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Variable Education Exposure and Cognitive Task Performance Among the Tsimane, Forager-Horticulturalists.

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by

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DISSERTATION

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Dedication

To my parents, Mary and Dave, for their support, and encouragement.

To Jack Campbell, for teaching me to see the forest for the trees.

"And you may ask yourself Well...How did I get here?" – David Byrne

Acknowledgments

Much like the path models in this dissertation, my own scholastic and individual success would not be possible without the myriad upstream variables that contributed to this project's completion. My family, mentors, friends, and colleagues all contributed support and investment (the study of which could practically be its own dissertation), and I am grateful for the opportunity to thank them, though I am afraid it will not begin to express my unwavering gratitude and appreciation.

I am grateful to the Tsimané people. Thank you for allowing me to work with you, and learn from you. Thank you for inviting me into your home, sharing stories and meals, and patiently teaching me your language. I hope my work can contribute to your quality of life as much as the experience of working in your communities has contributed to the quality of mine.

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Abstract

At present, we know very little about the transition from traditional learning skills to models of standardized learning, and how it can influence the way one understands and solves problems. This research will examine cognitive performance and the factors affecting variation across communities and between individuals as it changes with age.

The objective of this dissertation is to measure cognitive performance among children between 8 and 18 years of age exposed to variable levels of formal schooling in order to investigate three main research questions: (1) Whether exposure to schooling and increased performance in school-based abilities, such as math and reading, are positively correlated with performance on tests that measure cognitive ability.

(2) How training to the test affects performance within schooled and unschooled populations. And, (3) how upstream factors, including parental embodied capital and family size, can impact child outcomes in school and on cognitive tests.

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Chapter 1

Introduction

Many unresolved issues exist surrounding the adaptive nature of human cognitive abilities. Humans, in particular, are noted for an extensive degree of cognitive and behavioral plasticity, which may in fact be the very definition of intelligence or innovation. As a result of trying to understand what constitutes and forms intelligence, we are led to ask ourselves several questions. What is the nature of human cognitive adaptation? And to what extent does it transform in response to ever-changing modern environments?

In most market-based economies, unlike in our evolutionary past, much of our human capital now developed in the classroom (Schultz, 1961; Barro & Becker, 1989; Cromer, 1993; Hart & Risley, 1995; Kaplan et al., 2003). With the rapid introduction of the western model of education throughout the developing world, we have seen this trend spread (Steer & Baudienville, 2009), and alter the landscape of traditional and localized learning (May & Aikman, 2003; Champagne, 2009). This phenomenon presents an unique opportunity to explore issues related to how human educational capital is accrued, valued, and applied, within a given population. It may also provide an understanding of the extent that cognitive development is shaped by formal schooling as opposed to inherited traits. Prior research into variable educational exposure with the developed and developing world has revealed that significant performance gaps emerge and developmental lags occur regularly (Ceci, 1991; Blair et al., 2005). Extrinsic variation, in particular access to resources (Flynn, 2009) and socioeconomic status (Mani et al., 2013), have been identified as possible causes for some of the observed discrepancies. An investigation of introductory formal education in developing societies may give greater insight into variable scholastic performance.

The primary goal of this dissertation is to explore the conditions that affect variation in cognitive performance among children recently exposed to formal education programs. Drawing from research in the cognitive sciences and applying a life history framework, the specific goal of this research is to explore the extrinsic and intrinsic factors affecting variation in cognitive task performance among school-aged children at the lower end of the educational continuum. More specifically, the research detailed within will discuss (1) the effect that increased exposure to formal schooling has on measures of cognitive performance, (2) the relationship between training and schooling, (3) how parental and individual characteristics and behaviors can effect variation in performance on cognitive task assessments, and (4) possible trade-offs parents and children face as determinants of an individual's level of investment in a novel environmental factor (*i.e.*, formal education).

1.1 Life history theory and the evolution of an extended period of juvenile dependency

Adaptation is a curious thing. In a way, organisms are always trying to fit in. Altered or novel environment creates difficult decisions when you're struggling to survive. Constant adjustments are required throughout one's lifetime, as well as over many generations, in order to maintain productivity and thrive under varying and changing constraints. These adjustments are more concretely understood through the framework of Life History Theory (LHT). Resources in any environment are finite, and a given individual must decide how best to use those resources. When time and energy are invested into one activity, the opportunity cost equals lost time that could have been invested into another activity. The variations in the allocation of time, energy, and effort across and between species provide information about how that species grows, reproduces and maintains itself. This framework is widely used in many fields to study the evolutionary development of life history traits. Understanding how various species balance these trade-offs provides insight into their evolutionary development and can also be used to predict how organisms will respond to environmental changes.

Applying this framework to humans has changed the landscape of behavioral research (Kaplan et al., 2003; Walker et al., 2006; Gurven et al., 2007). One area in particular that is of great interest is the development of an extended period of delayed maturation-what costs it will incur, and the benefits we as a species gain from that additional time. Like most organisms, humans experience a developmental or growth period before they reach reproductive age; therefore, there exists a trade-off between continuing to allocate energy towards increasing body size or diverting energy towards reproduction. Virtually all sexual, multicellular organisms must grow before they reproduce. This life history trade-off concerns energy that must be allocated towards growing larger or redirecting this energy towards reproduction, thereby generating an 'age-schedule' of fertility (Kaplan & Gangestad, 2005).

Research on this topic has suggested that this period of delayed reproduction opens a door for humans to develop skills, and invest more time into growing and training a larger brain. Explaining why humans have developed such large brains has been a central task of evolutionists and bears directly on the potential adaptive significance of the extended human growth period. Kaplan et al. (2000) discuss four distinct human characteristics, as compared to other mammals and primates, and considers the implications of these characteristics for human encephalization: 1) extended period of juvenile dependence; 2) long lifespan; 3) support for post-reproductive members of the social and kin-network and; 4) provisioning of children by males (male parental investment). When looking at just the extended period of juvenile development, Gurven et al. (2007) create an integrated model which provides explanations for this extended juvenile period including, but not limited to: 1) more time required to develop social skills and competency; 2) the risk-aversion hypothesis, (Gurven et al., 2007) which promotes the idea that slow growth occurs in species who suffer from large fluctuations of food and resources; 3) trade-offs between continuing to grow and delaying reproduction, or ceasing growth and beginning reproduction; 4) models concerning development of skill through extended periods of learning, or the Embodied Capital Model (ECM). Kaplan et al. (2003) posits that the human economic niche and childbearing/rearing practices require substantial skill and knowledge, thereby emphasizing the importance of an extended juvenile period required to learn these skills– though it is important to note this energy input should vary according to environment and, like other forms of investment, will eventually result in diminishing returns (see Fig. 1.1). Using the ECM as a template, one begins to investigate the implications of an extended juvenile developmental period, and its impact on how and why humans invest so much energy into learning.

1.2 Sequential development and implications for learning

Childhood could potentially be very costly because of continued dependency on others due to high energetic demands for growth and maintenance of neural tissue, which

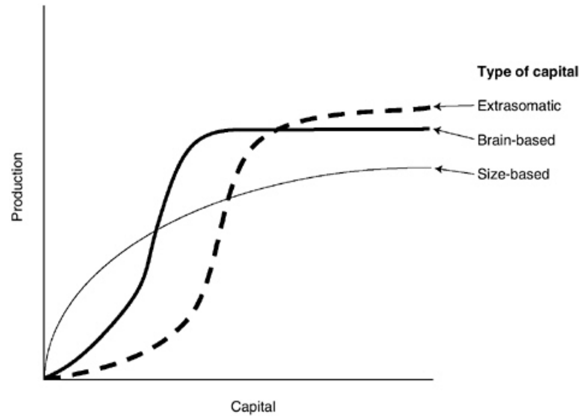

Figure 1.1: Taken from (Kaplan et al., 2003): Production as a function of the capital stock NOTE: The relationship between production and each form of capital varies with ecology and the resources produced. Capital may be size-based, brain-based, or extrasomatic. More or less initial investment may be required before returns increase, and with further increases in investment, returns may diminish rapidly or slowly.

is metabolically expensive; however, middle childhood lays out a long, less demanding period on growth. This phase is recognized as unique to the human lifecourse. Middle childhood is situated between early childhood and adolescence, between the ages of 6-12, and is responsible for providing time to increase cognitive capacity– through constant social interactions, observation, and play (Campbell, 2011). Middle childhood is also seen as the stage in life where children learn emotional regulation and social independence by establishing relationships with peers (Moller, 1992), social norms and expectations through problem solving and language development (Piaget & Eames, 1980; Chawla, 1998), and it is the period that marks the beginnings of a sexual division of labor (Crognier et al., 2002). During this phase juveniles begin to establish themselves into labor and responsibility niches and see increased expectations from adults (Campbell, 2011), which continue to define them into adolescence (Chawla, 1998).

With such a long period of slow growth and increased exposure to social and functional tasks, the study of middle childhood can shed insight into the complexity of human cognition. Viewed as an emergent property resulting from building skills upon earlier skills as suggested by Bock (2004) and foundational theorists in the field of cognitive development (Piaget & Eames, 1980). The stepwise changes over evolutionary time suggest that the initial conditions of cognitive development (genes, *in utero* environment, early infancy and so on) are just as meaningful as the later stages of development including early/middle childhood and adolescence. In order to more clearly understand the progression of cognitive development, one can imagine life is made up of a number of phases. Each one is specifically adapted to learning and development and were defined and attributed only to humans by Piaget & Eames (1980) and later by Premack & Woodruff (1978). Both the Theory of Mind (ToM) and constructivism suggest that humans and apes develop in crystallized stages that, although not rigidly defined by the age of the child, will consistently develop in the same order (Piaget & Eames, 1980; Geary, 2005; Geary & Huffman, 2002).

Despite a substantial body of literature implicating a sequential timing of juvenile cognitive developmental stages, a great deal of debate exists over the universality of such cognitive stages (Povinelli & Giambrone, 2001). Furthermore, many of the models that utilize the Piagetian framework do not consider the impact that experience and environment have on individual learning. This proves particularly problematic when attempting to assess cross-cultural variability.

In contrast to Piaget's work on the Theory of Mind (ToM), Bering & Povinelli (2003) posited that humans developed a sort of 'parasitic' branch-off from traits common in our ancestral thread. ToM is still unique to our species but developed as a way to interpret and communicate various behavior patterns (Povinelli & Giambrone, 2001) such as reconciliation, detecting cheaters, deceptive behavior, and following another's gaze as well as pattern recognition (Dehaene, 2009; Grainger et al., 2012), which can be ultimately understood as the foundation of literacy. These are behaviors humans share with other non-human primates, but the development of the ToM and abstract thinking marks the point at which the ontogeny of human cognition separates humans from other related species. Therefore, the extended period of middle childhood becomes something uniquely human. And it is this unique period that may provide more time to experience, to learn, and to develop skills.

It is clear that humans invest extra-somatically, but the open question is how much this pattern is the result of a specific selection pressure that produced an extended childhood period or, again, whether this extension is simply the result of selective pressures on other human life history features such as longevity and decreasing pre-adolescent energetic requirements. If this period did, in fact, develop to enhance already existing features then social learning and play during middle childhood would have developed to help establish a strong grasp of abstract concepts and non-verbal communication.

Elaborating on these ideas, Bock (2002b) developed what he considered a new model for human growth and learning. His work focused on age-specific task performance and life history characteristics due to constraints on growth and learning. He suggested that a trade-off exists between the Embodied Capital Model and early productivity in children, and that children, with parental input, will variably invest in production or higher learning activities depending on, for example, the number of laborers such as "helpers at the nest" needed by the family. He notes that some skills or abilities must develop early in order to aid production while other more difficult tasks (like hunting) require substantial learning effort and investment over many years. This tradeoff between learning and work (production) may have developed in order to facilitate the time and energy needed to enhance the already existing features associated with Theory of Mind, which were present in our evolutionary past.

1.3 Assessing individual variation in cognitive development

Despite there being a great deal of debate about how big brains and the extended periods of juvenile dependency evolved, the field maintains consistent interest in measuring variation in cognitive performance, and this is where the story becomes even more intriguing.

The concept of intelligence encompasses many skills and related abilities. In particular, problem solving and abstract reasoning skills are often evaluated through the use of psychometrics, which are standardized tests and assessments meant to measure variation in knowledge, educational performance, personality traits, and so on. Francis Galton is considered to be the father of the study of individual differences, and his research functions as the foundation of intelligence. Since the first round of intelligence testing was commissioned by the French government in 1904 there has been much effort devoted to the study of skill development and cognitive performance through the application of psychometric tests (Jensen, 1989). Numerous tests assessing cognitive task performance have been developed within the last century. A handful of these tests require limited verbal exchange focusing on pictures and pointing their responses, which is advantageous because language incongruity is a known confounder for many types of intelligence tests.

Attempts have been made to evaluate populations cross-culturally, but that has produced more questions than answers, polarizing the fields of cognitive science. Many researchers do report population level differences (Gottfredson, 2005; Rushton & Jensen, 2005), and large gaps in cross-cultural comparisons (Flynn, 2000; Gottfredson, 2003; Flynn, 2009) have been recorded. Some approaches suggest that psychometrics evaluate only an individual's inherent abilities, rather than the manifestations of intelligence molded by everyday life (Weinberg, 1989); whereas, alternative explanations suggest causes in population-level differences could be caused by (a) systematic biases in testing, (b) environmental factors (including, but not limited to, socioeconomics and educational deprivation), and (c) a genes by environment interaction effect (Reynolds, 2000). Thus, they argue psychometric testing cannot be culture neutral, nor culture fair.

Published work by Lucy (1992) showed that due to linguistic variation in Mayan dialects, speakers categorized objects by the material they were made from, rather than by shape, as native English-speakers did. Similarly, systematic differences were found between linguistically different populations concerning memory recall (Gumperz & Levinson, 1996), and categorization of objects (Resnick, 1976). These group level differences create what Nessier et al. (1996) refer to as Euro-centric biases in testing, a bias that extends so far that it fails to consider that the meaning of a test may, in its very nature, lack relevance to some populations (Irvine & Berry, 1988; Ardila & Moreno, 2001)

Environmental factors have also been shown to be correlated with test performance. Exposure and access to resources (Fryer & Levitt, 2006; Flynn, 2007, 2009), education quality and literacy (Blair et al., 2005; Ceci & Others, 2009; Marks, 2010), as well as health factors, including nutritional supplementation (Ivanovic et al., 2004), exposure to CO_2 (Dix-Cooper et al., 2012; Munroe & Gauvain, 2012), and disease exposure (Eppig et al., 2010) have all been linked to lower performance scores on psychometric tests.

Still, the importance of cognitive assessment cannot be denied. Valid and empirically tested explanations of group-level differences can help to identify the root causes of observed variation. And, if the causes are not wholly genetic, help identify, and perhaps remedy, discrepancies resource availability and institutionalized euro-centric programming.

1.4 Overview

The research presented in this dissertation covers many different factors and possible explanations for observed variation in cognitive performance among children at the lower end of the education continuum. Specifically, my research has contributed to the larger body of cognitive research by providing results from a longitudinal, natural experiment, which by its very nature removes many of the confounding variables affecting other research projects dealing with similar issues.

The Second Chapter provides background information on the study population, the Tsimané of Central Bolivia, and an in-depth explanation of the unique features of the population, as well as an explanation why the Tsimané were best suited for this research project.

The Third Chapter outlines the methodology. It provides a description of the study population and the selection of the participants Information on the types of data collection are discussed in detail, and information on Human Subjects Consideration and Clearance From IRB are provided.

Chapter Four presents cognitive performance data on school-aged children between the ages of 8 and 18. It will address specifically the variation between schooled and non-schooled communities in a culturally homogenous population. By using village level variation the chapter weeds out confounding variables that would, otherwise, interfere with assessing variation in performance across populations. Furthermore, several analytical approaches are employed to evaluate training effects on cognitive task performance tests.

The Fifth Chapter presents evidence from Tsimané demography including measures of wealth, general health, as well as parental education and student educational performance measures. This chapter expands the analysis to explore potential correlations among all of the variables. These measures are used to help tell the story of individual variation in cognitive task performance among children in schooled villages. A path model will outline the relationship between casual factors that play direct and indirect roles on individual cognitive performance. Overall, this chapter attempts to understand the relationship between the trade-offs an individual faces when a novel element, in this case schooling, is presented by using the Embodied Capital Model as its foundation.

The Sixth Chapter, or final chapter, summarizes the results and addresses possible future directions of research. The concluding section reviews the current findings and places them within the larger context of anthropology and human life history theory.

Chapter 2

Background information

This chapter will provide general background information on the study population and will discuss the social, political, educational, and developmental parameters that apply to examining Tsimané cognitive performance within and across villages. This chapter provides complete background information for the following chapter on cognitive, health, and educational findings; however, additional background information and methodological details are provided at the beginning of each subsequent chapter that are relevant to any additional theoretical and method-based tests described therein.

2.1 Ethnographic overview

2.1.1 Introduction

Over the last twenty years, the Tsimané have been studied extensively, with a resulting wealth of ethnographic and life-history information largely the outcome of two major projects based in the United States. One of the projects, the Tsimané Health and Life History Project, is directed by Hillard Kaplan and Michael Gurven. It is one of the most extensive research projects of its kind, providing details regarding virtually every facet of Tsimané life from ethnography to the fitting of life history models with empirical data. In relation to this project, the following introduction will emphasize the history of the western model of schooling, the Tsimané family unit, the developmental and life history landmarks, and choices related to adolescent growth and reproduction, respectively.

2.1.2 Historical context

The Tsimané people are first recorded during contact with Europeans in the 16th century. There is evidence that chiefdoms existed throughout the territory (Denevan, 1966), but the extent of Tsimané involvement, as well as further information about their social, political, and settlement histories are unknown. After a few unsuccessful attempts by Roman Catholic religious orders, the Jesuit Missionaries were finally able to establish settlements in the hard sub-tropical regions in the late 17th century (Chicchón, 1992). However, their success did not last long and they were expelled from Bolivia less than a hundred years later. Some groups underwent conversion, such as the Motesen, who are culturally and linguistically related to the Tsimané (Aldazabal, 1988), but the Tsimané remained unlinked to a western religious ethos until the mid-twentieth century.

It was in the 1950s that several different Mission posts were established near Tsimané territory (Chicchón, 1992). Among these groups was the New Tribes Mission, which recorded the Tsimané language and created the first bilingual school system with Tsimané teachers. Today the New Tribes Mission has a productive radio station and settlement outside of San Borja known as Horeb (named for Mount Horeb from the book of Exodus). Because of this and the fact that it is the headquarters of the

Gran Consejo, the elected governing body of the Tsimané people, San Borja serves as a commercial trading and market center for the Tsimané people.

2.1.3 Ecology, language, and economy

Occupying a large area of both wet-forest and savanna lands, their territory spreads across the Andean foothills to the Moxos savanna (Reyes-Garcia et al., 2005); approximately 9,000 Tsimané people inhabit villages (∼90) between the market towns of San Borja and San Ignacio de Moxos (Jiménez & Lizárraga, 2003) located within Beni, the second largest of Bolivia's nine departments (or provinces). The region is, overall, warm and wet. The rainy season occurs from November until April, with peak precipitation from January through March. Beni is mostly flat (averaging about 155 meters above sea level) with a series of Amazonian tributaries running through the region. As a result, the region has massive wetlands and is particularly susceptible to flooding during the rainy season. The dry season lasts from May until October.

Bolivia has a diverse population with numerous languages and dialects (Apuntes Juridicos, 2012), and Beni is no exception. Many of the dialects and languages within Beni are related, but, with the exception of Motesen, the Tsimané language is linguistically unlike that of neighboring groups. Though they have had consistent contact with other neighboring populations, their language remains an isolate from other groups in the region (Byron, 2003). Their linguistic group, Awaruna, is considered a discreet part of the Aguaruna language group, spoken by 16.6% of the Amazonian indigenous populations in Peru (Campbell & Grondona, 2012).

The Tsimané have remained resilient to major changes in subsistence and lifestyle over the last century by shifting their settlements to more remote areas. However, due to outside encroachment, a number of villages are now located closer to market towns with ensuing increased access to wage labor opportunities, resulting in a mixed economy. They practice swidden agriculture and remain heavily dependent upon forest goods and subsistence horticulture (Vadez et al., 2004; Reyes-García et al., 2008). Among the cultigens, rice, corn, sweet manioc, and plantain are the most prolific, though upwards of 80 species of other raised plants have been recorded on Tsimané lands (Piland, 1991).

Farm animals are prevalent in Tsimané communities, with pigs and chickens being the most common domesticated animals found in the villages. Some wealthier families raise cattle; some have even begun land-sharing or tending the herds of Bolivian nationals as a form of wage labor. It is therefore not surprising that, with their ability to sell goods and raise cattle, villages closer to market towns generally deforest much larger areas of land than the more remote ones (Vadez et al., 2004).

Game densities vary considerably depending on proximity to market towns and wage labor and market exchange is steadily becoming more common, leading to greater access to market goods. Still, despite game level fluctuations and the supplementation of purchased fats and proteins found in items such as cooking oils and canned fish, the Tsimané continue to rely heavily on hunting and fishing. The use of shotguns and rifles is employed when possible and is often the hunting method of choice. Dogs are frequently used on hunting trips and flashlights are employed to lamp nocturnal animals and secure the kill. When ammunition is not available, bow and arrow hunting is practiced, especially in more remote villages. Gurven (2006) listed the most important hunted game (by total biomass) as collard peccary, Brazilian tapir, gray deer, howler monkey, agouti paca, white-faced capuchin monkey, and coatimundi. Armadillo, spider monkey, and smaller game, such as squirrel, are also common meat products for the Tsimané. When fishing the Tsimané generally use one of five methods: hook and line, bebe (the use of slatted dams in narrow river passages or bottlenecks), and bow and arrow fishing, each of which can be done alone or in groups. Netting fish and barbasco, which uses native plants to stun and poison fish in an area closed off and monitored by the hunters, are done in communal groups.

2.1.4 Family life and household composition

Households usually consist of one to four nuclear families clustered near one another, and are comprised of affinal and consanguineal kin. Married couples tend to live close to their in-laws (Ellis, 1997), usually the wife's natal kin. It is common practice, though not formally defined, that men should engage in subsistence service to the wife's family during first few years of marriage. The majority of marriages are monogamous, though some polygamous marriages have been recorded (Winking et al., 2007, 2011).

The Tsimané are categorized as a natural fertility population. In many natural fertility populations throughout the world, despite the increase in medical care, education, and lower infant mortality rates, many people in developing regions continue to have comparatively large families (Casterline, 2001), and this applies to the Tsimané as well. Despite the fact that women report they want smaller families, fertility rates are high, even among women living close to market towns, with access to contraception and reproductive education (McAllister et al., 2012). In general, women marry by 16 years of age (Rucas et al., 2006), reach the age of first birth at 18.6 years (Walker et al., 2006), and, given their short inter-birth-intervals, have an average total lifetime fertility of 8.5 live births (Kaplan et al., 2010).

Within the individual family unit, both sexes actively engage in cooperative tasks with a well-defined division of labor according to sex. Tsimané men are most often responsible for hunting, fishing, and engaging in wage labor, while women focus on domestic tasks, including food preparation and childcare. However, with each new child comes a greater demand on parental units to provision their offspring. An infant lowers a mother's total energy production through altricial needs and time requirements (Hames, 1988; Hurtado et al., 1992). They remain nutritionally dependent on parents until their mid to late teens (Kaplan, 1994; Kramer, 2002, 2005b). Even when adults reach periods of peak production, provisioning from extended kin is necessary because the net demands of multiple offspring (Lee & Kramer, 2002; Gurven & Walker, 2006) is so great. Investment from other kin, conditional on their strength and skills, (Kaplan et al., 2005), and from older children (Stieglitz et al., 2013) is necessary to offset the energetic demands placed on parents.

2.2 Access to health care and health statistics

2.2.1 Introduction

The Tsimané have considerably high mortality and morbidity rates compared with the western world. Even though life expectancy at birth has improved within the population in the last 20 years, infant mortality rates are still high at ~13% (Gurven et al., 2012), nearly one and a half times that of the greater Bolivian population, and 12 times higher than for the United States (CIA 2004). Tsimané living in more remote regions — further from market towns such as San Borja — have 2-4 times higher mortality rates from birth through adulthood than those living in more acculturated regions; this is most likely due to variations in access to doctoral ministrations and medical supplies, distrust of western medicine, and lack of public health infrastructure (Gurven et al., 2007). Infection-malnutrition links are also a factor in morbidity rates among the Tsimané. In a resource-scarce environment with high pathogen loads, micronutrient deficiencies affect child growth (Walker et al., 2007), can impair intellect (Nokes et al., 1992; Black, 2003), and increase mortality and susceptibility to further infection (Pelletier et al., 1993, 1995; Katona & Katona-Apte, 2008).

2.2.2 Public health infrastructure

Tsimané homes are traditionally constructed of materials harvested from the surrounding forests. The frame of wooden poles supports a roof of woven and dried palm leaves. Houses in less acculturated villages are left open, but as material wealth increases in certain households and villages, a greater number of people secure their homes with walls of wood. Families tend to sleep together within one home. Sleeping arrangements vary with beds either elevated off the ground or made of woven palm leaves on the floor. It is typical for two to four people to sleep within each bed. Domestic animals including pigs, chickens, cats, and dogs are not penned, and therefore feces are found throughout villages and pathways. Families generally try to keep their yards and homes clean of excrement, but lack of proper shoes and large numbers of roaming domesticated animals can make this difficult. Public health records within Tsimané villages suggested that nearly 40% of homes had some animal excrement located near the house itself. Most Tsimané families living in larger villages have their own latrines, though they are generally shallow and hand dug. Some villages have cement latrines put in place by missionaries or through community development projects. In more remote villages with lower population densities, it is not uncommon to use fields or the perimeter of the forest for defecation.

The Tsimané get most of their water from two sources: surface water and wells. During 2010 and 2011, Engineers Without Borders collected samples from water sources for four Tsimané villages. Findings included discoloration, strong odor, and infectious agents (*e.g.* E. coli hits 0-12 CFU/mL, Fecal coliform 10-59 CFU/mL, and coliforms TNTC–diluted 10:1) within the water supply.

2.2.3 Access to medical care

Medical care is available through Horeb and in some cases at the hospital in San Borja. Free vaccinations are provided to mothers and small children including small-pox, polio, and measles, mumps, and rubella. It is difficult to travel the long distance to hospitals to treat time-sensitive illnesses. Other issues involve the misuse of antibiotics and other medicines purchased over-the-counter or from traveling salesmen. Families will often store part of a prescription in their home for future use, or buy a single pill due to financial constraints. Beginning in 2001, the Tsimané Health and Life History Project began visiting villages and providing medical care on a bi-annual basis. Now in its 12^{th} year, there are ~90 villages within the project. Programs providing treatment have changed, and in many instances families are brought to San Borja to the Tsimané project's headquarters to receive proper testing and medical treatment.

2.3 Access to education

2.3.1 Introduction

An educational transition occurred in the western world shortly after the industrial revolution (Sewell & Hauser, 1972), and it is now compulsory to have some formal education in most countries according to UNESCO (2006). Sincere efforts have been made focusing on reducing illiteracy rates and providing primary education within emerging economies over the last 30 years, increasing literacy 11% between 1960 and 2000 (Human Index Report 2007/2008). Efforts increased in this area when it was revealed that most developing nations were not able to sustain economic growth without maintaining a minimum adult literacy rate of 40 percent. (Center for Global

Development Annual Report 2007). Improvement for both males and females has been noted (Human Index Report 2007/2008, UN Global Fund 2010), but cultural norms, childcare and family labor, as well as the nature and location of available work (typically manual labor requiring travel), result in costly education (Ishida, 2004), and discourage consistent education among children in lower socio-economic brackets, and, in particular, girls (Bustillo, 1993; Behrman & Deolalikar, 1995; Post, 2001; Pasqua, 2005).

2.3.2 Educational reforms in Bolivia

Much has changed in educational programing among Bolivia's indigenous populations over the last few decades (Howard, 2009), and the Tsimané are no exception to the trend. The first introduction of schools to the population in the 1970s through the support of the New Tribes Mission, a theologically evangelical Christian mission organization based in the United States. In addition to establishing a mission center and a radio broadcast center, the New Tribes created a bilingual school system that trained Tsimané teachers within villages downstream from Fatima, the Tsimané village and Catholic mission. These schools initially provided basic primary education in reading, writing, and arithmetic. All teachers within the villages were Tsimané and they were paid salaries through mission funds.

In 1990 Bolivia began reforming education programs, but it was not until the after the election of Evo Morales in 2006 that some of these programs began to receive consistent funding. In addition to funding primary education, programs supporting and teaching in mother-tongue languages became more prevalent (Howard, 2009). However despite these programs Bolivia retains one of the lowest literacy rates in the Americas (see Table 2.1 references within), and constantly deals with educational setbacks- like the recent law lowering the entry age of children into the workforce, despite World Bank recommendations (Gunnarsson et al., 2006).

TABLE I: Regional and population level statistics for education and literacy

		Currently enrolled	Avg. years of school completed	Spanish fluency	Literacy
Bolivia	indigenous (64%[a])	82.4[c]	5.9[d]	74%[e]	85.5%[d]
	non-indigenous (48%[a])	57.6%[c]	9.6[d]		100%[d]
Tsimane pop.	M		1.99 (2.41 SD[f])	49.82%	18.3%[g]
	W		1.25 (1.51 SD[f])	12.11%[f]	7.6%[g]
Tsimane parents in sample	M		2.303 (2.15 SD[g])	23.3%[g]	36.9%[g](25.7%[h])
	W		1.37 (1.72 SD[g])	2.5%[g]	19.5%[g] (2.5%[h])
Tsimane children	B	58.2%[g]		32%[g]	48.9%[g]
	G	41.8%[g]		21%[g]	29.5%[g]

[a] Percent of population living in poverty[b]
[b] World Dev. Ind. Database, World Bank, 2002
[c] Source: 2008 Household survey data, INE using (Jiménez & Vera, 2006)
[d] World Bank Indigenous Peoples Poverty and Human Dev. 1994-2004, Report May 2005
[e] Klein (2003)
[f] Godoy et al. (2013)
[g] Data collected by HED & THLHP
[h] Self reported

Table 2.1: Regional and population level statistics for education and literacy

Today in most Tsimané villages children begin attending school around the age of five or six. Initial educational instruction is conducted solely in Tsimané. Children learn to count and begin to familiarize themselves with the alphabet. Factors such as the location of school to the market towns, the size of village, and the number of teachers within the village play a considerably large role in determining the number of classrooms, the level of instruction, and the type of teachers within the school. However, regardless of the village size schools run for just four hours a day (from 8am until 12pm), excluding holidays, harvests, and cancellations due to weather and flooding (most often between the months of January and April).

In a smaller village, such as Jamanchi Uno, there is usually one school house. Built in the same style as traditional Tsimane homes, the schools have few or no walls, dirt floors, and a roof of woven palm fronds. In these instances there is generally

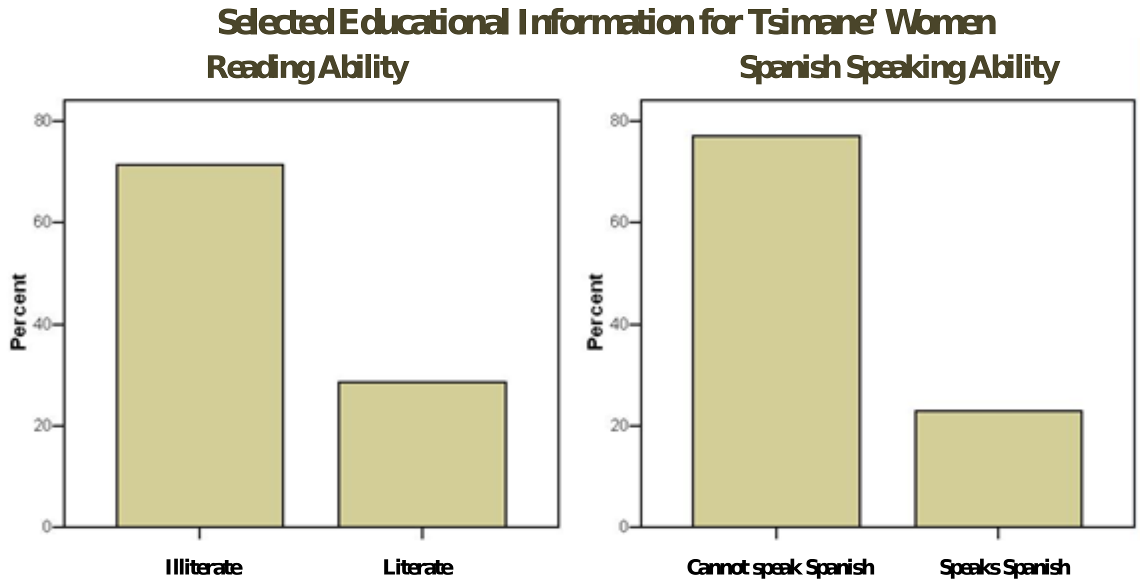

Figure 2.1: Bar graphs of reading ability and Spanish-speaking ability among Tsimané women.

one Tsimané teacher, usually a male, who is paid through the state. This teacher is responsible for the instruction of all the students in the classroom, regardless of age or grade level. This often means that classroom instruction is sometimes beyond the capacity of younger children, and the environment itself is often chaotic.

Classroom equipment can vary greatly in smaller village schools. Sometimes benches with posts dug into the ground act as the only seats. If the government has provided funds to the community one can often find chairs and tables, shared by three to four students, used as desks. There is usually one chalkboard in the classroom and children are most often responsible to provide their own pens and paper, which is more difficult as the villages become more remote. Books and materials are also often variable in regards to quality, condition, and relevance to the proposed coursework.

Larger villages have seen greater changes through the educational reforms. Unlike many of the smaller village schools, some or all of the school buildings have concrete floors, walls, and classroom equipment, such as desks, chalkboards, and materials. In villages such as Tacurual del Matto or Fatima, children are divided into classes based roughly around their individual age. Their initial instruction is still conducted solely in Tsimané, and teachers of the lower grade levels are still traditionally Tsimané men. However, once these students advance to higher level grades they begin to learn Spanish language instruction and reading skills. Because of the educational reforms these larger villages now have a greater number of non-Tsimané teachers and standardized Spanish taught curriculum. Non-Tsimané instructors generally live in the villages during the week, leaving Friday after classes let out and returning Sunday evening or Monday morning to resume teaching. These teachers spend little time in the communities outside of what is explicitly required of them (Reyes-García et al., 2013a).

Despite increased exposure to Spanish language curriculum, very few children below the age of 10 can read or write more than a few works in Spanish or Tsimané. Much of this is due to the late introduction of these skills in school, but also, as mentioned above, class days are shorter and, therefore, exposure to reading and writing is limited by time in the classroom. Furthermore, established schools with regularly followed schedules (weekly annually) are still uncommon, due in part to issues of infrastructure. Although some villages are located quite near comparatively larger towns, integration varies; no villages have consistently running water, and very few have electricity. Additionally, children often miss school to help with household chores and duties. Schooling therefore ranks as a relatively low priority with few checks and balances to ensure a strong, consistent curriculum across schools and communities. Overall, literacy rates among Tsimané, much like the rest of Bolivia, are still low. Only 20% of Tsimané women are able to read. Likewise, the ability to speak Spanish is also low among mothers within the sample population. The closer the Tsimané live to San Borja, however, the higher their associated literacy rate and Spanish-speaking ability (Figure 2.1). Until recently, the total number of years the Tsimané attended school was also relatively low, with the vast majority quitting schooling after only a few years ($M = 2.12$, $SE = 3.015$).

2.4 Methods

Quantitative methods used in this study included psychometric testing, scholastic testing, and behavioral observation, and health statistics. In addition, three initially qualitative methods were used: interviews with parents, children, and teachers, assessments of village schools, and teacher evaluations, which were later coded and scaled for use in data analyses. The methods described below were approved through The University of New Mexico's Human Subjects IRB (Protocol #08-398 and #26131). The study was formally closed after the Human Subjects Protection Office determined that compliance had been met on the 12^{th} of December 2012. Helen Elizabeth Davis (HED) and two other approved graduate students assisted in the collection of the data within six villages during the years 2007, 2008, and 2009, and Alberto Maito (AM), a trained Tsimané anthropologist, worked in translating and collecting data; AM administered the cognitive test and school assessments. Overall, 293 children were evaluated, though only 283 were included in the sample. Four children were excluded because the participant did not wish to continue the evaluation, and six were excluded because of interruptions during testing.

2.4.1 Cognitive assessment

2.4.1.1 Initial evaluation

Because cultural differences and illiteracy were inherent issues from the onset, using a test that had limited verbal exchange and culturally loaded references was paramount. For the study we selected a psychometric test known as Raven's Colored Progressive Matrices (RCPM), designed by John C. Raven in 1936, to address the issues above. Unlike Raven's other tests (Raven's Progressive Matrices and Advanced Matrices), this test is designed for children between the ages of 5 and 11 with an age effect expected (Raven, 1936); children are supposed to master the test by the age of 11 barring physical or mental disabilities. It requires limited verbal interaction, and because it uses patterns and/or pictures that follow one rule-set, it allows for increased difficulty with minimal exchange between the test-giver and the subject. This is advantageous because language incongruity is a known confounder for many types of intelligence tests (Raven, 1998). Additionally, it has been used extensively across a wide variety of settings among both adults and children (Carpenter et al., 1990; Jensen, 1998; Daley et al., 2003; Cotton et al., 2005; Kaplan & Saccuzzo, 2012).

Though there is limited verbal exchange, some instructions inevitably need to be provided. The test requires one person to explain the instructions and administer the test. Raven's was originally written in English, and so translations were required. A series of translations to Spanish, and then back to English were conducted to ensure that nothing was lost. The test was then translated into Tsimané with the help and expertise of the Tsimané Health Project's Tsimané anthropologists. Three individuals were asked separately to translate the test from Spanish, and then the versions were compared, exchanged, and back-translated. Once a consensus was reached on the appropriate translation, other bilingual Tsimané anthropologists were asked to translate the completed draft into Spanish. When the team was satisfied with the results and translations, an administrator was selected. Alberto Maito, a Tsimané anthropologist from Tacuaral del Matto was selected. Alberto administered every test in the study over the course of six years. He was trained extensively in administering the test in Spanish and in Tsimané. The first 30 tests in the sample were thrown out to control for any errors during initial phase of the study.

Raven's consists of a set of 36 schematic colored figures in which one is asked to find a rule connecting a set of figures and to complete the set according to the rule. The test is divided into three subtests, entitled A, B, and A_B, and has 12 individual puzzles, which increase in difficultly by number and by section. Each page depicts one figure (in the first two subtests the figures are colored images on white backgrounds; the third subtest consists of a combination of colored, and black and white images), which has a piece missing in the lower right hand corner. Respondents are prompted to choose one of the six pieces — shown below each figure — that will fill in the missing space and complete the pattern (Raven, 1998). During a brief introduction and explanation of the task in their native tongue, the subject was told to examine the pattern and identify which piece fits into the missing space by pointing to the correct piece on the page. Either Davis or one of the other graduate students recorded the subject's answer before moving to the next puzzle. The first three items on the test are extremely easy and are designed to determine whether the task has been fully understood; if a subject incorrectly identified one of these items — as per the test's protocol — the above procedure was repeated until the subject answered correctly. As the test progresses the puzzles become more difficult. The puzzles in Raven's range from a single completion puzzle to a 2×2 matrix, where patterns, both vertical and horizontal, have to be evaluated correctly in order to select the correct piece. Raven's intention was to design a test that could successfully assess the subject's reasoning ability (Raven, 1936), which is considered an important factor of individual g.

As per test instructions, no time limit was given. Mean completion time was 8.45 minutes, $SD = .184$. If at any point a subject did not want to continue the test, it was concluded immediately. There was no penalty for leaving early, and everyone who participated received a small compensation of two pencils, two pens, and a notebook for school.

2.4.1.2 Retest and training evaluation

To evaluate whether performance in children's Raven's scores improved due to training, retests were given to a subsample of students ($N = 80$), where half of the retest sample was exposed to schooling and half was not. A training module, made by selecting nine puzzles (three from each subtest) from Raven's, was shown to half of the students in the sample. During the training AM explained to the students that he wanted to practice the test with them. AM would then follow the procedure outlined in the Raven's handbook until a participant answered a question incorrectly three times. As in the instructions, questions A1, A2, and A3 are provided to determine that the student understands the test. After the test-giver was aware that the participant did not understand the question before them, he would walk the student through the incorrect responses and why each piece did not fit the puzzle. Using the same strategy, AM walked each student through a subsample of questions and when they did not appear to understand how to solve the puzzle he would explain why each of the other pieces were incorrect, and why the correct piece completed the figure. This was done for all nine puzzles, and then the student was asked the same three interview questions.

After a period of four days, the same students were retested to determine whether there was a training effect, and if students who had received training would improve more so within schooled villages.

2.4.1.3 Educational assessments

After the Raven's test was completed, each participant was then asked to complete a reading and math assessment. The reading assessment consisted of a few sentences the subject was asked to read aloud, and were then asked a series of follow-up comprehension questions. Their overall performance was scored on a Likert scale from

0-5 (see Table 4.1) in order to ascribe a literacy level to each participant. The scale was as follows:

0 = No comprehension of letters or words

1 = Recognizes some letters but unable to sound out letters or word parts

2 = Recognizes letters; Able to sound out word parts

3 = Sounds out word parts; able to read some words and parts of sentences; little to no reading comprehension

4 = Able to read words; able to read sentences; had moderate to good reading comprehension

5 = Able to read full sentences; complete comprehension of the reading material

The math assessment was scored on the number of correct responses given to a series of math problems using addition, subtraction, and multiplication. Half points were given for attempts or if minor errors had been made; a small number of students who could not complete any of the questions, but did have the ability to recognize numbers and attempted to solve the problems, received a half point. Based on where each participant fell when all these factors were considered, they were binned in groups according to math literacy with a score between 0-3.

The same test was given to each child during tests and retests. The descriptives are listed 4.2 and show the observed variation across the sample population. In order to ensure that there was consistency in the coding, reliability was established through a series of practice tests and retests among the graduate students before assessments began.

2.4.1.4 Teacher evaluations

Basic Student Assessments were given to teachers. Using a Likert scale from 1-5, teachers were asked to evaluate each student's school performance, class participation, and attitude. Additionally, attendance records were used (with approval from the headmaster, parents, participating students, and Tsimané governing council) and coded to establish a measure of time spent in school over the sample period. An average attendance was coded for a period of 30-60 days.

2.4.2 Individual level differences

2.4.2.1 Age of the participants

Date of birth was taken from the demography database compiled by the Tsimané Health and Life History Project (for detailed description of these methods see (Gurven et al., 2007)). These data were collected through medical documentation, relative age lists, written accounts, dated events, and cross-validation of information with known historical and local timed events, as well as with related kin.

2.4.2.2 Measuring School Attendance

From 2002-2007, time allocation data was recorded by Davis and other anthropology graduate students working for the Tsimané Health and Life History Project (THLHP). Behaviors of individuals residing in a cluster of several geographically close households were recorded during 2-hour time blocks (7-9am, 9-11am, 11am-1pm, 1-3pm, 3-5pm, 5-7pm) at half-hour intervals (also known as instantaneous scans). Individuals at or near the residential cluster were observed directly, and the activities of absent individuals were obtained by informant reports. Activities were coded based on a scheme of over 150 standardized codes. Time blocks were sampled randomly and without replacement to ensure that all clusters were equally represented during daylight hours. This method was used in certain communities to verify, retrospectively, variation in school attendance. In particular, when children reported going to school, or when teachers stated that children had attended school, these data were used to determine reporting reliability. In addition to this, Davis would randomly visit and take attendance during field visits to each community and compare attendance records with those provided by the teachers at the schools.

2.4.2.3 Energetic status (body mass index (BMI), weight-for-age, peak weight-velocity, and peak height-velocity)

BMI and weight-for-age were calculated using anthropometric data collected from the Project's medical-anthropological team (for detailed description of these methods see (Gurven, 2012)). Tsimané specific weight-for-age (WAZ) scores and ZBMI scores were computed using Tsimané specific LMS tables. Tsimané specific growth curves were calculated to determine each child's peak height and weight velocity during puberty. The slope for the change in z-score was determined for each boy and girl for the two years following Tsimané-mean age of take-off growth (Walker et al., 2006). Weight was calculated to the 1/3 power to linearize the weight to height relationship. From these calculations, individual measurements were divided by time, giving us the slope of each score with the equation:

$$z = \left((\text{height}/\mu)^{\lambda} - 1\right) / (\lambda e^{\sigma}) \tag{2.1}$$

$$z = \left((\text{weight}^{\frac{1}{3}}/\mu)^{\lambda} - 1\right) / (\lambda e^{\sigma}) \tag{2.2}$$

2.4.2.4 Infectious status (acute and chronic)

This measure aimed to produce an understanding of the child's current infectious status leading up to and during the test. During each medical check-up with the THLHP, the medical staff recorded all diagnoses and prognoses and entered them into an Excel spreadsheet. For this project we coded each diagnosis using the ICD-10 codes. We did not differentiate between acute and chronic illnesses because both measures provided us with a general understanding of the child's health limitations at the time of the testing.

2.4.3 Family level differences

2.4.3.1 Interviews and family history

I. Participants were asked three questions, which were then compared to attendance data collected from the schools and parental interviews:

1. Are you currently enrolled in school? If no, why not?
2. If yes, did you miss any days of school in the last 5 days? If yes, why?
3. Do you like attending school?

II. Structured interviews with parents provided background information about parental educational history, residence history, and opinions on the importance of schooling overall. More than 90% of parents in the sample were interviewed. All interviews were conducted only after receiving consent from the parents and the participating children.

III. Detailed demographic data, collected by the THLHP, were used to supplement the parental interviews. Information on the educational history of parents, family residence patterns, and household wealth were added when missing and compared for consistency.

2.4.3.2 Distance from home to school

GPS points for each home and the village center (location of the school) were recorded using a Garmin Etrex GPS by the Project and Davis. The distance from each home to the village center d was calculated using the Great Circle Calculation.

$$d = 6371 * \arccos(\cos(90^\circ - Lat1) * \cos(90^\circ - Lat2) +$$
$$\sin(90^\circ - Lat1) * \sin(90^\circ - Lat2) * \cos(Long1 - Long2))$$

This provided each individual child in the sample with a measure of distance from their home to their school[1]. Additionally, distance from the market town was considered in village level analyses[2].

2.4.3.3 Living conditions

This latent variable was calculated using two measures derived from public health interviews, and collected by Tsimané anthropologists during routine medical visits

[1]Does not include marked village pathways. Distance is calculated as-the-crow-flies, while accounting for curvature of the earth.

[2]As previous studies have indicated (*e.g.* Godoy et al. 2004), travel distance to the San Borja market was used as a reliable predictor of village-level acculturation. This was used to control for possible biases in closer villages and to determine that we did not have a skewed sample by looking at distance and mean IQ, as well as education history of parents within the sample. There was no significant difference between mean IQ when controlling for education, in any villages in the sample, despite the difference in distance to the nearest market town.

to all participating villages within the THLPH. The interview was designed in two parts. First, the trained Tsimané anthropologist would scan the household (both exterior and interior) and determine the level of overall cleanliness, and specifically whether there was fecal matter present in the interior or exterior of the home. The list included fecal matter from pigs, dogs, cows, ducks/chickens, humans, or other sources. It was specified whether the fecal matter was in the interior or exterior of the home, and whether there was no fecal matter present, some present, or a great deal present. These numbers were used to calculate the amount of fecal matter found in and around the home. In the second part of the interview, the Tsimané anthropologist would ask the head of household how many members of each family shared each bed. This was used to calculate the number of beds per family. Both of these measures were used to determine the living conditions of each child.

2.4.3.4 Parents' embodied capital

Four measures were used to determine parental embodied capital: wealth, BMI, Spanish-speaking ability, and total years of education. All of these were used as proxies of measuring the embodied capital of each child's parents. Wealth was calculated using a number of interviews from the Tsimané project. A database developed by another graduate student calculated overall wealth, understood here as an amalgam of earned income, material wealth, and livestock. BMI, which was used as a proxy for parental subsistence/energetic production (Godoy et al., 2006), was taken during each medical visit from the The Tsimané project. Only measures for parents taken within one year prior to the Raven's testing of each child were included in the sample. The measurement for Spanish-speaking ability was collected through interviews by both Davis and the Project. A mean measure was calculated between the two interviews to create one consistent variable. Finally, total number of years schooled was determined from detailed demographic interviews conducted from 2002 to 2006.

Chapter 3

Schooling and cognitive task performance at the lower end of the educational continuum.

3.1 Introduction

As the fields of cognitive science continue to probe the questions regarding what intelligence is and how to effectively measure it, some researchers have asserted that the difficulty in assessing intelligence and its relationship with quality-variation in environmental factors is difficult, if not impossible, to tease apart (Neisser et al., 1996; Flynn, 2007; Johnson et al., 2010). IQ tests (often an organized series of smaller tests, known as a battery) aim to assess the overall cognitive capacity of an individual through standardized evaluations of their skills in linguistic aptitude, reasoning, and organization. The overall aim is to determine an individual's cognitive ability compared with the population. About 95% of the population falling within two standard deviations of the mean — adjusted to 100 — and cross-test correlation is considered high in the majority of standardized cognitive assessments and tests (Naglieri & Bornstein, 2003). However, when these batteries are used on populations outside the western world, critics argue that issues arise that call into question the accuracy of the measures cross-culturally. One of the greatest concerns is variation in exposure to formal education. Quantifying the difference between traditional and formalized teaching and learning has persisted as an important topic of research over the last few decades (Resnick, 1976; Irvine & Berry, 1988; Gumperz & Levinson, 1996; Ardila & Moreno, 2001; Pewewardy, 2002; May & Aikman, 2003; Chavajay, 2006) Since the mode of information transmission can vary greatly between populations (Lucy, 1992) it has been suggested that unraveling the interconnected relationship of IQ and education would be difficult (Ceci & Williams, 1997) unless certain criteria concerning population variation could be met (Flynn, 2007).

In an attempt to tackle some of the questions revolving around education exposure and IQ performance, we designed a research project that would investigate variation in schooling exposure and performance on tasks that evaluate cognitive performance. The research project was established in Central Bolivia under the guidance of the UNM-UCSB Tsimané Health and Life History Project. What makes the Tsimané particularly interesting given previous research constraints in the field is that, in addition to living on a geographical gradient, with some villages located close to the market town and others further away (closest village is .9697 km and furthest away 83.925 km), schools have been randomly introduced to villages both near and far to town. This has created a natural experiment with villages falling into one of four categories: schooled communities close to the market town; schooled communities far away from the market town; little to no schooling near the market town; and finally, little to no schooling far away from the market town. Overall, the unique features of the Tsimané's history, location, and differential access to the market economy create great variation among a culturally and ethnically similar population. This allows us to better evaluate possible contributing factors to variation in performance while controlling for confounding variables such as language, cultural identity, and social mores.

3.2 Review of the literature

3.2.1 Human cognition is unique

Our own life history, much like our primate relatives, exhibits long life spans (Austad & Fischer, 1992; Hill, 1993; Hill & Kaplan, 1999; Kaplan & Robson, 2002), slow growth rates (Leigh & Shea, 1996; Leigh & Park, 1998; Gurven & Walker, 2006), long periods of juvenile development (Prentice & Whitehead, 1987; Janson et al., 1993; Holman & Wood, 2001; Leigh, 2001; Knott, 2001; Robson & Wood, 2008), slow fertility rates (Charnov & Berrigan, 1993), as well as many of the characteristics associated with higher order intelligence (Lancaster, 1971; Premack & Woodruff, 1978; Markus & Croft, 1995; Van Schaik et al., 1996; Lancaster & Kaplan, 2000; Povinelli & Giambrone, 2001; Grainger et al., 2012; Ziegler et al., 2013). In regards to higher intelligence, anthropologists and psychologists have typically focused on the learning skills required for optimal adult functioning — particularly using foraging capabilities (Kaplan et al., 2000), social skills (Dunbar, 2003), ecological dominance (Flinn et al., 2005), or signaling (Miller, 2000) as explanatory factors. Investigations in these areas have keyed researchers into the importance of the adolescence period and human middle childhood as a critical phase of extensive learning. These phases are important to our own human life history (Piaget, 1972; Chawla, 1992; Kaplan et al., 2000; Walker et al., 2006; Kuzawa & Bragg, 2012) and, possibly, to some of the more recent features of human development (Bogin, 1999; Bock & Sellen, 2002; Bock, 2002b, 2004, 2005).

Because we possess these unique life history traits, humans are a highly resourceful and socialized species. Throughout a single lifetime, humans are able to learn from experiences and adapt to highly variable environments (see Kuzawa & Bragg, 2012 and references therein). Life history provides insight into how we have evolved characteristics to process information from an evolutionary perspective, but it may also help us to fully understand why one individual processes information better than another. At present, there is much published research concerning ecological intelligence, such as what it takes to be a good hunter (Lancaster & Lancaster, 1983; Hill et al., 1987; Foley et al., 1991; Kaplan & Hill, 1992; Hill & Kaplan, 1999; Walker et al., 2002; Robson & Kaplan, 2003; Gurven et al., 2006), and the acquisition of skills via traditional learning (see Reyes-Garcia, 2006 and references therein). Yet, we know very little about the transition from traditional learning skills to models of standardized learning — understood as the mode of information processing and retention — or the observed differences in individuals during this transition, and how we adapt to these changes when such a novel environmental factor is presented.

3.2.2 Developing a cross-cultural intelligence quotient

The topic of how to measure observed cognitive variation is widely debated. In the last century much effort has been devoted to the study of skill development and cognitive performance. These studies have primarily focused on the application of psychometric tests (Jensen, 1998). The majority of the theories and models in the field of psychometric testing and intelligence focus on individual differences — in particular g (*i.e.* general intelligence). This school of thought posits that g provides the most meaningful factor of which to measure intelligence, and that it is able to clearly differentiate between individual variation in many fundamental processes (Deary et al., 2010). Some of the most established models of g theory include two-factor theory (Spearman, 1904), Level I and Level II theory (Jensen, 1968), the investment theory of fluid (Gf) and crystallized intelligence (Gc) (reasoning versus knowledge based problem solving, respectively) (Cattell, 1963), and the biological g theory (Rushton & Jensen, 2005, 2010). Supporters argue that the correlations between g and important life outcomes, such as achievement in school and in the workplace (Gottfredson, 1997; Naglieri & Bornstein, 2003; Deary et al., 2007), provide the strongest evidence for genetic difference in general intelligence.

Alternatives to general factor hypotheses do exist. These models do not include the variable g as an explanatory construct, but also do not deny the strong correlations and robust results that have been previously reported (Kan et al., 2013). Examples of these alternative hypotheses include the mutualism theory (Van Der Maas et al., 2006), the social multiplier theory (Dickens & Flynn, 2001), and — more recently — the model of genotype-environment covariance (Kan et al., 2013). These models argue that different skills are required in different environmental niches, and that all of the observed variation between individuals cannot simply be explained through genetic differences. One such environmental factor could simply be exposure to novel ways of information processing (*e.g.* school).

3.2.3 Education as an important environmental condition

Flynn (2007) suggested that changes resulting from modernization mean that a larger proportion of the population is provided with a new way to process and organize information, especially abstract concepts. Thinking abstractly and dealing with novel problem solving techniques is reflected in IQ tests, which rely heavily on the manipulation of such abstract concepts (Flynn, 2000). One possible way to test this would be to study a population newly exposed to these techniques. The introduction of formalized schooling into a population adds a novel environmental element. As seen in adoption and twin studies during interventions, improved environmental conditions equaled improved cognitive performance (Turkheimer et al., 2003, 2005;

Harden et al., 2007). In this way, we view formal schooling as an intervention study of sorts. Exposure to schooling will be associated with higher scores, and higher quality schools should, in theory, have even higher scores — or, more precisely, a dosage-response effect should present itself. Furthermore, we could assume that in this intervention study, those exposed to the intervention of schooling would perform better after tutoring and training. Improvement on cognitive tests has been documented after training (Blackwell et al., 2007; Jaeggi et al., 2008). In order to begin investigation, we established a number of testable hypotheses to guide the project through the first three years of data collection.

The overarching hypothesis is that there is a positive correlation between exposure schooling and improved performance on cognitive tests. This dissertation will argue that exposure to two-dimensional learning (*e.g.* reading and mathematics), training people how to learn using the western education model, and ascribing value to scholastic performance (something that may otherwise be perceived as abstract and unimportant) translates into improved performance in some combination of those skills. In other words, if someone has no exposure to formal education, they might not have the skill-set required to appropriately evaluate and perform on standardized cognitive tests so as to accurately reflect their true cognitive capacity.

3.3 Hypotheses

3.3.1 Exposure to schooling

Early access to certain resources could account for large gaps and variations in cognitive performance between populations (Lee & Burkam, 2002; Todd & Wolpin, 2007; Wolf & Stoodley, 2008). Though these studies were conducted among US populations, they do bring to mind interesting questions concerning student educational variation — where some students have little to no access to scholastic resources (*i.e.* total learning time in the classroom, trained educators, standardized methods of teaching, books and academic materials, and even recent exposure to formal education). If one imagines education exposure as a continuum where quality and classroom time translate to degree and distance from the mean, then students on the lower end of the educational continuum would begin the learning experience with profound limitations when compared to populations where such standards persist (Ardila & Moreno, 2001). The hypotheses of cognitive performance at that at the lower end of the educational continuum state that (H1) exposure to schooling will be positively correlated with an age effect on standardized cognitive tasks. Furthermore, when quality of school increases (measured as time in operation and available materials), one would expect a dosage-response effect to emerge where (H2) increased exposure to schooling will be correlated with increased performance on cognitive task assessments.

3.3.2 Motivation

Being motivated has been shown to be a major factor in predicting math performance (Murayama et al., 2013), while attendance (a proxy for practicing and studying) has shown the relationship between increased exposure to reading and increased literary fluency (Rayner et al., 2001; Wolf & Stoodley, 2008). This research hypothesizes that (H3a) as performance on school-based abilities increases, scores on cognitive tests will also increase, and that (H3b) motivation, measured through attendance, will be positively correlated with performance on cognitive tests.

3.3.3 Learning to learn

Learning is a multidimensional process pulling from children's experiences at home and in the classroom. Students who come from a family unit without any history of formal learning within the unit will have a level of reading readiness (*e.g.* amount of time exposed to words and letters in the home or community) that is significantly lower than the average upon entering school, which has been shown to have a profound impact on their ability to read (Wolf & Stoodley, 2008). Though these findings have generally been noted in the western world, we suggest that these will be observed at the lower end of the educational continuum. We hypothesize that (H4a) higher parental literacy and Spanish speaking proficiency will be positively correlated with a child's literacy and performance on standardized cognitive performance tasks.

When children goes to school they become students. In school, they learn structured skills, such as reading and math. These skills allow the learner to derive meaning from symbols, such as letters and numbers (Adams, 1994). As learning structured skills progresses, increased abstract thinking skills develop (Cain & Oakhill (2009) and references within), and differentiating between concrete and formal operations (Blair et al., 2005; Flynn, 2007) become instrumental in how we process and understand new information. These lessons not only provide us with information, but also shape the way we learn. Therefore, the hypotheses suggest that (H4b) with higher rates of child literacy and school exposure, child students will show greater improvement after training on retests than their unschooled, illiterate counterparts.

3.4 Background

3.4.1 Education in Bolivia and within Tsimané villages

Schools in Bolivia were established with increased frequency in rural regions after 2006, though a large part of the population overall still has extremely low literacy rates (Howard, 2009). The Tsimané are no exception to this trend. Though nearly 40% of the population has access to primary schools (Reyes-García et al., 2013b), communities are plagued with many weakly established and poorly maintained schools, many without consistent schedules (weekly and annually). Many of the teachers live locally and rely on subsistence production for food and housing materials, so absenteeism is common not only for students but also their educators during planting and harvesting time. Another common reason for inconsistent schedules is that teachers and professors who come from Bolivian towns and villages prefer to spend little time in the communities outside of what is explicitly required of them. Therefore, during holidays, weekends, and even outside of mandated class time many non-Tsimané educators leave for market towns. Lastly, because formal schooling doesn't lend itself greatly to subsistence survival, many families rank schooling as a relatively low priority compared to other activities, such as household duties.

3.4.2 The sample population

The villages included in the sample were selected because of the presence or absence of schools, their proximity to the market town, and the quality of schooling within the village. Of the 283 children in the sample, 53 children came from villages with little to no access to schooling, 159 children came from villages with moderate access to schooling, and 71 children came from villages with schools categorized as consistent.

Within the six villages in the sample, two villages (one with little to no schooling, and one with consistent schooling ($N = 106$)) were classified as being near the market town, three villages (two with moderate schooling and one with little to no schooling ($N = 89$)) were classified as being far from a market town, and one village (classified as moderate schooling ($N = 87$)) was classified as remote. These classifications were determined using previous studies (Gurven, 2004; Godoy et al., 2007), which indicated travel distance to the San Borja market was a reliable predictor of village-level acculturation.

3.5 Data analysis

Statistical analyses and graphic productions were performed with SPSS (versions 21 & 22), and LaTex (version $LaTeX2\epsilon$). Linear, multiple regression analyses were all used with significance set at 0.05 in order to test whether performance on Raven's was a function of literacy, school-taught skills, and level of investment (hypotheses 1-4a). Finally, paired T-tests, and a Mann-Whitney U-test were conducted in order to test the effects of training to the test and whether improvement (meaning a positive change in score) on the test was significantly different in either schooled or non-schooled populations, respectively. Details of the statistical results will be discussed in each chapter.

3.6 Results

All in all, 18.4% of the total sample population came from villages with little to no school, 56.4% came from villages with moderate levels of schooling, and 25.2% came from villages that were consistently schooled (ranked ordered by number of days school was in session during the last calendar year, number of years the school had been in operation, and whether villages had teachers from inside the village, outside the village, or both). When categorized by remoteness (rank ordered using total distance (village < 30 km; village < 40 km, village > 40 km)) there was a slightly more even distribution with 38.1% of the sample in villages close to a market town, 25.3% in villages that were moderately far from the market town, and 36.7% in villages farthest from the market town.

In Chapter 2 (Table 2.1) we see that educational attainment and literacy rates are low in Bolivia, and lower still among indigenous populations, and the Tsimané are no exception. Within the THLHP's overall sample 70% of adult women cannot read, over 78% cannot speak Spanish (a proxy for degree of acculturation), and that the median number of years of school across all Tsimané men and women is only 2.12 years. Looking at just within-sample descriptive statistics (Table 3.1), overall educational attainment is not significantly different from the THLHP's data. Within schooled villages, both mothers and fathers have greater Spanish speaking proficiency (Table 3.1) than other communities. When categorized by village remoteness, we found that the educational attainment for fathers ($M = 2.09$, $SD = 2.33$) and mothers ($M = 2.44$, $SD = 2.21$) in remote villages was approximately equal to educational attainment for fathers ($M = 1.98$, $SD = 2.31$) and greater than mothers ($M = 1.95$, $SD = 2.29$) in villages closest to the market towns. However, fathers' mean Spanish speaking ability was slightly more proficient when living closer to a market town ($M = 1.25$, $SD = .57$) than those living in villages classified as remote ($M = 1.17$, $SD = .62$). A more pronounced difference could be seen in mothers' mean Spanish speaking ability (remote: $M = .44$, $SD = .68$; close to market town: $M = .56$, $SD = .53$). These descriptive statistics provide some insight in the degree and level of educational exposure within villages, as well as provide measures of baseline acculturation within the population.

The entire sample of school children was comprised of 41.8% girls and 58.2% boys.

Table 3.1: Descriptive statistics for parents of sample populations

	Consistently schooled		Moderately schooled		Little to no schooling	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
Fathers						
Spanish Ability (scale of 0-2)	127	1.32 (.53)	156	1.18 (.62)	43	.96 (.62)
Education in Years (scale of 0-9)	127	2.03 (2.38)	148	2.14 (2.35)	34	1.52 (1.88)
Mothers						
Spanish Ability (scale of 0-2)	126	.60 (.53)	108	.53 (.59)	36	.37 (.52)
Education in Years (scale of 0-9)	125	1.92 (2.31)	108	2.34 (2.17)	33	2.47 (2.37)

Table 3.2: Selected descriptive statistics for children by level of schooling

	Consistently schooled		Moderately schooled		Little to no schooling	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
Age	71	12.43 (3.28)	159	12.49 (3.17)	52	12.42 (3.92)
Raven's Perf.	71	14.62 (5.51)	159	11.82 (4.34)	52	11.13 (3.59)
Reading Comprehension (scale of 0-5)	68	2.00 (1.90)	159	1.22 (1.82)	52	.81 (1.33)
Math Comprehension (scale of 0-3)	68	1.47 (1.36)	159	1.12 (1.28)	52	.48 (1.01)
Attendance	64	.71 (.31)	109	.73 (.30)	—	—

The average age of the children tested was 12.46 years ($SD = 3.34$). We see in Table 3.2 that the mean age across the schooling distribution was approximately equal. Across the entire sample, 61% of children attended school at the time of testing. The average score on Raven's was 12.40 ($SD = 4.71$), reading ($M = 1.33$, $SD = 1.81$), and math ($M = 1.09$, $SD = 1.29$). Overall, 19.7% of students were ranked as literate, and 59.1% were labeled either illiterate or having extremely low reading skills. When the population is broken down into the three schooling categories an increase in the average score according to the level of schooling can be seen for Raven's, reading, and math (Table 3.2), which provided justification for further statistical analyses.

To test whether the first hypothesis, that exposure to schooling would be positively correlated with an age effect on standardized cognitive tasks, linear regressions were run with schooled and non-schooled villages with significance set to $p < .05$. In this analysis, only children in consistently schooled villages and those in villages with little-to-no schooling were tested. Within schooled villages age significantly predicted Raven's scores, $\beta = .456$, $t(2, 70) = 7.730$, $p < .000$. In schooled villages age also explained a significant proportion of variance in Raven's performance,

$R^2 = .208$, $F(2, 70) = 59.746$, $p < .000$. However, in unschooled communities an age effect was not observed $\beta = .204$, $t(1.443) = 48$, $p = .156$. A scatterplot of age by Raven's (RCPM) score was plotted in SPSS graphics (Figure 3.1). Here we are able to visualize the relationship between the expected age-effect on Raven's and villages with consistent schooling, and villages with little to no schooling. Those in schooled communities show increased ability as a function of age controlling for years in school. However, in the non-schooled communities there is little change between the younger and older participants.

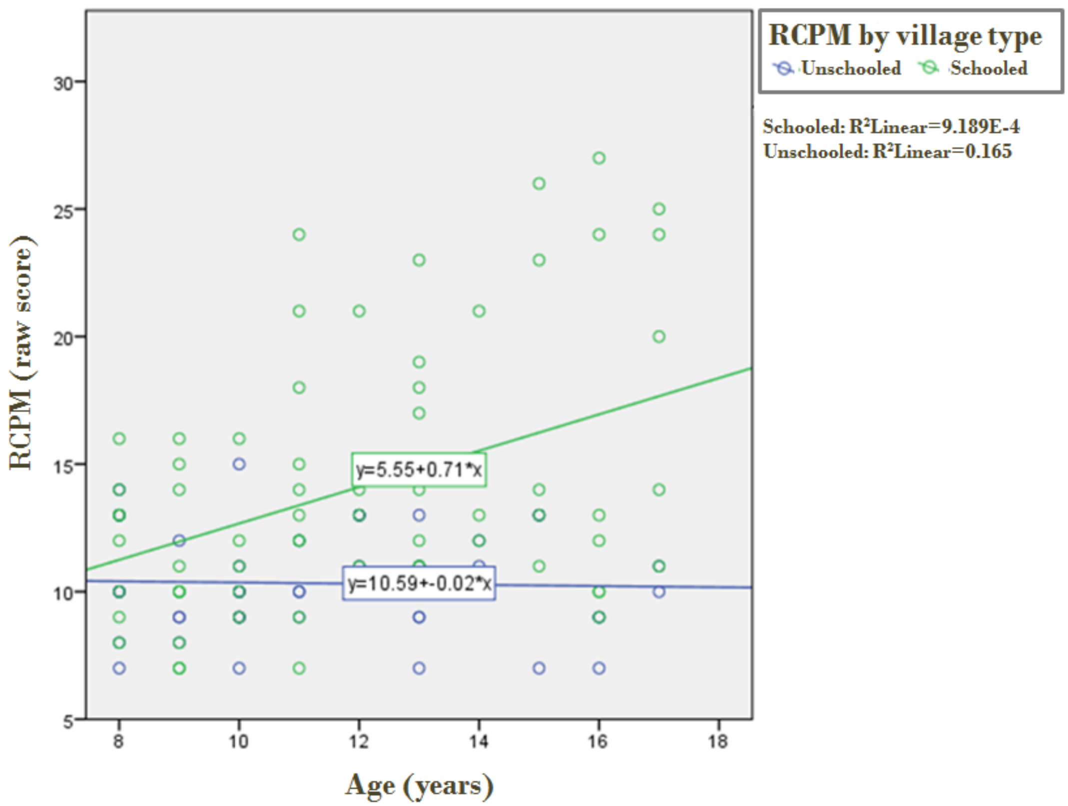

Figure 3.1: Scatterplot of performance on Raven's Colored Progressive Matrices among schooled and non-schooled children ($N = 198$) within three Tsimané villages. The lack of an age effect within non-schooled villages is clearly seen.

Next, to determine whether increased exposure to schooling is correlated with increased performance on cognitive task assessments (H2), we constructed a scatterplot of the entire sample divided by quality of school (Figure 3.2). When all three school types are included in the sample, the *floor effect* among the non-schooled villages becomes far more pronounced. Overall, a consistent age effect exists in the schooled villages, suggesting a dose-response effect.

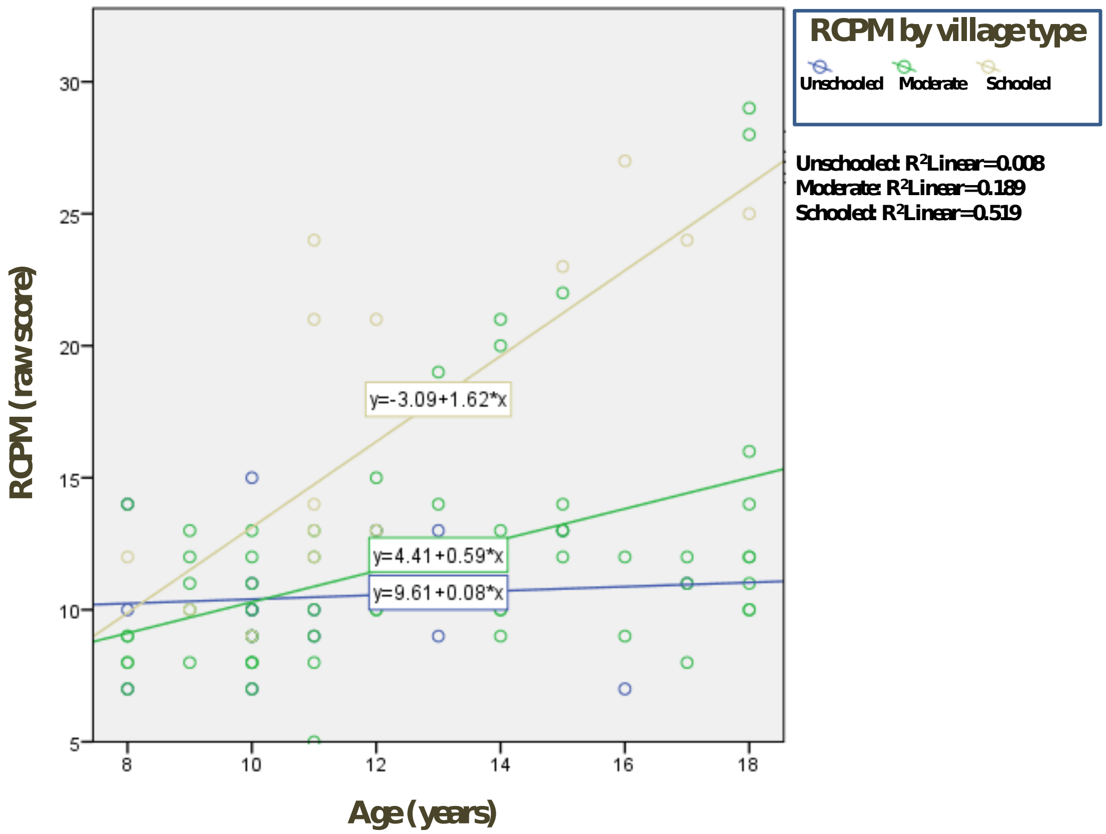

Figure 3.2: Scatterplot of performance on Raven's Colored Progressive Matrices among children in consistently schooled (1), moderately schooled (3), and unschooled villages (2) ($N = 283$). A dose-response effect is seen on Raven's performance where, with more schooling, improved performance was also observed.

Multiple regression analysis was conducted to investigate whether Raven's Colored Progressive Matrices was positively correlated with proficiency in reading and math (H3a), while controlling for confounding variables, such as age and sex. The

Variable	Model 1					Model 2				
	B	SE (B)	β	t	Sig. (p)	B	SE (B)	β	t	Sig. (p)
Age	.262	.073	.187	3.579	.000	.237	.099	.151	2.400	.017
Sex	1.330	.419	.122	2.706	.007	.926	.491	.100	1.888	.061
Level of Schooling	.936	.325	.133	2.879	.004	1.626	.378	.228	4.296	.000
Reading	1.330	.136	.519	9.748	.000	1.300	.163	.507	7.954	.000
Attendance						1.834	.824	.124	2.225	0.027

Table 3.3: Stepwise multiple linear regressions prediction performance on Raven's Colored Progressive Matrices among 273 school-aged children between the ages of 8-18 in villages with variable exposure to schooling

model found that the ability to read was the greatest predictor of Raven's performance, though level of schooling within the villages, and age were also highly significant (Table 3.3). Overall, the model explained a large proportion of variance in Raven's scores, $R^2 = .47$, $F(4, 269) = 58.472$, $p < .000$, and the increase in performance by reading level can be seen in Figure 3.3. Attendance (a proxy for motivation) was then added to the model to test (H3b) whether it had a positive effect on Raven's performance. The results (Table 3.3) show a significant effect of attendance on Raven's. All other variables, with the exception of sex, maintain significance at the $p < .05$ cut-off in the new model. $R^2 = .50$, $F(5, 188) = 36.879$, $p < .000$.

Reading performance was subjected to a univariate analyses of variance (ANOVA) using Bonferroni adjusted alpha levels (.05/4 = .0125). The ANOVA yielded an F ratio of $F(1, 173) = .3.654$, $p < .021$, indicating that the mean score was significantly greater in schooled communities ($M = 1.388$, $SD = .125$) than in non-schooled communities ($M = .818$, $SD = .262$). A main effect of father's ability to speak Spanish yielded an F ratio of $F(1, 173) = 6.843$, $p = .010$, and an age effect persisted $F(1, 173) = 65.378$, $p < .000$; however, neither sex nor father's years of schooling were significant $F(1, 173) = .016$, $p = .901$ and $F(1, 173) = .570$, $p = .451$, respectively. Making Raven's the dependent variable, we tried the model again. This time

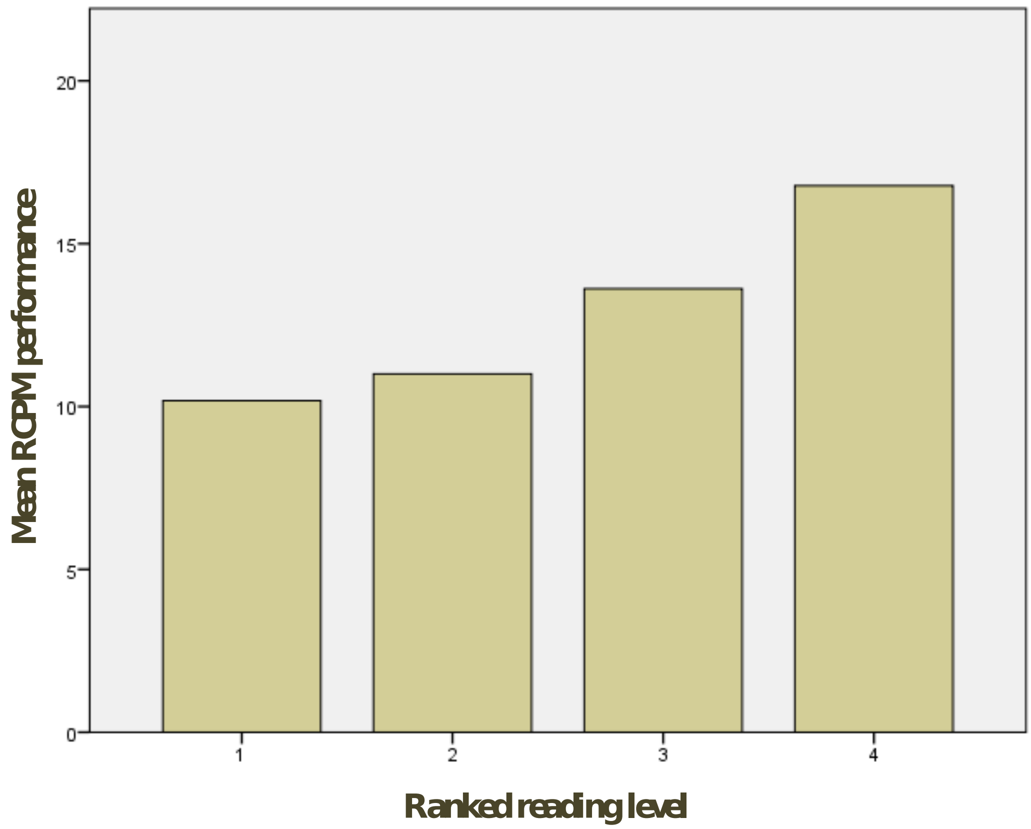

Figure 3.3: Performance on Raven's Colored Progressive Matrices by ranked reading assessment across all six Tsimané villages ($N = 283$).

father's Spanish speaking ability was non-significant $F(1, 172) = 3.284$, $p = .802$ when reading was included in the model $F(1, 172) = 45.896$, $p < .000$. All in all, reading remains the single greatest predictor of performance on Raven's (see Figure 3.3).

Finally, retests were conducted among a subsample of children in both schooled and non-schooled communities. A conceptual model of the testing schematic (Figure 3.4) outlines the testing strategy. At Time 1 a random sample of 80 children was selected with 40 children from schooled villages and 40 from unschooled. Half of each sample (20 children) was then exposed to training (treatment) and half received no training (control). Then all children in the sample were retested to determine if there was a significant difference in performance between children who had received training and those who hadn't, and whether a significant difference existed between the schooled and unschooled sample after training.

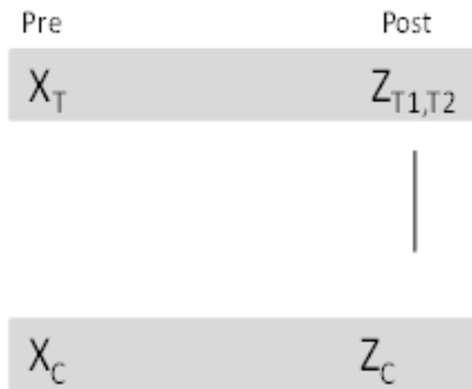

Figure 3.4: Raven's Colored Progressive Matrices (RCPM) retest with and without tutorial. Outline the testing design where X_T = treatment group (half schooled and half unschooled), and X_C = control group (half schooled and half unschooled). After the training (treatment) there are three distinct populations: Z_{T1} = Treated schooled sample, Z_{T2} = Treated unschooled sample, and Z_C = control group.

In order to test whether the populations were significantly different from the control group after training we first needed to determine what test would best fit the question. Because the dependent variable was measured on a continuous scale, the independent variable consisted of matched pairs, there were no significant outliers, and the distribution was approximately normally distributed, an independent T-test was run. The conditions of Levene's Test for Equality of Variances ($p = .957$) is greater than the .05 cutoff, meaning the variability in the two conditions is not significantly different. We can therefore continue with the model. There was a significant difference in the scores for tutorial ($M = 17.28$, $SD = 5.18$) and no tutorial ($M = 13.44$, $SD = 6.26$), conditions $t(94) = -3.586$, $p = .001$. The results suggest that training does have an effect on Raven's performance (Figure 3.5).

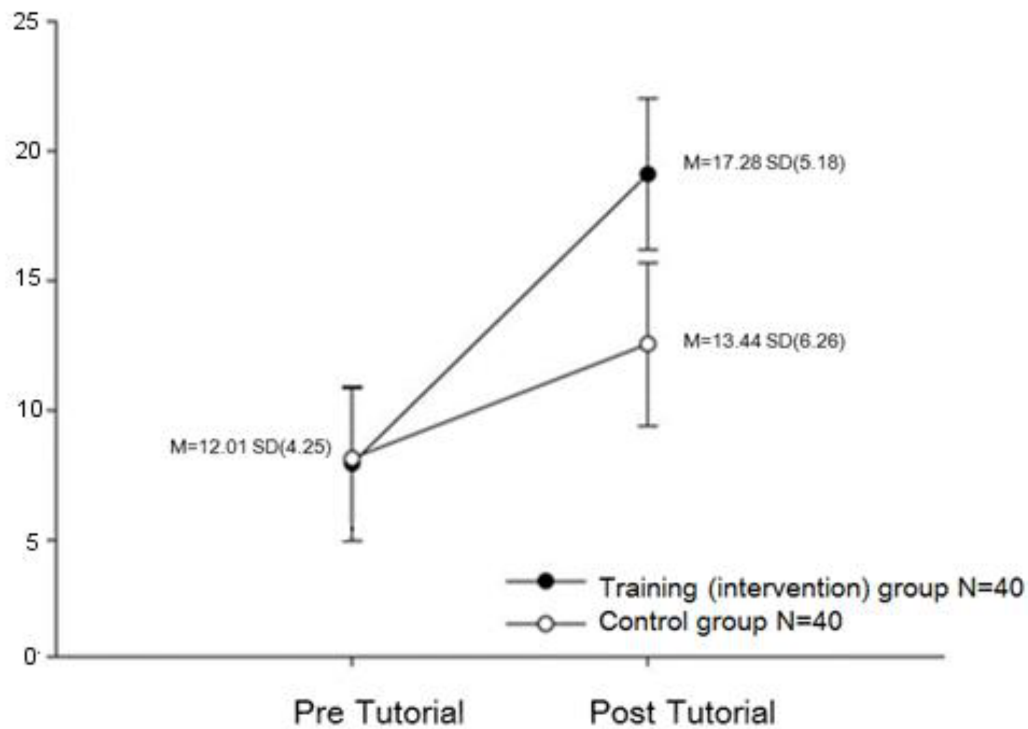

Figure 3.5: Plot of mean performance on Raven's Colored Progressive Matrices (RCPM) for entire sample before training (intervention), and mean RCPM performance of test group and control group after training.

However, this is only focuses on part of hypothesis 4b. We then wanted to know whether Raven's performance after the tutorial was significantly greater among schooled children than among non-schooled. If it is, then we can assume that schooling may have been driving the results of our independent t-test. Our first issue, however, is that once we split the groups by training (treatment) versus non-training (control), and then by schooling versus non-schooling we have fairly small sample sizes, so the sample was tested for normality. The skewness and Kurtosis in moderately and consistently schooled villages was above the suggested z-measures -1.96 to +1.96, and Levene's Test for Equal Variance was (p = .05), so nonparametric data

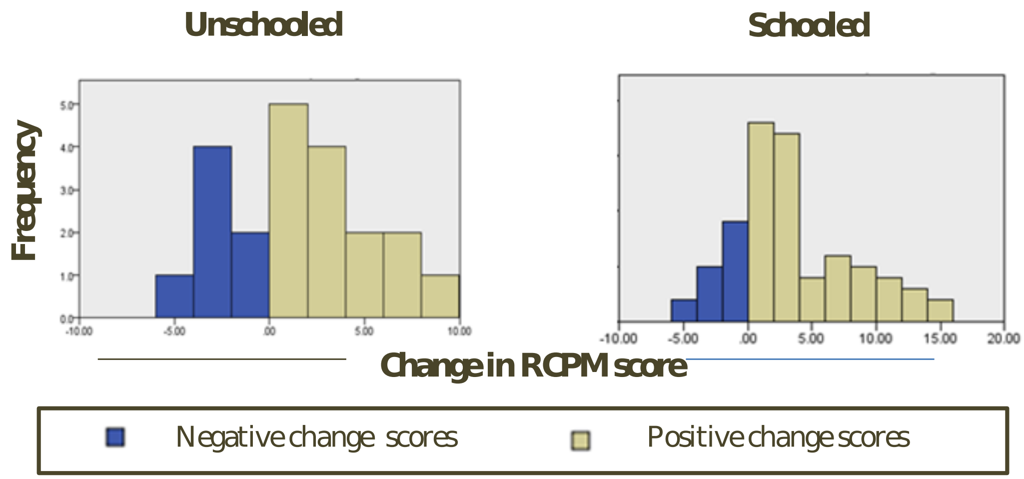

Figure 3.6: Change in Raven's Colored Progressive Matrices (RCPM) performance after tutorial in unschooled ($N = 20$) and schooled ($N = 20$) communities.

analysis is required. A Mann-Whitney test indicated that test improvement was greater for children who lived in schooled villages (Mdn = 27.19) than for children who did not live in a village with a school (Mdn = 16.45), $U = 280.500$, $p = .033$, $r = 40.07$ (where $r = Z/\sqrt{N}$). The change in scores between the initial test and the retest among children in schooled and unschooled villages can be seen in Figure 3.6.

3.7 Discussion

The objective of this paper was to investigate whether exposure to schooling had an effect on individual performance on standardized cognitive task performance tests. We selected the Raven's Colored Progressive Matrices (RCPM) as the standardized test because it is widely considered to be culturally neutral (Raven, 1998). We then developed a number of sub-hypotheses that could explain any observed variation that fit into one of three categories: exposure to schooling, motivation, and the learning to learn effect.

We hypothesized that education could be considered a novel environmental condition or resource, and that (H1) exposure to this novel condition would be positively correlated with an age effect on standardized cognitive tasks. As studies have shown in the past (Ardila & Moreno, 2001; Todd & Wolpin, 2007; Wolf & Stoodley, 2008), access to certain resources has been associated with large performance gaps. The results in this study showed that the Tsimané, though already at the lower end of the educational continuum (see Tables 3.1 & 3.2), had pronounced variation in performance if a school was present in their village. In fact, as we saw in Figure 3.2, there is a dose-response effect between schooling and Raven's performance by age. As children are exposed to more consistent schooling, the variation within and across that population becomes more robust (H2). When schooling is not available, we see a floor effect, with no variation and no age effect.

Building on these first hypotheses we see that, along with the referenced studies (Wolf & Stoodley, 2008; Murayama et al., 2013), attendance (used as a proxy for motivation) and better performance on school based subjects were predictive of Raven's performance. In fact, reading was the greatest predictor of performance Raven's, despite controlling for age and sex. Attendance was also strongly correlated with Raven's performance, though reading was such a strong indicator it might behoove the research to probe the upstream relationship between these variables in greater detail.

Finally, we attempted to probe the relationship between early environment and cognitive outcome (H4a), and the relationship between structured learning, training, and cognitive performance (H4b). Parents' education was correlated with Raven's performance and reading (the greatest predictor of Raven's), suggesting that home environment and parents' own education and level of acculturation contributes to their child's academic success. Because an effect between training and performance has been documented (Denney & Heidrich, 1990), we hypothesized that not only would a training effect be apparent in an intervention experiment, but that those children exposed to schooling would benefit more from the training because they had, essentially, already been trained how to learn. In both these instances, we were able to reject the null that there was no significant difference between the two sample populations. One caveat that should be noted is that nonparametric data analysis was necessary in the cross-community evaluation of training on Raven's performance. Increasing sample sizes would correct these shortcomings.

What these findings suggest is that there is a may be a greater role of culture (in terms of family and community environment), education, and early education experience in the effectiveness of measured intelligence (IQ). This is something that mainstream theories of intelligence are aware of, but often do not approach because of the difficulty in parsing out main effects from confounding factors. Overall, these findings show that some aspect of school exposure, as well as the amount of exposure, has an effect on one's cognitive performance performance. The results are striking at the lower end of the educational continuum where schooling is inconsistent and skill learning years behind western standards. Here we see that even small amounts of exposure to math and reading can have profound effects on IQ scores.

Chapter 4

Path models predict child's performance in school and on cognitive tests.

4.1 Introduction

Cognitive growth is finite, which implies that between-individual differences in limited resources or capacities will not only give rise to individual differences in developmental trajectories, but also at the ultimate level of information processing. In order to understand why the one individual develops differently than the other, one needs to take into account inter-individual differences. First, it has been established that there is a genetic component to individual variation in cognitive ability (McGue et al., 1993; Plomin, 1999; Bouchard & McGue, 2003; Colom et al., 2009; Deary et al., 2010; Karama et al., 2011; Menary, 2013). More recently, school-based skills — namely, math and reading — were shown to be genetically linked to one another (Davis et al., 2014). However, the question of what role environment plays persists, and the results highlight the complex role extrinsic conditions (Flynn, 1987; Bronfenbrenner & Ceci, 1994; Flynn, 1999; Turkheimer et al., 2003; Harden et al., 2007; Flynn, 2009; Mani et al., 2013), including parental investment (Kaplan et al., 2003; Edwards & Ureta, 2003; Chavajay, 2006, 2008), can have on a child's ability to invest in their own cognitive function and educational attainment. This is further complicated by questions of whether attempts to raise IQ through intervention (Herrnstein & Murry, 1994; Blackwell et al., 2007; Jaeggi et al., 2008), improved socio-economic conditions (Turkheimer, 1991; Ceci & Williams, 1997), or formal education and literacy (Ceci, 1991; Neisser et al., 1996; Marks, 2010; Thompson, 2014) are effective. Unfortunately, isolating these variables in regards to their individual efficacy is sometimes difficult in the western world (Turkheimer et al., 2003). However, if we look at the lower end of the educational continuum, where quality and degree of schooling is at its earliest stages in terms of structure and pay off, many issues can be investigated: determining which factors play into decisions related to schooling, investigating how the investment of parents' own embodied capital influences child outcomes, and discerning which factors directly and indirectly affect performance on IQ tests; these can all be addressed in a methodologically and ethically sound fashion.

As shown in Chapter 3, a large gap in performance exists between the Tsimané in schooled and non-schooled communities, the most salient example of this being that no age effect existed within the villages where formal schooling had not yet been introduced. In this chapter we focus on the factors responsible for variation within schooled villages. Because of the nature of this research question, we must focus on villages that have functioning and continually operating schools. The aim of this chapter is to review and test some of the relevant and supported hypotheses that specifically address variation in cognitive performance among school-aged children, particularly in emerging economies. After we discuss the foundational research that was previously conducted, we will use quantitative and qualitative data to test each factor in order to determine if they affect our test population directly, indirectly, or not at all. Specifically, we look at the dependent variables (performance on Raven's and school-based abilities) and how variation in individual characteristics, parental embodied capital, quality of living conditions, and the number of helpers at the nest affect each of the DVs. Each of these will be evaluated with age and sex differences, and their associated biases, in mind.

This chapter is organized into five sections: In the first section we outline the supporting literature for environmental impacts on cognitive performance, and possible reasons for variation in embodied capital investment. In the second section we outline and discuss our path model and the supporting literature that led to the inclusion of each variable within the model. The third section describes the sub-population selected for this study, and presents the results. Finally, the fourth section discusses the implications of the results on the theoretical framework previously discussed in Sections 1 and 2. Finally, part five addresses possible applications of this research to educational development, especially among transitioning populations.

4.2 Section 1

4.2.1 A life history theory framework: education and embodied capital

Physical growth and maintenance can be viewed as types of investment in somatic embodied capital, which includes the time it takes to improve speed and strength, the time it takes to build a strong immune system, and the development of a big brain (Kaplan et al., 2003). This investment gives us the ability to turn experience into improved future performance both for ourselves and our offspring (Kaplan & Robson, 2002; Bock, 2002b; Robson & Kaplan, 2003). From this foundation, the chapter addresses whether the ultimate development of certain cognitive skills differs across time and ecological space, with a specific focus on emergent social influences (*i.e.* market, educational, and parental systems) and environmental conditions (*i.e.* disease load and immune response as measured by child growth and body mass index (BMI)) by developing a general path model of these factors.

Flynn (2012) suggests that improvements in cognitive performance (measured as IQ) across time cannot be explained simply by genetic differences. He argues that environmental factors are robust and puissant contributors to observed improvement over multiple generations. If that is the case, then the difficulty lies in determining what environmental factors shape our cognitive capacity, or, at least, impact cognitive performance measures.

One environmental factor that must be addressed is the introduction of formal education. Though it is now compulsory to have some formal education in most countries (UNESCO, 2006), and serious efforts have focused on reducing the illiteracy rates and providing primary education within emerging economies, huge gaps in education and performance quality persist (King & Hill, 1997; Group, 2012). Bolivia, in particular, has the highest illiteracy rate in Latin America, and large discrepancies exist between urban and rural populations, as well as non-indigenous and indigenous populations (See Table 2.1). Moreover, cultural norms, childcare, family duties, and market labor prospects often make even primary education costly (Ishida, 2004). This high cost deters families in lower socio-economic brackets from providing access to consistent education to children, particularly girls (Behrman & Deolalikar, 1993; Parker & Pederzini, 2000; Pasqua, 2005). Colom et al. (2007) demonstrated vast differences in performance improvements between rural and urban populations within Brazil, suggesting that, even within a relatively small geographic region, slight variation in certain inputs might be responsible for gains in cognitive performance (Flynn, 2007). This chapter develops a model that considers these factors as important individual and family-level differences that may affect observed variation within and across populations by deterring or enhancing investment in education.

4.3 Section II

4.3.1 Path model and supporting literature

Figure 4.1 depicts the path model and factors hypothesized to have direct and indirect effects on individual cognitive performance. Measured (manifest) variables are represented by squares. The construct (latent) variables are represented in the path diagram with circles. A line with an arrow represents an hypothesized direct relationship between two variables. That relationship, either positive or negative, is indicated with a light or dark line, respectively.

4.3.2 Family level differences

4.3.2.1 Parental embodied capital

Parental investment strategies impact the quality of their offspring (Kaplan, 1996; Kaplan et al., 2003), and are contingent on the parents' own life histories. Parents with greater lifetime embodied capital — understood here as the accumulation of more income, more education, a greater development of specialized skills, and somatic resources — are better able to invest more in their offspring (Becker, 1981, 1985; Kaplan & Robson, 2002). We predict that parents with greater embodied capital — measured by years of primary education and Spanish-speaking ability, total wealth, and body mass index (used as a proxy for subsistence production) — will invest more in their children, as measured by the total number of each child's younger, dependent

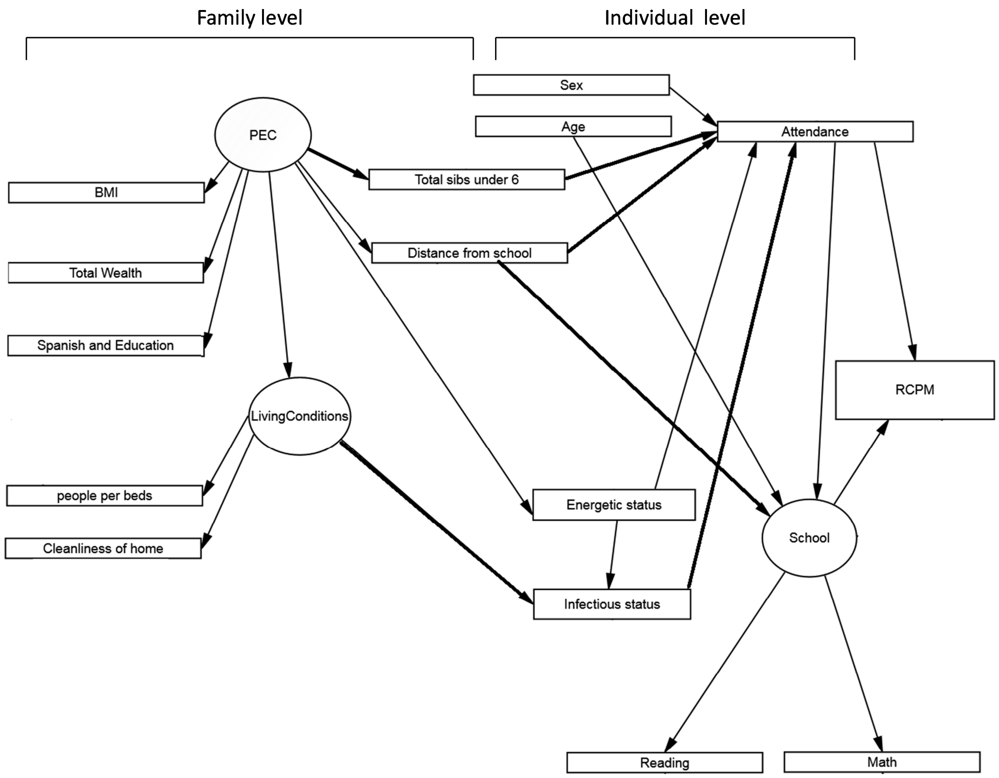

Figure 4.1: A path model of performance on Raven's Colored Progressive Matrices (RCPM).

siblings, and the quality of their home environment.

4.3.2.1.1 Parents' wealth and subsistence production (measured through total family wealth and parental body mass index (BMI))

Because there is an intergenerational transmission of wealth in small-scale societies (Alden Smith et al., 2010; Borgerhoff Mulder et al., 2009), differential investment by sex or birth order is often made (Mace, 1996; Borgerhoff Mulder, 2000; Dunbar, 2002). Additionally, poorer families invest less in their children's education (Gibson & Sear, 2010), and thus place a greater burden on their available mental resources (Mani et al., 2013).

4.3.2.1.2 Parents' education (measured through Spanish-speaking ability and schooling)

Considerable research has shown that if parents have previous exposure to education they are more likely to send their own children to school (Duncan et al., 1972; Featherman & Hauser, 1976; Heyneman, 1980; Ceci, 1991; Lam & Levison, 1992; Neisser et al., 1996; Heineck & Riphahn, 2007; Ceci & Williams, 1997; Lam & Duryea, 1999; Dickens & Flynn, 2001; Daley et al., 2003; Colom et al., 2005; Ceci & Papierno, 2005; Colom et al., 2007) Furthermore, parents with greater embodied capital will invest more into their children's embodied capital. Education capital is cumulative and environmentally sensitive (Cromer, 1993; Hart & Risley, 1995; Barro & Becker, 1989; Nonoyama-Tarumi & Ota, 2011; Lareau, 2011), suggesting that any net increase in a child's embodied capital is input dependent and depends heavily on the quality of parental input (Hart & Risley, 1995; Kaplan et al., 2003), and educational inputs (Anderson et al., 2001).

Debate has centered on how to characterize the relationship between intergenerational transfers of educational attainment and cognitive performance. With the variables listed above, we suggest direct and indirect relationships through the following hypotheses:

(H1) Parents who score higher on measures of embodied capital will have fewer young, dependent offspring.

(H2) There is a positive relationship between parental embodied capital and overall attendance rates.

(H3) Parents with low embodied capital will have a lower quality home environment.

4.3.2.2 Siblings

In most modern populations we see a trend towards reduced family size, which in turn allows more allocation of the family's resources to each dependent (Blau, 1967; Sewell et al., 1969; Sewell & Hauser, 1972; Kaplan, 1996; Angrist et al., 2005); pre-industrialized societies show a clear, positive relationship between reproductive success and resource abundance (Kaplan & Hill, 1985; Chagnon, 1988; Low & Clarke, 1992), with women's work generally organized around childcare (Hurtado & Hill, 1990; Hurtado et al., 1992; Lancaster & Kaplan, 2000; Kaplan et al., 2003). Parents with multiple young, dependent offspring require assistance from older children (Turke, 1988; Bock, 2002a; Bove et al., 2002; Kramer, 2002; Stieglitz et al., 2013; Mattison & Neill, 2013), particularly females (Hames & Draper, 2004; Stieglitz et al., 2013); these families benefit more readily (higher fertility and child survival) when children stay and work in the homes (Crognier et al., 2002).

We hypothesize:

(H4) Children with more young dependent siblings attend school less.

(H5) More young, dependent siblings will have a negative impact on children's school-based abilities.

4.3.2.3 Differential investment by sex and age

Becker (1981) posited that parents tend to invest more in higher-quality children because these are the offspring who are more likely to reap reproductive and inclusive fitness benefits across the lifespan. In the developing world, daughters typically deliver lower returns than sons, because women aren't able to work in many markets (Pasqua, 2005). Reasons for this pattern involve cultural norms, childcare or family labor requirements, or the nature and location of available labor (typically manual labor requiring travel). Consistent with this pattern, the level of education for girls in most poor or developing countries is still very low (Behrman & Deolalikar, 1993; Bustillo, 1993; Parker & Pederzini, 2001; Herz & Sperling, 2004). Therefore, daughters tend to suffer lower levels of educational investment, *ceteris paribus*, because they will produce the lowest returns from education.

Interestingly, it has been suggested that opportunity costs can be higher for women when their reproductive career begins earlier. Once a woman has children, her options for increasing her relative status decline (Musick & Mare, 2004). With this in mind, women who are not involved in the labor force should continue to have more children, and some do. Countries with a great deal of variability in access to resources show a correspondingly high level of variation in fertility and total completed family size (Omran & Roudi, 1993; Casterline, 2001). Among the Tsimané, the average age of first reproduction is 16 (McAllister et al., 2012), so we might expect a gap in performance based on sex. In addition to a general performance gap within schools, we might also expect to find a sex bias among those sent to school by parents. Previous research has suggested parents can incur large costs from losing helpers at the nest when sending their children off to school, especially when education is not bringing immediate benefits to the family. In fact, families appear to benefit more readily (higher fertility and child survival) when children stay at home and work for their families (Crognier et al., 2002). We hypothesize (H6) that a gap in performance on Raven's by sex will be observed within the sample population, where boys are doing, on average, better than their female counterparts because (H7) boys will have higher attendance rates than females.

4.3.2.4 Living conditions

In addition to family dynamics, other constraints or releasing mechanisms are important considerations for understanding cognitive performance and investment in educational capital, in particular diet and disease exposure. Investigations into variation of cognitive development and task performance within developing populations have provided robust evidence that test performance is related to poor health outcomes due to exposure to infectious diseases (Nokes et al., 1992; Hadidjaja et al., 1998; Abidin & Hadidjaja, 2003; Ezeamama et al., 2005; Venkataramani, 2012) and low quality nutrition (Colom et al., 2005). We hypothesize that children who live in poor living conditions will show lags in weight-for-age (H8), and will exhibit higher rates of morbidity than children from homes with better ranked living conditions (H9).

4.3.3 Individual level differences

4.3.3.1 Morbidity rates and weight-for-age

Looking at Life History Theory, trade-offs between immunocompetence and development in birds, Norris & Evans (2000) found that — although somewhat circumstantial but consistent — immune function was limited by resources. When investing in certain life history components they saw a decrease in overall immune function. Similar patterns have been found in humans. When an individual is under attack from disease, especially during the juvenile phase when cognitive development is crucial for learning techniques and skills for survival, cognitive performance can be drastically impaired (Nokes et al., 1992), and across human populations Eppig et al. (2010) showed trends which suggested that energy used to fight infections lowered cognitive function. They suggested that because both immune function and the development/maintenance of a large brain are energetically costly, impairment was more likely to occur within environments with higher disease burdens. We hypothesize (H10) children who suffer high morbidity rates will attend school less, and (H11) exhibit lower scores on tests of school based abilities.

4.4 Section III

4.4.1 Study population

Among the Tsimané, an Amazonian forager-horticulturalist group inhabiting a vast area of lowland forests and savannas east of the Andes in the Beni department of Bolivia, there are a number of villages becoming rapidly exposed to the market economy. Because an estimated forty percent of school-aged children speak only their mother tongue, these programs attempted to maintain indigenous languages through Intercultural Bilingual Education, or IBE (Howard, 2009). However, despite efforts to increase the number of educators and provisions for school (Jiménez & Vera, 2010), large obstacles regarding access to and continuation of education within Bolivian primary schools persist, seen especially in the low intergenerational social and economic mobility among indigenous Bolivians to date (Davis, 2002; Fundación, 2007; Mayer-Foulkes, 2008).

Results from the first round of analyses suggested that performance in schooled and non-schooled communities could not be compared despite coming from the same cultural, geographical, linguistic, and ethnic backgrounds. In all, six villages were assessed (two schooled consistently, two schooled moderately, and two with little to no schooling), and the results showed a dosage-response effect with the consistency of schooling. Those tested in villages with little to no schooling showed no increase with age on the test ($\beta = .225$, $p = .0923$, $R^2 = .169$), and the greatest predictor of performance across all villages was the ability to read, even when controlling for age and sex ($\beta = .569$, $p < .000$, $R^2 = .469$).

4.4.2 Selection criteria

For this round of analyses, only villages with moderate to consistent school exposure[1], where variation in performance was observed, were used. We plan to use this sample to analyze upstream factors (both intrinsic and extrinsic) hypothesized in the literature to be responsible for observed variation. Only three communities, a total of 180 children, were used for this study. The latent variables in the path model were operationalized (see Table 4.1), and the complete hypothesized path model was developed (see Figure 4.1).

[1] Determined by number of days the school was in session during four field visits, the number of teachers per school, and consistency of records and curriculum.

4.4.2.1 Measuring cognitive task performance

4.5 Section IV

4.5.1 Statistical analysis

Statistical analyses and graphic productions were performed with SPSS (versions 21 & 22), R (version 3.1.1 for Windows (32/64 bit), and LaTex (version $LaTeX2\epsilon$). The ANOVA analyses were performed in SPSS using the univariate option to assess the model of performance on Raven's.

After the model was vetted, multivariate analysis by structural equation modeling (SEM) was executed using AMOS (version 22 for SPSS). Though upstream relationships were established through General Linear Models (GLM), structured equation modeling provides the added advantage of modeling direct and indirect relationships using latent variables and can also account for measurement error (Ullman, 2006 and references within). The model was specified through GLM Analysis of Variance (ANOVA), and confirmed through exploratory factor analysis (EFA). Even though the model itself was hypothesis driven, ANOVA was not able to evaluate the correlations among predictor and construct variables, allow for specifications of the number of factors on each latent variable, or determine the paths from beginning to end of the model. However, because structural equation models are essentially sets of simultaneous linear equations the constraints must be defined in order to solve the set, and unless the set of equations is identified, correct parameter estimates cannot be derived. Specification of the model required that the Latent Variables (LV), manifest variables (MV), direct effects, indirect effects, and unanalyzed associations be defined. Three latent variables were predicted to have direct and indirect effects on cognitive performance (RCPM). These variables were (1) parental embodied capital (comprised of four manifest variables), (2) living conditions (comprised of two manifest variables), and (3) schooled abilities (comprised of two manifest variables) 4.1. Direct and indirect effects were outlined in the original hypothesized model 4.1. Parameters were specified and computer in AMOS. Fixed, free, and constrained variables were defined in AMOS. Because of the number of sources the data were extracted from, missing data points were unavoidable. To counter this during the structured equation models, full information maximum likelihood (IML) measures used all available data in order to generate maximum likelihood based statistics in AMOS. Goodness-of-Fit was assessed for the overall model and the results are listed below (see Results).

Finally, using a criteria of $p < .001$ we evaluated whether each variable and variable construct were composed of skewed or kurtotic values (see Table 4.2). The variables were mostly normally distributed, but because of the nature of the sample's age group, we needed to standardize many of the measures (in particular weight and height for age); therefore, all of the data were systemically standardized. Only standardized coefficients are reported in the results section of the structured equation models.

4.5.2 Results

4.5.2.1 Descriptives

Sixteen General Linear Models were conducted to develop an empirical understanding of first order upstream variables and their independent effects on Raven's Colored Progressive Matrices, reading, math, and attendance (See Figure 4.2). Each descriptive variable (DV) was first analyzed by age and sex, and then hypothesized influencing factors (taken from the literature) were assessed. Figure 4.2 shows the process used to determine the best fit model for each dependent variable. In the first model for the dependent variable Raven's Colored Progressive Matrices, an ANOVA showed a main effect of reading on Raven's performance, $F(5, 80) = 15.74$, $p = .000$, $\eta p2 = .502$. Once reading was established as the single greatest predictor of Raven's performance, another series of GLMs were conducted to determine the best fit model for determining reading ability. Because all children in the sample were from consistently schooled communities (see footnote under methods), a baseline of education exposure was established by only including children with access to higher quality schools relative to other communities within the sample. The final model with DV reading had a main effect of math performance, $F(5, 80) = 15.33$, $p = .000$, $\eta p2 = .489$). From here we developed another series of models, and with DV math, where attendance and age were the most predictive of math performance. An assessment of DV attendance was made and both parental wealth $F(2, 89) = 3.852$, $p = .036$, $\eta p2 = .124$, and total siblings under the age of six $F(2, 89) = 5.430$, $p = .009$, $\eta p2 = .112$ were shown to have main effects. Wealthy parents were more likely to have attended school for longer periods of time ($p < .01$) and have higher measures of BMI — proxy for subsistence production ($p < .01$) (see Table 4.3). These parents were also more likely to have higher numbers of young, dependent offspring. Wealth and education was also correlated with cleaner homes ($p < .01$) and more beds within the family home, meaning fewer individuals sharing a bed ($p < .01$).

4.5.2.2 Tests of hypotheses derived from the path models

Figures 4.3 and 4.4 depict the successful model predictions tested using structured equation models (SEM). We assess χ^2 to determine the overall model fit, the Root Mean Square Error of Approximation (RMSEA), and the comparative fit index (CFI). Hu and Bentler (1999) suggest a cut-off value for each to determine whether the model is significant. RMSEA values should be below or close to .06. For CFI, values need to be close to 0.95. When the model was first run with the initial hypothe-

Dependent Variable: Performance on RCPM

List of independent variables	Model 1 N=159		Model 2 N=133		Model 3 N=133		Model 4 N=133	
	B (6.092)	P	B (7.793)	P	B (1.502)	P	B (3.934)	P
Age	.556	.000	.647	.000	.090	.572		
Sex	[sex=0] -1.264 [sex=1] 0[a]	.053	[sex=0] -.985 [sex=1] 0[a]	.152				
Distance of home to village school			-.958	.002	-.609	.024	-.963	.007
Attendance					5.391	.003	4.053	.002
Parental wealth							.000	.029
Reading performance					.955	.000	1.280	.000
Math performance					.427	.156		
	R Squared= .110 (Adjusted R Squared=.099)		R Squared= .217 (Adjusted R Squared= .198)		R Squared= .428 (Adjusted R Squared= .406)		R Squared= .565 (Adjusted R Squared= .546)	

Dependent Variable: Reading Performance

List of independent variables	Model 1 N=159		Model 2 N=133		Model 3 N=133		Model 4 N=86	
	B (-2.830)	P	B (-2.529)	P	B (-2.429)	P	B (-2.491)	P
Age	.364	.000	.416	.000	.228	.000	.324	.000
Sex	[sex=0] -1.264 [sex=1] 0[a]	.247						
Distance of home to village school			-.305	.007	-.222	.024	-.151	.002
Attendance					1.359	.041	1.089	.203
Parental wealth							8.22	.774
Math performance					.588	.000	.252	.064
	R Squared= .248 (Adjusted R Squared=.239)		R Squared= .356 (Adjusted R Squared=.346)		R Squared= .523 (Adjusted R Squared=.508)		R Squared= .489 (Adjusted R Squared=.457)	

Dependent Variable: Math Performance

List of independent variables	Model 1 N=156		Model 2 N=133		Model 3 N=133		Model 4 N=159	
	B (-1.821)	P	B (-1.884)	P	B (-2.769)	P	B (-2.860)	P
Age	.271	.000	.308	.000	.302	.000	.266	.000
Sex	[sex=0] -.419 [sex=1] 0[a]	.024	[sex=0] -.274 [sex=1] 0[a]	.166				
Distance of home to village school			-.134	.124	-.135	.119		
Attendance					1.033	.077	1.033	.034
	R Squared= .249 (Adjusted R Squared=.240)		R Squared= .320 (Adjusted R Squared=.304)		R Squared= .327 (Adjusted R Squared=.311)		R Squared= .247 (Adjusted R Squared=.237)	

Dependent Variable: Attendance

List of independent variables	Model 1 (159)		Model 2 N=153		Model 3 N=90		Model 4 N=95	
	B (.814)	P	B (.909)	P	B (.803)	P	B (.897)	P
Age	.000	.951	-.005	.445	.008	.347		
Sex	[sex=0] -.002 [sex=1] 0[a]	.951						
Distance of home to village school			.016	.556				
Parental wealth					-1.20	.034	-1.31	.036
Total siblings under the age of Six			-.037	.002	-.036	.034	-.043	.009
	R Squared= .000 (Adjusted R Squared=.013)		R Squared= .060 (Adjusted R Squared=.042)		R Squared= .118 (Adjusted R Squared=.088)		R Squared= .112 (Adjusted R Squared=.091)	

Figure 4.2: General Linear Models conducted to determine best fit model for each DV.

Table 4.1: Coding scheme for path model variables

Variable	Measured	Operationalization
Child's Age		
Child's Sex		0 = girls 1 = boys
Performance on RCPM	scale of 1-36	
Attendance	% of time present during risk set	0 = does not attend school 1 = attends school
Reading		0 = cannot read at all 1 = recognizes letters and can sound out letters or parts of words 2 = pronounces 1-2 words 3 = can read complete sentences 4 = can read completely and fully with almost perfect comprehension 5 = can read with perfect comprehension
Math	# of correct answers in the problem sets	
# of siblings	# of dependent siblings below school age (≤ 6)	
Child's energetic status	BMI, growth velocity, weight-for-age	
Child's infectious status	# of chronic & acute illnesses during medical visit coded with IDC-10 codes	
Cleanliness of home (interior)		0 = clean (no fecal matter) 1 = little fecal matter present 2 = some fecal matter present 3 = much fecal matter present
Cleanliness of home (exterior)		0 = clean (no fecal matter) 1 = little fecal matter present 2 = some fecal matter present 3 = much fecal matter present
# of people per beds in household	# of total beds divided by total people in household	
Parents' subsist. production	BMI	
Spanish speaking		0 = speaks no Spanish 1 = has little comprehension 2 = has some comprehension 3 = has full comprehension
Parents' wealth	summary of income earned and household material wealth[a]	
Parents education	# of years mother and father attended school	

[a] Standardized pricing in 2010 Bolivianos.

TABLE II: Descriptive statistics for measured variables

Variable	M	SD	Skewness β	Skewness SE	Kurtosis β	Kurtosis SE
Child's Age	11.975	3.937	.370	.147	.554	.293
Child's Sex	283					
Performance on RCPM	12.825	5.024	1.419	.161	1.540	.320
Attendance	.735	.294	-1.512	.187	1.444	.373
School[a]						
Reading	1.37	1.79	.811	.186	-.956	.370
Math	1.20	1.32	.372	.186	-1.663	.370
# of Siblings under 6	1.185	1.189	.632	.144	-.198	.287
Child's energetic status (BMI)	.002	.013	-2.232	.170	20.588	.338
Child's infectious status	1.139	.514	1.141	.158	3.143	.315
Living Conditions[a]						
Cleanliness of home[b]	1.91	1.71	.619	.201	-.379	.399
# of beds per family member	2.61	1.27	-.047	.205	-.326	.407
Parent Embodied Capital[a]						
Total years in school	3.94	1.35	.179	.206	-.819	.410
Father's BMI	24.751	2.603	.446	.151	.073	.301
Mother's BMI	24.342	2.569	.347	.149	-.328	.297
Parental Wealth	8804.13	4574.99	.526	.237	-.755	.469
Ability to speak Spanish	1.81	1.00	.442	.189	-.480	.376

[a]construct variable
[b]combined interior and exterior

Table 4.2: Descriptive statistics for measured variables

TABLE III: Pearson's Correlation coefficient among indicator of parental embodied capital and family living conditions in the path model ($n = 170$)

	Total siblings under age six (1)	Parental embodied capital: Parental wealth (2)	Parental embodied capital: Total years in school (3)	Parental embodied capital: BMI (4)	Parental embodied capital: Ability to speak Spanish (5)	Living conditions: Cleanliness of home (6)	Living conditions: Number of beds per family member (7)
(1)	1						
(2)	.054	1					
(3)	**.199**[a]	**.235**[b]	1				
(4)	**-.140**[b]	**.218**[a]	.080	1			
(5)	.049	**.237**[a]	**.694**[a]	**.281**[a]	1		
(6)	-.037	**.205**[b]	**.298**[a]	.018	**.249**[a]	1	
(7)	-.042	**.271**[a]	**.240**[a]	.084	.144	**.376**[a]	1

[a]Correlation is significant at the 0.01 level (2-tailed).
[b]Correlation is significant at the 0.05 level (2-tailed).

Table 4.3: Pearson's Correlation Coefficient among indicators of parental embodied capital and family living conditions in the path model ($n = 170$)

ses listed (see Figure 4.1), we determined the model was not a good fit ($p < .001$, RMSEA = .08, CFI = .623). Upon further investigation we determined that certain factors in variable labeled Energetics Status (including peak weight velocity and BMI) had unexplained covariance with living conditions and infectious status. Furthermore, sex and age, once nested in the larger model, no longer predicted increased attendance or performance on Raven's. Further, we established that multiple SEMs would need to be run to fully address all of the hypotheses. Below are the results for the following models: (1) All children within schooled villages, (2) Children who live in schooled villages and attend school (where attendance > 0), and (3) Children who live in schooled villages and attend school by sex.

4.5.2.2.1 Structured Equation Model 1: All children within schooled villages

Age was adjusted from the initial model by an assigned direct effect on school abilities. In this model distance from school and number of siblings had no significant effect on attendance, nor did sex on attendance ($B = .122$, $p = .114$ and $B = .055$, $p = .445$, respectively). Further, attendance had no direct effect on Raven's performance ($B = .030$, $p = .600$). As stated above, both REMSEA and CFI measures suggested the original hypothesized model which included these variables was not a good fit. These variables were removed from the model, and the final path model for this sample population is shown in Figure 4.3 and Figure 4.4. This model was a much better fit ($\chi^2 = 283.224$, $p < .001$, RMSEA= .06, CFI= .896). Direct and indirect effects for this model are summarized in Tables 4.4 and 4.5, respectively. Parental embodied capital had a direct positive effect on living conditions ($B = .988$, $p = .001$), and in turn, living conditions had a direct negative effect on child's infectious status ($B = -.403$, $p = .001$). Parents' BMI and parental wealth were both highly correlated with child's energetic status (BMI) ($p = .045$ and $p = .051$). Infectious status ($B = -.161$, $p = .036$) was negatively correlated with attendance, meaning that those with higher rates of morbidity were less likely to attend school. Energetic status was a predictor of increased attendance ($B = 1.586$, $p = .054$).

TABLE IV: Effects of predictors on (1) RCPM and (2) Schooling among all children within schooled villages

	Raven Std. β			School Std. β		
Predictor	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect
School	**.782**^{a}	—	**.782**^{a}	—	—	—
Attendance	—	—	—	**.236**^{a}	—	**.236**^{a}
Infectious status	—	**-.124**^{b}	**-.124**^{b}	**-.091**^{b}	**-.038**^{b}	**-.129**^{b}
Living conditions	—	.050	.050	—	.052	.052
Parental embodied capital	—	**.058**^{a}	**.058**^{a}	—	.041	.041
Siblings	—	—	—	—	—	—
Sex	—	.—	—	—	—	—
Age	—	—	—	—	—	—

$^a p < 0.01$
$^b p < 0.05$

Table 4.4: Effects of predictors on (1) RCPM and (2) Schooling among all children within schooled villages

TABLE V: Effects of predictors on (1) RCPM and (2) Schooling among children attending school within schooled villages

	Raven Std. β			School Std. β		
Predictor	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect
School	**1.00**^{a}	—	**1.00**^{a}	—	—	—
Attendance	**.134**^{a}	**.186**^{b}	**.321**^{a}	**.184**^{a}	—	**.184**^{a}
Infectious status	—	**-.098**	**-.098**	**-.098**^{b}	—	**-.098**^{a}
Living conditions	—	.026	.026	—	.026	.026
Parental embodied capital	—	-.103	-.103	—	-.091	-.091
Siblings	—	**-.059**^{b}	**-.059**^{b}	—	**-.034**^{b}	**-.034**^{b}
Distance	—	-.187	-.187	**-.185**^{a}	—	**-.185**^{a}
Sex	—	.024	.024	—	.023	.023
Age	—	—	—	—	—	—

$^a p < 0.01$
$^b p < 0.05$

Table 4.5: Effects of predictors on (1) RCPM and (2) Schooling among children attending school within schooled villages

Table 4.6: Descriptives of parental embodied capital by father's age

Father's age	Mean # of siblings (≤ 6)	Mean parents' wealth	Mean father's education (SD)	Mean mother's education (SD)	Mean father's Spanish (SD)	Mean mother's Spanish (SD)	Mean father's BMI (SD)	Mean mother's BMI (SD)
25-35	1.692	4786.85	2.250 (1.848)	1.882 (1.495)	1.468 (.500)	.667 (.493)	23.018 (1.223)	24.140 (2.301)
36-45	1.504	7403.01	3.242 (1.930)	2.032 (1.835)	1.438 (.509)	.6101 (.635)	25.238 (2.936)	24.153 (2.683)
46-55	.913	11700.00	2.667 (2.495)	1.66 (2.035)	1.235 (.538)	.620 (.529)	25.333 (1.698)	24.690 (2.463)
56-65	.222	12111.12	1.100 (.876)	1.000 (1.038)	.725 (.399)	.391 (.347)	25.377 (2.429)	24.778 (2.660)
>65	.4667	3609.24	.1667 (.289)	.000 (.000)	.687 (.543)	.066 (.141)	21.160 (.666)	23.677 (2.082)

4.5.2.2.2 Structured Equation Model 2: All children within schooled villages who attend school

The second SEM model excluded students who did not attend school during the month prior to the date the test was administered (attendance > 0). The final path model is shown in Figure 4.3. This model's goodness-of-fit measures were acceptable with $\chi^2 = 212.184$, $p < .000$, RMSEA=.051, CFI=.848. Standardized direct and indirect effects are shown in Table 4.5. Most notable in this model was the need to remove BMI due to no effect on attendance and school performance; however, infectious status was still a significant predictor of attendance ($B = -.098, p.044$). Parental embodied capital had a direct positive effect on number of siblings under the age of six ($B = .464, p = .002$), and there was also a direct positive effect of parental embodied capital on distance from school ($B = .506, p = .001$). Father's age was correlated with all variables used to create our PEC construct variable (see breakdown by father's age in Table 4.6), but, though older fathers had more wealth, they had fewer children under the age of six, were less likely to speak Spanish, and had fewer years of schooling.

As in the hypothesized model we see a direct negative effect on attendance by number of younger siblings ($B = -.183, p = .022$) and a direct negative effect on distance from school and attendance rates ($B = -.185, p < .000$). Finally, attendance had a direct positive effect on Raven's performance ($B = .136, p = .026$).

4.5.2.2.3 Structured Equation Model 3: All children within schooled villages who attend school by sex

The purpose of the third SEM (not shown) was to determine whether more younger siblings would have a stronger direct negative impact on girls attending school than boys in our sample. There was a greater negative effect of younger siblings on girls' attendance rates ($B = -.674, p < .001$) and school based abilities ($B = -.180, p = .021$). Boys did not exhibit significant associations with either variable.

4.5.2.3 Overall findings in all structured equation models

In all of the models, schooling has the strongest direct effect on Raven's. Parental embodied capital and age had the strongest indirect effects on Raven's performance. Like the GLM models, attendance and age had the strongest direct effects on school abilities.

We hypothesized (H1) that parents with higher embodied capital would have fewer young, dependent offspring, but much in line with McAllister et al.'s (2012) results, it appears that despite more education, more material wealth, and greater overall subsistence production, these parents have more children. Even though trends toward smaller families in the developed world have been seen, and patterns of lowered fertility have been shown in a nearby market town (Snopkowski & Kaplan, 2014), the Tsimané continue to have larger families. This may help explain the curious result of wealth as a negative correlate with attendance in the initial analyses. Parents who had greater wealth are having larger families, and larger families were negatively correlated with attendance rates.

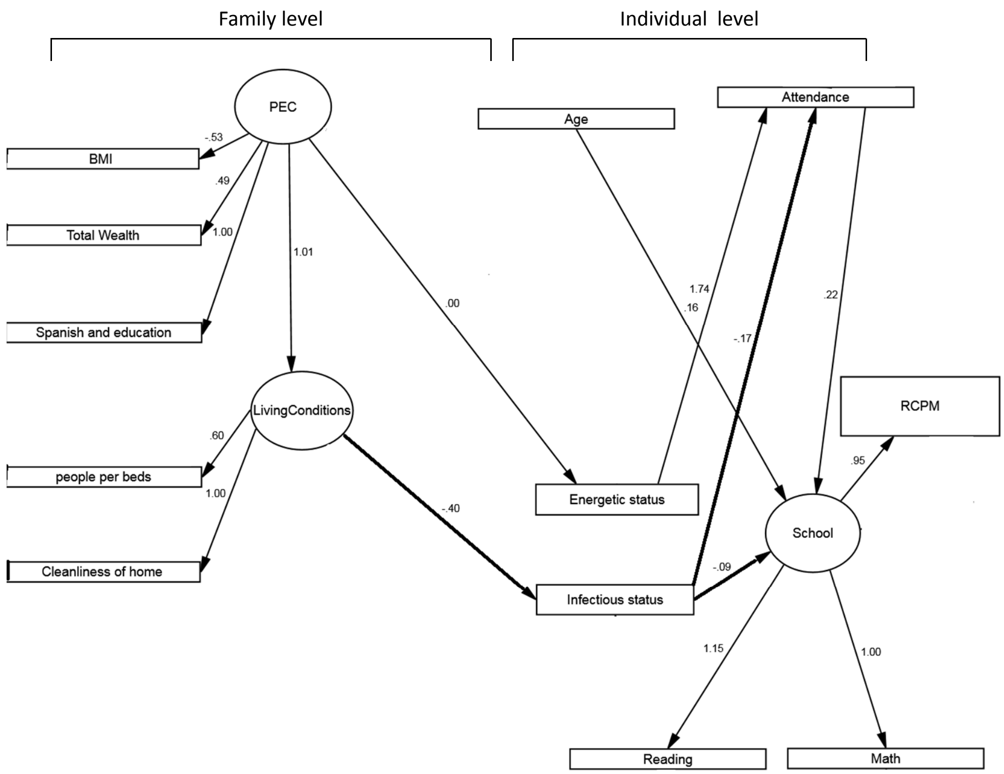

Figure 4.3: Results from path analysis among all students within schooled villages ($N = 298$). Standardized path coefficients listed for each related variable. Line thickness indicates significant negative path coefficients.

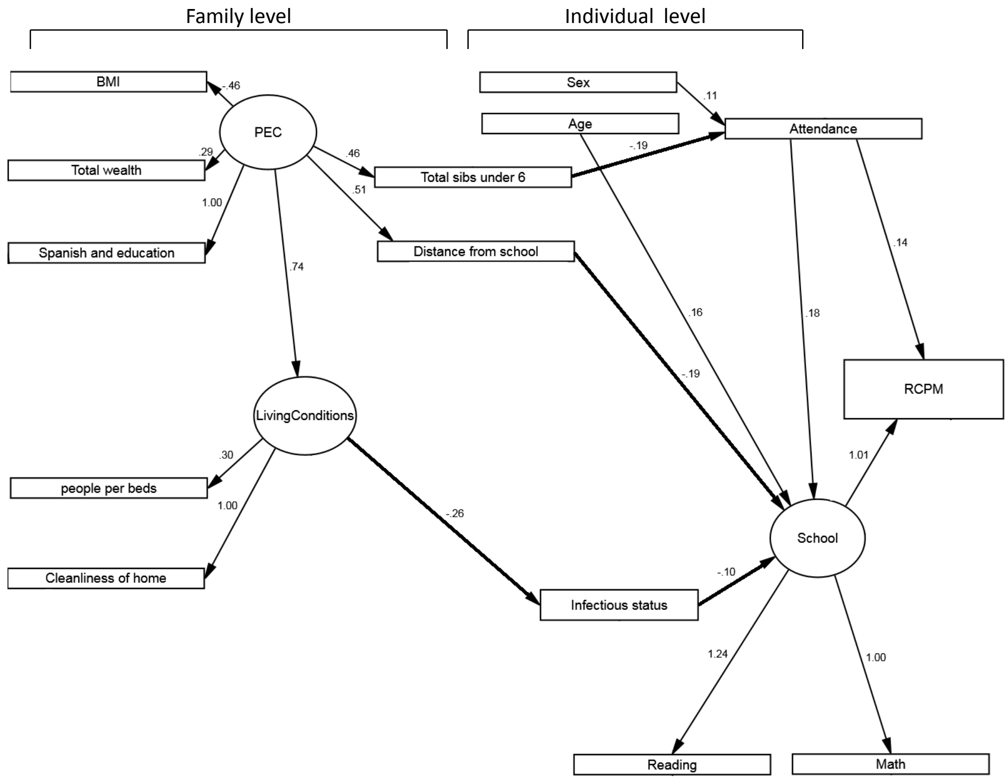

Figure 4.4: Results from path analysis among students in schooled villages sub-sample (only children who attended school within 30 days prior to testing (N = 223)). Standardized path coefficients listed for each related variable. Line thickness indicates significant negative path coefficients.

An indirect, and somewhat weak, relationship helped to support the second hypothesis that PEC would be correlated with increased rates of attendance ($B = 0.136$), and was mediated through child's infectious status and the number of dependent younger siblings. Though it was not a strong indirect effect, it does suggests that parents with more education are more likely to invest in their child's education which follows much of the literature already published on parental investment in children's education ((Kaplan & Lancaster, 2003) and references within). We also hypothesized that (H3) parents with low embodied capital would provide a lower quality living environment. The overall effect showed that higher embodied capital scores were associated with better scored living environments ($B = 1.055, p = .003$). The standardized total direct effect of parental embodied capital (PEC) on living conditions was .867.

Parents with multiple young dependent offspring have been shown to need helpers at the nest (Bock, 2002b; Kramer, 2005a; McKay, 2008; Stieglitz et al., 2013; Mattison & Neill, 2013). Females get the brunt of this work (Hames & Draper, 2004; Stieglitz et al., 2013), and when school is a possibility, older daughters often suffer from lower attendance rates (Bock, 2002a). These data did not show that younger siblings had a significant effect on attendance among older non-dependent children in general. However, reanalyzing the path model by sex (not shown), showed siblings had a significant negative effect on girls' attendance rates ($B = -.674, p < 001$) and school based abilities ($B = -.180, p = .021$). This result failed to support our fourth hypothesis that *all* children's attendance rates would suffer with more young, dependent offspring; however, girls showed a decreased attendance rate and performance on school based abilities. The sixth hypothesis was supported by a sex effect on school abilities ($B = .197, p = .023$). Boys are, on average, performing better than girls on reading and math. Notably, the effect is driven by older students in the sample. When the sample is divided into cohorts of only older children, ones with more gender-specific responsibilities as they near puberty (Bock, 2002a) show a sex effect on school-based abilities.

We evaluated the relationship between health and Raven's performance. Initial research suggested there was a Wald point estimate for parasitic infection was 1.143 with confidence limits at 0.799 and 1.634. Additionally, it was shown that significantly more children were infected than adults, and the heavier the parasite burden, the worse they did on school-based abilities across the sample. Taking this analysis a step further, an evaluation of measures of the children's overall infectious status (both acute and chronic illness). We also looked at whether living conditions played a role in determining infectious status. Ultimately, weight and peak weight velocity had to be removed from the model because they were unsuitable; however, there was a strong direct negative effect on infectious status (morbidity) as living conditions improved ($B = -.674, p < .000$). Overall, the results on energetic status (BMI, peak weight and height velocity, and weight-for-age) warrant further investigation because sampling size (namely ensuring that the data points had been taken within one calendar year of the date the test was administered) reduced the N significantly, and that (given the other constraints of the model) may have caused some of the non-significant result.

4.6 Section V

4.6.1 Discussion

The models help begin to unravel a somewhat complicated story. Parental embodied capital appears, in some ways, to be a double-edged sword for children going to school at the lower end of the education continuum. Getting to school is the first hurdle, and the data suggest that parents with more wealth and education (see Table 4.6) have living conditions that are cleaner and have more resources, such as more beds per household. As the structured equation models showed, these variables are directly, negatively correlated with a child's infectious status which in turn is negatively correlated with attendance. What this suggests is that parents who provide a better living environment have healthier children who can go to school. The first path model (see Figure 4.3) gives some insight into what might be driving a child's ability to attend school at all. Moreover, these factors all directly and indirectly affect the final outcome on RCPM. Performance is mediated by parental embodied capital through their living conditions and their resulting health status. To put it succinctly, healthier children go to school, and wealthier, better-educated parents play a large role in their child's improved health status.

However, once a child does attend school (Figure 4.3), what determines how often they go? Models of intergenerational labor allocation and conflicts of interest within the family unit suggest that such conflicts, especially related to maximizing parental fitness, do arise (Trivers & Willard, 1973; Becker, 1981; Lee & Kramer, 2002; Gurven & Kaplan, 2006; Stieglitz, 2010). We see evidence of that in the model as well. Parents with greater EC are having more children, and older kids, especially daughters, attend school less and have lower scores in school-based skills. This is predictive of performance on RCPM, which suggests that, within the context of cognitive functioning and formal schooling, the extent of individual educational investment differs by quality and degree. Within a particular environment, this is due, in part, to that environment.

Chapter 5

Conclusion

5.1 Summary of results

5.1.1 Village variation: Schooling and Raven's Colored Progressive Matrices

Because the Tsimané , like many populations in the developing world, are experiencing rapid transitions into the market economy, they provide a unique opportunity to investigate variation in cognitive performance as a function of schooling. In Chapter 3 we find evidence that exposure to schooling drastically effects performance on the Raven's Colored Progressive Matrices cognitive test. The data suggest that within a population with cultural, genetic and linguistic similarities there are vast differences between villages when measuring cognitive task performance. In fact, there appears to be dose-response effect between schooling and Raven's performance by age. Children with exposure to more schooling performed better on Raven's, while non-schooled communities had no age effect at all. Attendance (used as a proxy for motivation) also proved predictive of improved performance on school based subjects, and Raven's performance. Reading was the greatest predictor of performance Raven's, despite controlling for age and sex. Attendance was also strongly correlated with Raven's performance. These findings suggest that reading, or pattern recognition, could be fundamentally affecting the way an individual problem solves or learns to learn, and is somehow tapping into 'g'. Presumably the only way to learn to read is through schooling. It is, therefore, essential that children are exposed to formal education, have the motivation to go/stay in school, and are exposed to consistent, quality training in order to develop the skills associated with improved performance.

Furthermore, a number of questions concerning the validity of cognitive tests when used cross-culturally are apparent. For example, no child mastered the test during this research. In fact, the highest score logged within the entire sample population was an 18 year old female who scored 31 out of 36. According to the creators of the test children are supposed to score 100% correct by the age of 11. The results of the study raise interesting questions about the importance of determining a consistent baseline among the sample populations before comparing groups.

5.1.2 Training to the test

The relationship between structured learning, training, and cognitive performance was seen when a subsample of students was retested, half trained and half acting as the control. Training was correlated with test improvement on the retest, which was not surprising. However, those children who were exposed to schooling showed greater overall improvements on Raven's retests than children in non-schooled communities.

We hypothesized that, not only would a training effect be apparent in an intervention experiment, but that those children exposed to schooling would benefit more from the training. All children did show improvements on the test, however, those exposed to consistent schooling out performed the non-schooled children by greater than 1SD from the mean improvement score. This would suggest that one's learning environment can affect performance on cognitive tests.

5.2 Future research

The Tsimané, like many populations in the developing world, are experiencing rapid transitions into the market economy. The research conducted within this population has implications for both theoretical and applied work; however, more research is needed. Other factors, such as sex, birth order, differential parental investment, and health profiles might play a large role in individual differences. For instance, during early and middle childhood, sex differentiated social behaviors begin to emerge (Crognier et al., 2002). Investigating this with the Tsimané might reveal that girls begin to work more around the home, developing child-rearing skills and hindering their ability to attend school. Furthermore, the use of comprehensive demography and health data would help compare the cognitive performance among siblings, half-siblings, and first cousins in the same villages, and within other communities. These data can provide insight into the ecology of cognition and how development can adjust to variation within a given environment, further shedding light on theoretical questions about our human life history.

5.2.1 Parental embodied capital, living environment, and implications for child health and educational performance

With the application of formal education rapidly occurring in many populations in the developing world, this represents a unique opportunity to continue to explore issues related to how human educational capital is valued in terms of cognitive development and educational performance. The investment in education among Western societies has shown numerous interesting trends throughout the 19^{th} and 20^{th} centuries (Flynn, 1987; Ceci, 1991; Flynn, 1999; Blair et al., 2005; Flynn, 2007), and recent research in developing countries suggests there might be little reason to expect the process will be substantially different (Colom et al., 2007).

From the results we see that there is, in fact, an effect on school and Raven's Colored Progressive Matrices performance due to parental embodied capital, and that can be positive or negative. Getting to school is the first hurdle, and our data suggest that parents with more wealth and education provide better living conditions for children, who, in turn, are healthier. Those children who are sick more often attend school less and performed poorly.

There are also issues with task-delegation, age, and sex. Boys attend school more often and older girls are more likely to stay home when they have more younger siblings. Education is an investment in human capital, which may be producing direct benefits in the form of employable skills, but also provides indirect benefits in the form of status signaling within a community. The sex difference we observed may be explained by the fact that, in addition to general intelligence, more males participate in market exchange and, therefore, garner greater returns from formal education at the lower end of the educational continuum, while parents continue to use their daughters' labor to help with siblings while they are still living in the family home.

5.2.2 Parental investment and child self-selection

Carrying out further analysis of parental investment in the developing world would require measuring the social and economic benefits accruing to a parent based on investing (at a net cost to themselves) in the educational development of their children. Admittedly, some of these effects are difficult to measure and would ideally involve longitudinal designs, but the work shown here has some positive results. Another issue to consider in the future is what decisions children are making about investments in their own education (Willis 1979, Mayer 2008). Drawing again from the Embodied Capital Model (ECM) — (Kaplan et al. 2000; Kaplan et al. 2003) — children may be considering a myriad of factors concerning the costs and benefits of engaging and investing in schooling (*i.e.*, wages, status, lifetime reproduction, health and access to different resources). By using longitudinal data it would be possible to determine whether children who performed poorly at Time 1 were more or less likely to still be attending school at Time 3. Interviews with children about their own priorities might also give insight into whether or not they are making conscious decisions about school attendance.

5.2.3 Parental preferences

Parental preferences (based on sex, birth order or on individual performance) may be driving some of the variation we see, at least in schooled communities. Future areas of research could include interviewing parents and allowing them to rank order their children based on skill sets and their opinions on educational importance. Assessing attendance, task-delegation, and family conflicts based on sex of the child and birth order would also aid in understanding inter-family variation both in school and on IQ tests.

5.2.4 The role of genetics in cognitive performance

Finally, developing a genetic design in order to tease apart correlations between heritability, health, and environmental effects contributing to cognitive development and function in children would be useful. The use of comprehensive demography and health data will help compare the development of siblings, half-siblings and first cousins who are linked in same villages and within different villages. Variation in school performance and health indices of children, their parents and parents' siblings will be measured to determine how disease load and distribution compromises development. Linking the PEC model with heritability data would help to further probe the contributing genetic components associated with individual intelligence. Such data can provide insight into the ecology of cognition, thereby shedding light on theoretical questions about our human life history.

5.3 Conclusion

It's not difficult to imagine that one child is born slightly smarter, slightly faster, or slightly more insightful than another. It would suggest that genetic variation alone explains much, if not all, of the observed variation in cognition. Heritability has been well established as a contributing factor to IQ (Iacono & Lykken, 1993; Plomin, 1999; Jensen & Rushton 2005), however, what this dissertation has shown is that the baseline is the starting block, not the finish line. Environment matters; and, it matters a lot. Access to resources, adequate public health, and consistent schooling provide each child with stepping blocks, raising the baseline slowly.

But, it's not just a matter of infrastructure. It's also a matter of investment, both for children and parents. Delineating the two views of educational investment — increasing functional skills and increasing status — requires looking at problem as a continuum rather than a binary outcome or strategy. With the application of formal education rapidly establishing programming throughout the developing world, it is important that as researchers we recognize that research in this field has practical applications in addition to theoretical interest.

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