

Original Article

The Bilingual Brain: Human Evolution and Second Language Acquisition

L. Kirk Hagen, Arts and Humanities, University of Houston-Downtown, Houston, TX, USA. Email: hagenk@uhd.edu.

Abstract: For the past half-century, psycholinguistic research has concerned itself with two mysteries of human cognition: (1) that children universally acquire a highly abstract, computationally complex set of linguistic rules rapidly and effortlessly, and (2) that second language acquisition (SLA) among adults is, conversely, slow, laborious, highly variable, and virtually never results in native fluency. We now have a decent, if approximate, understanding of the biological foundations of first language acquisition, thanks in large part to Lenneberg's (1964, 1984) seminal work on the critical period hypothesis. More recently, the elements of a promising theory of language and evolution have emerged as well (see e.g. Bickerton, 1981, 1990; Lieberman, 1984, 1987). I argue here that the empirical foundations of an evolutionary theory of language are now solid enough to support an account of bilingualism and adult SLA as well. Specifically, I will show that evidence from the environment of evolutionary adaptation of paleolithic humans suggests that for our nomadic ancestors, the ability to master a language early in life was an eminently useful adaptation. However, the ability to acquire another language in adulthood was not, and consequently was not selected for propagation.

Keywords: bilingualism, evolutionary psychology, neurolinguistics, second language acquisition.

Introduction

In what follows I intend to examine the well-known differences between child first language (L1) acquisition and adult second language (L2) acquisition from the evolutionary perspective. In the first three sections of my paper, I will try to establish some bases for my arguments by reviewing (1) language acquisition as an ontogenetic phenomenon, (2) language and phylogeny, and (3) the environment of evolutionary adaptation (the EEA) in which humans became linguistically endowed creatures. My purpose in doing so is to show that the differences between L1 and L2 acquisition are the consequence of our evolutionary history. Let me begin by enumerating the most conspicuous of these differences:

- i. *L1 acquisition among children is an astonishingly rapid process.* For all of recorded history, children have managed to become fluent in a language in a period of three to four years, with virtually no explicit help from parents and peers. On the other hand, it is not the least bit uncommon to find adults who have struggled with a second language for a decade or more without achieving fluency.
- ii. *L1 acquisition is effortless.* Simply exposing children to a linguistically rich environment is enough to ensure fluency. Adults who try to learn a second language, on the other hand, find the process laborious, difficult, and frustrating.
- iii. *L1 acquisition requires no formal training.* Human languages are governed by highly abstract rules that speakers apply uniformly to utterances. Yet those same abstractions appear nowhere in grammar books. If they did, they would serve no purpose. Most children are nearly fluent speakers when they first start to read. People in non-literate cultures have no grammar manuals - many have no formal system of education at all - yet they learn complex languages too; languages that equally exploit one and the same set of principles as other languages (see Baker, 2002, for a general discussion). Adults, on the other hand, often do learn languages via explicit training, and they are generally said to benefit from such instruction.
- iv. *Stasis in the case of L1 acquisition is nearly invariable.* In the absence of gross mental, neurological or psychological abnormality, L1 acquisition is universal. All children in all cultures become native speakers; that is, indistinguishable on linguistic grounds from others in their community. Adult second language learners, on the other hand, vary considerably with respect to outcome. While children almost always achieve native fluency, adults almost never do.

Over the years a number of explanations for these differences have been proposed, including some that attempt to explain them without reference to any changes in neuroanatomy per se. We will return to those arguments shortly. For now, let me note that within linguistics and related disciplines there is general agreement as to the facts in i-iv above, so that any theory of language acquisition – evolutionary or otherwise - must account for them somehow.

Next let me enumerate a few postulates about how mental phenomena are understood from the evolutionary perspective. As a convenience, I will borrow from Damasio's (1994) excellent discussion of Cartesian dualism:

- i. The human brain and the rest of the body constitute an indissociable organism, integrated by means of mutually interactive biochemical and neural regulatory circuits.
- ii. The organism interacts with the environment as an ensemble: the interaction is neither of the body alone nor of the brain alone.
- iii. The physiological operations that we call mind are derived from the structural and functional ensemble rather than from the brain alone: *mental phenomena can be fully understood only in the context of an organism's interacting in an environment.* (xv-xvii, my emphasis)

Language acquisition, first or second, is obviously among the mental phenomena that Damasio has in mind. Thus I am simply assuming in this paper that such phenomena are the consequences of the machinations of our brain, which is a functional biological structure that ought to be analyzed like other functional structures such as hands, teeth, legs, and eyes. We analyze such structures by studying their properties in the context of the history of the organism in its environment.

Before we contextualize language acquisition and bilingualism in this manner, however, let us make sure that the differences I spelled out above are indeed firmly established as physical phenomena, rather than as sociological, psycho-pedagogical, or some other kinds of phenomena. In the following sections, I call attention to a substantial corpus of evidence from independent sources that converges on the conclusion that language acquisition is an age-sensitive cognitive process that results from as of yet poorly-understood maturational, neuroanatomical changes. My review will focus on pathological studies of language loss (see below), bilingual brain-mapping (see below), language deprivation (see below), and non-pathological studies of differences in L1 and L2 acquisition (see below).

Language Ontogeny and the Critical Period

It has been known for a long time that language acquisition and processing are associated with a specific part of the brain; namely the perisylvian region of the left hemisphere, at least for the vast majority of humans. It is, moreover, indisputable that those processes are subject to some kind of age constraints of the sort we see in other cognitive processes such as vision. Traditionally, those linguistic constraints have been studied under the rubric *critical period hypothesis* (CPH), which is most often associated with Eric Lenneberg's (1964, 1984) work on language loss in young children. The CPH claims that from roughly 1 year of age through adolescence, the human brain is optimally prepared to acquire a language. During that time, no special instruction is required to ensure that a child will become a fluent speaker. In the absence of gross physical defect, children will universally become native speakers of a language so long as they are exposed to a linguistically rich environment. As one approaches adolescence, the acquisition of native-like fluency becomes increasingly problematic.

Lenneberg based his conclusions mostly on pathological studies, noting for example that children who suffer left-hemisphere brain injury preverbally typically do not have any significant impairment later in life. Almost all studies of acquired childhood aphasia place recovery rates between 75% and 100%. It is rare to come across rates below 50%. In studies of adults, on the other hand, it is rare to find recovery rates *above* 50%. Most fall in the range of 20% to 50%. When adult recovery is not complete or at least substantial within three months, a prognosis of full recovery is not good.

Pathological Studies of Language Loss

Pathological research confirming the CPH dates back to the late 1800s (see Satz and Bullard-Bates, 1981). Let us look at a few illustrative cases. Bassler (1962) studied 30 children who showed signs of unilateral hemispheric injury soon after speech onset. Twenty of Bassler's subjects showed signs of non-fluent aphasia. Eighty-six percent of the cases involved left-hemisphere damage, and 46% right-hemisphere damage (approximately 90-95% of all humans have the language facility in the left hemisphere, running from

“Broca’s Area” in the inferior frontal gyrus to “Wernicke’s Area” in a posterior section of the superior temporal gyrus). Basser reported robust recovery in every case. Alajouanine and L’Hermitte (1965) published a study of language recovery of 32 children, ages six to fifteen, who had suffered left hemisphere injury. Fully 75% of their subjects had recovered after one year, including 66% who returned to school. “In two thirds of the patients,” conclude Alajouanine and L’Hermitte, “the recovery is an indisputable fact and one very particular to children” (p. 660). Woods and Teuber (1978) studied 65 children with brain lesions; 34 in the left hemisphere, and 31 in the right. While 25 of the left-hemisphere patients experienced aphasic symptoms, only 4 of the right-hemisphere patients did. Of those who experienced aphasia prior to the age of 8, every one recovered fully. Vargha-Khadem, O’Gorman and Watters (1985) used Computed Tomography to study cerebrally damaged children and concluded that age at onset and locus of the lesion, rather than the severity of insult, were associated with subsequent language impairments. Cranberg, Filley, Hart, and Alexander (1987) reported results of a study of eight patients, all younger than seventeen. They too concluded that recovery of fluency was faster and more robust in children than recovery rates that had been reported for adults. Martins and Ferro (1991, 1992) studied 29 children who had sustained brain lesions that led to aphasic symptoms. The majority, 76%, recovered completely. All children who had an onset age of less than 7 years (8 subjects in all) recovered fully. Among those age 13 years or older, only two of five recovered fully. In a second study in 1992 involving 32 children, Martins and Ferro report recovery rates of 75%. All of this led Cappa (1998, p. 537) to conclude that “[t]he effect of age is unequivocal in the case of childhood aphasia. A fast and relatively complete recovery can be expected in children with acquired aphasia.”

Patterns of language loss and recovery among bilinguals are generally consistent with those observed among monolinguals. Albert and Obler (1978) did a meta-analysis of more than 100 case studies of bilingual aphasia. Dividing their cases into “children,” “school-aged,” and “adults,” they found that all were equally likely to experience parallel loss (that is, more or less equal loss of language ability, relative to pre-morbid fluency) or discrepant loss (disproportionate loss of one language over another, relative to pre-morbid fluency). However, children alone were more likely to experience *parallel recovery* of the two languages. A second language acquired prior to age seven is generally more resilient to injury and disease than one acquired at a later age (Fabbro, 2001).

Bilingual brain-mapping

There is even evidence to suggest that second languages learned later in life end up in distinct regions of the brain, while those acquired early in life tend to be situated in regions coextensive with the L1. Ojemann and Whitaker (1978) report on case studies of a late Dutch/English bilingual and a late Spanish/English bilingual who underwent electrocortical stimulation prior to surgery. In both instances, they documented an area of the brain common to both languages as well as distinct sites where languages were differentially affected by testing. Kim, Hirsch, Relkin, De Laz Paz, and Lee (1997) did an fMRI study of early and late bilinguals that revealed distinct physical loci of second languages along the periphery of Broca’s and Wernicke’s regions in the case of late learners, but not in the case of early learners. Dehaene et al. (1997) published a study of French-English bilinguals, all of whom had acquired the L2 after the age of seven. In listening tests, an fMRI revealed common areas of activation in the left temporal lobe for

all subjects when the L1 was used. When the L2 was used in testing, researchers found highly variable areas of activation in both hemispheres. Halsband et al. (2002) used PET scans to study ten Finnish–English adult bilinguals, all of whom had acquired the L2 after the age of 10. They found differential areas of activation for the two languages in both Broca’s area and in the supramarginal gyrus, one of the convolutions lying between Broca’s and Wernicke’s Areas. Hernandez, Dapretto, Mazziotta, and Bookheimer (2001) studied six Spanish/English early bilinguals, all of whom had acquired both languages before the age of five. fMRI testing showed that the two languages were represented in overlapping regions of the brain. Wartenberger et al. (2003) used fMRI testing to study 32 Italian-German bilinguals in three groups, (i) eleven subjects who acquired the L2 in early childhood and were fluent native speakers, (ii) twelve subjects who acquired the L2 in adulthood but managed to attain a high level of proficiency, and (iii) nine subjects who had acquired the L2 late in life and had limited proficiency. They found that age of acquisition was a statistically significant variable in determining loci of grammatical processing in the brain, but less so in determining semantic processing. Taken together, these studies suggest that L1/L2 acquisition differences are not simply the consequence of inadequate or incomplete learning experiences, or of any psycho-affective factors, but that they result from fundamental changes in cognitive abilities that are in some way the consequence of our biological endowment.

Language Deprivation

Studies of language deprivation, though rare, are consistent with the CPH as well; in fact, there is no documented case that contradicts the CPH, so far as I know. The best known example is that of “Genie” (a pseudonym), an adolescent girl who had been isolated from linguistic input by her abusive parents until the age of thirteen (Curtiss, 1977; Nova, 1997). After she was removed from her deplorable environment, Genie underwent long-term psychological and speech therapy. Genie made slow but steady progress in many cognitive domains, but her language ability topped out fairly quickly, and despite years of training she never became a fluent speaker. In the nineteenth century, French physician Jean-Marc-Gaspard Itard documented a similar case of twelve year old Victor, the so-called “Wild Boy of Aveyron” (Shattuck, 1980). Like Genie, Victor had been raised in an environment virtually without language input. Victor too underwent intensive and long-term language training, also to no avail.

Another case involved a woman known as Chelsea, who, profoundly deaf since birth, was misdiagnosed as mentally retarded and institutionalized (Newport, 1991). At age 32, her true condition was discovered. Chelsea was fitted with hearing aids and subsequently underwent intensive language training. She was able to gain some mastery of word meanings, but her grammar remained markedly aberrant. Davis (1949) reports on an earlier case of language deprivation involving a girl called Isabelle, who like Genie had been isolated from language from a very early age. Unlike Genie and Chelsea, Isabelle’s circumstance was discovered when she was only six, and within two years she was a normal speaker. Isabelle would later attend school and lead a normal life. Newport (1991) studied hearing-impaired speakers who were exposed to American Sign Language (a) in infancy, (b) between the ages of four and six, or (c) sometime after puberty. Predictably, native signers were fluent. Those who were not exposed to ASL until adulthood

demonstrated noticeably inconsistent use of ASL morphology. Those exposed to ASL between the ages of four and six fell somewhere between the other two groups.

Non-pathological studies of the CPH

Studies of non-aphasic language learners lend even more support to Lenneberg's CPH. For instance, Oyama (1976) did a correlational study of foreign accents among immigrants to the United States. The variable *age at arrival* was a strong predictor of degree of accent; *length of stay* in the USA was not. Johnson and Newport (1989) tested of knowledge of English grammar among Korean and Chinese immigrants to the United States. Competence correlated negatively with age of arrival; those who arrived at an earlier age were more likely to evince mastery of English grammar. The correlation was of a robust .77 magnitude. Johnson and Newport's study could well serve as a model for research into age differences in bilingual populations because demographic investigations like hers are sound, reliable, and comparatively easy to replicate. Yet they are also surprisingly rare in applied linguistics, most likely because the outcome is a foregone conclusion.

What exactly is going on inside the brain that accounts for these observations? The precise machinations of the bilingual brain have largely eluded neuroanatomical studies. But one of the most promising accounts we have comes from Paradis (2004). Paradis anchors his model of bilingualism on the distinction between *implicit* and *explicit* knowledge of language; a distinction that dates back to the earliest days of generative syntax. He uses the expression "implicit computational procedure" to refer to subconscious and internalized set of rules that permits a speaker to assign a grammatical structure to strings of words in a manner compatible with how other native speakers assign structures to those strings (Paradis 2004, p. 33). Paradis theorizes that implicit linguistic knowledge is subserved by procedural memory, which is automatic and effortless, while explicit knowledge is subserved by declarative memory. There is indeed a sense in which assigning grammatical structure to a phrase involves a set of procedures; how to predicate a noun phrase of a verb, how to modify a noun, how to conjoin phrases, how to emphasize a topic by displacing a constituent, and so forth.

Paradis argues that it is the ability to incorporate knowledge into procedural memory that atrophies in adults. Adult second language learners therefore rely on their declarative memory – explicit knowledge, in other words – to compensate for what's missing from procedural memory. Some adult L2 speakers are quite adept at using declarative knowledge to compensate for the limits of procedural memory, although the result may be a more hesitant and less fluent manner of speaking. This would explain (1) the different loci of language activation in early versus late bilinguals, since declarative and procedural memory may not be in coextensive regions, and (2) why the acquisition of semantic knowledge – which is declarative knowledge rather than procedural – remains relatively unaffected by the critical period.

Alternate explanations of the CPH

Over the years there have been a number of non-pathological studies, mostly coming from pedagogical circles, which have denied that the brain is constrained by a critical period in the manner I have suggested above (see, for instance, Baker, 2000; Hakuta, Bialystok and Wiley, 2003; Samway and McKeon, 1999). These alternate accounts claim that environmental factors not related to physiology explain the CPH. It is sometimes

said, for example, that children are not as inhibited as adults, and that they are therefore more open to the kinds of interactions that are crucial to acquisition. Children are also said to be more motivated than adults. Another common suggestion is that adults, unlike children, retain an emotional attachment to their native language and culture and are reluctant to abandon it for new ones.

There is virtually no empirical support for any of these proposals. Some adults are indeed introverted, but then so are some children. As far as anyone knows, introverted children still outperform extroverted adults when it comes to learning new languages. As for motivation, it is very often the case that adult immigrants, who are responsible for providing for their children, are highly motivated to learn a second language. That, however, does not solve their language acquisition problems. Highly motivated adults make better learners than unmotivated adults, but again they are no match for children. And when it comes to parting with one's heritage, adults are sometimes reluctant and sometimes not. There are countless cases in which adults have fled their homeland to escape repression, persecution and even torture, not to mention abject poverty. Some immigrants will have nothing to do with the culture they have left behind and will integrate well into a new culture. But there is no evidence to suggest that this guarantees fluency in an L2. Long (1990) cites no fewer than eight studies that have rejected experiential explanations on empirical grounds. He notes, poignantly, that children vary considerably on parameters like self-esteem, inhibition, introversion/extroversion, and motivation, but that they vary only in trivial degrees in first language acquisition. So while the CPH remains somewhat controversial in educational and social studies, within the scientific community in general – and in the medical community in particular, where facts about age and the likelihood of language loss and recovery sometimes impinge on decisions of how to deal with serious medical conditions – it is now accepted without debate. That the acquisition process is thus contingent upon physical phenomena like disease, injury, and even normal maturation certainly suggests that language is far more than a cultural artifact. It is a trait deeply rooted in our biology, and one that must therefore have been highly advantageous for our ancestors (for commentary, see Laitman and Reidenberg, 1988, pp. 99-109).

Language and Phylogeny

The studies I have cited so far all have to do with language acquisition as an ontogenetic phenomenon. Now let us turn our attention to research on language as an phylogenetic phenomenon, so that we can focus on the evolutionary perspective of language acquisition. From comparative anatomical studies of the hominid fossil record, it is becoming increasingly clear that our endowment for language is indeed the result of some very specific physical mutations - in the cranium and brain, the pharynx, and the supralaryngeal vocal tract (SVT) – that our species alone has undergone. Our closest genetic relatives the chimpanzees do not have vocal tracts capable of forming the vowels and consonants that make up the acoustic repertoire of human languages, and not surprisingly, they have never been observed in the wild using anything like computationally complex languages that are universal among humans. While they are not *physically* endowed for language, there was, in the 1960s and 1970s, some debate among primatologists (not so much among linguists) as to whether chimps and apes were *cognitively* endowed for language. It would be a bizarre state of affairs if they were, since highly marked functional anatomical traits generally don't evolve in the absence of

corresponding behavioral traits (e.g., sheep do not have predatory instincts because they would do them no good without the physical wherewithal, and trying to “train” sheep to be predators would therefore be a futile undertaking). Nevertheless there were some concerted and highly publicized efforts in the 1970s and 1980s to teach language to chimps and apes via the use of sign language, lexigrams, and other gimmicks designed to overcome the physical limitations of the chimp vocal tract (see Blum, 1994). Since then, the weight of scientific evidence has come down squarely against ape language research. None of the training programs ever succeeded. The differences between human linguistic ability and ape linguistic ability are immense and irrefutable (Gardner, 1989; Nova, 1994; Wallman, 1992).

The failure of the ape language programs did, however, contribute indirectly to a second promising interdisciplinary collaboration in language acquisition research. At around the time when those programs were all the rage, Mary and Richard Leakey and their colleagues announced a historic find from a fossil dig in Hadar, Ethiopia. Archaeologists Donald Johanson and Tom Gray uncovered about 40% of the skeleton of a small (about 107 cm tall), bipedal female adult hominid that dated from about 3.2 million years BCE. When this skeleton was first discovered, its species *Australopithecus afarensis* was the oldest known. Since then, remains of what is believed to be a distinct and older (4.0 – 4.2 million BCE) hominid species *Australopithecus anamensis* have been uncovered in Kenya. *A. anamensis* is in turn preceded by *A. ramidus*, from about 4.4 million BCE. Because *A. ramidus* reveals a mixture of hominid and ape features, it is sometimes classified as a distinct genus *Ardipithecus* (see Haile-Selassie, 2001; White, Suwa, and Afsaw, 1994). Although australopithecines walked upright, their skulls were manifestly chimp-like rather than human-like, which makes it unlikely that they were any more linguistically endowed than modern apes. So if (a) our earliest known hominid ancestors were non-linguistic, and (b) modern *Homo sapiens* are universally linguistic and (c) there is an unbroken evolutionary chain between the two, then obviously our biological endowment mutated at some point in our past in a way that permitted speech.

Most of what we know about this transition we owe to Lieberman (1984; 1987; 1998; 2006). To provide some background on his work, let us establish a little more of a timeline of hominid evolution. The most significant evolutionary bifurcation in our history, after the one separating apes from australopithecines, comes at around 2 million BCE and is marked by the appearance of the new genus *Homo* (for background see Arsuaga, Martinez, Gracia, Carretero, and Carbonell, 1993; Bermudez de Castro, et al., 1997; Burenhult, 1993; Dean et al., 2001; Tattersall, 1993). This lineage includes both the soon-to-be-extinct *Homo rudolfensis* and our own forebears *H. habilis* (Johanson et al., 1987). It is the fossil record of the various species of the genus *Homo* that provides clues about the evolution of language. One of the prime indicators is cranial capacity. There was a gradual increase in cranial capacity of hominids; from about 400 cc for early australopithecines (circa 3 million years BCE, Falk, 1983), to around 800 cc for *Homo habilis* (2 million BCE) and 1000 cc for *Homo erectus* (1.5 million BCE, see Brown, Harris, Leakey, and Walker, 1985), and finally to an average of 1400 cc for anatomically modern *Homo sapiens*.

Fossils also show a gradual development in the flexion of the base of the skull, which permits a much longer pharynx. The modification of the pharynx in turn permits a larynx positioned lower in the throat, which allows for the large repertoire of phonemes

that characterize human languages. The skull of *Homo ergaster* (circa 1.8 million BCE, which may in fact be the same species as *H. erectus*) shows vague signs of flexion in the base. The skull of more recent *Homo heidelbergensis*, circa 1 million BCE, shows even more (Tattersall 1995, p. 172). *Ergaster* and *heidelbergensis* are precursors to both *neanderthalensis* and *sapiens*, which suggests that language ability is likely the result of a gradual evolution that spans a million years or more. Leakey and Lewin (1992) argue that *Homo erectus*, circa 1.5 million BCE, probably had considerable linguistic abilities. Bickerton (1990) proposed that *H. erectus* was endowed with a proto-language; that is, a computationally simpler “language minus the syntax,” as Jackendoff (1999, p. 272) calls it. Tobias’s (1991) research on cranial endocasts of *H. habilis* skulls suggests that even they had hemispheric specializations consistent with language ability, although Leakey (1994, p. 131) points out that larynges of hominid species predating *H. erectus* were in the same position as the larynx of chimpanzees.

Lieberman (1998) argues that these language-specific modifications came at a substantial cost. For instance, the low position of the larynx makes it easier for us to choke on food. Humans are the only mammals that cannot breathe and swallow at the same time. And since our SVT requires a smaller jaw, we are also more likely to have impacted wisdom teeth and hence infection; something our close cousins the Neanderthals never had to worry about. A smaller jaw means that we chew food less efficiently, which in turn results in a more restricted diet and a decrease in our ability to process nutrients (see Dean et al., 2001). The jaws of non-linguistic australopithecines were much better suited to crushing foodstuffs. This is not a trivial consideration, given that for much of our history starvation was an ever-present threat. All told, the fossil record suggests an incremental functional modification (an “exaptation,” as Gould (2002) liked to call it), of the human vocal tract from an eating mechanism to resonating chamber. Paleoanatomical studies thus point to the conclusion that our linguistic endowment is a highly marked physical and behavioral trait rather than a token of general intelligence: it derives from a structural and functional ensemble rather than from the brain or body alone, as Damasio would say.

The Environment of Evolutionary Adaptation

Let us sum up what we have concluded so far. By 200,000 BCE more or less, as attested by the fossil record, *Homo sapiens* had developed the unique anatomical structure that permits language. Our skulls had grown in size, our jaws had shortened, and our larynges had moved down the pharynx. Along with these physical changes came all the deficits that Lieberman and others have documented. On the cognitive side of the equation, studies of language loss, deprivation, and neuro-anatomical organization all point to the conclusion that these modifications are geared towards rapid language acquisition at a young age rather than invariable acquisition across the life span. Let us now ask what it was about our evolutionary past that would have favored this state of affairs over some other possible one.

The EEA and First Languages

First of all, while much remains unknown about the when and how of language evolution, there is really not much mystery about the why. Humans are far and away the most social of animals on the planet, and language is the social currency in which they deal. We have only to make a list of the things that would have been difficult or impossible for

non-linguistic hominids – for example group hunts, the distribution of foodstuffs and goods, and of course warfare – to understand why those endowed for language would have had a leg up on others. Nor is it difficult to understand why the ability to acquire a language rapidly at a young age would be doubly advantageous. Ruminants like deer and wildebeest are ambulatory within minutes of birth. Wolf pups are not mobile for weeks after birth. For humans, ambulation manifests itself only after many months. The reason, presumably, is that if you are potential food for a predator and not mobile soon after birth, then you are quickly weeded out of the gene pool. Since wolves do not have many natural predators, mobility at a young age is not as crucial as it is in the case of ruminants. In the case of humans, who have a vast social infrastructure for protecting and nurturing their young, walking can safely be deferred for a very long time, and the child's development can meanwhile be redirected to other skills. Many of those other skills – e.g. socialization, moral reasoning and the like – depend on language. Thus it is hardly surprising that language would be among the earliest cognitive traits to emerge in childhood.

The EEA and Second Languages

The study of our prehistory does not, however, offer much evidence that the ability to acquire a second language in *adulthood* would have been beneficial for the nomadic, hunting-and-gathering humans who represent the vast majority of our past. When anatomically modern *Homo sapiens* began migrating from Africa into the Eurasian continent around 120,000 BCE, they were probably fully linguistic, and probably had been for a hundred or so millennia. At that time, the human diaspora was exceedingly sparse by modern standards; probably never more than one-tenth of one percent of our current population during our entire pre-agricultural history (see Cavalli-Sforza, 2000; Gamble, 1993). Shermer (2004) offers an insightful summary of research by Bettinger (1991), Chagnon (1992), and Dunbar (1996) into the dynamics of population management among human groups. Apparently there is something significant about the number 150. Among the Yanomami of Amazonia, for instance, villages average around 150 members. The same is true among the contemporary Hutterian Brethren who live communally in North America, and in fact populations of between 100 and 200 are common among groups that lack sophisticated administrative infrastructures. When groups become too large, moral and social control becomes difficult, and the groups tend to splinter. Among nomadic peoples, splintering over time leads to a loss of contact with the former group, which in turn leads to language drift, new dialects, and eventually new languages. As a rule of thumb, a thousand years of isolation is about what it takes to ensure that dialects of a language will mutate to the point of mutual incomprehensibility. The diverse patchwork of languages that evolved across the African, Eurasian and later the American continents (thousands of mutually incomprehensible dialects, by any estimate), is testament to long periods of isolation and lack of sustained inter-cultural contact in our ancestors' world.

Baker (2002, pp. 210-212) points out that some, like Dyson (1979), have gone so far as to suggest that language diversity evolved precisely to establish and maintain cultural differences as a means of improving our odds of survival. By this argument, a linguistically and culturally homogeneous species would have to carry its adaptive eggs in a single basket, so to speak, while diversifying would allow more sub-groups more opportunities to flourish through innovation. This argument likely confounds cause and effect. Baker notes that humans commonly stigmatize others on the most trivial of linguistic differences, and

that language drift leading to mutually incomprehensible tongues is therefore well beyond what is necessary to create and maintain cultural divisions. Thus it seems more likely that linguistic diversity is a consequence of millennia of nomadism rather than a cause.

Genetic studies tell us, moreover, that there were several population bottlenecks in our past when our numbers dropped precipitously. The most dramatic of these occurred around 75,000 BCE and is sometimes attributed to the eruption of a massive volcano in Sumatra that spewed about four thousand times as much ash into the atmosphere as did the Mt. Saint Helens eruption in Washington State in 1981 (Ambrose 1998; Klein and Edgar, 2002, p. 269; Rampino and Ambrose 2000). This catastrophic drop in population left just a few thousand humans alive, from which every one of us today is a descendant. Such small numbers, coupled with a nomadic lifestyle and the unmanageability of large groups, would have all but assured a lack of sustained inter-cultural contacts among the paleolithic humans. A child requires three to four years of exposure to language to achieve fluency, and the opportunity for that is universally available in human cultures. But it is difficult to imagine circumstances in which all adult members of all cultures of nomadic hominids would have access to three to four years of steady exposure to a second language in adulthood. We can only guess at the life expectancy of our prehistoric forebears, but until very recently it has not been much more than 35 years. Archaic humans had little opportunity to learn anything in adulthood, simply because adulthood did not last much longer than childhood and adolescence. Long after the population bottleneck of ca. 75,000 BCE, when we began our transition from a nomadic to an agricultural lifestyle, we still numbered only about 5 million; roughly the population of Toronto, Canada, dispersed across six continents (Hawks et al., 2000). For vast stretches of our history – significantly, those during which our linguistic abilities evolved - inter-cultural contacts would have been occasional and brief at most. In an environment like that, the ability to acquire a second language in adulthood with the same degree of rapidity and effortlessness characteristic of first language acquisition in childhood would not have been useful. Indeed it would be surprising if ever a skill that required years of acquisition but then served no purpose for the overwhelming majority of people would have evolved universally among hunter-gatherers.

It is also relevant to consider what must have happened on those occasions when nomadic groups of humans did come into contact with others. It is true, with respect to *intra*-cultural interactions, that modern hunter-gatherers are uniformly egalitarian, and that they tend to consider generosity to be among the greatest virtues and, conversely, stinginess to be among the most shameful character flaws (see Bettinger, 1991; Wilson, 2002). Most anthropologists safely assume that those behaviors were the norm in prehistory as well. Extrapolating from such observations, one is tempted to imagine, as Rousseau once did, that on those occasions when hunter-gatherers did meet up with outsiders, their egalitarian disposition would have led them to engage in fellowship and trade, so that on a regular basis throughout the lifespan of an individual, the quick mastery of other languages would have been of critical importance. We might therefore imagine that commerce and other social intercourse would have been based on mutual respect, as every group would be repulsed at the thought of dominating any other. In such an environment, the ability to acquire a second language in adulthood would be indispensable for maintaining inter-cultural bonds and avoiding hostilities. And because humans are egalitarian, everyone is in on the act; thus the ability to become bilingual would therefore have evolved as a universal

trait among humans, just like first language acquisition. Seen in this light, Lenneberg's critical period hypothesis makes no evolutionary sense at all. Why would our ability to acquire language diminish at precisely the point in our lives when it would do us so much good?

Hobbes/Rousseau Redux

Questions like these show why the study of languages and early human populations is of special importance in understanding human evolution. Conflicts among humans are inevitable, and language is one of our most exceptional tools for conflict resolution. To be more precise, first languages are what we use to resolve intra-cultural conflicts, and second languages are what we use to resolve inter-cultural conflicts. The study of language acquisition thus leads us to rehash the classic Rousseauian / Hobbesian debate over human nature. Are we by nature pacifist or belligerent? Tolerant or xenophobic? Or, to ask the same questions from an evolutionary perspective, which set of behaviors would have improved our forebears' chances of passing genetic material on to subsequent generations?

The truth is that the world of Rousseauian egalitarianism and tolerance is only half of the story of our past. In his discussion of evolution and morals, Shermer (2004, pp. 224-231) notes that with respect to measures of inter-group aggression, human behavior resembles that of the notoriously violent *Pan troglodytes* that Jane Goodall (1971; 1986) studied for some fifteen years at the Gombe Stream National Park in Tanzania (Goodall documented some rather shocking examples of group warfare and murder among the chimpanzees). With respect to measures of intra-group violence, on the other hand, we are more akin to the peaceful *Pan paniscus* or Bonobo chimps, who are more given to eroticism than to conflict (de Waal, 1995). This suggests, ironically, that Rousseau and Hobbes were both right. That is, that there are countless activities in primitive societies that are not possible without peaceful cooperation. Ridley (1997) offers a superbly informative discussion of the dynamics of cooperation and altruism from the evolutionary perspective. There is no point in gathering foodstuffs for yourself and your family if a neighbor is going to rip off your bounty as soon as it's collected. If your neighbor gets sick, it is advantageous to take care of him until he gets better, because he will then be more likely to return the favor. If everyone has to stay up late at night to keep a lookout for intruders, then no one will get any sleep, so it is also advantageous to trust one person to serve as sentry while others rest. A skilled hunter may think up an elaborate plan for cornering and slaughtering game, but if he has no way of arranging the cooperation of fellow hunters, the plan does no one any good. And if you have a successful hunt and your neighbors do not, it's nice to share, because that will ensure special consideration towards you and your kin in the future. All of these activities require negotiation and agreement, which are not possible without a sophisticated means of communication. Evolution therefore seems to favor Rousseauian communalism, and language seems to serve a pivotal role in facilitating that spirit.

On the other hand, it is all but certain that early human groups had to compete with other groups for scarce resources. Keeley (1996) nicely sums up how such competition would have played out:

The newcomers are at least intruding, if not trespassing; often compete with the natives for land, water, game, firewood, and other limited materials; commonly change the local ecology; are inclined to be cavalier about the property rights of

others but are fastidious about their own; and exhibit inscrutably odd customs and tastes. It is seldom long before the colonists' behavior convinces the aborigines that the newcomers should be encouraged to be "new" someplace else (p. 136).

When newcomers and aborigines do not share a language, one or the other will turn to a second exceptional tool that humans have for resolving conflicts: violence. We have only to imagine two ancestral groups; one Rousseauian, peaceful, inexperienced in combat, welcoming of strangers, and always prepared to share with newcomers, the other Hobbesian, aggressive, violent, well-armed, and having no compunction about the pillage and conquest of outsiders. Which of the two is more likely to survive the lean times? Although we are here confronting a morally repugnant possibility, history tells us, through innumerable examples, that in our past violent intrusion has indeed worked towards the propagation of the species. Whenever the conquest of a belligerent culture has been checked, it has been by some other belligerent culture equally bent on conquest. Evolution now seems to favor Hobbesian competition model.

By all evidence, natural selection has come up with a surprising resolution to the Hobbes/Rousseau paradox. All human cultures have two moral codes; one that applies intra-culturally (to "us"), and one that applies inter-culturally (to "them," whoever they may be). Throughout history, humans have been capable of committing atrocities against others that would be considered morally offensive if committed against one of their own.

Looking beyond recorded history to prehistory, we find, in archaeological sites around the world (see, inter alia, Buss, 2005; Gibert and Palmquist, 1995; Keeley, 1996; and Martin and Frayer, 1997), evidence that confirms this account of human interaction. Approximately 486 pre-Columbian skeletons were unearthed at the Crow Creek site in South Dakota in 1978. All had been massacred. There were disproportionately few female skeletons in the reproductive age cohort 15-39 at Crow Creek (access to reproductively capable females is a common motivation for conquest in pre-industrial cultures). Fortification ditches found surrounding the site bear witness to an external threat. Approximately 16% of skeletons uncovered at an Oneota site along the Illinois River (circa 1300 CE) showed signs of violent death. A cemetery in Yaye, San Pedro de Atacama Chile, from around 1000 CE, yielded nearly 150 skulls, of which 30% showed signs of cranial trauma (Torres-Rouff, Costa-Junqueira, and Llagostera, 2005). A site near Jebel Sahaba, dating from around 11,000 BCE, yielded almost 60 skeletons, 40% of which showed evidence of death from stone projectiles (Wendorf and Schild, 1986). The victimologies of the remains point to attacks from outsiders (Keeley, 1996, p. 37). Pictographs from Northern Australia dated around 8,000 BCE depict scenes of inter-group warfare (Tacon and Chippendale, 1994). Skeletons from the Aurignacian culture of Western Europe ca. 30,000 BCE show signs of homicide. Roper (1969) even reported evidence of violent homicide among Neanderthals. Keeley's (1996) comprehensive review of prehistoric violence shows that 90% to 95% of cultures engaged in warfare of some kind, and that war between linguistically heterogeneous groups was usually "unrestricted...without rules and aimed at annihilation" (p. 65). This is hardly evidence of a mental disposition that would have favored the kinds of widespread and sustained inter-cultural contacts that would have demanded bilingualism.

One intriguing potential counter-example is the Chaco Culture, which thrived in the present-day Four Corners region of the American Southwest from 919 CE to around 1180

CE (Keeley 1996, pp. 30-32, discusses some other rare examples of relatively peaceful pre-state cultures). Approximately 125 Chaco villages have been identified. The largest settlement was in Chaco Canyon, the most expansive prehistoric architectural complex in North America. At its zenith, the Chaco complex could have accommodated as many as 6,000 residents (Frazier, 1986). But anthropologists and archaeologists have long been baffled by the paucity of human remains at Chaco; by some estimates, not even a third of what one would expect from a culture that occupied a massive, quasi-urban center for more than 200 years. Archaeologist Thomas Windes (see Lekson, 1984) was just as surprised by the small number of permanent fire pits in Chaco dwellings. The Chaco complex is 1,275 m (4,175 feet) above sea level, and temperatures have been known to vary as much as 30° C (60° F) in a single day. Average temperatures in December through February are below freezing: the lowest temperature ever recorded was -39° C (-38° F). Thus it is unlikely that anyone would have taken up long-term residence in Chaco without a permanent hearth for cooking and heating.

Windes and others have posited an interesting explanation for these discrepancies. They theorize that Chaco was not a permanent residence but a seasonally-occupied ceremonial and trading complex, roughly akin to the state and county fairgrounds that thrive in the rural United States today. A great deal of evidence from Chaco is consistent with that conclusion. That the Chacoans engaged in some degree of trade is certain: beads carved from sea shells, copper bells, and parrot skeletons found at Chaco all attest to inter-cultural exchanges, mostly with Mesoamerican cultures from present-day Mexico. The Chacoans also built an extensive grid of roads leading to outlying villages. If commerce was seasonal, one would expect a small permanent residence at the site for general maintenance (and there was, as is demonstrated by the presence of some permanent fire pits). This small contingent would have to know when to expect seasonal reunions, and that in turn would explain the presence of the diverse solar calendars found throughout the Chaco complex (Frazier, 1986, pp. 188-202).

Of particular importance to our discussion is the diversity of languages spoken by the present-day Pueblo Indians, who are generally accepted as descendants of the Chacoans. The Chaco site was abandoned less than 1,000 years ago. If its occupants dispersed and took to living in isolation, we would expect language drift more or less analogous to the drift that separates modern English from Old English circa 1000 CE (i.e., mutually incomprehensible dialects which, upon careful inspection, would reveal common linguistic roots). That is pretty much true for one language group: Tanoan. Tanoan is part of the larger language family Uto-Aztecan, which includes Kiowa as well as a number of indigenous languages from Northern Mexico such as Nahuatl and Tarahumara. Today three distinct Tanoan languages are spoken among the Pueblo Indians; Tiwa in three pueblos, Tewa in six, and Towa, which is limited to approximately 1,000 speakers at Jémez (Sando, 1998, pp. 6-12). The differences between Tewa, Towa, and Tiwi are about what one would expect from dispersement that began around the time of the abandonment of Chaco.

Tanoan, however, is just one of three language families among modern Pueblo Indians. Zuñi is a Penutian language related to languages of the American Northwest. Keresan, which is spoken in eight pueblos (including the Zia Pueblo, which is just a few miles from Towa-speaking Jémez) is a language isolate, unrelated to any other language. The modern pueblos of New Mexico evince a wide array of shared religious, architectural and other cultural traditions (Sando, 1998, p. 8) that point to a common heritage. If all are

descendant of the Chaco Culture, then it is likely that the Chacoans, whoever they were, were not monolingual. The 500 years of prehistory following the abandonment of the Chaco complex is not nearly enough time to explain the differences between the Tanoan, Penutian, and Keresan language groups.

However, before accepting the Chaco phenomenon in defense of a neo-Rousseauian revision of human nature, one must consider another side of Chaco culture. There are no fewer than 73 excavated sites in Chaco territory that show signs of violent homicide, including an astonishing 50 that reveal evidence of cannibalism. All told, archaeologists have uncovered about 300 skeletons bearing the signature of anthropophagy (Turner, 1999, p. 463). This is not something that can be attributed to the dire circumstance of starvation. The neighboring Hohokam and Mogollon Cultures lived in environments that were at least as inhospitable as the Chacoan environment, yet evidence of cannibalism is limited exclusively to Chacoan sites. Turner (1999, p. 482) speculates that the more likely cause was an “intrusive terrorism” that came to Chaco from Mesoamerica as a means of social control. The Mesoamerican Toltecs, who incorporated cannibalism into their religious practices, may have migrated north due to civil strife and subsequently introduced the practice into the Chaco culture when it was just beginning its ascent. There is no evidence of cannibalism in the region prior to or after the Chaco phenomenon. Interestingly enough, outlying pueblo villages appearing after 1180, when construction in the Chaco Canyon complex had stopped, were mostly built as citadels in remote and geographically defensible locations. Hillerman (1991, p. 137) says of the post-Chaco Anasazi: “They seemed to seek out-of-the-way places where there was no risk of meeting other human beings.” If Chaco really was an early experiment in multi-cultural tolerance, it was a rare exception to a general rule, and a short-lived one at that. Regardless of what the full story of Chaco turns out to be, there as elsewhere, from prehistory through antiquity to modernity, we find unmistakable and ubiquitous signs of a deep suspicion and contempt for outsiders, right alongside evidence of cooperation and altruism for one’s own. The evolutionary pressures on our ancestors may have favored a complex system of communication that could be acquired quickly at a young age (as a means of assuring inter-cultural interactions), but there would have been no substantial benefits from a cognitive disposition that would have similarly facilitated the acquisition of new languages throughout the life span.

Conclusion

Darwin himself was aware of this dual nature of morality when he first wrote about natural selection. “It is evident, in the first place,” he wrote in *The Descent of Man*, “that the instinctive impulses have different degrees of strength; a savage will risk his own life to save that of a member of the same community, but will be wholly indifferent about a stranger (1871/2004, p. 91).” He seemed to sense the cold logic of evolution: it requires less effort to conquer your enemy than it does to learn to communicate with him. The rewards of conquest can be substantial, especially when compared to the cost of learning the language of an enemy over a three to four year period. Our remarkable facility in learning a first language at an early age – and our equally famous difficulty in learning another one later on – are thus easily predictable consequences of our prehistoric heritage. If language evolved in some group that did not have sustained and peaceful contact with

others, then a bilingual brain would not be of much use, natural selection would not have favored it, and we would end up with exactly the state of affairs we now have.

In this respect, language acquisition is quite at home with other cognitive abilities whose maturational processes are linked to interactions with physical and social environments. It is a common observation that predatory animals raised in captivity never develop a hunting instinct. That is hardly surprising, because in the state of nature, a predator with no hunting instinct does not survive to maturity anyway, and therefore does not pass its genetic material on. If you don't acquire it early, you might as well not acquire it at all. Similarly, in 2000, there was considerable excitement surrounding the intraocular retinal prosthesis, or "eye chip," which promised to restore a semblance of vision to the blind (Bowen, 1999; Scribner et al., 2001). Researchers cautioned that the IRP would be much less effective - and probably not effective at all - for those who had been blind since birth. Such individuals will have suffered anomalous development of the visual cortex of the brain due to lack of visual stimuli during their formative years.

It is readily conceded that what I have presented above is a somewhat unflattering view of human cognitive potential. But then one of the reasons that evolutionary psychology has provoked so much hostility in the past is that it has, on more than one occasion, told us things about ourselves that we would rather not hear. Bad news aside, it is no argument to point out that *today* xenophobia and intra-cultural aggression work to the detriment of our species. Park (2000) sums up our circumstance nicely:

So here we are, saddled with stagnant genes that were selected for life as Pleistocene hunter-gatherers, trying to cope with a world of jet travel and computers. What provided a survival advantage in a Pleistocene wilderness, does not necessarily do so today (p. 35).

The global village is a very recent development in our history, and we can be optimistic that our species may be taking some baby steps away from its xenophobic past by finally grasping the benefits of cooperation and multiculturalism. But these developments impinge on a relatively small number of individuals and have come about much too recently in our evolutionary history to have made a difference in our neural architecture. Seen in this light, the differences between child L1 acquisition and adult L2 acquisition are not as mysterious as they once seemed. They actually fit rather nicely into the mosaic of evolutionary theory.

Received 16 January 2007; Revision submitted 26 November 2007; Accepted 11 December 2007

References

- Alajouanine, T., and L'Hermitte, F. (1965). Acquired aphasia in children. *Brain*, 88, 653-622.
- Albert, M.L. and Obler, L.K. (1978). *The Bilingual Brain: Neuropsychological and Neurolinguistic Aspects of Bilingualism*. New York: Academic Press.
- Ambrose, S. (1998). Late Pleistocene human population bottlenecks, volcanic winter, and differentiation of modern humans. *Journal of Human Evolution*, 34, 623-651.
- Arsuaga, J.-L., Martinez, I., Gracia, A., Carretero, J.-M., and Carbonell, E. (1993). Three new human skulls from the Sima de los Huesos middle Pleistocene site in Sierra de Atapuerca, Spain. *Nature*, 362, 534-537.

- Baker, C. (2000). *The Care and Education of Young Bilinguals: An Introduction for Professionals*. Clevedon: Multilingual Matters.
- Baker, M. (2002). *The Atoms of Language: The Mind's Hidden Rules of Grammar*. Oxford; Oxfordshire; New York: Oxford University Press.
- Basser, L.S. (1962). Hemiplegia of early onset and the faculty of speech with special reference to the effects of hemispherectomy. *Brain*, 85, 427-460.
- Bermudez de Castro, J.M., Arsuaga, J., Carbonell, E., Rosas, A., Martinez, I., and Mosquera, M. (1997). A hominid from the lower Pleistocene of Atapuerca, Spain: Possible ancestor to Neandertals and modern humans. *Science*, 276, 1392-1395.
- Bettinger, R.L. (1991). *Hunter-Gatherers: Archaeological and Evolutionary Theory*. New York: Plenum Press.
- Bickerton, D. (1981). *Roots of Language*. Ann Arbor: Karoma Publishers.
- Bickerton, D. (1990). *Language and Species*. Chicago: University of Chicago Press.
- Blum, D. (1994). *The Monkey Wars*. New York: Oxford University Press.
- Bowen, J. (1999). Sight for Stevie Wonder. *Salon.com*. December 3, 1999. Retrieved July 19, 2006 from:
http://www.salon.com/health/log/1999/12/03/stevie_wonder/index.html.
- Brown, F., Harris, J., Leakey, R.E., and Walker, A.C. (1985). Early Homo erectus skeleton from west lake Turkana, Kenya. *Nature*, 316, 788-792.
- Burenhult, G. (1993). *The First Humans: Human Origins and History to 10,000 BC*. New York: HarperCollins.
- Buss, D. (2005). *The Murderer Next Door: Why the Mind is Designed to Kill*. New York: Penguin Press.
- Cappa, S.F. (1998). Spontaneous recovery from aphasia. In B. Stemmer and H. A. Whitaker (Eds.), *Handbook of Neurolinguistics* (pp. 535-545). San Diego: Academic Press.
- Cavalli-Sforza, L.L. (2000). *Genes, People and Languages*. New York: North Point.
- Chagnon, N. (1992). *Yanomamo, 4th ed.* Fort Worth: Harcourt Brace College Publishers.
- Cranberg, L., Filley, C., Hart, E., and Alexander, M. (1987). Acquired aphasia in childhood: clinical and CT investigations. *Neurology*, 37, 1165-1172.
- Curtiss, S. (1977). *Genie: A Psycholinguistic Study of a Modern-Day "Wild Child"*. New York: Academic Press.
- Damasio, A.R. (1994). *Descartes' Error: Emotion, Reason, and the Human Brain*. New York: Putnam.
- Darwin, C. (1981). *Descent of Man*. Princeton: Princeton University Press (Originally published in 1871).
- Davis, K. (1949). *Human Society*. New York: Macmillan.
- de Waal, F. (1995). Bonobo sex and society: The behavior of a close relative challenges assumptions about male supremacy in human evolution. *Scientific American*, 272, 82-88.
- Dean, C., Leakey, M.G., Reid, D., Schrenk, F., Schwartz, G.T., Stringer, C.B., et al. (2001). Growth processes in teeth distinguish modern humans from homo erectus and earlier hominins. *Nature*, 414, 628-31.
- Dehaene, S., Dupoux, E., Mehler, J., Cohen, L., Paulesu, E., Perani, P. et al. (1997). Anatomical variability in the cortical representation of first and second language. *NeuroReport*, 8, 3809-3815.

- Dunbar, R. (1996). *Grooming, Gossip and the Evolution of Language*. Cambridge, MA: Harvard University Press.
- Dyson, F. (1979). *Disturbing the Universe*. New York: Harper and Row.
- Fabbro, F. (2001). The bilingual brain: cerebral representation of languages. *Brain and Language*, 79, 211- 222.
- Falk, D. (1983). Cerebral cortices of east African early hominids. *Science*, 221, 1072-1074.
- Frazier, K. (1986). *People of Chaco: A Canyon and its Culture*. New York: Norton.
- Gamble, C. (1993). *Timewalkers: The Prehistory of Global Colonization*. Cambridge, MA: Harvard University Press.
- Gardner, M. (1989). *Science, Good, Bad, and Bogus*. Buffalo, NY: Prometheus Book.
- Gibert, J., and Palmquist, P. (1995). Fractal analysis of the Orce skull sutures. *Journal of Human Evolution*, 28, 561-75.
- Goodall, J. (1971). *In the Shadow of Man*. Boston: Houghton Mifflin.
- Goodall, J. (1986). *The Chimpanzees of Gombe: Patterns of Behavior*. Cambridge, Mass.: Belknap Press of Harvard University Press.
- Gould, S.J. (2002). *The Structure of Evolutionary Theory*. Cambridge, MA.: Belknap Press of Harvard University Press.
- Haile-Selassie, Y. (2001). Late Miocene hominids from the Middle Awash, Ethiopia. *Nature*, 412, 178-81.
- Hakuta, K., Bialystok, E. and Wiley, E. (2003). Critical evidence: A test of the critical period hypothesis for second-language acquisition. *Psychological Science*, 14, 31-38.
- Halsband, U., Krause, B. J., Sipila, H., Teraas, M. and Laihinen, A. (2002). PET studies on the memory processing of word pairs in bilingual Finnish–English subjects. *Behavioural Brain Research*, 132, 47-57.
- Hernandez, A. E., Dapretto, M., Mazziotta, J., and Bookheimer, M. (2001). Language switching and language representation in Spanish–English bilinguals. *NeuroImage*, 14, 510–520.
- Hillerman, T. (1991). *Hillerman Country*. New York: HarperCollins.
- Jackendoff, R. (1999). Possible stages in the evolution of the language capacity. *Trends in Cognitive Science*, 3, 272-279.
- Johanson, D.C., Masao, F.T., Eck, G.G., White, T.D., Walter, R.C., Kimbel, W.H., et al. (1987). New partial skeleton of *Homo habilis* from Olduvai Gorge, Tanzania. *Nature*, 327, 205-209.
- Johnson, J.S., and Newport, E.L. (1989). Critical period effects in second language learning: The influence of maturational state on the acquisition of English as a second language. *Cognitive Psychology*, 21, 60-99.
- Keeley, L. H. (1996). *War Before Civilization*. New York: Oxford University Press.
- Kim, K.H., Hirsch, J., Relkin, N., De Laz Paz, R., and Lee, K.M., (1997). Distinct cortical areas associated with native and second languages. *Nature*, 388, 171-174.
- Klein, R.G., and Edgar, B. (2002). *The Dawn of Human Culture*. New York: Wiley.
- Laitman, J.T., and Reidenberg, J.S. (1988). Advances in understanding the relationship between the skull base and larynx with comments on the origins of speech. *Human Evolution*, 3, 99-109.
- Leakey, R. (1994). *The Origin of Humankind*. New York: Basic Books.

- Leakey, R., and Lewin, R. (1992). *Origins Reconsidered: In Search of What Makes us Human*. New York: Doubleday.
- Lekson, S.H. (1984). *Great Pueblo Architecture of Chaco Canyon, New Mexico*. Albuquerque, N.M.: National Park Service, U.S. Dept. of the Interior.
- Lenneberg, E. (1964). *New Directions in the Study of Language*. Cambridge: M.I.T. Press.
- Lenneberg, E. (1984). *Biological Foundations of Language*. Malabar, FL: R.E. Krieger.
- Lieberman, P. (1984). *The Biology and Evolution of Language*. Cambridge, MA: Harvard University Press.
- Lieberman, P. (1987). *On the Origins of Language: An Introduction to the Evolution of Human Speech*. Lanham, MD: University Press of America.
- Lieberman, P. (1998). *Eve Spoke: Human Language and Human Evolution*. New York: W.W. Norton.
- Lieberman, P. (2006). *Toward an Evolutionary Biology of Language*. Cambridge, MA: Belknap Press of Harvard University Press.
- Lieberman, P., and Crelin, E.S. (1971). On the speech of Neanderthal man. *Linguistic Inquiry*, 2, 203-222.
- Long, M. (1990). Maturation constraints on language development. *Studies in Second Language Acquisition*, 12, 251-285.
- Martin, D., and Frayer, D.W. (1997). *Troubled Times: Violence and Warfare in the Past*. Amsterdam: Gordon and Breach.
- Martins, I.P., and Ferro, J.M. (1991). Recovery from aphasia and lesion size in the temporal lobe. In I.P. Martins, (Ed.), *Acquired Aphasia in Children* (pp. 171-184). The Netherlands: Kluwer Academic Publishers.
- Martins, I.P., and Ferro, J.M. (1992). Recovery of acquired aphasia in children. *Aphasiology*, 6, 431-438.
- Newport, E. (1991). Contrasting concepts of the critical period for language. In S. Carey, and R. Gelman, (Eds.), *The Epigenesis of Mind: Essays on Biology and Cognition* (pp. 111-130). Hillsdale: Lawrence Erlbaum Associates.
- Noble, W. and Davidson, I. (1991). The evolutionary emergence of modern human behavior: Language and its archaeology. *Man*, 26, 223-254.
- Nova (1994, February 15). *Can Chimps Talk? (Transcripts of video program)*. Boston: WGBH. Retrieved January 20, 2002 from <http://www.geocities.com/>
- Nova (1997). *Secrets of the Wild Child (Video program)*. March 1997. Boston: WGBH. Retrieved January 28, 2003 from: <http://www.pbs.org/wgbh/nova/transcripts/2112gchild.html>.
- Ojemann, G.A., and Whitaker, H.A. (1978). The bilingual brain. *Archives of Neurology*, 35, 409-412.
- Oyama, S. (1976). A sensitive period for the acquisition of a nonnative phonological system. *Journal of Psycholinguistic Research*, 5, 261-283.
- Paradis, M. (2004). *A Neurolinguistic Theory of Bilingualism*. Amsterdam/Philadelphia: John Benjamins Publishing Co.
- Park, R. (2000). *Voodoo Science: The Road from Foolishness to Fraud*. New York: Oxford University Press.
- Rampino, M.R., and Ambrose, S. (2000). Volcanic winter in the garden of Eden: The Toba super-eruption and the late Pleistocene human population crash. In F.W. McCoy,

- and G. Heiken, (Eds.), *Volcanic Hazards and Disasters in Human Antiquity* (pp. 71-82). Boulder, CO: Geological Society of America (Special Paper 345).
- Ridley, M. (1997). *The Origins of Virtue: Human Instincts and the Evolution of Cooperation*. New York: Viking.
- Roper, K. (1969). A survey of the evidence for intrahuman killing in the Pleistocene. *Current Anthropology*, 10, 427-459.
- Samway, K., and McKeon, D. (1999). *Myths and Realities: Best Practices for Language Minority Students*. New York: Heinemann.
- Sando, J.S. (1998). *Pueblo Profiles: Cultural Identity through Centuries of Change*. Santa Fe, NM.: Clear Light Publishers.
- Satz, P., and Bullard-Bates, C. (1981). Acquired aphasia in children. In M.T. Sarno, (Ed.), *Acquired Aphasia* (pp. 399-426). New York: Academic Press.
- Scribner, D., Humayun, M., Justus, B., Merritt, C., Klein, R., Howard, J. G., et al. (2001). Intraocular retinal prosthesis test device. *23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Istanbul, Turkey, October 2001*. Retrieved July 16, 2006 from <http://www.nrl.navy.mil/nanoscience/files/IEEE01embc.pdf>.
- Shattuck, R. (1980). *The Forbidden Experiment: The Story of the Wild Boy of Aveyron*. New York: Kodansha International.
- Shermer, M. (2004). *The Science of Good and Evil: Why People Cheat, Gossip, Care, Share, and Follow the Golden Rule*. New York: Times Books.
- Tacon, P., and Chippindale, C. (1994). Australia's ancient warriors: Changing depictions of fighting in the rock art of Arnhem Land, N.T. *Cambridge Archaeological Journal*, 4, 211-248.
- Tattersall, I. (1993). *The Human Odyssey: Four Million Years of Human Evolution*. New York: Prentice Hall.
- Tattersall, I. (1995). *The Fossil Trail: How we Know what we Think we Know about Human Evolution*. New York: Oxford University Press.
- Tobias, P.V. (1991). The emergence of spoken language in hominid evolution. In J.D. Clark, (Ed.), *Cultural Beginnings: Approaches to Understanding Early Hominid Life-Ways in the African Savanna* (pp. 67-78). Bonn: Habelt.
- Torres-Rouff, C., Costa-Junqueira, M.A., and Llagostera, A. (2005). Violence in times of change: The late intermediate period in San Pedro de Atacama. *Revista de Antropología Chilena*, 37, 75-83.
- Turner, C. (1999). *Man Corn: Cannibalism and Violence in the Prehistoric American Southwest*. Salt Lake City: University of Utah Press.
- Vargha-Khadem, F., O'Gorman, A.M., and Watters, G.V. (1985). Aphasia and handedness in relation to hemispheric side, age at injury and severity of cerebral lesion during childhood. *Brain*, 108, 677-696.
- Wallman, J. (1992). *Aping Language*. Cambridge: University of Cambridge Press.
- Wartenburger, I., Heekeren, H.R., Abutalebi, J., Cappa, S.F, Villringer, A., and Perani, D. (2003). Early setting of grammatical processing in the bilingual brain. *Neuron*, 37, 159-170.
- Wendorf, F., and Schild, R. (1986). *The Prehistory of Wadi Kubbaniya*. Dallas, TX: Southern Methodist University

The bilingual brain

- White, T.D., Suwa, G., and Asfaw, B. (1994). Australopithecus ramidus, a new species of early hominid from Aramis, Ethiopia. *Nature*, 371, 306-12.
- Wilson, D. S. (2002). *Darwin's Cathedral: Evolution, Religion, and the Nature of Society*. Chicago: University of Chicago Press.
- Woods, B., and Teuber, H. (1978). Changing patterns of childhood aphasia. *Annals of Neurology*, 3, 273–280.