LEARNING, LIFE HISTORY, AND PRODUCTIVITY: CHILDREN'S LIVES IN THE OKAVANGO DELTA, BOTSWANA

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ABSTRACT

This paper introduces a new model of the relationship between growth and learning and tests a set of hypotheses related to the development of adult competency using time allocation, anthropometric, and experimental task performance data collected between 1992 and 1997 in a multi-ethnic community in the Okavango Delta, Botswana. Building on seminal work in life history theory by Hawkes, Blurton Jones and associates and Kaplan and associates, the punctuated development model presented here incorporates the effects of both growth and learning constraints on age-specific task performance. In addition, the payoff to investment in two forms of embodied capital, growth-based forms and learning-based forms, are examined in relation to features of the socioecology including subsistence economy and family composition.

The three main findings are:

1) The development of adult competency in specific tasks entails a step-like relationship between growth- and experience-based forms of embodied capital in the ontogeny of ability acquisition.

2) There is a trade-off between the acquisition of experience-based embodied capital in the form of skills and knowledge and immediate productivity among children. Time allocation to these alternatives is primarily determined by the short- and long-term costs and benefits to parents of investment in children’s embodied capital.

3) The availability of laborers and the overall labor requirements of the household are major determinants of investment in alternate forms of embodied capital and resulting variation in children’s time allocation. The value of children’s labor to their parents is dependent upon the opportunity costs to engaging in other activities not only for the child in question but for potential substitute laborers.

These results have important implications for our understanding of the role of growth and learning in the evolution of the human juvenile period, as well as for our understanding of cross-cultural variation in child growth and development and patterns of work and play.
INTRODUCTION

In this paper I show that an understanding of the evolution of the human life history can be used to comprehend and interpret the vast variation in the activities of children and children’s role in family and society in different cultures, and how these are influenced by the complex interplay of environment, an evolved psychology of parenting, and family demography and economy. Moreover, these aspects of childhood have important implications for other aspects of social and economic life.

The capacity to be a competent adult

In what ways does the juvenile period relate to adult competence? While there is a diversity of perspectives, a common element is that aspects of the juvenile period are preparatory for competent adulthood in some dimensions. Among anthropologists, there is a long history of viewing children’s work (Whiting and Whiting 1975, Munroe et al. 1984) and play (Lancy 1996) as relating to adult competency in productivity and psychosocial development. This view is shared by educators (Vygotskii 1978), demographers (Caldwell 1980), and psychologists (Leontev 1978, El’konin 1972). Among scholars using life history theory to examine the human juvenile period there are two related perspectives.

The “optimality view”

Hawkes, Blurton Jones, and associates (Hawkes et al. 1997, 1998) have argued, mostly based on Charnov (1993), that the primary selective force which acted to determine the length of the juvenile period in humans is the optimal growth asymptote related to the age at first reproduction. This view, which Blurton Jones and Marlowe (this issue) label the “optimality view” holds that the juvenile period is a period of growth, with other functions on hold until this optimal growth point is reached. The length of the period is epiphenomenal with respect to many other functions such as skill acquisition and learning. As a result, they argue, features of adult capacity unrelated to physical growth should be extremely quick to develop.
The path to adult competency in nonhumans

Framed in this way, this view seems at conflict with much conventional wisdom in biology, psychology, education, and anthropology.

Studies of fish have shown that adult capacity in foraging is related to the intensity of social learning (Pitcher and House 1987, Laland and Williams 1997). Similar results have been obtained in birds (see Wunderle 1991 for a complete review) and the role of developmental constraints is well recognized in delineating juvenile and adult bird foraging (Heinsohn 1991; see Marchetti and Price 1989 for a complete review). Yoerg (1998) has shown that the timing of foraging independence in birds is unrelated to decreases in parental provisioning but rather is related to the acquisition of foraging behavior during the juvenile period. Other studies show that foraging skills in several bird species continue to improve after the age of independent foraging (Davies 1976, Heinsohn 1991, Weathers and Sullivan 1991, Yoerg 1994). Several studies in rats show that social learning is a critical factor in developing foraging related skills and that the frequency and duration of contacts with other individuals are critical factors in determining foraging proficiency (Laland and Plotkin 1990, Galef and Allen 1995). The importance of the juvenile period for the development of skills related to adult competency have long been recognized in studies of nonhuman primates (Fairbanks 1993; see Dolhinow 1999 for a complete review). Johnson (2001) has shown that the difference between juvenile and adult feeding efficiency in free-ranging, wild baboons is far greater for food items which require skill intensive foraging than it is for items that exhibit more body size dependent foraging.

While none of these studies prove that the juvenile period in the life history of these taxa evolved through natural selection for increased exposure to socially transmitted information, the importance of repeated social interactions over a long period of time in the development of foraging skills in several vertebrate taxa is clear.

There is general agreement among psychologists and educators that development of cognitive and memory functions in childhood is related to the acquisition of skills related to adult roles (Eibl-Eibesfeldt 1989; Rubin et al. 1983,
Tudge et al. 1996). However, it could be argued that this is an artifact of the extremely complex skills (written communication, higher math, memorization based learning) prevalent in formal education (Whiting and Whiting 1975). Among traditional populations, the anthropologists Lancy (1996) and Reynolds (1988) both found that the development of skills related to both adult productivity and social roles were extremely time intensive in Liberia and Zambia, respectively. Moreover, there is strong evidence that the acquisition and establishment of higher cognitive functions is slow and requires great effort, and can occur only through sustained formal or informal education (Geary 1995; Gelman 1993, Ericsson et al. 1993, Siegler and Crowley 1994, Siegler 1996).

**Embodied capital theory**

Kaplan and associates (Kaplan et al. 1995, Kaplan 1996, Kaplan et al. 2000, Kaplan and Bock 2001) have proposed a theory of human life history evolution based on returns to investment in embodied capital. This theory integrates human capital theory in economics with life history theory from evolutionary biology by treating the processes of growth, development and maintenance as somatic investments. Investment in embodied capital has two aspects, the physical and functional. The physical payoff to investment in embodied capital is the actual tissue involved. The functional payoff to investment in embodied capital is manifested in qualities such as strength, immune function, coordination, skill, knowledge and other abilities which are based in organized somatic tissue (see Kaplan et al. 2000 for a complete treatment). The total of both the physical and functional aspects of embodied capital can be viewed in relation to the capacity to be a competent adult.

**Growth-based and experience-based embodied capital**

We can further distinguish embodied capital into growth-based forms and experience-based forms. Growth-based forms of embodied capital are attributes like body size, strength, balance, and general coordination. Experience-based forms of embodied capital are attributes such as cognitive function, memory function, task-specific skills, learned knowledge, endurance, and specific coordination. Growth-based forms tend to be more related to general
competency, while experience-based forms tend to be more related to specific competency. The ability to perform any task is comprised of a suite of both growth-based and experience-based embodied capital. Depending on the physical demands and complexity of the task, we can imagine the gamut from those heavily weighted towards growth-based embodied capital to those nearly entirely dependent on experience-based embodied capital, with many tasks requiring hefty portions of both.

For complex tasks there is a threshold of ability which must be reached before we can consider someone able to perform a task. It is possible for a person to have one or two of the necessary forms of embodied capital but still be unable to perform a task. One must achieve a certain level at each of these components before the threshold of ability is crossed. Even after one is able to perform the task at a rudimentary level, depending on the difficulty of the task there may be considerable opportunity for improvement.

**The hunting example**

A commonly used example is hunting (see Liebenberg 1990 for a complete breakdown of the mental and physical demands of big game hunting using traditional technology among Xo people of Botswana). The ability to be a successful hunter consists of many components. One needs to be able to find the prey. This requires substantial knowledge of the behavior and habits of the prey species, including issues such as the effect of time of day and seasonality on abundance. The hunter needs to be able to track animals which often entails examining signs such as partial, obscured, and layered spoor on and across uncertain substrates such as sand, rock, and vegetation. From the examination of those spoor and other signs (scat, trails) a hunter must ascertain the species, number of individuals, group composition (often in terms of age and sex), direction, and age of the spoor. The hunter must often be able to synthesize information garnered from spoor examination and knowledge of animal behavior to project location of the prey in time and space; this alone is a daunting feat (Liebenberg 1990). A hunter must then be able to navigate through an often harsh and hostile environment to rendezvous with the prey, and this must be
done with stealth. Moreover, to keep oneself safe requires great competence at survival skills. The pursuit may also require a great deal of stamina and endurance. Upon finding the prey, the hunter must be able to accurately and lethally deliver a projectile, and be able to locate the prey once it is dead. In addition, the hunter must often fabricate his own equipment.

Each of these components to hunting ability is either growth-based or experience-based embodied capital or may have aspects of both. It is clear, however, that growth-based embodied capital alone is insufficient. Blurton Jones and Marlowe (this issue) argue that their “optimality view” predicts that experience-based embodied capital related to hunting can be quickly acquired after growth-based forms. According to this view, components of hunting ability such as tracking, knowledge of animal behavior, and the cognitive functions related to synthesis of these should be quickly acquired by naïve adults. Ohtsuka (1989) shows that, controlling for strength and body size, Gidra Papuan men aged 35-45 have four times the hunting returns than that of men in their late teens to mid-20s. Ohtsuka attributes these differences to age-related experience and cumulative knowledge. A recent study among the Ache has found similar results related to encounter rate (Walker et al. nd). This hypothesis is also contradicted by experiences from several conservation projects employing men from foraging groups as trackers which show that these hunters are far more skilled at tracking and detecting animal sign than professional rangers and animal behaviorists (Stander et al. 1997, Liebenberg 1990, Hill et al. 1997). From anecdotal evidence as well, this appears to be an important reason why professional hunters, biologists, and even anthropologists employ indigenous peoples as guides.

**Punctuated development and punctuated acquisition**

While I would argue that this mitigates against the ability of naïve adults to quickly acquire certain experience-based forms of embodied capital, this does not mean that the entire juvenile period is necessary to acquire these skills. An alternative which is consistent with embodied capital theory is the concept of punctuated development. It has long been known that there are periods during
the ontogenetic process of the brain where certain experience-based forms of embodied capital are most effectively acquired; language being a prime example (Pinker and Bloom 1990). It is entirely possible that either as the result of adaptation to a hunting and gathering lifestyle or as an epiphenomenon there are periods where certain kinds of experience-based forms of embodied capital are most effectively acquired. This type of punctuated development and acquisition also could conceivably be related to the growth rate during the juvenile period. This would mean that when growth-based forms of embodied capital reach certain levels, experience-based forms are acquired. Since there is strong evidence that among humans growth is endogenously determined (Kaplan et al. 2000), punctuating the acquisition of embodied capital in this way could have the effect of “ratcheting” an individual’s ability level along. In this way competency could build by depositing new embodied capital, whether growth-based or experience-based, on top of that previously acquired.

In different subsistence ecologies and across different tasks, the amount of investment in growth which would bring a return in learning will vary. This means that for some tasks which require limited experience-based embodied capital, the relationship of growth-based to learning-based embodied capital during the process of ability acquisition and the development of competence might indeed look like the large step function proposed by Blurton Jones and Marlowe (see Figure 1). For more complex tasks and for those which require large amounts of experience-based embodied capital, the frequency and intensity of these steps will change. In essence, as growth-based embodied capital constrains the payoff to investment in experience-based embodied capital there will be diminishing returns to investment in learning. The degree to which growth constrains learning will vary as a function not only of subsistence ecology but also of the economics of production and may be strongly influenced by the value of labor and the opportunity cost to alternative activities. In foraging economies as in all others, the variety of tasks performed can be expected to reflect a number of different levels of growth constraints on payoffs to learning.
The optimality view proposed by Blurton Jones and Marlowe and the punctuated development model presented here can make the same prediction regarding the relationship of body size to adult competency while predicting vastly different ontogenetic patterns. While embodied capital theory makes no specific predictions about the age-specific process of skill acquisition, there is an implied linear relationship (Kaplan et al. 2000). The punctuated development model incorporates body size constraints (Charnov and Berrigan 1993, Janson and van Schaik 1993, Hawkes et al. 1998) and selection for learning capacity (Kaplan et al 2000) in a way that allows the ontogenetic processes of ability development to be addressed within the ecological constraints imposed by conformity to a specific feeding niche.

**The basket of competencies**

What constitutes the capacity to be a competent adult differs across time and place. In essence there is a basket of competencies in a number of areas ranging from productive activities, social relationships, reproductive and parenting behavior, and cultural and religious roles. The composition of this basket varies not only temporally and cross-culturally, but across societies has strong gender divisions. Moreover, within a society at any given time, the competencies embodied within individuals may vary widely based on features of microecology specific to any individual. And, within any one individual, the composition of the basket has the potential for drastic change through the life course.

To focus only on productive activities or only on children’s learning, social, or play activities makes it extremely difficult to capture the complexity of children’s social and economic integration. It is necessary to examine the interaction of time allocation to alternative and competing activities to begin to differentiate the multiple currencies, payoffs, and time frames in operation. At different points in the life course, there are varying costs and benefits to
investment in alternate forms of embodied capital. These differential payoffs are related to subsistence ecology, the organization of the household economy, and family demography, and especially to the opportunity costs to different activities in both the short- and long-term.

**The role of parents**

The activities of children have potential value to the child concerned and to his or her parents. This can be in the form of increased accruable wealth, effects on the reproductive status, fertility, and mortality of other family members, and effects on the child’s future success in terms of economic attainment, mate choice, and fertility. A child's time allocation to different activities can be manipulated by parents in an attempt to maximize the return on investment across children. It is expected that this manipulation will occur in the trade-off in a child's time budget between non-productive activities that may have a return in the future in the form of experience-based embodied capital such as skill acquisition or formal education and productive activities to which there is an immediate return (Bock 1995).

The kinds of short and long-term costs and benefits this hypothesis predicts will be important are those affecting immediate production and skill acquisition (Bock 1995, 1999). In the short-term, if children work, their labor will produce resources that may be used to increase the child’s growth-based embodied capital or probability of survival or to assist other related individuals. The short-term costs are in opportunity cost loss of income from other productive tasks. The long-term benefits of children’s time allocation to productive tasks are in the possible experience-based embodied capital acquired during the performance of that labor. The long-term costs are to the opportunity to acquire other skills.

Differences in the amount and forms of embodied capital which affect ability to perform a given activity are expected to affect the difference between child and adult return rates (Bock 1995). However, the impact of experience-based embodied capital on return rates for productive activities is likely to vary across activities. For productive activities that utilize skills that can be acquired
early in life, we expect that there will be little difference between adults’ and children’s return rates. Other activities require more well-developed skills or knowledge. For those activities, return rates are likely to differ considerably between adults and children. Another factor contributing to disparity between child and adult return rates is hypothesized to be aspects of growth-based embodied capital such as physical strength, general coordination, and balance. These factors are also expected to cause variation between children of the same sex of different ages.

This means that parents are motivated to manipulate children’s time differentially into productive activities and skill acquisition activities. This mix of productive and skill acquisition activities is expected to vary from child to child. Therefore, the knowledge and skills embodied in a particular child will vary as well. Based on the costs and benefits in the long- and short-term to each child and his or her parents, children are expected to experience considerable variation in their daily activities, experiences, and in the skills and knowledge embodied within them.

The substitution of labor

The long- and short-term costs and benefits outlined above for each child have major implications for the overall distribution of labor with the household (Bock 1995, Liu 1999a). This is effected two different ways. First, there can be substitution of labor between children in the household. If two children are equally able to perform one of the available productive tasks, then parents can substitute one child’s labor for another. For purposes of simplification, if we assume that one child’s labor is completely substituted for another, the second child is then freed to spend the time that would have been used in that productive task. Again, this time can be used for acquiring embodied capital or for immediate productivity, and parents must again make an allocation decision based on the costs and benefits. If there is no productive labor in which the child can efficiently engage, then there is no short-term cost to spending that time in embodied capital acquisition other than direct costs of provisioning. Conversely,
if there is productive labor in which that child’s labor would produce a greater benefit to the parent, then we would expect that acquisition to be foregone.

A second kind of labor substitution we would expect would be between parents and children (Bock 1995, 1999; Liu 1999a). If there are activities which both a child and a parent can do equally as well, then we would expect the parent to substitute the child’s labor for his or her own. This would free the parent to engage in activities in which the child’s labor would be worth much less, such as activities for which the child has insufficient ability but the parent is competent. If there are no activities in which a child can engage efficiently, then a parent weighing costs and benefits would have that child engage in skill acquisition with an eye to future benefits. In an economic system where children can perform few productive tasks efficiently, parents cannot trade-off children’s labor for their own. Parents are forced to provision children extensively while children are engaged in skill acquisition, with the hope of future benefit. This should be especially true if by provisioning those children, children have more time to develop skills, if this will bring a greater return in the future than if those children engaged in productive activities now.

**The costs and benefits of children’s play**

Another area in which we would expect to see the effects of the trade-off between skill acquisition and productivity is in the time spent by children in play activities to the extent that play activities develop skills. While there are diverse perspectives regarding the anthropology of play, there is good reason to believe from studies on both non-humans (Bekoff and Byers 1981, Fairbanks 1993) and human children (Bock 1995, Lancy 1996) that play has a strong impact on the acquisition of skills and knowledge. These can be social or labor oriented. In the model presented here, parents should be interested in children engaging in play activities which have benefits to the parent in terms of the acquisition of skill and knowledge.

**Conflicts of interest**

Within a household economic unit decision makers such as parents are faced with a set of problems related to investment in children’s embodied capital.
In a traditional community, such as the study community where the economy is mixed and people are living marginally, these are difficult and crucial decisions. Moreover, it is important to note that parents are usually making these decisions across a sibship of several children of different ages in the context of limited resources. What is best for one child may not be what is best for the parent, concerned with the entire sibship. While the child might want to spend most of his or her time acquiring skills, the parent may need that child’s labor now to support other children (Parsons and Goldin 1989). The parent may choose a course of action for an individual child that is detrimental in order to maximize returns to use for other purposes including investment in other offspring or other forms of reproductive effort (Trivers 1972).

It is important to recognize that in addition to conflicts of interests between parents and offspring, the interests of male and female parents are not necessarily congruent (Trivers 1972). When we are observing real situations it is crucial to realize that they are the outcome of a complicated matrix of decisions regarding the allocation of resources filtered through major conflicts of interests.

The recognition that neither economic nor evolutionary theory lead us to expect that parents will do what is good for an individual child is important (Blurton Jones 1993, Worthman 1999). It points the way to understanding many situations that are extremely detrimental to children’s health and welfare, such as abuse, neglect and infanticide (Daly and Wilson 1988) as well as children’s commercial labor (Bonnet 1993; Grootaert and Kanbur 1995; Liu 1999b, 2000; Nieuwenhuys 1996).

METHODS

The study community

These hypotheses were examined using data collected in a multi-ethnic community in the Okavango Delta of northwestern Botswana. Five ethnic groups are represented: Hambukushu, Dzeriku, Wayeyi, Xanekwe, and Bugakwe. Hambukushu, Dzeriku, and Wayeyi are Bantus who inhabit the Okavango River drainage from Angola through the Caprivi Strip of Namibia into northern Botswana. Historically, they have participated in mixed economies of farming;
fishing, hunting, and the collection of wild plant foods; and pastoralism. Xanekwe and Bugakwe are San speakers who inhabit the Okavango drainage in Namibia and Botswana. Xanekwe have historically had a riverine orientation in their foraging, while Bugakwe have been savanna foragers. The Xanekwe living in the study community practice a mixed economy, but farm at a much less intensive level than the Bantus. Moreover, among 50 Xanekwe there were only four head of cattle, while a typical Bantu homestead of 20 people had an average of 12 head. Bugakwe in this community are largely oriented towards fishing, hunting, and the collection of wild plant foods. None owned cattle, and their agricultural fields were very small. No Bugakwe are included in the study of grain processing.

At the time of the study, there was very little cash economy in the study community. Most men of all ethnic groups over the age of 35 had worked in the mines of South Africa for an average of four years. Proceeds from this labor were largely used to purchase clothes, consumer goods, or cattle. Many of the Xanekwe and Bugakwe men over the age of 25 had been soldiers in the South African Defence Force during the bush wars of the 1970s and 1980s. Few women, however, had ventured beyond the next community 30 km away. There was no school, clinic, or borehole, with water drawn from a river source. Of 122 children, in 1992 20 attended school. Of those, 15 attended a primary school in the next community, walking the 30 km to school on Sunday and home again on Fridays. Five children were attending secondary school in larger towns.

This community offered several important qualities as a field site. There was an extremely limited cash economy, a low rate of school attendance, and great economic diversity. The lack of a cash economy made measurement of household productivity possible. The low rate of school attendance meant that most children could be observed, allowing for exploration of their role in household and family economy. Lastly, the economic diversity meant that children’s and adults’ time allocation as well as parental investment in the embodied capital of offspring could be examined across a number of traditional economic pursuits.
Grain processing

For all the ethnic groups in the study community who are involved in agriculture, a drought resistant variety of millet, called *mahongo*, is an important food. A variety of sorghum called *tumbe* is also grown, and is harvested, processed, and consumed in the same manner as *mahongo*. When harvested in April, the *mahongo* cobs are removed from the stalk and piled on drying racks. A nearby termite mound is leveled, and the clay is mixed with water to form a hard surface. After drying for a few days, the cobs are placed on the hard surface and pounded by women to remove the kernels from the cob. Large baskets are then used to winnow out pieces of the cob that are mixed in. This first processing leaves the intact kernels, and the cob is discarded. These kernels are then transported back to the homestead, and stored in baskets sealed with clay. As *mahongo* is needed, it is removed from baskets and processed into flour. It is this second processing, which occurs daily as long as the grain supply lasts, that is the focus of investigation here.

*Mahongo* is processed into flour and mixed with water into a paste. The quantity of *mahongo* needed for the meal is placed in a mortar. The grain is then pounded with a pestle to break the hard outer hull off of the kernel. Small amounts of water (25-50 ml) are mixed in to help cohesion of the kernels so that the grain is not ejected. When the processor is satisfied that the outer hull has been broken off, the grain is removed from the mortar and winnowed using a flat basket. The processor sits on the ground, with a quantity of the grain on the flat basket, and holds the basket in front of her with both hands. Propping a large basket to the front and back of the flat basket, the processor uses a shaking motion which puts finer material in the rear basket and coarser material in the front. After removing the outer hull, the grain is returned to the mortar and the process repeated to remove the inner husk. After the inner husk is removed, the grain is pounded more to produce a fine flour.

*Mongongo* nut processing

*Mongongo* nut processing is an important economic activity for all of the ethnic groups in the community except the Xanekwe. Mongongo nuts are foraged
during the period May to August. The mongongo nut has a fruity pith covering an extremely hard shell. This shell, once cracked yields a smaller shell, which also must be cracked, revealing the nut meat. The outer fruit portion is usually removed by boiling or steaming it until soft, and then sucking on the nut. The outer shell must be cracked with care, since it is important that the inner shell remain intact. In this way, the nut can be preserved for very long periods of time. If the inner shell is cracked the nut must be consumed quickly.

Mongongo nuts are processed by adults using an axe and an additional axe blade. The individual sits with his or her legs directly in front of him or her, and places the axe handle under one knee so that the axe blade faces up between the legs. A nut is placed on the sharp edge of the blade, and the other blade is brought down upon the nut forcing the sharp edge into the shell. This is usually repeated around the nut, and the upright axe blade is then used as a wedge to pry away the outer shell.

**Data collection**

In this analysis, four types of data are used: behavioral observation, experimental tests of ability at productive tasks, household demographic data, and household economic data. The behavioral observation data consist of instantaneous scan samples collected over the course of 11 months in 1992. Extended family homesteads were sampled on a rotating basis repeatedly over three four hour periods, 0600-1000, 1000-1400, and 1400-1800 which roughly correspond to the daylight hours. On an hourly time point, the activity, location, and interactants of all residents of the homestead were noted. For residents who were not present, other residents were asked for that person's activity and location and this information was verified with the focal subject either upon his or her return or later. In addition, the commodity, amount, producer or collector, and recipient of all food brought into the homestead was recorded.

Experimental return data were collected in 1994 for a number of productive activities. To obtain these data for grain processing ability, 100 members of the community encompassing all age-sex classes were enlisted, and each person was given 500 g of tumbe *(mahongo)* was unavailable due to a
severe drought), and asked to process it as if he or she were at home. 250 ml of water were also provided. The person was timed through the entire process and through each stage. At completion the flour and chaff from outer and inner hulls were weighed. These data were then used to impute age-specific return curves for each sex for pounding, sifting, and total grain processing.

For log cutting, ten logs approximately 3 meters long and 8-9 cm in diameter were obtained. The logs were all from the same variety of hardwood tree. Stripes were painted at 20 cm intervals down the length of each log using white paint. Two axes were procured from local sources. Both these axes had a narrow blade made of spring steel and a handle made from the root bulb of a small tree. One axe was designed for adult men, while the other was designed for use by adolescent boys and women. Participants were shown a stripe, and were asked to cut the log at that point. People were given the choice of axe. The time taken to cut through the log was measured to the nearest hundredth second using a digital stopwatch, and the diameter of the log at the cut was measured to the nearest mm. If the log had not been severed at two minutes, the person was stopped and the deepest part of the cut measured to the nearest mm. The time limit was for safety reasons, since people who are not skilled at cutting become tired and lose a great deal of accuracy. For children under 7 the time limit was one minute, since children tended to become tired more quickly.

For the mongongo nut processing return rate experiments, a sack of mongongo nuts was bartered in return for transporting a group to a mongongo tree patch. A woman was then enlisted to perform the first stage of processing, leaving the nuts with their outer shell exposed ready to process. For the processing rate experiment, an individual was given 500 g of whole nuts in the outer shell. These were also counted. The individual was instructed to process them as if he or she was at home, and the digital timer started. After 15 minutes the individual was told to stop and the number of nuts processed was counted. The remaining nuts were weighed, as were the product. In addition, the number of intact inner-shelled nuts was counted, and it is this quantity which is used in the analysis.
Arm pull strength was obtained in order to estimate the effect of strength on task performance. A 25 kg or 50 kg Homs hanging spring balance was attached to a tree trunk. An individual would then sit cross-legged in the sand at such a distance from the tree that the person’s arm was fully extended when grabbing the hook on the balance, but not so that he or she needed to lean forward. A researcher sat or squatted behind the person so that the his or her back remained perpendicular to the ground during the test. The participant was instructed to grab the hook with whichever arm was stronger and to pull the hook towards him or her using only the arm, not the back, shoulders, or legs. If a person was using these other body parts, the test was begun again after further instruction. A researcher watched the scale on the spring balance to determine the maximum value that the individual could sustain, rather than a peak value resulting from a quick pull or jerk on the hook. This value was recorded to the nearest kg.

Interviews regarding household and family demography and economy were conducted in 1992 and 1994. An initial census was conducted asking who resided in each house within each homestead. In addition, data were collected on people who were occasional residents or who were considered residents but were currently elsewhere. The head of the household was then asked how each of these people were related to him or her. Also, reproductive histories were collected for all men over 20 and all women over 16, and these data were cross-checked with the census data. Both the census and reproductive history data have been regularly updated since 1992. On a monthly basis, each head of household was asked about non-monetary and monetary resource flow into the household. He or she was asked what resources including cattle were acquired, by whom, and from whom. These data, when combined with the acquisition data collected during the homestead instantaneous scans, give an accurate picture of resource flow. To establish the level of storable resources, a cattle census was conducted for each homestead in 1992, as well as measurement of the entire harvest production for each household in 1992.
RESULTS

Comparison of Experimental Results for Females and Males of All Ages

Because experiments were conducted for several productive activities, it is possible to compare ability measured as return rate for tasks related to foraging, farming, and pastoralism across sex and age. This is especially instructive, since most productive tasks in this community are strongly gendered, and it is possible to compare people of adult strength who have never or rarely performed a task with highly skilled people of the same age, albeit of the opposite sex. Tables 1A and 1B show the results of these experiments for females and males respectively.

The ability of females and males of all ages are compared here for mongongo nut processing, log cutting (both speed and depth cut), and grain processing (both the pounding and sifting components). For all activities except male log cutting ANOVA found significant age effects. As stated above, children younger than ten were not tested for mongongo nut processing ability. Female mongongo nut processing ability is significantly higher than males for the middle age group, but not the youngest or oldest. Within females, the two middle groups were significantly different from one another. Among males, the youngest group was significantly different from the two older groups. For log cutting, all males were significantly better than females of the same age in both speed and depth cut. The results are relatively the same for both speed and depth. Due to sample size, the differences were not significant between any of the male groups. For females, the youngest group was significantly different from all others in sifting and from the middle two in pounding; the

For grain processing, all females were significantly higher than males in the same age class for pounding, sifting, and total. For females, the youngest group differed from all others in sifting and from the middle two in pounding; the
youngest and oldest did not significantly differ for pounding or the total. For males, the youngest group differed from all others in pounding, while for sifting the first two were significantly different and the second and oldest group were significantly different. This is partially due to the high variance in male sifting skill. For total pounding returns, the first group differed significantly from the middle two.

For all female activities except mongongo nut processing, the two middle groups did not significantly differ, meaning 9 to 18 year old girls were as able as adult women. Mongongo nut processing is an intensively high skill activity as will be seen below. For all activities 3 to 8 year old girls were significantly worse than adult women, although for some activities the variance in the oldest group is too high to see an effect.

The same general pattern holds true for males. Boys rarely and men never process grain. Yet, the age pattern is identical to females. This largely indicates the partial effect of strength coupled with low levels of skill. The converse is true for log cutting. Girls and women rarely cut logs this size. Yet, the partial effect of strength coupled with low levels of skill mirrors the male pattern even though males of all ages are using axes daily. The age pattern is also duplicated between males and females with mongongo nuts. Boys never and men rarely process mongongo nuts. Yet, the strength effect shines through.

It is extremely difficult to disentangle the age-specific effects of strength. Arm pull strength and age covaried by .91 for males and .93 for females. This means that, for children, age is an accurate proxy for strength in this community.

Growth-based and experience-based forms of embodied capital appear to be additive, and the total of the components of task ability are manifested in the return rate data. This same relationship should be even more apparent when we examine grain processing by females in greater depth below.

**Ability and time allocation**

If parents are manipulating children's time allocation to grain processing based on their ability, then we would expect as girls' ability increases there should be a concomitant rise in the time spent processing grain. Figure 2 shows
the age-specific grain processing ability for girls 3 to 18 years old. Returns increase from zero at age 4 to 20 kcal/hr by age 8, increasing to 60 kcal/hr by age 12, and peaking around 70 kcal/hr by age 14. Piecewise regression analysis shows that ability measured in returns does not increase significantly from age 15 to 75, but does rise significantly from 4 to 14 ($n=21$, $p<.0001$, $r^2=.672$). Moreover, the slopes differ significantly from 4 to 8, 8 to 12, and 12 to 14 years of age.

**INSERT FIGURE 2 ABOUT HERE**

Based on the hypotheses outlined above, we would expect that time allocation to grain processing should increase sometime after age 8, when girls' grain processing ability starts to approach that of adult women. Figure 3 shows the time allocation to grain processing for girls 3 to 18 years of age. No girl under the age of 8 was observed grain processing, and the relationship of age to grain processing is linearly positive. Although there are five girls over the age of 8 who were not observed in grain processing activity, three were away at secondary school and two came from a family who, although traditionally agriculturists, had total crop failure in 1992.

**INSERT FIGURE 3 ABOUT HERE**

While not evidence of a causal relationship, these data show a clear association between age-specific grain processing ability and age-specific time allocation to grain processing. There seems to be a lag between reaching a threshold level of ability and the start of grain processing by girls (Figure 4). An interpretation of this is that through precursor activities that build the necessary strength and component skills, girls are reaching a level of ability around age 8 so that parents are comfortable allowing girls of that age to perform actual processing activities with grain. At that point, girls experience rapid improvement through learning by doing, using the appropriate materials for the task.
Play and adult competence

The pounding component of grain processing is both strength and skill based. To achieve sufficient accuracy and power in the downstroke, women have adopted a highly stylized motion. One of the most common play activities for girls is a fantasy game which I call "play pounding." In this activity, girls use a stick to simulate the pestle, and imagine a mortar filled with grain. Young girls will frequently begin play pounding when nearby women are pounding. At other times they will do so in the context of other play by children in groups. Figure 7 shows the time allocation to “play pounding” by girls 3 to 18. This activity is also more likely to be observed in girls from families with a stronger orientation towards agriculture. Regression analysis shows there is a significant positive effect of household agricultural production on time spent in play pounding (n=39, p=.01, $r^2=.15$) for girls 9 years old and younger.

If this play activity helps develop the pounding component of grain processing ability, then we would expect that the frequency of time allocation to play pounding should be positively correlated with grain processing ability and negatively correlated with time spent in grain processing. Figure 6 shows age-specific time allocation to "play pounding" superimposed with age-specific returns to grain processing for girls 3 to 18.

We would expect the point at which parents have reached enough confidence in girls’ abilities to trust them with real grain and real tools to signify the end to "play pounding" and a rapid increase in the time spent pounding.
Mistakes using grain and the processing equipment can be very costly to parents in terms of spilled and wasted grain, poorly processed grain, and damage to mortar and pestle. Figure 7 shows this effect.

If, indeed, "play pounding" is building pounding-related component skills of grain processing ability, then we should see different age-specific profiles of pounding and sifting. No precursor or skill-building play activities were observed for sifting. Rather, sifting appeared to be learned through intensive instruction coupled with learning by doing. The age-specific skill profile of sifting, then, should show abrupt improvement rather than the gradual improvement in pounding due to years of skill development through "play pounding."

**Strength and skill: partial and additive effects**

Examining the age-specific profile of the pounding component of grain processing for girls 3 to 18 (Figure 8), we can see that there is a linear increase in returns. When contrasted with the age-specific profile for the sifting returns for the same girls, there is a sudden increase in returns, signifying an improvement in sifting skill, at around the time girls start to spend time processing grain (Figure 9). Again, while this is not causal evidence, it is extremely strong circumstantial evidence.

**Intra-generational substitution of labor**

It was hypothesized above that if parents are manipulating labor time allocation within the household, then there should be substitution effects apparent for activities in which children's labor can easily be substituted for adults. From above, we know that girls' grain processing ability plateaus by age 14, and that girls of that age do not significantly differ from adult women in their
grain processing ability. Time allocation to grain processing by girls and women increases until the early 20’s, then rapidly decreases. Two substitution effects were predicted above, one where girls are substituting for one another’s labor and the other where girls are substituting for adult women’s labor. In these cases, controlling for a number of other variables, we would expect that time allocation to grain processing for age-mate girls and for women would decrease with increasing numbers of coresident potential substitutes. Tables 2A and 2B show the results of a multivariate probit analysis of the determinants of the time allocation to grain processing of girls 8 to 18. Controlling for the availability of grain (agricultural production and harvest time), age, and school attendance (both negative by being away at school and positive effects due to being home on the weekend), the availability of substitute laborers (NG3NS) has a significant negative effect on time spent in grain processing.

INSERT TABLES 2A AND 2B ABOUT HERE

**Inter-generational substitution effects**

When this analysis was repeated for adult women, however, the presence of child substitute laborers did not have a significant effect. It may be, however, that these effects are present only in older women, and that there is insufficient power due to sample size when focusing on those women.

Adult women from 27 through 45 are the primary mongongo nut processors in the community, and very few instances of others processing were observed or recorded. Women's' mongongo nut processing ability has a very rapid rise through the early twenties, peaking in the mid-thirties (Figure 20). This rise in ability, and closely following rise in time allocation to mongongo nut processing, corresponds closely to the drop off in women's time allocation to grain processing.
DISCUSSION

The results presented here provide strong support for the hypothesis that parental manipulation of children’s time allocation into a suite of productive and non-productive activities is based on the short- and long-term costs and benefits of alternative activities to parents. Moreover, the overall value of this time allocation is related to the basket of competencies related to adult capacity in a given time and place. The returns to investment in different forms of embodied capital are influenced by the value of returns to investment in alternate forms, the subsistence ecology, and to features of the household demography and economy. These alternate investments work to constrain one another, but they also may work to punctuate development especially through the ontogenetic relationship of growth- to experience-based forms of embodied capital.

Changes over the life course

Figure 11 is the hypothesized changing nature of the trade-off between skill acquisition and productivity over the life course in this community. Early in the life course children are acquiring experience-based embodied capital through play, observation, and instruction. We can expect that many of these skills are useful at early life stages or lay the groundwork for higher level skills later in the life course.

After thresholds of ability have been met, children engage in lower productivity tasks which require low levels of skill and continue to acquire skills and knowledge useful in the future. Through adolescence we expect adult strength and body size to be achieved and higher level skills and knowledge being acquired. For some tasks, children are as able as adults. In the 20s and 30s adults are peaking in their productivity. They have high levels of skill, knowledge, and strength translating into high levels of ability. As people age,
they lose strength and dexterity, and though they may still have high levels of skill and knowledge, their productivity in many tasks steadily declines.

**Task complexity is related to ability**

One of the most important findings in this study is that the ability to perform a task is determined by a suite of embodied capital investments in both growth-based and experience-based forms. Task complexity is directly related to the composition of this suite of embodied capital requirements. More complex tasks require more specific experience-based forms of embodied capital and/or forms of experience-based embodied capital which take longer to acquire.

The ability to process mongongo nuts, for instance, is not purely related to growth-based or experience-based embodied capital. Some threshold level of growth-based embodied capital is necessary in terms of the strength and coordination necessary to strike the nut properly. Yet no amount of growth-based embodied capital is sufficient. Experience-based forms of embodied capital related to mongongo nut processing apparently take some years to acquire after adults stop growing. Similar relationships among forms of embodied capital can be assumed to be in place for other complex tasks.

**Time allocation is related to ability**

A second major finding is that time allocation to a productive task is related to the ability to perform that task. In this community, the ability to perform commodity intensive tasks such as mongongo nut or grain processing is a major predictor of time allocated to those tasks. It may be that the opportunity cost to learning by doing in these commodity intensive tasks is extremely high due to ruination and spoilage of the commodity in question by inexperienced participants. Tasks which are not commodity intensive or which do not run this risk of spoilage may have far lower opportunity costs to experiential learning. These tasks may show time allocation patterns that are far less tied to ability, and this is an interesting avenue for further investigation.

**Time allocation decisions are related to family and household level characteristics**
Time allocation decisions are not necessarily centered on the intrinsic characteristics of the focal individual. A theoretical tenet in the study of education is that children should lead by their own interests (Riegeluth 1996). In the study community, characteristics of individual children are only one set of many different inputs regarding time allocation decisions. Rather than children leading through what interests them, it seems that parents face a set of short- and long-term costs and benefits related to differing possible baskets of competencies. Parents must choose among these differing baskets across all of their children, thereby maximizing their total return. From an individual child’s point of view, they may be stuck with a basket of competencies which is inferior to some other possibilities, but from the parents’ viewpoint this is optimal.

**Choices and adaptation in a mixed economy**

These findings also have more macro-level implications in terms of the choice of economic activity on a household level from a set of options in a mixed economy. The Xanekwe (also called //tanekwe, //ani kwe, and River Bushmen) of the Okavango Delta today have a mixed subsistence ecology which includes foraging, farming, herding, and wage labor. When the first safari camps in the Okavango were built in the mid-1960s opportunities for wage labor introduced alternatives to the hunting and gathering economy. By the 1980s very few people were pursuing the traditional semi-nomadic hunting and gathering lifestyle (Bock 1998, Bock and Johnson 2001). Those not involved in wage labor were adopting settlement and subsistence patterns similar to neighboring Bantu groups such as the Wayeyi, Hambukushu, and Dseriku. Xanekwe cultural history since 1960 apparently shows increasing acculturation, market incorporation, and a shift away from traditional subsistence pursuits. This same pattern of convergence on mixed economies can be seen among indigenous foraging peoples all over the world. The Ju’/hoansi (Wilmsen 1989) and Ache (Hill and Hurtado 1996) are known in the anthropological literature as hunter-gatherers, yet it has been at least a generation since hunting and gathering was the only reasonable adult economic pursuit. These peoples live in what could be characterized as mixed economies; foraging is but one of many available subsistence options. Perhaps
more importantly, when people come into contact with consumer markets through trade, the returns on investment to embodied capital in particular areas can change dramatically. This can lead to alterations in the assemblage of competencies comprising adult capacity.

Over the course of several years of discussing Xanekwe cultural history with older people, however, it became clear to me that Xanekwe had experienced many such changes over at least the last 100 years. Several elderly people told me that while Xanekwe had been semi-nomadic hunter-gatherers for most of their history, Xanekwe lived in villages when they were children (in the 1920s and 1930s) and had cattle and farms. By the 1940s people had shifted away from this sedentary agricultural lifestyle and returned to their semi-nomadic foraging one. This semi-nomadic foraging lifestyle, however, included one important change. Rather than hunting for food, men were using their formidable skills to acquire pelts which were taken down river to Maun, a large frontier town, and traded for consumer goods such as cooking pots, shoes, and blankets. In this case, rather than leading people to invest in alternative forms of embodied capital, market incorporation reinforced and increased the value of investing in traditional forms of embodied capital. Acquiring hunting ability accrued benefits not only within the traditional economy, but also through access to outside goods. Today, the majority of men in some areas work as guides in safari camps, escorting tourists through the bush by dugout canoe and foot. By bringing tourists very close to animals such as lions, elephants, hippos, and crocodiles men can get large tips and double or triple their salaries. In this case, although there is a great deal of market incorporation, economic conditions again reinforce and increase the value of investment in traditional forms of embodied capital related to hunting such as tracking and knowledge of animal behavior and the environment. In other areas without safari camps government restrictions on hunting have reduced the payoff to investment in these forms of embodied capital in favor of those related to farming, fishing, or herding.

By understanding the ways in which the basket of competencies related to adult capacity have varying costs and benefits across time and place, we can
gain insight into the mechanisms by which people choose their economic pursuits from a suite of possible alternatives.

**CONCLUSION**

Embodied capital theory has major implications for understanding the complex polyinfluence of subsistence ecology, family and household demography and economy, and parenting behavior on children’s time allocation to different activities. The returns to investment in two forms of embodied capital, growth-based and experience-based embodied capital, vary as a function of not only these exogenous factors but also endogenous characteristics of children such as age and gender.

Four main findings emerged from this study:

- The development of adult competency in specific tasks entails a step-like relationship between growth- and experience-based forms of embodied capital in the ontogeny of ability acquisition (the punctuated development model).

- There is a trade-off between the acquisition of experience-based embodied capital in the form of skills and knowledge and immediate productivity among children. Time allocation to these alternatives is primarily determined by the short- and long-term costs and benefits to parents of investment in children’s embodied capital. Time allocation to play can have important effects on the acquisition of experience-based embodied capital. Time allocation to play activities associated with developing skills related to specific productive tasks is traded-off against time allocated to actually performing that task.

- The availability of laborers and the overall labor requirements of the household are major determinants of children’s time allocation. The value of children’s labor to their parents is dependent upon the opportunity costs to engaging in other activities not only for the child in question but for potential substitute laborers
• The suite of competencies which relate to adult capacity vary across time and place. The forms of both growth-based embodied capital and experience-based embodied capital which make up those competencies can be understood through experimental manipulation.

These findings have major implications for our understanding of variation in children’s activities across and within societies, and how these different time budgets are related to differing levels of embodied capital related to adult roles. In addition, these findings provide important information which can contribute to our understanding of the evolution of the human life history. Lastly, these findings give us insight into the ways in which people choose economic activities from a set of alternative opportunities.

ACKNOWLEDGEMENTS

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REFERENCES


Table 1A. Summary of task performance experiments for females. ANOVA’s were conducted to test for an age effect for each activity. This effect was significant for all activities. In each cell are the mean returns for that age category, followed by the standard deviation in parentheses. The footnotes below a standard deviation denote the results of T-tests to determine differences between group means within an activity. A ‘1’ denotes that the group was different from 0-8 year olds at the .05 level of significance, a ‘2’ denotes a significant difference from 9 to 18 year olds, a ‘3’ denotes a significant difference from 19 to 45 year olds, and a ‘4’ denotes a significant difference from the over 45 age category. No footnote was used when there was no difference between the group in question and any other group.
<table>
<thead>
<tr>
<th>Activity</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3-8 (n=12)</td>
</tr>
<tr>
<td>Mongongo nut processing (whole nuts/15 minutes)</td>
<td>6.14 (5.75)</td>
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<tr>
<td>Wood chopping-depth (mm/stroke)</td>
<td>.91 (.34)</td>
</tr>
<tr>
<td>Wood chopping-speed (mm/min)</td>
<td>31.00 (11.31)</td>
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<tr>
<td>Grain processing-pounding (kcal/hr)</td>
<td>37.44 (35.47)</td>
</tr>
<tr>
<td>Grain processing-sifting (kcal/hr)</td>
<td>40.05 (37.43)</td>
</tr>
<tr>
<td>Grain processing-total (kcal/hr)</td>
<td>8.56 (7.08)</td>
</tr>
</tbody>
</table>

Table 1B. Summary of task performance experiments for males. ANOVA’s were conducted to test for an age effect for each activity. This effect was significant for all activities except for log cutting. In each cell are the mean returns for that age category, followed by the standard deviation in parentheses. The footnotes below a standard deviation denote the results of T-tests to determine differences between group means within an activity. A ‘1’ denotes that the group was different from 0-8 year olds at the .05 level of significance, a ‘2’ denotes a significant difference from 9 to 18 year olds, a ‘3’ denotes a significant difference from 19 to 45 year olds, and a ‘4’ denotes a significant difference from the over 45 age category. No footnote was used when there was no difference between the group in question and any other group.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Expected direction of effect</th>
<th>Description of variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>MILL_CAL</td>
<td>+</td>
<td>Mean daily caloric value of stored millet</td>
</tr>
<tr>
<td>NG3NS</td>
<td>-</td>
<td>Number of girls ages 10-14 coresident in the household</td>
</tr>
<tr>
<td>AGE3</td>
<td>+</td>
<td>Indicator variable for age 10-14</td>
</tr>
<tr>
<td>HOUR</td>
<td>+</td>
<td>Time of observation by top of the hour</td>
</tr>
<tr>
<td>SCHOOL</td>
<td>-</td>
<td>Whether or not girl attended school away from the community in 1992</td>
</tr>
<tr>
<td>WEEKEND</td>
<td>+</td>
<td>Whether the observation occurred from noon Friday to noon Sunday</td>
</tr>
<tr>
<td>HARVTIME</td>
<td>+</td>
<td>Harvest time: months of April and May</td>
</tr>
</tbody>
</table>

Table 2A. Model of probability of being observed processing grain for girls 8 to 18. This model is testing the labor substitution hypothesis. If NG3NS has a negative effect, controlling for these other independent variables, then girls are less likely to process grain if substitute laborers are present in the household. MILL_CAL controls for variation in millet on hand. Families with more millet stored would be expected to do more processing. AGE3 controls for the higher probability of observing girls 10-14 processing grain. HOUR controls for the higher likelihood of observing girls processing grain later in the day when the evening meal is being prepared. SCHOOL controls for the lower probability of observing girls who attended school in any activity during the week, while WEEKEND controls for the higher probability of observing these girls on the weekend. Lastly, HARVTIME controls for the higher probability of observing grain processing during the harvest period when grain is extremely plentiful.
Table 2B. Results of model tests. A multivariate probit regression was performed on this model. Variables were eliminated in a stepdown fashion based on their contribution to the W statistic. HARVTIME, SCHOOL, and WEEKEND did not significantly improve the model fit. The final model controls for MILL_CAL, AGE3, and HOUR and finds a strong significant negative effect of the presence of substitute laborers on the probability of a girl processing grain. This supports the substitution hypothesis.
Figure 1. Three models of the relationship of growth and learning during the juvenile period. The dashed S-shaped curve represents the optimality view of Blurton Jones and Marlowe. At an optimal body size (A), sufficient growth-based embodied capital has been acquired for an individual to invest in experience-based forms. Foraging related skills should be rapidly acquired. The straight dashed line represents the implied linear relationship of growth and learning present in most studies of child development. The solid stepped line represents the hypothetical relationship of growth and learning in the punctuated development model. Body size may limit the payoff to investment in learning, at many points in the juvenile period. However, the payoff to investment in growth may also be constrained by investment in learning at different ages. The effect is that growth and learning have a “ratcheting” effect on task performance ability and adult competency.
Figure 2. Age-specific grain processing returns for girls 4 to 18. Each point represents the results of grain processing experiments of a girl 4 to 18 years of age. A Lowess curve fit to the data shows the functional shape of the age-specific profile of grain processing returns. Note the rapid rise from 8 to 12 years of age. Regression analysis shows that there is a positive age effect until age 14 (n=21, p<.0001, $r^2=.672$), and after age 14 no effect.
Figure 3. Time allocation to grain processing by girls 4 to 18. Each point represents the mean daily time allocation to grain processing for one girl, based on instantaneous scan observations over the course of 10 months in 1992. There may be overlapping data points. Each girl was observed an average of 56 hours. Regression analysis shows a significant positive effect of age on time spent grain processing (n=38, p=.0002, $r^2=.255$) until age 15, and after that no effect.
Figure 4. Age-specific grain processing ability (dashed line) contrasted with age-specific time allocation to grain processing (solid line). These are the Lowess curves from Figures 2 and 3. The lag between ability and processing time can be clearly seen. Only when girls are able to produce about 20 kcal/hr at age 8 do they begin processing. Prior to this point, although girls are able to produce small amounts of flour, it is hypothesized that the costs to parents in terms of wasted and improperly processed grain and damaged equipment outweigh the benefits of these small amounts of production.
Figure 5. Time allocation to “play pounding” by girls 3 to 18. Each point represents the mean daily time allocation to “play pounding” for one girl, based on instantaneous scan observations over the course of 10 months in 1992. There may be overlapping data points. Each girl was observed an average of 56 hours, and some girls were not observed in this activity. Regression analysis shows a significant age effect in the form of a second order OLS regression representing an inverted U shape (n=35, p=.0062, $r^2=.1914$). This effect is significant only to age 10.
Figure 6. Age-specific returns to grain processing (dashed line) contrasted with time allocation to "play pounding" (solid line) for girls 3 to 18. These are the Lowess curves from Figures 2 and 5. The crossover point at age 8 represents the hypothesized point where sufficient skills have been acquired for girls to cease "play pounding" in favor of actually performing grain processing tasks.
Figure 7. Age-specific time allocation to grain processing (dashed line) contrasted with age-specific time allocation to "play pounding" (solid line) for girls 3 to 18 years of age. These are the Lowess curves from Figures 3 and 5. Compared to Figure 6, the crossover point is shifted down along the “play pounding” curve. This is the lag referred to in the caption to Figure 6 (also see text).
Figure 8. Age-specific pounding returns for girls age 4 to 18. Each point represents the returns to time spent pounding for an individual. There may be overlapping data points. Regression analysis shows a significant positive age effect ($n=26$, $p<.0001$, $r^2 = .524$). Note the linearly increasing and gradual effect.
Figure 9. Age-specific sifting returns for girls age 4 to 18. Each point represents the returns to time spent sifting for an individual. There may be overlapping data points. A Lowess curve fit to these data shows a steep increase in returns from time spent sifting starting at age 5, and this begins to level off about age 11, then reaching a plateau. This is in marked contrast to the pounding profile shown in Figure 8. Regression analysis shows a significant positive effect of age until age 11 (n=14, p=.0193, $r^2=.378$), then no relationship between age and sifting returns.
Figure 10. Age-specific mongongo nut processing returns for females of all ages. Each point represents the number of nuts successfully processed in 15 minutes. There may be overlapping data points. A Lowess curve fit to these data shows the sharp rise to the mid-20’s followed by a plateau in the 30’s and decline in ability with senescence. An 18 year old girl can process about 15 nuts in 15 minutes. This is less than even the oldest women in the sample. Regression analysis performed on these data show that there is a significant positive age effect from 11 to 35 years old (n=10, p=.0044, r^2=.657). There is a significant negative age effect in the age range from 35 to 75 (n=11, p=.0269, r^2=.437).
Figure 11. Productivity and experience-based embodied capital acquisition through the life course. This timeline represents the age-specific productivity and embodied capital acquisition of people in the study community over the life course. This relationship between productivity and skill acquisition is largely determined by the age-specific ability in task performance and the availability of substitute laborers for a given task.