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Cross-cultural Comparison of Learning in Human Hunting

Implications for Life History Evolution

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Abstract This paper is a cross-cultural examination of the development of hunting skills and the implications for the debate on the role of learning in the evolution of human life history patterns. While life history theory has proven to be a powerful tool for understanding the evolution of the human life course, other schools, such as cultural transmission and social learning theory, also provide theoretical insights. These disparate theories are reviewed, and alternative and exclusive predictions are identified. This study of cross-cultural regularities in how children learn hunting skills, based on the ethnographic literature on traditional hunters, complements existing empirical work and highlights future areas for investigation.

Keywords Cultural transmission · Human evolution · Hunting · Learning · Life history

Scholars who have attempted to apply life history theory to human evolution differ in their opinions as to the importance of learning adult social and subsistence skills in the lengthy human juvenile period. Charnov (1993) has developed a model in which other life history parameters, including age at reproductive maturity, are determined by adult mortality. The extended human life span can be explained in terms of the benefits to fitness of grandparents in caring for their grandchildren (O'Connell et al. 1999), although reduced early adult mortality may have caused the initial change in longevity (Hill et al. 2007). Based on this model, O'Connell et al. (1999) have argued that the extension of the juvenile period is a function of the extension of life span, and that therefore it has nothing to do with learning. In contrast, Kaplan et al. (2000) suggest that the need to learn complex foraging skills

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may have been critical in the evolution of human life history parameters. They argue that humans specialize in high-quality resources, some of which require skill-intensive techniques to harvest them, and highlight gathering underground storage organs (roots, tubers), hunting, and fishing as skill- and learning-intensive ways of foraging. In their theoretical model, Kaplan et al. (2000) introduce a term representing "investment in development" to the calculation of the costs and benefits of growth and reproduction. Investment in both learning and growth takes time and energy but could result in increased productivity later on. In this model, a switch to a diet based on learning- and skill-intensive foraging will increase both time spent in development and investment in behavior that will provide protection from predation and other causes of mortality. Finally, Bock (2002) distinguishes the role of growth and experience in such "embodied capital." There are periods when certain experience-based skills can be acquired most effectively based on growth or strength. Phases of growth may ratchet along phases of learning, leading to a punctuated development of skills. This is compatible with the model of Kaplan et al. (2000), but it also predicts the evolution of sensitive periods for learning certain skills.

An alternative view is that individuals benefit from acquiring complex subsistence skills relatively early and quickly, creating selection for efficient learning, based on efficient learning processes and a brain that performs such rapid learning (Blurton Jones et al. 2001; Shennan and Steele 1999). Costs of learning will be minimized when complex skills are learned at a relatively young age, possibly in a critical period when learning is most efficient (Shennan and Steele 1999). Complex imitation and teaching may be more common in humans than in other animals, and language makes social learning easier. When it involves these processes, human learning can be very rapid (Blurton Jones and Marlowe 2002). Selection for efficient learning could occur independently of the longer juvenile period (Blurton Jones et al. 2001). However, motor procedures tend to be learned primarily through relatively time-consuming processes of imitation, demonstration, and repeated practice (Gibson 1999). This suggests there may be constraints on learning processes for particular skills that are relevant to this model. Social learning theory highlights costs to the demonstrator as well as the learner, and evaluation of the fitness costs to the learner and demonstrator should take their genetic relatedness into account (Sibly 1999). Parents and, to a lesser extent, other people, such as grandparents, will benefit from their children's success and from their earlier independence (O'Connell et al. 1999; Shennan and Steele 1999). A more complicated view of these trade-offs is presented by Bock (2002, 2005), who suggests that parents will invest in children's learning, or manipulate children's time allocation, based on changing growth constraints on payoffs to learning as well as trade-offs with children's productive activities.

Human Life History Patterns

According to Bogin (1999), human growth after birth is characterized by the addition of two stages, childhood and adolescence, to the typical mammalian stages of infancy, the juvenile period and adulthood. The "childhood" stage highlights the

fact that in humans, weaning is early relative to dental development (Blurton Jones 2005; Bogin and Smith 1996). Brain growth in weight is extremely rapid in infancy and continues to age 7 (Cabana et al. 1993). The immaturity of dentition and the digestive tract and the rapid growth of the brain mean that children have special dietary requirements and are dependent on adults (Bogin 1999; Bogin and Smith 1996). At the end of the childhood phase, between ages 5 and 7, children show changes in behavior and psychological processes, and they begin to assist in shared caretaking and help with domestic tasks (Weisner 1996). Rates of body growth for humans are very slow compared with those of other primates for the entire period before puberty (Leigh 2001). Puberty begins at around 10 years of age in girls and 2 years later in boys (Bogin and Smith 1996), although the timing of pubertal onset may be affected by nutritional status and therefore varies across populations (Campbell et al. 2004). Humans also undergo a marked acceleration of skeletal growth, the adolescent growth spurt, shortly before the end of the growth period (Harrison et al. 1993: 339). This takes place between about ages 12.5 and 15.5 in boys, and in girls some 2 years earlier, and is comparable with the sub-adult growth spurt in other primates (Leigh 2001). Adolescence ends with the completion of the growth spurt, attainment of adult stature, and achievement of full reproductive maturity.

The models discussed above emphasize changes in the absolute length of the period between birth and reproductive maturity (Charnov 1993; Kaplan et al. 2000). According to Leigh (2001), the extension of the human growth period is based on relatively slow body growth between birth and puberty. Blurton Jones and Marlowe (2002) argue that relatively rapid and early brain growth in humans would reduce the benefits of a long juvenile period for learning. In this context, it is worth noting that the period of slow body growth continues after brain growth is completed. According to Leigh (2001), the investment model of Kaplan et al. (2000) predicts the extension of different growth phases based on the investment costs that are likely to be most important then. The extension of the earliest phase would suggest high costs of brain growth and basic knowledge acquisition rather than knowledge pertaining to adult behaviors, including foraging and social relations. In addition, selection for the development of particular cognitive or behavioral skills at particular stages of maturation could occur in the context of the punctuated development of key skills (Bock 2002): this could provide an interesting perspective on the 5- to 7-year-of-age shift.

Foraging Skill Acquisition

The hypotheses described above make different predictions regarding the age at which children will begin learning, the time taken, the learning processes involved, and the role of teaching in acquiring foraging skills. According to the first model, practice and experience have a limited effect on the acquisition of adult competence, and differences in children's and adults' foraging strategies and success can be explained in terms of differences in strength, size, and motivation (Bird and Bliege Bird 2003; Bliege Bird and Bird 2002; Hawkes et al. 1995). According to Kaplan et al. (2000), foraging skill is based on practice and experience and is therefore likely

to increase linearly with age. By contrast, Shennan and Steele (1999) would predict early acquisition of complex subsistence skills using intensive learning processes, including teaching by parents. Bock's (2002) model predicts a steplike pattern in the development of adult competency, the shape of which would vary depending on the skill and strength requirements specific to particular skills. Parents will manipulate children's time allocation to different activities so that children spend more time on productive abilities when their return rates are high, especially if there are costs associated with unskilled production (Bock 2002). In addition, play may contribute to adult competency when there are constraints on acquiring skill through experience (Bock and Johnson 2004).

Empirical studies have focused on testing particular predictions regarding differences in foraging skill in relation to age and experience, using quantitative data from contemporary hunter-gatherers (Bliege Bird and Bird 2002; Blurton Jones and Marlowe 2002; Bock 2002; Walker et al. 2002). Among the Aché, hunting ability increased with age and reached a peak surprisingly late in life, after peaks in strength (Walker et al. 2002). For the Hadza and Aché, success or return rates increase with age and strength in target archery and (for the Hadza) digging tubers (Blurton Jones and Marlowe 2002; Walker et al. 2002). In contrast, important subsistence skills (digging tubers, climbing baobab trees, and target archery) did not show significant variation with practice time (Blurton Jones and Marlowe 2002). Tsimane hunters reach peak success rates in some aspects of hunting skill, including locating and capturing prey, later than in others, including target archery (Gurven et al 2006). However, Martu children's hunting return rates are better explained by height (which is related to walking speed) than by age (Bird and Bliege Bird 2003). Bock (2002) found an association between time allocated to grain processing by girls and ability, and he interpreted this in terms of parents manipulating children's time allocation so that abler children spent more time working. In a study conducted among the Okavango Delta peoples of Botswana, Bock and Johnson (2004) found that children spent significantly more time in play activities related to tasks specific to their household subsistence activity and gender. In addition, children spend less time in such play activities when they start working at the subsistence activity (Bock 2002). These results are consistent with the suggestion that play is important in the development of adult subsistence skills and provides a way of learning when there are constraints on getting on-the-job experience. The sole study attempting to distinguish the role of social and individual learning found that learning from parents was the primary means of acquiring subsistence and other skills among Aka pygmies (Cavalli-Sforza and Hewlett 1986).

Method and Data

Here, I present a cross-cultural synthesis of how children learn to hunt, based on the ethnographic literature on traditional hunters, with the aim of evaluating the predictions outlined above. This adds to existing empirical studies by providing a cross-cultural comparison to assess regularities in how people learn hunting skills, and by addressing a wider range of alternative hypotheses. The sample includes both hunter-gatherer societies and groups with other forms of socioeconomic organiza-

tion who engage in hunting activities, and it covers a range of latitudes and environmental conditions. A number of authors have suggested that different aspects of hunting skill, including marksmanship and knowledge of animal behavior, may be more or less difficult to learn (Blurton Jones and Marlowe 2002; Bock 2002; Kaplan et al. 2000), so these are treated separately. This study is qualitative, as the relevant evidence from the ethnographic literature is either anecdotal or generalized and includes limited quantitative data. However, this review identifies productive areas for future research, which could include quantitative study.

Results

Learning to Use and Manufacture Hunting Weapons

In general, children start to get experience in using hunting weapons at a young age. In many cases adults or older children provide hunting tools for the children to play with (Gubser 1965: 102; Gusinde 1931, 1937; Lee 1979: 236; Marshall 1976: 131; Puri 1997: 402; Ray 1963: 107; Tayanin and Lindell 1991: 16; van Beek 1987: 94; Watanabe 1975: 42). These are always scaled down and sometimes made of different materials from the adult version (Gusinde 1931; Healey 1990: 89; van Beek 1987: 95; Watanabe 1975: 42), and they are occasionally unusable (Gusinde 1931). Larger, more powerful versions are provided as the children grow older. Ju/'hoansi mothers or older children teach toddlers how to shoot the bow and arrow (Lee 1979: 236; Marshall 1976: 131). In some cases, adults also offer advice on the peculiarities of the weapons and how to use them (Puri 1997: 325; van Beek 1987: 94). When they allow children to accompany them, Penan hunters may focus on prey and contexts which provide a relatively easy shot (Puri 1997: 324–334): this may also provide an opportunity to observe an adult's shooting. Children are often described as playing with miniature hunting weapons, or shooting at small prey, in areas around the village, forest camp, or fields and gardens (Healey 1990: 87; Marshall 1976: 130; Puri 1997: 285, 325; Tayanin and Lindell 1991: 16; van Beek 1987: 94–95). This frequent activity (van Beek 1987: 96) may continue throughout childhood (Marshall 1976: 130). According to Watanabe (1975), children first attempt to manufacture of the most common weapons with which they are familiar. For Kpelle children, learning to make traps involves observing their fathers' activities while accompanying them on hunting trips, then helping with specific aspects of trap production (Lancy 1996: 146). Later they try to make a trap themselves, and they can expect some advice and criticism from fathers, but not much. A majority of Aka pygmies indicated that they learned skills in manufacture and use of tools socially, primarily from parents (Cavalli-Sforza and Hewlett 1986).

While these descriptions suggest a limited role for teaching and observation in the acquisition of skills in using and manufacturing hunting tools, they also make it clear that the social context is an important part of the process. Provision of hunting weapons provides an opportunity for the children to play at shooting things, thus developing their marksmanship and ability to adjust their shooting to circumstances. It also allows parents to manipulate children's activities (Bock 2005: 127) and influences the acquisition of manufacturing skills. For Kpelle children learning

particular skills, there are abundant opportunities to observe the activities of those at the next stage (Lancy 1996: 146). The description of how Kpelle children learn trapping skills illustrates the subtle ways in which other people may influence a child's learning by providing a model, raw materials, opportunities to practice, or a little advice (Lancy 1996: 146).

In some cases children participate in games or exercises involving shooting at targets (Bock and Johnson 2004; Gusinde 1931, 1937, 1974; Lancy 1996:98; Lee 1979: 236; Ray 1963; Roulon-Doko 1998: 101–102). The targets include stationary and moving objects, the latter thrown or pulled along. In Gbaya games, a number of different targets are used, one of which moves more like a hooved mammal, another more like a large rodent (Roulon-Doko 1998: 101–102). In another game, the target is pulled rather than thrown. When adolescents play this game, the boy pulling the target announces which animal it represents, starting with small animals and working up (Roulon-Doko 1998). These exercises provide practice for skills in marksmanship, anticipating the movement of an animal, and adapting the way in which the spear is thrown to the way in which the animal runs. Such games are interesting in that they provide an opportunity to learn skills relevant to hunting that is not "on the job"—in other words, a part of children's foraging. There is little indication as to how much time boys spend in such exercises, but they do appear to begin while relatively young, in some cases before they start going on hunting expeditions (Lee 1979: 236), and continue during adolescence. According to Gusinde (1931, 1937, 1974) in the Tierra del Fuego groups these exercises continued until the boys were considered fully skilled. Quantitative study showed that the amount of time devoted to this type of game diminished towards zero by age 12, the age at which boys started to go on hunting expeditions (Bock and Johnson 2004).

Children may show a certain amount of skill in using a hunting weapon early: for instance, 5-year-old Waorani boys are expected to be proficient enough with a blowgun to be able to hit targets of fruit or leaves consistently. Two studies identify a particular age at which differences in individual skill in using hunting tools begin to be evident—at 12 years or older (Tayanin and Lindell 1991: 16; van Beek 1987: 97). Increases in skill may be related to both learning and sex-specific developments in skeletal and muscular specialization (Parker 1984). These descriptions suggest that learning continues into adolescence. Aka pygmies acquire particular tool manufacture and maintenance skills in adolescence and adulthood (Cavalli-Sforza and Hewlett 1986), and despite the early start, a Waorani boy does not become truly effective with the blowgun or lance until his late teens (Yost and Kelley 1983: 196). Quantitative studies indicate that skill in target archery increases with age and strength but is not affected by practice time (Blurton Jones and Marlowe 2002; Walker et al. 2002): further quantitative analysis would be necessary to test the effect of starting early on efficiency (Blurton Jones and Marlowe 2002: 227).

Knowledge of Animal Behavior and Signs of Behavior

A number of studies suggest that learning about animal behavior also begins early, through individual observation. Children learn to identify plants and animals, and identify their cries and behavior, within their play area (Lee 1979: 236; van Beek 1987: 96; Tayanin and Lindell 1991: 15). Waorani children are surrounded by a wide

range of birds and mammals that are kept as pets (Yost and Kelley 1983: 195). Children also practice stalking animals (Nelson 1969: 168), and adults (Konner 2005: 54), and play hunting described above may provide practice in stalking. Observation and imitation of animals is clearly important: for example, imitation of bird and animal calls (Puri 1997: 402; van Beek 1987: 96), and studying and imitating animal tracks (Goodale 1971: 41; Lee 1979: 236; Lowe 2002: 32). According to Liebenberg (1990: 69), older boys spend a lot of time studying animal tracks; following the spoor of insects, scorpions, and, later, small mammals; and reconstructing their feeding patterns and habits. According to some authors, children can identify, locate, and know about the behavior of many plants and animals in their environment by about age 10, or before adolescence (Cavalli-Sforza and Hewlett 1986; Lee 1979: 236; van Beek 1987: 96).

Children also learn about animals and plants when they accompany their elders on trips to check traps or hunt. Although reluctant to make detailed explanations in the forest, Penan fathers will point out plants and respond briefly to questions (Puri 1997: 401): Kammu adults are said to give active instruction about animal behavior in this context (Tayanin and Lindell 1991: 16). Children in Melville Island are shown signs that indicate the presence or passage of an animal when they accompany their elders on a hunt (Goodale 1971: 38). Lee (1979: 236) suggests that by setting snarelines boys get experience of animal behavior and feedback from successful and unsuccessful snaring. Children's knowledge of the names of most of the important animals and their behavioral characteristics increases after they start accompanying their fathers (Puri 1997: 400). According to Liebenberg (1990: 70), tracking skills cannot be taught directly. He notes that even when signs are pointed out by an experienced tracker, the learner must analyze them carefully and critically in order to understand them. Aka pygmies learn to identify and find plants and animals from other people, primarily their parents, and few indicate they learned individually (Cavalli-Sforza and Hewlett 1986). Some instruction may also occur in non-hunting contexts, such as initiation ceremonies (Gusinde 1931, 1937), but in other cases these have very limited practical content (Lancy 1996).

General conversation is likely to provide some of the information about animal behavior learned by children (and also cultural attitudes toward animals, such as which prey are preferred). In the case of the Penan, animal names and proverbs contain additional information about morphological or ecological traits, uses for humans, or behavior in a predator-prey interaction with humans (Puri 1997: 386–396). In most of these groups, children listen to stories about hunting told by the men (Binford 1978: 182; Gubser 1965: 110; Lee 1979: 236; Puri 1997: 386; Tayanin and Lindell 1991: 14; van Beek 1987: 95). They have access to the storytelling from a very early age and will continue to listen as they grow up. These stories include descriptions of past hunts, and sometimes myths or folktales. Hunting stories are said to contain information about animal behavior and how to kill animals (Lee 1979: 236; van Beek 1987: 95).

In some cases, learning about animal behavior is an ongoing process. For instance, Penan adults are described as continually updating traditional knowledge by personal experience (Puri 1997: 403). !Kung adults are intensely interested in animal behavior, observe animals more than is necessary for the success of a particular hunt, and tell stories for entertainment rather than because someone wants

to hunt a particular animal (Blurton Jones and Konner 1976). Walker et al. (2002) found that it took longer to reach a peak in rates of finding and pursuing prey, which may be influenced by knowledge of animal behavior and signs, than in marksmanship.

Growth and Experience

Young children play at tracking or hunting animals within a restricted area: in or around the camp or village (Puri 1997: 325; van Beek 1987: 94) and (sometimes when they are a bit older) around the fields or gardens and nearby paths (Healey 1990: 88; van Beek 1987: 95; Watanabe 1975: 71). Young boys and girls may experience a wider area and encounter a range of plant and animal species when they are carried by their parents on gathering trips (Berndt and Berndt 1964: 133; Goodale 1971: 35; Konner 2005: 50, 53; Marshall 1976). Martu children above the age of five often search for and pursue game animals (Bird and Bliege Bird 2003). As discussed above, children are described as beginning to acquire a range of hunting skills at an early age, including using hunting tools and learning about animal behavior. Some of these are learned outside a hunting context. In two cases, boys age 9–10 and older play competitive games involving shooting at targets (Lee 1979: 236; Roulon-Doko 1998: 101). This is before they start to go on hunting trips (Lee 1979: 236).

In most cases, children accompany their fathers or other adults on hunting trips (or to check traps) away from settlements and farmland (Birket-Smith and de Laguna 1938: 162; Gubser 1965: 109; Gusinde 1931, 1937; Lee 1979: 236; Murdoch 1892: 418; Puri 1997: 400; Ray 1963: 106; Tayanin and Lindell 1991: 16; van Beek 1987: 95). Certain geographical areas and animals will only be encountered on longer trips with adult hunters, as hunters tend to cover a wider area than people engaged in other activities (Kelly 1995: 47, 131): this may be more pronounced at higher latitudes. There is quite a lot of variation in the ages at which children begin accompanying adults on hunting or trapping trips, as shown in Table 1. A number of children start accompanying their fathers and other male relatives on hunting trips or to check traps at age 5 (Puri 1997: 400; van Beek 1987: 95) or 6 (Lancy 1996: 146; Turney-High 1941: 117). According to Puri (1997: 399), at this stage a child's education is concerned with forest survival techniques—geographical orientation, marking a trail, lighting a fire, sharpening a knife or spear, building a shelter, what to do if hurt or lost. A number of aspects of children's physical and intellectual development could be important at this stage: for Aka children, the ability to keep up with their parents is important (Konner 2005: 50–51). Some hunter-gatherers have a relatively late age at weaning, but Aka children are weaned before they are able to keep up with parents (Konner 2005: 50, 58).

In many cases, there seems to be a change or intensification in the character of the learning process at age 12 or above. In the Arctic, boys start to accompany their fathers as adolescents (Gubser 1965: 109; Murdoch 1892: 417). Neither Ju/'hoansi nor Australian Aborigine boys start to accompany their fathers until age 12 (Berndt and Berndt 1964: 133; Lee 1979: 236). In the cases where children accompany adults on expeditions at an earlier age, further changes occur around age 12. Penan adolescents are allowed to hunt with their older siblings and peers in the forest (Puri

Table 1 Ages at which children start participating in hunting activities

Group name	°Latitude (approximate)	Age (years)	Activity	People	Prey
Penan	<5	5	Hunting	Father	Any
		9–10	Hunting	Uncles, other adult men	Any
		14–20	Hunting	Siblings/peers	Any
		Adult	Techniques involving stealth, patience, silence		Any
Aka	<5	5+	Net hunt	Parents	Any
		11 or 12	Hunting	–	Small game
Bedamuni	<10	5	Checking traps/ snares	Father	–
		12+	Hunting and fishing	Older adolescent peers	Birds, fish
		12+	Collective hunts	Adult men	Pig
		16–18	Hunting	Solitary	Pig, cassowary
Aboriginal Australians	10–40	Adolescent	Hunting	Adult men	Wallaby and kangaroo
Ju/'hoansi	20	12	Hunting trip	Father, uncles or older brothers	Mongoose, genet, hare, game birds
		15–18	Kill first buck		Antelope
Kammu	23	10	Setting and checking traps	Adult men	–
		12–16	Checking traps, hunting	Father, uncles, elder brothers	–
Modoc	40	Adolescent	Hunting	Father	–
Kutenai	49.5	6	Hunting	Father	–
Eyak	60	Adolescent	Hunting	Father, maternal uncle	–
Nunamiut	68	Adolescent	Short hunting trip	Father	–
		Adolescent–after	Hunting trip	Solitary or with peers	Caribou
Inupiat	70	12–14	Hunting gun/ seal spear	Father	–

Sources: Berndt and Berndt (1964), Birket-Smith and de Laguna (1938), Gubser (1965), Konner (2005), Lee (1979), Murdoch (1892), Puri (1997), Ray (1963), Tayanin and Lindell (1991), Turney-High (1941), van Beek (1987)

1997: 402). Bedamuni children start to go on serious bird hunting or fishing trips, at first with older adolescents; accompany the men on collective hunting trips; and continue to hunt with their peers (van Beek 1987: 97). Aka males increase basic skills in net hunting and other hunting techniques in adolescence and adulthood (Cavalli-Sforza and Hewlett 1986). This contrasts with the acquisition of gathering skills, most of which takes place by age 10. The existence of a distinct stage in

hunting experience in a range of groups suggests that it may relate to changes in height and strength at this age (Harrison et al 1993: 339). Age-related changes in size, strength, or experience could remove constraints on hunting activities for children: for instance, the risk of encountering predators, becoming exhausted or dehydrated, or not being able to keep up and becoming lost. Alternatively, adult requirements in terms of hunting returns could set a constraint. The delay does not seem to be related to the size of prey—for instance, Ju/'hoansi boys, who begin to accompany their fathers as adolescents, are described as shooting medium-sized mammals and game birds (Lee 1979: 236). As Kelly (2003: 47) points out, the delay does not seem to be related to the severity of the climate—late starters include hunter-gatherers from the Arctic, Kalahari, and Australia. Further analysis of constraints would require primary research to assess the skill, strength, and experience of children who are or are not taken on hunting trips, and to calculate the effects on adult hunting returns of taking children along.

Young adults are more likely to go on solitary hunting expeditions, further from the settlement and after large game (Gubser 1965: 109; Puri 1997: 402; van Beek 1987: 97; Watanabe 1975: 72). By age 15 or 16 a young Nunamiut man will have killed several caribou on his own (Gubser 1965: 109). According to Lee (1979: 238), young Ju/'hoansi would traditionally work hard at hunting between ages 15 and 22, and they would kill their first buck at age 15–18. In these two cases, there seem to be strong social incentives to working hard during this period—in the Ju/'hoansi the first buck is celebrated with a ceremony, whereas a Nunamiut boy's reputation as a hunter is based on his performance by age 15 or 16, and this is a source of prestige. Blurton Jones et al. (1997) have suggested that adolescence is generally a time for displaying skill and making reputations. However, Walker et al. (2002) show that among the Aché hunting encounter and return rates are relatively low at this age. Some hunting strategies that are particularly difficult, dangerous, or require solitary hunting may be learned relatively late. Penan hunters learn techniques involving stealth, patience, silence, or complex mimicry when they are unmarried adults (Puri 1997: 402). Bedamuni hunters gain experience in solitary hunting of pigs and cassowaries after age 16–18, when they are already familiar with all other male hunting strategies (van Beek 1987: 97). Again, this implies that there may be constraints on practicing these techniques at younger ages: they may be constraints of strength (these are the largest game in these environments) or experience.

In several cases, marriage is explicitly linked to hunting ability (Lee 1979: 240; Puri 1997: 402). However, young men don't necessarily need to be fully skilled on marriage, and in-laws may not be too demanding (Lee 1979: 241) or may provide tools and advice (Gubser 1965: 65). A number of authors comment that men in their thirties and forties are at their peak in terms of hunting skill (Gubser 1965: 114; Lee 1979: 242). Several studies have shown that men in this age-group have the highest hunting return rates or encounter rates (Ohtsuka 1989; Walker et al. 2002). As Gubser (1965: 114) comments, these men may have more children and acquire more responsibility for the community as a whole. Older individuals with larger families may gain greater benefits from foraging more efficiently and getting greater harvests than younger individuals (Bliege Bird and Bird 2002). Both motivation and higher levels of experience and skill could increase return rates for this age group, and it seems likely that these factors interact.

Sex Differences in Learning Hunting Skills

In some cases both small boys and girls are described as playing at chasing and catching very small prey (Lee 1979: 236; van Beek 1987: 93). Nunamiut girls are described as showing a disinclination for play activities involving hunting small creatures (Gubser 1965: 107). Often toy or small versions of specific hunting weapons are provided to boys and not to girls (Gubser 1965: 102; Gusinde 1937, 1974; Tayanin and Lindell 1991: 15–16; van Beek 1987: 95; Watanabe 1975: 42); however, sometimes they are provided to both (Lee 1979:236). Competitive games with these weapons are only played by boys (Lee 1979: 236). Martu girls above age five hunt in groups with other children (Bird and Bliege Bird 2003). Parents are sometimes described as taking both girls and boys with them on hunting trips and instructing them in hunting skills (Goodale 1971: 38; Puri 1997: 399), although in the latter case girls are taken less frequently. More frequently, only boys are taken on hunting trips (Birket-Smith and de Laguna 1938: 162; Gubser 1965: 109; Lee 1979: 236; Marshall 1976: 130; Tayanin and Lindell 1991: 16; van Beek 1987: 95). There is considerable variation in the extent to which there are sex differences in how children learn hunting skills, and in the learning opportunities provided by parents.

Women in hunter-gatherer societies often hunt using strategies that differ from those of men in terms of prey species, technology, or context, particularly focusing on smaller game (Kelly 1995: 267), and these skills may be learned in different ways. Bedamuni girls are described as learning specifically "female" hunting skills by imitating women, while working in fields and gardens, and acquiring these skills by the early teens (van Beek 1987: 97). Likewise, Aka women's hunting skills are acquired relatively early (Cavalli-Sforza and Hewlett 1986; van Beek 1987: 97). By contrast, a large proportion of Agta women hunt large game (Goodman et al. 1985), and children of both sexes begin hunting after puberty (Konner 2005: 57).

Social Context

There seems to be a relatively large role for close male relatives in hunting education, particularly in providing weapons and taking children on hunting trips (as shown in Table 2). This is particularly the case at early stages (with first weapons and early hunting trips). Some accounts describe fathers and brothers providing toy or scaled-down hunting weapons (Gusinde 1931, 1937), or providing the first such weapons (van Beek 1987: 94; Watanabe 1975: 42). However, other adult men, mothers, and older children may also do so (Lee 1979: 236; Marshall 1976: 131; Watanabe 1975: 42). In a number of cases fathers are described as taking their children on their first hunting or trapping trips (Gubser 1965: 109; Puri 1997: 400; van Beek 1987: 95). Later, children went with uncles and other adult males (Puri 1997: 400). In other cases fathers, uncles, and elder brothers were all involved from the start (Lee 1979: 236; Tayanin and Lindell 1991: 16). Interestingly, when children go hunting relatively early they accompany their fathers (Gubser 1965: 109; Puri 1997: 400; van Beek 1987: 95), although the data are not sufficient to establish the significance of this pattern. The role of the older generation of relatives is limited, and it is most important in teaching manufacturing skills and trapping. Older Penan men sometimes took their grandchildren on hunts (Puri 1997: 325–326), and this

Table 2 Social context of learning hunting skills

	Role for adults					
	Provide first hunting weapon	Provide later weapon	Teach use of weapon	Accompany on first hunt	Accompany on later hunt	Teach manufacturing skills
Mother	Ju/'hoansi		Ju/'hoansi			Aka
Both parents				Tiwi, Aka		Aka
Older children	Ju/'hoansi, Klamath, Wonie		Ju/'hoansi			
Brother	Bedamuni					
Father	Yamana, Selk'nam, Bedamuni, Wonie, Klamath, Modoc	Ju/'hoansi, Bedamuni, Yamana, Selk'nam	Yamana, Klamath	Nunamiut, Penan, Bedamuni, Inupiat, Modoc, Eyak, Kutenai		Aka
Male relatives	Ju/'hoansi	Wonie		Kammu, Ju/'hoansi, Eyak		
Adults	Kammu, Penan	Kammu	Penan			
Adult men		Bedamuni			Penan, Bedamuni, Wonie	
Grandparents			Klamath	Penan		Nunamiut

Sources: Birket-Smith and de Laguna (1938), Goodale (1971), Gubser (1965), Gusinde (1931, 1937), Hewlett and Cavalli-Sforza (1986), Konner (2005), Lee (1979), Marshall (1976), Murdoch (1892), Pearsall (1950), Puri (1997), Ray (1963), Turney-High (1941), van Beek (1987), Watanabe (1975)

allowed children to learn the technique of hunting with a blowpipe, favored by older men. Ju/'hoansi boys build snarelines with their fathers and grandfathers: this too is a technique favored by older men (Lee 1979: 207, 236). According to Gubser (1965: 88), Nunamiut boys learned manufacturing skills from grandfathers or uncles if they were available. In a few cases, particular skills have a limited distribution within the group, so only some people are suitable as teachers. In one case, one man was an expert in the specialized skill of imitating a pigtail macaque, and he taught this skill to his nephews and several other men (Puri 1997: 402). On collective hunts children accompanied larger groups of adult men (van Beek 1987: 97; Watanabe 1975), and storytelling generally involves a range of adults. A wide range of people are involved in different parts of a child's hunting education, and there is considerable variation from group to group in the people concerned.

The sole quantitative study of cultural transmission of skills confirms some of these general patterns. Social learning, primarily from parents, is the most important way of acquiring hunting skills for the Aka (Cavalli-Sforza and Hewlett 1986). Men learn primarily from fathers, women from parents or mothers. A few hunting skills are relatively rare, so individuals need to learn from people other than parents; individuals observed particularly skilled individuals in one specialized activity, elephant hunting (Cavalli-Sforza and Hewlett 1986).

Bock (2005) points out that making tools incurs costs to the adult. In general, hunters give a limited amount of instruction to novices who accompany them on trapping or hunting trips (Goodale 1971: 38; Lancy 1996: 146; Nelson 1973: 9; Puri 1997: 401; van Beek 1987: 95), with some exceptions (Gubser 1965: 109; Tayanin and Lindell 1991: 16). However, hunters may alter their activities to accommodate children's learning of a range of hunting skills by changing the time of day and choice of target, and by talking. For instance, Penan hunters carry out practice sessions for stalking with a blowpipe during the day, may answer questions or offer advice, and focus on prey and contexts that provide a relatively easy shot (Puri 1997: 324–334). This is in contrast to the normal practice in which hunters set off before dawn to stalk arboreal prey in silence. Owing to these changes in behavior there are likely to be costs associated with taking children on hunting expeditions. Other activities, such as storytelling, may be relatively cost-free.

Conclusions and Future Directions

The sources discussed here suggest that a range of learning processes are involved in acquiring hunting skills, and that teaching and demonstration play a limited role. Descriptions of how children learn to use and manufacture hunting weapons indicate that teaching is unimportant relative to observation and practice. This is in accordance with learning theory, which suggests that motor procedures require a certain amount of practice for acquisition. By contrast, information about animal behavior could be acquired using relatively efficient and fast learning processes. However, descriptions of learning about animal behavior suggest that this activity goes on into adulthood and involves individual observation and imitation as well as limited instruction, and exposure to potentially useful information in linguistic forms or in hunting stories. The efficient learning hypothesis highlights benefits to learning complex skills early and quickly, using efficient and fast learning mechanisms. These data indicate a more complex range of mechanisms and time-spans, which may be explained by constraints on the acquisition of certain skills, as discussed below. However, more detailed description of learning processes, and measurement of time allocation to different learning processes and the effects of teaching on skill, would greatly improve these data.

Although there are relatively few descriptions in the literature of teaching or verbal instruction, adults do seem to incur costs as a result of helping children to acquire hunting skills. As Bock (2005) points out, tool manufacturing incurs costs to the adult and also enables them to direct children's activities. In allowing children to accompany them, adults alter their hunting behavior to give children opportunities to learn or practice. As less efficient hunters, children may reduce the chances of hunting success, particularly early on. Children may be more at risk while they learn basic survival skills, influencing the costs and benefits of teaching for parents. Consistent with the findings of Shennan and Steele (1999), fathers and close male relatives seem generally to be involved in early hunting expeditions. However, other people are frequently involved in children's hunting education at other stages. Although in many cases these are male relatives, in other cases children go hunting with other adults in the group or with experts in a particular skill, who are less likely

to benefit from participating in children's hunting education. This flexibility could be of benefit to children, who will have the opportunity to learn a wide repertoire of skills. It seems possible that costs would be lower at this stage. Primary research could quantify the costs associated with taking children on hunting expeditions, and how well they explain variation in the role of other people in hunting education, providing a better test of Shennan and Steele's (1999) hypothesis.

Play may contribute to adult competency when there are constraints on acquiring skill through experience (Bock and Johnson 2004). This seems to be the case with hunting. Skill with a hunting weapon can be learned outside the hunting context through play and target practice, is not subject to major growth constraints, and forms an early step in the acquisition of hunting skills. Adults facilitate this by providing children with toy or small hunting weapons at an early age. There is some evidence that time allocated to "aim games" decreases as adult competency increases, supporting the view that such games contribute to adult competency (Bock and Johnson 2004). In one case children begin to play such games several years before they first go on hunting expeditions, and Bock and Johnson (2004) describe how time spent playing an aim game declines as boys start to go on hunting trips. In addition, knowledge about animal behavior and a repertoire of hunting strategies may be acquired by observation and by listening to hunting stories. This begins long before children first go on hunting expeditions, and children start to show mastery of these skills relatively early. This suggests that the acquisition of hunting skill follows a sequence, with skills that can be acquired outside the hunting context developed first in some contexts.

Bock (2002) has suggested a steplike relationship between growth and experience in the ontogeny of acquisition of adult competency in skills, and this relationship is argued to be task-specific. Some strong temporal patterns in the acquisition of hunting skills have emerged from comparison of case studies. Children begin to accompany adults on hunting trips between ages 5 and 7. This may be related to changes in height and strength, language learning, and psychological processes, which could contribute to children's ability to keep up and to follow instructions. Children's hunting experiences change around age 12–13, when they begin to accompany adults on hunting trips, go on hunting trips with peers, or are introduced to more hunting strategies. This additional experience may relate to changes in height and strength around this age. There may be constraints on the acquisition of hunting skills, including constraints of size or strength (e.g., the risk of encountering predators or dangerous prey, becoming exhausted/dehydrated, not being able to keep up) or experience (for instance, the risk of becoming lost). Strategies used to catch larger game tend to be learned relatively late, and first kills of these species occur late in adolescence, suggesting that there may be stronger constraints on experience in hunting particularly large, aggressive, or dispersed species. Alternative hypotheses about the basis of growth constraints could be tested with primary research measuring children's skill and strength before and after they start hunting, and also comparing returns from hunts without children with early and later hunts with children. Based on Bock's (2002, 2005) model, growth constraints on the acquisition of hunting skills would discourage parents from putting effort into children's early hunting education: this provides an explanation of the patterns of social learning described above.

This discussion gives some idea of the changing costs and benefits with age of investment in a child's hunting experience. How would selection act on these costs and benefits if such skill were necessary for obtaining a critical resource? In the interpretation of Kaplan et al. (2000), constraints on learning costly hunting skills before adolescence would lead to an extension of the adolescent phase. This is not consistent with patterns of human growth (Leigh 2001). In Bock's (2002) punctuated development model, there could be selection for sensitive periods for learning particular skills in the phases where skills can be acquired most effectively. This would suggest a sensitive period before adolescence in which skills associated with marksmanship, such as hand-to-eye coordination, can be learned faster or more thoroughly. A further sensitive period in adolescence in which skills associated with hunting experience could be learned faster or more thoroughly would also be predicted. These predictions can be tested through studies of human development—for instance, quantitative study of the effects of early practice on the acquisition of skill with a hunting weapon in traditional societies.

Theories of life history evolution, social learning, and cultural transmission provide insights into the problem of the role of the juvenile period in human life history evolution. In order to understand cross-cultural regularities and variation in the development of foraging skills, we need to take into account changing costs and benefits of different activities with age, and costs to the demonstrator, as well as alternative learning mechanisms. Such an integrative approach is provided in the concepts of punctuated development of skills, and parental allocation of effort determined by the pattern of development and trade-offs with other activities (Bock 2002, 2005). Further quantitative analysis will be necessary to test the alternative predictions for the development of human hunting skills conclusively. Other foraging and social skills may be as or more important in life history evolution, and should be evaluated using these perspectives. In addition, fossil evidence for the evolutionary development of life history patterns is valuable in providing an alternative source of evidence.

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