-kin pairs of people in the local population. Thus a greater proportion of avoidance rather than joking behaviors will develop as non-kin persons marry. Joking will continue between cross-kin of the same generation in a more limited network. That is, while avoidances will occur with the broadening of social networks, joking is more often expressed among those of the same generation connected by parental and grandparental ties, narrowing social ties. To the extent that they each extend potentials for cooperation and conflict resolution, avoidances do so on a more extended population scale and joking on a smaller scale.

We have argued that avoidances provide a stronger form or at least broader spread of kinship network bonding than joking. Joking behavior tends to extend to a narrower circle of alliances. Managing the avoidance of conflict between affinals by the medium of one or more avoidance kin behaviors has the potential of expanding ties between families that both enlarge the circle of alliances and avoid conflict with affinals.

We further argue that as population gets denser, societies form other institutions to resolve conflicts and create social integration so that kin avoidances can be dropped without being detrimental to societal survival. Figure 3.3 and 3.4 show the frequency of the eight most common avoidances across population density and jurisdictional hierarchy above the local community which is the variable we use as a measure of a society's institutional complexity.

Figure 3.3: Mean Number of Avoidances vs Population Density

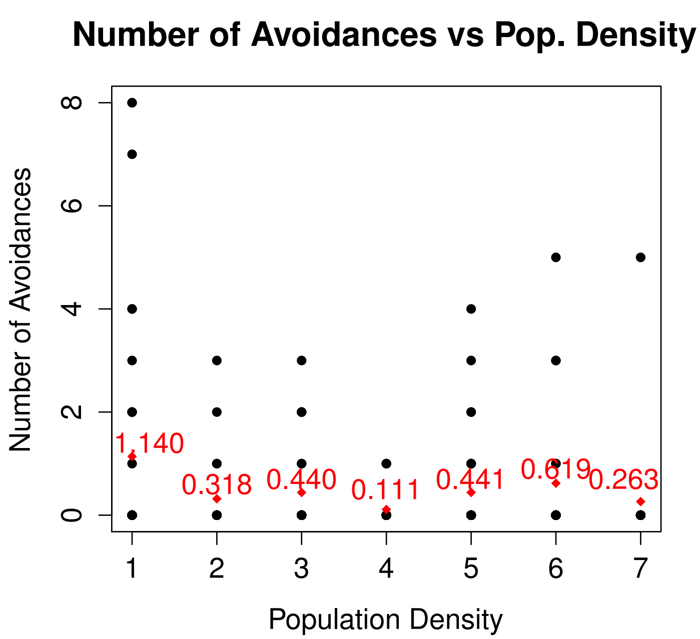
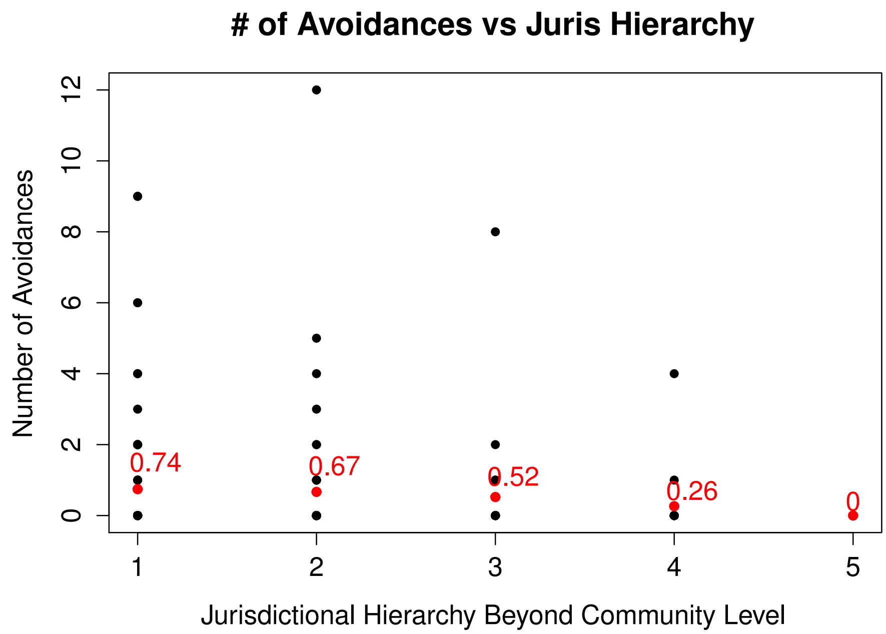


Figure 3.4: Mean Number of Avoidances vs Jurisdictional Hierarchy Beyond Community Level



In the following sections we first give a description of the SCCS dataset that we use and then present the Dow and Eff function (DEf) model results to test our hypothesis. The DEf models support the hypothesis that population density and jurisdictional hierarchies are significantly associated with kin avoidance behavior. Figure 3.2 shows that for small-scale hunter-gatherer societies, joking relations exist at lower population densities whereas avoidance operates at higher population densities. However, as we change our scope from hunter-gatherers to all societies present in the Standard Cross-Cultural Sample, this relationship gets reversed, that is to say, at higher population densities we do not observe kin avoidance behaviors any more which is expected as high population density at this scope is indicative of very complex societies in which avoidances are not needed for conflict resolution as these societies have devised other means for averting possible conflicts.

3.1 The Data and Descriptive Statistics

The Standard Cross-Cultural Sample (SCCS) consists of data collected in the last 2000 plus years of 186 world societies. Some of these societies are ancient civilizations such as Babylonians, Hebrews and Romans, some are more contemporary industrial civilizations like Russians and some are tribal groups. The mean date in the sample is 1860 ca. and the median date is 1910 ca. [37]

These societies were chosen to be as close to representative as possible of world societies to allow for cross-cultural comparative research. SCCS has over 2,000 variables on these societies ranging from ecology to social structure to kinship. In our models utilizing the SCCS dataset, we use population density (variable 64), hunting (variable 817), Jurisdictional Hierarchy of Local Community (variable 236), Jurisdictional Hierarchy beyond Local Community (variable 237), nuclear family (variable 80) and mean diurnal range (variable Bio.2) as independent variables whereas the dependent variables for the various models are Wife's Mother Avoidance (variable 1197), Wife's Father Avoidance (variable 1198), Husband's Father Avoidance (variable 1204), Husband's Mother Avoidance (variable 1205), Wife's Brother's Wife Avoidance (variable 1200).

Table 3.1: Avoidance Types and Frequencies

Avoidance Type	Present	Absent	Not Available	Total
Wife's Mother	25	35	126	186
Wife's Father	7	28	151	186
Husband's Mother	4	29	153	186
Husband's Father	14	36	136	186

By far the most frequent type of in-law avoidance is Wife's Mother (WiMo) with 25 recorded cases, it is followed by Husband's Father (HuFa) avoidance with 14 cases. Only four societies have Husband's Mother (HuMo) avoidance and only 7 societies have Wife's Father avoidance (WiFi).

3.2 Wife's Mother Avoidance Descriptive Statistics and Inferential Models

Wife's Mother avoidance (WiMo) is the most frequent type of stereotyped avoidance and we start out by analyzing it first.

We look at the independent variables of interest for the soceities in which WiMo is observed versus those that do not practice WiMo avoidance.

Table 3.2: Independent Variable Descriptives for Wife's Mother Avoidance

Independent Variables	Present N=25	Absent N=36	Not Available N=126	Marginal N=186
Population Density	2.88 ± 1.76	4.56 ± 1.98	3.72 ± 1.95	3.76 ± 1.98
Hunting	17.8 ± 18.49	13.29 ± 16.31	14.76 ± 15.90	14.89 ± 16.30
Jurisdictional Hierarchy Local	2.96 ± 0.54	2.88 ± 0.68	2.87 ± 0.59	2.89 ± 0.60
Jurisdictional Hierarchy Beyond Local	1.56 ± 0.92	2.35 ± 1.23	2.12 ± 1.30	2.08 ± 1.25
Nuclear Family	2.96 ± 1.17	3.31 ± 1.41	3.26 ± 1.20	3.23 ± 1.24
Mean Diurnal Rain	115.44 ± 35.37	103.71 ± 32.40	108.79 ± 30.23	108.73 ± 31.36

Table 3.2 shows that mean population density for societies that practice Wife's Mother avoidance is 2.88 with a standard deviation of 1.76 while mean population density for societies in which Wife's Mother avoidance is not observed is 4.56 with standard deviation 1.98. This descriptive statistic is indicative of the fact that at very high population densities societies do not rely on Wife's Mother avoidance as much for conflict resolution. In addition to population density, another independent variable of interest is Jurisdictional Hierarchy Beyond Local Community. As mentioned earlier, this variable can serve as a proxy for the extent to which societies have devised other institutional means for conflict resolution other than avoidances. The more and higher jurisdictional hierarchies beyond local community are observed, the less a society should require an avoidance relationship to serve as conflict aversion. Table 3.2 shows evidence towards this assertion as far as Wife's Mother avoidance is concerned

with a mean of 1.56 (±0.92) jurisdictional hierarchies beyond local community for societies with WiMo avoidance and a mean jurisdictional hierarchy beyond local community of 2.35 (±1.23) for those societies that do not practice WiMo avoidance.

We look at the distribution of Wife's Mother avoidance across the globe using the SCCS data.

Figure 3.5: Wife's Mother Avoidance Map

Figure 3.6: Wife's Mother Avoidance Map with Imputed Cases

In map 3.5, red dots represent SCCS societies in which Wife's Mother avoidance is practiced and blue dots represent the absence of Wife's Mother avoidance. In North West America, South America, Sub-Saharan Africa and Papua New Guinea there are societies where WiMo is practiced, while few sample points with available data in Europe and Asia Minor show absence of WiMo avoidance. There isn't a clear geographical proximity pattern for the presence of avoidances in Africa and Oceania but in North America coastal societies seem to have WiMo more than the inland societies.

Below are the logistic regression results for the unadjusted models for WiMo avoidance with independent variables: population density (v64) and jurisdictional hierarchy beyond the local community (v237) and the adjusted model including all these variables:

Table 3.3: Logistic Autocorrelation Regression Models for Wife's Mother Avoidance

	Unadjusted		Unadjusted2		Adjusted	
Covariates	Estimate	p-value	Estimate	p-value	Estimate	p-value
Network Lag Term	0.88	0.96	1.99	0.71	0.97	0.99
Population Density	0.64 $(0^+, 4.05 \times 10^4)$	0.08			0.71 $(0^+, 245.65)$	0.16
Jurisdictional Hierarchy Beyond Local Community			0.49 $(0^+, 896.83)$	0.12	0.62 $(0.04, 10.41)$	0.30

The autocorrelation regression results are as follows:

Table 3.4: Autocorrelation Regression Models for Wife's Mother Avoidance

	Unadjusted		Unadjusted2		Adjusted	
Covariates	Estimate	p-value	Estimate	p-value	Estimate	p-value
Network Lag Term	0.03	0.335	0.24	0.598	0.17	0.721
Population Density (v64)	−0.09	0.002			−0.11	0.001
Jurisdictional Hierarchy Beyond Local Community (v237)			−0.14	0.008	−0.05	0.411
Jurisdictional Hierarchy At the Local Community (v236)					0.24	0.008
Family Size (v80)					−0.11	0.013

First we model the predictors of Wife's Mother Avoidance, in Table 3.3 and 3.4. The models control for network lag effects first, which are known to cause Galton's problem and confound results, and then calculate coefficients of predictors and their significance with Wife's Mother Avoidance as the dependent variable. Controlling for distance and common language effects (i.e., cultural similarity) as autocorrelation effects, the logistic regression model tells us only that higher population density is a significant predictor of decline in WiMo Avoidance. The autocorrelation regression in table 3.4 also shows a highly significant effect on decline of Avoidance for population density (v64).

WiMo Avoidances are significantly more common with higher jurisdictional hierarchy in the local community indicating avoidances help build jurisdictional hierarchies at the community level however as jurisdictional hierarchies beyond local communities arise wife's mother avoidances start to get dropped (-0.05 with p-value 0.411). Our prior hypothesis suggested that avoidance provides greater social integration that co-enables an increase in jurisdictional hierarchy of the local community (v236) which is supported and the inverse relationship between avoidances and beyon community jurisdictional hierarchies (v237) is there as well but it is not significant.

Finally, Family Size (v80) has a negative association with Wife's Mother avoidance. Even though a move from small extended families to larger extended families in the spectrum leads to a decrease in the observance of WiMo avoidance, this relationship is curvilinear and at the lowest level which is nuclear families we do not expect the highest frequency of WiMo avoidance since nuclear family is a feature of complex societies and such societies tend to drop avoidance behaviors.

3.3 Wife's Father Avoidance Descriptive Statistics and Inferential Models

In this section we model Wife's Father avoidance behavior. Table 3.5 gives the descriptive statistics for the independent variables of interest across societies with and without Wife's Father avoidance.

Table 3.5: Independent Variable Descriptives for Wife's Father's Avoidance

Independent Variables	Present $N = 7$	Absent $N = 28$	Not Available $N = 151$	Marginal $N = 186$
Population Density	1.43 ± 0.79	4.07 ± 2.07	3.81 ± 1.94	3.76 ± 1.98
Hunting	22.14 ± 13.50	16.43 ± 20.41	14.27 ± 15.56	14.89 ± 16.30
Jurisdictional Hierarchy Local	3.14 ± 0.38	2.89 ± 0.61	2.87 ± 0.59	2.89 ± 0.60
Mean Temperature Dry	95.57 ± 163.71	181.71 ± 124.23	169.10 ± 122.12	168.96 ± 124.27

Just like in Wife's Mother avoidance there is a clear difference in population density between societies that have Wife's Father avoidance and those that do not. Societies with WiFa avoidance have on average a population density level of 1.43 (± 0.79) whereas the societies that do not have WiFa avoidance have a mean population density level of 4.07 with a standard deviation of 2.07. Again, at very highly dense populations, WiFa avoidance are not present. Local jurisdictional hierarchies are higher in societies with WiFa avoidance but we have to look at network autocorrelation models to see if these differences are significant when controlled for possible confounding effects. Those models are shown in Table 3.6. Now we look at the distribution of WiFa avoidance across the globe.

Figure 3.7: Wife's Father Avoidance Map

Figure 3.8: Wife's Father Avoidance Map with Imputed Cases

Unlike Wife's Mother avoidance, there seems to be an obvious geographical pattern to the distribution of Wife's Father avoidance: with the exception of one South African society, no other society in Africa, Europe, Asia Minor, Asia nor Oceania has WiFa avoidance. The only societies that practice WiFa avoidance are in North and South America. In Chapter 4, we use a different data set whose focus is only Western North American Indians and the model results for Wife's Father avoidance in Chapter 4 can shed more light to the underlying dynamics of its presence and absence in North America.

The autocorrelation regression results are as follows:

Table 3.6: Autocorrelation Regression Models for Wife's Father Avoidance

	Unadjusted		Unadjusted2		Adjusted	
Covariates	Estimate	p-value	Estimate	p-value	Estimate	p-value
Network Lag Term	-0.66	0.335	1.01	0.003	−1.523	0.001
Population Density	−0.11	0.002			−0.151	0.000
Jurisdictional Hierarchy At the Local Community			0.22	0.010	0.21	0.013
Hunting					0.007	0.064
Mean Temperature Dry Quarterly					−0.16	0.001

Three of the WiMo predictors apply to predictors of Wife's Father Avoidance, as shown in Table 3.6. Again we see that there is a significant association between population density and decline in Avoidance. Other predictors are Importance of Hunting, Low Mean Temperature in the Dry Quarter of the year, and Jurisdictional Hierarchy of Local Community (shared with WiMo), which we suspect is a not a cause but a consequence of WiMo Avoidance as a means of local cooperation, integration, and conflict reduction.

3.4 Husband's Mother Avoidance Descriptive Statistics and Inferential Models

Table 3.7 on next page shows the descriptive statistics for indepdendent variables for societies with and without Husband's Mother avoidance. Population density follows the same pattern as it did for Wife's Mother and Wife's Father avoidances, that is, those societies with very high population density do not require Husband's Mother avoidance (4.14 ± 2.10)

whereas those with lower population densities[1] tend to have more Husband's Mother avoidance (2.25 ± 2.50). Hunting is another variable we are interested in to model avoidances. Hunting requires well-integrated networks of kin groups as the group that is hunting needs to be both big enough and cooperative at the same time. Thus, avoidance behavior facilitates and accommodates hunting groups as it provides the necessary glue that holds extended affinal kin groups together. Those societies that do not have avoidance behavior are either one that cannot bring together big enough groups to hunt or they are too big and complex that they have dropped avoidances as a means for social integration but at the same time they do not depend on hunting anymore either. For Husband's Mother avoidance we observe mean hunting level 20 (standard deviation 10) for those who practice HuMo avoidance and a mean hunting level of 14.31 (standard deviation 19.17) for those wo do not practice HuMo avoidance where the variable hunting ranges from 0 to 80 with increments of 5 yielding 16 unique categories.

We need to be cautious with Husband's Mother avoidance models as the signal is not powerful with only 4 societies that practice HuMo avoidance in the data set. The descriptive statistics point towards some direction yet it is very unlikely to get the statistical power to get much significance in the results.

Table 3.7: Independent Variable Descriptives for Husband's Mother Avoidance

Independent Variables	Present N=4	Absent N=29	Not Available N=153	Marginal N=186
Population Density	2.25 ± 2.5	4.14 ± 2.10	3.72 ± 1.93	3.76 ± 1.98
Hunting	20 ± 10	14.31 ± 19.17	14.87 ± 15.90	14.89 ± 16.30
Mean Diurnal Range	121.25 ± 34.36	106.83 ± 36.71	108.76 ± 30.36	108.73 ± 31.36
Annual Mean Temperature	59.5 ± 105.46	175.14 ± 108.65	187.98 ± 94.21	183.22 ± 98.08
Niche Temperature	5.5 ± 3	1.86 ± 1.55	2 ± 1.86	2.05 ± 1.91

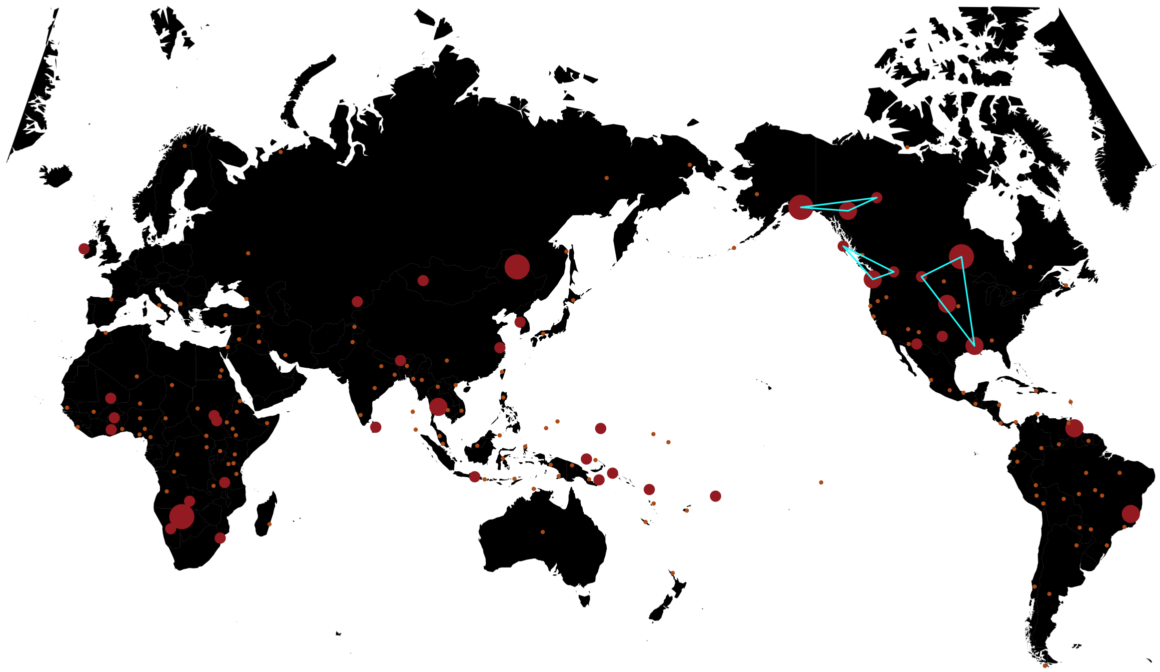
Map 3.9 shows the distribution of Husband's Mother avoidance across the globe. Out of

[1] above 9.1 people/km^2 threshold of density

the four data points with HuMo avoidance, we see two of them are located in North West America, one in south Africa and one in East Asia. No geographical pattern strikes the viewer as obvious in this map.

Figure 3.9: Husband's Mother Avoidance Map

Figure 3.10: Husband's Mother Avoidance Map with Imputed Cases



The autocorrelation regression results are as follow:

Table 3.8: Autocorrelation Regression Models for Husband's Mother Avoidance

	Unadjusted		Adjusted	
Covariates	Estimate	p-value	Estimate	p-value
Network Lag Term	-2.197	0.007	-0.958	0.0004
Population Density	-0.321	0.011	-0.302	0.003
$PopulationDensity^2$	0.028	0.020	0.032	0.003
Hunting			-0.011	0.0004
$NicheTemperature^2$			0.020	0.000
Mean Diurnal Range			0.097	0.007
$MeanTemperature^2$ Dry Quarterly			0.090	0.002

Table 3.9: Logistic Regression Models for Husband's Mother Avoidance

	Adjusted	
Covariates	Estimate	p-value
Network Lag Term	-167.05	0.044
Population Density	-98.70	0.021
$PopulationDensity^2$	9.77	0.018
Hunting	-5.27	0.031
$NicheTemperature^2$	2.15	0.076
Mean Diurnal Range	15.79	0.076
$MeanTemperature^2$ Dry Quarterly	-13.60	0.183

Here, the logistic regression tends to match almost exactly that of autocorrelation regression. The autocorrelation regression predictors in common are population density (v64, v64Sq), importance of hunting, and mean diurnal range (mean of monthly). No predictors involve jurisdictional hierarchies (v236, v237, v236*v237). Other climatic predictors are annual mean temperature squared, niche temperature, and monthly temperature range. All these model results must be taken with caution because the number of societies with HuMo avoidances is only four out of a total sample of 33.

3.5 Husband's Father Avoidance Descriptive Statistics and Inferential Models

The independent variable descriptives in Table 3.10 show patterns similar to the patterns of independent variable descriptives for Husband's Mother avoidance. Mean population density for the fourteen societies with Husband's Father avoidance is 3.07 (standard deviation 1.98) whereas the mean population density for the societies without Husband's Father avoidance is 4.72 (standard deviation 1.81). As for hunting, where Husbands' Father avoidance is observed mean hunting level is 17.86 (standard deviation 19.97) while mean hunting level is a mere 10 (standard deviation 14.09) for societies without Husband's Father avoidance.

Table 3.10: Independent Variable Descriptives for Husband's Father Avoidance

Independent Variables	Present N=14	Absent N=36	Not Available N=136	Marginal N=186
Population Density	3.07 ± 1.98	4.72 ± 1.81	3.57 ± 1.95	3.76 ± 1.98
Hunting	17.86 ± 19.97	10 ± 14.09	15.88 ± 16.31	14.89 ± 16.30
Mean Diurnal Range	106.94 ± 36.91	106.83 ± 36.71	109.37 ± 29.74	108.73 ± 31.36
Annual Mean Temperature	187.06 ± 102.14	175.14 ± 108.65	182.98 ± 95.91	183.22 ± 98.08
Niche Temperature	2.5 ± 2.56	1.78 ± 1.49	2.08 ± 1.93	2.05 ± 1.91

Map 3.11 shows the distribution of Husband's Father avoidance in SCCS sample across the globe. The fourteen societies with HuFa avoidances are: Kung Bushmen, Thonga, Nyakyusa,

Pastoral Fulani, Hausa, Lolo, Andamanese, Vedda, Kimam, Manus, Manchu, Gilyak, Eyak, Gros Ventre. These societies are dispersed around the globe and occupy such places as North West America, Sub-Saharan Africa, East and South East Asia, and Oceania.

Figure 3.11: Husband's Father Avoidance Map

Figure 3.12: Husband's Father Avoidance Map with Imputed Cases

Table 3.11: Autocorrelation Regression Models for Husband's Father Avoidance

	Unadjusted		Unadjusted2		Adjusted	
Covariates	Estimate	p-value	Estimate	p-value	Estimate	p-value
Network Lag Term	-0.66	0.33	1.01	0.00	-1.0011	0.0002
Population Density	-0.11	0.00			-0.28	0.006
$Population Density^2$	-0.11	0.00			0.03	0.006
Hunting					-0.01	0.000
$Niche Temperature^2$					0.02	0.000
Mean Diurnal Range					0.10	0.005
$Mean Temperature^2$ Dry Quarterly					-0.09	0.001

Husband's Father Avoidance (Table 3.11) also shows, as with WiMo and WiFa, Low population density (v64) and Low Importance of Hunting as predictors for increase of Avoidance. Population density squared (v64Sq), warm Niche Temperature Squared (v854Sq), Low Annual Mean Temp Squared (bio1.Sq), and Mean Diurnal Range-monthly (bio.2) are predictors of increase in HuFa Avoidance.

3.6 Wife's Brother's Wife Descriptive Statistics and Inferential Models

Wife's Brother's Wife avoidance is practiced in 7 out of the 13 societies that this type of avoidance was coded for. These societies are: Thonga, Shilluk, Andamanese, Kimam, Manus, Marshalles and Gros Ventre. Wife's Brother's Wife avoidance is another type of avoidance through which kin networks extend to non-blood related kins. In some societies a man's wife's brother is his trade partner. In such societies WBW avoidance helps secure this trade partnership by preventing the possibility of any sexual or other contact between a man and his trade partner's wife. The descriptive statistics in Table 3.12 shows that societies with WBW avoidance tend to have more dependency on fishing than those that do not have WBW avoidance. Again, a fishing culture is also indicative of possible trade networks connected through fishing and crossing of rivers [22]. Also the descriptive statistics seem to suggest societies with WBW avoidance tend to be more densly populated and have more both local and beyond local jurisdictional hierarchies than those without WBW avoidance.

Table 3.12: Independent Variable Descriptives for Wife's Brother's Wife Avoidance

Independent Variables	Present N=7	Absent N=6	Not Available N=173	Marginal N=186
Population Density	4 ± 2	3.33 ± 2.25	3.77 ± 1.98	3.76 ± 1.98
Fishing	20 ± 20.82	5.83 ± 4.92	16.16 ± 18.90	15.97 ± 18.73
Jurisdictional Hierarchy Local	2.71 ± 0.76	2.67 ± 0.82	2.90 ± 0.59	2.89 ± 0.60
Jurisdictional Hierarchy Beyond Local	1.71 ± 0.76	1.5 ± 0.84	2.12 ± 1.28	2.08 ± 1.25

Table 3.13: Autocorrelation Regression Models for Wife's Brother's Wife Avoidance

	Unadjusted		Unadjusted2		Adjusted	
Covariates	Estimate	p-value	Estimate	p-value	Estimate	p-value
Network Lag Term	-0.66	0.33	1.01	0.00	-1.0011	0.00
Population Density	-0.11	0.00			-0.28	0.00
Fishing	-0.11	0.00			-0.28	0.00
Jurisdictional Hierarchy Local	-0.11	0.00			0.03	0.01
Jurisdictional Hierarchy Beyond Local					-0.01	0.00

The autocorrelation regression results in table 3.13 support the hypothesis that high population density societies do not have WBW avoidance and also supports the hypothesis that WBW avoidance help build jurisdictional hierarchies at the local community but societies with jurisdictional hierarchies beyond the local community do not have WBW avoidance as much. The relationship with fishing gets reversed from the one we see in the descriptive statistics table once we control for population density.

3.7 Conclusion: An Overall Summary of All Avoidances Aggregated

The percentages of autocorrelation controlled for each model are given toward the bottom of Table 3.14 on the next page. The easiest explanation of that table is that WiMo Avoidance is the most common, ancestral invention, and is spread initially through language (65%) and ecology (35%). WiFa Avoidances probably evolves next, and spreads through optimal ecological conditions. The spread of the remaining three avoidances HuFa-HuMo, and WiBrWi Avoidances then spread, independently, through diffusion (distance autocorrelation 80 % each), the HuFa-HuMo pair probably spreading together given that their predictive models are very similar.

Results from correlational, logistic or regression models with autocorrelation controls fail to support standard hypotheses that connect stereotyped kin avoidances to kinship variables such as matri- versus patri- local residence rules and lineage organization. Residential and lineage variables are not predictors in any of the logistic or regression models.

Our interpretation of the local and larger political hierarchy variables is the same for all five Tables 3.4, 3.6, 3.9, 3.11, 3.13: Jurisdictional Hierarchies at the Local Community (v236) is a positive predictor for WiMo and WiFa and WBW Avoidances and Jurisdictional Hierarchies beyond Local Community (v237) is a negative predictor for WiMo and WBW avoidances.Thus, the evidence of both the logistic and autocorrelation regression models (3.4, 3.6, 3.9, 3.11, 3.13, both with autocorrelation controls) shows a connection toward the development of local community jurisdictional hierarchies with avoidances of the WiMo and WiFa and WBW types. A plausible hypothesis is that avoidances help feed the cooperativity that constructs community jurisdictional hierarchies among foragers. Beyond local communities, Jurisdictional Hierarchies advance to larger scales that are unlikely to be supported by avoidances, and replace them at large population levels. Thus it is only within certain ranges of population density on jurisdictional hierarchies that avoidances are likely to be crucial elements in how societies maintain and construct social integration, cooperation within smaller scales of local jurisdictional hierarchies or low extralocal jurisdictional hierarchies.

Table 3.14: All Avoidance Models Combined

Variables	WiMo	WiFa	HuFa	HuMa	WBW	Sum	Frequency
Population Density	Negative	Negative	Negative	Negative			4
Hunting		Positive	Negative	Negative			3
Juris. Hier. Loc	Positive	Positive			Positive		3
Juris. Hier. Beyond	Negative				Negative		2
Nuclear Family	Negative					Positive	2
Bio 2			Positive	Positive			2
$\mathbf{W}y$							
Distance	0%	0%	80%	80%	80%	20%	3 × 80%
Language	65%	20%	0%	0%	0%		1 × 65%
Ecology	35%	80%	20%	20%	20%	80%	1 × 80%
Marginal	4	3	3	3	2	1	$\frac{16}{36}$

Parent-in-law avoidances establish limits on communication between in-laws of different generations, at least for an initial period after a marriage. But once this initial period passes, avoidances lead to extension of ties that are cooperative because of the element of respect that they carry.

The most common hypothesis had been that uxori-/matrilocal residence creates conditions for husband's avoidance of wife's parents and viri-/patrilocal residence for wife's avoidances of husband's parents. Murdock's cross-sex psychoanalytics (WiMo, HuFa) offer no explanation for same sex avoidances (WiFa, HuMo). Decisively, correlations vary randomly for cross- and same-sex avoidances for both first hypothesis (r=.03 and .12 for WiMo and WiFa avoidance, p=.85 and .48) and the second (r=-.02 and -.11 for HuFa and HuMo avoidance, p=.88

and .56), and also for WiBrWi (r=.03 and p=-.11 for uxori-/matrilocal and p=.41 and .85 viri-/patrilocal residence). Same-sex WiBr-SiHu (WiElBr or WiYoBr) are also potential avoidances but not same-sex HuSi-BrWi (HuElSi or HuYoSi and their reciprocals).Thus we see no support for alternate hypothesis that try to explain in-law and WBW avoidances.

Finally in this chapter we visit hypothesis 3 which is the hypothesis that the spread of in-law avoidances matches the out-of-Africa migratory routes. Using Anthon Eff's multiple imputation procedure for the SCCS data, we created in-law avoidance maps for the fully imputed in-law avoidance variables. The two maps that are of importance here are Wife's Mother avoidance map 3.6 and Husband's Father avoidance map 3.12.

The red dots in the maps indicate the presence of the specified avoidance behavior. Bigger red dots mean avoidance was present in the original dataset whereas a smaller red dot means the avoidance is present only in the imputed variable and originally the datum for that society was missing. Similarly smaller orange dots indicate the absence of avoidance.

Wife's Mother Avoidance map 3.6 has red clusters starting from South Africa going all the way up to North East Africa towards Egypt and the Middle East. Then it reaches and clusters around Southeast Asia and another cluster in Oceania and then finally reaches South and North Americas. This route matches with the early out-of-Africa migration route and early matrilineality in Southeast Asia and North and South America.

As for Husband's Father map 3.12, the clustering in Africa and Southeast Asia is similar yet then comes a point of divergence and Husband's Father avoidances reach to Northeast Asia which is in accordance with a later patrilineal migratory route through Asia.

Therefore it can be conjectured that once population density of foraging societies goes beyond the packing threshold, kin avoidances help extend cooperative ties to affines across settlements. Men interconnect across wife's matrilocal/matrilineal groups hence the presence of Wife's Mother avoidance through the route that goes across Southeast Asia and Oceania and women interconnect with Husband's patrilocal/patrilineal groups hence the presence of Husband's Father avoidance through the route that goes across Northeast Asia.

Chapter 4

Stereotyped Kinship Avoidance Behavior in the New World

Replication of cross-cultural findings between a world sample (e.g., SCCS) and New World societies (e.g., WNAI) is complicated by differences of scale in the New versus the Old World and societies of the Pacific. In chapter 3, with SCCS data, we tested Radcliffe-Brown's [32] [29] [30] theory of kin avoidances as respect relationships, endorsed by Eggan [11] [10]. We extended this theory, with positive test results, to include the hypothesis that avoidances not only avoid conflict with newly-established affinals but have the potential of expanding ties between families in ways that enlarge the circle of kinship alliances. Our findings suggest that they are a source of social integration in small-scale societies that is superseded with the emergence of higher-level political organization. Here in chapter 4, we focus on kinship avoidances in the New World to see whether the same principles operate in the Western Indians (WNAI) region [15] where there are no state level societies but kinship avoidances are common.

4.1 The Data and Descriptive Statistics

The Western North American Indians (WNAI) dataset consists of 172 Indian tribes that populate the regions of North America from Alaska to northern Baja California and from the Pacific Coast to the Rocky Mountains.[15]. A total of 496 variables are coded for the societies in the dataset that describe the topography, climate, technology, subsistence, economy, social and political organization. Kinship avoidances are not initially included in the original 1970 dataset, however, until in 2013 Douglas R. White matched the societies in Jorgensen's dataset with Driver's [6] 1974 data on avoidances. This expansion in the WNAI data set that we use for our analyses in this chapter allowed the use of Eff and Dow's DEf functions R software. We will refer to this data set as WNAI, but the reader should understand the expanded data set goes beyond the original '74 data of Jorgensen.

Table 4.1: Avoidance Types and Frequencies (WNAI Driver-White)

Avoidance Type	Present	Absent	Not Available	Total
Wife's Mother	44	81	47	172
Wife's Father	32	93	47	172
Husband's Mother	10	115	47	172
Husband's Father	15	110	47	172

Table 4.1 shows that just like in the old world societies (SCCS), Wife's Mother avoidance is the most frequent type of avoidance. However in the Western North American Indian societies the second most frequent avoidance is Wife's Father. Table 4.2 gives the pairwise correlations between different types of avoidances. What we see is a drop in the magnitude of correlations as we go from most frequent (WiMo) to less frequent avoidances. The highest correlation is between the two most frequent avoidances, i.e., WiMo and WiFa. What is more interesting in Table 4.2 is that the closer in frequency the two avoidances are the higher the

correlation between them and the further apart in frequency the lower the correlation. This may suggest a possible entailment ordering of avoidances.

Table 4.2: Internal Correlations of Kin Avoidances

	Wife's Mother	Wife's Father	Husbands Father	Husbands' Mother
Wife's Mother	1	0.7959***	0.5010***	0.4001***
Wife's Father		1	0.5167***	0.5027***
Husband's Father			1	0.7078***
Husband's Mother				1

$\dagger =< 0.10, * =< 0.05, ** =< 0.01, *** =< 0.001$

Table 4.3 shows the correlations and entailments of the 4 types of patterned kin avoidances in WNAI. The pattern is quite visible in that Wife's Mother avoidance is the root of avoidance behavior in the sense that there is no society that has avoidances but not WiMo avoidance. 10 societies only have WiMo and no other avoidances, 18 have WiMo and WiFa only, 2 have WiMo and HuMo only, 4 have WiMo, WiFa and HuFa only, 1 has WiMo, WiFa, HuMo only and 9 have all four avoidance types.

The second avoidance in the entailment order is Wife's Father avoidance. If there was a strict entailment ordering, there should not have been any societies with HuFa and HuMo avoidances without them having WiFa avoidance as well. The empirical data is not as smooth as the theoretical entailment would suggest; however, it is still quite in line with theory with only 2 exceptions. There are only 2 societies that have WiMo and HuFa avoidance and NOT WiFa avoidance. Third in entailment order is HuFa and fourth is HuMo avoidances as Table 4.3 suggests. In our later anaylsis in this chapter, we take a look at phylogenetic trees to investigate the evolutionary split between Wife's Mother avoidance (1st order in entailment) and Wife's Father avoidance (2nd order in entailment).

Table 4.3: Frequency of Kin Avoidances

	Wife's Mother				10
		Wife's Father			0
			Husband's Father		0
				Husband's Mother	0
	Wife's Mother	Wife's Father			18
	Wife's Mother		Husband's Father		2
	Wife's Mother			Husband's Mother	0
		Wife's Father	Husband's Father		0
		Wife's Father		Husband's Mother	0
			Husband's Father	Husband's Mother	0
	Wife's Mother	Wife's Father	Husband's Father		4
	Wife's Mother	Wife's Father		Husband's Mother	1
	Wife's Mother		Husband's Father	Husband's Mother	0
		Wife's Father	Husband's Father	Husband's Mother	0
	Wife's Mother	Wife's Father	Husband's Father	Husband's Mother	9
Total	44	32	15	10	44

Table 4.4 shows correlations of avoidances with possible explanatory variables and in doing so it replicates the same variables in Driver's '74 article with the exception of last two rows that contain the independent variables we are particularly interested in that were not considered by Driver. These variables are population density and political organization and alliance formation. We are interested in population density because we believe avoidances help secure alliance ties formed by exogamous marriages which extend the kin group networks and this mechanism works at low population densities. As an early evolutionary step,

avoidances may have helped increase the cooperation between groups for societies who were not densely populated yet but they managed to extend across bigger territories connecting with outside groups. We are interested in political organization and alliance formation because kin avoidances should help societies form alliances as they integrate affines to the kin network which lead to the expansion of the network and help networks of people in these societies seek and form alliances easily.

In Table 4.4, we see high and significant (at the level of 0.01) correlations between Wife's Mother and Wife's Father avoidance in the Salishan language and California Penutian language families. As for sister-cousin terms, WiMo and WiFa avoidances are positively correlated with Omaha and negatively with Hawaiian kin terms while HuFa and HuMo are correlated with Crow sister-cousin kin terms and HuMo with Iroquois terms. We do not observe high correlations between descent and avoidances. But, we do observe high negative correlations between lineal mother-aunt terms for WiMo or WiFa avoidances. Avunculocal residence is correlated with WiMo and HuFa avoidances while Patrilocal residence is negatively correlated with WiMo and HuFa residence. Political Organization and Alliance Formation variable is correlated with all 4 types of avoidances yet population density isn't significantly correlated with any of the avoidance types.

Table 4.4: Correlation of Avoidances with Possible Explanatory Variables

	Wife's Mother	Wife's Father	Husband's Father	Husbands' Mother
Language Families				
Uto-Aztecan	$-0.14^{\dagger}$	-0.10	-0.02	0.04
Wakashan	$-0.16^{\dagger}$	-0.13	-0.08	-0.06
Salishan	-0.3^{**}	-0.2^{**}	$-0.2^{\dagger}$	-0.1
Hokan	-0.057	-0.01	0.04	-0.05
California Penutian	0.4^{***}	0.5^{***}	$0.2^{\dagger}$	0.3^{**}
Athaspaskan	0.3^{**}	0.01	0.01	-0.11
Algonkian	-0.1	-0.08	-0.05	-0.04
Sister-Cousin Terms				
Crow	0.08	0.15^{*}	0.21^{**}	0.17^{**}
Omaha	0.39^{***}	0.43^{***}	0.09	$0.16^{\dagger}$
Iroquois	0.08	-0.04	-0.05	-0.11^{*}
Hawaiian	-0.25^{**}	-0.22^{**}	-0.08	-0.05
Eskimo	$-0.16^{\dagger}$	-0.13	-0.08	-0.06
Descent				
Bilateral	$-0.16^{\dagger}$	-0.11	-0.11	-0.05
Patrilineal	0.02	0.14	0.03	0.11
Matrilineal	0.18^{*}	-0.01	0.11	-0.05
Mother-Aunt Terms				
Bifurcate Collateral	$0.17^{\dagger}$	0.14	0.08	0.07
Bifurcate Merging	0.12	0.03	0.03	-0.06
Lineal	-0.3^{**}	-0.3^{***}	-0.2	-0.1
Generational	-0.07	-0.05	-0.04	-0.03
Residence				
Avunculocal	0.23^{***}	0.13^{*}	0.27^{***}	0.08
Bilocal, Ambilocal, Neolocal	-0.03	0.05	-0.02	0.07
Patrilocal	-0.22^{**}	-0.05	-0.10	0.04
Matrilocal	$0.18^{\dagger}$	-0.11	0.04	-0.14
Political Organization and Alliance Formation	0.4^{***}	0.4^{***}	0.3^{**}	0.3^{**}
Population Density	-0.10	0.07	-0.10	0.09

$\dagger =< 0.10, * =< 0.05, ** =< 0.01, *** =< 0.001$

Now we will take a step further than replicating the analyses of Driver [6] (1974) and move on to investigating descriptive plots and tables for our own hypothesis regarding the relationship between kin avoidances and population density and political hierarchies.

The relationship between population density and avoidances are shown in Table 4.5. The chi-square tests for WiMo, WiFa and HuFa avoidances are all significant indicating a nonrandom assortment of avoidances across different levels of population density. However, we do not see a level by level increase or decrease of avoidances; what we do see is that at the lowest level of population density, the avoidances are most frequent and at higher levels of population densities avoidances are less frequent in comparison to the lowest level of population density. This indicates that avoidances do operate at low population density levels but we need to formally check this fact by controlling for network effects as well as other possible confounding variables.

Table 4.5: Avoidance Frequencies by Population Density (variable 288)

Population Density	Wife's Mother	Wife's Father	Husbands Father	Husbands' Mother
Level 1	0.6	0.3	0.38	0.08
Level 2	0.3	0.1	0.00	0.00
Level 3	0.2	0.2	0.09	0.09
Level 4	0.5	0.4	0.16	0.13
Level 5	0.0	0.0	0.00	0.00
chi-sq tests:	$p = 0.02$	$p = 0.08$	$p = 0.009$	$p = 0.4$

Table 4.6 shows correlations between avoidances and political organization and alliance formation. Here we see a clear pattern where the proportion of avoidances for all 4 types increases as political organization becomes more complex and alliance formation increases. This trend continues up until level 4 of political organization and alliance formation variable which is the level where no avoidance of any type is present. It is worth noting that at level 4 there are only four societies so this is a category with very few societies.

Table 4.6: Avoidance Frequencies by Political Organization and the Formation of Alliances (variable 342)

Political Organization and Alliance Formation	Wife's Mother	Wife's Father	Husbands Father	Husbands' Mother
Level 1	0.07	0.02	0.0	0.00
Level 2	0.42	0.32	0.1	0.05
Level 3	0.66	0.50	0.3	0.21
Level 4	0.00	0.00	0.0	0.00
chi-sq tests:	$p < 0.001$	$p < 0.001$	$p = 0.003$	$p = 0.004$

4.2 Wife's Mother Avoidance Model

Our first model results are for Wife's Mother avoidance which is the most frequently observed kind of avoidance relationship. The network effects have a positive coefficient with Wife's Mother avoidance with weights 0.80 for geographic distance and 0.20 for linguistic distance. Having controlled for the diffusive effects of language and distance we still observe that population density and political alliances have significant functional relations with WiMo avoidance. Using the lowest population density as the baseline, we observe that higher population densities have negative coefficients that are significant at .05 level. All else being equal, more densely populated societies tend to have less WiMo avoidances in comparison to those societies with the lowest level of population density. This result supports our hypothesis that WiMo avoidance operates at the low population density levels. The coefficient of the variable for alliance formation is also positive meaning those societies who form political alliances tend to have more WiMo avoidance relations than those who form fewer political alliances outside their group.

Among the other variables we controlled for since they are mentioned previously in literature on avoidances, matrilineages and Omaha kin-terms have positive significant associations with WiMo avoidance. In matrilineal decent systems, rights and property are inherited through the female line and the main relationship can be seen as the one between a woman and her brother. When a man from a different group marries into a matrilineal group, it makes sense that he is expected to show respect to his wife's mother. As far as the alliance between the matriline of the outsider man and the matriline he marries into is concerned, his wife's father has no real importance. After all, wife's father is part of his sister's matriline not his own wife's.

Omaha kinterms is part of a kin terminology system broadly known as Crow-Omaha. Both these systems have negative marriage rules that prohibit a man marrying certain kin but does not enforce positively who he has to marry - only who he cannot marry. Crow system is found in matrilineal descent groups whereas Omaha is found in patrilineal descent groups. In Omaha system, a man cannot marry woman from his own patriline, his mother's patriline or his father's mother's patriline [12]. By assigning the same kin term to certain people of the same sex in certain paternal lineages the Omaha system [5] practically forces men to marry out; effectively dispersing man outward and leading to many connections with outside groups that are not connected to one's own descent group before. Clearly, this increases the chances for alliances as the kin network is wired with other groups that are not already tied to it. These new connections however need to be secured and as our hypothesis suggests kin avoidances are means to enforce respect and avoid conflict on these newly established connections. So as opposed to patrilineal systems that directly exchange wifes with specific groups only alternating generations; the Omaha system that forces the group to connect with various other groups is better suited for wider level cooperation and alliance formation and as such the observance of more frequent WiMo avoidance in such patrilineages than those who perform direct exhange of wifes is in line with our hypothesis.

Table 4.7: Autocorrelation Regression Models for Wife's Mother Avoidance in WNAI

	Unadjusted		Unadjusted2		Adjusted	
Covariates	Estimate	p-value	Estimate	p-value	Estimate	p-value
Network Lag Term	1.33	0.00	1.14	0.00	0.93	0.00
Population Density Level 2 (v288)	-0.17	0.26			-0.26	0.03
Population Density Level 3 (v288)	-0.25	0.04			-0.34	0.02
Population Density Level 4 and 5 (v288)	-0.14	0.25			-0.21	0.01
Political organization and the formation of alliances (v342)			0.07	0.1	0.07	0.06
Population Size (v286)					-0.06	0.03
Omaha (v334)					0.36	0.00
Crow (v334)					-0.01	1.00
Iroquois (v334)					0.066	0.4
Matriline (v311)					0.32	0.03
Kindred (v312)					-0.08	0.02
Mean Temperature of Wettest Quarter (variable bio.8)					-0.09	0.01

4.3 Wife's Father, Husband's Mother and Husband's Father Avoidance Models

Wife's Father avoidance is the second most common type of avoidance behavior observed among Western North American Indians. The model results (see Appendix A.1) for WiFa avooidance show that network effects play a big role in its distribution (coefficient 0.81, p-value < 0.01). The only network effect at play is distance 100 per cent while language effects is 0 per cent. Political alliance and population density variables are in the direction that our hypothesis suggests yet they are not statistically significant.

Husband's Mother avoidance is the third most common in-law avoidance among the West North American Indians. The autocorrelation regression results (see appendix table A.3) indicate that those Native American societies in which Husband's Mother avoidance is observed tend to form more political alliances (coefficient 0.04, p-value 0.03). Population density is also in the direction as hypothesized meaning the least densely populated societies tend to have more HuMo avoidances but these coefficients are not significant. Again, the network effect for distance is significant at 0.01 level with a coefficient of 0.85.

Finally, Husband's Father avodance which is the least frequent of all in-law avoidances display similar pattern with regards to our hypothesis on population density and alliance formation. As population density levels increase the frequency of HuFa avoidance decreases (see Appendix table A.2). Similarly, the variable for alliance formation has a coefficient of 0.05 (marginally significant p-value 0.1) meaning those societies who form more alliances tend to have more HuFa avoidance when controlled for network effects and other confounding variables.

4.4 Analysis of the Entailment Structure of In-law Avoidances

In Sections 4.2 and 4.3 we looked at the functional and diffusive factors effecting the emergence of in-law avoidances. The conclusions were supportive of our two major hypotheses namely that in-law avoidances operate at low densities by allowing the extension of the kin networks to affinal groups and second, facilitating cooperation thus resulting in formation of political alliances.

This help us understand the major differences between those societies that have an in-law avoidance vs those that do not. However, there is another important question that needs answering: why do some societies have more than one kind of in-law avoidance while others have fewer? Related to this question, one other important issue is the pyramid like structure of avoidances, that is the entailment pattern seen in table 4.3. Is this structure indicative of an evolutionary change in practicing of in-law avoidances?

Looking at the distribution of each in-law avoidance on the map of the Americas sheds light to the entailment structure that we observe.

Map 4.1 shows the distribution of Wife's Mother avoidance behavior across the Western North America natives. The blue indicator is for those societies that have WiMo avoidance and the red indicator is for those that do not. The indicators are also coded by language phyla. Aztec-Tanoan, Hokan, Penutian language phyla have their own unique symbols and those societies whose language belong to any other phylum is represented with a plus sign.

It is best to read map 4.1 on WiMo avoidance along with maps 4.3 4.2 4.4 on WiFa, HuMo and HuFa and table 4.8 which shows the relative network effect weights of language and distance for each of the avoidance types.

In map 4.1 we observe 4 geographic regions where WiMo avoidance is clustered. These are around Pacific Nort West, West Coast of California-North of Baja California, Northern Inlands and the Southwest. In the DEf model for WiMo, the network effect of distance is 80 per cent which can account for the within diffusion of these four clusters but then there is a 20 per cent language (common origin) effect in play as well which can account for the dispersal across these four separate clusters. However when we move to maps for WiFa, HuMo and HuFa respectively we see the shrinkage and then almost total disappearance of 3 out of the 4 WiMo clusters and the only network effect at play for these avoidances is distance meaning these other 3 have spread via geographic diffusion and not at all related to common origin. The most resilient of the four clusters is the one along the California coast. This is also the region where most interaction with other societies is possible.

I argue due to an increased interaction with different societies with possibly different marriage systems, societies in this region that initially had WiMo avoidances needed to invent other forms of avoidances to secure alliances via respect relations and these possibly diffused within this cluster of societies in this region. For WiFa, HuMo and HuFa the only network effect is distance with weight 100 per cent also supporting the argument that these probably diffused around this region once invented.

Figure 4.1: Wife's Mother Avoidance Map (N=172, Present=44, Absent 81, NA=47)

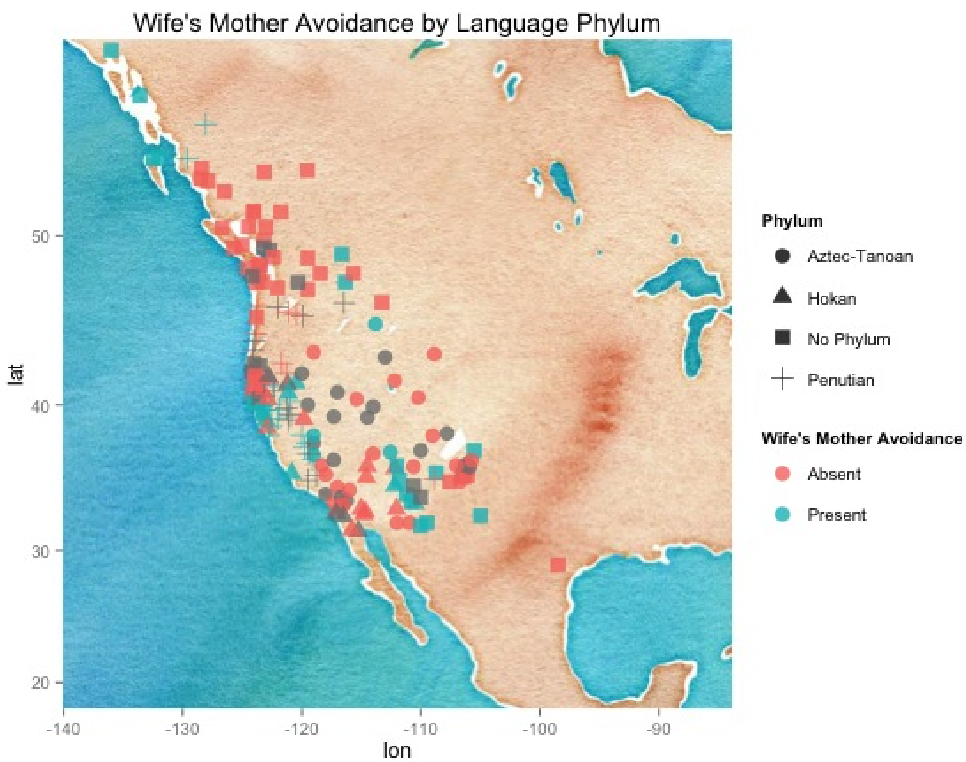


Figure 4.2: Husband's Mother Avoidance Map (N=172, Present=10, Absent 115, NA=47)

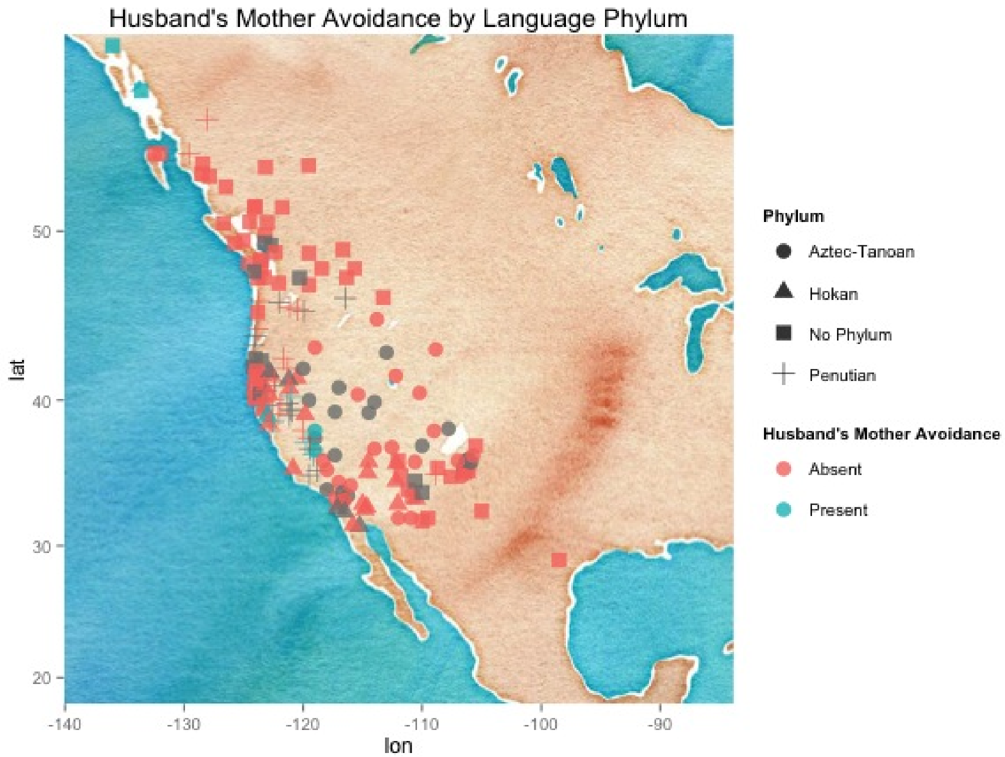


Figure 4.3: Wife's Father Avoidance Map (N=172, Present=32, Absent 93, NA=47)

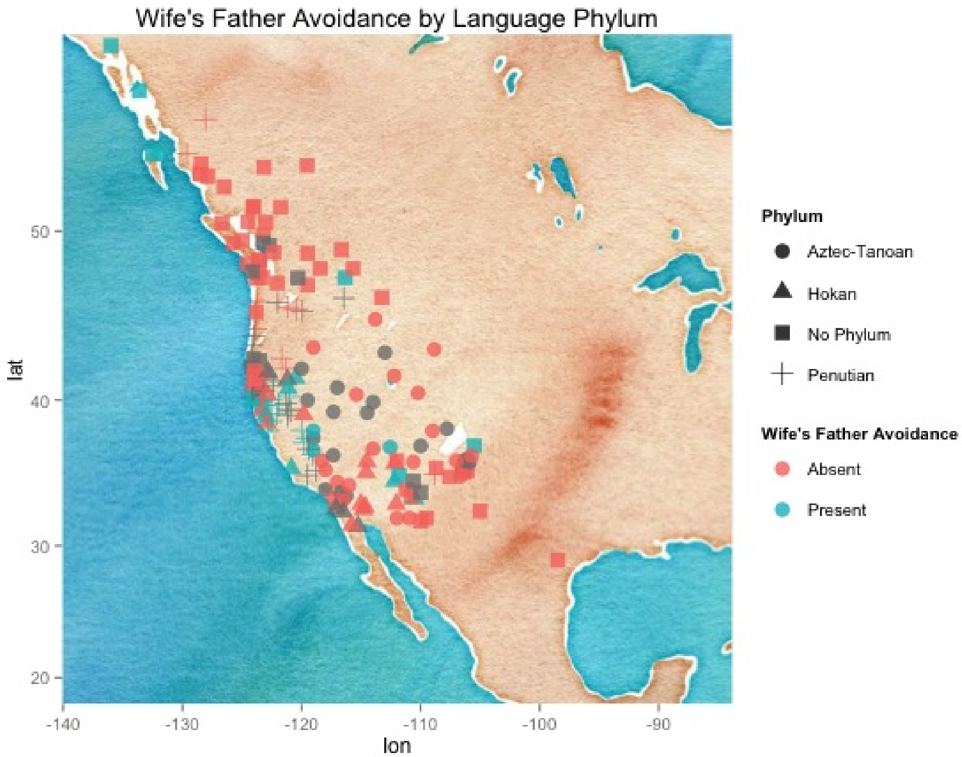


Figure 4.4: Husband's Father Avoidance Map (N=172, Present=15, Absent 110, NA=47)

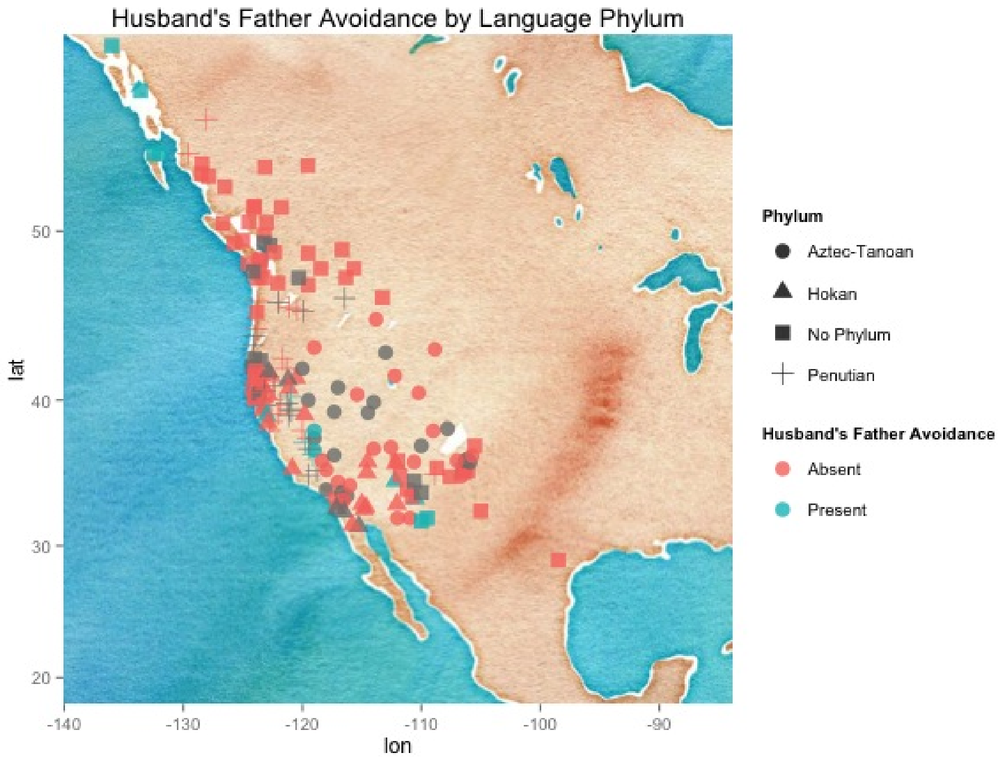


Table 4.8: Avoidance Models Autocorrelation Effects

Variables	WiMo	WiFa	HuFa	HuMa
Distance	80%	100%	100%	100%
Language	20%	0%	0%	0%
Ecology	0%	0%	0%	0%

Now that we have a hypothesis to test given the distribution of in-law avoidances on the maps, let us first get some descriptive statistics and then use the network autocorrelation regression method to test formally whether a shift from matrilineal descent may be the reason for multiple kinds of avoidances.

Table 4.9: Wife's Mother vs Other In-law Avoidances Descriptive Statistic

Variables	WiMo Only $N = 10$	WiFa $N = 18$	HuFa $N = 4$	HuMo $N = 9$
Descent				
Bilateral	4	11	1	4
Patrilineal	0	6	0	3
Matrilineal	6	1	3	1
Residence				
No demonstrated kinship units	2	10	1	4
Ambilocal	0	1	0	0
Patrilocal	1	5	0	3
Matrilocal	5	2	1	0
Avunculocal	2	0	2	2
Crow-Omaha				
Crow	0	0	2	2
Omaha	1	6	0	2
Other	9	10	2	5

Table 4.9 shows the descriptive statistics for those societies who have only Wife's Mother Avoidance and those who have WiMo + Wife's Father, WiMo + WiFa + Husband's Father and finally those who have all four types of in-law avoidances.

The first important observation in this table is that out of 10 societies that have only Wife's Mother avoidance none of them has patrilineal descent. They either have matrilineal or bilateral descent systems. This bolsters our belief that Wife's Mother avoidance which is the root of all avoidances in the entailment begins in matrilineal societies in which membership to the kinship group is traced through female line and as such showing respect to the mother of the group a man marries into is crucial.

As we look at the societies who adopt Wife's Father avoidance on top of Wife's Mother avoidance we now see a different pattern 17 out of 18 societies either have bilateral or patrilineal descent and only 1 out of 18 has matrilineal descent. This supports the idea that as societies transition to different descent systems (either due to outside contact or self-invention but outside contact is probably a bigger cause) they retain the idea of avoidance as means to show respect and form alliances but exhibit this behavior towards the father in-law now who is the key figure in patrilineal societies.

The type of residence shows a similar pattern. for Wife's Mother avoidance only, we see 5 matrilocal residences and 2 avunculocal residences which means the son is raised with the natal family but then is sent to maternal uncle upon reaching puberty. Again when we look at WiMo + Wife's Father avoidance we see an increase in the frequency of patrilocality and a sharp decrease in matrilocality.

Crow-Omaha kin terms is a third variable that we looked at the frequencies of across different in-law avoidances. The reason for this is mentioned briefly before but the basic logic is that in Crow-Omaha systems, the men are sent out to marry into other groups which effectively connnect the group to groups that have not been previously connected. In the Omaha system the men cannot marry a woman from his own patriline, his mother's patriline or his father's mother's patriline and in the Crow system is the matrilineal symmetry of the Omaha system. Both these systems force the group to connect other groups through negative marriage rules that prohibit man marrying woman that are already connected to their descent group. The fact that Crow-Omaha systems force the group to disperse and interact with other groups can make it easier for them to adopt new ways as they will be in connection with groups possibly with different customs and descent/residence rules.

No WiMo only society has the Crow system and only 1 has the Omaha system whereas

6 WiMo + WiFa societies have the Omaha system, 2 WiMo + WiFa + HuFa have the Crow and among those who have all four in-law avoidances 2 have the Crow and 2 have the Omaha system. So we can see the more these societies spread out their men/women and connect with other societies the more they tend to adopt different kinds of in-law avoidances. This also supports our hypothesis that spreading out, connecting with other kin groups and increasing the likelihood of interacting with other societies lead to the adoption of different in-law avoidances.

Table 4.10: Autocorrelation Regression Models for Wife's Mother Avoidance and Other In-law Avoidances

	Adjusted	
Covariates	Estimate	p-value
Network Lag Term	-13.32	0.005
Patriline	0.37	0.004
Crow	0.30	0.009
Omaha	0.06	0.671
Political Alliance Formation	0.19	0.06
Mean Temperature of Wettest Quarter	-0.13	0.184

Now we fit a network autocorrelation regression model to see if variables like patrilineage, crow-omaha terms have any significant effect after being controlled for the network effects of geographical distance and common origin (via language). Table 4.10 shows the model results.

The dependent variable is coded 1 for those societies who have WiMo avoidance and at least one more in-law avoidance on top and coded 0 for those who have only WiMo avoidance, and NA for those that do not have any in-law avoidances in order to restrict the sample to those with avoidances only.

Patrilineage is positively associated with having more than just WiMo avoidance (0.37, p-value= 0.004) even after we control for network effects. Crow and Omaha kin terms both have positive coefficients indicating they are also associated with having more than just WiMo avoidance; however, Omaha terms are not statistically significant only Crow is. Political alliance formation variable has a coefficient of 0.19 which is marginally significant (p-value 0.06). This tells us that having more than one type of in-law avoidance helps form more alliances compared to those with only WiMo avoidance.

Overall, we see a trend that starts with matrilineal societies having WiMo avoidance which serves as a respect relationship that help form alliances with other groups. With changing descent and residence systems, different types of in-law avoidances are incorporated and even more cooperation can be attained this way.

4.5 Phylogenetic Tree Analysis for In-Law Avoidances

In this section we utilize phylogenetic tree analysis methods to reconstruct ancestral in-law avoidance states so that we can get a better understanding of when in time Wife's Father avoidance emerged and diverged from Wife's Mother avoidance. Similarly, we use the same method to learn the evolutionary states of Crow-Omaha kin terms and their co-evolution with Wife's Mother avoidance.

4.5.1 Construction of the Trees

We construct phylogenetic trees using linguistic data on Western North American Indian societies. The linguistic distance across societies are calculated using the information on the classification of languages each society speaks in our sample. The linguistic distance matrix is then turned into a hierarchical cluster which is fed into the as.phylo function in the ape

R library [27].

For discrete variables, which is the case with in-law avoidance variables as they take two discrete states: 0 for absence and 1 for presence of a given avoidance, we use a maximum likelihood estimation method to reconstruct the ancestral states [26]. The ace function in package ape by default follows Pupko et. al. [34] in ancestral state reconstruction and uses a joint estimation procedure where all information on the character states for the nodes at the tips are used in the state reconstruction for each ancestral node.

The states at the tip nodes are determined by the data available on the extended WNAI dataset. We input the Wife's Mother, Wife's Father and Crow-Omaha kin terminology states of the current societies at the tip nodes of the trees and use the aforementioned methodology to get likelihood estimates for the ancestral states.

One important issue is the level of confidence we can place on the phylogenetic trees. One phylogenetic tree may not accurately represent the history of the evolution of human populations therefore assuming that the evolution of traits happened following one path only is unrealistic. To account for the uncertainty in the trees we use the bootstrapping method. We randomly sample the columns of the linguistic data matrix and build 200 different phylogenetic trees with the reshuffled linguistic data and see in how many of these trees the branches that are present in the original tree prevail. This gives us a probability for each branch in the tree indicating the level of confidence for each branch.

4.5.2 Results

Table 4.11 gives the estimates for transition rate parameters with their corresponding standard errors. In our model there are two discrete states: Presence of Avoidance Behavior or Absence of Avoidance Behavior. There can be instantaneous rates of change between these states and the parameter q_{AP} captures the rate of change from absence to presence of avoidance while the parameter q_{PA} captures the rate of change from presence to absence of avoidance. Table 4.11 has these parameters for the 4 language family classifications for both wife's mother and wife's father avoidances. The estimates q_{PA} and q_{AP} of wife's mother avoidance in Aztec-Tanoan language family have very high magnitudes and the model fit does not yield standard errors, all indications of a flat model fit and thus we should not trust these estimates however all other estimates have meaningful magnitudes and standard errors. Except for the Penutian language family, the rates of change to absence of avoidances are higher than the rates of change to presence of avoidances both for wife's mother and wife's father, indicating that the general tendency is towards the loss of this behavior in the language phylogenies other than Penutian.

Table 4.11: Transition Rates Between Avoidance States

		Aztec-Tanoan	Penutian	Hokan	No Phylum
Wife's Mother Avoidance	q_{AP}	536.289 (NA)	2.078 ± 1.283	4.995 ± 3.709	1.240 ± 1.123
	q_{PA}	2815.516 (NA)	1.240 ± 0.630	10.494 ± 7.977	2.524 ± 0.461
Wife's Father Avoidance	q_{AP}	0.908 ± 0.675	1.614 ± 0.844	3.895 ± 2.392	1.505 ± 0.624
	q_{PA}	6.350 ± 4.049	1.229 ± 0.623	10.034 ± 6.369	6.621 ± 3.643

q_{PA}: Rate of Transition from Present to Absent, q_{AP}: Rate of Transition from Absent to Present

Next, we look at the phylogenetic trees for the Penutian and Unclassified Language families and look for insights to the co-evolution of wife's mother with wife's father kin avoidance and Crow-Omaha kin terms. The trees for the same analysis for Aztec-Tanoan and Hokan language families can be found in the Appendix.

Figure 4.5 and 4.6 show the phylogenetic trees for the uncategorized language phyla in Western North American Indians. The tip nodes indicate the known Wife's Mother and Wife's Father avoidance states and we get likelihoods for the ancestral nodal states. The root node likelihood estimate for the presence of Wife's Mother avoidance in the Uncategorized Phyla Language families is 0.416 and it is 0.2514 for Wife's Father avoidance.

For Wife's Mother avoidance we see a very early split right out of the root node and the upper branch has a 0.55 likelihood for the presence of WiMo avoidance while the lower branches have only 0.27 and 0.26. This is a strong evidence towards the common origin of Wife' Mother avoidances for the following societies: Kato Atapaskan, Sinkyone, Huachuca Chiricahua Apache, Chiricahua, Mescalero Apache, Jicarilla Apache, South and North Tonto Western Apache, San Carlos Western Apache and Western and Eastern Navaho. However, there are still societies with Wife's Mother avoidances for which the distribution is not captured by linguistic distance. Those can be explained by geographic distance or independent invention.

For Wife's Father avoidance in the Uncategorized Phyla societies, we do not see an early branching like Wife' Mother but at the later branches we see that Haida, Northern Masset Haida Tlingit and North Tlingit are grouped together and they have Wife's Father Avoidance. This phylogenetic tree makes more sense when read along with Figure 4.8 which is the phylogenetic tree of kin terminology. There we see that the same societies (Haida, Northern Masset Haida Tlingit and North Tlingit) also branch out early on and develop the Crow kin terminolgy system. As mentioned earlier, the Crow system forces societies to marry outward and thus increase the frequency of interaction with outside. It is then no coincidence that those societies who develop the Crow system and expand outward are the same societies that develop the Wife's Father avoidance on top of Wife's Mother avoidance within their own unique evolutionary branch due to an increased level of outside interaction.

Figure 4.5: WiMo Avoidance Uncategorized Phylogeny

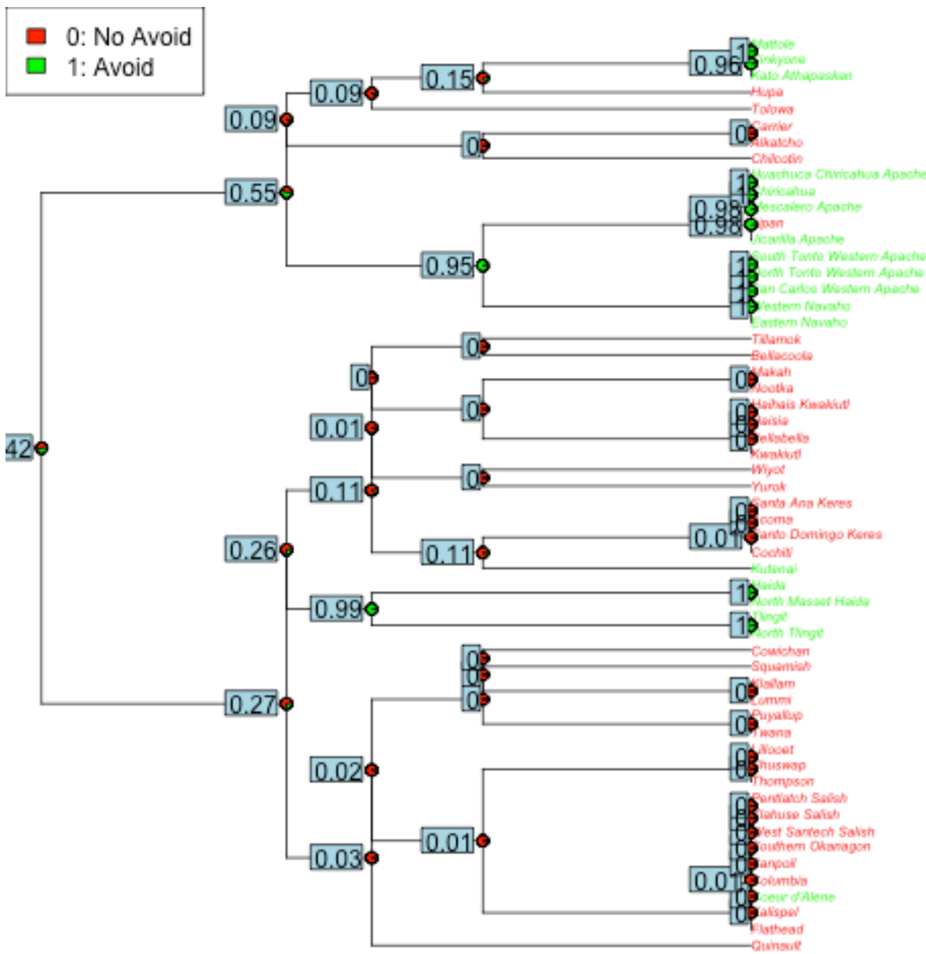


Figure 4.6: WiFa Avoidance Uncategorized Phylogeny

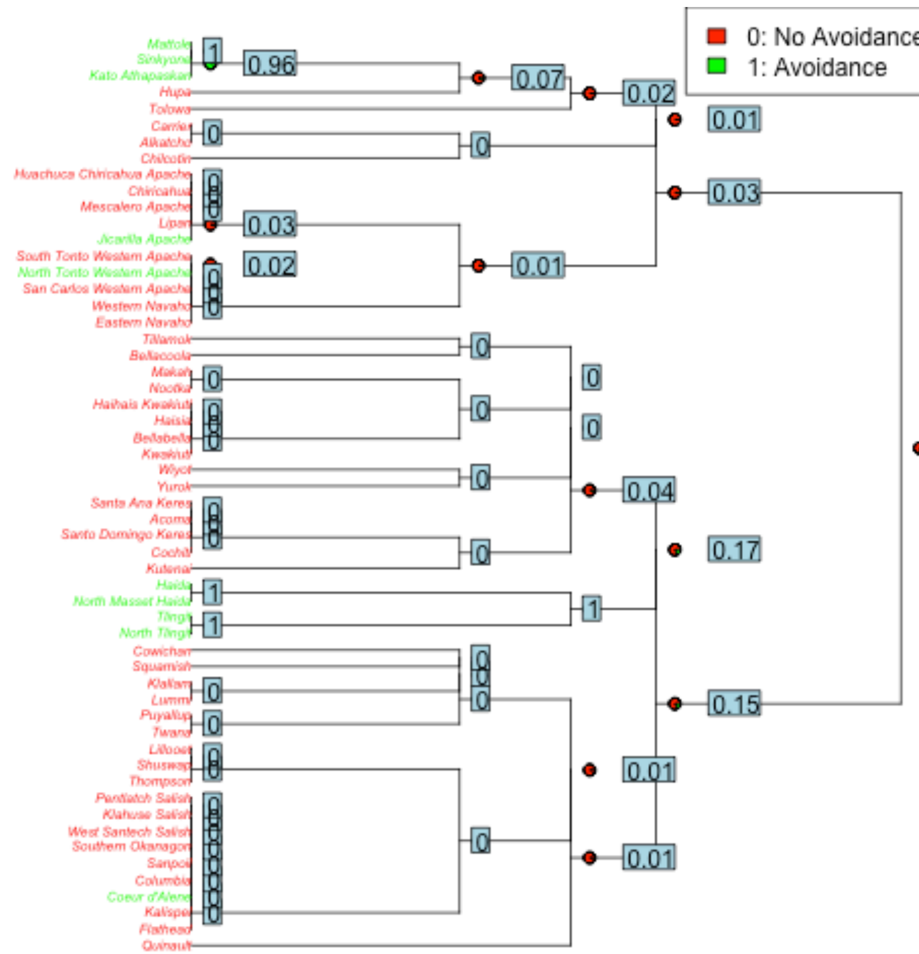


Figure 4.7: WiMo Avoidance Uncategorized Phylogeny

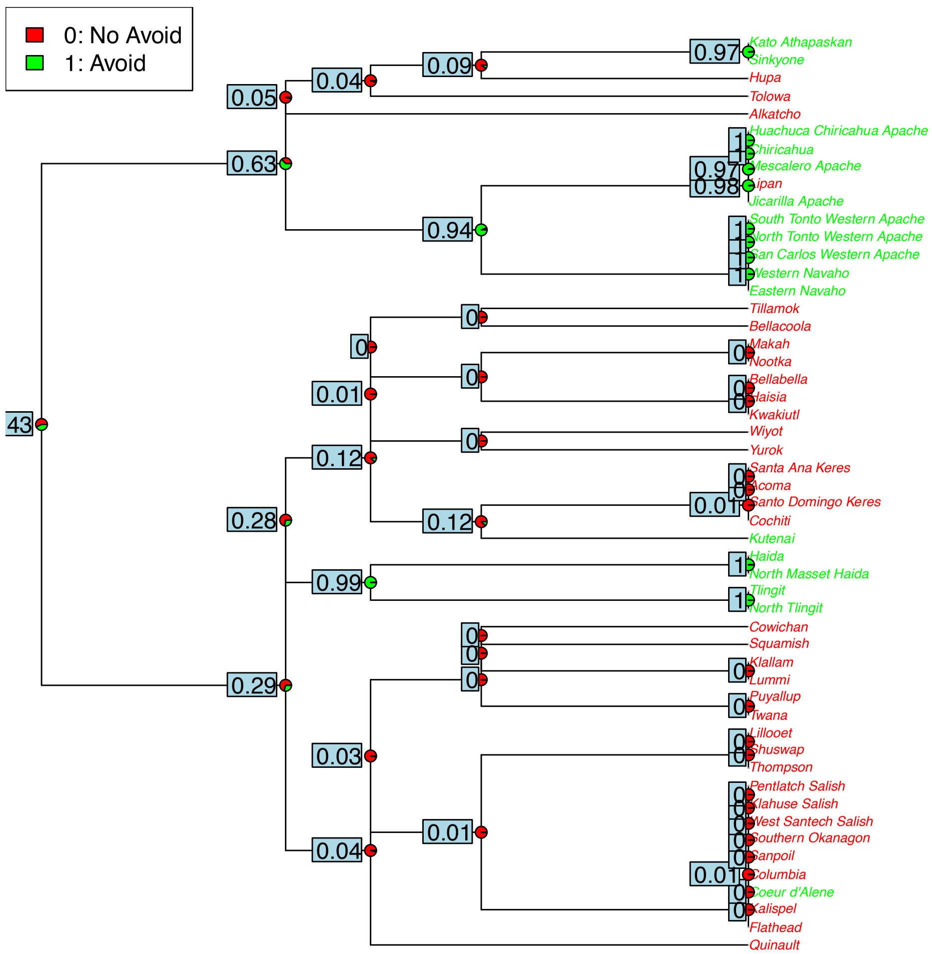
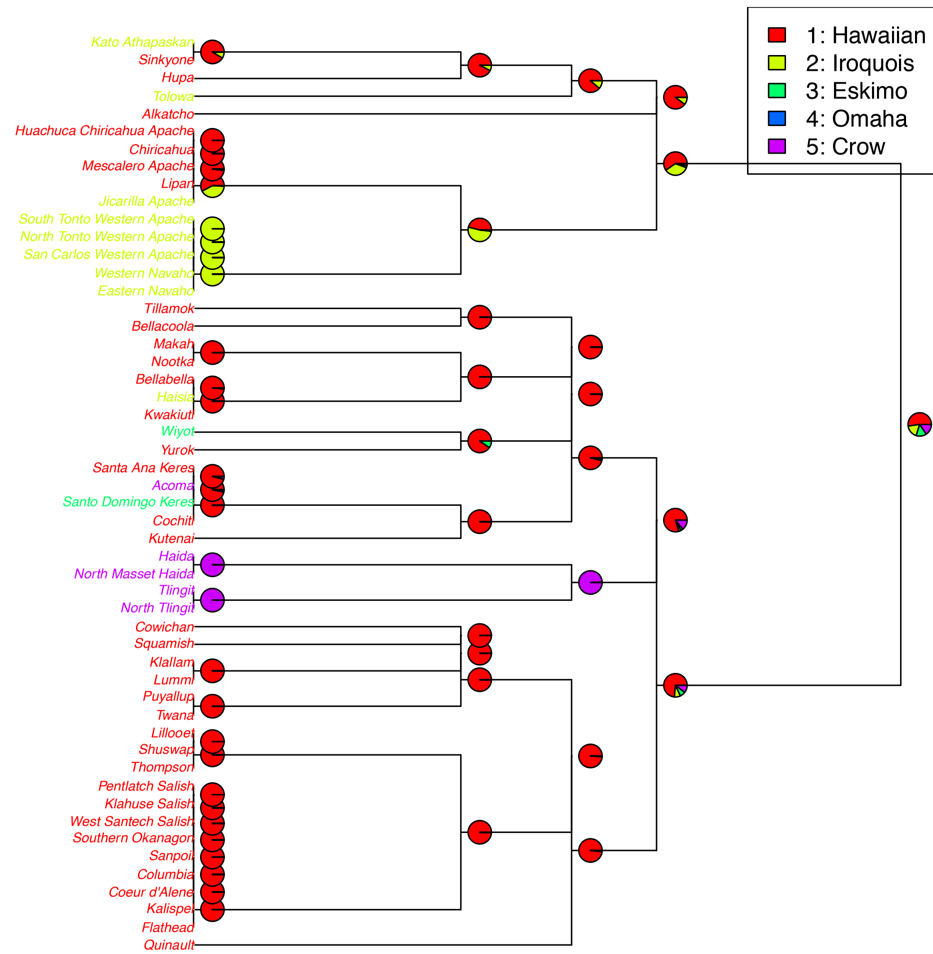


Figure 4.8: Kin Terms Uncategorized Phylogeny



The second phylogenetic tree we examine in this chapter belongs to the societies whose languages fall under the Penutian phylum. Unlike the uncategorized phyla societies and Hoka and Aztec-Tanoan societies, the root node of Penutian phylogenetic tree has a likelihood of 0.595 for the presence of Wife's Mother avoidance (Figure 4.9). We can conclude that it is more likely that the ancestral society of Penutian phylum societies had Wife's Mother avoidance.

As for Wife's Father - Wife's Mother coevolution on the Penution pylogenetic tree, we immediately realize that at the tips of the tree (i.e., the current avoidance distribution) there is almost a one-to-one match with WiMo and WiFa avoidances except for two societies (Gitksan and Tsimshian). The root node likelihood of the Penutian tree for the presence Wife's Father avoidance is 0.550 which also indicates a higher likelihood for the presence of this avoidance at the ancestral society.

Again the crucial point becomes apparent when we take into account the kin term phylogenetic tree (Figure 4.12). Here we see that at the top there is a branch whose pie chart is predominantly yellow which indicates the emergence of Iroquois kin terms while the remaining branches end up with Hawaaiian, Omaha or Crow kin term systems. Those societies who adopt the Iroquois kin terms do not have Wife's Father avoidance and similarly those at the end of the Hawaiian branch have neither Wife's Father nor Wife's Mother. The societies that have both Wife's Father and Wife's Mother avoidances are at the tip of the branches that develop Crow or Omaha systems. This again indicates how Wife's Father avoidance is added on with the adoption of Crow or Omaha kin terms.

Figure 4.9: WiMo Avoidance Penutian Phylogeny

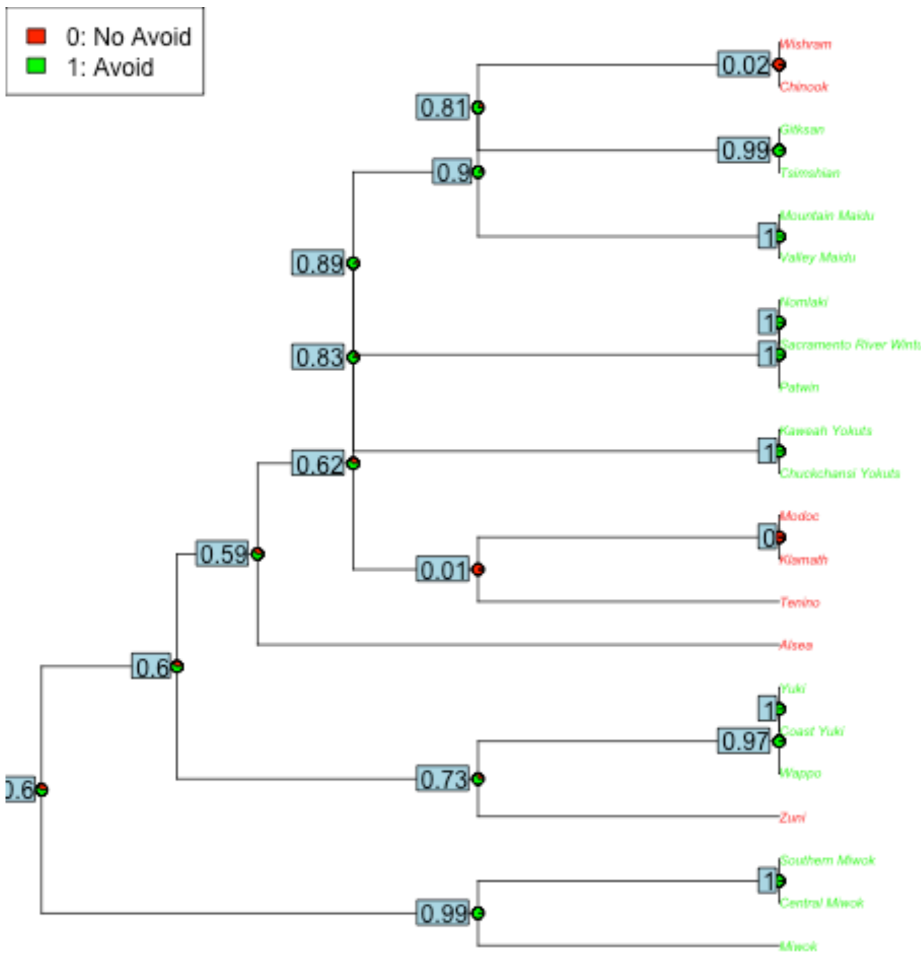


Figure 4.10: WiFa Avoidance Penutian Phylogeny

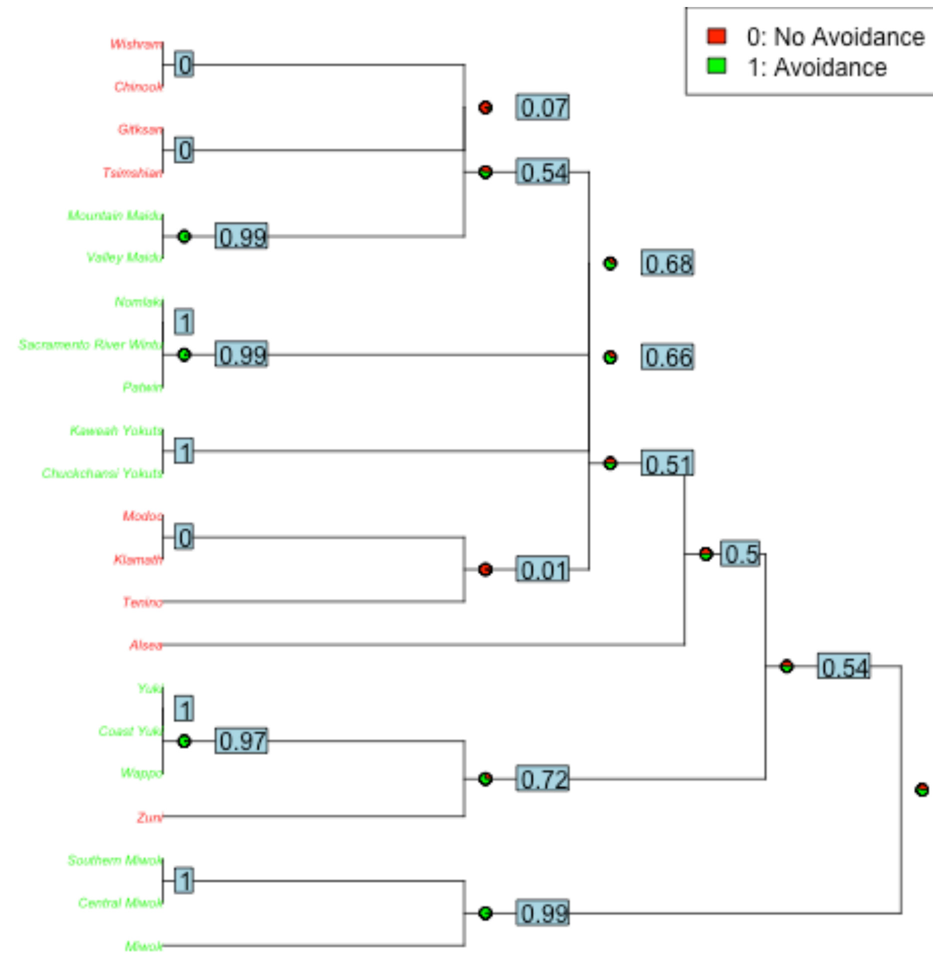


Figure 4.11: WiMo Avoidance Penutian Phylogeny

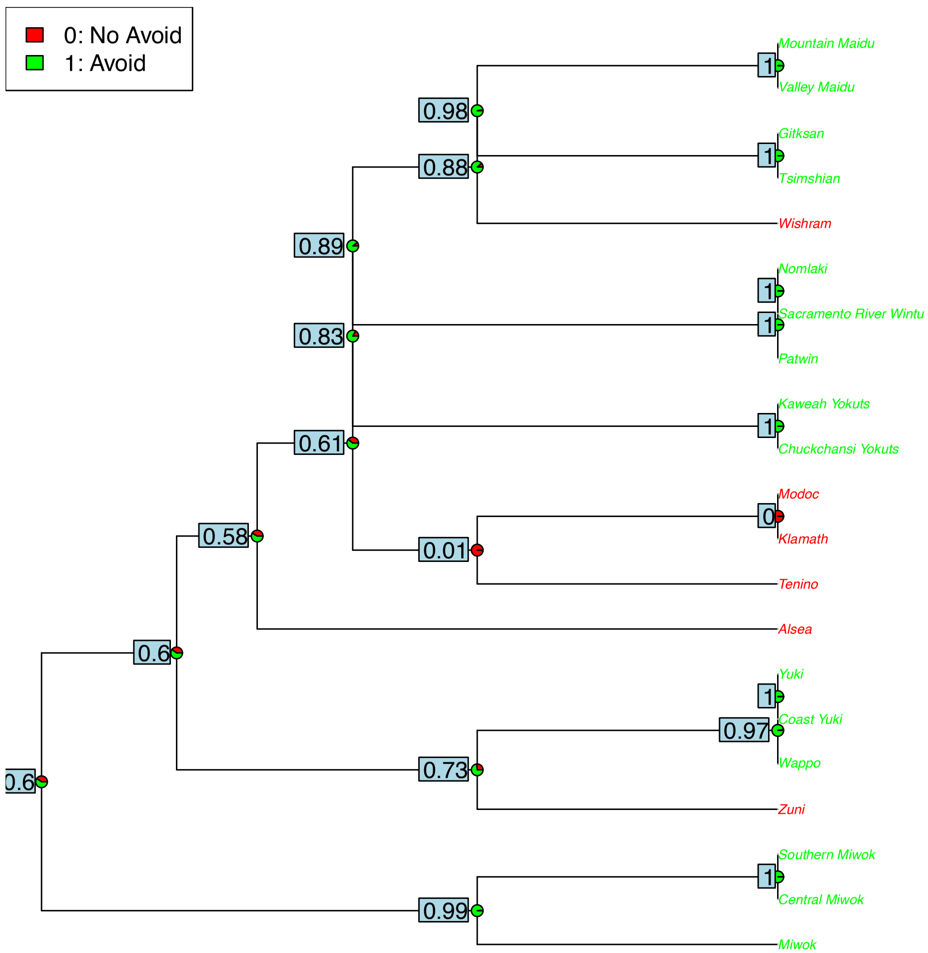
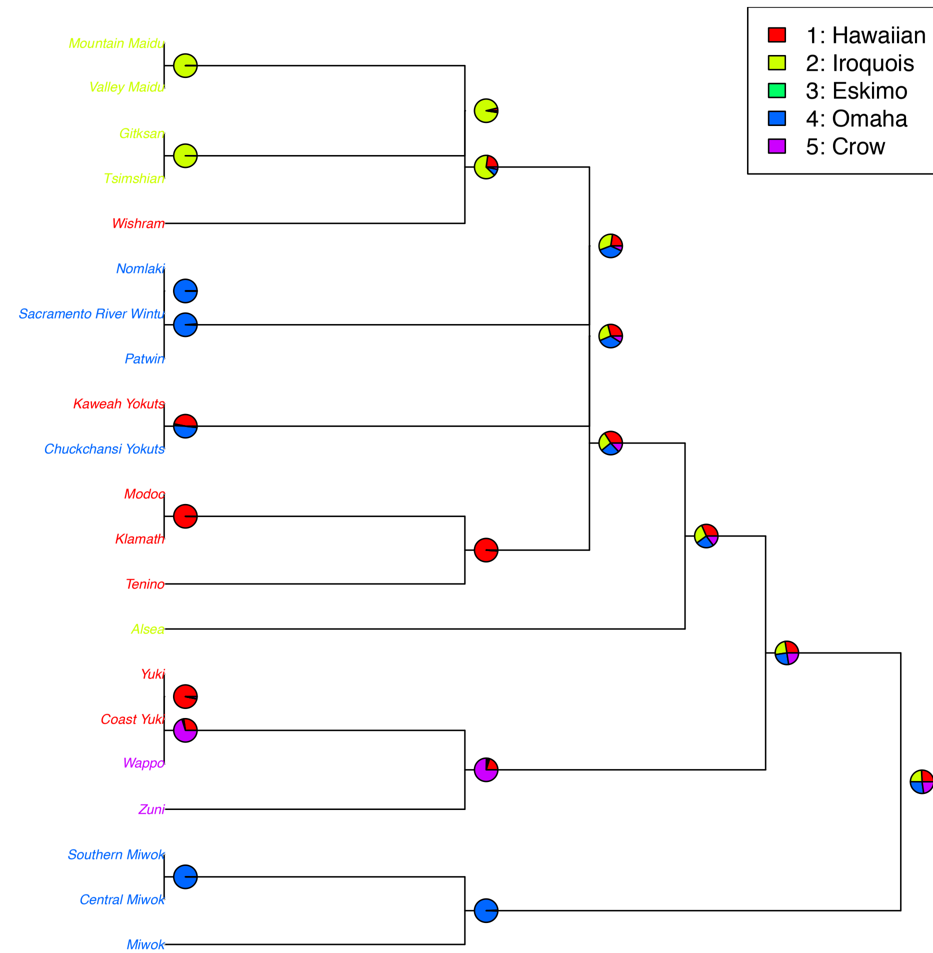


Figure 4.12: Kin Terms Penutian Phylogeny



One final comment on the phylogenetic trees about their robustness: As mentioned in the section describing the construction of the trees, it is unrealistic to assume that human evolution took this one path displayed in the trees. To account for other possibilities, we created 200 different trees via bootstrapping and calculated in how many of these versions, the branches we show in the original trees are retained and in how many of the version they are not there. We present this as a probability for each branch.

The bootstrapped probabilities for the branches in the phylogenetic tree of the Uncategorized Phyla societies look pretty stable in the first four branches out of the root node with probabilities 0.66, 0.77,0.83 and 0.88. However in the second level down, we do get some unreliable branches with probabilities only 0.12 and 0.22 and of course any further branching down those branches are therefore also unreliable.

The stability of the Penutian phylogenetic tree is more troublesome as the very first branch off of the root node has a probability of 0.45 and down the line we have branches with probabilities 0.16 and 0.22.

The reason why we have such small probabilities is because the data we use in the construction of the trees are the language family data. More accurate and robust trees can be constructed with the use of cognate data for each language in our dataset. However, no data at the cognate level are available for the Western North American Indian languages and therefore we had to resort to the language family data which is more sparse. These trees give a pretty good idea as to how evolutionary changes happened for traits such as kin terminology and kin avoidance behavior yet more insightful results can be obtained in the future if cognate level data become available.

Figure 4.13: Bootstrapped Probabilities for Uncategorized Phyla

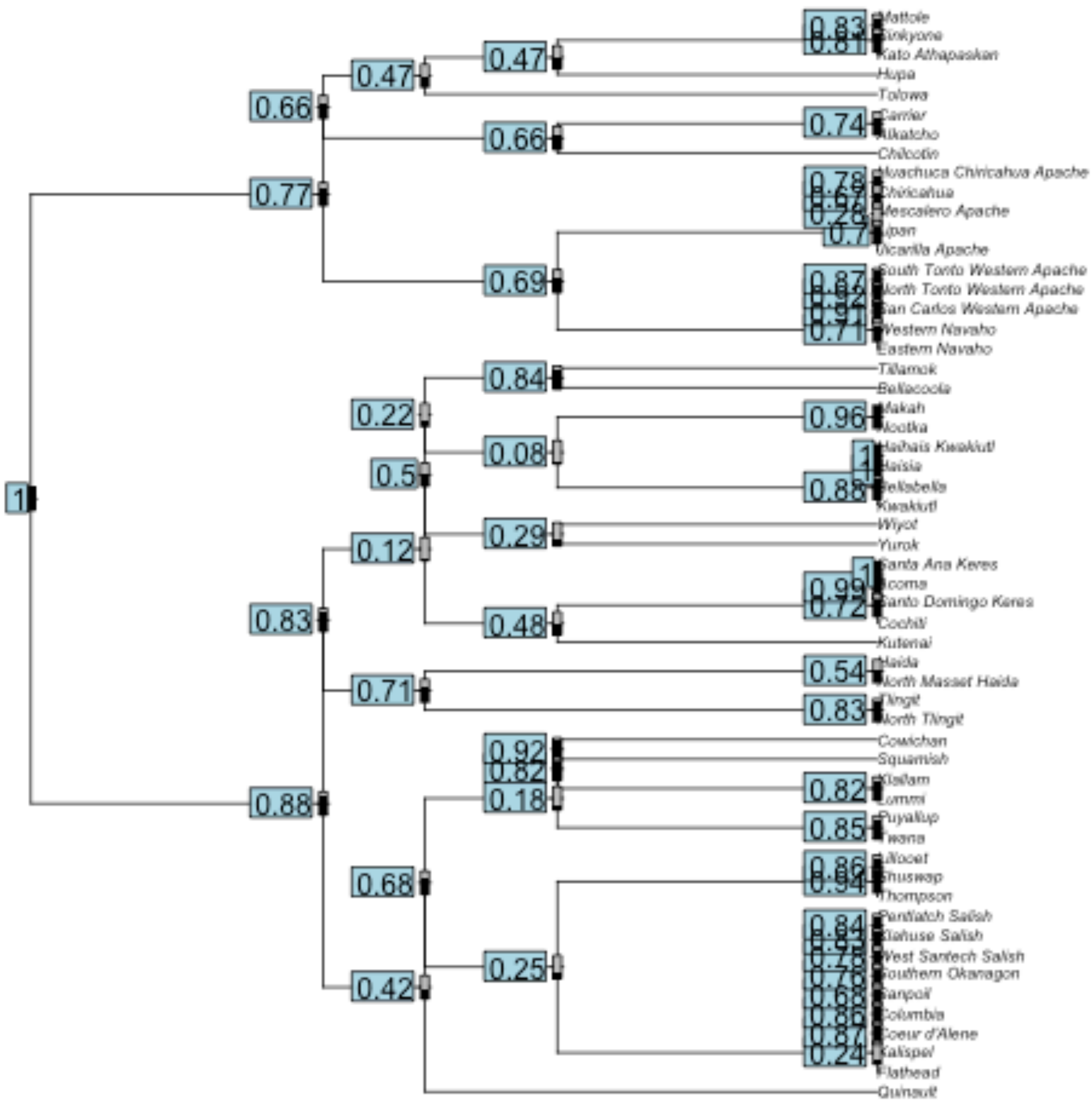
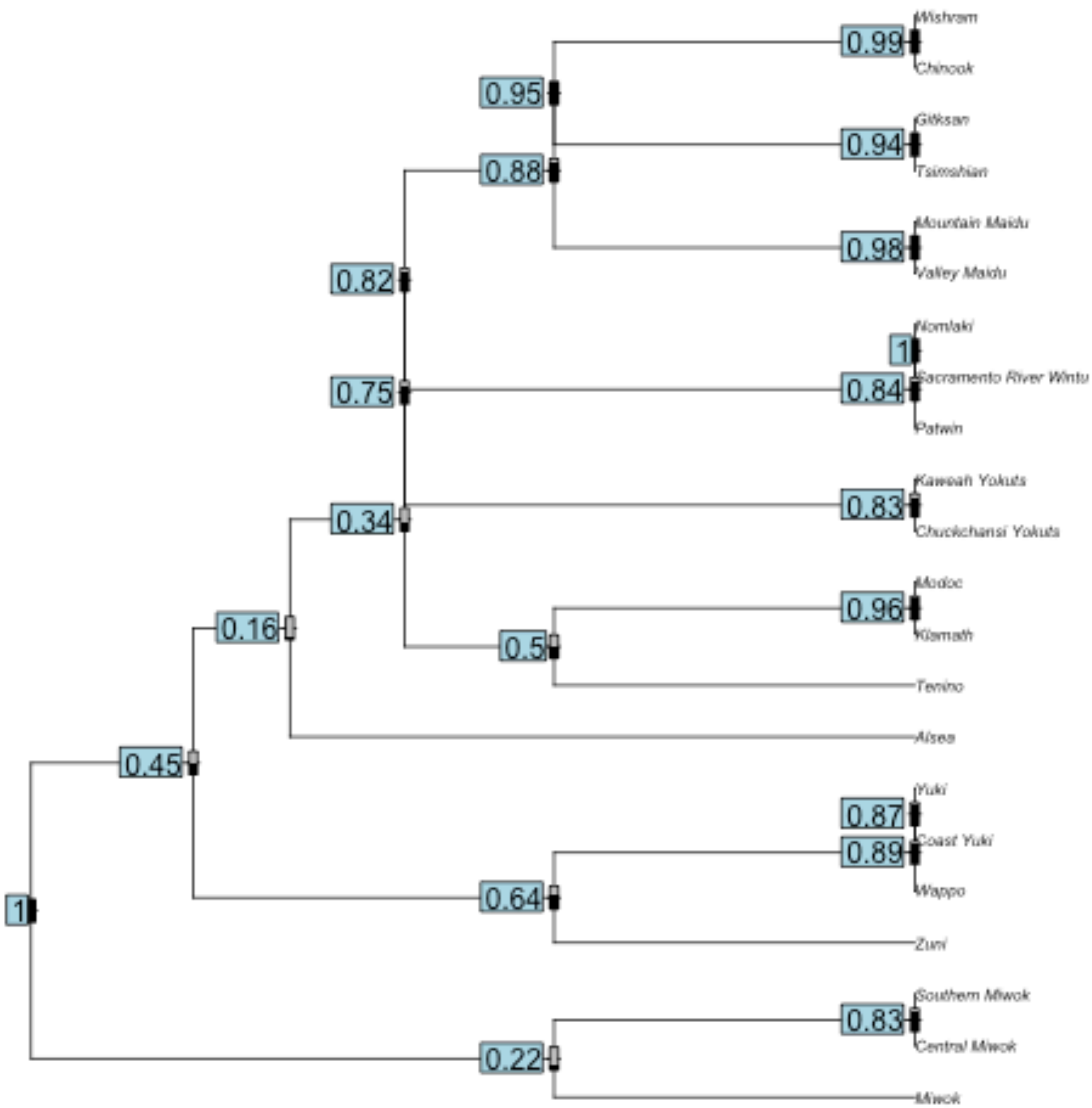


Figure 4.14: Bootstrapped Probabilities for Penutian Phylogeny



4.6 Conclusion

The network autocorrelation model results of the WNAI societies replicate the results from the SCCS societies in so far as in-law avoidances operate at low population densities. The results also support the hypothesis that in-law avoidances help extend and secure kinship ties to affines and thus facilitate the formation of alliances with outside groups. Unlike the old world societies, in the new world sample we do see an effect of descent and residence rules on avoidances. Especially, when we study the pyramid-like structure of existing avoidance relations, we see that the addition of other types of avoidances on top of the preliminary Wife's Mother avoidance is deeply connected to patrilineal or bilateral descent. We also conclude that the emergence of Crow-Omaha kin system is connected to this change which results in additional in-law avoidances and this observation is supported by both the network autocorrelation models and phylogenetic tree analysis.

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Appendix A

Appendix Title

Table A.1: Auto-Correlation Regression Models for Wife's Father Avoidance in WNAI

	Unadjusted		Unadjusted2		Adjusted	
Covariates	Estimate	p-value	Estimate	p-value	Estimate	p-value
Network Lag Term	1.15	0.00	1.05	0.00	0.81	0.00
Population Density Level 2	-0.17	0.3			-0.20	0.23
Population Density Level 3	-0.12	0.4			-0.17	0.24
Population Density Level 4 and 5	-0.09	0.5			-0.13	0.38
Political organization and the formation of alliances			0.05	0.11	0.04	0.23
Population Size					-0.01	0.66
Omaha					0.25	0.14
Crow					0.17	0.36
Iroquois					0.09	0.31
Matriline					0.05	0.65
Kindred					-0.03	0.71
Mean Temperature of Wettest Quarter					-0.05	0.07

Husband's Father Avoidance Model:

Table A.2: Auto-Correlation Regression Models for Husband's Father Avoidance in WNAI

	Unadjusted		Unadjusted2		Adjusted	
Covariates	Estimate	p-value	Estimate	p-value	Estimate	p-value
Network Lag Term	1.0	0.00	0.85	0.00	0.81	0.00
Population Density Level 2	-0.4	0.00			-0.39	0.003
Population Density Level 3	-0.3	0.04			-0.34	0.008
Population Density Level 4 and 5	-0.2	0.05			-0.34	0.01
Political organization and the formation of alliances			0.04	0.1	0.05	0.1
Population Size					0.04	0.2
Omaha					-0.02	0.9
Crow					0.11	0.5
Iroquois					0.02	0.8
Matriline					0.02	0.8
Kindred					0.01	0.9
Mean Temperature of Wettest Quarter					-0.04	0.10

Husband's Mother Model:

Table A.3: Auto-Correlation Regression Models for Husband's Mother Avoidance in WNAI

	Unadjusted		Unadjusted2		Adjusted	
Covariates	Estimate	p-value	Estimate	p-value	Estimate	p-value
Network Lag Term	0.89	0.00	0.84	0.00	0.85	0.00
Population Density Level 2	-0.07	0.2			-0.08	0.27
Population Density Level 3	-0.03	0.7			-0.08	0.28
Population Density Level 4 and 5	-0.03	0.6			-0.10	0.30
Political organization and the formation of alliances			0.03	0.06	0.04	0.03
Population Size					0.03	0.28
Omaha					-0.09	0.58
Crow					0.18	0.22
Iroquois					-0.001	0.99
Matriline					-0.01	0.85
Kindred					-0.02	0.67
Mean Temperature of Wettest Quarter					-0.03	0.22

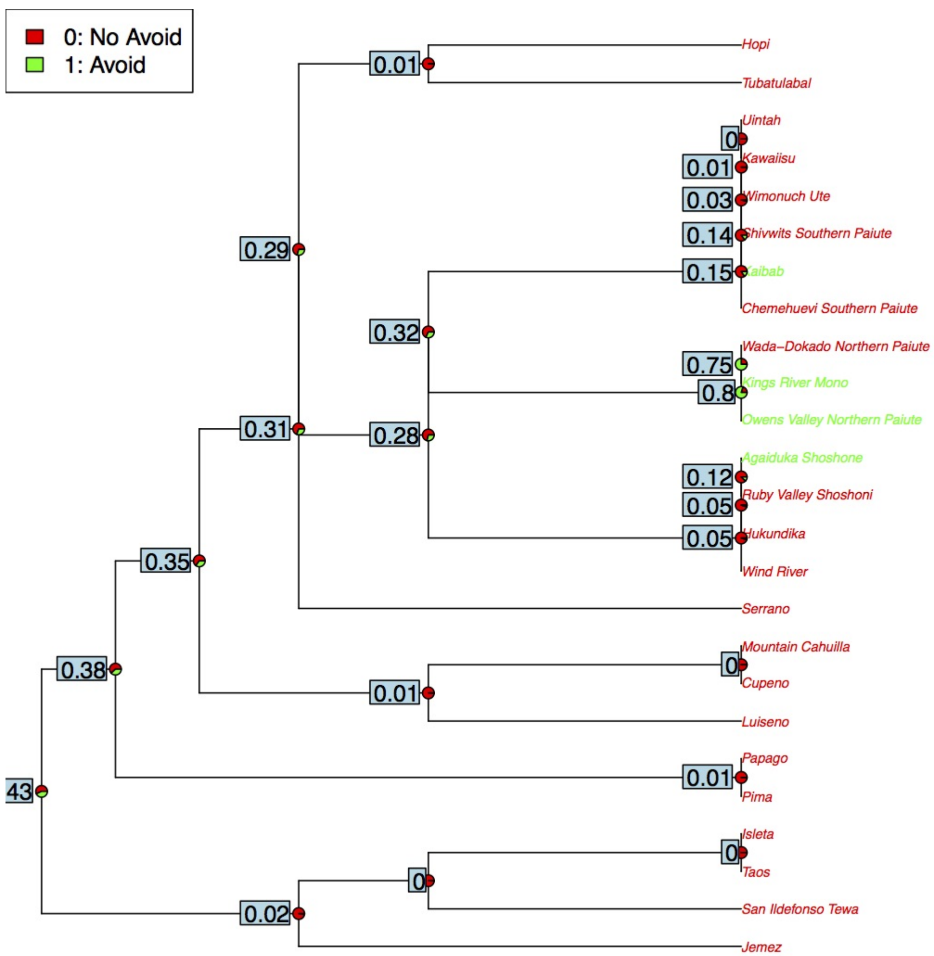

Figure A.1: WiMo Avoidance Aztec-Tanoan Phylogeny

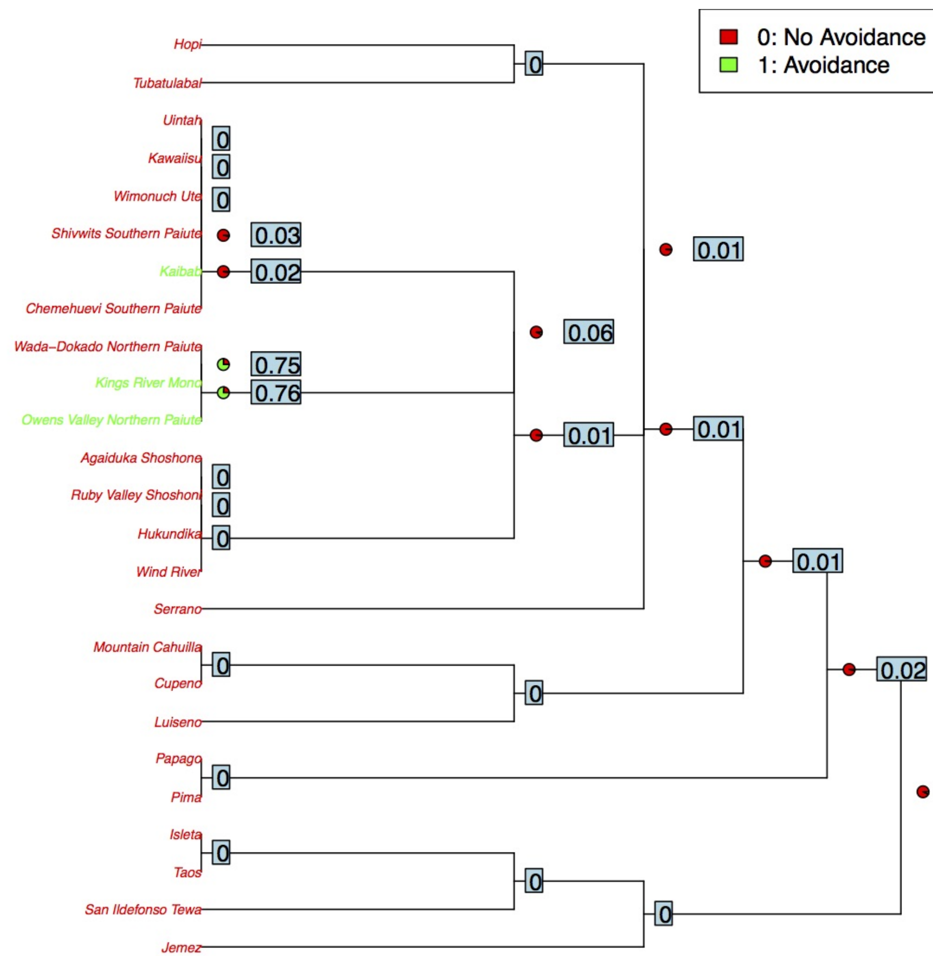

Figure A.2: WiFa Avoidance Aztec-Tanoan Phylogeny

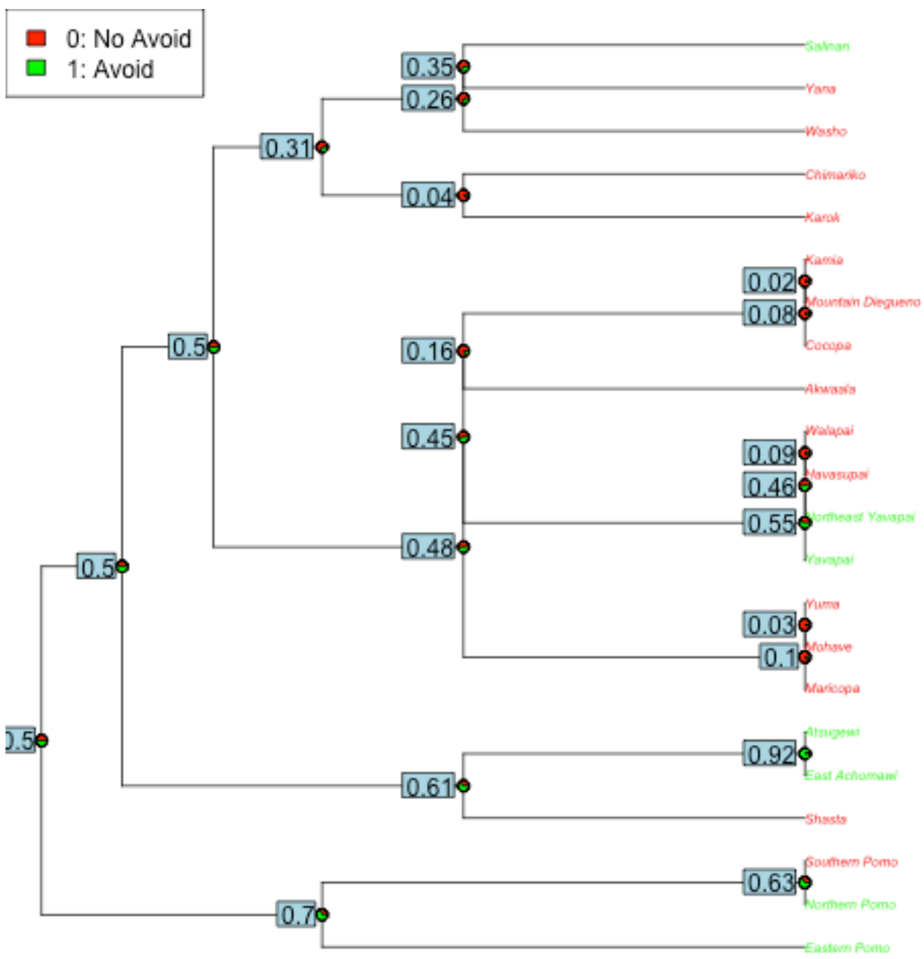

Figure A.3: WiMo Avoidance Hokan Phylogeny

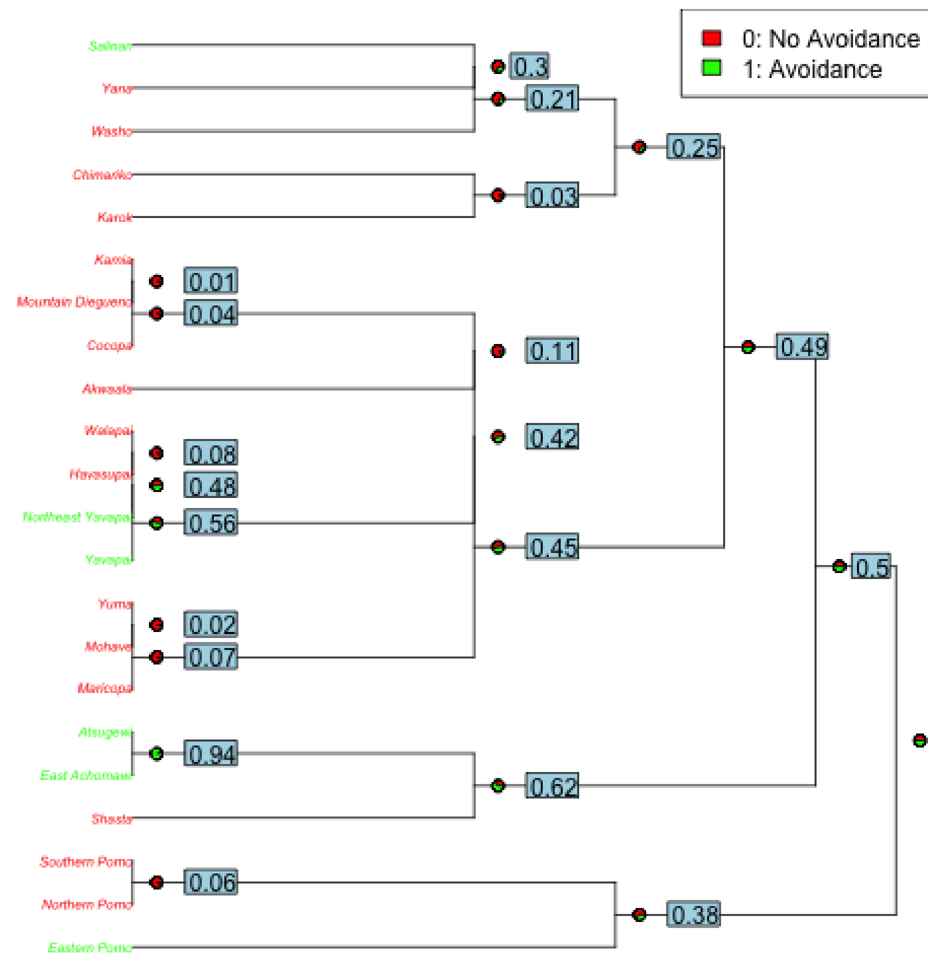

Figure A.4: WiFa Avoidance Hokan Phylogeny

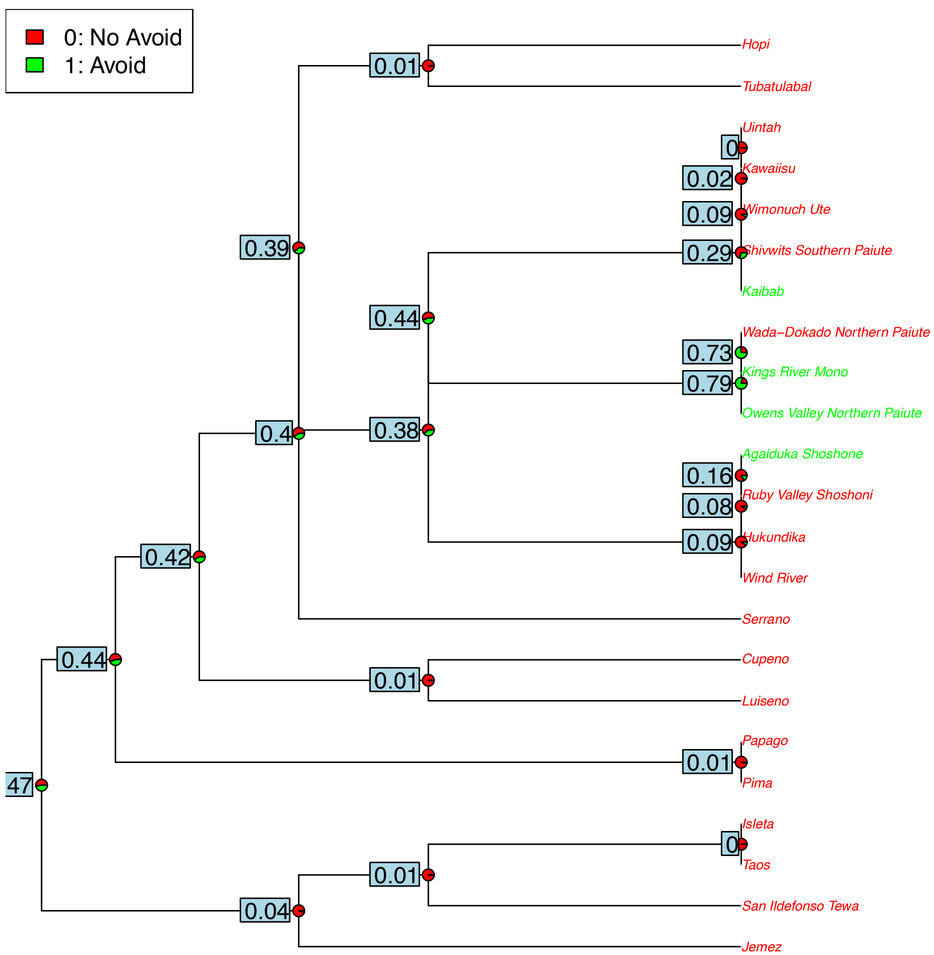

Figure A.5: WiMo Avoidance Aztec-Tanoan Phylogeny

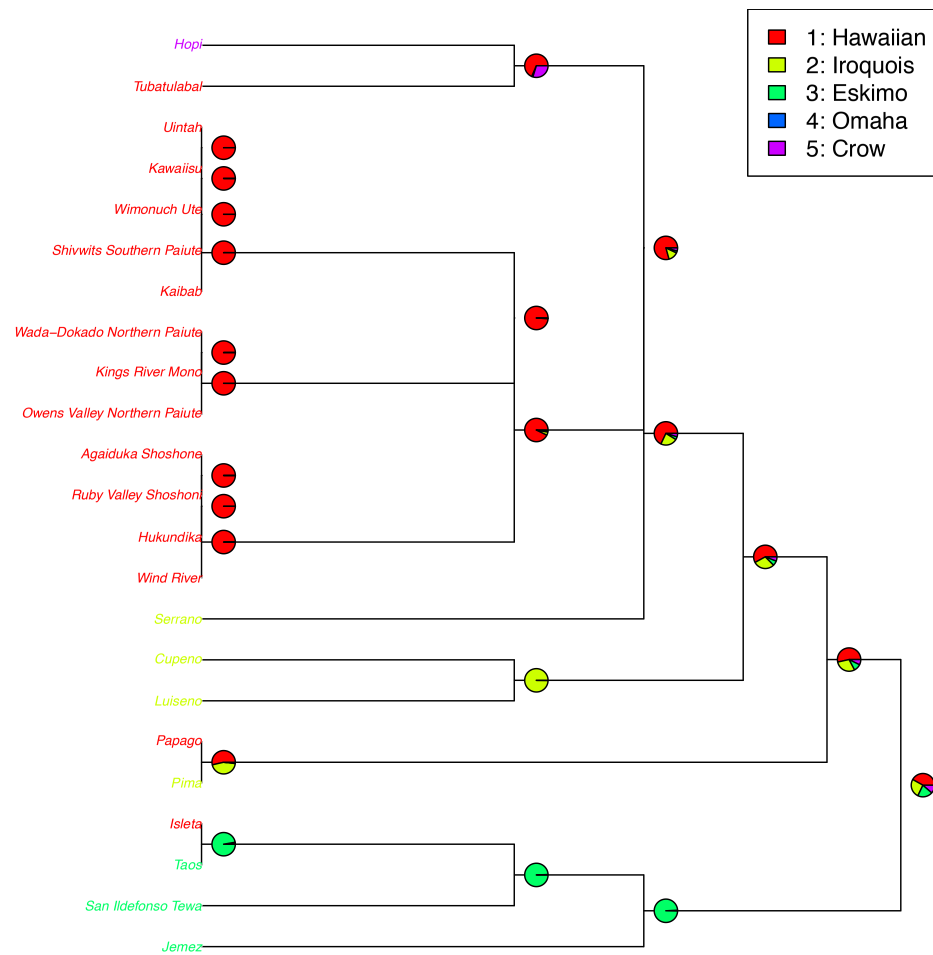

Figure A.6: Kin Terms Aztec-Tanoan Phylogeny

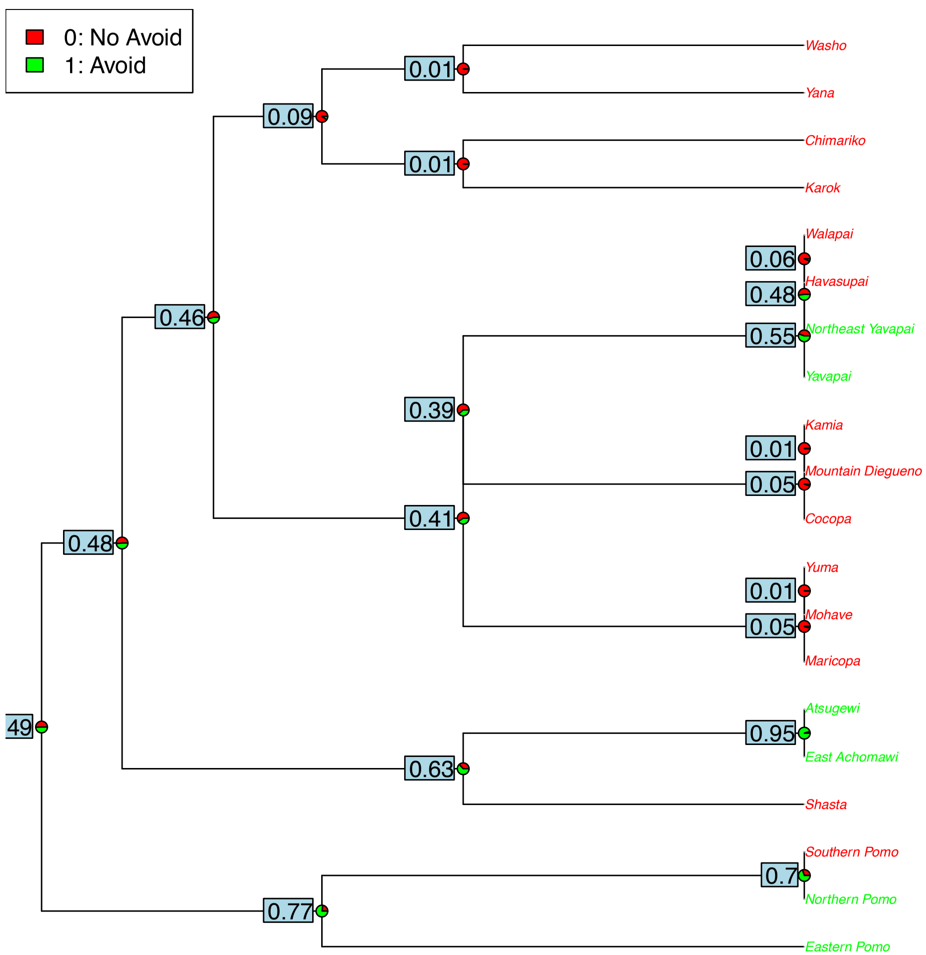

Figure A.7: WiMo Avoidance Hokan Phylogeny

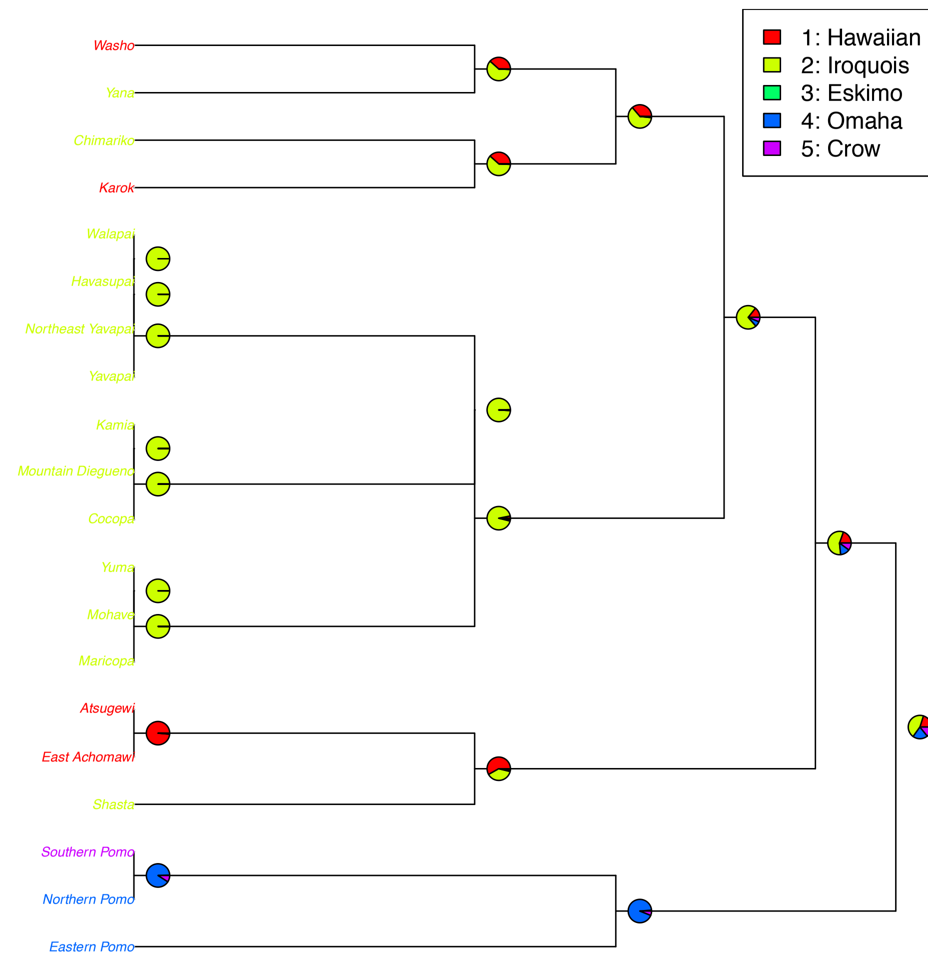

Figure A.8: Kin Terms Hokan Phylogeny