

A cross-cultural investigation of learning among Hadza and BaYaka hunter-gatherer children and adolescents from Tanzania and Congo

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March 2019

This dissertation is submitted for the degree of Doctor of Philosophy

Preface

- This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration except as declared in the Preface and specified in the text.
- It is not substantially the same as any that I have submitted, or, is being concurrently submitted for a degree or diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text. I further state that no substantial part of my dissertation has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text
- It does not exceed the prescribed word limit for the relevant Degree Committee.

Acknowledgements

Many people helped make this dissertation a reality. Michael Lamb's curiosity, humility, and commitment to bettering the lives of others through rigorous research are lessons that I will carry with me forward. Adam Boyette took me on my first solo field expedition. While lying awake in our tents during torrential downpours, we had many conversations which shaped my thinking on social learning. While we both cried when he left me alone in a remote Congolese village, I knew he was always a satellite phone call away. Alyssa Crittenden adopted me but treated me like one of her own. She mentored me not only in research, but in being human, and for that I am forever grateful. Barry Hewlett's comments on this project, from conception to publication, have helped me think deeper, and read more widely, on hunter-gatherers and the evolution of childhood. Robert Attenborough was always ready for a cup of coffee and advice on how to best organize my time and thoughts. I call these mentors 'Team Awesome', and this dissertation would not have been possible without them.

From Congo, I would like to thank; Prof. Clodion Bouka-Biona from IRSEN, whose commitment to science made everything possible; DZABATOU Moise who always had a solution to social and technical hurdles; and my field assistants, MIKOUNOU Paul and KOUTAIN Mindoula who made translating in real time look like a breeze. From Tanzania, I would like to thank; Prof. Audax Z. Mabulla from the University of Dar es Salaam, who facilitated the acquisition of research permits and infrastructure; Shani Msafiri who survived walking hours into the Tanzanian sun following kids who were themselves following honey guides, all while translating; and Ibrahim Audax Mabulla who brought his wisdom and experience to my research, and survived my horrid cooking.

I could not have a better support system than my family; my dad, the first anthropologist in my life, is the best example I have for pedagogical parenting (and it worked). My mom's commitment to social justice, and amplifying the voices of women and children, served as guiding principles throughout my fieldwork. My sisters, Myriam, Coco, and Clara, are testaments that humans can survive anything, including a stubborn sister. My husband, Michael, listened to my tirades about data, brought me endless cups of tea, and forced me to celebrate small accomplishments, all while conducting his own fieldwork.

Thanks as well to; Noa Lavi, Rachel Reckin, and Kate Ellis-Davies for insightful conversations on archaeology, culture, and child development; David Lancy, for his provocations to think more critically about childhood across cultures; ADPRG lab members, and especially Hayden Henderson, for reminding me that science should be fun; Mallika Sarma and Sarah Pope, who I had the privilege of doing fieldwork with; the Gates gang, especially Leah Weiss, Jose Circo Martinez, and Stephen Kissler, for long talks about politics and statistics; and WAS, especially Lucas and Nate, for forest adventures which taught me to be hungry and happy.

Thanks to the funding bodies that financed my research: the Cambridge International Trust, the SSHRC Doctoral Scholarship (Award no. 752-2016-0555), the Ruggles-Gates Fund for Anthropological Scholarship of the Royal Anthropological Institute of Great Britain and Ireland, the Smuts Memorial Fund, the Worts Travelling Grant, and the Cambridge School of Biological Sciences Fieldwork Fund.

Finally, and most importantly, thanks to the Hadza and BaYaka families whose lives are reflected in the pages of this dissertation. The children taught me to sing, talked to me when no one would, made me laugh, fell asleep in my arms, built fires for me, drank my coffee, shared honey and caterpillars with me, and tolerated me as I watched them for hours at a time. Their parents were infinitely patient with my many inabilities. They forever changed my life for the better.

Abstract

Unlike other species, humans can be found in nearly every ecological niche in the world, from the Kalahari Desert to the Arctic Circle. Humans are able to inhabit these environments because we rely on skill and knowledge transmitted and improved upon from one generation to the next. Thus, studying learning is essential to understanding the diversity in, and evolution of, human cultures. Hunter-gatherers may be especially important to study knowledge transmission because these populations are culturally distinct from Western societies, and because hunting and gathering is the oldest human subsistence strategy. Thus, hunter-gatherers can shed light on the cultural variability in, and evolution of, learning in humans.

This dissertation sought to explore how teaching, play, and participation contribute to knowledge acquisition using an observational dataset of 46 Hadza and 65 BaYaka children and adolescents from Tanzania and Congo. Specifically, I sought to investigate (1) how similarities and differences in the socioecologies of forager childhood contributed to variation in teaching, (2) the development of gender-typed play and gender segregation during play among hunter-gatherer children and adolescents, and (3) how cultural and ecological variation contributed to differences in children's participation in economic work.

Results showed that child-to-child teaching was common among foragers, but that the identity of specific child teachers varied according to subsistence and settlement patterns. Features inherent to hunter-gatherer life, such as living in small, mobile camps with few age mates, and a gendered division of labour in adulthood, explained observed gender differences in the play of hunter-gatherer children. Finally, BaYaka and Hadza adults provided opportunities for children's autonomous participation, and in doing so, facilitated the acquisition of both skill-based knowledge, the foundational schema of autonomy, and gender norms.

Taken together, these findings challenged the accepted notion that children are passive recipients of resources, instead highlighting the ways in which children actively seek, and transmit, knowledge. These findings also highlighted the importance of examining ecological, cultural, and demographic contexts for child development.

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Chapter 1: Introduction

Humans have exceptionally long pre-reproductive lifespans, or childhoods, especially for our body size and clade (Bogin, 2006; Kaplan, Hill, Lancaster, & Hurtado, 2000). Childhood is characterized by a long developmental period, delayed reproduction, and extended parental provisioning (Bock, 2002; Kaplan et al., 2000; Kramer, 2005). Humans can also be found in nearly every ecological niche in the world, from the Kalahari Desert to the Arctic circle. Humans are able to inhabit these environments because we rely on cumulative culture, or skill and knowledge transmitted and improved upon from one generation to the next (Boyd & Richerson, 1985). Considering the complexity of the human cultural repertoire, both in terms of subsistence technology and social institutions and customs (Legare & Nielsen, 2015), human childhood may have evolved as a period for knowledge acquisition (Kaplan et al., 2000). This dissertation examined the cultural diversity in, and evolution of, learning in humans by investigating how knowledge is acquired in two hunter-gatherer societies; the Hadza of Tanzania, and the BaYaka of Congo. In what follows, I outline the rationale for the study of learning among hunter-gatherers.

Why Study Learning among Hunter-Gatherers?

Hunter-gatherers—or foragers—are mobile societies that rarely store food, live in small camps of, on average, 25-45 individuals, have low population densities, and are multilocal in residence (Kelly, 1995). Foragers are important to the study of learning because hunting and gathering is the oldest human subsistence strategy (Marlowe, 2005). Indeed, while foragers are diverse in their histories, including episodes of migration, isolation, incorporation, and exchange with neighbouring herders, farmers, and more recently, the nation-state (Reyes-García & Pyhälä, 2016), studying modern-day hunter-gatherers provides researchers with the closest analogy for understanding how demography and mobility contributed to the evolution of learning.

Furthermore, our understanding of child development mostly comes from studies conducted in the West, thus overlooking a majority of the world's populations (Joseph Henrich,

Heine, & Norenzayan, 2010; Kline, Shamsudheen, & Broesch, 2018; Lancy, Bock, & Gaskins, 2010; Nielsen & Haun, 2016). Indeed, surveys consistently find that 94-96% of studies in psychology journals are conducted in Western post-industrial countries, which represent only 12% of the world's population (Arnett, 2008; Joseph Henrich et al., 2010; Rad, Martingano, & Ginges, 2018). Furthermore, these studies usually assume that their findings are generalizable to humans as a species, without considering the role of culture in influencing human behaviour.

Because foragers are culturally distinct from Western and other small-scale societies, studying these populations can provide insight on how cultural norms of behaviour affect learning. Foragers are highly egalitarian, with mechanisms in place to prevent the accumulation of wealth, power, and prestige (Woodburn, 1982). Egalitarianism is maintained by demand sharing, which facilitates the redistribution of food, goods and knowledge (Bird-David, 1990; Peterson, 1993). Sharing is also central to the formation and maintenance of forager social relationships (Bird-David, 1992; Myers, 1986; Peterson, 1993). Finally, foragers often display what Endicott (2011) terms “cooperative autonomy”. As opposed to categories such as “individualism” or “collectivism” into which cultures are often lumped (e.g. Triandis, 2001), cooperative autonomy is “based on a combination of obligations to the group and protections for individuals against coercion by others” (Endicott, 2011, p. 81). Taken together, egalitarianism, sharing, and cooperative autonomy make up the foundational schemas, or “cultural values and ways of thinking and feeling that pervade several domains of life” (Hewlett, Fouts, Boyette, & Hewlett, 2011, p. 1171) of foragers, and may influence how, and from whom, children learn.

Stages of Childhood

This dissertation is concerned with how children learn in early childhood, middle childhood, and adolescence—which I refer to collectively as “childhood”. Early childhood is a uniquely human stage of development where, though children are weaned, they are not capable of feeding themselves. Physiologically, children in early childhood have deciduous teeth and underdeveloped digestive systems (Bogin, 1997, 2006). Thus, in early childhood, children are dependent on mothers and alloparents—or other-than-mother caretakers—for easy to digest, calorie-dense food. Among foragers, these children are encouraged to explore their

environments autonomously, and adults rarely interfere when children play with dangerous objects, such as knives and fire (Hewlett, Lamb, Shannon, Leyendecker, & Scholmerich, 1998; Lew-Levy, Lavi, Reckin, Cristóbal-Azkarate, & Ellis-Davies, 2018; Chapter 5). During early childhood, children also transition from the mother's arms to the multi-aged, mixed-gendered autonomous playgroup, which becomes the dominant setting for children's socialization (Boyette, 2016b; Eickelkamp, 2017; Gardner, 1966; Konner, 2016; Lew-Levy, Reckin, Lavi, Cristóbal-Azkarate, & Ellis-Davies, 2017).

Children transition from early to middle childhood during the five-to-seven-year shift (Sameroff & Haith, 1996). Physiologically, the transition from early to middle childhood is marked by the eruption of the first molar and the midgrowth spurt (Konner, 2010). Cross-culturally, middle childhood is recognized as a period when children gain sense, and take on more productive roles in the household economy (Lancy & Grove, 2011). Children demonstrate greater intersubjective teaching and learning (Ashley & Tomasello, 1998; Tomasello, 1999), a growing understanding of family and gender roles (Maccoby, 1998; Watson & Amgott-Kwan, 1983), and an increased knowledge of moral norms (House et al., 2013; Konner, 2010). Foragers in middle childhood are capable of harvesting some of their own food, depending on ecological constraints (Bird & Bliege Bird, 2002; Crittenden, Conklin-Brittain, Zes, Schoeninger, & Marlowe, 2013; Hawkes, O'Connell, & Blurton Jones, 1995; Tucker & Young, 2005).

Puberty marks the transition from middle childhood to adolescence. During puberty, children reach sexual maturity, and experience a growth spurt that is relatively late in absolute age and peak velocity when compared to other primates (Bogin, 2006; Demirjian, 1985). While forager adolescents are fully capable of participating in childcare and subsistence work, they are still primarily provisioned by others (Hewlett & Hewlett, 2012). This frees adolescents to travel widely, visiting with family and friends in distant camps and villages to search for mates as well as teachers who can transmit specialized knowledge such as basketry, hunting, and healing skills (Dira & Hewlett, 2016; Hewlett, 2013, 2016; Hewlett & Hewlett, 2012; MacDonald & Hewlett, 1999).

Variations in Hunter-Gatherer Childhoods

In his work with the !Kung, and subsequent comparison of the !Kung with other forager societies, Konner (see 2005, 2010 for review) noted several features of infancy and childhood which seemed to be shared among these populations. These included (1) close physical contact with mother, (2) indulgence towards infants (3) frequent nursing, (4) co-sleeping, (5) weaning around three years of age, and four-year birth spacing, (6) separation and stranger rejection, (7) dense social contexts (8) primary care by the mother (9) more father care than in other societies, (10) transition into a multi-aged, mixed-gender playgroup, (11) little child responsibility for subsistence and childcare, and (12) few restrictions on childhood and adolescent sexuality. Together, these features were considered to represent the childcare practices of humans in the environment of evolutionary adaptedness in what Konner termed the Hunter-Gatherer Childhood (HGC) model.

More recent observational research on infancy and early childhood largely support the finding of the HGC model (but see Hewlett, 1991b; Hill & Hurtado, 1996; Morelli, Henry, & Foerster, 2014 for exceptions), including studies comparing the childrearing practices of foragers with neighbouring farmers and pastoralists (e.g. Fouts & Lamb, 2005; Hewlett, Lamb, Leyendecker, & Scholmerich, 2000). However, some elements of the HGC model pertaining to middle childhood are more variable than previously thought. Specifically, children's participation in economic work, and certain forms of teaching, such as task assignment, vary considerably across hunter-gatherer societies. These may represent more facultative adaption to specific ecological and cultural contexts (Konner, 2010; Tronick, Morelli, & Winn, 1987). Still, no studies to-date have formally investigated cross-cultural variation in social learning among hunter-gatherers, including learning through play, participation and teaching.

Learning Outside the West

Teaching can be defined as (1) activities which involves teachers modifying their behaviour to enhance learning in other individuals, (2) not the by-product of another activity, and (3) involves a teacher's sensitivity to the knowledge and skill of the learner (Hewlett & Roulette, 2016). While teaching likely occurs among various social animals, such as ants, meerkats, and pied babblers

(Thornton & Raihani, 2008), human teaching is unique in that it contributes to the development of skills that are not biologically inherent to the individual (Flynn, Laland, Kendal, & Kendal, 2013). Teaching allows for the accurate transmission of complex knowledge, and thus, likely facilitated cumulative cultural evolution (Castro & Toro, 2014; Strauss, Calero, & Sigman, 2014). Developmental psychologists Strauss and Ziv (2012) have argued that teaching is a unique cognitive feature in humans because it is complexly structured for solving a specific type of adaptive problem, develops reliably in neuro-typical individuals without conscious effort, is distinct from other information processing abilities, and is species-typical and species-unique. However, some anthropologists have countered their claim. For example, Lancy (2010) argued that, outside the West, teaching minimally contributes to knowledge transmission. He stated that “the kind of nuanced, student-centred, developmentally appropriate instruction by dedicated adults that we today take as the operational definition of teaching is a recent product of a long process of educational change” (Lancy, 2010, p. 26). Although his definition historicized teaching as it occurs today in the West, it also systematically excluded children as potential teachers. Considering the dominance of the multi-aged playgroup during forager childhoods (Konner, 2005), child-to-child teaching may be prevalent in these populations.

Next, play has been defined as “all locomotor activity performed postnatally which appears to an observer to have no obvious immediate benefits for the player, in which motor patterns resembling those used in serious functional contexts may be used in modified terms. The motor acts constituting play have some or all of the following structural features; exaggeration of movements, repetition of motor acts, and fragmentation or disordering of sequences of motor acts” (Bekoff & Byers, 1981, p. 301). Since play takes up an appreciable amount of the time budget of children, and is energetically costly (Bekoff & Byers, 1992; Boyette, 2016a; Gosso, Morais, & Otta, 2007), play may have evolved to provide children with opportunities to learn the skills necessary for survival in adulthood (Smith, 1982). For example, exercise play has been linked to physical training (Byers & Walker, 1995; Pellegrini & Smith, 1998a); object play is hypothesized to facilitate tool use capabilities (Pellegrini & Gustafson, 2005); social play promotes social bonding and cooperation (Pellegrini & Smith, 1998a); structured games likely contribute to children’s moral development (Piaget, 1965); and pretense

play may enrich various aspects of children's cognition (Burns & Brainerd, 1979; Pellegrini & Galda, 1982; Sylva, Bruner, & Genova, 1976). Researchers examining the adaptive function of play have argued that observed gender differences in the play of Western children (e.g., girls preferring to play with dolls, boys participating in more exercise play than girls) may have prepared girls for their role as gatherers and mothers, and boys for the role of hunters during our evolutionary past (e.g. Pellegrini & Bjorklund, 2004; Smith, 1982). Since the gendered work of forager adults is more flexible than these studies claim, with women hunting (e.g. Goodman, Bion Griffin, & Estioko-Griffin, 1985; Noss & Hewlett, 2001) and men gathering (e.g. Hewlett, 1991b; Marlowe, 2007) in some societies, research is needed to determine whether gender differences in play observed in the West hold true among extant foragers (Hewlett & Boyette, 2013).

Furthermore, play usually occurs in gender segregated groups, with children as young as three preferring to play with same-gender children (Hines & Kaufman, 1994; Lafreniere, Strayer, & Gauthier, 1984; Maccoby, 1998; Moller & Serbin, 1996; Pellegrini, 2004). However, contextual features may facilitate or impede gender-segregation (Harkness & Super, 1985). When same-aged peers are absent, segregating by gender may be difficult. For example, among the San foragers of the Kalahari Desert, who have especially low fertility rates, Konner (1976b) reported that there would likely be six to eight children, ranging in age from infancy to adolescence, and of both genders, with whom to play (see also Draper, 1976; Hewlett, 1991). While such demographic constraints may explain why forager children have been observed playing primarily in mixed-gender groups (Draper, 1976; Hewlett, 1991a; Konner, 1976, 2005), the relationship between access to playmates and gender-segregation during play has not been empirically tested.

Finally, while children in all societies learn through participation (e.g. language learning--Rogoff, Paradise, Arauz, Correa-Chávez, & Angelillo, 2003), children in the West are often segregated from the productive activities of adults. In small-scale societies, on the other hand, children are included in many aspects of adult life, and thus, can learn by paying attention to, and working alongside, adults (Gutierrez & Rogoff, 2003; Rogoff, 2014; Rogoff et al., 1993). Parents in many small-scale societies facilitate participation by providing children with opportunities to contribute to the family economy through chore assignment, which acts as both a way to gage,

and increase, children's skill level in order to facilitate learning (Lancy, 2012). However, the degree to which children are expected to participate in adult tasks is dependent on environmental risks and cultural beliefs about child autonomy. For example, agricultural activities provides a safe, managed, and predictable environment in which children can participate in low-skill work (Hames & Draper, 2004; Lee & Kramer, 2002), while non-domesticated resources are unpredictable, unmanaged, and in some cases, unsafe to pursue (Draper & Cashdan, 1988; Hames & Draper, 2004; Munroe, Munroe, & Shimmin, 1984). As a result, forager children's participation in work is more directly tied to ecological variables. In the only series of studies investigating how variation in ecology translates to variation in forager children's work, Blurton Jones, Hawkes, and colleagues (1994; 1995) found that San children did not forage as frequently as Hadza children because the former had limited access to water and landmarks while away from camp, thus making foraging a riskier endeavour. However, the foraging returns of San mother-child pairs was higher when San children processed *mongongo* nuts in camp than when foraging with mothers (Blurton Jones et al., 1994), suggesting that when children cannot contribute directly to food production, they may substitute food production with other forms of work. In addition, because of the schemas of autonomy and egalitarianism, there is minimal status differences between adults and children, and children are not expected to defer to adults (Endicott, 2011; Gardner, 1991). As a result, forager children receive fewer chore assignment than their farmer counterparts (Boyette, 2016a; Boyette & Lew-Levy, Under review; Draper & Cashdan, 1988; Lew-Levy et al., 2018; Morelli, 1997). However, no studies have investigated how ecological variation contributes to children's learning through participation, nor how adults facilitate participation in work in the near absence of chore assignment.

Research Questions

Considering the literature reviewed above, this dissertation had three main research questions; (1) who teaches children to forage? (2) how do social and cultural contexts influence the gender-typed and gender-segregated play of forager children? and (3) how do forager parents facilitate children's knowledge acquisition through participation in diverse ecologies? This dissertation took a comparative approach in that it investigated how cultural and ecological differences

influenced children's learning in two forager societies; the Hadza of Tanzania and the BaYaka of Congo. It also took a developmental approach by focusing on how knowledge acquisition changes throughout childhood. Finally, this dissertation took an integrative approach by drawing upon theories and findings from anthropology, psychology, and the evolutionary sciences. In what follows, the ethnographic setting for the three studies conducted as part of this dissertation, and methods used to answer these research questions, are outlined.

Methods

Ethnographic Settings

The BaYaka are forest foragers from the Congo Basin (Figure 1.1). The BaYaka make up nearly 60% of the rural populations of northern Congo, where the research took place (Lewis, 2002). The BaYaka hunt with bows, cross-bows, spears, guns, and snares (Bahuchet, 1988; Kitanishi, 1995). Furthermore, the BaYaka harvest yams, mushrooms, caterpillars, and other forest products for subsistence. Finally, honey harvesting is an important activity during the dry season. Compared to other foragers, the BaYaka maintain especially egalitarian gender relations, with men participating in gathering and childcare alongside women (Hewlett, 1991b; Lewis, 2008; Marlowe, 2007). The BaYaka maintain trade relations with their farming neighbours through fictive kinship ties (Grinker, 1994; Joiris, 2003; Rupp, 2014). The BaYaka surveyed as part of this dissertation are most closely related to the Mbendjele BaYaka.

The Hadza are foragers who live in the arid savanna woodlands of the Eastern rift, south east of Lake Eyasi in Tanzania (Figure 1.2) (Hawkes, O'Connell, & Jones, 2001; Marlowe, 2010). Fewer than 150 Hadza continue to hunt and gather for subsistence (Crittenden, 2009). The Hadza maintain a strict gendered division of labour (Crittenden, 2009). Men harvest honey throughout the year, and use bows and arrows with poisoned tips to harvest large and small game (Crittenden, 2009; Marlowe, 2010; Marlowe et al., 2014). Women harvest berries, baobab fruit, and tubers. The Hadza have experienced many episodes of forced settlement, starting under British colonial rule in 1927, and by the Tanzanian government from independence until now. Today, much of Hadza traditional territory is encroached on by Datoga pastoralists and luxury

hunters (Gibbons, 2018). Corn, provided by missionaries, is becoming a staple in the Hadza diet (Crittenden et al., 2017).

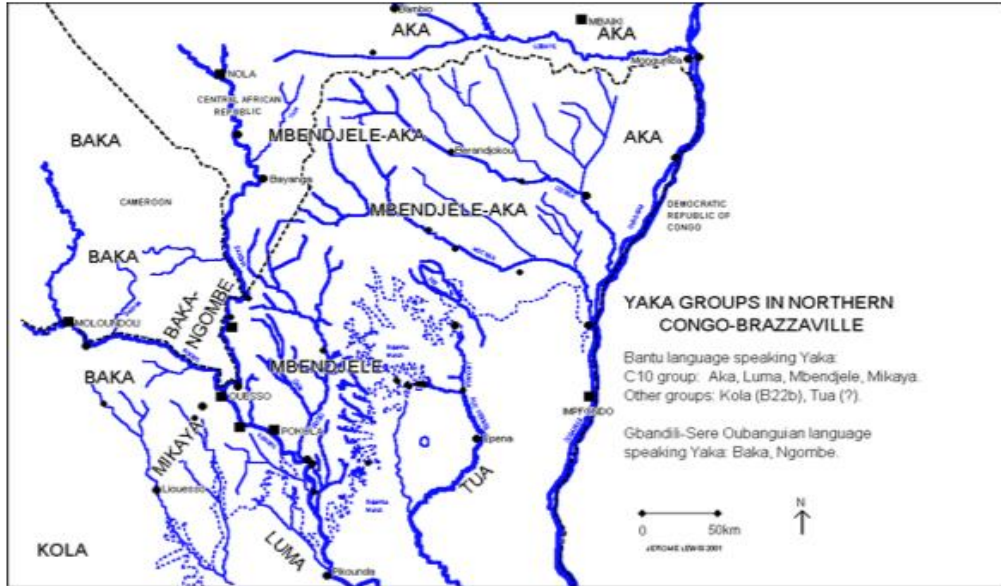


Figure 1.1. Map of BaYaka territory, from Lewis (2002 p. 50).



Figure 1.2. Map of Hadza territory, from Crittenden (2009, p.9).

Data Collection

Data collection took place in March and April 2017 in three camps among the Hadza, and June through September 2016, 2017, and 2018 in seven camps among the BaYaka. Data were collected using behavioural observations, interviews, and participant observation.

Behavioural observations. The primary method used throughout this dissertation was the focal follow sampling of children aged three to eighteen (total Hadza $N=46$, 41% female, total BaYaka $N=65$, 48% female). Altmann (1974, p. 242) described the focal follow procedure as involving the following steps: “(i) all occurrences of specified (inter)actions of an individual, or specified group of individuals, are recorded during each sample period, and (ii) a record is made of the length of each sample period and, for each focal individual, the amount of time during the sample that it is actually in view. Once chosen, a focal individual is followed to whatever extent possible during each of his sample periods.” Focal follows are ideal for establishing overall time allocation to activities of interest (Lehner, 1998). Focal follows have been used in other studies examining children’s time allocation to play (Boyette, 2016a; Fouts, Bader, & Neitzel, 2016), teaching (Boyette & Hewlett, 2017a; Kline, 2016) and work (Crittenden et al., 2013; Froehle et al., 2019) in small-scale societies. For this dissertation, children’s behaviours were recorded at 1-minute intervals, with a 30-second observation window followed by a 30-second recording window. The ethogram developed for this study can be found in the Appendix, but, briefly, I recorded children’s work and work type, and children’s play, play type, and whether children were playing in mixed-gender or single-gender groups. In a subset of observations, I also recorded any teaching which occurred to or from the focal child, the identity of the teaching partner, and the domain of knowledge in which teaching occurred. Teaching follows were conducted with an interpreter, in order to ensure that more subtle, linguistic forms of teaching could be appropriately recorded. Children were followed over two 2-hour sampling blocks, usually once in the morning, and once in the afternoon. In 2016, these sampling blocks were scheduled on two separate days, while in 2017 and 2018, these sampling blocks were scheduled on a single day. Further relevant details about the data collection methods are presented in chapters 3-5.

Interviews. In addition to focal follows, formal and informal interviews were conducted to supplement my understanding of BaYaka and Hadza behaviour. Informal interviews were

conducted throughout the stay, and primarily involved asking adults about how they learned to perform subsistence tasks (e.g., “How did you learn to fish?”). Short structured interviews were performed in each camp once a day for seven to 13 days. With the help of an interpreter, I asked adults what activities they had engaged in that day, whether children had accompanied them, and why. This was to obtain an emic understanding regarding why adults do and do not forage with children. The results of these interviews are outlined in chapter 5.

Participant observation. Participant observation is a method commonly used in the qualitative social sciences in which a researcher learns about a society and culture by sharing in group activities (Claster & Schwartz, 1972). Because I lived in camp with participants, I was able to participate in various cultural activities such as foraging, childcare, dancing, singing, and ceremonies. Because I spent twelve months among the BaYaka, I gained basic language competencies, which helped me understand what participants were saying to each other, and to their children. I was also able to observe, and ask questions about, child rearing, teaching, play, and local perceptions of child development. My time in Hadzaland was considerably shorter, spanning only two months. Thus, my own observations of Hadza childrearing was supplemented by Alyssa Crittenden (Department of Anthropology, University of Nevada, Las Vegas), who supervised the Hadza portion of my fieldwork, and who has spent over 20 months of fieldwork studying Hadza childhood between 2004 and 2016. The data collected through participant observation provided important contextual information for children’s play (Chapter 4), and adult facilitation of participation (Chapter 5).

Chapter Summaries

This dissertation presents the written reports of four studies. Each study was written as a stand-alone paper¹. Chapter 2 is a meta-ethnographic review of previously published studies on how forager children learn to hunt and gather². Like systematic reviews, meta-ethnographies allow researchers to examine common themes in the available published literature; unlike systematic

¹ Each chapter is presented as submitted/published, with references changed to APA style throughout.

² This chapter is published as Lew-Levy, S., Reckin, R., Lavi, N., Cristobal-Azkarate, J., Ellis-Davies, K. (2017). How do hunter-gatherer children learn subsistence skills? A meta-ethnographic review. *Human Nature* 28(4): 367-394.

reviews, meta-ethnographies allow for the synthesis of both qualitative and quantitative findings (Campbell et al., 2003). Collectively, the 58 studies which met the inclusion criteria showed that in early and middle childhood, children transition into the multi-age playgroup, where they learn skills through play, observation, and participation. By the end of middle childhood, most children are proficient food collectors. However, it is not until adolescence that adults (not necessarily parents) directly teach children complex skills such as hunting and complex tool manufacture. Furthermore, child-to-child teaching was often mentioned by ethnographers, but was rarely systematically studied.

Chapter 3 used the Social Relations Model, a type of social network analysis (Koster & Leckie, 2014) to investigate the effect of age, sex, and kinship on the teaching of subsistence skills among the Hadza and BaYaka, with an emphasis on child-to-child teaching³. This study showed that child-to-child teaching was more frequent than adult-child teaching. Additionally, children taught more with age, teaching was more likely to occur within same-sex than opposite-sex dyads, and close kin were more likely to teach than non-kin. The Hadza and BaYaka also showed distinct learning patterns; teaching was more likely to occur between sibling dyads among the Hadza than among the BaYaka, and a multistage learning model where younger children learn from peers, and older children from adults, was evident for the BaYaka, but not for the Hadza. These differences were attributed to differences in subsistence and settlement patterns.

Chapter 4 compared the development of gender-typed play and gender segregation during the play of Hadza and BaYaka children⁴. In support of the hypothesis that children would be less likely to segregate by gender in smaller camps, results showed that children were more likely to play in single-gender groups in camps with more child inhabitants. The results also showed limited gender differences in play types, with gender differences in rough-and-tumble play only significant in adolescence. Finally, chapter 4 showed that children's pretense play emulated

³ This chapter is currently under review as Lew-Levy, S., Kissler, S.M., Boyette, A.H., Crittenden, A.N., Mabulla, I.A., Hewlett, B.S. Who teaches children to forage? Exploring the primacy of child-to-child teaching among the Hadza and BaYaka hunter-gatherers of Tanzania and Congo. *Evolution and Human Behavior*.

⁴ This chapter is being revised for resubmission as Lew-Levy, S., Boyette, A.H., Crittenden, A.N., Hewlett, B.S., Lamb, M.E. Gender-typed and gender-segregated play among Tanzanian Hadza and Congolese BaYaka hunter-gatherer children and adolescents. *Child Development*.

gender-specific adult activities; for the Hadza, where a gendered division of labour was more pronounced, girls were more likely than boys to play with dolls and to participate in foraging play. Among the BaYaka, where men participated in gathering, and where “fathers do more infant caregiving than fathers in any other known society” (Hewlett, 1991b, p. 169), no gender differences in doll and foraging play were observed. Taken together, this chapter demonstrated that contextual features, such as demographic constraints, and cultural features, such as the gendered division of labour in adulthood, influence children’s gender-typed and gender-segregated play.

Finally, chapter 5 investigated how cultural and ecological variation contributed to differences in Hadza and BaYaka children’s participation in economic work, and how forager adults facilitated learning through participation⁵. Results showed that, by providing tools, assigning chores, and foraging with children, Hadza and BaYaka adults provided opportunities for autonomous learning by facilitating participation. Furthermore, whereas both Hadza and BaYaka children foraged alongside adults when they could be of help, Hadza children were more likely than BaYaka children to forage independently from adults, while BaYaka children were more likely than Hadza children to participate in domestic tasks. This difference is likely due to the fact that the resources targeted by the Hadza are more readily available to children than those targeted by the BaYaka. Taken together, these findings showed that children are independently motivated to learn through participation in culturally relevant activities, including subsistence, but that opportunities for participation are ecologically dependent.

⁵ This chapter is in press as Lew-Levy, S., Crittenden, A.N., Boyette, A.H., Mabulla, I.A., Hewlett, B.S., Lamb, M.E. Inter- and intra-cultural variation in learning-through-participation among Hadza and BaYaka forager children and adolescents from Tanzania and Congo. *Journal of Psychology in Africa*.

Chapter 2: How Do Hunter-Gatherer Children Learn Subsistence Skills?

Humans have an exceptionally long pre-reproductive lifespan for our body size (Bogin, 2006). Humans are also unique in our ability to transmit vast quantities of cultural knowledge from one generation to the next. This transmission of knowledge and accumulation of culture allows us to update our technologies and environmental knowledge in response to changing surroundings (Boyd et al., 2011; Laland, 2004). Some have argued that this human emphasis on learning has shaped our especially long childhoods (e.g. Kaplan & Robson, 2002). Since hunting and gathering has been humanity's subsistence strategy for more than 90% of our evolutionary history, data from modern hunter-gatherer children can be and has been used to test theories about how knowledge transmission has shaped the evolution of our life history strategy (Marlowe, 2005). And yet modern foragers are not direct analogues to the past, nor are they a homogenous group; it is their immense cultural diversity that makes the traits many foraging groups hold in common all the more striking. In addition, studying the social learning of foragers in particular can help us understand the diversity that exists among small-scale societies in general (Boyette & Hewlett, 2017a).

Unfortunately, of the few studies that exist on the topic of learning subsistence skills among foragers, only a handful employ a cross-cultural approach (e.g. Barry, Bacon, & Child, 1957; Barry, Child, & Bacon, 1959; MacDonald, 2007). Yet sociocultural perspectives support the cross-cultural study of learning, in recognition of the interdependence of social and individual processes in the co-construction of knowledge (John-Steiner & Mahn, 1996; Nielsen & Haun, 2016). The few existing cross-cultural studies of hunter-gatherer learning usually focus on a particular skill, such as hunting, and thus fail to recognize how learning might be similar or different across various skill domains.

To address this gap, the present paper adopts a meta-ethnographic approach in order to understand how hunter-gatherer children from around the world learn subsistence skills. Our goal is to answer three main questions: first, how do hunter-gatherer children learn those subsistence skills necessary to survival? Second, how long does it take to learn those various

skills? Finally, from whom do children learn subsistence skills? Our approach is novel; though other publications have used a systematic cross-cultural approach (Barry et al., 1957, 1959), the particular methods associated with a meta-ethnographic review have never been applied to these questions, though they are ideal for distilling patterns from broad data. By searching for learning behaviours in both quantitative and qualitative literature, a meta-ethnographic review process can help uncover trends that apply to foragers cross-culturally, as well as behaviours that stand out as culture-specific (Blurton Jones et al., 1994; Harkness & Super, 1983). Findings can then, cautiously, be used to test theories about humanity's foraging past. Before we describe our methods and results, we offer some background on human life history patterns, and outline features of social and individual learning in humans.

Background

Primates in general, and chimpanzees, bonobos, and humans in particular, have adopted a long and slow life history strategy known as K-selection (MacArthur & Wilson, 2001; Smith, 1989). Like other K-selected species, we have relatively large bodies and invest heavily in a small number of offspring that take a long time to mature. Though humans are similar in size to chimpanzees, some of our life history traits do not fit the expected pattern for our clade. We have longer pre-reproductive lifespans, higher fertility, and shorter interbirth intervals than expected for our body size, even when considering the variability in human birth spacing and fertility (Chisholm, 1993; Kaplan, Lancaster, & Robson, 2003; Lancaster, Kaplan, Hill, & Hurtado, 2000; Leigh, 2001). Primates have a period of infancy, from birth throughout the process of weaning. This is directly followed by juvenility, where individuals are independent from direct provisioning from parents but are not sexually mature. However, Bogin (2006) suggests that humans have inserted another life history stage between these: early childhood, defined as a period in which, though weaned, children still rely on adults for direct care (Bogin, 1997).

Why do humans have this extended childhood? Kaplan and Robson (2002) argue that it is an adaptation for learning complex extractive subsistence skills, especially hunting. Kaplan et al. (2003) point to the fact that, during early childhood, children's bodies grow relatively little, whereas their brains reach 95% of adult size by the time they transition into juvenility around

age six (Bogin, 1997, 2006; Konner, 2010). Since humans make use of resources that require complex skill and knowledge to extract, investment in a large brain in early childhood sets the groundwork for complex learning later in life and thus increases future performance (Kaplan et al., 2003; Kaplan & Robson, 2002). This investment in embodied capital, according to Kaplan et al. (2000), is a driving factor in the evolution of human ontogeny.

So, by what mechanisms do children learn, no matter their subsistence context? Children can learn through play, participation, observation, and imitation. Play, specifically, is an important tool through which children learn community-wide social norms and practice their “chore curriculum” (Chick, 2009; Elias & Berk, 2002; Artin Göncü, Jain, & Turner, 2006; Lancy, 1996, 2015). Play also serves as a key venue for developing skills such as harvesting and hunting (Bock, 2002, 2005; Bock & Johnson, 2004). Indeed, Bock and Johnson (2004) and Boyette (2016a) found that children played less and worked more as they aged. More specifically, Bock (2002, 2005) and Bock and Johnson (2004) found that, as children grow older, play that emulated specific, complex adult activities, such as pounding grain or hunting, becomes less frequent, while actual participation in these activities increases. This suggests that play may provide children with an opportunity to practice complex activities. In addition, participating in adult activities alongside either adults or other children, such as gathering water or firewood, allows a child to develop the necessary competencies to complete these tasks independently (Gaskins, 2000; Lancy, 2012; Rogoff et al., 2003). Finally, in small-scale societies where adult activities are not segregated from those of children, children have ample opportunities to observe adults and to imitate their behaviours (Fouts et al., 2016; Gaskins & Paradise, 2009; Odden & Rochat, 2004).

Not only are children active imitators, they are also overimitators, defined as the imitation of a model’s relevant as well as irrelevant actions (Lyons, Young, & Keil, 2007), as demonstrated by various experiments in WEIRD—Western, Educated, Industrial, Rich, and Developed (Joseph Henrich et al., 2010)—societies. For example, in an experiment conducted by Lyons et al. (2007), a model demonstrated how to open a variety of containers through a series of relevant and irrelevant actions. The 3- to 5-year-old children involved in the study were asked to identify any irrelevant action after each demonstration. Though they did so successfully, when shown how to open the next container with relevant and irrelevant actions, children imitated the sequence

modelled by the adult faithfully. Over and Carpenter (2012) argue that overimitation allows children to learn technologies and cultural practices whose meaning is opaque, allowing for fidelity of transmission across generations. On the other hand, children appear to be incredibly selective in how and from whom they learn (Meltzoff, 1995; Over & Carpenter, 2012, 2013). In one study, 14- to 18-month-olds imitated individuals who showed intentionality in their action, marked by the model saying “There!” If the same action seemed accidental—marked by the model saying “Whoops!”—children were less likely to copy the action (Carpenter, Akhtar, & Tomasello, 1998). Some consider imitation and innovation the dual engines of cultural learning, as both are required for the evolution of cumulative culture (Legare & Harris, 2016; Legare & Nielsen, 2015).

Innovation, also known as individual learning, is especially adaptive when an environment is in flux, and when new, novel innovations must be generated to better adapt to ecological changes (Aoki et al., 2012; Boyd et al., 2011; Enquist, Eriksson, & Ghirlanda, 2007). However, individual learning is costly, in that many attempts must be made before a useful innovation is developed (Boyd et al., 2011; Kline, Boyd, & Henrich, 2013). Predictive models suggest that, in order to learn adaptively, social learning should occur early in life, and trial-and-error learning should occur later, once baseline competencies have been reached (Aoki et al., 2012). Successful innovative behaviours are then diffused throughout the social group.

Finally, children learn from a wide variety of individuals, including parents, other adults, and, importantly, other children. Vertical or parent-to-child transmission (Cavalli-Sforza, Feldman, Chen, & Dornbusch, 1982; Hewlett et al., 2011) seems to be less conducive to innovation, meaning it is more common in stable environments where information need not change rapidly. Various studies have also noted that most vertical transmission is sex-segregated, meaning that mothers teach their daughters and men teach their sons (Chen, Cavalli-Sforza, & Feldman, 1982; Hewlett & Cavalli-Sforza, 1986). Oblique transmission takes place when other adults from the parents’ generation teach children. Oblique transmission is common for learning ceremonial practices, for example, where many members of a cultural group share the same information. Child oblique transmission is when older children teach younger ones. Horizontal transmission occurs within members of the same generation—in this case, children to children—

and allows for the rapid diffusion of information. Thus, some theorists have suggested that horizontal transmission would be favoured in a rapidly changing environment (Cavalli-Sforza et al., 1982).

One growing debate in the field of social learning is whether teaching occurs in small-scale societies, including among foragers. The human propensity for language, overimitation, and prosociality are all necessary for effective teaching, which some believe to be a uniquely human adaptation, essential to the evolution of cumulative culture (Dean et al., 2012; Gergely & Csibra, 2006; Kline, 2015; Tomasello, Kruger, & Ratner, 1993; but see Caro & Hauser, 1992 for examples of teaching in nonhuman animals). And yet, not all agree that teaching occurs across human cultures. Sociocultural anthropologist Lancy (Lancy, 2010, n. 1) defines teaching as “the active and systematic intervention of a teacher whose goal is to change the behaviour of a learner.” This definition closely resembles classroom teaching in a Western setting, and Lancy ultimately concludes that this kind of teaching does not exist in small-scale societies. Using this definition, MacDonald’s (2007) review of foragers learning to hunt also argued that teaching rarely occurs. And yet Kline (2015) demonstrates that teaching has been variously defined depending on the research field in question. A more functional definition derived from ethological studies defines teaching as the process an individual uses to modify their behaviour for the benefit of facilitating another’s learning (Kline, 2015). Therefore, importantly, teaching comes at a cost to the teacher (Caro & Hauser, 1992). Under this definition, behaviours such as chore assignment, commands, and positive and negative feedback would be considered teaching, whereas under Lancy’s definition they would not. Indeed, using this more functional definition, various authors, exploring small-scale agricultural and foraging societies, have found evidence for teaching (Boyette & Hewlett, 2017a; Hewlett et al., 2011; Hewlett & Roulette, 2016; Kline et al., 2013).

After considering the research on learning presented above, the present paper systematically compares previous findings on how children learn subsistence skills in forager societies. Since foragers are culturally distinct from other small-scale societies (Hewlett, Lamb, Leyendecker, & Scholmerich, 2000) and since our evolutionary history has largely been a foraging one (Marlowe, 2005), focusing on foragers can provide us with unique insights into the contributions of learning on the evolution of modern human life history. Furthermore, of those

studies focused on the association between the human life history strategy and learning in foragers, few have employed a cross-cultural approach, which allows us to draw broader trends from the literature. For example, Bliege Bird and Bird (2002), studying Meriam foraging, found that children made optimal foraging decisions based on their size, and thus size and not learning could explain their differing foraging returns. On the other hand, Walker et al. (2002) found that it takes Ache men more than 35 years to become proficient hunters, despite the fact that peak strength and size is reached in their twenties. Is methodology, environment, or culture the cause of these differences? Without a cross-cultural, comparative approach, it is difficult to say. Furthermore, hunting is not the only skill that is complex: toolmaking, for example, can also take a lifetime to master (e.g. Jordan, 2014). And yet, no studies consider these skills through a life history framework. Thus, a broader approach to studying skill acquisition in general, as opposed to particular skills, is warranted. The present study aims to address both of these gaps by comparing cross-cultural data and studying skill acquisition as part of life history.

Methods

Meta-ethnographies are primarily used to synthesize qualitative data for medical research, but they have important applications across various fields (Britten et al., 2002; Campbell et al., 2003; MacEachen, Clarke, Franche, & Irvin, 2006). As with a systematic literature review, meta-ethnographies allow researchers to extract common themes and findings from studies from a variety of fields. However, unlike a systematic literature review, a meta-ethnography allows for the inclusion of both qualitative and quantitative studies so that our results may encompass a broader, more interdisciplinary range of publications.

Search Strategy

The electronic databases used for this search included PsycInfo, JStor, Springer, Wiley, and ScienceDirect. We identified books and book chapters using the above search engines as well as Google Books and the Cambridge University library search system, which has referenced every book published in the UK. We found unpublished theses and dissertations using ProQuest. Our search terms paired the words “forager” OR “hunter-gatherer” with “child” and with “learn” OR “transmission” OR “socialization” OR “skill acquisition.”

In an effort to identify and include older anthropological publications on learning, we also surveyed the electronic Human Relations Area Files (eHRAF) World Cultures (ehrafworldcultures.yale.edu) online as of January 2016. We limited our search to those societies HRAF staff codes as hunter-gatherers and “primarily hunter-gatherers.” Then we searched for ethnographic passages coded by eHRAF staff as “socialization” (OCM code 860), “infancy” and “childhood” (OCM code 850), “learning behaviour” (modification of behaviour; OCM code 153), and “learning process” (ethnopsychology; OCM code 828) from the Outline of Cultural Materials (Murdock et al., 2008). eHRAF provided us with a list of papers that mentioned learning. We investigated each to determine whether they contained significant emphasis on hunter-gatherer learning in childhood.

We designed the final steps of our search in hopes of finding studies that we may otherwise have missed. First, we searched the references of relevant articles and book chapters. Second, we searched the references of qualitative literature reviews on learning in hunter-gatherer children. Third, we searched the publication lists of first authors of relevant publications. Fourth, we contacted the first authors of relevant publications. We provided them with our publication list, to ensure that we were not missing key texts, doctoral dissertations, or unpublished manuscripts. We also contacted all authors who contributed to the Cambridge Encyclopaedia of Hunters and Gatherers (Lee & Daly, 1999) for any published or unpublished manuscripts on learning in their study communities. Finally, we sorted the studies into two overall groups: studies on learning social skills and gendered behaviours (Lew-Levy et al., 2018) and studies on learning subsistence skills. This paper focuses on the latter topic.

Eligibility Criteria and Study Selection

We included studies based on three criteria. First, that the societies in question were hunter-gatherers. Second, that the studies had primarily focused on learning. Third, that the studies considered the learning of children.

Academic definitions of hunter-gatherers have varied broadly over the years, with some focusing on a social definition of small-scale, egalitarian societies; others on a pure economy of foraging; and others still on the importance of mobility. For each of the various definitions of hunter-gatherers, the diversity of foragers across the world means there is always a group that

will not fit (Kelly, 1995). We chose to focus on socially defined small-scale, relatively egalitarian and traditionally foraging societies. There are no foragers today who do not accept economic input from domesticated plants and animals. Thus, we included groups such as the Penan, who sometimes participate in rice swidden agriculture, and the Aka, who trade with farming neighbours. Because of our focus on a social definition of small-scale foragers, we excluded some groups who, economically, are purely foragers, but whose societies are highly stratified. For example, we excluded North America's Pacific Northwestern Kwakiutl, Nootka, and Makah, who subsisted entirely on wild foods, including plentiful salmon runs, but also held slaves. In considering the inclusion of studies on native North Americans and Australians more broadly, we exercised our judgment. Many of these cultures are, of course, foundationally foraging ones, though they have been forcibly removed from that lifeway. For this reason, we included studies of Indigenous socialization or mid-century ethnographies of Native Americans that discuss children's learning. We would like to note here that we included studies of foragers who attended school, as long as these studies focused on children's foraging activities. The reasons for this are twofold: first, not all studies noted the degree to which children were formally educated. Second, two studies included in this review noted that years spent in school did not significantly influence children's foraging performance (Blurton Jones & Marlowe, 2002; Kawabe, 1983). However, we specifically excluded any studies about learning in school. And, where we feel schooling might have influenced the results of a study, we explicitly address this topic (e.g. Nielsen, Mushin, Tomaselli, & Whiten, 2016, 2014; Nielsen & Tomaselli, 2010). Finally, many foraging groups are not represented in this study, and that may well be because there are no relevant studies about that group, not because we do not consider them to be foragers.

In this review, we only included studies that focused specifically on learning subsistence skills, or the processes associated with subsistence skills. We did not include studies that mentioned learning but did not specifically explore this topic. However, in older publications retrieved from eHRAF, mostly early- to mid-twentieth-century ethnographies, sections entitled "childhood" sometimes include detailed descriptions of socialization practices. These were included. We included studies that the authors in question define as focused on childhood. We also expected those studies we selected for inclusion to have at least some original data. These

include studies that use various qualitative ethnographic methods (interviews, participant observation, etc.), experimental designs, quantitative behavioural observations, and quantitative interview techniques. We excluded studies that rely entirely on secondary data we could access elsewhere. However, we used the references from these studies to find their primary sources wherever possible. Finally, we excluded conference proceedings, as well as publications in a language other than English.

Data Extraction and Synthesis

Data collection took place between January and March 2016. We extracted three types of data for each study included in this survey. (1) Descriptive data: the hunter-gatherer group(s) surveyed, the age group(s) surveyed, and the year in which the paper was published. (2) Methodological data: the objective of the study and the study design (interview, participant observation, behavioural observation, etc.). (3) The findings of the study in relation to the three questions of interest: How do hunter-gatherer children learn subsistence skills? How long does it take to learn these various skills? From whom do children learn these skills? As in all meta-ethnographies, in order to synthesize our findings, we organized the results according to themes that appear common in the literature.

Results

Descriptive Statistics

Our initial keyword search, after eliminating duplicates, yielded 1202 potential studies (Figure 2.1). We discarded 966 of these after screening the titles, publication type, and abstracts, and we selected 236 studies for full-text reading. From those studies meeting our criteria, we searched their references for relevant publications and contacted 60 first authors (we could not locate 4 email addresses), half of whom responded. We also contacted 37 contributors from the Cambridge Encyclopaedia of Hunters and Gatherers (we could not locate 14 email addresses), of whom 9 responded. We also examined the references from six relevant reviews (Bugarin, 2006; Eickelkamp, 2010; Herzog, 1984; Hewlett, 2014; Keith, 2008; MacDonald, 2007). This yielded

another 340 publications for full-text reading. The 58 publications that provided information addressing our three questions on learning subsistence skills were included in the present study.

Of the 58 publications that we included, 7 (12%) use experimental data to answer their questions, 5 (9%) use narrative accounts of learning, 30 (51%) use quantitative data, and 33 (57%) use qualitative data. The earliest publication in our list is from 1939, with the great majority (39 vs. 19) being produced after the year 2000 and particularly in the past 5 years (2010–2015; 26 papers) (Figure 2.2). Our list includes studies on 34 different cultures—plus two general studies of Australian Aboriginals—from five continents (Table 2.1).

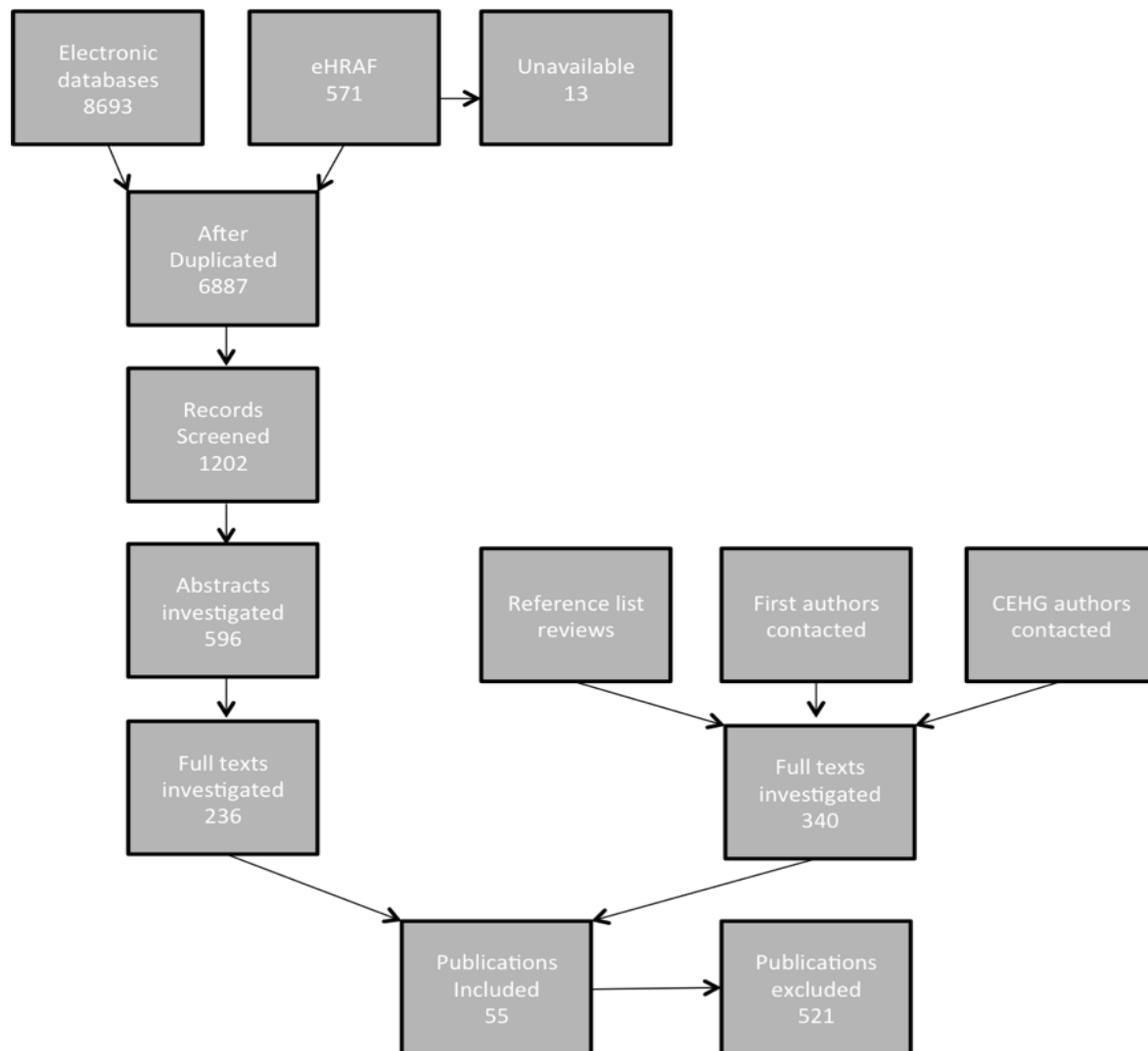


Figure 2.1. Flow chart of the publication retrieval procedure.

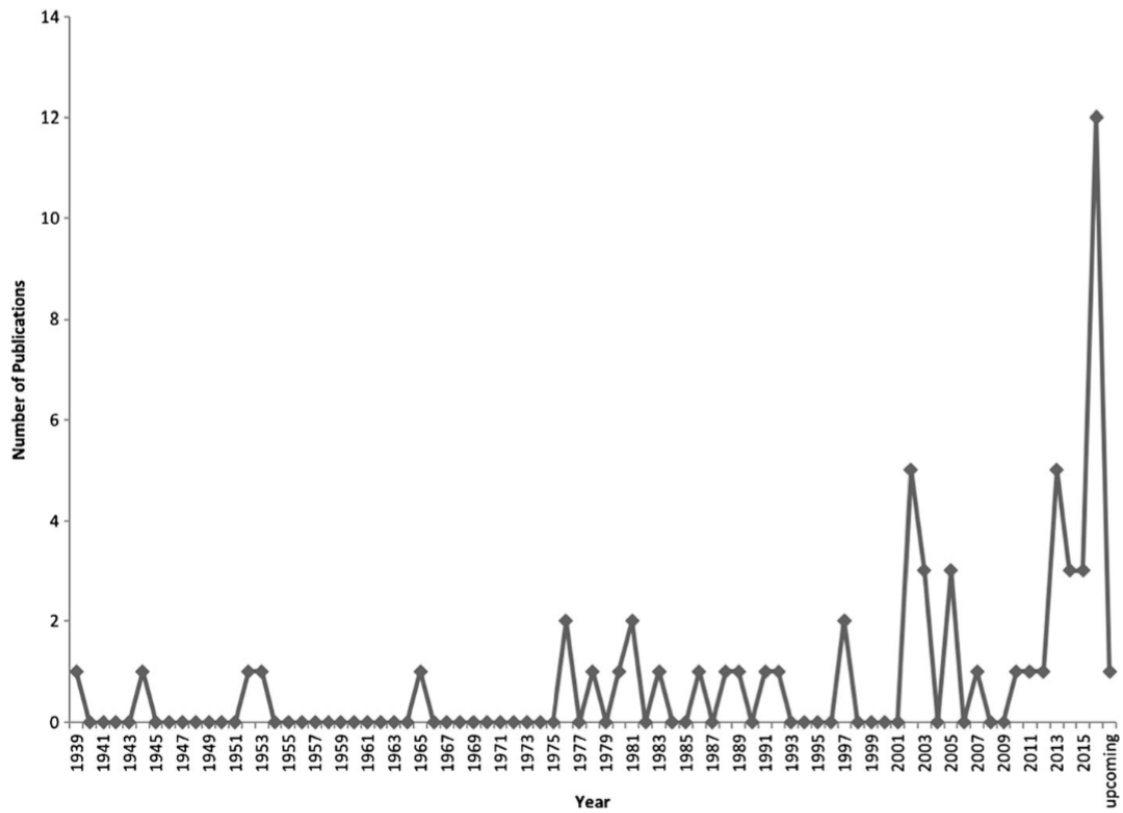


Figure 2.2. Number of publications per year on learning to forage among hunter-gatherers.

Table 2.1. Contributing authors and number of studies included in the review by culture and continent.

Country	Culture (<i>n</i> of studies)	First Author
Africa		
Botswana/South Africa	San (9) ^a	Draper, Imamura, Shostak, Nielsen
Cameroon	Baka (3)	Gallois, Sonoda
CAR	Aka (11) ^a	Neuwelt-Trunzer, B. S. Hewlett, Boyette, B. L. Hewlett, Berl, Fouts
CAR	Bofi (1)	Fouts
DRC	Efe (1)	Morelli
Ethiopia	Chabu (2)	B. L. Hewlett, Dira
Madagascar	Mikea (1)	Tucker
Republic of Congo	Mbendjele (1)	Lewis
Tanzania	Hadza (2)	Blurton Jones, Crittenden
Asia		
India	Jenu Keruba (1)	Demps
India	Nayaka (1)	Naveh
India	Ongee (1)	Pandya
Malaysia	Batek (1)	Lye
Malaysia/Borneo	Penan Benalui (2)	Puri
Sibera	Khanty (1)	Jordan
Siberia	Yukaghir (1)	Willerslev
Australia and Oceania		
Australia	Indigenous (not specified) (2)	Nielsen
Australia	Kaytetye (1)	Thompson
Australia	Mardudjara (1)	Tonkinson
Australia	Martu (1)	Bird
Australia	Meriam (2)	Bird, Bliege Bird
Australia	Pitjantjatjara (1)	Ilyatjari
Australia	Yolngu (1)	Harris
Papua New Guinea	Gidra (3)	Kawabe, Ohtsuka, Nishiaki
North America		
Canada	Chippewayan (1)	Vanstone
Canada	Cree (1)	Ohmagari
Canada	Montagnais (1)	Burgesse
Canada	Dene (1)	Gardner
USA	Comanche (1)	Wallace
USA.	Gros Ventre (1)	Flannery
USA.	Sioux (1)	Erikson
South America		
Paraguay	Ache (1)	Walker
Peru	Matsigenka (1)	Johnson

Two studies (one by Nielsen and one by Fouts) discussed more than one culture and are counted twice in this table. Nielsen included both the San and Aboriginal Australians. Fouts included both Aka and Bofi foragers.

Our team identified five themes to organize our results: learning methods, learning to harvest and to hunt and trap small game, learning to hunt big game, learning to make material culture, and the impact of strength and skill on the age of skill acquisition. 18 studies (31%) explicitly focus on three learning methods: teaching (11 studies), overimitation (4 studies), and innovation (3 studies). 37 studies (64%) focus on children learning to gather and to hunt and trap small game. The authors argued that same-sex vertical transmission (8 studies), observation (15 studies), play (15 studies), and participation (20 studies) are especially common ways to learn these skills, and thus we outline each of these separately. 10 studies (17%) discuss learning to hunt big game. 11 studies (19%) focus on how children learned to make material culture. Finally, 5 studies (9%) focus on determining whether strength, skill, and experience are factors in the age of skill acquisition.

Learning Processes

Though the process of learning is widely discussed in the publications, some works are more specifically focused on learning processes such as teaching, imitation, and innovation. We address those specialized papers here.

Teaching. When teaching is not limited to Western-style direct instruction but is defined to include demonstration, commands, and positive and negative feedback, many authors have found that teaching does play a role in forager children's learning. In fact, a series of four studies based on systematic behavioural observations of the Aka found, unsurprisingly, that the Aka style of teaching is qualitatively different from teaching in WEIRD societies (Boyette, 2013; Boyette & Hewlett, 2017a; Hewlett et al., 2011; Hewlett & Roulette, 2016). In addition, these authors found that, among the Aka, teachers are more likely to be biologically related to the learner in question, and that mothers are the most significant contributors to teaching. Specifically, Boyette's (2013; Boyette & Hewlett, 2017a) cross-cultural study of teaching among Aka foragers and Ngandu farmers found that direct instruction does occur among both groups, but it is significantly more common among the Ngandu. Boyette also found that commands are the most frequent form of teaching for both groups, though the Ngandu tend to be commanded specifically to perform work tasks, whereas Aka children are commanded to perform behaviours across various skill domains. Negative feedback is the next most common form of teaching for the Aka and is usually in

response to breaches of social norms, especially sharing (Boyette, 2013). Finally, in the case of children teaching other children, children are most likely to be taught by those older than them, and by same-sexed children (Boyette & Hewlett, 2017a).

Another broad theme across many ethnographic studies is the importance placed on children's autonomy in their own learning process, meaning that adults prefer to allow children to observe and experiment with minimal interference. Among people as broadly ranging as the San (Draper & Cashdan, 1988), Nayaka (Naveh, 2014), Batek (Lye, 1997), Matsigenka (Johnson, 2003), and Yukaghir (Willerslev, 2007), adults actively refrain from instructing, directing, explaining, or correcting, valuing first-hand knowledge gained by the child through personal experience over any kind of second-hand knowledge. Learning is therefore characterized by processes of trial and error and is embedded in the context of living in close quarters, and having the opportunity to observe others through everyday tasks and conduct (Naveh, 2014). Among the Dene, individual autonomy and learning in childhood are not competing aims, with children actively provided with opportunities to watch an especially careful but silent version of a task, rather than explicit instruction (Christian & Gardner, 1977). And although the Dene consider paying attention critical to learning, at no point do they insist that the learner pay attention. Similarly, Draper (1976) described a scene in which an adult was stretching a hide. Next to him, a child watched his actions intently, but the man did not change his behaviour to accommodate the child. Children in these contexts initiate their own learning; experiment with objects, bodies, and feelings; and adjust their behaviour according to the results of their actions. Christian and Gardner (1977) and Naveh (2014) both argued that such learning leads to diverse understandings, with no attempt to form a systematic and unified standard form of either social or practical knowledge. Similarly, Lye (1997) highlighted that among the Batek, though instruction does occur, personal experience of moving in the forest, monitoring one's own skills, and training one's body is considered the best way of acquiring knowledge.

Overimitation. Though imitation is a common form of children's learning across the world, researchers have recently become interested in how culture influences the frequency of overimitation as a way of pinpointing basic differences in how children learn. Using experimental designs, many studies have found overimitation to be common in WEIRD children, but among

hunter-gatherer children the results are more mixed. Four studies exist that are specifically on foragers, and all use puzzle boxes in their experimental design (Nielsen et al., 2016; Nielsen, Mushin, et al., 2014; Nielsen & Tomaselli, 2010). Nielsen and colleagues have conducted four studies on overimitation comparing Brisbane preschoolers, San hunter-gatherers from Botswana and South Africa, and/or Australian Aboriginal children, all ranging in age from two to six. They found that, across the board, hunter-gatherer children overimitated at the same frequency as Brisbane children. In contrast with these findings, Berl and Hewlett (2015) found that Aka children ranging in age from four to seven engaged in overimitation far less than Ngandu farmer children of the same age, and less than Aka adults, though all participants were more likely to perform the irrelevant actions than not.

Innovation. Three studies specifically on forager children's ability to innovate suggest that innovative behaviours do not fully emerge until adulthood, but that these innovations are then transmitted primarily to adolescents. Nielsen et al. (2014) used an experimental design to determine whether South African San and Brisbane children between the ages of three and five could innovate new tools to fetch a toy from a bucket. The children had access to a multitude of tools, including a pipe cleaner that could be bent to retrieve the toy. The results indicate that few children chose the pipe cleaner as their first tool. Half of the children were unable to innovate a tool to retrieve the toy. However, once these children were shown how to produce the tool—for example, shape the pipe cleaner into a hook—nearly all were capable of producing and using them. Thus, Nielsen argued that innovative behaviours are not yet fully developed in early childhood, irrespective of culture. Hewlett has also conducted a study of innovation among Chabu (Hewlett, 2016) and Aka (Hewlett, 2013) adolescents and found that, in both groups, adults were the key innovators. Adolescents sought prestigious innovators who could teach well, irrespective of how far away they lived. Furthermore, adolescents affirmed that they utilized innovations to find a mate, and also to provide for their families. According to Hewlett, adolescents are more likely to seek out innovative teachers than children or other adults, and these teachers are usually not their parents.

Learning to Forage and to Hunt and Trap Small Game

For hunter-gatherers, learning subsistence skills begins early in life. In infancy, children accompany parents, especially mothers, on foraging expeditions, where they have ample opportunity to watch subsistence activities (Hewlett et al., 2011; Lye, 1997). Children in infancy and early childhood also play with their parents' tools, including potentially dangerous ones such as machetes (Hewlett et al., 2011; Lewis, 2002; Lye, 1997). Authors described parents making toy versions of fishing lines, baskets, digging sticks, spears, and bows and arrows for children across cultures, including the Gidra (Nishiaki, 2013), Batek (Lye, 1997), Kaytetye (Thompson, 2003), Chabu (Dira & Hewlett, 2016), Aka (Hewlett et al., 2011; Neuwelt-Truntzer, 1981), Comanche (Wallace & Hoebel, 1952), Hadza (Crittenden, 2016a), and the San (Imamura, 2016). Among the Batek, by two years of age children are already learning ecological taxonomies (Lye, 1997). By the age of six, Meriam, San, Batek, Chabu, and Pitjantjatjara children have an understanding of environmental hazards (Bliege Bird & Bird, 2002; Dira & Hewlett, 2016; Ilyatjari, 1991; Imamura & Akiyama, 2016; Lye, 1997). These are learned from parents (Bird & Bliege Bird, 2002) and through stories (Dira & Hewlett, 2016). By adolescence, at the latest, various authors note that children are already competent food collectors, though they may refine more complex skills, such as hunting, throughout their adult life (Crittenden, 2016a; Dira & Hewlett, 2016; Gallois, Duda, Hewlett, & Reyes-garcía, 2015; Hewlett & Cavalli-Sforza, 1986; Lye, 1997). The major ways that children learn varying foraging skills include same-sex vertical transmission, observation, play, and participation. We address the results for each of these learning mechanisms in turn.

Same-sex Vertical Transmission. Hewlett and Cavalli-Sforza (1986), Thompson (2003), Ilyatjari (1991), Flannery (1953) and Burgesse (1944), among others, have argued that children learn many foraging skills through vertical transmission from same-sex parents. For example, among the Gros Ventre, formal training for skills necessary to women's work, such as collecting berries and digging roots, comes from female relatives (Erikson, 1939). Among the Sioux, mothers are the primary transmitters of food preparation knowledge, shelter building, and hide work to their daughters (Flannery, 1953). For the Aka, parents are the primary transmitters of food acquisition skills, with fathers generally transmitting skills to their sons, and mothers, to their daughters (Hewlett, 2012; Hewlett & Cavalli-Sforza, 1986). For example, Aka men know more

than women about hunting, and therefore fathers contribute more to the acquisition of those skills. Demps et al. (2012) argued that Jenu Keruba fathers are also particularly important in transmitting knowledge about honey collecting—an activity typically performed by men—to sons between the ages of six and nine.

Observation. Observation appears to be central to how forager children establish competency in many foraging tasks while still very young (Boyette, 2013; Burgesse, 1944; Draper, 1976; Flannery, 1953; Harris, 1980; Imamura & Akiyama, 2016; Ohmagari & Berkes, 1997; Tonkinson, 1978; Vanstone, 1965). For example, Morelli et al. (2003) noted that Efe children between the ages of two and three spent a quarter of the authors' scan observations observing work. Indeed, Neuwelt-Truntzer (1981) argued more generally that Aka children spend much of their time simply watching all adult activities. Children are, after all, almost constantly in view of adults, particularly when they are very young (Draper, 1976; Hewlett et al., 2011; Lye, 1997). Naveh (2014) noted that, among the Nayaka, children watch adults set traps and then simply practice trap setting themselves. Jenu Kuruba adolescent boys learn to make smoky torches and cut honeycombs by observing older kin as they collect honey from locations too dangerous or difficult for the children to actually participate in the process (Demps et al., 2012).

Play. The authors we include emphasize play as a crucial method for children to learn foraging skills. According to Morelli et al. (2003), Efe children spend significantly more time emulating adult activities in play than American children. Boyette (2013, 2016a) and Gallois et al. (2015) found that, as children grow older, they play less and work more, suggesting that play helps them learn subsistence behaviours. In comparing Aka and Bofi foragers with Bofi farmers, Fouts et al. (2016) found that, though Bofi farmer children between the ages of one and four participated in more work-themed play than their foraging counterparts, forager children were in closer proximity to adults and were more likely to use objects when performing work-themed play. Parental beliefs may contribute to cultural beliefs with regard to play; Neuwelt-Truntzer (1981) argued that Aka parents believe that if children do not play, they will fail to learn. Among a vast cross-cultural sample including the Mbendjele, Hadza, San, Katetye, Aka, Mardudjara, Pitjantjatjara, Chippewayans, and Gros Ventre, children build small huts and hearths (Crittenden, 2016a; Flannery, 1953; Ilyatjari, 1991; Lewis, 2002; Neuwelt-Truntzer, 1981; Shostak, 1976;

Thompson, 2003; Tonkinson, 1978; Vanstone, 1965). Near these huts, children pretend to dig yams, to hunt, and pretend to be animals. Through these kinds of games, children also learn human-animal relationships. Naveh (2014) suggested that children who play hunted animals in such games vocalize the animal's feelings, fears, and emotions. Through this activity, children learn to sympathize with animals and to see animals as sentient persons sharing the forest world with them.

Participation. Children do not just observe their parents' subsistence activities; they also learn through participation. In fact, among the Aka, Neuwelt-Truntzer (1981) noted that children may be included in any adult activity. Hewlett (2014) also noted that Aka girls learned to forage by walking in the forest with their parents. Sonoda (2016b, 2016a) described adults acknowledging Baka children when they enter situations where hunting and gathering is taking place, and giving the children access to resources. Both adolescents and adults help children learn through participation by providing them with verbal instruction and other subtle forms of teaching. According to Dira and Hewlett (2016), Chabu adults allow children and adolescents to participate in the killing of animals. Vanstone (1965) mentioned that Chippewayan children learn adult skills and attitudes by participating directly in the household economy. From early childhood onward, Baka children are also expected to participate in household chores, such as fetching water and firewood (Gallois et al., 2015). Among the Cree, women report hands-on experience as the primary way they learn a variety of skills as children and adolescents, including fur preparation, food preparation, camp-related skills, hunting, fishing, and trapping (Ohmagari & Berkes, 1997). That being said, Draper and Cashdan (1988) found that the work of San parents, such as nut cracking, is more efficiently done by adults, and the nature of this work can make it difficult for children to participate.

At times, however, children participate in adult activities without adults being present, shifting the locus of learning to child-to-child knowledge transmission. Neuwelt-Truntzer (1981) noted that in middle childhood, children participate in work groups in which they display self-reliant behaviours such as food harvesting. Indeed, Crittenden (2016a) highlighted the importance of "learning by doing" that occurs within children's playgroups. Crittenden (2016a), Lewis (2002), and Gallois et al. (2015) described children collecting wild foods and roasting them

on their own hearths. In fact, Crittenden (2016a) argued that children are the only Hadza who harvest weaver-birds, a skill primarily transmitted within the playgroup. Among the Meriam and Martu, details and strategies for foraging are learned through other children, and children make decisions to optimize their foraging returns based on their size and strength (Bird & Bliege Bird, 2002, 2005; Bliege Bird & Bird, 2002). Similarly, Tucker and Young (2005) noted that Mikea children allocate as much time to foraging as do adolescents. Thus, foraging emerges as an extension of play. For example, they described children harvesting tubers (work), and then having a food fight (play) with those same tubers. Gallois et al. (2015) also highlighted that though children are not expected to participate in economic activities, they do so out of enjoyment. Jenu Kuruba children learn to climb trees to collect honey through games played with their peer groups (Demps et al., 2012). Through these playgroups, older children also transmit early hunting skills (Crittenden, 2016; Hewlett et al., 2011; Imamura, 2016; Imamura & Akiyama, 2016; Thompson, 2003). It is through older children that San children learn how to bait traps, for example (Imamura, 2016; Imamura & Akiyama, 2016). Through peer group participation, Baka children learn to identify edible wild plants, navigate the landscape, and use increasingly complex tools (Gallois et al., 2015).

Learning Big-Game Hunting

Hunting is one of the most difficult skills that children, primarily boys, learn. Though children seem to become proficient at small-game hunting relatively early in life, big-game hunting may require a lifetime to master. At first, much of this learning process takes the form of translating observed adult activities into organized games played with peer groups. A hide-and-seek game played by the Ongee, for example, helps children develop the skillset to find animals hiding in the bush (Pandya, 1992). Among the Chabu, children play collaborative role-playing games of hunter and hunted (Dira & Hewlett, 2016). Similarly, Nisa, a San woman, described playing at hunting during her childhood (Shostak, 1976, 1981). Nisa and her friends followed tracks, and when they spotted prey, they shot make-believe arrows at them. Then, they took leaves and put them on a stick, pretended it was meat, and carried it back to the village. Among the Mbendjele, Pitjantjatjara, and Kaytetye, spear-throwing games and other target practice, such as boomerang competitions, are important for developing accuracy (Ilyatjari, 1991; Lewis, 2002; Thompson,

2003). Similarly, according to Wallace and Hoebel (1952), peer-group learning is central to Comanche children's development of shooting accuracy.

Yet hunting seems also to be one of the most prominent exceptions to the general lack of direct instruction among hunter-gatherers, likely because of the complexity of hunting. And, in several cases, direct instruction in hunting-related skills begins in early childhood. Around the ages of six or seven, Chabu children listen to hunting stories by their fathers (Dira & Hewlett, 2016). These stories transmit important information regarding animal sign and behaviour, as well as dangers associated with hunting. Batek children learn to imitate animal sounds by age six, and they regularly practice dart hunting by age nine (Lye, 1997). Before adolescence, Batek children are already proficient at hunting birds and squirrels.

During adolescence, children in many cultures receive prominent direct instruction in hunting skills. Among the Chabu, Dira and Hewlett (2016) recorded observation, demonstration, verbal instruction, pointing, and teasing as important teaching processes when adolescents are learning to hunt from their mentors. For the Penan, for whom extensive speaking in the forest is taboo, teachers help children learn to hunt by pointing and describing actions, by providing children with opportunities to watch hunting, and by imitating bird and animal calls (Puri, 2005). Among both the Chabu and the Batek, boys choose their hunting teachers (Dira & Hewlett, 2016; Lye, 1997). They trail these hunters and are tutored by them. Chabu adolescents choose teachers based on their hunting ability, skill as teachers, or knowledge of ecology. Chabu adolescents primarily learn to spear hunt from other adults as well as peers, beginning between the ages of nine and twelve. For Penan boys (and sometimes girls), fathers, uncles, and other elders are the primary teachers of hunting skills between the ages of four and fourteen; older boys between ages 14 and 20 learn hunting with peers (Puri, 2005). Wallace and Hoebel (1952) argued that Comanche grandfathers specifically are heavily involved in teaching their grandsons to ride horses, shoot, and hunt.

Learning to Make Material Culture

Studies of how children learn to produce material culture seem to demonstrate that such skills are transmitted mostly vertically, from parents to offspring, and also commonly from older children. As one might expect, in many cases children begin to learn craft skills by making small-

scaled versions of items such as bows, arrows, and sledges. In a study of how Baka children spend the majority of their time, Gallois et al. (2015) determined that they participate in subsistence and leisure activities more frequently than in handicrafts. This trend generally holds true among the publications included here; that is to say, hunter-gatherers do not seem to emphasize structured instruction on creating material culture, especially among their younger children.

During early and middle childhood, children continue to learn from models, and the role of other children in their learning process becomes more prominent. Between the ages of four and five, Batek (Lye, 1997), San (Imamura, 2016; Imamura & Akiyama, 2016), and Kaytetye (Thompson, 2003) children begin making their own tools. In these cases, parents gift children with bows and arrows while they are still too young to use the tools, let alone to produce them. Among the Batek (Lye, 1997), parents correct children's mistakes on tool construction; among the San (Imamura & Akiyama, 2016) and Kaytetye (Thompson, 2003), younger children imitate older children to learn how to construct these tools, and they are also corrected by other children. By ages four and five, San and Batek children have constructed the bows and arrows they will use to hunt birds and lizards until adolescence (Imamura, 2016; Lye, 1997). Nishiaki (2013) argued that Gidra parents intend their gifts to be a form of education. Rather than directly teaching children how to produce bows and arrows, parents gift them with well-made scale models from which they are expected to reverse-engineer their own tools. This may also be true among the Aka, who made fragments of nets available to children so they can examine them (Neuwelt-Truntzer, 1981). Gidra children do not skilfully produce bows and arrows until approximately 14 years old. On the other hand, Imamura and Akiyama (2016) argued that, after mothers first gift their two- to three-year-old sons with bows and arrows, the boys then refine their skills in bowmaking and in the hunting of small game largely with the help of older boys. Imamura (2016) emphasized the role of older San boys as well, stating that older children will take over and complete toys for younger children when they are struggling with the skill.

Direct instruction from adult to child in the production of material culture seems to be clustered later in childhood and in early adolescence, when children begin producing more complex material culture. Other handicraft skills, including basketry (Puri, 2013), hideworking (Erikson, 1939; Ohmagari & Berkes, 1997), and the production of skis, sledges, and canoes

(Jordan, 2014), seem to be taught using vertical and oblique transmission in late childhood to early adolescence. Jordan (2014) argued the Khanty transmit skills such as ski, sledge, and canoe production vertically, and that children learn from observation, imitation, and direct instruction. When learning to construct sledges, children in late childhood create exact models of adult sledges. Cree women report learning hideworking skills between the ages of 11 and 16, mostly from hands-on experience and family instruction (Ohmagari & Berkes, 1997). Sioux hideworking is learned early on, primarily from mothers (Erikson, 1939). Among the Penan, Puri (2013) found that women report beginning to learn basketmaking at age 14, on average, whereas males begin somewhat later, at 17. However, he acknowledged that among some families, for whom basket making is especially important, children begin to learn as early as age eight. Because men and women make and use different baskets, boys tend to learn from men and girls from women, usually family members but not necessarily parents.

Strength, Size, Skill and Experience in Foraging Proficiency

Though this review is primarily concerned with learning in childhood, we include studies concerning how body size and strength as opposed to skill and experience can impact foraging proficiency. Children's learning processes are, after all, framed by their size and their relative lack of experience. Overall, these studies find that the more complex the activity, such as hunting in particular, the more important experience may be. Walker et al. (2002), working with the Ache, conducted an experimental and quantitative observational study on individuals ranging from 12 to 40+ years of age. The authors found that prey finding rates peak in the late thirties, as do hunting abilities. However, ability to hunt monkeys, one of the most difficult prey in the Ache ecosystem, peaks in the forties. Walker et al. (2002) also found that previous lack of experience adversely affects hunting ability. Similarly, Ohtsuka (1989), working with the Gidra, found that, independent of strength and size, individuals between the ages of 35 and 45 have four times the hunting success of teenagers and young adults. These two studies suggest that strength is less important than skill in hunting proficiency. Kawabe (1983) found that Gidra boys hunt a larger variety of animals as they grow older. These expand from small animals, which are easy to hunt, to larger animals, which can be hunted with developed skills. Though older boys vary in success rates, Kawabe suggested that this is related to differences in environmental knowledge, not

arrow shooting proficiency. Finally, Hewlett and Cavalli-Sforza (1986) found that though Aka girls and boys between the ages of seven and twelve have developed a majority of their foraging skills, only the boys will continue to increase their skills in net hunting and other hunting techniques through adolescence and adulthood.

Other individual components of hunting activity, such as shooting accuracy, seem to require less experience to achieve proficiency. And some simpler foraging activities, such as tuber digging or tree climbing, require a baseline of strength, after which increased experience does not significantly improve returns. In an experimental study with the Hadza, Blurton Jones and Marlowe (2002) considered the importance of practice in proficiency at tree-climbing, target shooting with bows and arrows, and tuber digging through an “Olympics”-style competition, including children, adolescents, and adults of both sexes. The authors found that women and men were equally proficient at digging tubers, despite the fact that women had significantly more experience doing so. Similarly, the authors found that adolescents who attend boarding school were just as proficient at climbing trees and just as accurate in shooting as their unschooled peers, despite having practiced these skills less. Kawabe (1983) also found no remarkable difference between schooled and unschooled Gidra boys in some foraging tasks, possibly because schooled boys take advantage of hunting opportunities when they return to the village during long vacation.

Discussion

These results indicate a meta-ethnographic approach has utility for answering the kind of broad ethnographic and evolutionary questions we have posed here; how do children learn subsistence skills, from whom do they learn them, and how long does it take to reach proficiency? In recent years, a growing number of researchers have been interested in these questions. However, this interest is unevenly distributed, with the San and the Aka receiving the most consistent attention on learning in childhood. This is likely due to the interests of researchers such as Patricia Draper and Barry and Bonnie Hewlett, who have contributed immensely to the field of learning in hunter-gatherer childhood. However, this represents an African bias in the literature. More studies are needed on learning in childhood among foragers on other continents.

Nonetheless, taken cumulatively, the studies demonstrate that social learning occurs before individual learning among hunter-gatherers, which aligns with what several authors have predicted to be the most adaptive progression of learning. Our results also emphasize the importance of observation, participation, and same-sex parental transmission in learning subsistence skills. In particular, the playgroup and playful learning allow forager children to take increasing responsibility for provisioning themselves (though they do not always do so) without considering subsistence activities to be a burden. Our results clearly show that teaching exists among hunter-gatherers in the form of feedback and demonstration. Direct instruction appears to be largely reserved for adolescents, and for complex skills such as hunting and multicomponent toolmaking. We have found that adolescents are not innovators, but they are the primary acquirers of innovative behaviours. And, finally, our results suggest that while innovation may not explain our extended childhoods, children do spend their entire childhoods learning the complexities of hunting in particular. They do not, however, require an entire extended human adolescence to become proficient foragers of many plants and small game. In order to unpack our results more fully, we address the following points in our discussion: (1) Does teaching, overimitation, and innovation occur during hunter-gatherer childhood? (2) How and from whom do children learn? and (3) Does it take 20 years to learn to hunt and gather?

Teaching, Overimitation, and Innovation

In the debate about teaching among hunter-gatherers, our results demonstrate a stark divide between ethnographic studies, which generally argue against the presence of teaching, and quantitative approaches, which find that it does occur. We would argue this debate is largely the result of a lack of consensus about the definition of teaching itself. We support Kline's (2015) integrative definition of teaching, which includes the following behaviours: teaching by social tolerance, teaching by providing opportunities, teaching by stimulus or local enhancement, teaching by evaluative feedback, and direct, active teaching. Using this broad definition, we argue that each of these teaching styles exists to varying degrees in hunter-gatherer populations. For example, teaching through local enhancement occurs when children help butcher an animal (e.g. Dira & Hewlett, 2016). Teaching through evaluative feedback occurs when parents correct children's toolmaking (e.g. Jordan, 2014). When children actively watch an adult tanning a hide,

they are experiencing social tolerance (e.g. Draper, 1976). Direct, active teaching also seems to occur, but is rare, and is most commonly used in adolescence to learn skills such as hunting and complex tool making (e.g. Dira & Hewlett, 2016). However, even where direct teaching does occur among hunter-gatherers, it is qualitatively different than classroom teaching. It is specific to context—such as being out on a hunt—and depends on the child’s willing participation. Because the current teaching debate seems to hinge so heavily on semantics, we hope that researchers will adopt a more holistic definition like Kline’s, which would foster interdisciplinary conversation on the topic.

The varying results we report here on overimitation, with San and Aboriginal children found to overimitate much more prominently than Aka children, may be the result of compulsory Western schooling. The San and Aboriginal groups studied by Nielsen et al. (2014) have access to classroom-based schools (Berl & Hewlett, 2015). The Aka children studied did not. Children quickly learn to defer to teachers in a school setting and thus are more likely to imitate adults’ relevant and irrelevant actions. Indeed, some studies suggest that children generally are more likely to copy adults than they are to copy other children (Wood, Kendal, & Flynn, 2012; Zmyj & Seehagen, 2013). Among hunter-gatherers, though, autonomy and egalitarianism reduce the degree to which any individual defers to another based on age, gender, or status (Lewis, Vinicius, Strods, Mace, & Migliano, 2014; Woodburn, 1982). Since schooling often acts as a tool to incorporate marginal groups into the dominant culture, it seems likely that not only cultural values, but also learning processes, change (Berl & Hewlett, 2015; Mesoudi, Chang, Murray, & Lu, 2014). Further research into the presence of overimitation in foraging societies with differing access to schools could, therefore, provide important insight into how foraging children’s learning processes change. Furthermore, future research should also examine the degree to which social goals, such as group membership, and learning goals, such as proficiency at a given task, influence imitative behaviours (Over & Carpenter, 2012, 2013).

Some have argued that the extension of childhood can be explained as an adaptation that provides children time to develop innovative behaviours (Bateson, 2014; Carruthers, 2002). Specifically, children’s play may be crucial to the development of the kind of human innovation that allowed anatomically modern humans to inhabit every ecosystem on the globe (Carruthers,

2002). Yet, among modern hunter-gatherers our results do not support extended juvenility as time used for innovation. They do, however, potentially support the hypothesis that the skills learned in childhood create a foundation for future innovation during adulthood. Children cross-culturally do not appear to truly innovate, in the sense that they do not generally create new technologies or significantly different foraging methods for themselves (Hewlett, 2013). Instead, our results suggest that forager children act as problem-solvers—using combinations of all of their knowledge in flexible iterations so they are prepared to truly innovate in adulthood (e.g. Naveh, 2014). For example, Meriam children make their own decisions about resource choice, decisions that are couched in their background knowledge of the dangers and opportunities of the reef as a whole (Bliege Bird & Bird, 2002). Indeed, Hewlett (2013) found that Aka adolescents seek out very skilled innovators to learn from, but they themselves do not innovate. Instead, children’s propensity for engaging in group social learning earlier in life and in innovation later on allows them to quickly gain a wide base of knowledge, which they can update with their own innovations as adults (Aoki et al., 2012).

How and From Whom Do Children Learn?

Lehmann et al. (2013) argued that vertical transmission is most adaptive during infancy and early childhood, and that horizontal transmission and innovative, individual learning should occur throughout the rest of childhood. Our results support this pattern. In infancy we find that parents, not siblings, are primary caregivers (Draper & Cashdan, 1988), and thus vertical transmission is common at this age. Many studies find same-sex vertical transmission to be especially important. Mothers teach their daughters gendered skills such as hide tanning, while fathers teach their sons to hunt. Parents have also been found to be the primary transmitters of social skills, such as sharing (Boyette, 2013). In early and middle childhood, both horizontal and oblique (child) transmission are important. Older children correct the tool manufacture of younger ones and show them how to bait traps (Imamura & Akiyama, 2016). Play is also an important medium for horizontal transmission (Crittenden, 2016a). In adolescence, both oblique and vertical transmission are important for teaching and demonstrating more complex tasks, such as multicomponent tool manufacture and hunting (Dira & Hewlett, 2016). Again, somewhat contrary to Lehmann et al.’s (2013) expectations, we do not find truly innovative behaviours emerging until after adolescence.

Specifically, our results emphasize the importance of children's playgroups for learning subsistence skills, especially in middle childhood. Hunter-gatherer children are active learners who participate in learning by choice, and for whom learning is an ongoing, playful activity, not separated from the rest of life. Our results show again and again the prominence of what Gaskins and Paradise (2009) call "open attention," a form of learning found in small-scale societies where children are in such constant contact with adults and older children as they work that learning occurs without the child or the "teacher" specifically intending it. In these contexts, learning may be an "incidental byproduct of social life" (Gaskins & Paradise, 2009, p. 85). This type of learning is exemplified by our findings that, cross-culturally, children continue to participate in foraging activities even when away from adults. This is markedly different from studies of small-scale farmers that emphasize a compulsory chore curriculum (Gaskins & Paradise, 2009; Lancy, 2012). It would seem that, through play, forager children can offset the cost of their burden of care, reducing the need for direct parental teaching.

This finding highlights Crittenden's (2016a) and Tucker and Young's (2005) argument that play and work should not be distinguished since they are not distinguished by forager children themselves. Indeed, it would seem that, at least in the hunter-gatherer context, both play and work are a form of participation, and children transition seamlessly between the two. This finding supports arguments about the primacy of play in learning made by Bock and colleagues (Bock, 2002, 2005; Bock & Johnson, 2004), and the sociocultural approach to learning (John-Steiner & Mahn, 1996; Lancy, 2015). In his work with the Okavango Delta peoples, Bock (2005) found that children trade-off play with work, depending on the needs of the household and the complexity of the task at hand. For example, the playing at pounding grain allowed girls to practice this task without wasting grain, and boys' participation in target games diminished as participation in actual hunting increased. These findings are supported by Boyette (2013, 2016a) and Gallois et al. (2015), who also found that play and work traded off with age. Small-game hunting and trapping, which we found to be primarily learned in the playgroup, are excellent examples of these types of activities, wherein children can begin to assist in provisioning themselves while also learning important skills for later hunting of larger animals. Others, such as Göncü et al. (2006), suggest that play helps children situate themselves within a cultural world. Our findings

that foraging children imitate the entire structure of adult subsistence activities through their play, such as building small huts and cooking their own foods on their own small hearths, supports Göncü's hypothesis.

Does It Take 20 Years to Learn to Hunt and Gather?

Yet another hypothetical driver for humans' extended juvenility is our need for an extended period of learning (Kaplan & Robson, 2002). So, does it take 20 years for a modern hunter-gatherer child to learn to hunt and gather? Yes and no. In many ways, children are competent foragers by the end of late childhood, able to make simple tools, to gather plants and to hunt small animals, and even to make optimal foraging decisions about which resources they can most effectively exploit. However, the most complex skills of a hunter-gatherer's life, such as big-game hunting, ecological knowledge, or the production of multicomponent tools, seem to be learned at the very latest stages of childhood and into adulthood. And these findings do not seem to be restricted to egalitarian foraging populations. Among the Tsimane, Bolivian forager-horticulturalists who fish and hunt extensively, a series of studies on hunting skills (Gurven, Kaplan, & Gutierrez, 2006; Schniter, Gurven, Kaplan, Wilcox, & Hooper, 2015) argued that learning itself, not physical development or body size, seemed to determine hunting success. In fact, although Gurven et al. (2006) found that indirect encounters with game are most frequent in individuals' mid-twenties, overall kill rates across multiple categories of game did not peak until age thirty-nine. Thus, the integration of all of a child's individual skills into his or her maximum foraging potential may not occur until far past his or her transition into adulthood. This finding supports the theory that humans require a long juvenile period to learn to extract complex resources, though they do not need that long to learn all of their constituent foraging skills (Kaplan & Robson, 2002).

Conclusion

Through the years, more and more studies have focused on how foraging children learn subsistence skills. This meta-ethnography has allowed us to draw broad cross-cultural patterns from that positive trend in research. In infancy, children accompany parents on subsistence tasks and are given small versions of tools such as digging sticks and bows and arrows. During the

transition from infancy to early childhood, when children join playgroups, they learn a majority of their subsistence skills, such as harvesting, trapping, small-game hunting, and some elements of honey harvesting, such as tree climbing. Children learn these skills through a variety of mechanisms, including participation in activities with adults and other children, through play, and via observation. It would seem that most children are proficient at these skills by the end of middle childhood. However, skills such as hunting, making complex tools, and learning innovative behaviours—skills that are more difficult and potentially more hazardous— continue to be learned into adolescence. These skills especially are learned obliquely, from expert adults, though parents seem to be prominent in teaching about material culture. The more complex the skill, the more common teaching seems to be. Finally, our results suggest that learning to hunt continues into adulthood.

A large-scale meta-ethnography will necessarily have limitations brought on by the sheer breadth of our sources, both in age and in methods. We did not include studies with general, passing mentions of learning, meaning that fragmentary observations in the literature are missing from this work. Many of the studies we did include only address positive observations without referencing the absence of specific behaviours, potentially introducing further bias. And, the relatively qualitative nature of our results and discussion means that we translated some quantitative results into qualitative findings, potentially misrepresenting their magnitude. Furthermore, many of the publications used different methods that are difficult to compare, especially as they were published over a 77-year timespan. However, because we are attempting to address extremely broad trends in hunter-gatherer behaviour, it is our hope that these limitations are counteracted by the sheer quantity of data we include.

As we consider all of the papers included in this study, several general gaps in research become apparent. First, perhaps unsurprisingly, many papers focus on hunting activities; plant harvesting and other activities such as food preparation and childcare are given much less attention. In fact, we found no studies on how children learn to cook. Furthermore, studies on highly complex foraging activities such as medicinal plant use are lacking, and studies of the methods and timing of broad traditional ecological knowledge transmission are also scarce. This means, generally, that studies of women's subsistence skills and material culture are

underrepresented. Similarly, we only extracted two studies on learning to harvest honey. Crittenden (2011) has recently hypothesized that eating honey may have had important implications for the evolution of modern humans, and future studies should more thoroughly explore how honey harvesting is learned. The second major gap we note is the lack of studies addressing how children learn subsistence skills from one another. Specifically, we would be interested in work addressing how same-sex children teach one another particular skills. Such occurrences are mentioned obliquely in a number of our studies—boys helping one another with bows, for example—but are not developed. Given the emphasis we are seeing on peer group learning and the prevalence of vertical transmission from same-sex parents, we wonder how extensively those two trends converge in the form of same-sex children teaching one another. In addition, Africa is overrepresented in studies on learning subsistence skills. We would welcome further studies from Asia or South America. Another important oversight is the correlation between how children learn and the degree to which they rely on foraged, farmed and/or purchased food. Unfortunately, these data were rarely available in the papers surveyed, so we did not include it. However, such data would make important contributions to understanding how forager children’s learning behaviours change in association with their dependence on foraged foods. Finally, very few studies include a narrative approach in which foragers themselves explain how they learn, which would be valuable for understanding how people see their own learning process.

The present research has important implications for broadly ranging fields. Hunter-gatherer archaeologists find it especially difficult to pinpoint the role of children in the creation of the material record. Collectively, these studies demonstrate the importance of children in producing smaller versions of “adult” material culture, and they also address the complexities of human innovation as a product of entire communities, a topic that always preoccupies archaeologists. For psychologists and anthropologists particularly interested in human evolution and life history, our findings have implications for long-running debates about innovation, learning, and the reason for extended human juvenility. Furthermore, this review can facilitate comparisons with other research on small-scale agricultural, horticultural, and pastoral societies, to determine the degree to which forager learning behaviours differ from, or are similar to, those

of the more commonly studied small-scale societies. Overall, it is our hope that the growing trend in studying the learning processes of foraging children continues.

Chapter 3: Who Teaches Children to Forage?

Teaching is a ubiquitous process of knowledge transmission in diverse cultural settings (Boyette & Hewlett, 2017a, 2017b; Kline et al., 2013; Maynard, 2002), and was likely necessary for the evolution of cumulative culture because it increases the learning fidelity of information otherwise hard to acquire (Castro & Toro, 2014; Fogarty, Strimling, & Laland, 2011). While adults are usually assumed to be the primary teachers of children, child-to-child teaching is understudied, but may be particularly prevalent in small-scale societies, where much socialization occurs independently of adults (Boyette & Hewlett, 2017a; Imamura & Akiyama, 2016; Maynard & Tovote, 2009). Here, we investigated child-to-child teaching using focal follow data collected among Hadza and BaYaka hunter-gatherer children from Tanzania and Congo respectively. Hunter-gatherers are especially important to studying how, and from whom, teaching occurs because these populations are culturally distinct from the West, and because hunting and gathering is the oldest human subsistence strategy (Marlowe, 2005). By comparing two foraging societies, we aim to understand how similarities and differences in the socioecologies of childhood contribute to the cultural diversity in, and evolution of, teaching in humans (Kline et al., 2018). We show that child-to-child teaching is common among the BaYaka and Hadza, but that rates of sibling and peer teaching vary alongside subsistence and settlement patterns.

Teaching in Hunter-Gatherers

Whether teaching occurs in hunter-gatherer, or forager, societies has been a matter of debate. Usually, contradictory findings can be explained by investigating the underlying definitions of teaching used by researchers from diverse fields (see Boyette & Hewlett, 2017b; Garfield, Garfield, & Hewlett, 2016; Lew-Levy et al., 2017 for review). Some ethnographers argue that teaching is rare in foragers because it violates the foundational schemas—or “cultural values and ways of thinking and feeling that pervade several domains of life” (Hewlett et al., 2011, p. 1171)—shared by many foragers, including an ethos of egalitarianism (Woodburn, 1982) and autonomy (Gardner, 1991). For example, Naveh (2016) stated that Nayaka foragers value first-hand

knowledge obtained autonomously more than knowledge acquired through teaching (see also Christian & Gardner, 1977). These ethnographers usually define teaching as “student-centered, developmentally appropriate instruction by dedicated adults” (Lancy, 2010), a definition which challenges the universality of Western classroom style teaching paradigms, but systematically excludes children as potential teachers.

Quantitative studies of teaching in hunter-gatherers find that teaching does occur, but that it is relatively rare and qualitatively different from the teaching observed in the West (Boyette & Hewlett, 2017a). These studies adhere to what Kline (2015) broadly calls functionalist definitions, where teachers modify their behaviour in the presence of a naïve learner in order to facilitate the learner’s knowledge acquisition, and should come at a cost to the teacher (Byrne & Rapaport, 2011; Caro & Hauser, 1992). From a functionalist standpoint, the teaching of sharing (Weissner, 1982), kinship terms (Guemple, 1988), and social and subsistence skills (Hewlett & Roulette, 2016) to children has been documented among !Kung, Inuit, and Aka foragers. In the only study of teaching in foragers which included children in early childhood, middle childhood, and adolescence, Boyette and Hewlett (2017a) found that child-to-child teaching was as frequent as adult-child teaching among the Aka.

Here, we build on Boyette and Hewlett’s work (2017a) by developing predictions regarding child-to-child teaching within the domain of subsistence skills. We focus on subsistence skills due to their primacy in everyday life, their relative difficulty, and their evolutionary significance (Kaplan et al., 2000)—making it likely that teaching will be observed in this domain. Like Hewlett and Roulette (2016) and others (Boyette & Hewlett, 2017b; Garfield et al., 2016; Hewlett et al., 2011; Kline, 2015) we define teaching as (1) a teacher modifying their behaviour to enhance learning in another individual, (2) not the by-product of another activity, and (3) involving sensitivity between the teacher and learner. This definition allows us to consider both children and adults as potential teachers. In what follows, we derive predictions by reviewing the available cultural, psychological, and evolutionary literature on knowledge acquisition through teaching across the lifespan, with a special emphasis on children as teachers.

Who Teaches Whom?

Children's teaching capabilities seem to increase throughout childhood (Boyette & Hewlett, 2017a; Maynard & Tovote, 2009; Strauss & Ziv, 2012). Furthermore, children may be especially skilled at teaching other children because they are closer in development, and thus, have privileged knowledge of another child's "Zone of Proximal Development", defined as the distance between what a child can accomplish on their own and what a child can accomplish with help (Vygotsky, 1978a). Considering this, Reyes Garcia and colleagues (2016) proposed a multistage learning model for understanding cultural transmission across the life course, with children learning basic competencies from friends first, and updating this knowledge by learning from preferred models later in life. In support of the multistage learning model, child-to-child transmission has been found to occur in forager playgroups in early and middle childhood (Boyette, 2016b; Crittenden, 2016a; Konner, 2005), while forager adolescents travel relatively long distances to learn complex tasks such as hunting and basketry design (Dira & Hewlett, 2016; Hewlett, 2013, 2016; Hewlett & Hewlett, 2012). In addition, simulation studies investigating the optimal learning schedule for the development of cumulative culture suggest that individuals should learn socially (e.g. through teaching and imitation) before they learn individually (e.g. through trial-and-error) (Lehmann et al., 2013). Although certain domains of knowledge such as large game hunting are acquired later in life (Dira & Hewlett, 2016; Walker et al., 2002), the overall frequency of social learning should decline with age. Considering these factors, the present study investigated the distribution of giving and receiving teaching across the life span.

Furthermore, if teaching is a cooperative behaviour (Thornton & Raihani, 2008), then inclusive fitness theory holds that the cost of teaching is more likely to be incurred by teachers who are more closely related to the learner (Hamilton, 1964). Theorists have usually assumed that, in early life, teachers should be parents, since parents are closely related to, and presumably more knowledgeable than, their children (Shennan & Steele, 1999). However, siblings are as related to each other as they are to their parents. Furthermore, older siblings have fewer constraints on their time than parents do, and are likely to know more than their younger siblings. Finally, a child can only ever have two genetic parents, but having more than two siblings is normative in many forager societies (Hewlett, 1991a; Morelli, Henry, & Foerster, 2014). Thus, it

may be that siblings are better able to distribute the cost of teaching amongst themselves. Evidence for the prevalence of sibling teaching was found among the Maya (Maynard, 2002; Maynard & Tovote, 2009; Zarger, 2002), Aka, and Ngandu (Boyette & Hewlett, 2017a). Taking subsistence skills as its focal point, the present study investigated the kinship relationship between teachers and learners, including siblings.

Next, previous ethnographic studies suggest that, due to the division of labour within most small-scale societies, including among foragers (Brown, 1970; Marlowe, 2007), children are more likely to learn from same-sex than opposite-sex individuals. Cross-culturally, this prediction seems to hold true (Hewlett & Cavalli-Sforza, 1986; MacDonald, 2007; Maynard & Tovote, 2009; Montgomery, 2009) and is hypothesized to facilitate the transmission of sex-relevant skills (Henrich & Gil-White, 2001). Thus, this study investigated the prevalence of teaching in same-sex vs. opposite-sex dyads. Finally, we also investigated reciprocal teaching. Reciprocity permeates much of forager life, as has been documented in food sharing (Allen-Arave, Gurven, & Hill, 2008; Crittenden & Zes, 2015; Hewlett, 2008; Peterson, 1993) and childcare (Ivey, 2000). Here, for the first time, we examined whether teaching occurs reciprocally among foragers.

Study sites

The literature reviewed above outlined how child-to-child teaching may occur generally. Here, we describe the ethnographic setting for our research. Both the Hadza and BaYaka share the foundational schemas of autonomy, egalitarianism, and sharing; individuals rarely coerce each other or impose their will on one another (Gardner, 1991), there is no inherited hierarchy according to age, no formal leaders, few differences in status according to sex (Woodburn, 1982), food is shared widely within camps (Hewlett et al., 2011; Woodburn, 1982) and food storage is rare (Kelly, 1995). However, the Hadza and BaYaka differ in their settlement and subsistence practices, which may lead to cross-cultural variation in teaching.

Settlement Patterns

The Hadza and the BaYaka inhabit markedly different ecologies; average annual rainfall and temperature in Hadzaland are 500mm and 35°C respectively vs. 1700mm and 24.5°C in the Congo Basin (Blurton Jones, 2016; Marlowe, 2010; Thomas & Bahuchet, 1991). Primary Biomass

is approximately 11.3 kg/m² in Hadzaland vs. 25.4 kg/m² in the Congo Basin (Kelly, 1995). Both Hadza and BaYaka camps can fluctuate from 20-100 inhabitants according to the distribution of seasonal resources (Bahuchet, 1988; Blurton Jones, 2016; Kitanishi, 1995; Marlowe, 2010; O'Connell, Hawkes, & Blurton Jones, 1991). Nonetheless, ecological differences have consequences for the settlement structure of camps in both populations; Hadza camp areas are much larger than BaYaka camp areas, at 795m² compared to 262 m² (Hewlett, Hudson, Boyette, & Fouts, In press; O'Connell et al., 1991). Furthermore, the mean area per person in camp is 19.2m² for the Hadza, and 11.5m² for the BaYaka, and nearest neighbour data suggests that Hadza houses are usually 5.9 meters apart on average, while BaYaka houses are usually 4.9 meters apart on average (Hewlett et al., In press; O'Connell et al., 1991). Put simply, Hadza camps can be larger and more spread out—though they are not always so (Marlowe, 2010; Woodburn, 1968)—partially due to variation in natural environment (Whitelaw, 1991), and because of differing patterns of cooperation and sharing (Hewlett et al., In press). Functionally, this means that Hadza children may have more opportunities to be in camp without being visible to adults and even more opportunities to be outside the purview of parents. In fact, Marlowe (2010) noted that men provided less direct care to their own children while inhabiting larger camps. The present study thus considered whether differences in settlement structure between Hadza and BaYaka camps influenced the frequency of sibling and parental teaching.

Subsistence Activities

Though both the Hadza and BaYaka hunt and gather for subsistence, the resources they target, and the tools they use to target these resources, differ. The Hadza collect baobab, tubers, fruit, honey, and eggs, and hunt small game and birds as well as medium to large game animals with bows and arrows (Blurton Jones & Marlowe, 2002; Crittenden et al., 2013; Marlowe, 2010). In addition, the Hadza consume some maize and other domesticated grains provided by local missionaries, tourist companies, or purchased/traded from neighbouring pastoralists (Blurton Jones, 2016; Crittenden et al., 2017; Pollom, Herlosky, Mabulla, Under review). The BaYaka forage for tubers, nuts, mushrooms, caterpillars, insect grub, and liana fruit (Kitanishi, 1995). The BaYaka also fish with poison, hook-and-line, and by bail fishing, and trap and hunt small and large animals with snares, spears and guns. Though the BaYaka are far less mobile today than reported

in earlier texts (Bahuchet, 1990; Lewis, 2002), the families with whom we worked still frequently lived in the forest for extended periods of time, including during honey seasons, caterpillar season, pepper season, bail fishing season, and periodically while hunting with guns belonging to their farmer neighbours, with whom they maintain extensive trade relations (Joiris, 2003). Finally, the BaYaka keep small gardens where they cultivate bananas, cassava, and maize. Access to schools is sporadic in both Hadza and BaYaka communities surveyed here, and none of the children sampled attended school at the time of data collection. However, most BaYaka children in our sample had spent at least a few months in school prior to data collection, and children in one of the three Hadza camps lived near a school, with a handful of children attending daily.

It has been widely reported that Hadza children participate in foraging from an early age; for example, Blurton Jones, Hawkes and colleagues (1994; 1995) showed that children above the age of five collected up to 50% of their daily energy requirements. More recently, Crittenden et al. (2013) found that Hadza children as young as six produced between 25 and 100% of their daily energetic requirements, depending on sex, age, individual motivation, and the type of resource being targeted. Both sets of studies noted that children primarily focus their foraging efforts on baobab, berries, small game, and birds. Parents encourage children's participation in foraging by making small digging sticks for girls and small bows and arrows for boys, which are used to hunt mice and birds around camp (Crittenden et al., 2013). More limited research on BaYaka children's foraging has found that BaYaka children contributed up to 18% of grams of meat returned to camp, and also participated, alongside adults, in various types of fishing, representing 13% of all grams of food returned to camp (Hagino & Yamauchi, 2016). Though weight of food (grams) is not always readily comparable to energy provided (kilocalories), these studies still suggest that BaYaka children participate in foraging far less than the Hadza. The present study thus considered whether differences in children's participation in foraging influenced knowledge acquisition through teaching.

Predictions

Considering the literature reviewed above, we used focal follow data collected among BaYaka and Hadza forager 3- to 18-year-olds to test the following predictions regarding the teaching of

subsistence skills to children: (1) The frequency of teaching by children is positively associated with age; (2) the frequency by which children receive teaching is inversely associated with age; (3) consistent with a multistage model of knowledge acquisition, younger children are more likely to be taught by other children while adolescents are more likely to be taught by adults; (4) teaching is more likely to occur between more closely related individuals; (5) teaching will be more likely within same-sex dyads; and (6) teaching will be reciprocal. Furthermore, we considered settlement structure and participation in foraging as potential sources for cross-cultural variation in teaching among the Hadza and BaYaka.

Methods and Analyses

Data Collection

Behavioural data were collected among the Hadza of Tanzania by SLL in March and April 2017 and among the BaYaka of Congo in August through September 2017. Data collection for both the Hadza and BaYaka took place in seasons when children were particularly productive: for the Hadza, data collection straddled honey and berry seasons (Marlowe & Berbesque, 2009) while for the BaYaka, data collection straddled bail fishing and caterpillar seasons (Bahuchet, 1988; Kitanishi, 1995). Both children and adults participate in these activities, often together.

A subset of 35 Hadza children ($M_{\text{age}}=10.06$, $SD=3.93$, 40% female) and 38 BaYaka children ($M_{\text{age}}=10.53$, $SD=4.16$, 39% female), all between approx. 3 and 18 years of age, and not married or with children, were followed. BaYaka children were sampled from 5 camps that ranged from 7 to 43 inhabitants ($M=23.00$, $SD=15.05$), and Hadza children were sampled from 3 camps that ranged from 41 to 73 inhabitants ($M=53.67$, $SD=17.01$). Because few of the Hadza and BaYaka in our sample knew their ages in years, we followed Crittenden et al. (2013) and others by ranking individuals within the camp—allowing for ties—from oldest to youngest, either within a nuclear family or within a set of closely related cousins. Based on this ranking system, the research team estimated their age. For individuals under 20, estimates were made at 1-year intervals. Because adult age was more difficult to estimate, it was estimated at ten-year intervals starting from 25 onwards.

In order to understand camp demographics, a full census of camp members was conducted upon our arrival. This list was modified during our stay to reflect only individuals whom, at the time of data collection, were permanent camp residents. Based on this census, kinship was inferred by conducting genealogical interviews in each camp, both upon arrival in a camp and prior to departure, as well as informally throughout our stay, in order to obtain the clearest possible picture of kin relations.

Observations of teaching were systematically recorded using a focal follow procedure (Altmann, 1974). Each child was observed for two 2-hour time blocks over a randomly assigned single day, scheduled once in the morning (usually between 8-11am) and once in the afternoon (usually between 12-3pm) using a 30-second observe/30-second record procedure. In cases of especially bad weather, or community events in which the researcher could not participate, observation blocks were paused or postponed, and resumed as soon as possible, usually the same day. Follows occurred both in and outside of camp (Hadza; 43% in camp, BaYaka; 57% in camp), and were conducted with a field assistant who translated any interactions (either in participants' first language or their second language—Hadzane and Swahili for the Hadza, BaYaka or Lingala for the BaYaka) which occurred between the focal child and other individuals inhabiting the camp. SLL and the assistant stayed close to the focal child for approximately one hour prior to the start of the follow, in order to habituate the child to their presence, and avoid the child leaving camp without them. If the child showed obvious signs of nervousness or fear within the allotted hour, they did not proceed with the follow. They also stopped focal follows if, during the follow, the researcher or assistant noticed the child growing uncomfortable or distracted by their presence. If a child was not available during the assigned day, that child was rescheduled or omitted. On average, children were observed for 218.81 (SD=39.32) minutes, totalling 15,973 observations.

The teaching behaviours coded during observations were modelled after similar coding schemes (Boyette & Hewlett, 2017a; Childs & Greenfield, 1980; Kline, 2015, 2016; Maynard, 2002) and are described in Table 3.1. The first teaching event which occurred in the 30-second-observation window was recorded. We also recorded the direction of the teaching event (i.e. to or from the focal child), and the names of up to two individuals with whom the teaching event

occurred. Seven percent of teaching observations for the Hadza and 3% of teaching observations for the BaYaka included multiple individuals; these were counted as separate teaching events in the analysis. Finally, throughout the follows, SLL noted whether children were in proximity to adults (binary variable) for every observation. We defined proximity as within speaking and/or sight distance of the focal child, thus close enough to monitor children's behaviours if they so choose and intervene when necessary. Hadza and BaYaka children were in proximity of adults in 57% and 69% of observations respectively.

The analyses presented here are based only on overall teaching and not separated according to teaching type (instruction, demonstration, etc.). We also only included teaching events which were in the domain of subsistence skills, such as "food procurement, preparation, and cultivation, as well as the procurement and use of plants for the construction of houses, household items, and crafts" which are necessary to survival (tools, containers, etc.) (Zarger, 2002, p. 2). The observed frequency for each category of behaviour identified as teaching for subsistence skills, and the frequency of teaching observed for each type of subsistence skill are in Tables 3.2 and 3.3. Camp-wide, as well as parent and child verbal consent, was obtained before data collection began according to procedures approved by the Cambridge Psychology Research Ethics Committee (PRE.2016.026), the Tanzanian Commission for Science and Technology (COSTECH), and in Congo from the Centre de Recherche et D'Etudes en Sciences Sociales et Humaines (CRESSH).

Inter-Coder Reliability

We validated the coding scheme by collecting inter-coder reliability data between June and July 2017 among BaYaka children living in a village setting. The Congo research team (SLL and AHB) simultaneously followed 7 focal children for a total of 711 observations. Qualitative reliability assessments were conducted after each follow, and SLL and AHB reviewed any disagreements in order to improve reliability for subsequent follows. The calculation of Cohen's Kappa was only conducted after all reliability data was collected. Reliability was high across all codes; teaching (yes/no) ($K=0.92$, $SE=0.03$), direction (to/from) ($K=0.92$, $SE=0.03$), type of teaching ($K=0.88$, $SE=0.04$), and whom to/from teaching occurred ($K=0.84$, $SE=0.04$). Intercoder reliability was not determined for adult proximity.

Analyses

These data were analyzed using the Social Relations Model (SRM) developed by Kenny and colleagues (Back & Kenny, 2010; Kenny & La Voie, 1984) and extended to multilevel count data by Koster and colleagues (Koster & Leckie, 2014; Koster et al., 2015). A type of social network analysis, SRMs were designed to account for the variance contributed by individuals and dyads within a multilevel model. Thus, using SRMs, we can explore the role of the teacher, learner, and teacher-learner dyads during teaching interactions. Here, we fit three models: Model 1 included the intercept only, and random effects of teacher, learner, and dyad. In Model 2 we added fixed effects to Model 1. Finally, Model 3 included random effects, fixed effects, and interaction effects. These models are each described in turn.

Model 1: The intercept-only model

From our focal follow data, we calculated the frequency (y) and direction of teaching events between a focal child and any other child or adult who inhabited the camp at the time of data collection. Using the notation provided by Koster and colleagues (2014; 2015) we specified the intercept-only model as follows for y_{ij} , the observed number of teaching events from individual i to individual j ($i, j=1\dots N$):

$$y_{ij} \sim \text{Poisson}(\mu_{ij})$$

$$\log(\mu_{ij}) = \beta_0 + t_i + l_j + d_{ij} + \log t_{obs}$$

$$\begin{pmatrix} t_i \\ l_i \end{pmatrix} \sim N \left\{ \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_t^2 & \\ \sigma_{tl} & \sigma_l^2 \end{pmatrix} \right\}$$

$$\begin{pmatrix} d_{ij} \\ d_{ji} \end{pmatrix} \sim N \left\{ \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_d^2 & \\ \sigma_{dd} & \sigma_d^2 \end{pmatrix} \right\}$$

Table 3.1. Behaviours coded as teaching during focal follows, based on Boyette and Hewlett (2017a) and Kline (2016).

Type	Description	Example
<i>Direct Active Teaching</i>		
Verbal Instruction	Teacher provides verbal explanation about how something is done (skill), or what something is (knowledge)	Tree felling: “if the tree starts to fall we have to run!” Mat weaving: “don’t cut the stems too short.”
<i>Opportunity Provisioning</i>		
Invitation Command	Teacher invites learner to participate in an activity	Honey collecting: “let’s go [collect honey]!”
Assistance	Teacher helps learner undertake an action the learner could not accomplish without teacher’s help, or provides the learner with an opportunity to practice using a tool	Butchering: Mother holds meat as daughter cuts Cutting: Older brother hands younger brother a knife
Task Assignment	Teacher commands a learner to undertake an action or behaviour	Chores: “Bring Firewood” Collect: “Go collect mushrooms”
<i>Evaluative Feedback</i>		
Negative Feedback	Teacher makes displeasing sound, verbally and/or physically reprimands learner in learner’s presence	Nut cracking: “Hm!” [for trying to take Machete] Cooking: “Don’t touch my cooking pot!”
Positive Feedback	Teacher makes pleasing sound, verbally and/or physically celebrates learner in learner’s presence	Tubers: “You found a big tuber!” Carrying: “Well done” [for carrying heavy palm nuts to camp]
Teasing	Verbal play in which teacher calls attention to learner’s improper behaviour or lack of knowledge, indicated by smiling and/or laughing	Tubers: Child 1 teases child 2 for following a tuber vine child 1 had already dug
Safety Commands	Teacher calls attention to danger by commanding learner to modify their behaviour	Knife sharpening: “Get back”
<i>Enhancement</i>		
Verbal Demonstration	Teacher verbally directs learner’s attention towards an object, location, other person, or the teacher themselves, sometimes using words like “look”, “here”, “like this”, etc.	Tubers: “That’s a big vine” [also points] Wayfinding: “Here’s the path”
Non-Verbal Demonstration	Teacher non-verbally directs learner’s attention towards an object, location, other person, or the teacher themselves	Cooking: Child points to location of cooking put with her lip Hunting: Child uses finger to point to area where he heard a monkey
Pedagogical and Collaborative Questions	Teacher directs learner’s attention towards an object, location, or activity through questions	Wayfinding: “Do you know that trail?” –asked by older teenager who frequently travels along this trail, to younger teenager who does not Tubers: “Should we collect tubers?”

Table 3.2. Observations of teaching by teaching type. Values represent percentage of teaching.

	Hadza (%)	BaYaka (%)
Assistance	0.95	0.73
Instruction	15.74	20.34
Invitation command	9.06	9.01
Negative feedback	5.44	4.30
Non-verbal demonstration	1.24	0.84
Pedagogical questions	1.91	1.36
Positive feedback	0.76	0.84
Safety command	4.48	1.15
Task assignment	25.86	29.56
Teasing	4.87	2.41
Verbal demonstration	29.68	29.45

Table 3.3. Observations of teaching by activity type. Values represent percentage of teaching.

	Hadza (%)	BaYaka (%)
Domestic work	10.97	26.10
Collect	21.85	5.87
Fish	NA	2.94
Garden	NA	3.46
General/Other	16.41	19.81
Honey	27.29	1.57
House construction	0.38	2.20
Hunt and trap	8.49	9.12
Tool maintenance/manufacture	5.92	3.98
Tubers	8.68	24.95

where μ_{ij} denotes the expected number of teaching events from individual i to individual j . The intercept β_0 measures the logged expected number of teaching events from individual i to individual j . The parameters t_i , l_j , and d_{ij} decompose the random effects of the intercept (β_0) into contributions from the teacher's identity, the learner's identity, and the teacher-learner relationship, respectively. In other words, t_i gives the logged expected additional number of teaching events offered by individual i , l_j gives the logged expected additional number of learning events received by individual j , and d_{ij} gives the logged expected additional number of teaching events from individual i to individual j not yet explained by their inherent propensities toward teaching and learning. We thus estimated the variance attributed to the the teacher as σ_t^2 , to the learner as σ_l^2 , and their covariance as σ_{tl} (Back & Kenny, 2010; Kenny & La Voie, 1984; Koster & Leckie, 2014; Koster et al., 2015). "Generalized reciprocity"—the degree to which an individual, in general, reciprocates teaching—is calculated as $\rho_{tl} = \sigma_{tl} / \sqrt{\sigma_t^2 \sigma_l^2}$. Furthermore, we estimated the variance attributed to dyadic relationships as σ_{dd}^2 and its covariance, σ_{dd} . "Dyadic reciprocity"—or the degree to which, on average, teaching was reciprocated within a dyad—was calculated as $\rho_{dd} = \sigma_{dd} / \sigma_{dd}^2$. The individual teacher and learner random effects (t_i and l_i), and the dyad-level relationship random effects (d_{ij} and d_{ji}) were assumed to be bivariate normally distributed with zero means and homogenous (symmetric) 2x2 relationship covariance matrices (Koster & Leckie, 2014).

For our purposes, if dyadic reciprocity was positive, individuals who tend to teach specific individuals more than others tend to be taught more by those same individuals. Thus, dyadic reciprocity is a proxy for reciprocal teaching at the level of the dyads. Because we hypothesized that teaching among foragers would be reciprocal, we hypothesized that this value would be positive. Should teaching be unidirectional, this value would be negative. Note that though we report the value for generalized reciprocity, we did not interpret it.

Not all individuals in the camp were observed, and not all children under observation were observed for the same amount of time. In order to account for this variation, we included as an offset the natural logarithm of the total observations t_{obs} , which we calculated as the total number of observations in which each individual within each dyad was observed. Also note that

only child-child and child-adult dyads were included in this analysis as we had no data on adult-adult teaching interactions. Finally, we also calculated the variance partition coefficient (VPC—Goldstein, Browne, & Rasbash, 2002) which estimates the relative importance of the teacher, learner, and relationship random effects as sources of variation in teaching. We did so by dividing each estimated variance by the sum of all three estimated variances (Koster & Leckie, 2014).

Model 2: The fixed-effect model

In addition to the random effects described in Model 1, Model 2 included additional predictor variables to determine individual, dyadic, and group level effects on teaching. Sample characteristics can be found in table 3.4.

Age. In order to examine the effect of age on teaching and being taught, we included the age of teacher and age of learner in the model. We z-score standardized these variables in order to facilitate estimations in *Rstan*, and to facilitate interpretation (Koster & McElreath, 2017; McElreath, 2015). We included both the linear and quadratic effects of age of teacher and age of learner to account for the possibility that this relationship might be U-shaped.

Kinship. In order to determine whether kinship relationship predicted teaching, the main effect of kinship relation was included in the model. The coefficient of relatedness (r) was calculated using the aforementioned genealogical data with the R package *kinship2* (Therneau, Atkinson, Sinnwell, Schaid, & McDonnell, 2015). In order to compare sibling and parent-child teaching, we transformed these coefficients into dummy categories; parent-offspring ties ($r=0.5$), sibling ties ($r=0.5$), and other kinship ties ($0.125 \leq r < 0.5$). The omitted reference category was non-kin ties ($r < 0.125$). To identify differences in teaching tendencies between kinship levels, we calculated ‘contrasts’, i.e. posterior estimates of the effect of kinship differences on the expected number of teaching events (McElreath, 2015).

Sex. In order to determine whether individuals were more likely to be taught by others of the same sex, the binary relationship variable ‘same-sex’ was considered true if both the teacher and learner had the same sex, and false otherwise. Teacher and learner sex were also included in the model as control variables and were considered to be true if male.

Adult proximity. To account for the possibility that observed trends in child-child and adult-child teaching were the result of association patterns, adult proximity was included as a control

variable in the model. To account for differences in observation time, frequency with which children in a dyad were in proximity to adults throughout the follow was divided by the total number of observations for each dyad. This value was then z-score standardized.

Ethnicity. In order to examine cross-cultural differences in teaching, we included a binary variable for ethnicity in the model. Ethnicity was considered true if an individual was BaYaka, and false otherwise.

Camp. In order to account for variation in teaching resulting from differences in camp demographics, we included seven dummy variables for camp in the model.

The fixed-effects model that described the observed number of teaching events y_{ij} from individual i to individual j thus took the form

$$y_{ij} \sim \text{Poisson}(\mu_{ij})$$

$$\log(\mu_{ij}) = \beta_0 + \left[\sum_{k=1}^m \beta_k x_{kij} \right] + t_i + l_j + d_{ij} + \log t_{obs}$$

$$\begin{pmatrix} t_i \\ l_i \end{pmatrix} \sim N \left\{ \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_t^2 & \\ & \sigma_l^2 \end{pmatrix} \right\}$$

$$\begin{pmatrix} d_{ij} \\ d_{ji} \end{pmatrix} \sim N \left\{ \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_d^2 & \\ & \sigma_{dd}^2 \end{pmatrix} \right\}$$

where x_{kij} represents fixed effect k , which may depend on the teacher i and/or learner j , and β_k is the estimated coefficient associated with fixed effect k . There were 19 fixed-effect parameters ($m = 19$). The other parameters in the model remained as before. Model 3: The fixed- and interaction-effect model

In addition to the fixed effects described in Model 2, Model 3 included a series of interaction effects. First, in order to test whether child-to-child teaching was more likely to occur when children were younger and adult-child teaching was more likely to occur when children were older, we included the two-way interaction between teacher's and learner's age. Second, in order to further examine differences in Hadza and BaYaka teaching, we included two-way interactions for ethnicity and age variables, ethnicity and kinship categories, ethnicity and sex variables, and ethnicity and adult proximity. We also included the three-way interaction term for ethnicity, age of teacher, and age of learner in order to determine whether the age-specific relationship between teacher and learner differed for the Hadza and BaYaka. Following Koster (2018), model predictions were generated for younger children (set at 5 years) and older children (set at 15

years) in each ethnicity in order to interpret these effects. Mathematically, the model took the same form as Model 2 (Section 4.3.2) with upper summation index $m = 34$.

Table 3.4. Variable names, descriptions, and summary statistics.

Variable	Description	N	Mean	SD	N	Mean	SD
Individual-level variables		BaYaka			Hadza		
Sex	Dummy variable to denote that the individual is male	95	0.53	0.50	161	0.54	0.50
Age	Age in years	95	22.41	18.79	161	23.00	19.20
Relationship-level variables							
Parent	Dummy variable to denote parent-offspring ties, $r=0.5$	939	0.06	0.23	1894	0.02	0.15
Sibling	Dummy variable to denote sibling ties, $r=0.5$	939	0.05	0.23	1894	0.03	0.18
Other Kin	Dummy variable to denote other kinship ties, $0.125 \leq r < 0.5$	939	0.11	0.32	1894	0.14	0.35
Same-Sex	Dummy variable to denote that the teacher and learner are of the same-sex	939	0.50	0.50	1894	0.53	0.50
Adult Proximity	Proportion of observations in proximity to adults	939	0.69	0.24	1894	0.58	0.38

Notes: 15 BaYaka individuals inhabited two separate camps during data collection; 1 BaYaka individual inhabited three separate camps; and 1 BaYaka individual inhabited 4 separate camps. These individuals are included as inhabitants in each camp, leading to repeated observations for these individuals, as well as repeated observations for 9 BaYaka dyads. A camp with no overlap in participants was chosen as the reference category.

Estimation

The parameter values for our collection of SRMs were fit using Hamiltonian Monte Carlo estimation, implemented in *RStan* and *rethinking* (McElreath, 2015; Stan Development Team, 2016). We specified flat priors for the fixed parameters in the model. We ran the model on four chains of 2000 iterations each, half of which were warmup iterations. We assessed convergence through the R-hat Gelman and Rubin convergence diagnostic (McElreath, 2015). All R-hat values were smaller than 1.01, and there were no divergent iterations, suggesting good mixing across all models. We compared the model fit by calculating the Widely Applicable Information Criteria (WAIC) (McElreath, 2015). Like other information criteria, a model with a lower WAIC indicates a preferable model, as this model will make better predictions on new data when compared to other models under consideration. We further considered Akaike weight, which is an estimate of the probability that the model would make the best predictions using new data. We report the means, standard deviations, and 95% credible intervals for the parameter estimates in all three models, as well as their WAIC.

Results

When considering only unique cases, 14% of Hadza children's observational time and 11% of BaYaka children's observational time units were spent teaching or being taught subsistence skills. Only 25% of teaching in the domain of subsistence skills occurred within adult-child dyads (Hadza; 23%, BaYaka; 27%). The results of the SRMs for all models are presented in table 3.5. Model 3 had the lowest WAIC, and a weight of 1, meaning that this model was the best fit to the data; thus, we expand on the results of this model in what follows. Although our model showed several variables for whom the credible intervals do not cross zero, the figures presented below show that these credible intervals are wide, likely due to the fact that data were sparse, so we report our findings with the caveat that they should be interpreted cautiously.

Age. In support of prediction 1, there was a strong and negative association between the quadratic effect of teacher's age, and the frequency of teaching ($\beta_3=-0.48$), suggesting that the relationship between the age of teacher and the frequency of teaching followed an inverted-U curve. Figure 3.1 shows that teaching increased throughout childhood and young adulthood, peaking around 30 years of age, after which it decreased. We found limited support for prediction 2, as there was only a weak relationship between learner's age and teaching. In partial support of prediction 3, the three-way interaction between ethnicity, teacher's age, and learner's age was a strong predictor for teaching ($\beta_{34}=2.18$). Figure 3.2 plots this relationship, suggesting that, for the BaYaka only, younger children were more likely to be taught by other children while older children were more likely to be taught by adults.

Table 3.5. Social Relations Model results.

Parameter		Model 1		Model 2		Model 3	
		Mean	SD	Mean	SD	Mean	SD
β_0	Intercept	-11.09	0.28	-12.70	0.53	-12.55	0.66
Teacher-Level Variables							
β_1	Sex		-0.39	0.25		-0.64	0.35
β_2	Age		0.52	0.20		0.83	0.44
β_3	Age ²		-0.36	0.10		-0.48	0.18
Learner-Level Variables							
β_4	Sex		-0.34	0.21		-0.32	0.32
β_5	Age		-0.78	0.18		-0.42	0.41
β_6	Age ²		0.04	0.09		-0.15	0.17
Relationship-Level Variables							
β_7	Same-Sex		1.30	0.21		1.09	0.28
β_8	Parent-Child		3.05	0.48		3.11	0.77
β_9	Sibling		3.18	0.39		3.98	0.55
β_{10}	Other Kin		1.92	0.29		1.97	0.37
β_{12}	Adult Proximity		0.22	0.17		0.16	0.22
β_{13}	Teacher Age X Learner Age					0.58	0.73
β_{14}	Teacher Age ² X Learner Age ²					0.55	0.39
Group-Level Variables							
β_{15}	Ethnicity		2.11	2.07		2.26	2.15
β_{16}	Camp1		0.59	2.07		0.72	2.05
β_{17}	Camp2		2.06	2.26		2.10	2.30
β_{18}	Camp3		0.29	0.61		0.20	0.68
β_{19}	Camp4		1.14	0.67		1.13	0.78
β_{20}	Camp5		1.26	2.09		1.09	2.09
β_{21}	Camp6		-0.95	2.07		-1.11	2.06
β_{222}	Camp7		-1.14	2.06		-1.11	2.06
Group-Level Differences							
β_{23}	Ethnicity X Teacher-Sex					0.38	0.52
β_{24}	Ethnicity X Teacher-Age					0.81	0.63
β_{25}	Ethnicity X Teacher-Age ²					-0.21	0.27
β_{26}	Ethnicity X Learner-Sex					-0.17	0.45
β_{27}	Ethnicity X Learner-Age					0.54	0.58
β_{28}	Ethnicity X Learner-Age ²					0.04	0.25
β_{29}	Ethnicity X Same-Sex					0.40	0.41
β_{30}	Ethnicity X Parent-Child					0.38	0.95
β_{31}	Ethnicity X Sibling					-1.72	0.75
β_{32}	Ethnicity X Other Kin					0.12	0.58
β_{33}	Ethnicity X Adult Proximity					0.44	0.42
β_{34}	Ethnicity X Teacher-Age X Learner-Age					2.18	1.05
β_{35}	Ethnicity X Teacher-Age ² X Learner-Age ²					0.40	0.61
Random Effects							
σ_t^2	Teacher Variance	0.94	0.32	1.41	0.43	1.82	0.50
σ_l^2	Learner Variance	0.81	0.34	0.75	0.28	1.03	0.34
σ_{tl}	Relationship Variance	9.06	0.82	7.39	0.71	7.28	0.70
ρ_{tl}	Generalized Reciprocity Correlation	0.65	0.13	0.91	0.05	0.93	0.03
σ_{dd}^2	Dyadic Reciprocity Correlation	0.95	0.01	0.96	0.01	0.96	0.01
Pt	Teacher VPC	0.09	0.03	0.15	0.04	0.18	0.04
Pl	Learner VPC	0.07	0.03	0.08	0.03	0.10	0.03
Ptl	Relationship VPC	0.84	0.05	0.78	0.06	0.72	0.06
	WAIC		3346.7		3161.1		3147.5

Note: All models run for 2000 iterations on four chains (1000 iterations per chain are warmups). Diffuse priors on all parameters. Values in bold represent 95% credible intervals which do not include zero.

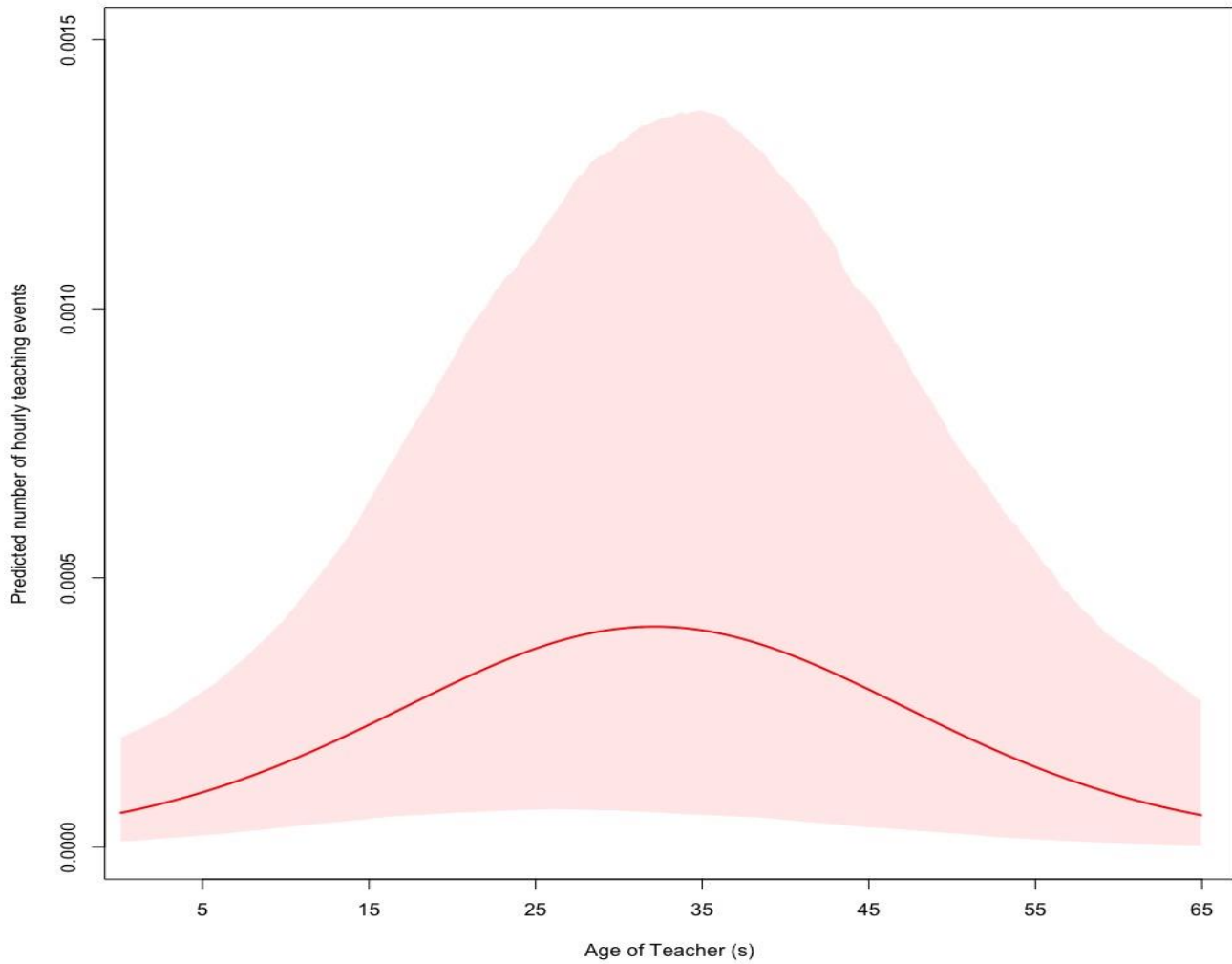


Figure 3.1. Predictions of Model 3 showing the quadratic effect of teacher’s age on teaching. Other predictions are held constant at their mean or reference value. Shaded areas depict the 95th percentile credible intervals around the model predictions. Predictions are for one hour.

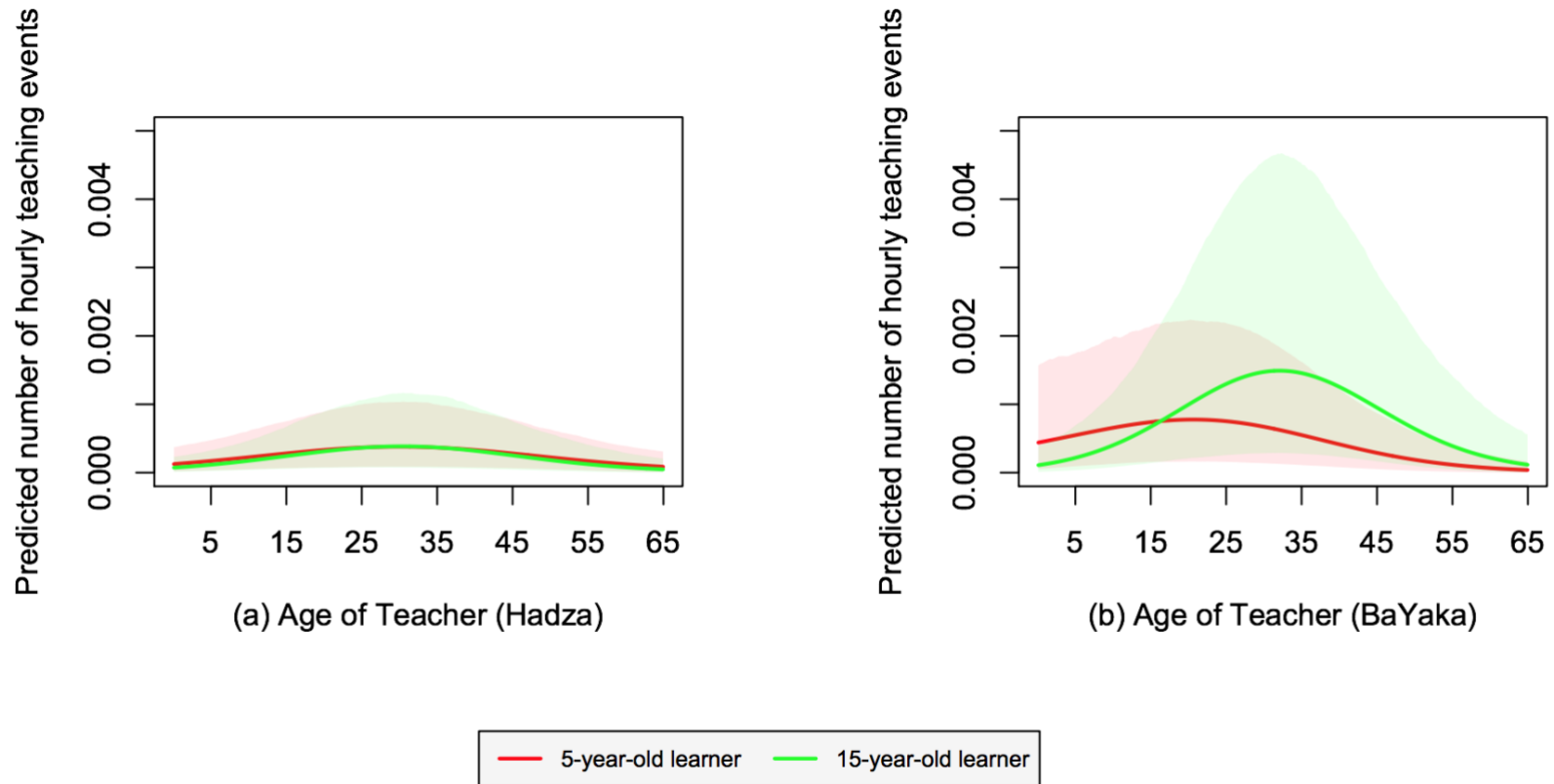


Figure 3.2. Predictions of Model 3 showing the interaction between ethnicity, age of teacher, and age of learner. For younger and older children, predictions are based on children aged 5 and 15 years respectively. Other predictions are held constant at their mean or reference value, except for camp, which was set to a BaYaka camp for the BaYaka, and to the reference value of a Hadza camp for the Hadza. Shaded areas depict the 95th percentile credible intervals around the model predictions. Predictions are for one hour.

Kinship. For the Hadza, parent-child dyads ($\beta_8=3.11$), sibling dyads ($\beta_9=3.98$), and other-kin dyads ($\beta_{10}=1.97$) were more likely to experience teaching than non-kin dyads. Contrasts revealed that BaYaka parent-child dyads, sibling dyads, and other-kin dyads were also more likely to experience teaching than non-kin dyads (Table 3.6). Thus, in support of prediction 4, our results showed that, in both ethnic groups, related dyads were more likely than unrelated dyads to exchange teaching. We also found a strong relationship between ethnicity and teaching between sibling dyads ($\beta_{31}=-1.72$); Hadza sibling dyads were more likely to exchange teaching than BaYaka sibling dyads (Figure 3.3).

Sex. In support of prediction 5, we found that teaching was more likely to occur between same-sex than opposite-sex dyads ($\beta_7=1.09$).

Adult proximity. Adult proximity and the interaction between adult proximity and ethnicity were not strong predictors of teaching.

Random Effects. In support of prediction 6, the variance and correlated random effects showed that dyadic reciprocity was high ($\sigma_{dd}^2=0.96$), and that 72% of the variation in the model could be explained by the effect of the relationship (*PtI*). In addition, 18% of the variation in the model was explained by the effect of the teacher (*Pt*) and 10% of the variation in the model was explained by the effect of the learner (*PI*).

Table 3.6. Posterior means (standard deviations in parentheses) of contrasts for kinship categories.

	Parent-Child	Sibling	Other Kin	Non-Kin
Parent-Child		0.88 (0.90)	1.12 (0.82)	3.11 (0.77)
Sibling	-1.23 (0.73)		2.00 (0.57)	3.98 (0.55)
Other Kin	1.41 (0.68)	0.17 (0.64)		1.97 (0.37)
Non-Kin	3.49 (0.59)	2.26 (0.54)	2.09 (0.46)	

Parameters in bold represent estimates whose 95% credible intervals do not include zero. The top half of the matrix depicts contrasts for the Hadza, the bottom half depicts contrasts for the BaYaka.

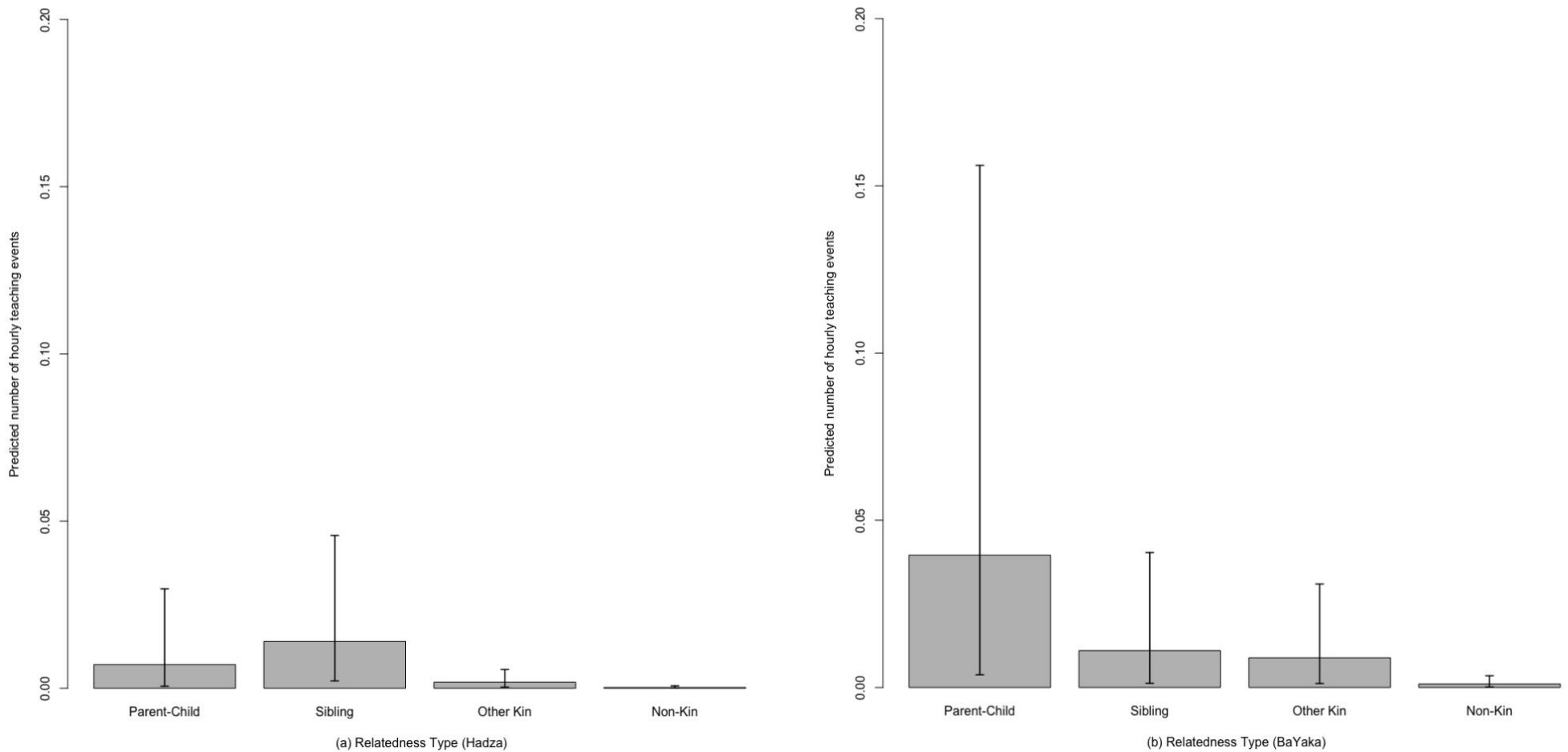


Figure 3.3. Predictions of Model 3 showing the effect of kinship type including parent-child dyads ($r=0.5$), sibling dyads ($r=0.5$), other kin dyads ($0.125 \leq r < 0.5$) and non-kin ($r < 0.125$) for the (a) Hadza and (b) BaYaka. Other predictions are held constant at their mean or reference value, except for camp, which was set to a BaYaka camp for the BaYaka, and to the reference value of a Hadza camp for the Hadza. Error bars depict the 95th percentile credible intervals around the model predictions. Predictions are for one hour.

Discussion

The present study aimed to investigate how age, sex, kinship, and interpersonal relations influenced the teaching of subsistence skills in BaYaka and Hadza forager 3- to 18-year-olds, with a specific focus on child-to-child teaching. Using a broad definition of teaching, our findings suggest that Hadza and BaYaka children participated in teaching, either as a teacher or as a learner, between 6 and 8 times an hour. Other forms of learning, such as work-themed play (Boyette, 2016a, 2016b; Crittenden, 2016; Fouts, Bader, & Neitzel, 2016; Lew-Levy & Boyette, 2018; Chapter 4) and observation (Boyette & Hewlett, 2017a), represent a much larger proportion of hunter-gatherer children's time cross-culturally, and are thus likely to be the primary ways by which forager children acquire subsistence knowledge. However, a majority of teaching occurred within child dyads, with only about one quarter of overall teaching occurring between child-adult dyads. Thus, alongside research among the Aka and Ngandu (Boyette & Hewlett, 2017a; Hewlett & Roulette, 2016), Baka (Gallois et al., 2015), Maya (Maynard, 2002; Zarger, 2002), and Fijians (Kline, 2016), our results show the central role children play as teachers, and not just acquirers, of cultural knowledge.

Children in both populations taught more with age, with overall teaching peaking in adulthood. Teaching likely develops with age because children's teaching abilities continue to increase, and because they have more knowledge to share with others (Strauss & Ziv, 2012). Though the development of children's teaching abilities have been documented in multiple Western societies (see Strauss & Ziv, 2012 for review), our findings lend support to a growing body of evidence demonstrating that this development occurs independently of intensive formal schooling in non-Western societies (Boyette & Hewlett, 2017a; Maynard & Tovote, 2009). Interestingly, after approximately 30, teaching actually decreased with age. We provide one explanation why this may be; in studying children's contributions to parental reproductive success in Mayan households, Lee and Kramer (2002) found that, although children are a net cost to their parents throughout childhood and into early adulthood, children, as a whole, offset a substantial portion of their cumulative consumption costs, thus allowing mothers to reproduce more often than if children made no contributions. While Lee and Kramer studied the costs associated with childrearing from the viewpoint of consumption, children are not only costly

because they need to be provisioned, but also because they need to acquire adult skills (Kaplan et al., 2000). By 30, most adults have children who are old enough to teach their younger siblings. Thus, beyond productive labour, children's contributions to teaching may be another way in which children liberate parents to engage in other survival and reproductive activities.

Mathematical models investigating optimal learning strategies suggest that individual learning should occur only after children have acquired knowledge socially (Aoki et al., 2012; Borenstein, Feldman, & Aoki, 2008; Lehmann et al., 2013). Although previous studies of play (Bock & Johnson, 2004), observation (Patricia Marks Greenfield, 2004), and teaching (Boyette & Hewlett, 2017a) found that social learning declined with age, presumably because older individuals have begun to refine learned behaviour through individual practice, our final model found only a weak negative relationship between learner's age and teaching. However, we note that learner's age was a strong negative predictor in Model 2; it may be that including the interaction between teacher and learner's age reduced the main effect of learner's age. Thus, our data suggests children continue to be taught across childhood but the frequency of teaching in relation to learner's age in these populations needs further study.

While there were no differences with regards to the development of teaching between the Hadza and BaYaka, the identity of the child teacher did vary in these populations. First, and consistent with kin selection theory, teaching was more likely to occur between related dyads than unrelated dyads in both groups. However, sibling teaching was more common among the Hadza than among the BaYaka. As noted earlier, BaYaka camps are typically more compact than Hadza camps (Hewlett et al., In press) partially because of the constraints imposed by living in a forested environment rather than in the savannah. As a result, BaYaka children are invariably close to their parents any time both child and parent are in camp, while Hadza children can be in most parts of camp without being visible to a parent. Our findings tentatively suggest that access to parents mediates sibling teaching. In other words, siblings may have a 'teach when parent absent' strategy; in the presence of parents, siblings may defer to parental teaching expertise, leading to higher rates of sibling teaching for the Hadza when compared to the BaYaka. Future studies should test this hypothesis, as well as investigate how intra-site variation in settlement structure influences the distribution of parent and sibling teaching.

Second, we found that, for the BaYaka only, younger children were more likely to be taught by other children while BaYaka adolescents were more likely to be taught by adults. This finding is consistent with the multistage model of knowledge acquisition, which suggests that children develop basic skills from their friends and family before seeking skilled teachers from whom they can update their knowledge, and who might also be more willing to teach more competent individuals than beginners (Aunger, 2000; Henrich & Henrich, 2010; Reyes-García et al., 2016). While our data support a multistage model of learning among the BaYaka, we found little difference in teacher's age for younger and older learners among the Hadza. While unexpected, this finding may be explained by examining foraging participation. Hadza children collect between 25-50% and sometimes even 100% of their daily caloric needs from an early age (Crittenden et al., 2013; Hawkes et al., 1995). Although children tend to target easier to access resources such as berries and baobab when they are younger, they are provided with opportunities to practice more complex resource acquisition throughout childhood; for example, boys as young as two are made small, functional bows, and girls are provided with small, appropriately sized digging sticks (Crittenden, 2016a). Thus, for the Hadza, teaching by adults may primarily occur through stimulus enhancement in early life, after which children are more likely to learn complex skills through participation in foraging with other children than through teaching by adults. Though a multistage learning model where children learn with other children when younger, and by adults when older may be more common, it may nonetheless depend on the foraging niche in which learning occurs. Future studies should thus take seriously the role of ecological context when investigating the distribution of learning processes across the lifespan.

Next, same-sex teaching was hypothesized to increase the likelihood that children would learn sex-specific skills (Henrich & Gil-White, 2001). Same-sex bias in learning has been noted among foragers the world over (Boyette & Hewlett, 2017a; Draper, 1975; Hewlett & Cavalli-Sforza, 1986; Lew-Levy et al., 2018; MacDonald, 2007). Here, we also found strong evidence for same-sex teaching among both the BaYaka and the Hadza. Finally, as in other aspects of forager life (Allen-Arave et al., 2008; Crittenden & Zes, 2015; Peterson, 1993), we predicted that teaching would be reciprocal. In support of this prediction, we found evidence for high dyadic reciprocity, and a large effect of the dyad, in teaching.

Conclusion

As with other cross-cultural research conducted in small-scale societies, our study was limited in its scope by our small sample size, precluding us from investigating the full range of potential interactions. Though our results tentatively suggested that the trends in teaching were robust when considering adult proximity, we did not have data on the availability of all camp members at every given observation, limiting our ability to determine whether teaching is independent, or a byproduct, of other social and cooperative relationships, such as friendship (Gallois, Lubbers, Hewlett, & Reyes-García, 2018; Kline et al., 2013). Next, since fieldwork was only conducted during part of the year, we were unable to observe every foraging activity (e.g. *kombi* fishing for the BaYaka, weaver-bird collecting for the Hadza); thus, future studies will examine seasonal variation in knowledge acquisition (Crittenden & Schnorr, 2017; Gallois et al., 2015). In addition, as demonstrated in Table 3.3, we observed little teaching in especially complex domains, such as hunting and trapping. This may be because these skills are acquired later in life (Gurven et al., 2006; Ohtsuka, 1989; Walker et al., 2002), while the age cutoff for the present study was approximately eighteen. More longitudinal studies on the distribution of knowledge acquisition across seasons, and across the lifespan, including adulthood are needed. Finally, after-dark storytelling was outside the scope of our paper, which may be an important source of teaching in both populations (Weissner, 2014). Nonetheless, our findings challenged the accepted notion that children are passive recipients of knowledge, instead showing that child-to-child teaching frequently occurs among Hadza and BaYaka foragers. We also showed that subsistence patterns and camp structure should be considered when investigating cross-cultural variation in teaching.

Chapter 4: Gender-Typed and Gender-Segregated Play

Play is a universal feature of human childhood (Konner, 2010) and likely contributes to children's physical and intellectual development, including the acquisition of gendered roles and skills (Edwards, Knoche, & Kumru, 2004). Research conducted in Western, pastoralist and small-scale farming societies find that access to playmates and adult work lead to variations in boys and girls gender-typed and gender-segregated play (Edwards, 1993; Harkness & Super, 1985; Maccoby, 1998; Morelli et al., 2003; Munroe & Romney, 2006). However, few studies on the play of hunter-gatherer children exist (Hewlett & Boyette, 2013). Research on hunter-gatherers can help elucidate how culture and biology interact to shape the development of children's gendered play behaviours because these populations share cultural and demographic features which are distinct from those of Western and other small-scale societies. Hunter-gatherer camps are small, which limits children's access to playmates (Konner, 1976b), children have extensive free time to participate in play (Draper, 1975; Hewlett, Fouts, Boyette, & Hewlett, 2011), and adults maintain a gendered division of labour (Brown, 1970; Marlowe, 2007). Furthermore, because hunter-gatherers are diverse in their cultural practices, beliefs, histories, and ecologies (Reyes-García & Pyhälä, 2016), comparative studies can examine how these differences influence children's gendered play. Thus, the present paper used observational data to compare the development of gender-typed and gender-segregated play of children and adolescents among Hadza and BaYaka hunter-gatherers from Tanzania and the Republic of Congo.

The Developmental Function of Play

Play is an evolved feature of juvenility across mammalian species (Byers & Walker, 1995). It is considered to have the following features: (1) no obvious, immediate benefit; (2) characterized as a voluntary, pleasurable activity; (3) involves movements which are exaggerated, repeated, or fragmented, and (4) occurs in the absence of stress (Fagen, 1981). Time spent in play typically decreases as individuals approach maturity (Byers & Walker, 1995). The pervasiveness of play in human childhood suggests that it may enable children to learn the physical and social skills

necessary for adulthood, including gender-specific norms and activities (Bock & Johnson, 2004; Lancy, 2016a; Montgomery, 2009; Pellegrini & Smith, 1998b).

Three main categories of play have been theoretically and empirically tied to learning during the mammalian juvenile period: exercise play, object play, and social play (Fagen, 1981). Exercise play, such as running or climbing, may contribute to physical training of neuromuscular and cardiovascular systems (Byers & Walker, 1995), as well as improved skill and economy of movement (Pellegrini & Smith, 1998a). In humans, exercise play occurs more frequently and at higher levels of intensity in boys than in girls (Biddle, Atkin, Cavill, & Foster, 2010; Pellegrini & Smith, 1998a) and peaks between three and four years of age. Object play, which involves object manipulation, is hypothesized to facilitate tool use and construction capabilities (Pellegrini & Bjorklund, 2004). Object play peaks in middle childhood, after which it decreases in early adolescence (Bjorklund & Gardiner, 2010; Pellegrini, Dupuis, & Smith, 2007). Some studies also suggest that boys engage in object play more frequently than girls (Bjorklund & Gardiner, 2012; Pellegrini & Bjorklund, 2004). Social play, such as rough-and-tumble play (RTP), involves a balance between cooperation and competition, and takes special priority during the juvenile period in nearly all social mammals (Pellegrini & Smith, 1998a). Usually unrelated to aggression, RTP in early and middle childhood may facilitate the development of social (Flanders, Leo, Paquette, Pihl, & Séguin, 2009) and fighting skills (Fry, 2014). In adolescence, RTP may help establish dominance in order to attract mates (Pellegrini, 2003). RTP appears to be a male-dominated form of play (Fry, 2014; Pellegrini & Smith, 1998a), and, in the West, increases throughout middle childhood, peaks between 11 and 12 years, and declines thereafter (Humphreys & Smith, 1987; Pellegrini, 1995).

In addition, two human-specific play types may also contribute to learning: structured games and pretense play. Structured games may contribute to the development of children's moral and role-taking capabilities (Piaget, 1965). Studies investigating gender differences in children's structured games largely suggest that boys spend more time in structured games than girls (Blatchford, Baines, & Pellegrini, 2003; Deaner et al., 2012; Lever, 1978; Mauldin & Meeks, 1990), while 11-year-olds engage in more structured games than 7- and 9-year-olds do (Humphreys & Smith, 1987). Pretense play, defined by Lillard (1993, p. 349) as "the projecting of

a supposed situation onto an actual one, in the spirit of fun”, emerges between 18 and 24 months of age. Pretense may enrich various aspects of children’s cognition, including creative thinking (Mullineaux & Dilalla, 2009), narrative and linguistic competence (Hoffmann & Russ, 2012), and theory of mind (Goldstein & Winner, 2011). Since children often imitate the work of same-gender adults in their pretense, pretense play may be a setting in which children practice gendered skills (Bock & Johnson, 2004; Fein, 1981; Lew-Levy & Boyette, 2018). Findings regarding gendered participation in pretense have been mixed, with some experimental and naturalistic play studies reporting that girls participate in pretense more than boys, whereas other naturalistic studies report no such difference (see Göncü, Patt, & Kouba, 2002 for review). In the West, pretense play peaks in early childhood, representing 33% of kindergartner’s play, after which it declines (Fein, 1981).

Beyond gender-typed play, preferences for same-gender playmates are also pervasive in childhood (Maccoby, 1998; Moller & Serbin, 1996; Munroe & Romney, 2006; Whiting & Edwards, 1973). Lee et al. (2007) found that only 11% of six- to twelve-year-old children’s self-reported social networks included opposite-gendered individuals. In adolescence, when children have more freedom to choose the contexts in which they interact with peers, adolescents still prefer to ‘hang out’ with same-gender peers (Strough & Covatto, 2002), even as heterosexual teenagers begin to explore romantic relationships (Connolly, Craig, Goldberg, & Pepler, 2004). While most studies suggest that children begin to segregate by gender around the age of three (Maccoby, 1998), cultural features may also influence the timing of children’s gender segregation. For example, Harkness and Super (1985) found that Kipsigis pastoralist children primarily interacted in mixed-gender groups until the age of six. Between seven and nine, however, children increasingly assorted into single gender groups, perhaps because children in middle childhood were afforded greater freedom to choose their play partners, and were expected to carry out gender-typed household chores.

Children may prefer to play with same-gender others because their behaviours are more compatible (Maccoby, 1998; Pellegrini, 2004). For example, because boys are more physically active than girls (Biddle et al., 2010; Fabes, Martin, & Hanish, 2003), they may find it more satisfying to play with other boys. In a study of preschoolers, boys tended to play more vigorously

than girls in single-gender groups, and single-gender playgroups were more frequent than mixed-gender playgroups (Fabes et al., 2003). However, when playing in mixed-gender groups, boys played less vigorously, and girls more vigorously, than when in single-gender groups. Children also participated in less gender typical play in mixed-gender groups. Thus, while energetic expenditure may motivate gender segregation (Pellegrini, 2004), children nonetheless adjust their play styles to match those of their play partners.

Play in Hunter-Gatherers

Hunter-gatherers can be broadly categorized into two groups: delayed-return and immediate-return. Delayed-return hunter-gatherers tend to rely on aquatic resources, which are more conducive to village-style settlements, and thus expansive accumulation of material culture as well as complex political systems and, in some cases, slavery (Roscoe, 2006). Immediate return hunter-gatherers rely on less predictable land resources, and as a result, are mobile, live in small camps of, on average, 25-45 individuals, have low population densities, and have multiple residences (Kelly, 1995). This paper is concerned with immediate-return hunter-gatherers, which we refer to simply as 'hunter-gatherers' throughout the text.

Hunter-gatherers often share a similar ethos of political, gender, and age egalitarianism, personal autonomy, and widespread sharing (Hewlett, 1991b; Kelly, 1995; Marlowe, 2010). Although all hunter-gatherers maintain a gendered division of labour, with men typically targeting animal products and women typically targeting plant products, the degree to which men and women divide labour varies by culture and ecology (Brown, 1970; Kelly, 1995). Because hunter-gatherer children are afforded extensive individual autonomy (Konner, 2016), self-socialization, including through play, is central to their gender development (Draper, 1975).

Although there have been few studies of gender segregation by hunter-gatherer children during play, the extant studies overwhelmingly reported little or no gender segregation. For example, in the only systematic study of gender segregation in play among hunter-gatherer children, Fouts and colleagues (2013) found that Bofi children from the Central African Republic were less likely than their farmer neighbours to play in gender-segregated groups in early childhood. Similarly, in a cross-cultural survey of six hunter-gatherer societies from Asia, Africa,

and South America, Konner (2005) also found play in multi-aged, mixed-gender groups to be the norm. This may be due to the demographic constraints inherent to hunting and gathering as a mode of subsistence, where band size is relatively small, and thus, children have limited opportunities to choose same-aged and same-gender playmates (Hewlett, 1991a; Konner, 1976). As a result, both boys and girls may need to adjust their energetic play to match that of opposite-gender playmates (Draper, 1975; Fabes et al., 2003), and thus, gender differences in play usually considered gender-typical, such as RTP, may be less pronounced.

Indeed, researchers working with hunter-gatherers in diverse contexts, including the San of the Kalahari, the Aka of the Central African Republic, and the Parakaña of Brazil have found no significant gender differences in the frequency of RTP, whereas these same studies reported differences in RTP in the farming and urban populations studied (Blurton Jones & Konner, 1973; Boyette, 2016a, 2016b; Draper & Cashdan, 1988; Gosso et al., 2007). Although differences in RTP may be attenuated, gender differences in other types of play may not be. Indeed, various studies have found that hunter-gatherer children preferentially imitate gender-specific work activities in their pretense play, suggesting that, as in non-hunter-gatherer societies, some gender roles may be acquired through pretense (Bock & Johnson, 2004; Draper, 1975; Gosso et al., 2007; Lew-Levy & Boyette, 2018). Whereas most of the studies described here focused on single hunting and gathering populations, or compare hunter-gatherers to farmers, more research is needed to uncover how the gendered play of hunter-gatherer children differs from one society to the next.

The Study

Considering the literature reviewed above, the present study aimed to examine cross-cultural differences in gender-typed and gender-segregated play among BaYaka and Hadza hunter-gatherers. Our study included participants in early childhood, middle childhood, and adolescence. Although many studies of play track its development during the transition from early to middle childhood, when children demonstrate a growing understanding of family and gender roles (Maccoby, 1998; Moller, Hymel, & Rubin, 1992; Montgomery, 2009), and a greater knowledge of moral norms (House et al., 2013; Konner, 2010), the inclusion of adolescents requires justification. First and foremost, adolescent activities are under-studied in small-scale

societies generally (Schlegel & Hewlett, 2011). Hunter-gatherer adolescence is a unique period in development because, although many adolescents can and do assist in childcare and foraging tasks, they are not required to do so and are still primarily provisioned by others (Hewlett & Hewlett, 2012). As such, hunter-gatherer adolescents spend much of their time exploring and learning subsistence, social, and sexual skills through imitation, observation, and play (Hewlett & Hewlett, 2012). Thus, it may be informative to include adolescents when seeking to elucidate developmental trends in gendered play among hunter-gatherers.

This study tested a series of hypotheses derived from previous developmental and anthropological research. First, we investigated the relation between gender and the allocation of children's and adolescent's time to play. Studies of farmers suggest that girls enter the workforce earlier than boys, and, as a result, devote less time to play with age than boys (Bock & Johnson, 2004; Boyette, 2016a; Nag et al., 1978; Whiting & Edwards, 1973). In the only analysis of gender, age, and time allocation to play which included data from hunter-gatherers, Boyette (2016a) found that Aka hunter-gatherer and Ngandu farmer girls devoted less time to play with age than boys. Here, with a larger sample of hunter-gatherer children and adolescents, we revisited Boyette's original hypothesis, which posits that, because hunter-gatherer children and adolescents are provided extensive autonomy, gender differences in child and adolescent time allocation to play should be limited.

Second, we investigated the association between play partner availability and gender segregation. Consistent with previous observations that hunter-gatherer children predominately play in mixed-age and -gender groups (Konner, 2016), and that small camp size limits children's access to same-gender and same-aged children (Konner, 1976b), we hypothesized that Hadza and BaYaka children and adolescents would be more likely to segregate by gender during social play in larger camps than in smaller camps. Third, whereas studies conducted in the West have found consistent gender differences in certain play types, such as RTP, these findings have not been replicated among hunter-gatherers. This may be because hunter-gatherer children have fewer opportunities to segregate by gender and thus may have to adjust their energetic play to match that of their opposite-gender playmates. Here, we tested whether the gender differences observed in object, exercise, RTP, structured games, and pretense play in the West were also

evident in the two hunter-gatherer populations surveyed. We hypothesized that hunter-gatherer children and adolescents would show few gender differences in these types of play.

Finally, we investigated gender differences in the pretense themes engaged in by Hadza and BaYaka children and adolescents. Hadza and BaYaka adults differ in the degree to which men and women participate in overlapping foraging activities. For example, one study of BaYaka net-hunters found that husbands and wives were within view of each other 47% of daylight hours, including during foraging, whereas Hadza spouses were less likely to forage together (Blurton Jones, 2016; Hewlett, 1992; Marlowe, 2010). BaYaka gender roles are also more flexible in other domains. In particular, BaYaka fathers engage in extensive childcare, with Hewlett (1991b, p. 169) reporting that “fathers do more infant caregiving than fathers in any other known society” (see also Konner, 2016). We thus expected BaYaka children and adolescents to show fewer gendered differences in work-themed pretense play than the Hadza because the BaYaka division of labour is less pronounced than that of the Hadza. Although we did not test other specific predictions regarding cultural differences in the play of Hadza and BaYaka children and adolescents, we describe the ethnographic settings for the study, placing special emphasis on socialization and subsistence differences which may lead to cross-cultural variation in play.

Methods

Ethnographic Settings

The Hadza live in arid savanna-woodlands in Northern Tanzania (Blurton Jones, 2016; Marlowe, 2010). Living in camps of 20-100 inhabitants, only approximately 150 of a total population of 1000 Hadza still hunt and gather for subsistence. As noted above, the Hadza maintain a gendered division of labour (Blurton Jones, 2016; Marlowe, 2010). Honey collecting and bow-and-arrow hunting of small and large game are performed by men while women collect berries and baobab fruit and dig for tubers (Blurton Jones, 2016; Marlowe, 2010). Hadza children extensively participate in foraging, sometimes producing 25% to over 100% of their daily caloric needs (Crittenden et al., 2013). Compared to other foraging societies, in which adults mostly indulge children and rarely reprimand them (Hewlett, 1991b; Konner, 2016), Hadza parents use physical punishment and shout at children (Blurton Jones, 1993). Recently, the Hadza have increased their

dietary reliance on domesticated cultigens (e.g., wheat, maize) provided to them by local missionaries, ethnotour companies, and sometimes researchers (Blurton Jones, 2016; Gibbons, 2018). Children increasingly attend boarding schools, meaning that fewer children live in the bush year-round; this trend seems to be especially accentuated for Hadza girls.

The subgroup of BaYaka surveyed in the present research are sometimes called Mbendjele BaYaka (Lewis, 2002). The BaYaka inhabit the dense tropical rainforest of the Congo Basin, and live in camps averaging 22 inhabitants (Hewlett, 1991a). The BaYaka foraging ecology is diverse; collected species include tubers, and especially wild yams, as well as nuts, mushrooms, caterpillars, insect grubs and liana fruit. Various forms of fishing are also conducted, including bail fishing, fishing with traps, poison fishing, and fishing with hook and line. Both collecting and fishing are usually, but not exclusively, conducted by women. Collecting honey, gun hunting, spear hunting, and trapping with wire snares are almost exclusively done by men. Historically, men hunted with crossbows while both men and women hunted with nets but these activities no longer occur at the research site. Finally, both men and women maintain gardens, in which they grow cassava, plantain, taro, corn, and sweet potato. The BaYaka maintain extensive trade relations with their farming neighbours (Hewlett, 1991b; Lewis, 2002). In contrast to the Hadza, hitting a child rarely occurs and could be grounds for divorce (Hewlett, 1991b). While BaYaka children now have access to schools in most village settings, children usually only attend for 2-3 months of the year during less abundant foraging seasons.

Participants

For the BaYaka, data collection took place in August through September 2016, 2017, and 2018 in the Likouala province of northern Congo. Sixty-five BaYaka children were sampled from 7 camps (48% female). Of these, 10 children inhabited camps surveyed over two years, and four inhabited camps surveyed in all three years, leading to repeated observations of these individuals. For the Hadza, data collection took place in March and April 2017 near Lake Eyasi, Tanzania. Forty-six Hadza children were sampled from 3 camps (41% female). Nearly all (86.7%) of the 3- to 18-year-old children in the Hadza and BaYaka communities were studied, with children excluded only because they were afraid, shy, or ill, or because there were more children in a camp than we

could sample during our allocated stay. No children were followed while they were attending school. Table 4.1 shows the sample characteristic by age category, gender, and ethnicity.

Table 4.1. Age categories used in the analysis, and number of participants based on gender, age, and ethnicity.

Age (years)	Developmental stage	Hadza (N=46)		BaYaka (N=65)		Total
		<i>N girls</i>	<i>N boys</i>	<i>N girls</i>	<i>N boys</i>	
3-6	Early childhood	3	6	6	7	22
7-12	Middle childhood	10	12	11	15	48
13-18	Adolescence	6	9	14	12	41
Total		19	27	31	34	

For repeated observations of BaYaka participants, only the age category of the first year in which a child was observed is included.

Upon arrival at a camp, a census was conducted in order to determine who lived in the camp. This census indicated that, on average, 15.7 three- to 18-year-old children lived in each camp (SD=7.9), with 3 to 24 children in BaYaka camps and 11 to 26 children in Hadza camps. Neither Hadza nor BaYaka children were able to report their biological age. Therefore, in order to estimate children’s ages, we ranked children from oldest to youngest by asking parents about children’s birth order, either within a nuclear family or within a set of closely related cousins, allowing for ties (Boyette, 2016a; Fouts et al., 2013). Alongside this rank, SLL and a field assistant considered children’s physical maturation and capabilities (e.g., can the child touch their left ear with their right hand? Does the child help with household tasks?), dentition (e.g., does the child still have deciduous teeth? (Smith, 1991)), and average inter-birth interval for each population, and then assigned a numerical age to each child. This method is commonly used by anthropologists working in populations that do not know their age in years (e.g. Boyette, 2016a; Crittenden, Conklin-Brittain, Zes, Schoeninger, & Marlowe, 2013). All consent procedures and research protocols were approved by the University of Cambridge Research Ethics Committee (PRE.2016.026). In-country permission was received from the Tanzanian Commission for Science and Technology (COSTECH) and for Congo from the Centre de Recherche et D’Etudes en Sciences

Sociales et Humaines (CRESSH) and the Institute de Recherche en Sciences Exactes et Naturelles (IRSEN).

Procedure

Observations were systematically recorded in situ using a focal follow procedure (Boyette, 2016a). SLL lived in the camps where data collection took place, and, in order to build rapport with participants, waited one to two days before data collection started. Individual children were then assigned two 2-hour sampling blocks: one in the morning (usually between 8 and 11am) and one in the afternoon (usually between 12 and 3pm). Observations were paused or postponed in cases of especially bad weather or community events in which the researcher could not participate (e.g. community meetings, dances) and resumed as soon as possible, usually the same day. The timing of these observation blocks allowed us to sample children both inside and outside of camp (Hadza; 45.3% observations in camp, BaYaka; 57.3% observations in camp). We stayed in close proximity to the focal child for approximately one hour before the start of the follow in order to habituate the child to our presence. Follows were terminated if we noticed the child growing tired or anxious about our presence. Each child was observed, on average, for 256.7 minutes (SD=123.5), totalling 28,494 1-minute long observations. In 2016, these blocks were randomly assigned over two separate days whereas in 2017 and 2018 these sampling blocks occurred over a single, randomly assigned day.

Child and adolescent activities were observed for 30 seconds after which SLL recorded this activity on her data sheet for an additional 30 seconds before commencing observations again. When play was coded, the observer assigned the play to one of seven specific types (Table 4.2). Five of these (object play, exercise play, RTP, structured games, and pretense play) were derived from previous studies of human and non-human play generally and gender-typed play specifically. An additional two play types, roaming and gentle-and-tumble, were derived from previous studies of play in hunter-gatherer populations (Boyette, 2016a; Konner, 1972). Because these two additional categories were infrequently observed, and are not related to our hypotheses, we included them in measures of overall play, but did not consider them in further analyses. In the case of pretense play, the theme of the play was recorded, and categorized upon return from the field. From 2017 onwards, we also noted whether children and adolescents were

interacting in mixed-gender or same-gender groups during social play. Social play involved individuals who were actively playing together, as well as individuals who were participating in ‘onlooker’ play, or interacting with players during play (Hughes, 2010). Thus, social play could include adults, and did not necessarily involve collaborative play. Observations of older children playing with infants in the context of childcare was not coded as play.

Table 4.2. Categories coded as play, and associated definitions. All categories are mutually exclusive.

<i>Play types Coded During Fieldwork</i>	
Object play	Included activities such as playing with balls (but not soccer), throwing rocks, chopping down trees for the purpose of fun, building toys, such as making balls out of rubber or leaves, fixing dolls, fixing play spears, and making toys. Did not include instances where objects were used in the context of other forms of play (e.g., the construction of houses for pretense).
Exercise Play	Playing hide and seek/ tag or chasing one another outside of the context of pretense (when playing spirit or animals, chasing would sometimes occur. This was not included here); playing with one’s own body, such as cartwheels, downward-facing dog-like postures, etc.; Climbing trees outside of the context of foraging.
Rough-and-Tumble Play	Playful karate chopping, wrestling, hitting, slapping, etc. Did not include play-fighting in the context of pretense (e.g. imitation of adult domestic violence)
Structured Games	Organized fun which usually included rules, such as jacks, soccer, and games that involved marching around camp with a rope tied around everyone, etc.
Pretense Play	Included activities such as pretending to sleep, pretending to do spirit dances, pretending to be animals, pretending to hunt, pretending to harvest honey, pretending to cook, and doll play.
Gentle-and-Tumble Play (Not investigated here)	Rolling around on a blanket and sex play.
Roam (Not investigated here)	This usually consisted of looking for butterflies to catch, looking for play objects in the forest, and walking around camp with no purpose. The child was focused on exploring the environment.
<i>Pretense Themes Coded After Fieldwork</i>	
Playing House	Making small huts and hearth, play cooking, cleaning, etc.
Play Hunting	Imitating hunting during play, such as pretending to set traps, pretending to hunt with spears, and playing hunter/hunted.
Play Foraging	Pretending to collect fruits, mushrooms, nuts, etc., and pretending to dig tubers.
Doll Play	Portraying an object as a doll and treating it as an infant. For the Hadza, the objects included infant bush babies, baobab fruit, and cloth dolls. For the BaYaka, the objects included infant monkeys and stalks of banana.
Play Honey Collecting	Pretending to collect honey, pretending to search for honey, and climbing trees in a manner used for honey collecting.
Play Tool Manufacture	Pretending to make bows, arrows, baskets, matts, and rope.
Play Fishing	Pretending to bail water for fishing, pretending to fish with hooks, pretending to fish with poison (BaYaka only).
Non Work-Themed Play	Non work-themed pretense such as pretending to sleep, pretending to ride in cars, pretending to be animals, imitating adult social interactions, and imitating religious ceremonies.

Inter-Coder Reliability

Inter-coder reliability data was collected among the BaYaka only before the start of the 2017 field season. The Congo research team (SLL and AHB) simultaneously followed 7 village-dwelling children for a total of 711 observations (female=4, early childhood=1, middle childhood=2, adolescence=4). Reliability was high across all codes; group composition by gender (mixed-gender, yes/no), $K=0.99$, $SE=0.005$; play (yes/no), $K=0.92$, $SE=0.02$; and play type, $K=0.92$, $SE=0.02$. After each focal follow, reliability assessments were conducted, and any disagreements were resolved by consensus. We did not conduct reliability on pretense play themes, as these were determined by consulting field notes upon return from fieldwork. Reliability could not be conducted with the Hadza, as SLL did not have access to another coder in Tanzania.

Data Analysis

Because our dependent variables were counts (i.e. number of events), seven Poisson generalized linear mixed-models (GLMMs) were fit using *glmer* function with the *bobyqa* optimiser in the *lme4* package in R (Bates, Mächler, Bolker, & Walker, 2015). In order to test the hypothesis that there would be no gender difference in the age-dependent decrease in play among Hadza and BaYaka children and adolescents, Model 1 investigated overall time allocation to play across childhood. Counts of total observations in which play occurred (i.e. all play behaviours outlined in Table 4.2) per child per year sampled was the dependent variable. The main effects of gender (0=girl, 1=boy), age, and ethnicity (0=Hadza, 1=BaYaka), and the two-way interactions between gender and ethnicity, gender and age, and ethnicity and age were included in the model. In order to compare across developmental periods, we grouped age into three categories; early childhood (3-6 years; reference category), middle childhood (7-12 years), and adolescence (13-18 years). Comparisons between children in middle childhood and adolescence were conducted using a post hoc Tukey test with the package *lsmeans* (Lenth, 2016). In order to account for variation in children's observation time, we included as an offset the log of the total number of observations for each child per year sampled.

In order to test the hypothesis that gender segregation would be more common in camps with a greater availability of play partners, Model 2 investigated time allocation to social play in

mixed-gender groups. Counts of social play observations in mixed-gender groups per child per year sampled was the dependent variable. The main effects of ethnicity, gender, age, and the number of children available in camp (continuous), as well as the two-way interactions between gender and ethnicity, gender and age, and ethnicity and age were included in the model. In order to account for variation in children's time spent in social play, we also included as an offset the log of the total number of observations spent in social play for each child per year sampled. Because mixed-gender play was not measured in 2016, this model included data from 2017 and 2018 only. A further three children never participated in social play during follows and were omitted from this analysis. Thus, the total sample size for Model 2 was 96 children (45 Hadza, 51 BaYaka).

In order to test the hypothesis that Hadza and BaYaka children would show few gender differences in play types, Models 3-7 investigated play time allocation to five types of play. Count of total observations per child per year sampled of object play (Model 3), exercise play (Model 4), RTP (Model 5), structured games (Model 6), and pretense play (Model 7) were the dependent variables. Models 3-7 included the main effect of ethnicity, gender, and age, and the interactions between ethnicity and age, ethnicity and gender, and age and gender. Each of these five models included as an offset the log of the total number of observations spent in play for each child per year sampled. Two children never participated in play during follows and were omitted from this analysis. Thus, the total sample size for Models 3-7 was 109 children (46 Hadza, 63 BaYaka).

In addition to the fixed and interactive effects described above, two random effects were included in Models 1-7; first, because over-dispersion is common in observational studies of behaviour, and because 14 BaYaka children were sampled in more than one year, we nested observations within participating children. Second, in order to account for the possibility that children's behaviours were influenced by other camp members, we also included a random effect for camp.

Finally, in order to investigate children's gendered participation in pretense themes, we conducted a series of Mann-Whitney U tests. This non-parametric alternative was preferred to the Poisson regressions due to the sparsity of data. The dependent variables were the

proportions of pretense play by theme per child. Analyses were conducted on the Hadza and BaYaka separately, with gender as the grouping variable. Since age was not a predictor variable in this analysis, counts of participation in pretense play were summed across years for children with repeated observations. Thirteen Hadza children and 16 BaYaka children never participated in pretense play; thus, the Mann-Whitney U tests included sample sizes of 33 Hadza and 49 BaYaka children.

Results

Description of Children's Play

To situate our findings, we first describe the setting and context of play. Although both Hadza and BaYaka children and adolescents participated in a great variety of activities through the day, play represented a large proportion of children's time budget in both societies (Table 4.3). Play usually occurred in or on the immediate periphery of camp (Hadza; 70.4%, BaYaka; 71.8%). Consistent with prior research, we observed that, from infancy onwards, both Hadza and BaYaka children played with adult tools, such as baobab pounding stones and digging sticks in the case of the Hadza, and knives and machetes in the case of the BaYaka (Chapter 5). By early childhood, children could, and did, participate in most of the types of play in their cultural repertoires (Figure 4.1). Much of this play was social (92.5% of Hadza play, 83.9% of BaYaka play). Both Hadza and BaYaka children made dolls; for the Hadza, dolls were usually made with baobab fruit or mud (Crittenden, 2016a). Children carried these dolls in slings, and sometimes soothed or groomed them. Among the BaYaka, children made dolls using banana shoots or empty bottles. Hadza and BaYaka children also played tag, climbed trees, and occasionally wrestled (Crittenden, 2016a; J. Lewis, 2002). Both Hadza and BaYaka children participated in extensive pretense play. For example, children in both societies manufactured small huts by collecting poles, grass, and leaves. Usually, several huts were constructed side-by-side, in the likeness of a camp. Children sometimes brought their bedding into their huts and pretended to nap. Boys often participated in complementary pretense play, pretending to hunt nearby for the play-camp. Girls tended small fires in front of their huts, usually cooking in small cooking pots borrowed from adults. For the most part, children cooked very small portions of food, such as corn meal among the Hadza and

plantains among the BaYaka. These portions were then eaten by the playgroup, with older children carefully sharing the food to ensure all parties received an equal amount. Hadza children also participated in work play, playfully feeding themselves by conducting non-adult foraging activities such as trapping weaver bird fledglings with sap (Crittenden, 2016a). Although both Hadza and BaYaka adults perceived play as the work of childhood, adults rarely encouraged or discouraged children’s play with the exception of *bolu*, a type of spirit play conducted by BaYaka children (Lewis, 2002). When children initiated *bolu*, adults often acted approvingly, clapped along, joined the dance, and gave advice regarding singing and performance.

Table 4.3. Child and adolescent overall time budgets and play budgets by gender and ethnicity.

	Hadza			BaYaka		
	Girls	Boys	Total	Girls	Boys	Total
	% total observations					
Play	20.39	15.44	17.59	21.65	32.70	27.68
Foraging/Gardening	14.37	18.62	16.78	14.36	10.37	12.18
Domestic work	6.81	3.86	5.14	17.42	7.00	11.73
Childcare ¹	2.52	0.86	1.58	3.80	0.83	2.05
Music	1.03	3.43	2.39	1.44	0.31	0.82
Travel	24.13	23.23	23.62	16.70	18.29	17.56
Rest	26.71	26.36	26.52	16.31	21.43	19.10
Maintenance ²	17.31	14.06	15.47	14.04	11.28	12.53
	% play					
Object Play	12.59	21.90	17.21	30.04	35.09	33.29
Exercise Play	18.99	12.98	16.00	12.83	17.33	15.74
RTP	4.12	9.27	6.68	0.76	1.53	1.26
Structured Games	4.00	26.77	15.31	10.98	13.33	12.50
Pretense Play	58.58	23.99	41.39	36.97	27.20	30.68

Note: From 2017 onward, two activities could be coded concurrently. This represented 7.08% of the observations from 2017 and 2018. Thus, values may add up to >100%. Reported percentages represent population proportions. 1. BaYaka values for childcare are from 2017 and 2018 only; childcare was not systematically recorded in 2016. 2. Maintenance activities include hygiene, grooming, and eating.



a



b



c



d



e



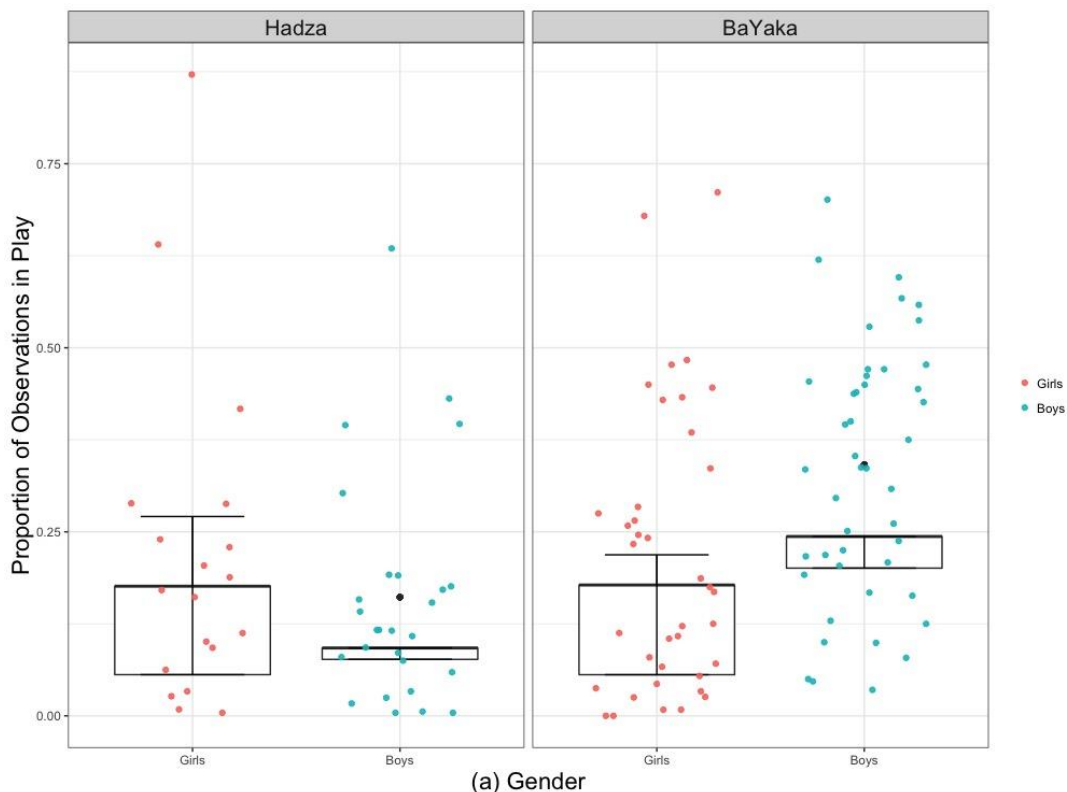
f

Figure 4.1. Hadza and BaYaka children's play.

(a) Hadza and (b) BaYaka children making play houses in or near camp. (c) Hadza and (d) BaYaka children with dolls made from mud and an empty bottle, respectively. (e) Hadza children in work play. (f) BaYaka children playing *montika*, a game played similarly to jacks. Hadza photos by ANC. BaYaka photos by SLL.

Gendered Development of Play Across Childhood

Overall, children and adolescents in the sample devoted 24.2% of their time to play; this represented 17.6% of Hadza child and adolescent time, and 27.7% of BaYaka child and adolescent time (Table 4.3). The results of Model 1 investigating the association between ethnicity, age, gender, and frequency of overall play can be found in Table S4.1. The results show that adolescents were 4.84 times less likely than children in early childhood to participate in play, 95%CI[-2.50, -0.65], $p < 0.001$. A post hoc Tukey test revealed that adolescents were also 1.95 times less likely than children in middle childhood to participate in play, 95%CI[0.23, 1.12], $p = 0.001$. The interaction between ethnicity and gender was significant, 95%CI[0.21, 1.71], $p = 0.01$. However, figure 4.2a reveals that BaYaka boys were more likely to play than their Hadza counterparts, with no strong differences when comparing the play rates of boys and girls within each ethnic group. Contrary to our hypothesis that Hadza and BaYaka children would show no gender differences in the allocation of time to play with age, the interaction between age and gender was also significant, 95%CI[0.12, 1.55], $p = 0.02$. Figure 4.2b shows that adolescent girls were less likely to play than girls in early and middle childhood, while this same effect was not true for adolescent boys.



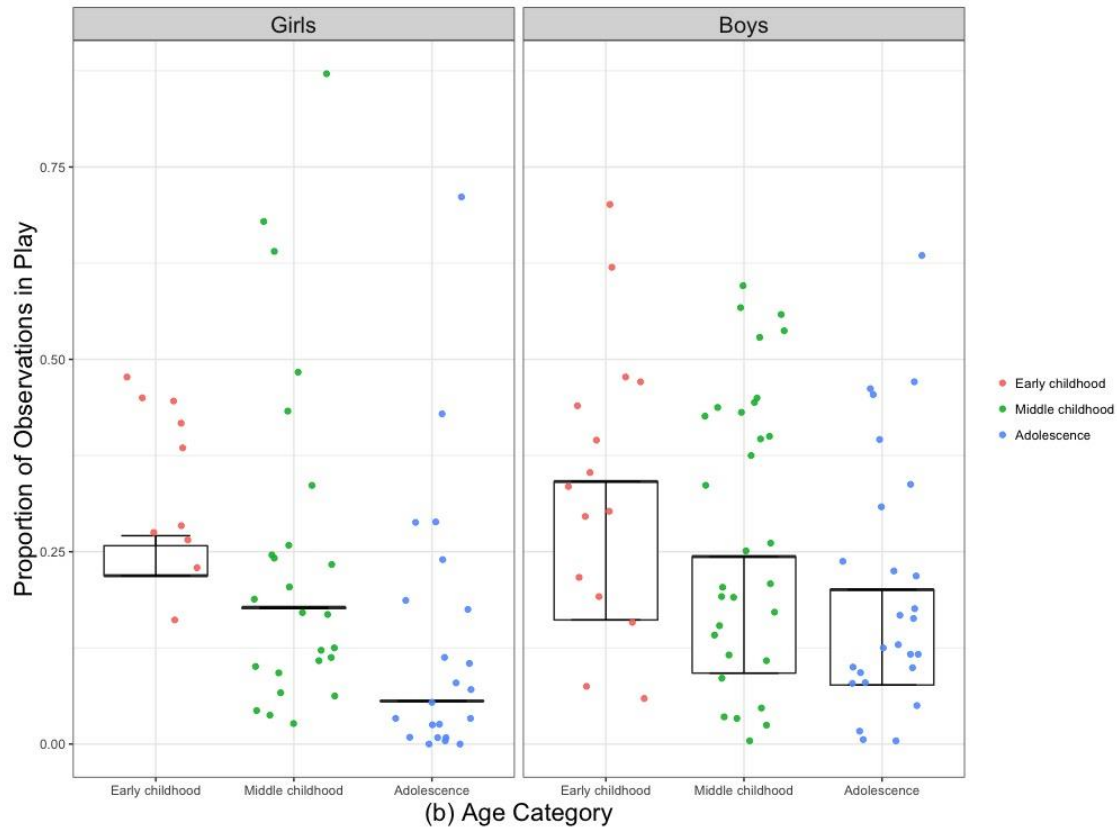


Figure 4.2. Predictions from Model 1

(with random effects held at 0) showing the proportion of total observations spent in play by (a) gender and ethnicity and (b) gender and age category (early childhood; 3-6 years, middle childhood; 7-12 years, adolescence, 13-18 years). Scatterplot of observed data is overlaid.

Gender Segregation During Play

Overall, children in our sample spent 60.1% of their social play observations in mixed-gender groups, representing 70.1% of social play observations for the Hadza and 54.8% for the BaYaka. Model 2, testing the associations between ethnicity, age, gender, and frequency of social play in mixed-gender groups, can be found in Table S4.2. In support of the hypothesis that children were more likely to segregate by gender in larger camps, the number of child inhabitants in a camp was significantly and negatively associated with social play in mixed-gender groups, indicating that, for every additional child in a camp, children were 1.03 times less likely to play in mixed-gender groups, 95%CI[-0.05, -0.02], $p < 0.001$. Age, gender, ethnicity, and their interactions were not significant predictors of play in mixed-gender groups.

Gendered Participation in Types of Play

Among both the Hadza and BaYaka, children spent the greatest percentage of play participating in pretense and object play, and the smallest percentage participating in RTP (Table 4.3). The results of Models 3-7, testing the associations between ethnicity, age, gender, and types of play, can be found in Table S4.3. The main effects of ethnicity, gender, and age were not significant predictors for participation in object play. However, the interaction between age and ethnicity was significant, middle childhood; 95% CI[0.30, 2.47], $p=0.01$, adolescence; 95% CI[0.48, 3.05], $p=0.007$. This indicates that for the BaYaka only, play time devoted to object play increased with age. Furthermore, the interaction between ethnicity and gender was also significant, 95%CI[-2.22, -0.09], $p=0.03$. However, contrasts revealed no within-ethnicity effect of gender on object play. Ethnicity was a significant predictor of participation in RTP, with Hadza children 25.11 times more likely than BaYaka children to participate in this form of play, 95% CI [-5.64, -0.81], $p=0.009$. Although the main effect of gender was not a significant predictor of participation in RTP, the interaction between gender and age showed that adolescent boys were more likely than adolescent girls to participate in this form of play, 95% CI[0.18, 5.82], $p=0.04$. Gender was a significant predictor of participation in pretense play, with girls 3.38 times more likely to participate in pretense play than boys, 95% CI[-2.42, -0.02], $p=0.047$. The interaction between ethnicity and age was also significant, indicating that BaYaka children in middle childhood were more likely to participate in pretense play than Hadza children in middle childhood, 95% CI[-2.71, -0.26], $p=0.02$. The effects of age, gender, ethnicity, and their interactions were not significant predictors of participation in structured games or exercise play. These results show mixed support for our prediction that hunter-gatherer would minimally differ in their participation in play types.

Gendered participation in culturally-specific pretense themes

Children devoted a quarter or less of their pretense play to non-work themes (Table 4.4). In support of our hypothesis, we found that BaYaka children showed fewer gendered differences in work-themed pretense play than Hadza children. Both Hadza and BaYaka girls were significantly more likely than boys to play house, Hadza; $Z=2.33$, $p=0.02$, BaYaka; $Z=2.98$, $p=0.003$. Both Hadza

and BaYaka boys were significantly more likely to participate in hunting play than girls, Hadza; $Z=2.59$, $p=0.01$, BaYaka; $Z=3.91$, $p<0.001$. Hadza girls were significantly more likely to play at foraging and to play with dolls than Hadza boys, foraging; $Z=2.39$, $p=0.02$, doll; $Z=2.77$, $p=0.006$. BaYaka boys were significantly more likely to play at collecting honey than BaYaka girls, $Z=2.43$, $p=0.02$.

Table 4.4. Proportion of pretense spent in different themes (%) and results of Mann-Whitney U tests by proportion of theme by pretense. The analyses were run on the Hadza and BaYaka separately, with gender as the grouping variable.

	Hadza (N=33)				BaYaka (N=50)			
	Girls	Boys	U	<i>r</i>	Girls	Boys	U	<i>r</i>
Playing House	40.23	1.45	181*	0.40	57.61	4.54	447.5**	0.43
Play Hunting	2.34	33.82	72*	0.45	7.53	42.26	106***	0.56
Play Foraging	24.61	35.27	180*	0.42	5.61	3.76	354	0.19
Doll Play	16.80	0.00	180.5**	0.48	5.61	5.09	352	0.27
Play Honey Collecting	2.93	1.45	128.5	0.06	1.33	18.69	209*	0.35
Play Tool Manufacture	0.20	1.93	121	0.13	3.99	3.65	284	0.05
Play Fishing	--	--	--	--	0.15	1.88	297	0.05
Non-Work-Themed	12.89	26.09	152	0.12	18.17	20.13	262	0.10

p. values: * ≤ 0.05 ; ** ≤ 0.01 ; *** ≤ 0.001 . Reported percentages represent population proportions.

Discussion

This paper used observational data to quantitatively compare the gender-typed and gender-segregated play of Hadza and BaYaka hunter-gatherer children. We specifically examined (1) the effect of gender on time allocation to play, (2) whether access to play partners influenced gender segregation during play, (3) children's participation in gender-typed play, and (4) whether children's participation in work-themed pretense mirrored the gendered division of labour in adulthood in their respective societies. Here, we revisit each of these topics in turn.

Gendered Development of Play Across Childhood

Play is hypothesized to provide children with opportunities to learn about subsistence and culture (Bock & Johnson, 2004; Smith, 1982). Like other studies of play in small-scale societies

(Boyette, 2016a; Edwards, 2005; Gosso et al., 2007), we found that play took up between a fifth and a quarter of the time budgets of Hadza and BaYaka children. That the Hadza played less than the BaYaka is consistent with Crittenden's (2016a) observation that, for Hadza children, foraging itself may be considered play. Work play provides children with culture-learning opportunities alongside opportunities to contribute to their own and their families' subsistence (Lancy, 2016a). Thus, though some cases of work play are coded as play in the present study, such as children targeting child-only foods, others may have been missed, representing an important limitation of our coding scheme, and a potential explanation for the observed difference in BaYaka and Hadza rates of play.

In line with previous studies (e.g. Bock & Johnson, 2004), we found that participation in play decreased with age, consistent with the hypothesis that play contributes to skill development, and that children trade-off practicing through play with practicing through work. Furthermore, contrary to our hypothesis that there would be no relationship between gender and play in the two populations surveyed, age-related decreases in play were more pronounced for girls than for boys. Thus, even among the Hadza and BaYaka, where children are afforded extensive autonomy, girls played less at an earlier age than boys. However, the ethnographic literature on girls' earlier entry into the workforce and girls diminished participation in play compared to boys, suggests that, cross-culturally, this transition usually occurs in middle childhood (Montgomery, 2009). Here, we found that girls were only less likely to play than boys in adolescence; thus, the autonomy afforded to girls may delay their transition away from play and towards other productive activities (Froehle et al., 2019; Lew-Levy, Lavi, Reckin, Cristóbal-Azkarate, & Ellis-Davies, 2018).

Gender Segregation During Play

From the age of three onwards, children have been observed to segregate into same-gender playgroups in Western, small-scale farming, and pastoralist societies (Maccoby, 1998; Moller & Serbin, 1996; Munroe & Romney, 2006; Whiting & Edwards, 1973). However, in a survey of six hunter-gatherer societies, Konner (2016) found that much of children's play occurred in multi-aged, mixed-gender playgroups. And, in a study comparing Bofi farmers and hunter-gatherers, Fouts and colleagues (2013) found that hunter-gatherer children were more likely to be observed

in mixed-gender groups than their farmer neighbours. Considering that hunter-gatherer children have limited access to same-aged and same-gender playmates (Draper, 1976; Konner, 1976b), we hypothesized that children in camps with a larger population of potential playmates would be more likely to segregate by gender than children in smaller camps. Our findings supported this hypothesis, showing a strong and negative relationship between the availability of play partners and play in mixed-gender groups. This finding highlights the potentially important role of demographic constraints on the social context for children's development.

Gendered Participation in Types of Play

Although gender differences in exercise play, object play, structured games, pretense play and, most notably, RTP have been found in a variety of settings, and, in the case of pretense play, have been mixed (see Göncü et al., 2002; Lafreniere, 2011; Pellegrini & Smith, 1998a for review), few researchers have explicitly examined these play types in hunter-gatherer societies. Because hunter-gatherer children primarily played in mixed-gender groups, we hypothesized that both boys and girls would adjust their play levels to match opposite-gender individuals (Fabes et al., 2003), leading to fewer gender differences in play types. In mixed support for this hypothesis, we found gender differences in RTP and pretense play, but no evidence for gender differences in object play, exercise play, or structured games.

Object play is hypothesized to provide children with opportunities to practice using tools and to learn their affordances (Pellegrini & Bjorklund, 2004). Previous studies of children's object play in Western preschool settings suggest that boys participate in more object play than girls (Pellegrini & Bjorklund, 2004; Pellegrini & Smith, 1998b). Here, we found no significant differences in object play by gender, consistent with the fact that both Hadza and BaYaka male and female adults use tools in nearly all aspects of subsistence. We also found that, among the BaYaka, children devoted more play time to object play as they aged. This finding accords with our observation that cutting tools are more frequently used by the BaYaka than by the Hadza in cooking, basket weaving, and trail clearing. Thus, BaYaka children's increased play with objects as they aged may reflect their access to, and the importance of, knives and other tools in their daily activities.

RTP is hypothesized to provide opportunities to practice fighting skills (Lafreniere, 2011), and is consistently performed more frequently by boys than girls in non-hunter-gatherer societies. As in previous hunter-gatherer research (Blurton Jones & Konner, 1973; Boyette, 2016a; Draper & Cashdan, 1988; Gosso et al., 2007), we found no main effect of gender on participation in RTP among the Hadza and BaYaka. However, most of these studies did not include adolescents, or did not consider the effect of age on participation in RTP. Our results showed that adolescent boys participated in more RTP than adolescent girls, consistent with Pellegrini's study of RTP in adolescence in American schools (Pellegrini, 2003). These findings suggest that RTP may play a role in establishing dominance in an effort to attract mates.

Beyond gender, some scholars have suggested that children growing up in more violent communities are more likely to participate in RTP. For example, Fry (1990) found that Zapotec Mayan children living in a more peaceful community were less likely to participate in RTP than those living in a more violent community. Similarly, Kung and colleagues (2018) found that, independent of gender, German preschoolers who participated in more "masculine" activities including RTP at 3.5 years were more likely to be aggressive at thirteen. Thus, higher rates of RTP among the Hadza may reflect the levels of aggression experienced and observed by children in both societies.

Hadza and BaYaka foraging tasks require extensive energy expenditure for both males and females (Pontzer et al., 2015). It should come of no surprise, then, that we found no gender differences in Hadza and BaYaka children's exercise play, considering the role of this form of play in physical training and economy of movement (Byers & Walker, 1995; Pellegrini & Smith, 1998a). We further found no gender differences in children's participation in structured games.

Girls' and boys' differential participation in pretense may be influenced by their environment, availability of play materials, and availability of toys (Göncü et al., 2002), leading to mixed findings regarding gender differences in pretense play. Here, in a naturalistic setting with few gendered toys, we found that girls were more likely than boys to participate in pretense play. Furthermore, as in other societies, a majority of Hadza and BaYaka children's pretense play involved the imitation of work, consistent with the theory that work-themed play affords children opportunities to practice activities central to survival and reproduction, including gender-specific

skills (Bock & Johnson, 2004).

Gendered Participation in Culturally-Specific Pretense Themes

In support of our hypothesis that BaYaka children would show fewer gendered differences in work-themed pretense play than Hadza children, gender was a significant predictor for participation in foraging play and doll play among the Hadza but not among the BaYaka. House play was the most popular pretense play activity among both Hadza and BaYaka girls. Both Hadza and BaYaka boys were observed imitating hunting in play more frequently than girls. These gender differences accord with the gendered division of labour in adulthood. House construction is almost exclusively performed by women in both societies. And, while both Hadza and BaYaka men do the majority of the hunting, BaYaka men are reported to participate in foraging and childcare more than their Hadza counterparts (Hewlett, 1991b, 1992; Marlowe, 2010).

BaYaka boys also participated in more honey collecting play than BaYaka girls, but there were so such gender differences among the Hadza. Whereas both Hadza and BaYaka men primarily collect honey, the lack of gender difference for this type of play among the Hadza may be due to the fact that Hadza boys can more easily access various forms of honey, such as that from stingless bees which is found in shrubby trees. Among the BaYaka, on the other hand, honey is primarily found in very tall trees that require greater strength and skill to climb. Thus, whereas Hadza boys in middle childhood can easily participate in the collection of honey from some bee species, BaYaka children cannot, suggesting that, in the absence of practice-through-participation, BaYaka children primarily practice their honey-collecting skills through pretense (Boyette, 2016b; Lew-Levy & Boyette, 2018). Overall, then, pretense play, and, in particular, work-themed pretense play, may serve as a flexible tool through which children come to imitate key aspects of culture, and in doing so, learn appropriate gendered behaviours through identification with same-gender adults (Bock & Johnson, 2004; Lancy, 2016a).

Conclusion

The present study represented the first quantitative and comparative research on gender-typed play and gender-segregation during play in two hunting and gathering societies. We have argued that contextual features, such as demographic constraints, and cultural features, such as the

gendered division of labour in adulthood, may explain observed differences in Hadza and BaYaka children's gender-typed and gender-segregated play. In doing so, this paper moved beyond the usual 'West vs. rest' approach to cross-cultural research by systematically exploring similarities and differences in the play activities of children in two different hunting and gathering societies. Nonetheless, we suffered from small sample sizes and relatively short observation periods. We were also unable to test the reliability of our coding scheme among the Hadza. Furthermore, our data collection was restricted to one or two foraging seasons; data collected throughout the year may show how gendered play changes as camp size and activities available to children change. And, because we had no access to reliable electricity, we were not able to film our follows, limiting our ability to add more nuanced data, such as social interaction, to this analysis. Future research should investigate how hunter-gatherer children interact with, and orient towards play partners of their same and opposite gender, how play partners influence play quality, and how parents conceive of the role of play in child development. Future studies should also investigate how sedentarization, a process shown to change children's behaviours in other domains, such as subsistence and chore assignment (Draper & Cashdan, 1988; Pollom, Herlosky, Mabulla, & Crittenden, Under review), influences play.

Chapter 5: Inter- and Intra-Cultural Variation in Learning-Through-Participation

Child development is influenced by a variety of factors including physical and social settings, customs of childcare, ethnotheories regarding appropriate child and parent behaviour, and peer cultures (Nsamenang & Lamb, 1995; Super & Harkness, 1986). For example, in Western societies, adults primarily organize children's learning didactically, with school teachers and parents striving to facilitate knowledge acquisition through explicit instruction and pedagogical conversations (Morelli et al., 2003). In small-scale subsistence societies, on the other hand, children's learning is woven into the fabric of everyday practice and experience; by meaningfully participating in economic activities in collaboration with adults and other children, children also develop moral, social, and intellectual competencies (Paradise & Rogoff, 2009; Serpell, 2011).

Bame Nsamenang frequently bemoaned the ways in which contemporary psychology retained a Eurocentric bias, highlighting the persistent colonial nature of the field (Nsamenang, 2007). In his work with the Nso of Northwest Cameroon, for example, Nsamenang challenged the assumption that child development was unaffected by the social and cultural setting in which it occurred (Nsamenang, 1995; Nsamenang & Lamb, 1993, 1995). He demonstrated that socialization practices varied *within* cultures alongside gender, generation, religion, and education, and that socialization was achieved through anticipatory socialization, guided participation, peer culture, and parental expectations. In doing so, he prioritized indigenous African cultural traditions while acknowledging the role of Arabic/Islamic influences and Western cultural legacies on contemporary Africa's educational landscape.

In honour of Nsamenang's commitment to research on indigenous African socialization, this paper aimed to explore inter- and intra-cultural variation in children's learning-through-participation (Rogoff et al., 2003) within two African hunter-gatherer societies; the Hadza of Tanzania and the BaYaka of the Republic of Congo. Unlike agricultural societies like the Nso studied by Nsamenang, hunter-gatherers, or foragers, are mobile populations that primarily rely on non-domesticated resources; are fiercely egalitarian in the sense that there is no inherited

hierarchy according to age, and little differentiation of status according to sex (Woodburn, 1982); value autonomy in the sense that individuals rarely direct each other or impose their will on one another (Gardner, 1991); share food widely (Kitanishi, 1998); rarely store food; and have few material belongings (Kelly, 1995). Despite these cultural similarities, BaYaka and Hadza children's contributions to subsistence are variable, ranging from rare to substantial (Crittenden et al., 2013; Hagino & Yamauchi, 2016). This variation is likely due to ecological constraints (e.g. access to easily acquirable food, risk of getting lost) and ethnotheories about children's capabilities, roles, and responsibilities. Here, using qualitative and quantitative observational and interview data, we sought to investigate how cultural and ecological variation contributed to differences in Hadza and BaYaka children's participation in economic work, and how forager adults facilitated this participation.

Ethnographic Contexts

The Hadza are arid savanna-woodland foragers from Northern Tanzania (Blurton Jones, 2016; Marlowe, 2010). Approximately 150 of the 1000 Hadza still hunt and gather as their primary means of subsistence. These foraging Hadza maintain a strict division of labour; Hadza men primarily collect honey and bow-hunt small and large game. Women gather berries, baobab, and tubers (Blurton Jones, 2016; Marlowe, 2010). As a result of climate change and encroachment on their lands by pastoralists (Mabulla, 2012), the Hadza are increasingly reliant on maize and other domesticates gifted by missionaries and ethno-tour companies or acquired by trade with neighbouring pastoralists (Yatsuka, 2015). In the past, Hadza camps were highly nomadic and moved every two to three months (Marlowe, 2010); presently, most camps are semi-permanent.

The BaYaka surveyed as part of this dissertation are most closely related to the Mbendjele BaYaka (Lewis, 2002). They live in the tropical rainforest of the Congo Basin. Men primarily collect honey, and hunt with spears, crossbows, traps, and nets. Men also hunt with guns provided by their farming neighbours, with whom they maintain extensive trade relationships (Joiris, 2003). Women focus on collecting wild yams, nuts, mushrooms, *koko* (*Gnetum spp*) and other greens. Both men and women tend low-maintenance forest gardens, collect liana fruit and caterpillars, and fish (Kitanishi, 1995). Compared to the Hadza, BaYaka men and women's foraging activities

often overlap, with men sometimes gathering, and women sometimes participating in hunting activities (Hewlett, 1991). The BaYaka surveyed here live in a village setting for approximately six months of the year, though overnight fishing, hunting, and gardening trips often occur during this time. Approximately two months of the year are spent at caterpillar camps, and another three to four months at long-term fishing camps. Data collection for this paper straddled honey and berry collecting seasons among the Hadza (Marlowe & Berbesque, 2009), and fishing and caterpillar seasons among the BaYaka (Kitanishi, 1995). Data were considered comparable because children in both societies are relatively productive during these seasons and often work alongside adults.

Methods

Among the BaYaka, quantitative data were collected in August through September 2016, 2017, and 2018 in 7 camps ranging in size from 8 to 51 inhabitants (mean=31, SD=17.98). Among the Hadza, quantitative data were collected in March and April 2017 in 3 camps of 41 to 73 inhabitants (mean= 53.67, SD=17.01). Upon arrival in a camp, a census was conducted to learn the names of all permanent residents and their kinship relationships, marital status, number of children, and age. In order to estimate the age of children, we asked adults to rank their own children, or a set of cousins, from oldest to youngest. Age was estimated based on this rank, as well as developmental cues and dentition. All consent procedures and research protocols were approved by the University of Cambridge Department of Psychology Research Ethics Committee (PRE.2016.026). In-country permission was received from the Tanzanian Commission for Science and Technology (COSTECH) and for the Republic of Congo from the Centre de Recherche et D'Etudes en Sciences Sociales et Humaines (CRESSH) and the Institute de Recherche en Sciences Exactes et Naturelles (IRSEN).

Behavioural Observations

Forty-six Hadza (mean age=9.98, 41% female) and 65 BaYaka children (14 children sampled >1 year, mean age in first year observed=10.58, 48% female) between the ages of three and 18 were observed using a focal follow procedure. Focal children and adolescents—which we will refer to collectively as children—were assigned two 2-hour sampling blocks; one in the morning (usually between 8 and 11am) and one in the afternoon (usually between 12 and 3pm). In 2016, these

sampling blocks were scheduled over two randomly assigned days; in 2017 and 2018, these were scheduled on the same day. Focal follows were terminated if we perceived that the child was growing uncomfortable or anxious in of our presence. If a child was not available during the assigned sampling block, the block was rescheduled or omitted based on circumstance. Each child was observed, on average, for 256.7 minutes (SD=123.52), totalling 28,494 1-minute long observations.

Using a 30-second observe, 30-second record procedure, we first recorded whether the focal child was working, and then described the type of work they were engaged in. We defined work following Munroe et al. (1984, p. 369) as “all instrumental activities judged to contribute to the maintenance of the household or the well-being of its members.” Following data collection, we then grouped work activities into five categories using the descriptions in our notes. These categories were determined based on our perception of task difficulty, both in terms of finding resources, and the strength and knowledge needed to successfully collect them (Lew-Levy & Boyette, 2018). These were (1) *gathering*, for the Hadza, of berries, baobab, and greens, and for the BaYaka, of fruit, caterpillars, grub, garden products, fish, tree gum, and greens; (2) *Hunting and trapping*, for the Hadza, with bows and arrows or by hand, and for the BaYaka, with spears, snares, guns, and sling shots; (3) *honey collecting*; (4) *collecting wild tubers*, and (5) *household chores*, including fetching water, firewood, participating in household construction, doing dishes, laundry, sweeping, manufacturing tools and containers, and cooking. Throughout the follows, we also recorded whether children were interacting with adults, and whether adults were in proximity of children. Proximity was defined as within speaking and/or sight distance of the focal child, and thus close enough to monitor their behaviour and intervene when necessary. Finally, in a subset of observations, we recorded any chores assigned to the focal child during the 30-second-observation window (Chapter 3).

Inter-coder reliability was assessed among the BaYaka only in 2017. SLL and AHB simultaneously followed 7 village-dwelling children for a total of 711 observations (female=4, early childhood=1, middle childhood=2, adolescence=4). Reliability was high across all codes; participation in work (yes/no), Kappa=0.93, Z=24.9; working alongside adults, Kappa=0.93,

Z=24.9, and chore assignment (yes/no), Kappa=0.89, Z=23.8. We did not assess the reliability of adult proximity ratings.

Adult Interviews

Interviews were conducted in four of seven BaYaka camps and all three Hadza camps. Interviews were conducted with all individuals determined to be 'adults'—individuals of marriageable age (approximately >18 years of age), though not necessarily married or with children. The following questions were asked every evening in each camp for 7 to 13 days in a row; (1) "What did you do today?" If the participant said that they had foraged, we asked (2) "Who did you forage with?" If the participant did not name a child, we asked (3a) "Why didn't you take a child foraging with you?" If the participant did name a child, we asked (3b) "Why did you take this child foraging with you?" In Congo, these interviews were primarily conducted in BaYaka, the first language of the participants; in Tanzania, they were primarily conducted in Swahili, the second language of the participants. In cases where individuals who had foraged together were also together during the interviews, we asked one of these individuals, and then asked the other individual if they had anything to add. We included these responses as having been given by both individuals. In cases where individuals who had foraged together were not together during the interviews, we asked each participant separately. If an individual was not in camp during the interview period, we followed up in the morning or evening of the following day. When participants visited other locations overnight (for foraging trips, visits with kin in other camps, or village visits), we asked them about their whereabouts upon their return. If we could not confirm the location of a participant, the interview was omitted. For the Hadza, this yielded a total of 469 interviews of 73 Hadza adults (female= 49%), with a mean of 6.42 responses per individual (SD=1.18). For the BaYaka, this yielded a total of 475 interviews of 52 BaYaka adults (female: 56%). Six BaYaka adults were sampled twice or more, as they inhabited more than one sampled camp during the 2016 and 2017 field seasons. This yielded a mean of 9.13 responses per BaYaka individual (SD=6.23).

Participation Observation

Participant observation was conducted over 12 months between 2016 and 2018 by SLL among the BaYaka, and over 20 months between 2004 and 2016 by ANC among the Hadza, with an

additional two months conducted in 2017 by SLL. We participated in culturally salient activities including foraging, cooking, childcare, dancing, singing, and ceremonies, and conducted informal interviews on learning and life history with children and adults. Because the ethnographic work occurred over several years, we were able to qualitatively examine how children's participation in adult activities changed with age.

Analysis

We tested for differences in overall time allocation to work, proximity to adults during work, and interaction with adults during work using Mann-Whitney U tests. In order to examine cross-cultural variation in these activities, the first set of analyses were conducted on the sample as a whole, with ethnicity as the grouping variable. In order to investigate intra-cultural sex differences in activities, the second set of analyses were conducted on the Hadza and BaYaka samples separately, with sex as a grouping variable. Since age was not a predictor variable in these analyses, counts of time allocation to work, proximity to adults during work, and interaction with adults during work were summed across years for children with repeated observations. To examine cross-cultural variation in why adults did or did not forage with children, we created response categories based on the interviews. These were the dependent variables in a series of multilevel logistic regressions, which included the main effects of sex, ethnicity, and their interaction. Because these interviews were made up of repeated responses, and because different camps were sampled, we included interviewee and camp as random effects.

Results

The population proportions for work activities, adult availability, and interaction with adults by ethnicity and sex can be found in Table 5.1. While Hadza boys and girls participated in work at similar rates ($U=251.5$, $p=0.92$), BaYaka girls participated in work significantly more than BaYaka boys ($U=811.5$, $p<0.001$). However, there were stronger sex differences in work types among the Hadza than the BaYaka, consistent with a more rigid sexual division of labour among the former (Froehle et al., 2019; Chapter 4). Finally, Hadza children were less likely to be in proximity of

adults ($U=1061, p=0.03$) or interact with adults ($U=1094.5, p=0.048$) during work when compared to BaYaka children.

Table 5.1. Percent of observations and Mann-Whitney U tests results examining inter-ethnic and intra-ethnic sex differences in work participation an adult proximity and interaction during work.

	Hadza			BaYaka			Total		
	Female	Male	Z	Female	Male	Z	Hadza	BaYaka	Z
% total observations									
Gather	9.19	3.90	1.97*	6.69	3.48	1.06	6.20	4.94	-0.26
Honey	0.28	7.03	-3.10**	0.07	1.43	-0.98	4.10	0.81	4.73***
Household	6.81	3.86	-0.57	17.42	7.00	4.22***	5.14	11.73	-3.87***
Tubers	4.81	2.11	2.85**	7.54	3.45	1.61	3.28	5.31	-1.31
Hunt/Trap	0.09	5.58	-2.44*	0.05	2.01	-1.38	3.20	1.12	1.86
Total Work	21.19	22.48	-0.11	31.78	17.37	3.74***	21.92	23.91	-0.45
% work									
Proximity to adults	47.91	29.04	1.90	67.03	52.12	0.41	36.95	61.12	-2.20*
Interaction with adults	25.88	14.56	1.76	33.90	21.59	1.11	19.31	29.02	-1.98*

Percentages represent population proportions. Wilcoxon rank-sum tests were conducted on participation proportions; for work activities, the denominator was total observations; for proximity and interaction with adults, the denominator was total observations spent in work. Positive z-scores indicate that children in the first column (female/Hadza) participate in said activity more than children in the second column (male/BaYaka); negative values indicate the opposite. P. values: * ≤ 0.05 ; ** ≤ 0.01 ; *** ≤ 0.001 .

Hadza adults reported foraging on 54.3% of interview days, representing a total of 160 foraging trips. The 32.5% of Hadza foraging trips which included children included an average of 1.8 children (max=7, SD=1.5). BaYaka adults reported foraging on 62.6% of interview days, representing a total of 212 foraging trips. The 37.7% of BaYaka foraging trips which included children also included an average of 1.8 children (max=7, SD=1.3). Women in both societies were more likely to report foraging with children than men (Hadza; 48.0% vs. 28.4%, BaYaka; 43.3% vs. 33.1%). The kinship relationships between adults and children who foraged together can be found in Table 5.2. Table 5.3 outlines the percent of foraging days adults spent in different foraging activities and shows that Hadza adults were most likely to report foraging with children when targeting honey (50% of honey collecting trips, usually from stingless bees), while BaYaka adults were most likely to report foraging with children when gathering (62.5% of gathering trips).

Table 5.2. Percent of foraging groups that contained at least one related adult-child/adolescent dyad.

	Hadza	BaYaka
Parent-offspring	34.62	46.25
Sibling	13.46	12.50
Aunt/uncle-niece/nephew	15.38	16.25
Grandparent/grandchild	15.38	17.50
Other/no kin dyads	36.54	23.75

Values add up to >100% because groups contained more than one type of adult-child/adolescent dyad.

Table 5.3. Percent of foraging reports that included various foraging activities.

Activity	Hadza				BaYaka			
	Total foraging days	Female foraging days	Male foraging days	With children/adolescents	Total foraging days	Female foraging days	Male foraging days	With children/adolescents
Honey	46.72	15.60	69.33	50.00	6.92	2.92	12.71	2.78
Hunt/Trap	13.13	3.67	20.00	16.67	24.22	6.43	50.00	15.28
Gather	32.43	50.46	19.33	29.76	56.06	61.99	47.46	62.50
Tubers	18.53	40.37	2.67	20.24	25.26	37.43	7.63	26.39

Values represent population proportions. Note that these are self-reports regarding the resources targeting during foraging trips; individuals foraging in groups sometimes reported resources that were collected by the group, not necessary by the individuals themselves (e.g. Hadza women rarely collected honey, but sometimes accompanied their husbands during honey collection trips). Values add up to >100% because some individuals reported participating in more than one activity per trip.

Why Do, or Don't, Adults Forage With Children?

Results for the logistic regressions investigating reasons for foraging/not foraging with children can be found in Table S5.1. Adults cited a multitude of reasons for not foraging with children. The main reasons involved *distance*, *danger*, *autonomy*, and *disturbance*. Concerns regarding distance included that the foraging patch was too far, children were not able to walk well, or that children were too slow. Men were 2.94 times more likely than women to cite distance as a reason not to forage with children, 95%CI [0.20, 1.95], $p=0.02$. Concerns regarding dangers included

weather (e.g. rain, high or low temperatures), presence of elephants, lack of food, having to walk through deep waters, or risks involving climbing on rocks. Sex, ethnicity, and their interaction were not significant predictors for citing danger as a reason not to forage with children. Adults also cited autonomy as a reason not to take children; children were already occupied, either in play or work, or in a subset of cases (9%) adults themselves did not want to forage with children. The BaYaka were 7.91 times more likely than the Hadza, 95%CI [0.90, 3.24], $p < 0.001$, and women 3.33 times more likely than men, 95%CI [-2.02, -0.39], $p = 0.004$, to cite autonomy as a reason not to forage with children. However, the interaction between sex and ethnicity was also significant, 95%CI [0.09, 2.22], $p = 0.03$, indicating that the effect of sex on citing autonomy as a reason to forage with children was true for the Hadza only. Disturbances such as fussing for food or the possibility of scaring off animals with noise or motion were cited by the Hadza only. Sex was not a significant predictor for citing disturbance among the Hadza.

Adults also cited several reasons for why they foraged with children. These were grouped into *company*, *autonomy*, *imparting knowledge*, and *help*. Both the Hadza and BaYaka stated that they took children for company, either because adults themselves had no one to forage with, because there was no one in camp to watch the children, or because adults enjoyed foraging with children. Sex, ethnicity, and the interaction between sex and ethnicity were not significant predictors for citing company as a reason to forage with children. Adults also reported that they foraged with children because children followed them independently. The Hadza were 12.92 times more likely than the BaYaka to state that children autonomously joined adult foraging groups, 95% CI [-4.64, -0.48], $p = 0.02$. Because of low cell counts, we could not investigate the effect of the interaction between sex and ethnicity on citing autonomy as a reason to forage with children. Imparting knowledge (in BaYaka; *boresi mayele*, literally, to show knowledge, in Swahili; *kufundisha*, literally, to teach) was also cited as a reason to forage with children. This included imparting knowledge about foraging, medicinal plants, and changing the behaviour of children who were misbehaving when left in camp. Sex, ethnicity, and their interactions were not significant predictors for citing imparting knowledge as a reason to forage with children. Adults also cited taking children to forage in order for children to help with work. For the Hadza, this included carrying baobab, collecting firewood, starting fires, making pegs for honey harvesting,

or providing childcare. For the BaYaka, this included finding tubers, taking care of infants, and leading the way to a resource that a child had previously located. Men were 3.11 times more likely than women to cite help as a reason to forage with children, 95%CI [0.18, 2.09], $p=0.02$. The interaction between sex and ethnicity was also significant, indicating that Hadza men were more likely than BaYaka men to mention foraging with children for help, 95%CI [-4.17, -1.14], $p<0.001$.

How Did Adults Facilitate Children's Work?

Drawing from our ethnographic observations, we now further outline three ways in which Hadza and BaYaka adults facilitated children's participation in work: providing tools, assigning chores, and composing foraging groups.

Providing tools. When BaYaka and Hadza infants can hold themselves up independently, mothers take children on foraging expeditions. As among other foragers (e.g. Konner, 1976), infants are carried in a sling on the mother's side; however, during work, children are sometimes placed high in slings on their mother's back (Figure 5.1). This forward-facing position allows children to see the mother's activities, including the use of tools, such as digging sticks or pounding stones in the case of the Hadza, or knives and machetes in the case of the BaYaka. By the time infants in both populations can sit independently, they are routinely in close proximity to foraging tools, often reaching for them when they are in sight. Between twelve and eighteen months, both Hadza and BaYaka infants played with tools, which in some cases were handed to them as distractions while parents were involved in other tasks, or to facilitate instruction (Hewlett, 1991). Although some anthropologists have described forager parenting as 'laissez-faire' (Lancy, 2016b), parents in both populations appeared to be aware of what their children were doing with potentially dangerous objects (Hewlett, 2012), and monitored accordingly. For example, BaYaka mothers and teenage girls removed especially sharp or heavy knives from toddlers' hands, replacing them with lighter or duller knives, or oriented young toddlers with knives away from other children. Nonetheless, children in both societies are sometimes injured by fire or knives, even when in the presence of caregivers.



a



b

Figure 5.1. (a) Hadza and (b) BaYaka toddlers looking over their mothers' shoulders as they work. Hadza and BaYaka children are often worn high on the back while mothers work, from where they can observe activities, such as (a) digging tubers or (b) bail fishing. Hadza photo by Alyssa N. Crittenden. BaYaka photo a still from a video made by Sarah M. Pope.

Hadza and BaYaka adults also made child-sized versions of tools for young children, which children were encouraged to use for practice (Figure 5.2). For example, among the BaYaka, girls carried small baskets made by female relatives on short foraging expeditions with friends or parents; fruit or tubers were removed or added to the child's basket by adults during the walk home, based on their perception of their child's strength and carrying capability (see also Hewlett, Lamb, Leyendecker, & Scholmerich, 2000). Among the Hadza, tools included small digging sticks and small bows and arrows furnished by adults or older children (Crittenden, 2016a). Parents also introduced smaller sized pounding stones for baobab processing or small containers in which Hadza children could boil their own food over their own small fires. By middle childhood, children regularly used tools in play (Chapter 4), and, by adolescence, children were proficient at using tools during foraging activities.



a



b

Figure 5.2. (a) Hadza boys with bows made with the help of older siblings and parents, and (b) BaYaka toddler with hatchet made for her by her father. Hadza photo by Alyssa N. Crittenden. BaYaka photo by Sarah M. Pope.

Chore assignment. From the moment they can walk, BaYaka and Hadza children were assigned tasks which increase in complexity as children age (Crittenden, 2016b; Lancy, 2012). Toddlers were often tasked with bringing objects across camp, and when the task was completed successfully, sometimes received praise. Perhaps in anticipation of future chore assignments, children in both populations practiced more complex tasks alongside adults. For example, a BaYaka mother cutting *koko* leaves into thin strips, a task which requires fine motor skills, sometimes did so alongside her five-year-old daughter, herself also cutting *koko*, though with less success. Among the Hadza, a young child waiting while her mother dug tubers sometimes assisted her mother or dug in an adjacent hole with a smaller digging stick, whether or not the hole actually yielded a tuber. As children aged, they received fewer assigned chores, but were tasked with more difficult chores which took them farther from home. For example, a five-year-old boy might be asked to fetch 5L of water from a nearby watering hole, while an adolescent girl

might be asked to carry greater volumes from farther distances. Thus, although our systematic observations suggested that children and adolescents were rarely assigned chores (Hadza; 2% of observations, BaYaka; 2.1% of observations), our ethnographic observations show that chore assignment nonetheless contributed to children's knowledge acquisition.

Foraging groups. As shown earlier, BaYaka children were more likely than Hadza children to forage alongside adults. Our ethnographic material suggests that this difference is normative. For example, SLL observed several instances in which BaYaka parents invited their children to forage with them. In one instance, an adolescent girl who preferred to forage with her friends was asked repeatedly by her mother, and then by her father, to join them in their foraging excursion (Boyette & Lew-Levy, Under review). Rather unhappily, this adolescent girl eventually conceded. Among the Hadza, on the other hand, ANC has rarely observed parents insisting that their children forage alongside them.

Although both Hadza and BaYaka adults primarily reported learning to perform subsistence tasks from their parents while foraging, the Hadza also stated that they learned to forage with their friends. For example, a recently divorced Hadza man with several young children explained that he learned to collect honey in the following way: "My father and friends who were older than me [taught me]. They used to take me to the bush and sometimes take me very far to be experienced. They used to make me set fire to the comb, blow soot to make the bees flee." A young adult, known to ANC since he was a child, and now a father of two, explained how he first learned to hunt smaller animals before graduating to larger prey; "I started to go in the bush with my older brother, and when he saw a small animal, like a *chacha* [bush baby], he would let me shoot it. When I got a bit older, I then started to hunt big animals, like antelope, by myself." During his adolescence, this same individual often took his own younger brother with him on hunting excursions with the explicit intention of helping him gain hunting and tracking knowledge.

Among the BaYaka, few adults mentioned learning from siblings and other children. Instead, adults reported that their parents or grandparents invited them on foraging trips, sometimes with the expressed purpose of imparting knowledge. For example, an older BaYaka man, a father and grandfather himself, explained how he learned to collect honey in the following

way; “when I woke up in the morning, my father said ‘come walk with me to find honey’. I saw how to collect honey by being close to him. He said ‘cut the rope, and tie it here’. I was still young, so I couldn’t tie the rope. My father tied the knot and showed me. He told me how to look for honey [by climbing] in the tree. I found the honey in the tree, but didn’t know how to cut the comb, so my father sent me down to make a fire. My father climbed the tree to show me how to get honey.” Another woman explained how she learned to gather; “I learned to gather by walking in the forest with my mother. My mother made me a basket. My mother showed me [how] to find everything.”

Discussion

Using quantitative and qualitative observational and interview data collected among Hadza and BaYaka foragers, we sought to understand variation in children’s participation in work, and how forager adults facilitated knowledge acquisition through participation. As among other foragers (Gardner, 1991; Naveh, 2016), Hadza and BaYaka children were rarely assigned chores. Children decided whether to forage, and with whom. Adults respected children’s decisions to forage with or without adults, even if these decisions countered normative foraging group compositions (i.e. Hadza children foraging with other children; BaYaka children foraging with adults). Taken together, these findings demonstrated that the cultural value of autonomy shared by many foragers is evident in the childrearing practices of Hadza and BaYaka parents (Hewlett et al., 2000). Whereas Nsamenang (2006, p. 295) noted the indigenous African social ontogenetic paradigm “is premised not on an independent or autonomous frame; its foundational principle is an interdependent or relational script”, our data instead suggested that, for Hadza and BaYaka foragers, individual autonomy precedes interdependence, even as foragers cooperate in all aspects of life (Endicott, 2011; Gardner, 1991).

However, our results did not show that autonomy translates to laissez-faire socialization. Indeed, adults actively exposed children to child-sized and adult-sized tools, and, when foraging with children, reported imparting knowledge. Furthermore, while rare, chore assignment was recognized as a way in which parents facilitated knowledge acquisition. Overall, then, Hadza and BaYaka adults were attuned to children’s skills, and provided opportunities for learning through

intent participation rather than explicit instruction (see also Lancy, 2016a; Nsamenang & Lamb, 1993; Rogoff et al., 1993). While learning was primarily in the domain of subsistence, children also developed an understanding of cultural values and norms of behaviour, such as the sexual division of labour and autonomy.

While ethnotheories of child development shape the learning experiences of children (Super & Harkness, 1986), the opportunities and constraints inherent to children's ecology also affected the degree to which children can safely learn through participation. For example, adults reported foraging with children when collecting resources that required little skill for success, such as honey from stingless bees (*kanoa*) among the Hadza, or fruits, greens and mushroom among the BaYaka. Adults also reported soliciting children's help when participating in these safer foraging activities. More risky activities, such as hunting among the Hadza and climbing tall trees to collect honey from stinging bees (*banjui*) among the BaYaka, were usually not conducted with children because adults were concerned about children's abilities to walk, inclement weather, and animal encounters.

When unable to forage with adults, our data showed that Hadza and BaYaka children employed different strategies for participating in work. Hadza children usually foraged in child-only groups, independently from adults. This finding is consistent with that of Hawkes and colleagues (1995), who found that Hadza children primarily targeted resources which matched their size and capabilities, such as shallow tubers and small birds located closer to camp, while adults ventured farther away (see also Crittenden et al., 2013). Thus, Hadza children contributed economically by 'making the best of a small situation' (Bird & Bliege Bird, 2002), in the sense that they collected resources which matched their size and capabilities.

Unlike Hadza children, BaYaka children primarily contributed through household and food processing work. While easy-to-acquire resources were less accessible to BaYaka children (Hagino & Yamauchi, 2016), BaYaka food processing is extensive, and includes nut cracking, grating cassava leaves, cutting fine strips of *koko*, soaking cassava tubers, and pressing palm nuts into oil, alongside other food processing activities done by both the Hadza and BaYaka, such as roasting and butchering. Thus, though BaYaka children's contributions were not primarily in the form of foodstuffs, they contributed to the household economy through processing, cooking, and

other household work. Similar results were found when comparing child productivity among Hadza and !Kung forager children from the Kalahari in the 1980s (Blurton Jones et al., 1994; Hawkes et al., 1995). These ecologically-dependent strategies provided Hadza and BaYaka children with opportunities to learn while growing into productive participants in the family and camp economy.

Limitations

The interview format restricted us from investigating how child-specific variables (e.g. child age, child sex) influenced the responses of adults. For example, adults who stated that they did not forage with children because they walked too slowly may have had younger children in mind. Furthermore, our data collection was restricted to one or two foraging seasons; a year-long observational study encompassing seasonal variation in resources may reveal different patterns of participation for Hadza and BaYaka children. While none of our child participants were in school at the time of data collection, many had attended a school at some point in their lives, which may have consequences for children's learning and cognition (Davis, 2014). Climate change and logging have contributed to resource stress among the BaYaka, perhaps leading to different patterns of participation among children (Fernández-Llamazares et al., 2015). Climate change, presence of missionaries and NGOs, and ethno-tourism may also have affected resource availability among the Hadza, and thus, children's activities (Pollom, Herlosky, Mabulla, & Crittenden, Under review; Yatsuka, 2015).

Conclusion

Nsamenang advocated for research focused on how children from Africa's diverse cultures acquired knowledge through participation in adult tasks. Building on his work, the present paper explored this topic among two populations of African foragers. Our study suggested that, due to environmental risks, resource complexity, and ethnotheories regarding appropriate child and parent behaviour, Hadza and BaYaka children participated in different work activities. Nonetheless, and likely more so than for farmers, Hadza and BaYaka forager children were guided through autonomous participation in culturally relevant activities, including subsistence

(Boyette, 2016a; Gallois et al., 2015; Lancy, 2016a; Rogoff et al., 2003). Future studies should consider differences in subsistence and environment when investigating learning cross-culturally.

Chapter 6: General Discussion

Using structured and unstructured observations and interviews, this dissertation examined how Hadza and BaYaka children and adolescents learned social and subsistence skills. Overall, the four chapters of this dissertation suggest that teaching, participation, and play contributed to knowledge acquisition, but that environmental and cultural differences lead to distinct learning patterns in each society.

Using a meta-ethnographic approach, Chapter 2 reviewed the available literature on forager children's learning. The 58 publications included in the review, based on data from 33 societies, suggested that forager children learn through teaching, but that this teaching is qualitatively different than the teaching experienced in the West. While young children were not competent tool innovators, as determined by experimental paradigms, adolescents travelled long distances to acquire innovations such as basketry design and hunting techniques. A majority of subsistence skills are acquired through observation, participation, and play, usually from same-sex individuals. While, by twelve, children are proficient at most subsistence skills, more complex skills, such as hunting big game and making complex tools, are acquired throughout adolescence and into adulthood.

Chapter 3 examined how age, sex, and kinship influenced teaching using the social relations model. This chapter showed that child-to-child teaching was more common than adult-child teaching among both the Hadza and BaYaka. Teaching increased with age until individuals were in their mid-30s, after which adults taught children less. These findings were interpreted through the lens of alloparenting; by 30, most adults have multiple offspring, meaning that older children can offset their cost of care by teaching their younger siblings. Hadza children experienced more teaching within sibling dyads than BaYaka children, potentially due to the structure of Hadza camps, which are larger, and thus provide children with more opportunities to be in camp and outside the purview of adults. Finally, consistent with a multistage learning model, BaYaka children learned from peers when younger, and from adults in adolescence. However, the multistage learning model was not evident for the Hadza, potentially because

Hadza parents made children functional tools early in life, which limited the need for adult teaching later on.

Chapter 4 examined gender-typed and gender-segregated play. The findings presented in this chapter suggested that girls participated in less play with age than boys, consistent with cross-cultural trends showing that girls enter the workforce earlier than boys. Results relating to play types showed that girls participated in more pretense play than boys. Furthermore, the pretense themes engaged in by the Hadza showed stronger gender differences than those engaged in by the BaYaka, consistent with a more pronounced gendered division of labour among the former. In terms of rough-and-tumble play, we found that the Hadza engaged in this type of play more than the BaYaka. This finding was interpreted as reflecting the harsher treatment of children by Hadza adults. Furthermore, while the main effect of gender on RTP was not significant, the interaction of gender and age was significant, and showed that adolescent boys participated in more RTP than adolescent girls. Thus, RTP may have different social functions throughout childhood; in early and middle childhood, RTP may allow children to learn culturally appropriate gendered aggression, while, in adolescence, RTP may be more directly related to showing off to attract potential mates. We also found that Hadza boys participated in more object play than Hadza girls, consistent with the gendered tool use of Hadza adults. Finally, results suggested that number of available play partners was significantly, and negatively, related to play in mixed-gender groups. These results thus showed that demographic constraints limited children's ability to segregate by gender during play.

Finally, Chapter 5 outlined how Hadza and BaYaka children learned through participation. The results presented in this chapter showed that, although autonomy is foundational to socialization in both societies, adults nonetheless provided developmentally appropriate opportunities for participation from infancy onwards. Furthermore, children's participation was constrained by their ecology. Among the Hadza, where children could target resources such as baobab and shallow tubers close to camp, children foraged independently from adults. Because foraging independently is more difficult in the Congo Basin, BaYaka children learned through participating in household work. In what follows, I outline the implications of this research for cultural, developmental, and evolutionary perspectives on learning in childhood.

Cultural Similarities

Super and Harkness (1986) argued that child development is shaped by the cultural context in which children grow, which they termed the *developmental niche* (see also Bronfenbrenner, 1979; Weisner, 1984). The physical and social setting, such as the structure of the household and environmental dangers, influence how children will be cared for and by whom. Culturally regulated customs of child care and child rearing also influence child development; for example, as described in Chapter 5, carrying infants on the back while mothers foraged provided a vantage point for observing work and thus may contribute to learning. The types of playthings available to children, and made for children by adults, also make up customs of childcare. Finally, the developmental niche is also constructed by beliefs about developmental milestones, and the roles of others in helping children achieve these milestones (e.g. does learning occur autonomously, or is it dependent on adults teaching children?).

While the Hadza and BaYaka differed in their culture and ecology, one element of their developmental niche was similar; that of the foundational schema of autonomy. Importantly, hunter-gatherer autonomy is not individualistic, but instead cooperative, in the sense that all community members work towards the benefit of the group (e.g. sharing), and have collective mechanisms in place for protecting personal autonomy (e.g. mobility) (Endicott, 2011). The value of cooperative autonomy translates to the following practices:

pressure on children for self-reliance, independence, and individual achievement; individual decision making in matters having to do with family, power, property, ritual, etc.; extreme egalitarianism, including extreme gender egalitarianism; techniques for prestige avoidance and social levelling; absence of leaders; what Meillassoux and Woodburn call instantaneous or immediate [return] economic transactions; individual mobility and a corresponding openness and turnover in band membership; resolution of conflict through fission and mobility rather than by violence or appeal to authorities; bilateral social structure; a general tendency toward informal arrangements and individually generated, ad hoc structures; and relatively high levels of interpersonal variability in concepts, beliefs, and manner of expression (Gardner, 1991, pp. 547–549).

The findings of this dissertation show that cooperative autonomy structures the learning of Hadza and BaYaka children. For example, child-to-child teaching was more common than adult-child teaching among the Hadza, who were surveyed in large camps, and among the BaYaka, who lived in smaller camps. Beyond teaching, play made up between a fifth and a quarter of children's

time budgets. Through play, children not only acquired the skills necessary for subsistence (e.g. tool use through object play), they also acquired gender-specific skills by imitating the gendered division of labour in their respective societies. And, while both Hadza and BaYaka children were rarely assigned chores, they independently participated in economic activities when possible. Thus, while Hadza and BaYaka children inhabited different ecological and historical contexts, children in both societies were similarly afforded considerable autonomy in how and when they learned. Collaboration also permeated their learning experiences; children taught each other, played together, and foraged with other children or adults when possible.

Autonomy and collaboration in learning have been shown to promote children's innovative and exploratory behaviours. Indeed, while parent-child transmission leads to cultural conservation, in the sense that each generation's knowledge is reproduced in the following generation, parent-child transmission also leads to low rates of innovation (Chen et al., 1982; Hewlett & Cavalli-Sforza, 1986). Whereas autonomous learning may be costlier, it is also more likely to produce novel solutions to problems. For example, in an experiment conducted with American preschoolers, children who were explicitly taught how to solve a puzzle box in order to retrieve a treat learned to do so faster than their un-instructed peers, but were less likely to find new ways of solving the puzzle (Bonawitz et al., 2011, 2012). Collaborative learning is also additive, as each child shares knowledge with a peer, and generative, in the sense that, in sharing knowledge together, children may come to learn new aspects of the task at hand, aspects unknown to either previously (Dunn, 1983; Tomasello, 1999; Tomasello et al., 1993; Wood, Wood, Ainsworth, & Malley, 1995).

The data presented in this dissertation did not specifically investigate whether forager children innovated. However, whereas Nielsen and colleagues found that Indigenous Australian children and San children who regularly attended school did not create novel tools in experimental settings (Neldner, Mushin, & Nielsen, 2017; Nielsen, Tomaselli, et al., 2014), ethnographic accounts of non-schooled foragers suggest that children are in fact innovative. For example, Crittenden (2016a) described how Hadza children collected weaverbirds by making sticky traps, which adults do not do; weaverbird trapping is transmitted from one child to another (see also Kamei, 2005). During my own fieldwork, I observed both Hadza and BaYaka children

playing in new areas of the bush, and in doing so, finding resources such as honey and palm nuts which they then showed to their parents. By learning autonomously and collaboratively, forager children may produce new knowledge which facilitates the acquisition of foraged resources that shift in space and time. Furthermore, children's playgroup activities may serve as cultural repositories for novel technologies, and may serve as necessary practice for future innovations (Bateson, 2014; Carruthers, 2002). Thus, the autonomy afforded to children in their learning may in turn maintain hunting and gathering as a mode of subsistence.

Cultural and Ecological Differences

Vygotsky's (1978b) social development theory stressed that "information regarding tools and practices is transmitted through children's interaction with more experienced members of society during development, and patterns of interpersonal relations are organized by institutional conventions and the availability of cultural tools" (Rogoff & Morelli, 1989, p. 347). Our data suggest that differences in norms regarding social interaction with adults, access to functioning tools, and ecological environment lead to differences in when and from whom Hadza and BaYaka children learned.

From an early age, Hadza and BaYaka children were exposed to the tools and subsistence activities inherent to their cultural context, such as pounding stones for the Hadza, or knives and machetes for the BaYaka. In early and middle childhood, children in both societies spent much of their time in the playgroup, learning from other children. However, Hadza children were less likely to be in proximity to adults than BaYaka children, more likely to be taught by siblings, and less likely to play than BaYaka children. Adolescents also showed different patterns of teaching and learning; BaYaka adolescents were primarily taught by adults, while Hadza adolescents were no more likely to be taught by adults than in early or middle childhood.

Differences in the socioecologies of the Hadza and BaYaka may have resulted in diverging learning patterns throughout development. For example, norms regarding social interaction with adults may have resulted in more peer learning among the Hadza than the BaYaka. Indeed, although BaYaka children were actively encouraged to forage with and alongside adults, Hadza children were not. Even when in camp, Hadza children were less likely to be in proximity of adults

than BaYaka children because camps were more spread out. As a result, Hadza adults played a smaller role in direct teaching than BaYaka adults. However, Hadza adults facilitated knowledge acquisition in a different way; they manufactured functional, child-sized tools which provided children with opportunities to practice activities through work. Furthermore, because foraged resources, such as baobab and shallow tubers, were available in relatively close proximity to camp, Hadza children could more easily participate in foraging than BaYaka children. Hadza children's participation usually occurred through what Crittenden (2016a) termed 'work play', or the playful production of food. On the other hand, the foraged resources in the Congo Basin were more difficult for children to acquire independently from adults. For example, *doka* fishing involves damming and bailing out water from small ponds. While children in early and middle childhood do not have the expertise needed for building dams, nor the strength needed to bail water for extended periods of time, they can participate in collecting the fish left in the pond once the water has been removed. Furthermore, BaYaka parents rarely made functional tools for their children and viewed teaching children to forage as central to parenting efforts (Boyette et al. In prep). Because of these factors, it seems that BaYaka parents contributed to children's knowledge acquisition more than Hadza parents. BaYaka children did not acquire more complex skills until adolescence, and during this time, relied more heavily on teaching from adults. In sum, culture and ecology influenced what children were capable of doing independently from adults, and in turn, how and when knowledge acquisition occurred. These findings lend support to notion that children's participation in subsistence and learning is more facultative than other features of hunter-gatherer childhood (Konner, 2010).

Implications for Evolution

Before the advent of agriculture, humans relied on difficult-to-acquire resources such as hunted meat and tubers for subsistence. Because collecting these resources required extensive knowledge and skill, Kaplan and colleagues (2000) argued that childhood evolved as a learning phase for the production of more calorie-dense resources later in life. Yet, recent studies have challenged this claim, showing that children can be, and often are, producers, that children sometimes produce a surplus of calories which can be shared with the parental generation, and

that children's production contributes to parental reproduction. For example, the foraging returns of some young Hadza children can surpass their daily caloric needs (Crittenden et al., 2013). Mikea children and adolescents from Madagascar devote as much time to food production as adults (Tucker & Young, 2005). And, Mardu children from Australia are successful hunters of goanna lizards from an early age (Bird & Bliege Bird, 2005). Beyond direct food production, children participate in the household economy by assisting in childcare (Boyette, In press; Kramer, 2005, 2010; Weisner et al., 1977) and domestic tasks (Blurton Jones et al., 1994; Froehle et al., 2019; Munroe et al., 1984; Stieglitz, Gurven, Kaplan, & Hooper, 2013; Tucker & Young, 2005). For example, among the Yucatec Maya, children's participation in domestic tasks alongside food production offsets the cost of their care, thus increasing parental fertility (Lee & Kramer, 2002).

Like studies of children's productivity, many studies on the evolution of cumulative culture assume that transmission occurs from parents to offspring (e.g. Borenstein, Feldman, & Aoki, 2008). However, the research reported in this dissertation showed that children independently and actively participated in activities which contributed to their knowledge acquisition. Through play and work, children learned the subsistence skills which conformed to the gendered division of labour in their respective societies. When possible, children also learned by participating in the family economy, such as through foraging among the Hadza and domestic work among the BaYaka. In doing so, children in both societies likely offset some of their provisioning costs (Crittenden et al., 2013; Hawkes et al., 1995; Lee & Kramer, 2002). Beyond seeking knowledge, children also taught each other, potentially liberating parents to perform other subsistence and reproductive activities (Konner, 1976; Lehmann et al., 2013; MacDonald, 2007).

Thus, like recent studies on children's work (e.g. Crittenden et al., 2013; Kramer, 2014), the findings reported here challenged the accepted notion that children are passive recipients of resources; in this case, knowledge. Instead, our findings suggested that childhood may not only have evolved as a time for learning complex skills, but also as a time for transmitting simpler skills to peers and younger children.

Limitations and Future Research

Beyond the limitations presented in each individual chapter, the research presented in this dissertation was limited in its examination of parental ethnotheories about appropriate behaviour, child development, and learning. For example, while the Hadza and BaYaka similarly share the foundational schema of autonomy, how autonomy is expressed differs in the two populations. For the Hadza, Woodburn (1982) suggested that access to hunting weapons was “not mediated through formal institutions” (Woodburn, 1982, pp. 436–437), and thus served as a levelling mechanism because all men had the power to injure others. Lewis (2016) suggested that BaYaka autonomy is maintained through polyphonic singing which encourages improvisation while contributing to the whole. These differences may lead to differences in children’s antagonistic and play behaviour (e.g. RTP; Chapter 4), and the ways in which autonomy is socialized across the lifespan.

Furthermore, the categories used in my coding scheme were based on other studies of teaching and play in small-scale societies (e.g. Boyette, 2016a; Boyette & Hewlett, 2017; Kline, 2016). At least when it comes to teaching, my conversations with BaYaka adults suggested that their definition of teaching was much broader than the one I used. For example, in showing the BaYaka videos of neighbouring Aka adult-child interactions (taken as part of a study on teaching in infancy by Hewlett & Roulette, 2016), the BaYaka claimed that activities such as picking lice out of children’s hair was teaching. In fact, in my conversation with key informants, it has become clear that BaYaka adults view any activity done in the company of children as teaching. Thus, researchers need to explore parental ethnotheories of child development in order to reconcile the anthropological and psychological definitions of play and work used in observational research with those used by the Hadza and BaYaka themselves.

Although I avoided studying “the strange behaviour of children in strange situations with strange adults for the briefest possible periods of time” (Bronfenbrenner, 1979, p. 19) by using more naturalistic approaches to studying learning, the findings of this dissertation only address interpsychological—or social—learning (Vygotsky, 1978b) and not intrapsychological cognitive development. Thus, future studies should use experimental paradigms alongside observations to

examine how play, participation, and teaching contribute to the development of underlying cognitive mechanisms such as imitation, innovation, and executive functioning.

The research presented as part of this dissertation also lacks a temporal perspective on learning. Children were sampled in one or two foraging seasons; however, work by Gallois and colleagues (2015) suggested that there are seasonal variations in children's activities, which in turn may influence children's learning. At an even wider scale, both the Hadza and BaYaka have experienced cultural changes that may influence their learning now and in the future. For the Hadza, the influx of researchers⁶, missionaries, tourists and pastoralists has changed the resources they have access to. For example, cows brought in by the Datoga, themselves climate refugees, has changed the landscape in such a way that wild tubers are harder to find. Perhaps as a response, missionaries now provide tons of corn to the bush-dwelling Hadza every year. The ecological and health impacts of these dietary changes are profound (Crittenden et al., 2017; Gibbons, 2018; Mabulla, 2012; Pollom et al., Under review). Furthermore, most Hadza no longer live in the bush, and yet most researchers, myself included, rarely work with village-dwelling Hadza. Similarly, while the village where I work in Congo has no road access and thus is not market integrated, other villages are. Research among the Maya suggests that market integration alters how children learn to weave, from learning traditional patterns from expert weavers to experimenting with new patterns that fit the aesthetic of the tourists who visit the region (Greenfield, Maynard, & Childs, 2000). Schooling also influences not only what children learn, but also how they perceive the world (Rogoff & Morelli, 1989; Ruiz-Mallén, Morsello, Reyes-garcía, & De Faria, 2013). Thus, research is currently planned to investigate how learning changes alongside other aspects of culture.

Despite these limitations, this dissertation's research was the first to systematically compare the learning of children in two hunter-gatherer societies. Early comparative research on child development (e.g. Whiting & Whiting, 1975) did not survey hunter-gatherer children. Subsequent studies (Draper, 1976) suggested that the unique subsistence and settlement

⁶ The old adage "a San family is made up of a mom, a dad, two kids and a researcher" can easily be applied to the Hadza.

patterns of foragers lead to different socialization practices when compared to farmers, pastoralists, and post-industrial populations. Building on these works, the findings of this dissertation suggested that subsistence and settlement patterns also lead to variations in how hunter-gatherer children from two different societies and ecologies learn, and highlighted the need to consider how access to resources, adult involvement, and cultural norms and practices influence children's learning among hunter-gatherers and in other societies.

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Appendix: Observational Coding Scheme

Setting

- 1=forest camp
- 2=forest trail
- 3=forest water
- 4=forest other
- 5=garden
- 6=village

group

- 0=alone
- 1=children only
- 2=children and adults
- 3=adults only

Sex

- 0=girls only
- 1=boys only
- 2=mixed-group (incl. child)

Primary activity

- 1=eats/drinks
- 2=hunt/gather/work
- 3=rest
- 4=dance/sing
- 5=hygiene
- 6=travels
- 8=solo play
- 9=social play
- 10=grooming
- 11=childcare
- 12=cries/has tantrum

Play

- 1=object play
- 2=pretence play
- 3=rule play (not soccer)
- 4=rough & tumble
- 5=explore/roam
- 6=gentle & tumble
- 7=hide & seek/tag
- 8=tree climb
- 9=knife play
- 10=doll play
- 12=work-themed play
- 13=swing
- 14=gymnastic/other play
- 16=toy construction
- 17=soccer
- 18=jengi toy play
- 19=water play

Teach/learn

- 1=teaching received
- 2=teaching given

1/2=Teaching

- 1=positive feedback
 - 2=negative feedback
 - 3=opportunity scaffolding
 - 4=non-verbal demonstration
 - 5=verbal demonstration
 - 6=instruction
 - 7=task assignment (y/n?)
 - 8=safety commands
 - 9=invitation commands
 - 10=moves body
 - 11=teasing
 - 12/13=asks pedagogical/suggestive question
-

Supplementary Tables

Table S4.1. Multilevel Poisson regression results for Model 1 investigating the association between age, gender, ethnicity, and frequency of observations spent in play.

Term	B	SE	z-score
(Intercept)	-1.31**	0.41	-3.17
Ethnicity	-0.21	0.45	-0.47
Middle childhood	-0.43	0.40	-1.07
Adolescence	-1.58***	0.47	-3.34
Gender	-0.52	0.36	-1.45
Ethnicity X Gender	0.96*	0.38	2.51
Ethnicity X Middle childhood	0.22	0.40	0.56
Ethnicity X Adolescence	0.21	0.45	0.47
Gender X Middle childhood	-0.13	0.22	-0.59
Gender X Adolescence	0.83*	0.37	2.28

p. values: * ≤ 0.05 ; ** ≤ 0.01 ; *** ≤ 0.001 . Analysis conducted on 129 observations of 111 children and adolescents from 10 camps. For gender, 0=female, 1=male. For ethnicity, 0=Hadza, 1=BaYaka. children 3-6 years were considered to be in early childhood (reference category); children 7-12 years were considered to be in middle childhood; children 13-18 years were considered to be in adolescence. Offset was the log of the total observations per child per year sampled. The model included two random effects for participant and camp. Participant Var: 0.85, SD: 0.92
Camp Var: 0.04, SD: 0.21
AIC: 1490.7, BIC: 1525.0, LogL: -733.3

Table S4.2. Multilevel Poisson regression results for Model 2 investigating the association between age, gender, ethnicity, number of child inhabitants in a camp, and frequency of observations spent in mixed-gender social play.

Term	B	SE	z-score
(Intercept)	0.33	0.42	0.79
Number of child inhabitants	-0.03***	0.01	-4.14
Gender	-0.75	0.45	-1.67
Middle childhood	-0.06	0.44	-0.13
Adolescence	0.14	0.48	0.28
Ethnicity	0.20	0.46	0.44
Ethnicity X Gender	0.30	0.36	0.83
Ethnicity X Middle childhood	-0.55	0.48	-1.14
Ethnicity X Adolescence	-0.67	0.51	-1.31
Gender X Middle childhood	-0.06	0.49	-0.13
Gender X Adolescence	-0.18	0.52	-0.34

p. values: * ≤ 0.05 ; ** ≤ 0.01 ; *** ≤ 0.001 . Analysis conducted on 102 observations of 96 children and adolescents from 9 camps. Number of child inhabitants was the count of total children aged 3-18 living in camp at the time of data collection. For gender, 0=female, 1=male. For ethnicity, 0=Hadza, 1=BaYaka. children 3-6 years were considered to be in early childhood (reference category); children 7-12 years were considered to be in middle childhood; children 13-18 years were considered to be in adolescence. Offset was the log of the total observations of social play per child per year sampled. The model included two random effects for participant and camp.

Participant Var: 0.60, SD: 0.77

Camp Var: 0.00 SD: 0.00

AIC: 847.2, BIC: 881.3, LogL: -410.6

Table S4.3. Multilevel Poisson regression results for Models 3-7 investigating the association between age, gender, ethnicity, and play types.

Term	Object ¹			Exercise ²			Rough-and-tumble ³			Structured games ⁴			Pretense ⁵		
	B	SE	z-score	B	SE	z-score	B	SE	z-score	B	SE	z-score	B	SE	z-score
(Intercept)	-2.48***	0.56	-4.44	-1.85**	0.69	-2.69	-3.04**	1.02	-2.99	-8.00***	2.09	-3.84	-0.40	0.71	-0.57
Ethnicity	0.52	0.61	0.86	-1.10	0.77	-1.43	-3.22**	1.23	-2.62	3.80	2.23	1.71	-0.12	0.81	-0.14
Gender	0.89	0.52	1.70	-0.35	0.69	-0.50	-0.89	1.15	-0.78	-1.21	1.94	-0.62	-1.22*	0.61	-1.99
Middle childhood	-0.69	0.56	-1.23	-0.03	0.71	-0.04	-1.27	1.14	-1.11	0.80	2.11	0.38	-0.72	0.62	-1.16
Adolescence	-0.97	0.68	-1.43	-1.09	0.85	-1.28	-2.29	1.37	-1.67	3.04	2.29	1.33	-1.37	0.80	-1.73
Ethnicity X Gender	-1.16*	0.54	-2.13	1.12	0.66	1.70	-0.31	1.02	-0.30	-1.22	1.59	-0.77	1.08	0.62	1.73
Ethnicity X Middle childhood	1.39*	0.55	2.51	0.19	0.70	0.27	1.02	1.25	0.82	-1.51	2.15	-0.70	-1.48*	0.63	-2.37
Ethnicity X Adolescence	1.76**	0.66	2.69	1.05	0.82	1.29	2.61	1.37	1.91	-3.15	2.27	-1.39	0.12	0.78	0.16
Gender X Middle childhood	0.05	0.34	0.15	-0.54	0.58	-0.93	1.70	1.24	1.37	3.02	1.68	1.80	0.32	0.45	0.73
Gender X Adolescence	0.68	0.55	1.24	0.44	0.75	0.59	3.00*	1.44	2.08	1.77	1.88	0.94	-0.02	0.67	-0.03

p. values: * ≤0.05; ** ≤0.01; *** ≤0.001. Analysis conducted on 127 observations of 109 children and adolescents from 10 camps. For gender, 0=female, 1=male. For ethnicity, 0=Hadza, 1=BaYaka. children 3-6 years were considered to be in early childhood (reference category); children 7-12 years were considered to be in middle childhood; children 13-18 years were considered to be in adolescence. Offset was the log of the total observations in play per child per year sampled. All models included two random effects for participant and camp.

1. Participant Var: 1.27, SD: 1.13
Camp Var: 0.05, 0.22
AIC: 963.8, BIC: 997.9, LogL: -469.9
2. Participant Var: 1.98, SD: 1.41
Camp Var: 0.11, SD: 0.33
AIC: 798.2, BIC: 832.4, LogL: -387.1
3. Participant Var: 3.06, SD: 1.75
Camp Var: 0.09, SD: 0.30
AIC: 348.4, BIC: 382.5, LogL: -162.2
4. Participant Var: 8.66, SD: 2.94
Camp Var: 1.05, SD: 1.02
AIC: 635.2, BIC: 669.3, LogL: -305.6
5. Participant Var: 1.72, SD: 1.31
Camp Var: 0.42, SD: 0.65
AIC: 955.4, BIC: 989.6, LogL: -465.7

Table S5.1. Results of the multilevel logistic regressions examining reasons to forage, or not, with children. For fixed and interaction effects, values represent B (SE). For random effects, values represent variance (SD).

Dependent Variable	<i>Fixed effects</i>			<i>Interaction</i>	<i>Random effects</i>	
	Intercept	Sex	Ethnicity	Ethnicity X Sex	Individual	Camp
<i>Reasons not to forage with children¹</i>						
Distance	-0.99(0.37)**	1.08(0.45)*	-0.99(0.51)	-0.95(0.69)	0.64(0.80)	0.00(0.00)
Danger	-1.95(0.69)**	-0.03(0.55)	-1.43(0.97)	1.08(0.83)	0.42(0.65)	0.76(0.87)
Autonomy	-0.78(0.44)	-1.20(0.41)**	2.07(0.60)***	1.15(0.55)*	0.00(0.00)	0.30(0.55)
Disturbance (Hadza only)	-6.44(2.08)**	0.19(1.47)	NA	NA	31.25(5.59)	0.00(0.00)
<i>Reasons to forage with children²</i>						
Company	-1.69(0.53)**	-1.69(0.91)	-0.71(0.64)	1.44(1.25)	1.15(1.07)	0.00(0.00)
Autonomy	-2.23(0.44)***	0.17(0.64)	-2.56(1.06)*	NA	0.00(0.00)	0.00(0.00)
Knowledge	-1.13(0.53)*	-0.94(0.59)	0.77(0.70)	0.41(0.79)	0.27(0.52)	0.43(0.66)
Help	-1.23(0.46)**	1.14(0.49)*	0.79(0.59)	-2.66(0.77)***	0.13(0.37)	0.25(0.50)

P. values: * ≤ 0.05 ; ** ≤ 0.01 ; *** ≤ 0.001 .

1. Based on 338 interviews with 108 Hadza and BaYaka individuals who had not foraged with children that day, except for disturbance, based on 163 observations from 63 individuals for the Hadza only.
2. Based on 210 interviews with 88 Hadza and BaYaka individuals who had foraged with children than day.

